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Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence across the translational pipeline of research-to-practice

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Complete List of Authors:	Meikle, Brandon; Queensland Children's Hospital, Centre for Children's Burns and Trauma Research; The University of Queensland Faculty of Medicine, Children's Health Research Centre Simons, Megan; Queensland Children's Hospital, Occupational Therapy; The University of Queensland, Children's Health Research Centre Mahoney, Tamsin; Metro North Hospital and Health Service, Surgical, Treatment and Rehabilitation Services (STARS) Reddan, Tristan; Children's Health Queensland Hospital and Health Service, Medical Imaging and Nuclear Medicine; Queensland University of Technology, School of Clinical Sciences, Faculty of Health Dai, Bryan; The University of Queensland Kimble, Roy; Children's Health Queensland Hospital and Health Service, Pegg Leditschke Children's Burns Centre; The University of Queensland, Faculty of Medicine Tyack, Zephaniah; The University of Queensland, Children's Health Research Centre, Faculty of Medicine; Queensland University of Technology, Australian Centre for Health Service Innovation (AusHI), Centre for Healthcare Transformation, and School of Public Health and Social Work
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3 1 Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence
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5 2 across the translational pipeline of research-to-practice*
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8 **Running Title:** Review of scar thickness measurement with ultrasound
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14 5 Brandon Meikle^{1,2**}, Megan Simons^{2,3,7}, Tamsin Mahoney⁴, Tristan Reddan^{5,6}, Bryan Dai²,
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16 6 Roy M Kimble^{1,2,6,7} and Zephania Tyack^{2,8}
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21
22 8 ¹ Centre for Children's Burns and Trauma Research, Queensland Children's Hospital,
23
24 9 Brisbane, Queensland, Australia
25
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27
28 10 ² Children's Health Research Centre, Faculty of Medicine, The University of Queensland,
29
30 11 Herston, Queensland, Australia
31
32

33 12 ³ Occupational Therapy Department, Queensland Children's Hospital, Children's Health
34
35 13 Queensland Hospital and Health Service, Brisbane, Queensland, Australia
36
37

38 14 ⁴ Surgical, Treatment and Rehabilitation Services (STARS), Metro North Hospital and Health
39
40 15 Service, Brisbane, Queensland, Australia
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42

43 16 ⁵ Medical Imaging and Nuclear Medicine, Queensland Children's Hospital and Health
44
45 17 Service, Brisbane, Queensland, Australia
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49 18 ⁶ School of Clinical Sciences, Faculty of Health, Queensland University of Technology,
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51 19 Brisbane, Queensland, Australia
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54 20 ⁷ Pegg Leditschke Children's Burns Centre, Queensland Children's Hospital, Children's
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56 21 Health Queensland Hospital and Health Service, Brisbane, Queensland, Australia
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2
3 22 ⁸ Australian Centre for Health Service Innovation (AusHI), Centre for Healthcare
4
5 23 Transformation, and School of Public Health and Social Work, Queensland University of
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7
8 24 Technology, Brisbane, Queensland, Australia
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10
11 25 ** Corresponding author
12

13
14 26 E-mail: brandon.meikle@uq.net.au (BM)
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20 28 *Parts of this paper were presented at the Australian and New Zealand Burn Association
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22 29 (ANZBA) 2022 Annual Scientific Meeting, the 2022 Centre for Children's Health Research
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24 30 Symposium, Child Health Research Centre, The University of Queensland, and the 2023
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26 31 British Burn Association Annual Conference.
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3 **32 ABSTRACT:**
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6 **33 Objectives:** To identify the ultrasound methods used in the literature to measure traumatic
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8 **34** scar thickness, and map gaps in the translation of these methods using evidence across the
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11 **35** research-to-practice pipeline.
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14 **36 Design:** Scoping review
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17 **37 Data Sources:** Electronic database searches of Ovid MEDLINE, Embase, Cumulative Index
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19 **38** of Nursing and Allied Health Literature (CINAHL) and Web of Science. Grey literature
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21 **39** searches were conducted in Google. Searches were conducted from inception (date last
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23 **40** searched 27/05/2022).
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26
27 **41 Data Extraction:** Records using B-mode ultrasound to measure scar and skin thickness
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29 **42** across the research-to-practice pipeline of evidence were included. Data was extracted from
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31 **43** included records pertaining to: methods used; reliability and measurement error; clinical,
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33 **44** health service, implementation and feasibility outcomes; factors influencing measurement
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35 **45** methods; strengths and limitations; and use of measurement guidelines and/or frameworks.
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39 **46 Results:** Of the 9309 records identified, 118 were included for analysis (n = 82 journal
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41 **47** articles, n = 36 abstracts) encompassing 5213 participants. Reporting of methods used was
42
43 **48** poor. B-mode, including high-frequency (i.e., > 20 MHz) ultrasound was the most common
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45 **49** type of ultrasound used (n = 72; 61%), and measurement of the combined epidermal and
46
47 **50** dermal thickness (n = 28; 24%) was more commonly measured than the epidermis or dermis
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49 **51** alone (n = 7, 6%). The scar characteristics most commonly reported to be measured were
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51 **52** epidermal oedema, and dermal fibrosis and hair follicle density. Most records analysed (n =
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53 **53** 115; 97%) pertained to the early stages of the research-to-practice pipeline, as part of
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55 **54** research initiatives.
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3 55 **Conclusions:** The lack of evaluation of measurement initiatives in routine clinical practice
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5 56 was identified as an evidence gap. Considerations for the ultrasound measurement of
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7 57 cutaneous traumatic scarring in research and clinical practice are presented based on the
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9 58 review findings. Standardising the core methodological components of ultrasound
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11 59 measurement is recommended based on poor methodological reporting in some records.
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15 60 **STRENGTHS AND LIMITATIONS OF THIS STUDY:**

- 16
17 61 • Evidence pertaining to the implementation of ultrasound measurement in routine
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19 62 clinical practice and research-to-practice gaps were determined by categorising
20
21 63 included records into one of the four Australian Government Department of Health
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23 64 and Aged Care Medical Research Future Fund research-to-practice pipeline phases.
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25 65 • Clinical, health service, implementation and feasibility outcomes related to ultrasound
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27 66 measurement in included records were summarised to determine what is needed to
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29 67 close the research-to-practice gap for ultrasound measurement of scar thickness.
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31 68 • The reported methods compiled in this review were used to inform the development
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33 69 of nine methodological considerations to guide health practitioners and researchers
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35 70 using ultrasound to measure scar and skin thickness.
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37 71 • A limitation is that only articles available in English or with an English abstract were
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39 72 considered for inclusion and data extraction, although the large number of included
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41 73 records means this is unlikely to have changed the review findings.
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75 INTRODUCTION:

76 Traumatic cutaneous injury, caused by sharp object penetration (e.g., surgery or vaccination)
77 or burns (including thermal, chemical and friction) may result in the formation of
78 hypertrophic scarring.¹ While major injuries to non-fetal skin heal through the formation of
79 scar tissue, most resultant scars are small, linear and/or barely visible.²⁻⁵ Hypertrophic scars,
80 however, result from an aberrant healing response that leads to the formation of red, raised
81 scars, often accompanied by pruritus and skin tightening, which remain within the boundaries
82 of the initial injury.⁶⁻¹¹ The sequelae of hypertrophic scars have the potential to impact
83 patient's physical and psychosocial quality of life.^{12 13}

84 A characteristic of hypertrophic scarring that both patients and clinicians have identified as
85 being important, and which has subsequently been used as a way to measure clinical and
86 treatment outcomes, is scar thickness.¹³⁻²¹ Scar thickness can be measured both subjectively,
87 through clinician assessment and patient-reported outcomes, or objectively, utilising medical
88 imaging methods.^{22 23} The pathological complexity of hypertrophic scars means that they
89 generally extend below the level of the surrounding skin, supporting the use of medical
90 imaging modalities such as ultrasound for thickness quantification, as these are capable of
91 providing information about subcutaneous structures and processes.^{23 24} Scar thickness
92 measurement using ultrasound can be conducted in both clinical and research contexts. For
93 example, ultrasound is regularly used in our own clinical practice at the Pegg Leditschke
94 Children's Burn Centre to measure scar thickness,²⁵ particularly prior to treatment with
95 ablative fractional CO₂ laser, where scar thickness measurement is used to determine the
96 required depth of penetration.²⁶ The routine use of measurements like ultrasound to guide
97 clinical decision-making has been termed measurement-based care.²⁷

98 There are several clinical skills that assessors or practitioners are required to master to
99 effectively conduct measurement of scar thickness with ultrasound. Proficiency in these skills

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3 100 may aid in bridging the gap between its use predominantly in research methods, to more
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5 101 widespread use in routine clinical practice. These skills have previously been described as
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7 102 part of a training curriculum in point-of-care ultrasound,²⁸ but can equally be applied to scar
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9 103 thickness measurement using ultrasound. These include: 1) understanding when to conduct
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11 104 scar thickness measurement with ultrasound; 2) the ability to operate an ultrasound machine
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13 105 to obtain useful images; 3) the ability to recognise physiological and pathological skin
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15 106 features (i.e., epidermis, dermis) on ultrasound images, and be able to measure the thickness
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17 107 of each; and 4) successfully utilising the thickness measurement as the basis of measurement-
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19 108 based care, including quantifying changes in scar thickness in response to treatment.²⁸ For
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21 109 example, a study of ultrasound measurement in people with systemic sclerosis identified
22
23 110 that ultrasound may be capable of differentiating between early oedema and fibrosis, and
24
25 111 detect thickening before it is observed clinically, thus providing opportunities to prevent or
26
27 112 treat fibrosis early.²⁹ Whilst it is ideal for all ultrasound assessors to have the skills
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29 113 mentioned, the number of assessors required to be proficient in these skills differs in research
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31 114 and clinical practice. In research, a small number of researchers are generally responsible for
32
33 115 conducting ultrasound measurement, whereas members across the entire multi-disciplinary
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35 116 team may be required to conduct these measurements in routine clinical practice, and thus
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37 117 require some level of proficiency.³⁰

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39 118 Ultrasound, itself, is a popular, safe, non-invasive and largely cost-effective (compared to
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41 119 other imaging modalities) imaging method with measurement utility in both adult and
42
43 120 paediatric populations.^{25 31 32} Modern B-mode (brightness mode) ultrasound, particularly
44
45 121 high- (i.e., ≥ 20 MHz) or ultra-high frequency (30-100 MHz)³³ ultrasonography, has the
46
47 122 capacity to allow differentiation between the epidermis and dermis, permitting quantification
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49 123 of skin layer-specific scar characteristics. This allows assessors to observe and understand the
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51 124 pathological mechanisms of individual scars and adjust treatment protocols accordingly.^{25 34-}

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3 125 ³⁹ Indeed, measurement of scar thickness using these methods may allow quantification of
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5 126 fibrosis and oedema within the scar, and can also be used to distinguish scar tissue from
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7 127 uninjured skin by measuring the presence and density of hair follicles. ⁴⁰⁻⁴³ B-mode
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9 128 ultrasound is also commonly used as the basis for other imaging methods, such as colour
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11 129 Doppler ultrasound or elastography, which can allow quantification of additional scar
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13 130 characteristics, such as their elastic properties. ^{34-37 44 45}
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17 131 Despite the clinical advantages of B-mode ultrasound for scar thickness measurement,
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19 132 methods utilised in the literature are poorly reported and lack standardisation. This casts
20
21 133 doubt on the validity of clinical decision-making in measurement-based care initiatives (e.g.,
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23 134 setting depth of AF_{CO2} penetration) informed by research findings (e.g., response to
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25 135 treatment) where ultrasound measurements are used. ⁴⁶ Lack of standardisation also makes
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27 136 between-study comparison, such as systematic reviews and meta-analyses, difficult, ⁴⁷ and
28
29 137 poor methodological reporting hampers the ability to accurately replicate findings. This
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31 138 scoping review focusses on mapping and identifying gaps in ultrasound methods and
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33 139 evaluation reported in the current literature along the research-to-clinical practice pipeline.
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35 140 Methodological considerations for assessors or practitioners performing scar thickness
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37 141 measurements using ultrasound are presented based on the review findings.
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142 **METHODS:**

143 **Protocol Publication and Review Structure:**

144 The protocol for this review has been published *a priori*. ⁴⁸ This scoping review was
145 conducted and is reported according to the Arksey and O'Malley (2005) ⁴⁹ framework. The
146 steps outlined in this framework are: 1) identifying the research question; 2) identifying
147 relevant records; 3) selecting appropriate records; 4) charting extracted data; and 5) collating,
148 summarising and reporting the results. ⁴⁹

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3 149 **Research Question:**
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6 150 The primary question of this scoping review was: “What do we know and not know about the
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8 151 measurement of traumatic cutaneous scar thickness using ultrasound?” This question was
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10 152 addressed through exploration of: methods used; reliability and measurement error; clinical,
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12 153 health service, implementation and feasibility outcomes; factors influencing ultrasound
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14 154 imaging and measurement methods; strengths and limitations of measurement methods; and
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16 155 use of measurement guidelines and/or frameworks. While the focus of this review was the
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18 156 measurement of traumatic cutaneous scar thickness with ultrasound, methods used to measure
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20 157 the thickness of unscarred skin were reported where these were used in combination with
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22 158 measurement of scar thickness (e.g., as control or comparator measurements).
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27 159 **Identifying Relevant Records:**
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30 160 A standardised search strategy was developed and piloted with the assistance of a medical
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32 161 librarian using the concepts ‘ultrasound’, ‘skin’, ‘thickness’ and ‘measure’, with associated
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34 162 terms and truncations (supplementary box 1). Ovid MEDLINE, Embase, Cumulative Index of
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36 163 Nursing and Allied Health Literature (CINAHL) and Web of Science electronic databases
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38 164 were searched from conception to identify original studies (date last searched 27th May
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40 165 2022).
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45 166 The phrase ‘ultrasound scar thickness measurement’ was used to conduct additional searches
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47 167 in 1) Google Scholar, and 2) Google to identify original studies in grey literature, and studies
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49 168 not identified in database searches. Title and abstract searches in Google Scholar and Google
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51 169 were limited to the first 200 results.⁵⁰
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55 170 **Record Selection:**
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58 171 Following de-duplication, six reviewers screened records using Covidence (Veritas Health
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60 172 Innovation, Melbourne, Australia; available at www.covidence.org) for eligibility according

173 to the inclusion criteria (Table 1). During both title and abstract and full text screening, one
 174 researcher (BM) screened all records as a single reviewer, while other researchers (MS, TM,
 175 TR, BD and ZT) screened records as a second reviewer. Conflicts were resolved through
 176 discussion between at least two authors to reach agreement. A third author was used as a
 177 tiebreaker where agreement could not be reached.

178 **Table 1. Inclusion and exclusion criteria for studies included in the scoping review.**

Inclusion	Exclusion
<ul style="list-style-type: none"> • Traumatic scars measured with ultrasound based on B-mode ultrasound (including high-frequency, ultra-high-frequency and Doppler) • Measurements taken of living, human individuals • Measurement of traumatic cutaneous scarring arising from penetration of the skin with sharp objects (including surgery or vaccination), or as a result of burns, (including thermal, chemical or friction) • Articles written in English, or with English abstracts 	<ul style="list-style-type: none"> • Reviews, discussion papers, opinion pieces • Measurement of non-traumatic scars (e.g., acne scars) • Measurement of skin thickness in non-traumatic conditions (e.g., diabetes) • Measurement of skin thickness where there is no cutaneous involvement in the trauma (e.g., traumatic brain injury) • Measurement using A-mode ultrasound

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180 **Charting the Data:**

181 The data extraction table was developed in Microsoft Excel and piloted by two authors (BM
 182 and ZT) through independent extraction and comparison of data from two records. The table
 183 was then modified to include the scar characteristics (e.g., fibrosis, oedema) measured,
 184 measurer/assessor training, and the number of measurements taken (Supplementary Table 1).
 185 Full text data extraction was completed by four authors (BM, MS, TM and ZT). An
 186 additional author (BD) independently extracted data from five randomly selected records,
 187 which was compared to data extracted by other authors. Minimal differences between data
 188 extracted by the independent author and that by other authors were observed, thus further

189 independent extraction was not performed. As is typical in scoping reviews, the certainty or
190 quality of evidence was not appraised.⁴⁹

191 The research-to-practice pipeline published by the Australian Government Department of
192 Health and Aged Care Medical Research Future Fund (figure 1) was used to categorise each
193 included record based on their stated aims into one of the four phases.⁵¹ The final phase of
194 this pipeline (phase 4) indicates initiatives used in routine clinical practice.

195 Where clinical (e.g., treatment satisfaction, scar symptoms), health service (e.g., efficiency,
196 safety, effectiveness, equity, patient-centredness and timeliness) and implementation (e.g.,
197 acceptability, adoption, appropriateness, fidelity, cost, penetration and sustainability)
198 outcomes were addressed, they were reported according to Proctor *et al.*⁵². Measurement
199 instrument-specific feasibility outcomes defined by Prinsen *et al.*⁵³ are reported in the current
200 review. These outcomes included ease of administration, standardisation, completion time,
201 instrument cost and availability, and ease of score calculation.⁵³ Reliability and measurement
202 error were defined according to COnsensus-based Standards for the selection of health
203 Measurement INstruments (COSMIN) tools.^{54,55} Measurements with an intraclass correlation
204 coefficient (ICC) of 0.7 or greater were considered reliable.⁵⁵ Measurement error was
205 assessed by comparing the reported standard error of the measurement (SEM) with the
206 reported smallest detectable change (SDC). Where the reported measurement error was
207 smaller than the reported smallest detectable change, it was interpreted as indicating real
208 change or variance can be detected, and that change or variance is not a result of error.⁵⁵

209 **Patient and Public Involvement**

210 There was no patient and/or public involvement in the design, conduct, reporting or
211 dissemination of information in this scoping review.

212 **RESULTS:**

Electronic database searches identified 9309 records. After removal of 3703 duplicate records, the titles and abstracts of 5606 records were screened for relevance according to the inclusion criteria (Table 1). Following full-text screening, 104 records proceeded to data extraction. Searches in Google and Google Scholar identified an additional 14 records, providing a total of 118 records for data extraction. Search and screening results are presented according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram (figure 2).⁵⁶

Record Characteristics:

Of the 118 records included in this review, 82 were journal articles (69%) and 36 were abstracts (31%) (Table 2), representing a total of 5213 participants. The majority (n = 44; 37% of included records) measured adults aged 8 years or older,^{21 26 34 36-38 42 43 57-94} and were measurements of burn scars (n = 69 records; 58%) (Table 2).^{21 25 26 31 32 35 36 38 42 59 64 66-71 74-78 84-87 91 92 94-133} Most identified records used ultrasound measurement of scar thickness as part of research initiatives, and were categorised as either phase 2 (n= 70; 59%)^{21 31 34 39 42 43 57 59-63 66 67 69 70 73 74 77-80 83 84 87-90 92 93 95-98 100-102 105-107 113 116-122 124-126 128 133-151} or phase 3 (n = 45; 38%)^{25 26 32 35-38 58 64 65 68 71 72 75 76 81 82 85 86 91 94 103 108 110-112 114 115 123 127 129-132 152-161} on the research-to-practice pipeline.⁵¹ Three records (3%)^{99 104 109} used ultrasound to measure treatment response to an intervention already used in routine clinical practice (phase 4), including compression garments^{99 109} and CO₂ fractional laser.¹⁰⁴

Table 2. Characteristics of records included in this review

First Author (year)	Sample Size (n)	Population Type	Scar Aetiology	Translational Pipeline Phase*
<i>Journal articles</i>				
Agabalyan (2017)	10	Adult	Not specified	2
Alsharnoubi (2018)	15	Paediatric	Burn	2
Alsharnoubi (2018)	15	Paediatric	Burn	2
Alshehari (2015)	30	Not reported	Mixed	2

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3	Avetikov (2018)	50	Paediatric & adult	Not	3
4				specified	
5	Berry (1985)	16	Paediatric & adult	Burn	4
6	Blome-Eberwein	16	Paediatric & adult	Burn	2
7	(2012)				
8	Blome-Eberwein	36	Adult	Not	2
9	(2016)			specified	
10	Blome-Eberwein	19	Adult	Burn	2
11	(2019)				
12	Cai (2019)	51	Adult	Not	2
13				specified	
14	Candy (2010)	17	Adult	Not	2
15				specified	
16	Chae (2016)	23	Adult	Not	3
17				specified	
18	Chang (2014)	60	Adult	Surgical	2
19	Chan (2004)	56	Paediatric & adult	Burn	2
20	Cheng (2001)	58	Paediatric	Burn	3
21	Cho (2014)	146	Not reported	Burn	2
22	Danin (2012)	22	Paediatric & adult	Burn	3
23	Deng (2019)	20	Adult	Not	2
24				specified	
25	Deng (2021)	31	Adult	Not	2
26				specified	
27	Deng (2021)	45	Adult	Not	2
28				specified	
29	Dunkin (2007)	113	Adult	Surgical	2
30	Elrefaie (2020)	22	Paediatric & adult	Not	2
31				specified	
32	Engrav (2010)	67	Paediatric & adult	Burn	4
33	Fabbrocini (2016)	20	Adult	Mixed	2
34	Fong (1997)	16	Paediatric & adult	Burn	3
35	Fraccalvieri (2013)	3	Paediatric & adult	Mixed	2
36	Fraccalvieri (2011)	5	Adult	Mixed	2
37	Gankande (2014)	30	Adult	Burn	3
38	Ge (2022)	21	Paediatric & adult	Mixed	3
39	Gee Kee (2016)	43	Paediatric	Burn	2
40	Guo (2020)	87	Paediatric & adult	Not	3
41				specified	
42	Huang (2017)	1	Adult	Burn	3
43	Huang (2021)	5	Adult	Burn	3
44	Huang (2020)	43	Adult	Not	3
45				specified	
46	Issler-Fisher (2021)	187	Adult	Burn	2
47	Issler-Fisher (2020)	78	Adult	Burn	3
48	Issler-Fisher (2017)	47	Paediatric & adult	Burn	3
49	Joo (2020)	48	Adult	Not	2
50				specified	
51	Katz (1985)	4	Not reported	Burn	3
52	Kemp Bohan (2021)	21	Not reported	Burn	3
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Kim (2018)	148	Not reported	Burn	3
Lacarrubba (2008)	8	Paediatric & adult	Mixed	2
Lau (2005)	100	Paediatric & adult	Burn	2
Lee (2020)	55	Adult	Burn	2
Lee (2019)	55	Adult	Burn	2
Li (2013)	7	Adult	Burn	2
Li (2020)	21	Paediatric & adult	Mixed	2
Li (2021)	165	Paediatric	Mixed	2
Li (2018)	34	Adult	Burn	3
Li (2021)	105	Adult	Burn	2
Li-Tsang (2005)	101	Adult	Surgical	3
Li-Tsang (2006)	45	Adult	Not specified	2
Li-Tsang (2010)	104	Paediatric & adult	Mixed	2
Lobos (2017)	35	Paediatric & adult	Not specified	3
Mamdouh (2021)	40	Adult	Not specified	2
Meirte (2016)	9	Adult	Burn	2
Miletta (2021)	29	Paediatric & adult	Burn	2
Nedelec (2014)	46	Adult	Burn	3
Nedelec (2008)	32	Adult	Burn	3
Nedelec (2019)	70	Adult	Burn	2
Nedelec (2020)	51	Adult	Burn	2
Nicoletti (2015)	27	Paediatric & adult	Surgical	2
Niessen (1998)	145	Paediatric & adult	Surgical	2
Reinholz (2020)	25	Adult	Mixed	2
Reinholz (2016)	8	Adult	Not specified	3
Schwaiger (2018)	15	Adult	Mixed	2
Simons (2017)	49	Paediatric	Burn	3
Soykan (2014)	87	Adult	Surgical	3
Timar-Banu (2011)	30	Adult	Mixed	3
Ud-Din (2019)	62	Adult	Not specified	3
van den Kerckhove (2005)	60	Adult	Burn	2
van den Kerckhove (2003)	6	Adult	Burn	3
van der Veer (2010)	44	Adult	Surgical	2
Wang (2009)	22	Adult	Burn	2
Wang (2010)	21	Paediatric	Burn	3
Wiseman (2020, 2021)	153	Paediatric	Burn	2
Wood (1996)	1	Paediatric	Burn	3
Xuan (2021)	72	Not reported	Not specified	2
Yeol Lee (2022)	16	Adult	Mixed	3
Yim (2010)	31	Paediatric & adult	Burn	2
Zadkowski (2016)	47	Paediatric	Burn	2

<i>Abstracts</i>					
Agabalyan (2016)	10	Not reported	Burn	2	
Anthonissen (2015)	N.R.	Not reported	Burn	3	
Bajouri (2018)	20	Not reported	Burn	2	
Bezugly (2019)	438	Not reported	Not specified	3	
Bezugly (2014)	103	Not reported	Mixed	3	
Blome-Eberwein (2011, 2012)	16	Paediatric & adult	Mixed	2	
Blome-Eberwein (2012)	19	Adult	Burn	3	
Blome-Eberwein (2014)	66	Not reported	Burn	2	
Cho (2012)	30	Not reported	Burn	4	
Cho (2012)	60	Paediatric & adult	Burn	2	
Comstock (2018)	1	Adult	Burn	2	
Cooper (2021)	25	Not reported	Burn	2	
Du (2006)	1	Adult	Burn	3	
Edgar-Lacoursière (2022)	44	Not reported	Burn	3	
El-Zawhary (2007)	57	Not reported	Mixed	2	
George (2019)	11	Not reported	Burn	3	
Jacobs (2016)	6	Paediatric & adult	Burn	2	
Jang (2009)	20	Not reported	Not specified	2	
Kim (2009)	5	Paediatric & adult	Burn	2	
Li (2016)	34	Not reported	Burn	3	
Li-Tsang (2011)	4	Not reported	Not specified	2	
Li-Tsang (2010)	45	Not reported	Not specified	2	
Maari (2017)	12	Not reported	Not specified	2	
Moortgat (2020)	10	Not reported	Burn	2	
Nedelec (2018)	60	Not reported	Burn	2	
Peters (2018)	5	Not reported	Burn	2	
Seo (2011)	48	Not reported	Burn	3	
Siwy (2016)	15	Not reported	Burn	2	
Timina (2013)	49	Not reported	Not specified	3	
Tu (2014)	59	Not reported	Not specified	2	
Ud-Din (2017)	20	Not reported	Surgical	2	
Ud-Din (2017)	20	Not reported	Surgical	3	
Ud-Din (2018)	62	Not reported	Surgical	3	
Zuccaro (2021)	20	Paediatric	Burn	3	
Zuccaro (2019)	13	Paediatric	Burn	3	
Zuccaro (2021)	20	Paediatric	Burn	3	

Legend: Paediatric: measurement of patients under the age of 18; Adult: measurement of patients aged 18 years or older; N.R.: Not reported; Burn: scars caused by thermal,

chemical or friction injury; Surgical: scars caused by surgical procedures (including biopsies); Mixed: participant scars caused by mixed trauma (e.g., burn and acne)
Footnotes: *Stage in the research to clinical practice translational pipeline, based on the Australian Government Department of Health and Aged Care⁵¹

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234 Methods used to measure traumatic cutaneous scar thickness:

235 B-mode, including high-frequency (i.e., ≥ 20 MHz) B-mode ultrasound was the most
236 commonly reported ultrasound type (n = 72; 61%) (Table 3). Specialised B-mode ultrasound
237 devices, including the Tissue Ultrasound Palpation System (TUPS; a B-mode ultrasound
238 transducer in-series with a load cell to allow measured compression of the skin),^{72 117 141 144}
239 and colour Doppler ultrasound,^{61 156} were used in six records (Table 3).

240 **Table 3. Measurement methods used in included records.**

First Author (year)	Ultrasound Type	Ultrasound Frequency (MHz)	Measurement Parameters	Scar Characteristic Measured	Scar Relocation
<i>Journal articles</i>					
Agabalyan (2017)	High-frequency	20	Epidermal, dermal & combined	N.R.	Not relevant – single measurement
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis	N.R.
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis [†]	N.R.
Alshehari (2015)	N.R.	N.R.	Maximum elevation above normal skin	N.R.	N.R.
Avetikov (2018)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Berry (1985)	N.R.	N.R.	N.R.	N.R.	N.R. [‡]
Blome- Eberwein (2012)	B-mode	N.R.	Combined epidermal & dermal [§]	N.R.	N.R. [‡]
Blome- Eberwein (2016)	High-frequency	50	N.R.	Fibrosis [†]	N.R. [‡]
Blome- Eberwein (2019)	High-frequency	35	Dermal	Fibrosis, hair follicle density	N.R.
Cai (2019)	High-frequency	50	Dermal	N.R.	N.R. [‡]
Candy (2010)	B-mode	N.R.	N.R.	N.R.	Scar boundaries traced
Chae (2016)	N.R.	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Chang (2014)	N.R.	12	N.R.	N.R.	N.R.

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3	Chan (2004)	N.R.	N.R.	N.R.	N.R.	Tracing
4	Cheng (2001)	B-mode	5-10	Combined epidermal & dermal	N.R.	Tracing & cutting out paper
5						Photographs
6	Cho (2014)	High-frequency	7.5	N.R.	N.R.	N.R.
7	Danin (2012)	B-mode	20	Epidermal & dermal	N.R.	N.R.
8	Deng (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
9	Deng (2021)	Colour Doppler	4-15	Dermal	Fibrosis [†]	N.R.
10	Deng (2021)	B-mode	8-12	Epidermal & dermal	Fibrosis [†]	Photographs
11	Dunkin (2007)	High-frequency	N.R.	N.R.	Fibrosis & oedema [†]	Measurements taken at set
12						linear distances along scar
13	Elrefaie (2020)	High-frequency	13	N.R.	Fibrosis & oedema [†]	N.R. [‡]
14						
15	Engrav (2010)	N.R.	N.R.	N.R.	N.R.	N.R.
16	Fabbrocini (2016)	N.R.	N.R.	N.R.	Fibrosis & oedema [†]	N.R. [‡]
17	Fong (1997)	B-mode	7.5	N.R.	Fibrosis [†]	Tracing
18	Fraccalvieri (2013)	High-frequency	7-10 & 10-13	N.R.	Fibrosis & oedema [†]	N.R.
19	Fraccalvieri (2011)	High-frequency	10-13	Combined epidermal & dermal	Fibrosis [†]	N.R.
20	Gankande (2014)	High-frequency	20	Combined epidermal & dermal	N.R.	Scar marked & photographed
21	Ge (2022)	N.R.	N.R.	N.R.	N.R.	N.R.
22	Gee Kee (2016)	B-mode	8-18	Combined epidermal & dermal	N.R.	Transducer in centre of original burn site where no scar present
23						Thickest site on peripheral regions
24	Guo (2020)	N.R.	2-15 & 4-15	Combined epidermal & dermal ^c	Fibrosis [†]	Marked & linear measurements from bony landmarks
25	Huang (2017)	N.R.	N.R.	Combined epidermal & dermal	N.R.	
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3	Huang (2021)	B-mode	5-12	N.R.	Oedema [†]	Not relevant – single measurement
4						
5	Huang (2020)	B-mode	5-12	Combined epidermal & dermal	N.R.	N.R.
6	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	Photograph & measurement of thickest area
7	(2021)					
8	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	N.R.
9	(2020)					
10	Issler-Fisher	N.R.	N.R.	N.R.	Fibrosis [†]	Scar mapped with drawing
11	(2017)					Thickest area measured
12	Joo (2020)	N.R.	N.R.	N.R.	Fibrosis [†]	N.R.
13	Katz (1985)	B-mode	10	Combined epidermal & dermal	N.R.	N.R.
14	Kemp Bohan	High-frequency	12	N.R.	Fibrosis [†]	Tracing – thickest area & adjacent landmarks marked
15	(2021)					
16	Kim (2018)	N.R.	22	Combined epidermal & dermal	N.R.	Not relevant – single measurement
17						
18	Lacarrubba	B-mode	20	Combined epidermal & dermal	N.R.	N.R.
19	(2008)					
20	Lau (2005)	Tissue Ultrasound Palpation System	5 (burn) & 10 (surgical)	N.R.	N.R.	Tracing – most severe/prominent site
21						
22	Lee (2020)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Not relevant – single measurement
23						
24	Lee (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Marked with pen
25	Li (2013)	High-frequency	12	Combined epidermal & dermal	Fibrosis [†]	Tracing
26	Li (2020)	N.R.	10	N.R.	Fibrosis [†]	N.R.
27	Li (2021)	High-frequency	20	N.R.	N.R.	Thickest area
28	Li (2021)	High-frequency	20	N.R. [§]	Fibrosis [†]	Thickest area
29	Li (2018)	N.R.	N.R.	Combined epidermal & dermal	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound Palpation System	N.R.	N.R.	N.R.	N.R.
31	(2005)					
32	Li-Tsang	B-mode	N.R.	N.R.	N.R.	N.R. [‡]
33	(2006)					
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3	Li-Tsang	B-mode	N.R.	N.R.	Fibrosis [†]	N.R.
4	(2010)					
5	Lobos (2017)	B-mode & colour	18	N.R.	Fibrosis [†]	Not relevant – single
6		Doppler				measurement
7	Mamdouh	High-frequency	N.R.	Combined epidermal & dermal [§]	Fibrosis [†]	N.R.
8	(2021)					
9	Meirte (2016)	High-frequency	22	Dermal	Fibrosis &	Marked with surgical pen, including boundaries of probe. Photograph of body position & probe location Tracing – worst scar
10					oedema [†]	
11	Miletta (2021)	N.R.	50	N.R.	Fibrosis [†]	
12	Nedelec (2014)	High-frequency	20	Combined epidermal & dermal	N.R.	
13						Tracing including notable
14						landmarks. Measurement site
15	Nedelec (2008)	High-frequency	20	Combined epidermal & dermal	N.R.	circled. Photograph
16						Tracing including notable
17						landmarks. Measurement site
18						circled. Photograph
19	Nedelec (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis &	Tracing. Hole cut over
20					oedema [†]	measurement area
21	Nedelec (2020)	High-frequency	20	Combined epidermal & dermal	N.R.	Photograph
22	Nicoletti	N.R.	22	Epidermis to fascia	N.R.	N.R.
23	(2015)					
24	Niessen (1998)	B-mode	N.R.	N.R.	Fibrosis &	3cm border marked with tape
25					oedema [†]	– measurements lateral
26	Reinholz	B-mode	11	Combined epidermal & dermal	Fibrosis &	N.R.
27	(2020)				oedema [†]	
28	Reinholz	B-mode	11	Combined epidermal & dermal [§]	Fibrosis &	N.R.
29	(2016)				oedema [†]	
30	Schwaiger	B-mode	11	N.R.	Fibrosis &	N.R.
31	(2018)				oedema [†]	
32	Simons (2017)	B-mode	8-18	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical
33						landmarks
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3	Soykan (2014)	N.R.	3-9	N.R.	Fibrosis [†]	N.R.	
4	Timar-Banu	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	N.R.	
5	(2001)						
6	Ud-Din (2019)	High-frequency	50	Combined epidermal & dermal	Fibrosis	Defined anatomical location	
7	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test sites marked.	
8	Kerckhove					Thermoplastic splints created	
9	(2003)					with space for transducer	
10	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test site boundaries marked	
11	Kerckhove					& traced	
12	(2005)						
13	van der Veer	N.R.	7.5	N.R.	Fibrosis [†]	Standardised linear	
14	(2010)					measurement points	
15	Wang (2009)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.	
16	Wang (2010)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical	
17						landmarks	
18	Wiseman	B-mode	N.R.	Combined epidermal & dermal	Fibrosis [†]	Centrally site of interest	
19	(2020, 2021)						
20	Wood (1996)	B-mode	7 & 10	N.R.	N.R.	Transducer affixed to	
21						tracking arm	
22	Xuan (2021)	High-frequency	20	N.R.	Fibrosis [†]	N.R.	
23	Yeol Lee	B-mode	7-16	N.R.	N.R.	N.R.	
24	(2022)						
25	Yim (2010)	High-frequency	12	N.R.	N.R.	N.R.	
26	Zadkowski	B-mode	N.R.	Combined epidermal & dermal	N.R.	N.R.	
27	(2016)						
28	<i>Abstracts</i>						
29							
30	Agabalyan	N.R.	20	Epidermal, dermal & combined	N.R.	N.R.	
31	(2016)						
32	Anthonissen	N.R.	22	Epidermal & dermal	N.R.	N.R.	
33	(2015)						
34	Bajouri (2018)	N.R.	N.R.	Epidermal & dermal	N.R.	N.R.	
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3	Bezugly (2019)	High-frequency	22, 33 & 75	Epidermal & dermal	N.R.	N.R.
4	Bezugly (2014)	High-frequency	33 & 75	Epidermal & dermal	N.R.	N.R.
5	Blome-	N.R.	N.R.	N.R.	N.R.	N.R.
6	Eberwein					
7	(2011, 2012)					
8	Blome-	High-frequency	N.R.	N.R.	Fibrosis	N.R.
9	Eberwein					
10	(2012)					
11	Blome-	High-frequency	N.R.	N.R.	N.R.	N.R.
12	Eberwein					
13	(2014)					
14	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
15	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
16	Comstock	N.R.	N.R.	N.R.	N.R.	N.R.
17	(2018)					
18	Cooper (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
19	Du (2006)	B-mode	15	N.R.	N.R.	N.R.
20	Edgar-	N.R.	N.R.	N.R.	N.R.	N.R.
21	Lacoursière					
22	(2022)					
23	El-Zawhary	N.R.	N.R.	N.R.	N.R.	N.R.
24	(2007)					
25	George (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
26	Jacobs (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
27	Jang (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
28	Kim (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
29	Li (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
31	(2011)	Palpation System				
32	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
33	(2010)	Palpation System				
34	Maari (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
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Moortgat (2020)	High-frequency	N.R.	Dermal	N.R.	N.R.
Nedelec (2018)	N.R.	N.R.	N.R.	N.R.	N.R.
Peters (2018)	High-frequency	22	N.R.	N.R.	N.R.
Seo (2011)	N.R.	7.5	N.R.	N.R.	Thickest point
Siwy (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
Timina (2013)	N.R.	20-40	N.R.	N.R.	N.R.
Tu (2014)	High-frequency ultrasound biomicroscopy	N.R.	N.R.	N.R.	N.R.
Ud-Din (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
Ud-Din (2017)	High-frequency	50	N.R.	N.R.	N.R.
Ud-Din (2018)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.
Zuccaro (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
Zuccaro (2019)	B-mode	N.R.	N.R.	N.R.	N.R.
Zuccaro (2021)	B-mode	6-18	Combined epidermal & dermal	N.R.	Scar outlined & photographed

Legend: B-mode: brightness-mode ultrasound (< 20 MHz); High-frequency: high-frequency B-mode ultrasound (> 20 MHz); N.R.: Not reported

Footnotes: [†]Indirect reference made in record (e.g. in introduction or discussion); [‡]Photographs taken of the scar but not specified whether used for relocation; [§]Not stated in methods, so images provided in record used by authors of this review to provide subjective judgement

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3 242 The type of scar and skin thickness measurement (i.e., thickness of the dermis, epidermis, or
4
5 243 combined epidermal and dermal measurement) was reported in 39 records (33%) (Table 3).
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7
8 244 Where reported, combined measurement of epidermal and dermal thickness was the most
9
10 245 common method (n = 28; 24%).^{21 25 31 32 35 37 58 63 65 69 70 75 76 78 82 86 87 91 94 103 108 112 125 126 128 129}
11
12 246 ^{145 149} Separate epidermal and dermal thickness measurements were reported in seven records
13
14 247 (6%).^{34 74 89 95 98 132 153 154} Of these records, two authors provided a rationale for this decision:
15
16 248 each skin layer provided different information on the scar;³⁴ or responded differently to
17
18 249 treatment.^{74 92}
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22 250 Four records (3%) directly reported that fibrosis was the scar characteristic targeted by the
23
24 251 measurement.^{36 42 96 160} One of these records also quantified hair follicle density to assess the
25
26 252 difference between scarred and unscarred skin.⁴² An additional 26 records (22%) made
27
28 253 indirect reference (i.e., within the introduction or discussion) to the measurement of fibrosis.
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30 254 ^{21 61 63 67-70 73 81-84 89 92 93 97 110 115 119 125 126 142 150 151 155 156 160} Ten records (8%) made indirect
31
32 255 reference to the measurement of both oedema and fibrosis,^{39 43 62 74 77 79 80 139 146 157} and one
33
34 256 record made indirect reference to the measurement of oedema.⁶⁴
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39 257 Additional objective and subjective measurement methods were employed alongside
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41 258 ultrasound measurement in 115 records (97%) (Supplementary Table 2). All three phase 4
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43 259 studies involving implementation in routine clinical practice utilised additional
44
45 260 measurements.^{99 104 109} The additional objective measurements included elastography
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47 261 (elasticity), cutometric assessment (pliability) and Doppler ultrasound (vascularity). The
48
49 262 additional subjective measurements were conducted using clinician-based rating scales (e.g.,
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51 263 Vancouver Scar Scale, used in 46 records^{21 26 39 42 43 58 61 66 67 69 71 72 76 85 88 90-93 96-98 100 101 103 104}
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53 264 ^{108 113-115 117 127-129 134-137 139 141-144 147 150}) or patient-reported outcome measures (PROMs).^{59 63}
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55 265 ^{65 75-78 85 89 91 93 96 97 100-102 105 106 108 110 112 116 118 120-124 129-131 133 135 136 139 140 142 143 155}
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3 266 Methods used to relocate the scar for repeated measurements were reported in 34 records
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5 267 (29%) (Table 3). The most common relocation method was tracing the outline or boundaries
6
7 268 of the scar on a transparent or translucent sheet (n = 14; 12%),^{32 70 77 87 88 102 103 110 119 129 141}
8
9
10 269 occasionally including prominent or bony landmarks close to the scar.^{25 68 75} Photographs (n
11
12 270 =11; 9%) and linear measurements from defined points or anatomical landmarks on or around
13
14 271 the scar (n = 4; 3%) were also used for scar relocation. The ‘worst’ or ‘thickest’ part of the
15
16 272 scar, as determined by patients or assessors, was chosen as the measurement site in 15
17
18 273 records (13%).^{26 32 39 61 62 66 91 92 115 123 125 126 139 143 155}
19
20
21
22 274 Measurement of unscarred skin, either contralateral or adjacent to the scar, was performed in
23
24 275 29 records (25%). These measurements were primarily used as controls or comparators to
25
26 276 scar measurements (n = 27, 23%).^{21 31 32 36 37 42 57 60 63-65 69 76 82 85 86 89 91 92 108 110 112 127 129 130 138}
27
28 277 ^{152 155} Additionally, three records (3%) evaluating treatment efficacy measured both
29
30 278 unaffected skin thickness and the thickness of a ‘control’ or untreated scar.^{93 100 131} All
31
32 279 instances where additional ultrasound measurements were taken of unscarred skin or
33
34 280 untreated scars were reported as part of research initiatives aligning with phases 2 and 3 of
35
36 281 the research-to-practice pipeline (figure 1).⁵¹
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41 282 **Reliability and measurement error**

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43
44 283 Reliability was calculated for both scarred and unscarred skin in 14 records (12%) and was
45
46 284 generally acceptable (Supplementary Table 2). This included inter-rater reliability (n = 5; 4%
47
48 285 of included records),^{62 69 76 110 137} intra-rater reliability (n = 3; 2% of included records),^{31 32 70}
49
50 286 and both inter- and intra-rater reliability (n = 7; 6%)^{21 25 91 94 123 132 141}. The intraclass
51
52 287 correlation coefficient (ICC) was the most commonly reported reliability statistic (n = 10; 8%
53
54 288 of included records),^{21 25 69 70 76 91 94 110 132 141} where it was reported for both scar and
55
56 289 unscarred skin measurements in four records (3%).^{21 25 76 91} The reported combined thickness
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3 290 (i.e., epidermal and dermal) ICCs for inter-rater reliability of scarred skin ranged from 0.82 to
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5 291 0.985, while the inter-rater ICC for the measurement of unscarred skin ranged from 0.33 to
6
7 292 0.98, with one of the four records reporting an ICC below the threshold value of 0.7 (ICC =
8
9 293 0.33)²⁵ and one record simply reported that the inter-rater ICC for scarred skin was
10
11 294 “acceptable to high”.⁶⁹ The reported intra-rater reliability for combined thickness
12
13 295 measurements of scarred skin ranged from 0.89 to 0.983, and for unscarred skin ranged from
14
15 296 0.61 to 0.982, with one record reporting an ICC below the threshold of 0.7 (ICC = 0.61).²⁵
16
17 297 One record reported both the inter- and intra-rater ICCs for individual epidermal (inter-rater
18
19 298 ICC = 0.297; intra-rater ICC = 0.809) and dermal (inter-rater ICC = 0.991; intra-rater ICC =
20
21 299 0.991) scar thickness measurement.¹³² Four records (3% of included records) reporting
22
23 300 reliability used Pearson’s R, an undisclosed method, or description (e.g., high) as detailed in
24
25 301 supplementary table 2.^{31 62 123 137}
26
27 302 Measurement error for inter-rater and intra-rater reliability of combined, epidermal or dermal
28
29 303 thickness was reported in five records (4%) using standard error of the measurement (SEM).
30
31 304 The inter-rater SEM for the combined epidermal and dermal thickness of scarred skin ranged
32
33 305 from 0.11 mm to 0.5 mm, and the intra-rater SEMs ranged from 0.18 to 0.52 mm. Individual
34
35 306 records reported SEM values for unscarred skin, and separate epidermal and dermal
36
37 307 measurements, available in supplementary table 2.^{21 25 32 94 132} Only one record reported
38
39 308 calculation of the smallest detectable change (SDC). In that record the inter- and intra-rater
40
41 309 SDC was calculated for both scarred and unscarred skin. The scarred skin SDCs were 1.4 mm
42
43 310 (inter-rater) and 0.6 mm (intra-rater), and unscarred skin SDCs were 0.8 mm (inter-rater) and
44
45 311 0.5 mm (intra-rater).²⁵ The reported SEMs were all close to or below the largest SDC value
46
47 312 reported. This finding may indicate that ultrasound can detect true variance in scar thickness
48
49 313 above measurement error for traumatic scar and skin thickness.

50 314 **Clinical, health service, implementation and feasibility outcomes:**

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2
3 315 No record specifically investigated clinical, health service, implementation or feasibility
4
5 316 outcomes of ultrasound as a measurement-based-care initiative. Ultrasound was used to
6
7 317 assess the clinical outcomes of scar treatment initiatives in all included records. Clinical,
8
9 318 health service, implementation and feasibility outcomes related to ultrasound measurement
10
11 319 were, however, reported in 67 records that focused on scar treatments.^{21 25 31 32 34-36 39 42 57 58 60}
12
13 320 62-71 73-78 82 86 90 91 93-95 99 100 102 103 109-112 115 120 123 127 129 132 133 138 139 141 145-147 150 153-160
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17 321 The clinical outcome of patient satisfaction related to ultrasound measurement was only
18
19 322 reported in one record. Whilst patient satisfaction was not directly measured in that record, a
20
21 323 proxy measure of satisfaction was reported by the authors stating that no paediatric patient or
22
23 324 their caregiver refused ultrasound measurement once the purpose was explained.²⁵
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27 325 Timeliness was the only reported health service outcome, reported as the time required to
28
29 326 take ultrasound measurements. Where reported, this was short, taking between one to five
30
31 327 minutes,^{25 35 112}.
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35 328 The most common implementation outcomes reported in the identified records were fidelity,
36
37 329 acceptability and appropriateness. Fidelity to the measurement method was reported through
38
39 330 the use of experienced or trained assessors (n = 7; 6%),^{25 86 91 132 146 150 155} and/or utilising the
40
41 331 same assessor/s for all measurement sessions (n = 5; 4%).^{25 66 139 146 155} Differences between
42
43 332 intended and actual measurement methods were not discussed. The training and/or experience
44
45 333 of the assessors was discussed in 24 records (20%),^{21 25 32 35 60 63 64 67-71 74 76 86 91 102 103 110 129 139}
46
47 334 141 146 156 where measurements were either taken by a clinician (n = 13; 11%),^{21 25 32 64 69-71 74 86}
48
49 335 92 110 141 143 members of the research team (n = 6; 5%),^{67 68 76 91 102 146} or by specialist
50
51 336 sonographers and/or radiologists (n = 5; 4%).^{63 103 129 139 156} Only one record reported on
52
53 337 fidelity in the context of routine clinical practice. In this instance, ultrasound was conducted
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55 338 in the department of radiology, however the role or training of the staff was not reported.¹⁰⁹
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3 339 The acceptability and appropriateness of the ultrasound methods used in individual records
4
5 340 were generally based on author opinion and outlined in the discussion. Acceptability was
6
7 341 reported in 25 records (21%),^{21 25 31 32 34-36 39 69 73 77 78 82 91 94 95 103 109-112 115 141 145 156 157} including
8
9 342 for paediatric populations, where one record reported potential difficulty in measuring this
10
11 343 population,³¹ contrasting that which reported that measurement was acceptable to both
12
13 344 children and their caregivers.²⁵ One record reported acceptability where the intervention
14
15 345 being analysed by ultrasound was already part of routine clinical practice. In this instance, the
16
17 346 authors referenced additional publications which stated that ultrasound had an accuracy of 0.5
18
19 347 mm, which was judged by the authors to be sufficient for assessment of scar thickness.^{109 25}
20
21 348^{35 112} Potential difficulty was identified in the measurement of open wounds,²⁵ and
22
23 349 traditionally hard-to-reach areas (such as the axillae or groin).³¹

24
25
26 350 The appropriateness of the ultrasound methods was reported in 46 records (39%), and was
27
28 351 generally addressed in the discussion.^{25 31 34 35 39 42 57 58 62 65 66 69-71 75-78 82 90 91 93-95 99 100 103 109 110}
29
30 352^{112 115 120 123 127 132 138 141 147 153-160} Of these records, two (2%) determined that ultrasound was
31
32 353 not appropriate for scar measurement. The first stated that it was too inaccurate and complex;
33
34 354⁹⁵ and the second, which reported on initiatives within routine clinical practice, determined
35
36 355 that the minimum resolution of the Disonography ultrasonic scanner (Nuclear Enterprises,
37
38 356 Edinburgh, UK) precluded its use in scars thinner than 3mm.⁹⁹

39
40
41 357 The feasibility of ultrasound was reported in 12 records (10%).^{25 31 34 73 82 91 93 109 110 133 141} Five
42
43 358 records considered ultrasound not feasible for scar measurements. The rationale presented
44
45 359 included high-frequency 20 MHz ultrasound having an inadequate penetration depth;^{34 91} and
46
47 360 ultrasound measurement and training of investigators requiring too much time (as reported in
48
49 361 one record in phase 4 of the research-to-practice pipeline).^{31 109 110} Another factor identified
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51 362 as precluding feasibility was the inability to consistently relocate the measurement site.²⁵
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53 363 Conversely, one record reported ultrasound to be feasible in combination with Vancouver

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3 364 Scar Scale (VSS) measurement,⁷³ and another stated that ultrasound was able to distinguish
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5 365 between subcutaneous fat and muscle, which was interpreted by the authors of that record to
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7 366 mean that skin thickness measurements were accurate.¹³³ The majority (n = 11; 92%) of the
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10 367 records reporting feasibility were research initiatives in phase 2 or 3 of the research to
11
12 368 practice pipeline. One record examined feasibility in the context of routine clinical practice
13
14 369 (i.e., phase 4; figure 1),¹⁰⁹ where it was determined that ultrasound was not suitable for use in
15
16 370 their twelve-year longitudinal study due to changes in staff, equipment and software over
17
18 371 such a long time period, which introduced additional variables to the measurement process
19
20 372 that were impossible to control.¹⁰⁹

23 24 373 **Factors influencing ultrasound images and measurement methods:**

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26
27 374 The only factor that was reported to influence the imaging and measurement methods was the
28
29 375 measurement of scars with open wounds. This was reported in one record, which determined
30
31 376 that ultrasound and ultrasound gel was unsuitable in this instance. The authors of that record
32
33 377 suggested the use of a flexible transparent plastic wrap, which is placed over the
34
35 378 measurement area prior to measurement with ultrasound.²⁵

36 37 38 39 379 **Reported strengths and limitations of the measurement methods:**

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41
42 380 The safety, practicality, objectivity, versatility, reliability and non-invasive nature of
43
44 381 ultrasound were all reported as strengths of the measurement method.^{31 35-37 42 58 66 68 69 80 82 91}
45
46 382 ^{94 109 111 123 132 133 138 141 147 149 153 155 157 159} When compared to other subjective or clinical
47
48 383 measurement methods (e.g., VSS) and 3D camera, ultrasound was viewed as the superior
49
50 384 measurement method of scar and skin thickness, due to its improved accuracy, greater
51
52 385 sensitivity to change and objectivity.^{25 69 76 103 110} The ability of ultrasound to differentiate
53
54 386 between scarred and unscarred skin was also highlighted (n = 4; 3%),^{42 65 75 112} as was the

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3 387 versatility of ultrasound in its ability to measure a variety of anatomical areas and be used
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5 388 with child participants (i.e., <18 years) (n = 2; 2%).^{31 156}
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8 389 The poor correlation between ultrasound and histological thickness measurements,⁹⁵ and the
9
10 390 established inverse relationship between ultrasound penetration depth and the resolution of
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12 391 superficial structures were identified as limitations of ultrasound in the measurement of scar
13
14 392 thickness.^{34 35 82 99 153 156 157}. One record, reporting on a longitudinal study that was conducted
15
16 393 over twelve years, reported that the continuous development of ultrasound software and
17
18 394 hardware over that time limited the usefulness of ultrasound.¹⁰⁹ Despite being reported
19
20 395 elsewhere as acceptable (i.e., between one to five minutes^{25 35 112}), one record reported that
21
22 396 the time-consuming nature of measurement and the requirement for assessors to be trained in
23
24 397 the operation of, and techniques required for, ultrasonography was a limitation of the method.
25
26 398 ¹¹⁰ Methodologically, concerns were raised around the pressure caused by application of the
27
28 399 ultrasound transducer to the skin, and how that may influence thickness measurement.^{26 66 68}
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30 400 ¹⁴¹ The size of the transducer head relative to the size of scars was also considered a potential
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32 401 limitation, as multiple measurements are required for quantification of larger scars.⁹¹ Finally,
33
34 402 it was recognised that there may be a difference between changes to the scar that can be
35
36 403 measured by ultrasound, and what is felt and/or experienced by the patient.^{78 82 125 126} It was
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38 404 suggested that changes that are detectable by ultrasound may be smaller than those able to be
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40 405 detected by patients. A minimum change in scar thickness as measured by ultrasound of
41
42 406 between 1 to 6 mm is required before a patient may report noticing any difference to their
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44 407 scar thickness,^{25 78} indicating that a holistic approach to scar thickness using the patient's
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46 408 opinion as well as objective measurement through ultrasound may be beneficial.

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55 409 **Guidelines or frameworks used to guide the measurement methods:**
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3 410 No records reported using any guidelines or frameworks to inform their measurement
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5 411 methods. One record utilised suggestions from The American Wound Healing Society to
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7 412 support the measurement of contralateral, unscarred skin thickness on the same individual as
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9 413 a control or comparator.⁷⁸
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13 414 **Methodological Considerations:**

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16 415 Based on the ultrasound methods and outcomes identified in this review, a list of
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18 416 methodological considerations have been compiled (Supplementary Table 4). These are
19
20 417 intended to guide the decision-making and methodological reporting of researchers and/or
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22 418 clinicians undertaking scar or skin thickness ultrasound measurement.
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26 419 **DISCUSSION:**

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29 420 This review mapped the methods used in the published literature to measure traumatic scar
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31 421 thickness using ultrasound across the research-to-practice translational pipeline. No record
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33 422 reported their methods with sufficient detail to allow them to be independently replicated.
34
35 423 Overall, there was a lack of consistent rationale underpinning which skin layers (i.e.,
36
37 424 epidermis, dermis and combined) were measured, and little consideration was given to the
38
39 425 training and experience required by assessors. The included records mainly aligned with the
40
41 426 second and third phases of the research-to-practice pipeline (figure 1), with only three
42
43 427 reporting the use of ultrasound in routine clinical practice.^{99 104 109} This suggests a research
44
45 428 translational gap, where ultrasound is either most commonly used as an outcome measure for
46
47 429 research initiatives and is not regularly used to evaluate care once treatments are
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49 430 implemented into routine clinical practice, or that use in routine clinical practice is not
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51 431 reported or evaluated.
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57 432 While efforts have been made to standardise ultrasound measurement procedures elsewhere
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59 433 in dermatology (including tumours, cancers, vascular anomalies, and systemic sclerosis^{46 47}),
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3 434 this same effort has not yet extended to the measurement of traumatic scarring.
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5 435 Methodological standardisation has the potential to increase confidence in the use of
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7 436 ultrasound as the basis of measurement-based care initiatives for clinical decision-making,
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9 437 allowing patient care and scar treatments to be tailored towards individual needs.^{26 161 162}
10
11 438 Standardising the core methodological components of ultrasound measurement of scar
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13 439 thickness, or at the very least, creating a standardised framework for methodological
14
15 440 decision-making, may support implementation of ultrasound measurement into routine
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17 441 clinical practice, supported by strategies to overcome barriers to implementation at local sites.
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19 442 ¹⁶³
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24 443 This review identified novel insights into the identification of the composition of cutaneous
25
26 444 scars using ultrasound, and highlighted the apparent lack of consistent understanding of, or
27
28 445 rationale behind, what scar thickness characteristics were being measured. Fibrosis is
29
30 446 generally understood to be the primary cause of scar thickness through the deposition of
31
32 447 excessive extracellular matrix proteins such as collagen.^{164 165} This has been confirmed
33
34 448 through histological analysis, which has shown the presence of excess collagen and other
35
36 449 extracellular matrix proteins in the dermis of hypertrophic scars.^{40 41} An additional method
37
38 450 for assessing the effects of scarring on the dermis, as identified by one record in this review,
39
40 451 ⁴² is through quantification of the presence and density of hair follicles. This quantification
41
42 452 may serve as a method of differentiation between scarred and physiological skin, and may
43
44 453 also serve as a measure of skin function.⁴² What is less understood, and perhaps largely
45
46 454 overlooked, is the function of the epidermis in scar thickness. In the one record identified in
47
48 455 this review that directly report the measurement of the epidermis, the authors noted that the
49
50 456 measurement quantified the presence of oedema.⁴³ This was further supported by two records
51
52 457 that noted that the epidermis and dermis responded differently to treatment,^{74 92} indicating
53
54 458 that there is likely a difference in the composition of the scar between these skin layers.
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3 459 Cutaneous oedema has been observed using high-frequency ultrasound in other pathologies,
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5 460 including atopic dermatitis and skin ageing, where it is characterised by the presence of a
6
7 461 sub-epidermal low echogenic band (SLEB), which is a hyperechoic band at the
8
9 462 dermoepidermal junction.¹⁶⁶ Understanding the interplay between epidermal oedema, dermal
10
11 463 fibrosis and the presence and density of hair follicles may result in an increased
12
13 464 understanding of the mechanisms and treatment responses of cutaneous scarring. With better
14
15 465 understanding, more targeted scar treatments that inform a greater understanding of scar
16
17 466 responsivity may arise.

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22 467 Another important, but potential limiting factor for the use of ultrasound to measure scar
23
24 468 thickness raised in this review is the training and/or experience required of assessors, and the
25
26 469 ramifications this likely has on the reliability of measurements and interpretation.¹⁶⁷ This
27
28 470 review identified 24 records where assessor experience was discussed, however none made
29
30 471 any recommendations on the optimal training and/or experience. Identifying the training
31
32 472 requirements of assessors may prove an important step towards more widespread
33
34 473 implementation of reliable ultrasound scar thickness measurement in research trials and as the
35
36 474 basis for measurement-based care in routine clinical practice.²⁸ A panel of dermatological
37
38 475 and ultrasound experts has previously recommended that a physician with a minimum of 300
39
40 476 examinations per year should hold responsibility for ultrasound measurements.⁴⁶ It has also
41
42 477 been suggested that training existing members of clinical teams and standardising
43
44 478 measurement method/s may be the most effective way to achieve minimum reliability
45
46 479 standards under clinical conditions. This could allow measurement to be reliably conducted
47
48 480 within an outpatient clinic setting by a number of healthcare providers assisting workflow,
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50 481 negating the requirement for patients to wait for an experienced radiographer.^{25 28} In the
51
52 482 current review reliability estimates were generally acceptable but were tested under research
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54 483 conditions.

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3 484 **Study Limitations:**
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6 485 Only articles available in English or with an English abstract were considered for inclusion
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8 486 and data extraction, which may have resulted in the omission of eligible information. Data
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10 487 extraction was completed on the translated English abstracts of two non-English articles,
11
12 488 however the non-English articles themselves were not available to the authors, and thus could
13
14 489 not be analysed. Based on the number of records included in this review, however, it is
15
16 490 unlikely that this would have impacted review findings. An additional limitation was that
17
18 491 authors of included records were not contacted to provide clarification or further information,
19
20 492 as this was not feasible given the number of results identified. It should also be acknowledged
21
22 493 that the included records were not designed to align with the specific aims of this review,
23
24 494 which likely explains some of the lack of reporting on outcomes of interest in our review,
25
26 495 particularly clinical, health service and implementation outcomes. Furthermore, as this
27
28 496 review relied on published information (including grey literature), routine practices employed
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30 497 within organisations may not have been considered and unpublished industry sponsored
31
32 498 reports may not have been identified.
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38

39 499 It is also important to consider the limitations of ultrasound itself for the holistic
40
41 500 quantification of cutaneous scarring. Ultrasound transducers are generally small, meaning
42
43 501 that it is difficult to assess the entirety of a scar, necessitating multiple measurements.¹⁶⁸
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45 502 Additionally, thickness is often not the only scar parameter of clinical or research interest. It
46
47 503 has therefore been recommended that multi-modal measurement techniques are employed,
48
49 504 which include both subjective and objective measurements.^{169 170} However, use of these
50
51 505 methods may be challenging in routine clinical practice, due to the length of time and training
52
53 506 required. Thus, feasibility and implementation outcomes are of importance in evaluating
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55 507 measurement-based care initiatives involving ultrasound alone or multimodal measurement
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57 508 tools in scar care practice – a field in its infancy based on this review.
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3 **509 Future Directions:**
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6 510 It is intended that the results of this review will be used to inform the creation of a Delphi
7
8 511 consensus study, leading to the formation of a guideline for the measurement of traumatic
9
10 512 scar thickness using ultrasound. This guideline can then be used by researchers and clinicians
11
12 513 to standardise the measurement of scars. In preparation for this study, we have provided a list
13
14 514 of methodological considerations for assessors or practitioners when planning to conduct scar
15
16 515 thickness measurements with ultrasound (Supplementary Table 4). Future research could also
17
18 516 investigate aspects that were beyond the scope of this review including factors influencing
19
20 517 the implementation of ultrasound-based care initiatives, strategies to support implementation,
21
22 518 and how research-based initiatives could be applied in practice. Further studies are needed
23
24 519 that compare SDCs to SEMs to interpret reliability estimates to confirm our interpretation
25
26 520 that ultrasound may have the ability to detect true change or variance in scar thickness above
27
28 521 measurement error, which was based on the SDC reported by a single study. Our
29
30 522 interpretation is supported by mostly acceptable reliability estimates of ultrasound thickness
31
32 523 for other cutaneous conditions.^{29 171}
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40
41

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45
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47
48

49 **528 COMPETING INTERESTS:**
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51

52 529 The authors declare no competing interests. The research presented in this publication was
53
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55
56 531 University of Queensland.
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59

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6
7
8 535 execution of the database searches for this review.
9

10 536 **AUTHOR CONTRIBUTIONS**

11
12 537 BM and ZT conceived the project after identifying this area as a knowledge gap in existing
13
14 538 literature. BM developed the research questions and study methodology, conducted the
15
16
17 539 literature search, screened all articles and extracted data. Record screening and data
18
19 540 extraction was completed by BM, MS, TM, and TR, with additional extraction completed by
20
21 541 BD to assess consistency. MS, TM, TR and RK provided advice to BM on the clinical
22
23 542 implications of ultrasound measurement. MS, RK and ZT contributed to the supervision of
24
25 543 BM as a PhD student. BM drafted the paper, and ZT and MS provided critical appraisal of
26
27 544 the drafted manuscript, with further advice provided by TM, TR, BD and RK.
28
29

30 545 **FIGURE LEGENDS:**

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33 546 **Figure 1: Research to clinical practice pipeline.**

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36 547 **Figure 2. Preferred Reporting Items for Systematic reviews and Meta-Analyses**
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38 548 **(PRISMA) flow diagram for this study.**
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References:

1. Jagdeo J, Shumaker PR. Traumatic scarring. *JAMA Dermatol (Patient Page)* 2017;153(3):364-64. doi: 10.1001/jamadermatol.2016.5232
2. Armour A, Scott PG, Tredget EE. Cellular and molecular pathology of HTS: basis for treatment. *Wound Repair and Regeneration* 2007;15(s1):S6. doi: 10.1111/j.1524-475X.2007.00219.x
3. Eming SA, Martin P, Tomic-Canic M. Wound repair and regeneration: Mechanisms, signaling, and translation. *Sci Transl Med* 2014;6(265) doi: 10.1126/scitranslmed.3009337
4. Berman B, Maderal A, Raphael B. Keloids and hypertrophic scars: Pathophysiology, classification, and treatment. *Dermatol Surg* 2017;43 Suppl 1(sS1):S3-S18. doi: 10.1097/DSS.0000000000000819
5. Slemper AE, Kirschner RE. Keloids and scars: A review of keloids and scars, their pathogenesis, risk factors, and management. *Curr Opin Pediatr* 2006;18(4):396-402. doi: 10.1097/01.mop.0000236389.41462.ef
6. Lawrence WJ, Mason TS, Schomer BK, et al. Epidemiology and Impact of Scarring After Burn Injury: A Systematic Review of the Literature. *Journal of Burn Care & Research* 2012;33(1):136-46. doi: 10.1097/BCR.0b013e3182374452
7. Bayat A, McGrouther DA, Ferguson MWJ. Skin scarring. *BMJ* 2003;326(7380):88-92. doi: 10.1136/bmj.326.7380.88
8. Lee H, Jang Y. Recent Understandings of Biology, Prophylaxis and Treatment Strategies for Hypertrophic Scars and Keloids. *Int J Mol Sci* 2018;19(3) doi: 10.3390/ijms19030711
9. Rabello FB, Souza CD, Farina Júnior JA. Update on hypertrophic scar treatment. *Clinics* 2014;69(8):565-73. doi: 10.6061/clinics/2014(08)11
10. English RS, Shenefelt PD. Keloids and Hypertrophic Scars. Boston, MA, USA: Blackwell Science Inc, 1999:631-38.
11. Niessen BF, Spauwen HMP, Schalkwijk HMJ, et al. On the Nature of Hypertrophic Scars and Keloids: A Review. *Plastic and Reconstructive Surgery* 1999;104(5):1435-58. doi: 10.1097/00006534-199910000-00031
12. Simons M, Price N, Kimble R, et al. Patient experiences of burn scars in adults and children and development of a health-related quality of life conceptual model: A qualitative study. *Burns* 2016;42(3):620-32. doi: 10.1016/j.burns.2015.11.012
13. Tyack Z, Ziviani J, Kimble R, et al. Measuring the impact of burn scarring on health-related quality of life: Development and preliminary content validation of the Brisbane Burn Scar Impact Profile (BBSIP) for children and adults. *Burns* 2015;41(7):1405-19. doi: 10.1016/j.burns.2015.05.021
14. Sullivan T, Smith J, Kermode J, et al. Rating the burn scar. *J Burn Care Rehabil* 1990;11(3):256-60. doi: 10.1097/00004630-199005000-00014
15. Draaijers JL, Tempelman RHF, Botman AMY, et al. The patient and observer scar assessment scale: A reliable and feasible tool for scar evaluation. *Plast Reconstr Surg* 2004;113(7):1960-65. doi: 10.1097/01.PRS.0000122207.28773.56
16. Tyack Z, Wasiak J, Spinks A, et al. A guide to choosing a burn scar rating scale for clinical or research use. *Burns* 2013;39(7):1341-50. doi: 10.1016/j.burns.2013.04.021
17. Gold HM, McGuire AM, Mustoe AT, et al. Updated international clinical recommendations on scar management: Part 2 - Algorithms for scar prevention and treatment. *Dermatol Surg* 2014;40(8):825-31. doi: 10.1111/dsu.0000000000000050
18. Jones LL, Calvert M, Moiemien N, et al. Outcomes important to burns patients during scar management and how they compare to the concepts captured in burn-specific patient reported outcome measures. *Burns* 2017;43(8):1682-92. doi: 10.1016/j.burns.2017.09.004
19. McGarry S, Elliott C, McDonald A, et al. Paediatric burns: From the voice of the child. *Burns* 2014;40(4):606-15. doi: 10.1016/j.burns.2013.08.031

- 1
2
3 600 20. Bloemen MCT, van Der Veer WM, Ulrich MMW, et al. Prevention and curative management of
4 601 hypertrophic scar formation. *Burns* 2009;35(4):463-75. doi: 10.1016/j.burns.2008.07.016
5 602
6 603 21. Lee KC, Bamford A, Gardiner F, et al. Investigating the intra- and inter-rater reliability of a panel
7 604 of subjective and objective burn scar measurement tools. *Burns* 2019;45(6):1311-24. doi:
8 605 10.1016/j.burns.2019.02.002
9 606 22. Brusselaers N, Pirayesh A, Hoeksema H, et al. Burn Scar Assessment: A Systematic Review of
10 607 Different Scar Scales. *Journal of Surgical Research* 2010;164(1):e115-e23. doi:
11 608 10.1016/j.jss.2010.05.056
12 609 23. Brusselaers N, Pirayesh A, Hoeksema H, et al. Burn scar assessment: A systematic review of
13 610 objective scar assessment tools. *Burns* 2010;36(8):1157-64. doi:
14 611 10.1016/j.burns.2010.03.016
15 612 24. Hambleton J, Shakespeare PG, Pratt BJ. The progress of hypertrophic scars monitored by
16 613 ultrasound measurements of thickness. *Burns* 1992;18(4):301-07. doi: 10.1016/0305-
17 614 4179(92)90151-J
18 615 25. Simons M, Kee EG, Kimble R, et al. Ultrasound is a reproducible and valid tool for measuring scar
19 616 height in children with burn scars: A cross-sectional study of the psychometric properties
20 617 and utility of the ultrasound and 3D camera. *Burns* 2017;43(5):993-1001. doi:
21 618 10.1016/j.burns.2017.01.034
22 619 26. Issler-Fisher AC, Fisher OM, Haertsch P, et al. Ablative fractional resurfacing with laser-facilitated
23 620 steroid delivery for burn scar management: Does the depth of laser penetration matter?
24 621 *Lasers Surg Med* 2020;52(2):149-58. doi: 10.1002/lsm.23166
25 622 27. Sonsbeek AMSv, Hutschemaekers GJM, Veerman JW, et al. The results of clinician-focused
26 623 implementation strategies on uptake and outcomes of Measurement-Based Care (MBC) in
27 624 general mental health care. *BMC Health Serv Res* 2023;23(1):326-26. doi: 10.1186/s12913-
28 625 023-09343-5
29 626 28. Russell FM, Herbert A, Ferre RM, et al. Development and implementation of a point of care
30 627 ultrasound curriculum at a multi-site institution. *Ultrasound J* 2021;13(1):9-9. doi:
31 628 10.1186/s13089-021-00214-w
32 629 29. Li H, Furst DE, Jin H, et al. High-frequency ultrasound of the skin in systemic sclerosis: an
33 630 exploratory study to examine correlation with disease activity and to define the minimally
34 631 detectable difference. *Arthritis Res Ther* 2018;20(1):181-81. doi: 10.1186/s13075-018-1686-
35 632 9
36 633 30. Cambiaso-Daniel J, Suman OE, Jaco M, et al. Teamwork for Total Burn Care: Burn Centers and
37 634 Multidisciplinary Burn Teams. In: Herndon DN, ed. *Total Burn Care*. 5 ed. China: Elsevier
38 635 2018:8-13.
39 636 31. Gee Kee EL, Kimble RM, Cuttle L, et al. Scar outcome of children with partial thickness burns: A 3
40 637 and 6 month follow up. *Burns* 2016;42(1):97-103. doi: 10.1016/j.burns.2015.06.019
41 638 32. Wang X-Q, Mill J, Kravchuk O, et al. Ultrasound assessed thickness of burn scars in association
42 639 with laser Doppler imaging determined depth of burns in paediatric patients. *Burns*
43 640 2010;36(8):1254-62. doi: 10.1016/j.burns.2010.05.018
44 641 33. Izzetti R, Vitali S, Aringhieri G, et al. Ultra-high frequency ultrasound, a promising diagnostic
45 642 technique: review of the literature and single-center experience. *Can Assoc Radiol J*
46 643 2021;72(3):418-31. doi: 10.1177/0846537120940684
47 644 34. Agabalyan NA, Su S, Sinha S, et al. Comparison between high-frequency ultrasonography and
48 645 histological assessment reveals weak correlation for measurements of scar tissue thickness.
49 646 *Burns* 2016;43(3):531-38. doi: 10.1016/j.burns.2016.09.008
50 647 35. Kim JD, Oh SJ, Kim SG, et al. Ultrasonographic findings of re-epithelialized skin after partial-
51 648 thickness burns. *Burns Trauma* 2018;6(1):21-21. doi: 10.1186/s41038-018-0122-3
52 649 36. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in burn
53 650 scars using high frequency ultrasound. *J Burn Care Res* 2012;33(2):S105.
54
55
56
57
58
59
60

- 1
2
3 650 37. Ud-Din S, Foden P, Stocking K, et al. Objective assessment of dermal fibrosis in cutaneous
4 651 scarring, using optical coherence tomography, high-frequency ultrasound and
5 652 immunohistomorphometry of human skin. *Br J Dermatol* 2019;181(4):722-32. doi:
6 653 10.1111/bjd.17739
- 7 654 38. Du Y-C, Lin C-M, Chen Y-F, et al. Implementation of a burn scar assessment system by ultrasound
8 655 techniques. *Conf Proc IEEE Eng Med Biol Soc* 2006:2328-31. doi:
9 656 10.1109/IEMBS.2006.260018
- 10 657 39. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and hypertrophic
11 658 scar assessment. *Lasers Med Sci* 2019;35(2):379-85. doi: 10.1007/s10103-019-02830-4
- 12 659 40. Kwan P, Desmouliere A, Tredget EE. Molecular and cellular basis of hypertrophic scarring. In:
13 660 Herndon DN, ed. *Total Burn Care*. 5 ed. China: Elsevier 2018:455-65.
- 14 661 41. Hellström M, Hellström S, Engström-Laurent A, et al. The structure of the basement membrane
15 662 zone differs between keloids, hypertrophic scars and normal skin: A possible background to
16 663 an impaired function. *J Plast Reconstr Aesthet Surg* 2014;67(11):1564-72. doi:
17 664 10.1016/j.bjps.2014.06.014
- 18 665 42. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal tissue
19 666 thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res*
20 667 2020;41(2):421-26. doi: 10.1093/jbcr/irz191
- 21 668 43. Fabbrocini G, Marasca C, Ammad S, et al. Assessment of the combined efficacy of needling and
22 669 the use of silicone gel in the treatment of C-section and other surgical hypertrophic scars
23 670 and keloids. *Adv Skin Wound Care* 2016;29(9):408-11. doi:
24 671 10.1097/01.ASW.0000490028.37994.14
- 25 672 44. Jasaitiene D, Valiukeviciene S, Linkeviciute G, et al. Principles of high-frequency ultrasonography
26 673 for investigation of skin pathology. *J Eur Acad Dermatol Venereol* 2011;25(4):375-82. doi:
27 674 10.1111/j.1468-3083.2010.03837.x
- 28 675 45. Rodríguez Bandera AI, Sebaratnam DF, Feito Rodríguez M, et al. Cutaneous ultrasound and its
29 676 utility in pediatric dermatology. Part I: Lumps, bumps, and inflammatory conditions. *Pediatr*
30 677 *Dermatol* 2020;37(1):29-39. doi: 10.1111/pde.14033
- 31 678 46. Wortsman X, Alfageme F, Roustan G, et al. Guidelines for performing dermatologic ultrasound
32 679 examinations by the DERMUS Group. *J Ultrasound Med* 2016;35(3):577-80. doi:
33 680 10.7863/ultra.15.06046
- 34 681 47. Vanhaecke A, Cutolo M, Heeman L, et al. High frequency ultrasonography: Reliable tool to
35 682 measure skin fibrosis in SSC? A systematic literature review and additional pilot study.
36 683 *Rheumatology (Oxford)* 2022;61(1):42-52. doi: 10.1093/rheumatology/keab462
- 37 684 48. Meikle B, Kimble RM, Tyack Z. Ultrasound measurements of pathological and physiological skin
38 685 thickness: A scoping review protocol. *BMJ Open* 2022;12(1):e056720-e20. doi:
39 686 10.1136/bmjopen-2021-056720
- 40 687 49. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res*
41 688 *Methodol* 2005;8(1):19-32. doi: 10.1080/1364557032000119616
- 42 689 50. Haddaway NR, Collins AM, Coughlin D, et al. The role of google scholar in evidence reviews and
43 690 its applicability to grey literature searching. *PLoS One* 2015;10(9):e0138237-e37. doi:
44 691 10.1371/journal.pone.0138237
- 45 692 51. Australian Government Department of Health and Aged Care Medical Research Future Fund.
46 693 Research Translation Australia2022 [Available from: <https://www.health.gov.au/our-work/medical-research-future-fund/mrff-research-themes/research-translation#what-is-the-research-pipeline> accessed 29/05/2023].
- 47 694 52. Proctor E, Proctor E, Silmere H, et al. Outcomes for Implementation Research: Conceptual
48 695 Distinctions, Measurement Challenges, and Research Agenda. *Adm Policy Ment Health*
49 696 2011;38(2):65-76. doi: 10.1007/s10488-010-0319-7
- 50
51
52
53
54
55
56
57
58
59
60

- 1
2
3 699 53. Prinsen CAC, Vohra S, Rose MR, et al. How to select outcome measurement instruments for
4 700 outcomes included in a "Core Outcome Set" - a practical guideline. *Trials*
5 701 2016;17:urn:issn:1745-6215.
6 702
7 702 54. Mokkink LB, Boers M, van der Vleuten CPM, et al. COSMIN Risk of Bias tool to assess the quality
8 703 of studies on reliability or measurement error of outcome measurement instruments: a
9 704 Delphi study. *BMC Med Res Methodol* 2020;20(1):1-13. doi: 10.1186/s12874-020-01179-5
10 705
11 706 55. Terwee CB, Bot SDM, de Boer MR, et al. Quality criteria were proposed for measurement
12 707 properties of health status questionnaires. *J Clin Epidemiol* 2007;60(1):34-42. doi:
13 708 10.1016/j.jclinepi.2006.03.012
14 709
15 710 56. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for
16 711 reporting systematic reviews. *BMJ* 2021;372:n71-n71. doi: 10.1136/bmj.n71
17 712
18 712 57. Cai L, Hu M, Lin L, et al. Evaluation of the efficacy of triamcinolone acetone in the treatment of
19 713 keloids by high-frequency ultrasound. *Skin Res Technol* 2020;26(4):489-93. doi:
20 714 10.1111/srt.12820
21 715
22 716 58. Chae JK, Kim JH, Kim EJ, et al. Values of a patient and observer scar assessment scale to evaluate
23 717 the facial skin graft scar. *Ann Dermatol* 2016;28(5):615-23. doi: 10.5021/ad.2016.28.5.615
24 718
25 719 59. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn Care*
26 720 *Res* 2018;39(suppl_1):S219-S20. doi: 10.1093/jbcr/iry006.416
27 721
28 722 60. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
29 723 Construct validity and predictive ability of scar thickness change. *Skin Res Technol*
30 724 2020;26(3):369-75. doi: 10.1111/srt.12812
31 725
32 726 61. Deng K, Xiao H, Liu X, et al. Strontium-90 brachytherapy following intralesional triamcinolone and
33 727 5-fluorouracil injections for keloid treatment: A randomized controlled trial. *PLoS One*
34 728 2021;16(3):e0248799. doi: 10.1371/journal.pone.0248799
35 729
36 730 62. Dunkin CSJ, Pleat JM, Gillespie PH, et al. Scarring occurs at a critical depth of skin injury: Precise
37 731 measurement in a graduated dermal scratch in human volunteers. *Plast Reconstr Surg*
38 732 2007;119(6):1722-32. doi: 10.1097/01.prs.0000258829.07399.f0
39 733
40 734 63. Fracalvieri M, Zingarelli E, Ruka E, et al. Negative pressure wound therapy using gauze and
41 735 foam: histological, immunohistochemical and ultrasonography morphological analysis of the
42 736 granulation tissue and scar tissue. Preliminary report of a clinical study. *Int Wound J*
43 737 2011;8(4):355-64. doi: 10.1111/j.1742-481X.2011.00798.x
44 738
45 739 64. Huang P-W, Lu C-W, Chu K-T, et al. Assessing thickness of burn scars through ultrasound
46 740 measurement for patients with arm burns. *J Med Biol Eng* 2021;41(1):84-91. doi:
47 741 10.1007/s40846-020-00592-x
48 742
49 743 65. Huang S-Y, Xiang X, Guo R-Q, et al. Quantitative assessment of treatment efficacy in keloids using
50 744 high-frequency ultrasound and shear wave elastography: a preliminary study. *Sci Rep*
51 745 2020;10(1):1375-75. doi: 10.1038/s41598-020-58209-x
52 746
53 747 66. Issler-Fisher AC, Fisher OM, Haertsch PA, et al. Effectiveness and safety of ablative fractional CO2
54 748 laser for the treatment of burn scars: A case-control study. *Burns* 2021;47(4):785-95. doi:
55 749 10.1016/j.burns.2020.10.002
56 750
57 751 67. Joo SY, Lee SY, Cho YS, et al. Clinical utility of extracorporeal shock wave therapy on hypertrophic
58 752 scars of the hand caused by burn injury: A prospective, randomized, double-blinded study. *J*
59 753 *Clin Med* 2020;9(5):1376. doi: 10.3390/jcm9051376
60 754
61 755 68. Kemp Bohan PM, Cooper LE, Lu KN, et al. Fractionated ablative carbon dioxide laser therapy
62 756 decreases ultrasound thickness of hypertrophic burn scar: A prospective process
63 757 improvement initiative. *Ann Plast Surg* 2020;86(3):273-78. doi:
64 758 10.1097/SAP.0000000000002517
65 759
66 760 69. Lee KC, Bamford A, Gardiner F, et al. Burns objective scar scale (BOSS): Validation of an objective
67 761 measurement devices based burn scar scale panel. *Burns* 2020;46(1):110-20. doi:
68 762 10.1016/j.burns.2019.05.008
69
70

1
2
3
4
5
6
7
8
9
10
11
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13
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41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

70. Li JQ, Li-Tsang CWP, Huang YP, et al. Detection of changes of scar thickness under mechanical loading using ultrasonic measurement. *Burns* 2012;39(1):89-97. doi: 10.1016/j.burns.2012.05.009
71. Li P, Li-Tsang CWP, Deng X, et al. The recovery of post-burn hypertrophic scar in a monitored pressure therapy intervention programme and the timing of intervention. *Burns* 2018;44(6):1451-67. doi: 10.1016/j.burns.2018.01.008
72. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its characteristics among the Chinese population. *Burns* 2005;31(5):610-16. doi: 10.1016/j.burns.2005.01.022
73. Mamdouh M, Omar GA, Hafiz HSA, et al. Role of vitamin D in treatment of keloid. *J Cosmet Dermatol* 2022;21(1):331-36. doi: 10.1111/jocd.14070
74. Meirte J, Moortgat P, Anthonissen M, et al. Short-term effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an experimental study. *Burns Trauma* 2016;4:27-27. doi: 10.1186/s41038-016-0052-x
75. Nedelec B, Correa JA, de Oliveira A, et al. Longitudinal burn scar quantification. *Burns* 2014;40(8):1504-12. doi: 10.1016/j.burns.2014.03.002
76. Nedelec B, Correa JA, Rachelska G, et al. Quantitative measurement of hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res* 2008;29(3):501-11. doi: 10.1097/BCR.0b013e3181710881
77. Nedelec B, Couture M-A, Calva V, et al. Randomized controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns* 2019;45(1):128-39. doi: 10.1016/j.burns.2018.08.018
78. Nedelec B, LaSalle L, de Oliveira A, et al. Within-patient, single-blinded, randomized controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res* 2020;41(4):761-69. doi: 10.1093/jbcr/iraa057
79. Reinholz M, Guertler A, Schwaiger H, et al. Treatment of keloids using 5-fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol* 2020;34(10):2436-44. doi: 10.1111/jdv.16354
80. Schwaiger H, Reinholz M, Poetschke J, et al. Evaluating the therapeutic success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive objective measures. *Dermatol Surg* 2018;44(5):635-44. doi: 10.1097/DSS.0000000000001427
81. Soykan EA, Butzelaar L, de Kroon TL, et al. Minimal extracorporeal circulation (MECC) does not result in less hypertrophic scar formation as compared to conventional extracorporeal circulation (CECC) with dexamethasone. *Perfusion* 2014;29(3):249-59. doi: 10.1177/0267659113511656
82. Timar-Banu O, Beauregard H, Tousignant J, et al. Development of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scar in humans. *Wound Repair Regen* 2001;9(2):123-32. doi: 10.1046/j.1524-475x.2001.00123.x
83. van der Veer WM, Ferreira JA, de Jong EH, et al. Perioperative conditions affect long-term hypertrophic scar formation. *Ann Plast Surg* 2010;65(3):321-25. doi: 10.1097/SAP.0b013e3181c60f88
84. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix. *Burns* 2008;35(3):352-55. doi: 10.1016/j.burns.2008.06.021
85. Lee SY, Cho YS, Kim L, et al. The Intra-rater reliability and validity of ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns* 2022 doi: 10.1016/j.burns.2022.03.016
86. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on third-degree burns through ultrasonic measurement. *J Cytol Histol* 2017;8(5) doi: 10.4172/2157-7099.1000488

- 1
2
3 800 87. Van den Kerckhove E, Stappaerts K, Fieuws S, et al. The assessment of erythema and thickness on
4 801 burn related scars during pressure garment therapy as a preventive measure for
5 802 hypertrophic scarring. *Burns* 2005;31(6):696-702. doi: 10.1016/j.burns.2005.04.014
6 803
7 804 88. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic scar
8 805 in a Chinese population. *Burns* 2010;36(8):1234-41. doi: 10.1016/j.burns.2010.05.008
9 806
10 806 89. Deng H, Tan T, Luo G, et al. Vascularity and thickness changes in immature hypertrophic scars
11 807 treated with a pulsed dye laser. *Lasers Surg Med* 2021;53(7):914-21. doi: 10.1002/lsm.23366
12 808
13 808 90. Li-Tsang CWP, Lau JCM, Choi J, et al. A prospective randomized clinical trial to investigate the
14 809 effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among the
15 810 Chinese population. *Burns* 2006;32(6):678-83. doi: 10.1016/j.burns.2006.01.016
16 811
17 812 91. Gankande TU, Duke JM, Danielsen PL, et al. Reliability of scar assessments performed with an
18 813 integrated skin testing device – The DermaLab Combo. *Burns* 2014;40(8):1521-29. doi:
19 814 10.1016/j.burns.2014.01.025
20 815
21 816 92. Li N, Yang L, Cheng J, et al. Early intervention by Z-plasty combined with fractional CO2 laser
22 817 therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet Surg*
23 818 2021;74(11):3087-93. doi: 10.1016/j.bjps.2021.03.079
24 819
25 819 93. Blome-Eberwein S, Gogal C, Weiss MJ, et al. Prospective evaluation of fractional CO2 laser
26 820 treatment of mature burn scars. *J Burn Care Res* 2016;37(6):379-87. doi:
27 821 10.1097/BCR.0000000000000383
28 822
29 823 94. Van den Kerckhove E, Staes F, Flour M, et al. Reproducibility of repeated measurements on post-
30 824 burn scars with Dermascan C. *Skin Res Technol* 2003;9(1):81-84. doi: 10.1034/j.1600-
31 825 0846.2003.00375.x [published Online First: Accepted for publication 3 April 2002]
32 826
33 826 95. Agabalyan NA, Su S, Sinha V, et al. Evaluating high frequency ultrasonography for the non-
34 827 invasive measurement of human scarring. *J Burn Care Res* 2016;37
35 828
36 829 96. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers Med*
37 830 *Sci* 2017;33(3):497-501. doi: 10.1007/s10103-017-2387-3
38 831
39 832 97. Alsharnoubi J, Shoukry KE-S, Fawzy MW, et al. Evaluation of scars in children after treatment
40 833 with low-level laser. *Lasers Med Sci* 2018;33(9):1991-95. doi: 10.1007/s10103-018-2572-z
41 834
42 834 98. Bajouri A, Kajoor AS, Fallah N, et al. Autologous human stromal vascular fraction injection in
43 835 post-burn hypertrophic scar: A double-blinded placebo-controlled clinical trial. *Bioimpacts*
44 836 2018;8:37-38.
45 837
46 838 99. Berry RB, Tan OT, Cooke ED, et al. Transcutaneous oxygen tension as an index of maturity in
47 839 hypertrophic scars treated by compression. *Br J Plast Surg* 1985;38(2):163-73. doi:
48 840 10.1016/0007-1226(85)90045-1
49 841
50 842 100. Blome-Eberwein S, Roarabaugh C, Gogal C, et al. Exploration of nonsurgical scar modification
51 843 options: Can the irregular surface of matured mesh graft scars be smoothed with
52 844 microdermabrasion? *J Burn Care Res* 2012;33(3):e133-40.
53 845
54 845 101. Blome-Eberwein S, Pagella P, Boorse D, et al. Treatment of hypertrophic burn scars with
55 846 different laser modalities. *Lasers Surg Med* 2014;46:6-7.
56 847
57 848 102. Chan HH, Wong DSY, Ho WS, et al. The use of pulsed dye laser for the prevention and treatment
58 849 of hypertrophic scars in Chinese persons. *Dermatol Surg* 2004;30(7):987-94. doi:
59 850 10.1111/j.1524-4725.2004.30303.x
60 851
61 851 103. Cheng W, Saing H, Zhou H, et al. Ultrasound assessment of scald scars in Asian children
62 852 receiving pressure garment therapy. *J Pediatr Surg* 2001;36(3):466-69. doi:
63 853 10.1053/jpsu.2001.21613
64 854
65 854 104. Cho J, Choi J, Hur J, et al. The effect of CO2 fractional laser (pixel®) on hypertrophic burn scars. *J*
66 855 *Burn Care Res* 2012;33(2):S132.
67 856
68 857 105. Cho J, Jang Y, Hur J, et al. Effectiveness of emu oil on burn scar. *J Burn Care Res* 2012;33(2):S71.
69 858
70 858 106. Cho YS, Jeon JH, Hong A, et al. The effect of burn rehabilitation massage therapy on
hypertrophic scar after burn: A randomized controlled trial. *Burns* 2014;40(8):1513-20. doi:
10.1016/j.burns.2014.02.005

- 1
2
3 851 107. Cooper LE, Bohan PK, Hatem VD, et al. Analysis of the utility of CO2 and pulse-dye lasers in the
4 852 treatment of hypertrophic burn scars. *J Burn Care Res* 2021;42(Supplement_1):S28-S29. doi:
5 853 10.1093/jbcr/irab032.041
6
7 854 108. Danin A, Georgesco G, Le Touze A, et al. Assessment of burned hands reconstructed with
8 855 Integra® by ultrasonography and elastometry. *Burns* 2012;38(7):998-1004. doi:
9 856 10.1016/j.burns.2012.02.017
10 857 109. Engrav LH, Heimbach DM, Rivara FP, et al. 12-Year within-wound study of the effectiveness of
11 858 custom pressure garment therapy. *Burns* 2010;36(7):975-83. doi:
12 859 10.1016/j.burns.2010.04.014
13 860 110. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of
14 861 postburn hypertrophic scar: A preliminary study. *Burns* 1997;23(1):S12-S18. doi:
15 862 10.1016/S0305-4179(96)00095-2
16 863 111. George R, Siordia H, Buhler J, et al. The use of high frequency ultrasound to monitor treatment
17 864 of hypertrophic burn scars with fractionated ablative CO2 laser therapy. *J Burn Care Res*
18 865 2019;40(Supplement_1):S135-S35. doi: 10.1093/jbcr/irz013.229
19 866 112. Katz SM, Frank DH, Leopold GR, et al. Objective measurement of hypertrophic burn scar: A
20 867 preliminary study of tonometry and ultrasonography. *Ann Plast Surg* 1985;14(2):121-27. doi:
21 868 10.1097/0000637-198502000-00005
22 869 113. Kim SK, Park JM, Jang YH, et al. Management of hypertrophic scar after burn wound using
23 870 microneedling procedure (dermastamp). *Burns* 2009;35:S37-S37. doi:
24 871 10.1016/j.burns.2009.06.146
25 872 114. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-monitored
26 873 suit in the management of post-burn hypertrophic scar: A clinical controlled study with
27 874 objective assessment. *J Burn Care Res* 2016;37:S199.
28 875 115. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar
29 876 reconstruction: An extensive subjective and objective short-term outcome analysis of a
30 877 prospective treatment cohort. *Burns* 2017;43(3):573-82. doi: 10.1016/j.burns.2016.09.014
31 878 116. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes of
32 879 burn scars treated with laser therapy. *J Burn Care Res* 2016;37:S106.
33 880 117. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and related
34 881 research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns)* 2010;26(6):411-5.
35 882 118. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the
36 883 efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult
37 884 burn patients. *J Am Acad Dermatol* 2017;76(6):AB212-AB12. doi:
38 885 10.1016/j.jaad.2017.04.1113
39 886 119. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for
40 887 hypertrophic burn scars: A prospective study of objective and subjective outcomes. *Ann Surg*
41 888 2021;274(6):E574-E80. doi: 10.1097/SLA.0000000000003576
42 889 120. Moortgat P, Vanhullebusch T, Anthonissen M, et al. Tension reducing taping as a
43 890 mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot study. *Wound*
44 891 *Repair Regen* 2020;28(2):A21.
45 892 121. Nedelec B, Couture M, Calva V, et al. Randomized controlled trial of the immediate and long-
46 893 term effect of massage on adult postburn scar. *J Burn Care Res* 2018;39(suppl_1):S57-S57.
47 894 doi: 10.1093/jbcr/iry006.106
48 895 122. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report.
49 896 *Wound Repair Regen* 2018;26(2):A28-A28.
50 897 123. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res*
51 898 2011;32:S167-S67.
52 899 124. Siwy KG, Lee K, Donelan MB, et al. Fractionated CO2 laser and burn scar contractures:
53 900 Evaluation of post treatment scar function and appearance. *J Burn Care Res* 2016;37:S202-
54 901 S02.

- 1
2
3 902 125. Wiseman J, Simons M, Kimble R, et al. Effectiveness of topical silicone gel and pressure garment
4 903 therapy for burn scar prevention and management in children 12-months postburn: A
5 904 parallel group randomised controlled trial. *Clin Rehabil* 2021;35(8):1126-41. doi:
6 905 10.1177/02692155211020351
7
8 906 126. Wiseman J, Ware RS, Simons M, et al. Effectiveness of topical silicone gel and pressure garment
9 907 therapy for burn scar prevention and management in children: a randomized controlled trial.
10 908 *Clin Rehabil* 2020;34(1):120-31. doi: 10.1177/0269215519877516
11 909 127. Wood FM, Currie K, Backman B, et al. Current difficulties and the possible future directions in
12 910 scar assessment. *Burns* 1996;22(6):455-58. doi: 10.1016/0305-4179(95)00168-9
13 911 128. Żądkowski T, Nachulewicz P, Mazgaj M, et al. A new CO2 laser technique for the treatment of
14 912 pediatric hypertrophic burn scars: An observational study. *Medicine (Baltimore)*
15 913 2016;95(42):e5168-e68. doi: 10.1097/MD.0000000000005168
16 914 129. Zuccaro J, Kelly C, Perez M, et al. The effectiveness of laser therapy for hypertrophic burn scars
17 915 in pediatric patients: A prospective investigation. *J Burn Care Res* 2021;42(5):847-56. doi:
18 916 10.1093/jbcr/irab090
19 917 130. Zuccaro J, Perez M, Mohanta A, et al. Elastography-Based Quantification of Burn Scar Stiffness. *J*
20 918 *Burn Care Res* 2019;40(Supplement_1):S215-S15. doi: 10.1093/jbcr/irz013.374
21 919 131. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, et al. Objective quantification of hypertrophic
22 920 scar and donor scar between 2 to 7 months post-burn injury. *J Burn Care Res* 2022;43:S103.
23 921 132. Anthonissen M, Meirte J, Moortgat P, et al. Intrarater and interrater reliability of an open
24 922 22MHz ultrasound scanning system to assess thickness and density of burn scars. *Ann Burns*
25 923 *Fire Disasters* 2015;28
26 924 133. Yim H, Cho YS, Seo CH, et al. The use of AlloDerm on major burn patients: AlloDerm prevents
27 925 post-burn joint contracture. *Burns* 2009;36(3):322-28. doi: 10.1016/j.burns.2009.10.018
28 926 134. Alshehari A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid
29 927 injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars.
30 928 *Archives of the Balkan Medical Union* 2015;50(3):364-66.
31 929 135. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
32 930 scarring. *Lasers Surg Med* 2012;44:61.
33 931 136. Blome-Eberwein S, Blaine C, Gogal C, et al. Fractional Er:Glass photothermolysis laser therapy to
34 932 treat hypertrophic scarring. *J Burn Care Res* 2011;32:S95.
35 933 137. Chang C-S, Wallace CG, Hsiao Y-C, et al. Botulinum toxin to improve results in cleft lip repair: A
36 934 double-blinded, randomized, vehicle-controlled clinical trial. *PLoS One* 2014;9(12):e115690-
37 935 e90. doi: 10.1371/journal.pone.0115690
38 936 138. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, et al. Ultrasound biomicroscopy in
39 937 the diagnosis of skin diseases. *Eur J Dermatol* 2007;17(6):469-74.
40 938 139. Fracalvieri M, Sarno A, Gasperini S, et al. Can single use negative pressure wound therapy be
41 939 an alternative method to manage keloid scarring? A preliminary report of a clinical and
42 940 ultrasound/colour-power-doppler study. *Int Wound J* 2013;10(3):340-44. doi:
43 941 10.1111/j.1742-481X.2012.00988.x
44 942 140. Jang KU, Lee JY, Choi JS, et al. 5 FU and triamcinolone injection to the hypertrophic scar were
45 943 compared. *Burns* 2009;35:S41-S42. doi: 10.1016/j.burns.2009.06.166
46 944 141. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS) in
47 945 objective scar evaluation. *Burns* 2005;31(4):445-52. doi: 10.1016/j.burns.2004.07.016
48 946 142. Li K, Nicoli F, Cui C, et al. Treatment of hypertrophic scars and keloids using an intralesional
49 947 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive technique. *Sci Rep*
50 948 2020;10(1):21694-94. doi: 10.1038/s41598-020-78738-9
51 949 143. Li N, Yang L, Cheng J, et al. A retrospective study to identify the optimal parameters for pulsed
52 950 dye laser in the treatment of hypertrophic burn scars in Chinese children with Fitzpatrick
53 951 skin types III and IV. *Lasers Med Sci* 2021;36(8):1671-79. doi: 10.1007/s10103-021-03252-x
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3 952 144. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case
4 953 review. *J Burn Care Res* 2011;32:S169-S69.
- 5 954 145. Nicoletti G, Brenta F, Bleve M, et al. Long-term in vivo assessment of bioengineered skin
6 955 substitutes: a clinical study. *J Tissue Eng Regen Med* 2015;9(4):460-68. doi:
7 956 10.1002/term.1939
- 8 957 146. Niessen FB, Spauwen PHM, Robinson PH, et al. The use of silicone occlusive sheeting (Sil-K) and
9 958 silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation. *Plast*
10 959 *Reconstr Surg* 1998;102(6):1962-72. doi: 10.1097/00006534-199811000-00023
- 11 960 147. Tu P, Wang Z-G, Zhang Q-X, et al. High frequency ultrasound in dynamic observation on effect
12 961 of local injection with diprospan for treating pathological scar. *Chinese Journal of*
13 962 *Interventional Imaging and Therapy* 2014;11(4):217-20.
- 14 963 148. Ud-Din S, Foden P, Douglas M, et al. A double-blind randomized controlled trial demonstrates
15 964 for the first time evidence for the role of topical epigallocatechin-3-gallate in reducing
16 965 angiogenesis, inflammation, and skin thickness in human skin scarring: A noninvasive,
17 966 morphological and immu. *Wound Repair and Regeneration* 2017;25(4):A3.
- 18 967 149. Lacarrubba F, Patania L, Perrotta R, et al. An open-label pilot study to evaluate the efficacy and
19 968 tolerability of a silicone gel in the treatment of hypertrophic scars using clinical and
20 969 ultrasound assessments. *J Dermatolog Treat* 2008;19(1):50-53. doi:
21 970 10.1080/09546630701387009
- 22 971 150. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone gel
23 972 dressing and pressure therapy on posttraumatic hypertrophic scars. *J Burn Care Res*
24 973 2010;31(3):448-57. doi: 10.1097/BCR.0b013e3181db52a7
- 25 974 151. Zhidong X, Haixia L, Chao L, et al. Wavelet Bilateral Filter Algorithm-Based High-Frequency
26 975 Ultrasound Image Analysis on Effects of Skin Scar Repair. *Scientific programming* 2021;2021
27 976 doi: 10.1155/2021/9573474
- 28 977 152. Avetikov DS, Bukhanchenko OP, Skikevich MG, et al. Features of ultrasound diagnostics of
29 978 postoperative hypertrophic and keloid scars. *The New Armenian Medical Journal*
30 979 2018;12(4):43-48.
- 31 980 153. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and
32 981 diagnostics. *J Dermatol Nurses Assoc* 2020;12(2)
- 33 982 154. Bezugly A, Potekaev N. In vivo skin morphology monitoring of patients with acne, scars and
34 983 dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol* 2014;41:4.
- 35 984 155. Guo R, Xiang X, Wang L, et al. Quantitative assessment of keloids using ultrasound shear wave
36 985 elastography. *Ultrasound Med Biol* 2020;46(5):1169-78. doi:
37 986 10.1016/j.ultrasmedbio.2020.01.010
- 38 987 156. Lobos N, Wortsman X, Valenzuela F, et al. Color Doppler ultrasound assessment of activity in
39 988 keloids. *Dermatol Surg* 2017;43(6):817-25. doi: 10.1097/DSS.0000000000001052
- 40 989 157. Reinholz M, Schwaiger H, Poetschke J, et al. Objective and subjective treatment evaluation of
41 990 scars using optical coherence tomography, sonography, photography, and standardised
42 991 questionnaires. *Eur J Dermatol* 2017;26(6):599-608. doi: 10.1684/ejd.2016.2873
- 43 992 158. Timina I, Sharobaro V, Trykova I. A potential of the high-frequency ultrasonic investigation in
44 993 the differential diagnostics of scars. *Ultraschall Med* 2013;34(S 01) doi: 10.1055/s-0033-
45 994 1355042
- 46 995 159. Ud-Din S, Foden P, Mazhari M, et al. Histomorphologic assessment of noninvasive quantitative
47 996 imaging in progression of cutaneous healing in human skin: Dynamic optical coherence
48 997 tomography versus high frequency ultrasound. *Wound Repair Regen* 2017;25(4):A3-A4.
- 49 998 160. Ud-Din S, Foden P, M M, et al. Quantitative index for skin fibrosis: Combined optical coherence
50 999 tomography with ultrasound validated by histology and immunohistochemistry. *Wound*
51 1000 *Repair Regen* 2018;26(4):A11-A12.
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2
3 1001 161. Ge X, Sun Y, Lin J, et al. Effects of multiple modes of UltraPulse fractional CO2 laser treatment
4 1002 on extensive scarring: a retrospective study. *Lasers Med Sci* 2021;37(3):1575-82. doi:
5 1003 10.1007/s10103-021-03406-x
6 1004 162. Jameson JL, Longo DL. Precision medicine — personalized, problematic, and promising. *N Engl J*
7 1005 *Med* 2015;372(23):2229-34. doi: 10.1056/NEJMs1503104
8 1006 163. Robinson T, Bailey C, Morris H, et al. Bridging the research-practice gap in healthcare: A rapid
9 1007 review of research translation centres in England and Australia. *Health research policy and*
10 1008 *systems* 2020;18(1):1-117. doi: 10.1186/s12961-020-00621-w
11 1009 164. Wynn T. Cellular and molecular mechanisms of fibrosis. In: Altmann DM, Douek DC, eds.
12 1010 Chichester, UK: John Wiley & Sons, Ltd., 2008:199-210.
13 1011 165. Willenborg S, Eming SA. Cellular networks in wound healing. *Science* 2018;362(6417):891-92.
14 1012 doi: 10.1126/science.aav5542
15 1013 166. Nicolescu AC, Ionescu S, Ancuta I, et al. Subepidermal Low-Echogenic Band—Its Utility in Clinical
16 1014 Practice: A Systematic Review. *Diagnostics (Basel)* 2023;13(5):970. doi:
17 1015 10.3390/diagnostics13050970
18 1016 167. Laverde-Saad A, Simard A, Nassim D, et al. Performance of ultrasound for identifying
19 1017 morphological characteristics and thickness of cutaneous basal cell carcinoma: A systematic
20 1018 review. *Dermatology* 2022;1-19. doi: 10.1159/000520751
21 1019 168. Perry DM, McGrouther DA, Bayat A. Current Tools for Noninvasive Objective Assessment of Skin
22 1020 Scars. *Plastic and Reconstructive Surgery* 2010;126(3):912-23. doi:
23 1021 10.1097/PRS.0b013e3181e6046b
24 1022 169. Powers PS, Sarkar S, Goldgof DB, et al. Scar assessment: current problems and future solutions.
25 1023 *The Journal of burn care & rehabilitation* 1999;20(1 Pt 1):54-60. doi: 10.1097/00004630-
26 1024 199901001-00011
27 1025 170. Nguyen DQA, Potokar T, Price P. A review of current objective and subjective scar assessment
28 1026 tools. *Journal of Wound Care* 2008;17(3):101-06. doi: 10.12968/jowc.2008.17.3.28666
29 1027 171. Santiago T, Santos E, Ruaro B, et al. Ultrasound and elastography in the assessment of skin
30 1028 involvement in systemic sclerosis: A systematic literature review focusing on validation and
31 1029 standardization – WSF Skin Ultrasound Group. *Semin Arthritis Rheum* 2022;52:151954-54.
32 1030 doi: 10.1016/j.semarthrit.2022.151954
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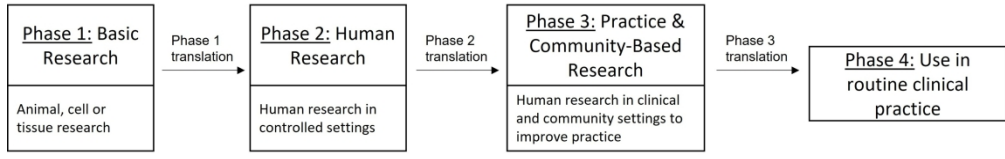


Figure 1: Research to clinical practice pipeline.

275x42mm (300 x 300 DPI)

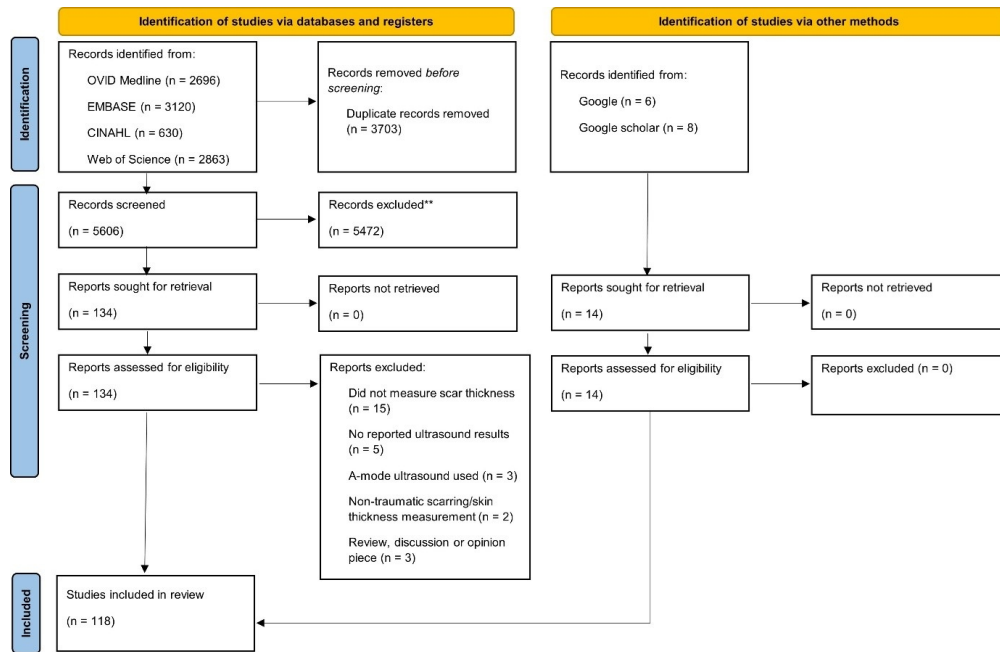


Figure 2. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram for this study.

159x102mm (220 x 220 DPI)

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1
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3 **Supplementary Box 1. Full search strategy for Ovid MEDLINE.**
4

5 ((ultrasound.ti,ab. OR ultra sound.ti,ab. OR sonograph*.ti,ab. OR ultrasonic.ti,ab. OR high-
6 frequency.ti,ab. OR high frequency.ti,ab. OR hfus.ti,ab. OR ultrasonog*.ti,ab. OR exp
7 Ultrasonography/)

8 AND
9

10 ((skin.ti,ab. OR epiderm*.ti,ab. OR derm*.ti,ab. OR cutaneous.ti,ab OR scar*.ti,ab OR
11 keloid*.ti,ab OR cicatri*.ti,ab OR exp Skin/ OR exp Dermatology/ OR exp Cicatrix/)

12
13 AND
14

15 (thickness*.ti,ab. OR thicken*.ti,ab. OR depth.ti,ab. OR volume.ti,ab. OR height.ti,ab. OR
16 vancouver scar scale.ti,ab)

17
18 ADJ10
19

20 (measure*.ti,ab. OR quantif*.ti,ab. OR calculat*.ti,ab OR estimat*.ti,ab OR assess*.ti,ab.
21 OR determin*.ti,ab. OR evaluat*.ti,ab OR imag*.ti,ab OR exam*.ti,ab)))
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23 NOT (exp animals/ NOT exp humans/)
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25
26 **Legend:** ab, abstract (searches the abstract of the publication); adj10, adjacency (search
27 terms must be located within 10 words of one another); exp, explode (used to include all
28 subheadings when searching MeSH headings); ti, title (searches the title of the publication)
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Supplementary Table 1: Extraction categories and fields

Extraction category	Extraction field
Publication details	First author
	Year of publication
	Title of publication
	Country (first author)
	Country (study)
	Country (recruited)
	Publication type (e.g., peer-reviewed journal article, abstract)
	Journal name
	Corresponding author contact details
	Use of scar thickness measurement (e.g., longitudinal study, response to treatment)
Study details	Aim/objective
	Research questions
	Target population/topics
	Study design (e.g., RCT, mixed methods)
	Data and analysis (i.e., statistical methods)
	Removal of scar treatments before ultrasound measurement (e.g., length of time before measurement)
	Reason for measurement (e.g., research, clinical initiative)
	Inclusion/exclusion criteria
	Dates of data collection
	Ultrasound thickness collection methods (e.g., direct collection, collected from medical records)
	Contralateral/unaffected/comparator skin thickness measurement
	Other methods used
	Use of guidelines/frameworks for measurement methods
	How previously published methods/guidelines were used
	Research pipeline stage
	Participant details
Scar type (e.g., burn scar, surgical scar)	
Number of participants	
Population type (e.g., adult/paediatric)	
Gender ratio	
Ultrasound methods	Patient involvement in thickness determination
	How patients were involved in thickness determination
	Ultrasound mode
	Device name and manufacturer
	Frequency used
	Number of measurements taken
	What did researchers report they were measuring (e.g., fibrosis, oedema)
	Anatomical locations/functional measurement units measured
	Patient orientation
	Ultrasound transducer orientation
Methods used to prevent skin compression	
Psychometric properties*	Measurement site relocation strategies
	Type of skin measurement (i.e., epidermis/dermis/combined)
	Measurer training
Feasibility† outcomes	Reliability
	Measurement error
Feasibility† outcomes	Time taken for measurement
	Availability of measurement method

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1		
2		
3		Ease of administration
4		Number of steps required
5		Number of people required to conduct measurements
6		Considerations for special populations
7	Implementation [‡] outcomes	Acceptability
8		Adoption
9		Appropriateness
10		Cost
11		Feasibility
12		Fidelity
13		Sustainability
14	Strengths and limitations of	Strengths
15	measurement methods	Limitations
16		Barriers
17		Enablers
18	Findings	Ultrasound-related findings
19		

*Psychometric properties as outlined in the COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments¹

[†]Feasibility outcomes as per Prinsen *et al.*²

[‡]Implementation outcomes as per Proctor *et al.*³

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Supplementary Table 2. Additional measurement methods used alongside ultrasound in included studies

First author (year)	Objective measurement methods	Clinician-based rating scale	PROM
<i>Journal articles</i>			
Agabalyan (2017)	Histology	-	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alshehari (2015)	-	VSS	-
Avetikov (2018)	-	-	-
Berry (1985)	Transcutaneous oxygen measurement	Scar redness and hypertrophy rating scale (0-5 Likert scale)	Scar redness and hypertrophy rating scale (0-5 Likert scale)
Blome-Eberwein (2012)	Doppler flowmeter – vascularity Cutometer – pliability Semmes-Weinstein monofilament Aesthesiometer testing set – sensation	VSS POSAS-O	POSAS-P
Blome-Eberwein (2016)	Cutometer – pliability Dermaspectrometer – colour Semmes-Weinstein Aesthesiometer Monofilament Testing Set – sensation	VSS POSAS-O	POSAS-P
Blome-Eberwein (2019)	-	VSS	-
Cai (2019)	-	Clinical evaluation	-
Candy (2010)	Spectrocolorimeter – colour	VSS	-
Chae (2016)	Spectrophotometer – pigmentation	VSS POSAS-O	POSAS-P
Chang (2014)	-	VSS Photographic evaluation (0-10 VAS)	-
Chan (2004)	Cutometer – viscoelasticity Spectrophotometer – pigmentation	-	-
Cheng (2001)	-	VSS	-
Cho (2014)	Mexameter – colour	Treatment efficacy (0-10 VAS)	Itching scale (0-4 Likert scale)

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3		Tewameter – trans-epidermal water		
4		loss		
5		Sebumeter – sebum		
6		Cutometer – elasticity		
7	Danin (2012)	Cutometer – elasticity	VSS	-
8	Deng (2019)	DermaLab Combo – colour	POSAS-O	-
9		Dermoscopy – vascularity		
10	Deng (2021)	-	VSS	-
11	Deng (2021)	Doppler – blood perfusion	POSAS-O	POSAS-P
12		Dermlite Foto IPro – erythema		
13	Dunkin (2007)	-	-	-
14	Elrefaie (2020)	Ultrasound – echogenicity, compressibility & vascularity	VSS	-
15	Engrav (2010)	Durometer – hardness	Clinical appearance based on	-
16		Chromameter – colour	photographs	
17	Fabbrocini (2016)	-	mVSS (vascularity, pigmentation, pliability)	-
18	Fong (1997)	Cutometer – elasticity	Clinical rating – colour change, consistent itch, hypersensitivity, blistering	-
19				
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23				
24	Fraccalvieri (2013)	Colour power Doppler – vascularisation	VSS Visual analogue scale – pain and itch	
25				
26				
27	Fraccalvieri (2011)	Histology	-	-
28		Echocontrastography – neovascularisation		
29				
30	Gankande (2014)	DermLab combo – erythema & elasticity	mVSS (some participants)	-
31				
32	Ge (2022)	-	POSAS-O Subjective reports on patient range of movement	POSAS-P
33				
34				
35				
36	Gee Kee (2016)	3D photography – thickness	POSAS-O	POSAS-P
37	Guo (2020)	Ultrasound – blood flow grade	-	-
38		Shear wave elastography – scar stiffness		
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3	Huang (2017)	-	-	-
4	Huang (2021)	-	-	-
5	Huang (2020)	Shear wave elastography – scar stiffness	-	-
6				
7	Issler-Fisher (2021)	-	VSS	POSAS-P
8			POSAS-O	
9	Issler-Fisher (2020)	-	VSS	POSAS-P
10			POSAS-O	Patient pain & itch scales
11	Issler-Fisher (2017)	-	VSS	POSAS-P
12			POSAS-O	Patient pain, itch & quality of life rating scales
13				
14	Joo (2020)	-	VSS	Pain severity (0-10 VAS)
15	Katz (1985)	Cicatrometer – firmness	-	-
16	Kemp Bohan (2021)	-	-	-
17	Kim (2018)	-	-	-
18	Lacarrubba (2008)	-	Clinical evaluation of lesion size	-
19	Lau (2005)	-	VSS	-
20	Lee (2020)	-	mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
21			POSAS-O	
22			mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
23	Lee (2019)	-	POSAS-O	
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27	Li (2013)	Micrometer – tissue thickness	-	-
28		Force/torque sensor – load applied to scar		
29				
30	Li (2020)	Cutometer – elasticity	VSS	Quality of life questionnaire
31		Mexameter – colour		
32		PeriCam PSI system and mexameter – blood supply		
33				
34	Li (2021)	Laser Doppler flowmetry – perfusion	VSS	-
35	Li (2018)	Spectrocolourimeter – scar colour	VSS	Pain & itch (0-10 VAS)
36	Li (2021)	-	VSS	Treatment satisfaction
37	Li-Tsang (2005)	Spectrocolourimeter – scar colour	VSS	Pain & itch (VAS scale not specified)
38	Li-Tsang (2006)	Spectrocolorimeter – colour	VSS	Pain & itch (VAS)
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3	Li-Tsang (2010)	Spectrocolorimeter – colour	VSS (pliability)	Pain & itch (10-point VAS)
4	Lobos (2017)	-	Modified Seattle Scar Scale	-
5			Clinical opinion	
6	Mamdouh (2021)	-	VSS	Patient satisfaction (VAS)
7	Meirte (2016)	-	-	-
8	Miletta (2021)	Colourmeter – scar colour	Unclear, likely POSAS-O	Unclear, likely POSAS-P
9		Dermal torque meter – scar compliance		Short Form 36 Quality of Life Survey
10				
11	Nedelec (2014)	Cutometer – elasticity	-	-
12		Mexameter – colour		
13	Nedelec (2008)	Cutometer – elasticity	mVSS	-
14		Mexameter – colour		
15	Nedelec (2019)	Cutometer – elasticity	-	-
16		Mexameter – colour		
17	Nedelec (2020)	Cutometer – elasticity	-	Pain & itch (10cm line VAS)
18		Mexameter – colour		
19	Nicoletti (2015)	-	-	-
20	Niessen (1998)	Histology	-	-
21	Reinholz (2020)	3D topographic imaging device	POSAS-O	Dermatology Quality of Life Index
22				POSAS-P
23	Reinholz (2016)	Optical coherence tomography – thickness	POSAS-O	Dermatology Quality of Life Index
24				POSAS-P
25	Schwaiger (2018)	3D topographic imaging device	-	-
26	Simons (2017)	3D camera – scar height	POSAS-O	-
27	Soykan (2014)	Slide calliper – dimensions	POSAS-O	POSAS-P
28	Timar-Banu (2001)	Metric ruler – dimensions	Validated 3-point scoring system for redness, hardness, itching & pain	-
29				
30				
31				
32	Ud-Din (2019)	Optical coherence tomography – thickness	-	-
33		Histology		
34	van den Kerckhove (2005)	Chromameter – erythema	-	-
35	van der Veer (2010)	Slide calliper – dimensions	-	-
36	Wang (2009)	Histology	-	-
37	Wang (2010)	-	-	-
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3	Wiseman (2020, 2021)	-	POSAS-O	POSAS-P
4				Numeric rating scale for itch
5				Toronto Paediatric Itch Scale
6				CH-9D
7				BBSIP
8	Wood (1996)	-	VSS	-
9	Xuan (2021)	Histology	-	-
10	Yeol Lee (2022)	Cutometer – elasticity	mVSS	-
11		Elastography		
12	Yim (2010)	Cutometer – elasticity	-	-
13		Tewameter – trans-epidermal water		
14		loss		
15		Mexameter – colour		
16	Zadkowski (2016)	-	VSS	-
17	<hr/>			
18	<i>Abstracts</i>			
19	<hr/>			
20	Agabalyan (2016)	Histology	-	-
21	Bajouri (2018)	-	VSS	-
22	Bezugly (2019)	Clinical or histopathological	-	-
23		diagnosis		
24	Bezugly (2014)	-	-	-
25	Blome-Eberwein (2011, 2012)	Doppler vascularity, elasticity and	VSS	Pain and itching scale (0-10 Likert
26		sensation		scale)
27	Blome-Eberwein (2012)	-	-	-
28	Blome-Eberwein (2014)	Doppler flowmeter – vascularity	VSS	POSAS-P
29		Cutometer – pliability		
30		Semmes-Weinstein monofilament		
31		aesthesiometer testing set – sensation		
32	Cho (2012)	-	VSS	-
33	Cho (2012)	CK-MPA Multi-Probe adaptor –	-	-
34		pigmentation, erythema and trans-		
35		epidermal water loss		
36		Cutometer – elasticity		
37	Comstock (2018)	Computer-based tools – Thickness &	Unclear, likely POSAS-O	Unclear, likely POSAS-P
38		pliability		
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3	Cooper (2021)	Colorimeter – pigmentation	Unclear, likely POSAS-O	Unclear, likely POSAS-P
4	Du (2006)	-	-	-
5	Edgar-Lacoursière (2022)	Cutometer – elasticity	-	-
6		Mexameter – colour		
7	El-Zawhary (2007)	Histology	-	-
8	George (2019)	-	-	-
9	Jacobs (2016)	Cutometer – pliability	POSAS-O	-
10		Colorimeter – colour		
11	Jang (2009)	Mexameter – pigmentation	-	-
12		Tewameter – trans-epidermal water		
13		loss		
14		Sebumeter – sebum		
15		Cutometer – elasticity		
16		Laser Doppler – perfusion		
17		Histology	VSS	-
18	Kim (2009)	Histology	VSS	-
19	Li (2016)	Spectrocolourimeter – scar colour	VSS	Patient report of pain & itch
20	Li-Tsang (2011)	-	VSS (thickness, pliability and pigmentation)	-
21		Histology	VSS	Self-report questionnaire
22	Li-Tsang (2010)	Spectrocolourimeter – scar colour		
23		Cutometer – elasticity	-	-
24	Maari (2017)	Mexameter – pigmentation		
25		Cutometer – elasticity	Unclear, likely POSAS-O	Unclear, likely POSAS-P
26	Moortgat (2020)	Chromameter – colour		
27		Tewameter – trans-epidermal water		
28		loss		
29		Corneometer – hydration		
30		Cutometer – elasticity	-	-
31	Nedelec (2018)	Mexameter – colour		
32		Cutometer – elasticity	POSAS-O	POSAS-P
33	Peters (2018)	Colourimeter – colour		
34		Cutometer – elasticity		
35	Seo 2011	Cutometer – elasticity		
36	Siwy (2016)	Colourimeter – colour	-	SF-36 Quality of Life Measurement
37		Torque meter – pliability & elasticity		POSAS-P
38	Timina (2013)	-	-	-
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3	Tu (2014)	-	VSS	-
4	Ud-Din (2017)	Laser perfusion imaging	-	-
5		Optical coherence tomography –		
6		thickness		
7		Histology		
8	Ud-Din (2017)	Optical coherence tomography –	-	-
9		thickness		
10	Ud-Din (2018)	Optical coherence tomography –	-	-
11		thickness		
12		Histology		
13	Zuccaro (2021)	Multi-parameter skin analysis device	VSS	Unclear, likely POSAS-P
14			Unclear, likely POSAS-O	
15	Zuccaro (2019)	Acoustic radiation force impulse	-	-
16		ultrasound elastography		
17	Zuccaro (2021)	Acoustic radiation force impulse –	VSS	POSAS-P
18		stiffness	POSAS-O (did not include	
19		DermLab Combo elasticity probe –	surface area and relief subscales)	
20		elasticity		
21		DermLab Combo colour probe –		
22		colour		
23				

Legend: (m)VSS: (Modified) Vancouver Scar Scale; POSAS: Patient and Observer Scar Assessment Scale (POSAS-O: POSAS observer scale; POSAS-P: POSAS patient scale); VAS: Visual Analogue Scale; CHU-9D: Child Health Utility-9D; BBSIP: Brisbane Burn Scar Impact Profile

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Supplementary Table 3: Reliability of ultrasound methods reported in each included study

First Author (year)	Reliability Test & Measurement Error	Reliability & Measurement Error Test Statistics & Details
<i>Inter-rater reliability</i>		
Anthonissen (2015)	ICC; SEM	Epidermal – 0.297; 0.02mm Dermal – 0.991; 0.13mm
Chang (2014)	Pearson correlation	R=0.90, p<0.001
Dunkin (2007)	N.R.	N.R.
Fong (1997)	ICC	0.93, p=0.146
Gankande (2014)	ICC (95% CI)	<u>Individual site:</u> Rater 1 vs rater 2 ‘Best scar’ – 0.95 (0.92, 0.96) ‘Worst scar’ – 0.95 (0.91, 0.97) ‘Normal skin’ – 0.94 (0.91, 0.96) Rater 1 vs rater 3: ‘Best scar’ – 0.86 (0.78, 0.91) ‘Worst scar’ – 0.91 (0.85, 0.95) ‘Normal skin’ – 0.92 (0.88, 0.95) Rater 2 vs rater 3: ‘Best scar’ – 0.93 (0.89, 0.95) ‘Worst scar’ – 0.96 (0.92, 0.97) ‘Normal skin’ – 0.95 (0.92, 0.97) <u>Average site:</u> Rater 1 vs rater 2 ‘Best scar’ – 0.97 (0.94, 0.99) ‘Worst scar’ – 0.98 (0.96, 0.99) ‘Normal skin’ – 0.97 (0.93, 0.98) Rater 1 vs rater 3 ‘Best scar’ – 0.90 (0.77, 0.95) ‘Worst scar’ – 0.97 (0.91, 0.98) ‘Normal skin’ – 0.96 (0.92, 0.98) Rater 2 vs rater 2 ‘Best scar’ – 0.95 (0.88, 0.98) ‘Worst scar’ – 0.98 (0.94, 0.99) ‘Normal skin’ – 0.98 (0.97, 0.99)
Lau (2005)	ICC	0.84, p<0.01
Lee (2020)	ICC	“Acceptable to high”
Lee (2019)	ICC (95% CI); SEM	<u>Scar:</u> Single: 0.957 (0.934-0.973) Average: 0.985 (0.977-0.991) SEM: 0.10 mm <u>Unscarred skin:</u> Single: 0.967 (0.949-0.980) Average: 0.989 (0.982-0.993) SEM: 0.04 mm
Nedelec (2008)	ICC (95% CI)	Most severe scar: 0.90 (0.84-0.95) Less severe scar: 0.91 (0.85-0.95) Donor site: 0.89 (0.82-0.94) Normal skin: 0.85 (0.75-0.92)
Seo (2011)	N.R.	“High”
Simons (2017)	ICC (95% CI); SEM	Scar: 0.82 (0.7-0.89); 0.05 cm Normal skin: 0.33 (0.08-0.54); 0.03 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	<u>One day:</u> 0.88 (0.81-0.95); 0.29 mm

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		<u>Day-to-day:</u> 0.94 (0.90-0.98); 0.21mm
<hr/>		
<i>Intra-rater reliability</i>		
<hr/>		
Anthonissen (2015)	ICC; SEM	Epidermal – 0.809; 0.01mm Dermal – 0.991; 0.13mm
Gankande (2014)	ICC (95% CI)	‘Best scar’ – 0.97 (0.89, 0.94) ‘Worst scar’ – 0.92 (0.88, 0.95) ‘Normal skin’ – 0.86 (0.81, 0.89)
Gee Kee (2016)	N.R.	N.R.
Lau (2005)	ICC	Intra-rater: 0.98, p<0.01
Lee (2019)	ICC (95% CI)	<u>Scar:</u> Single: 0.951 (0.871-0.987) Average: 0.983 (0.953-0.966) SEM: 0.10 mm
		<u>Unscarred skin:</u> Single: 0.948 (0.881-0.976) Average: 0.982 (0.954-0.993) SEM: 0.04 mm
Li (2013)	ICC	0.89
Seo (2011)	N.R.	“High”
Simons (2017)	ICC (95% CI); SEM	Scar: 0.95 (0.91-0.97); 0.02 cm Normal skin: 0.61 (0.41-0.75); 0.02 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	0.98 (0.97-0.99); 0.11mm
Wang (2010)	SE	Peak: 0.032 3 months: 0.018 6 months: 0.399 9 months: 0.353
<hr/>		
Abbreviations used in tables: N.R.: Not reported; ICC: Intraclass Correlation Coefficient; 95% CI: 95% Confidence Interval; SEM: Standard Error of Measurement; SE: Standard Error		
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Summary of findings for measurement error:

The reported inter-rater SEM measurements for the combined (i.e., epidermal and dermal) thickness measurement of scars was reported in two records as 0.11 mm⁴ and 0.5 mm.⁵ The inter-rater SEM for the combined thickness measurement of unscarred skin was also calculated in one record (SEM = 0.3 mm).⁵ The inter-rater SEM was calculated in one record for the measurement of epidermal (SEM = 0.02 mm) and dermal (0.13) measurements⁶, and one record reported only the dermal SEM for scar thickness (SEM = 0.1 mm) and unscarred skin (0.04 mm).⁷ The intra-rater SEM for the combined thickness measurement of scarred skin ranged from 0.18 mm to 0.52 mm, and was measured at 0.2 mm for unscarred skin in one record.⁵ One record reported the intra-rater SEM for epidermal (0.01 mm) and dermal (0.12 mm),⁶ and one record reported the intra-rater SEM for dermal scar (0.1 mm) and unscarred skin (0.04).⁷

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Supplementary Table 4. Methodological considerations for researchers and/or clinicians undertaking measurement of scar thickness using ultrasound.

Consideration	Details & examples of considerations	Publications in our review addressing the consideration	Details reported in included review records
Preventing skin compression during measurement	Using standoff methods (e.g., ultrasound gel, water bath) to prevent transducer touching the skin	5,8-12	- Use of ultrasound gel to prevent contact between ultrasound transducer and skin surface to minimise compression applied by direct application of transducer ^{5,8-11}
	Application of minimal pressure by transducer	13-17	- Silicone pad placed underneath transducer ¹² - Transducer held to maintain minimal pressure on scar ^{13,14,16} - Training users to apply minimal force on transducer to prevent scar or skin distortion ^{15,17}
	Deliberately compressing skin to quantify scar compressibility	18-20	- Measurement of thickness with and without compression with transducer ^{18,20} - Thickness measurements taken using TUPS, which uses controlled and metered compression during measurement ¹⁹
Orienting the patient	Orienting the patient during measurement (e.g., upright, supine, prone or seated)	7,17,21	- Patient supine throughout measurement to allow measurement to be taken in the same position ^{7,17,21}
	Maintaining patient stillness during measurement	8	- Patients asked to hold breath during measurement of scars on the chest to allow shear-wave ultrasound ⁸
Placing ultrasound transducer	Orientating ultrasound transducer [e.g., vertical (superior to inferior/cranial to caudal), horizontal (medial to lateral)]	22	- Direction of transducer recorded to ensure consistency ²²

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1			
2			
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5			
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9			
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11			
12			
13	Relocating	Mapping measurement	5,11,15,17,19,21,26-31
14	scars for	area (e.g., tracing,	
15	longitudinal	schematic diagram)	
16	measurement		
17			
18			
19			
20			
21			
22			
23			
24		Photographing	23,25,32
25		measurement area	
26			
27			
28		Measuring specific scar	5,7,8,12,18-20,22,29,32-36
29		locations (e.g., centre	
30		of scar, worst area of	
31		scar, counting	
32		transducer lengths)	
33			
34			
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- Transducer oriented perpendicular to the skin surface to provide optimal image ^{8,14,17,21,23-25}

- Exclusion of fingers and toes in paediatric measurements due to size of measurement area and thin skin ⁵

- Scars traced using translucent paper ^{17,19,21,26,28,30,31}

- Scars and surrounding anatomical landmarks traced using translucent paper ¹⁵

- Scar mapped on transparent paper, which was then cut out ²⁷

- Scar mapped with drawing, no elaboration provided ²⁹

- Scars traced using Visitrak (Smith & Nephew Medical Limited, England) ^{5,11}

- Assessed area marked and photograph taken in initial consultation ^{23,32}

- Photographs of scars taken ²⁵

- Measurement taken at standardised transducer lengths along surgically created scars of pre-specified dimensions ³³

- Measurements taken at thickest/most severe point ^{18-20,29,32,34,36}, as determined by the patient and/or clinician ⁷

- Transducer placed on thickest site on peripheral regions ⁸

- Transducer placed on area initially identified to have greatest burn depth ²²

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1				
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7				
8		Conducting linear	16,37	
9		measurements from		
10		nearby anatomical		
11		landmarks		
12				
13				
14	Acclimatising	Removing scar	7,11,19,21,23-25,27,28,38,39	
15	scar to	treatments prior to		
16	measurement	ultrasound		
17	conditions	measurement		
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30		Acclimatising patient to	4,17,21,28,40-45	
31		room prior to		
32		measurement		
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- Measurement area selected by the measurer with -selected area marked with tape ¹²
- Measurements taken at set linear distances from cranial/caudal border of linear sternal scar ³⁵
- Linear measurements from anatomical landmark to measurement site ¹⁶
- Transducer placement mapped in 3-dimensional space using a surgical precision tracking arm ³⁷
- Pressure garments removed 10 minutes before measurement ²⁷
- Pressure garments removed 15 minutes before measurement to regain original (uncompressed) scar thickness or to reduce blanching effects on measurement ^{19,39}
- Pressure garments/gels/moisturisers removed 20 minutes before measurement ^{7,21,28}
- Pressure garments removed 30 minutes before measurement ^{11,24,25,38}
- Sequential measurement of scars following direct treatment with vacuum massage at 5, 30, 60 and 120 minutes to monitor effect of treatment ²³
- Patients rested for minimum 5 minutes before measurement ^{4,17,21}
- Scar exposed to room conditions for 10 minutes ²⁸ to allow equilibrium to be reached with surrounding environment ⁴⁰
- Patients resting in room with constant temperature for 15 mins ⁴¹ to allow scar to stabilise ⁴³

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1				
2				
3				
4				- Patients rested for 20 minutes prior to measurement ^{28,44}
5				- Patients resting for 10 minutes before repeated measurements taken ⁴²
6				- Patients wait in testing room holding position for 5 min before measurement to stabilise cutaneous blood flow ⁴
7				- Patients allowed to adapt in controlled room to exclude external variables ⁴⁵
8				- Patients remained supine for at least 5 minutes before measurement to avoid artefacts on Doppler imaging ¹²
9				- Patients allowed to acclimatise to room and assumed a supine position for a minimum of 10 minutes before measurements of biophysical parameters ¹⁰
10				- Measurement of epidermal, dermal and combined epidermal and dermal thickness to allow comparison with histological measurement ^{46,47}
11				- Measurement of the epidermal and dermal thickness ^{44,48} , combined with layer acoustic density ⁶
12				- Measurement of the epidermal, dermal and subcutaneous thickness, combined with acoustic density ^{49,50}
13				- Measurement of dermal thickness as treatment thought to affect/target the dermis ^{23,36,51-53}
14		Maintaining patient position before measurement ^{10,12}		- Combined epidermal and dermal thickness measurement to provide information on the full thickness of the scar ^{4,5,7,10,11,14,16,17,21,22,25,27,34,39,54-67}
15				
16				
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21				
22	Measuring different skin layers	Measuring epidermis and/or dermis individually ^{6,23,36,44,46-53}		
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
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36		Measuring both epidermis/dermis combined (no		
37				
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1				
2				
3		individual		
4		measurement)		
5	Measurement	Measuring	7,9,10,12,13,15,16,23,24,28-31,33,35,36,44,53,57,59,60,62,63,68-81	- Measurement of fibrosis or collagen
6	objective	fibrosis/oedema/hair		architecture ^{7,10,16,23,28-31,33,35,36,44,53,57,60,62,63,68,69,71-}
7		follicles		73,76-78,81
8				- Measurement of inflammation/oedema ¹³
9				- Quantification of the sub epidermal low
10				echogenic band, indicating oedema ⁵⁹
11				- Measurement of both fibrosis and oedema
12				9,12,15,24,57,70,74,75,79,80
13				- Measurement of the presence and density of
14				hair follicles to differentiate scarred and
15				unscarred skin ⁵³
16	Factors	Measuring contralateral	8,13,14,22,28,29,51,54-57,82-87 5,7,11,17,21,24,37,42,53,58-60,65,88,89	- Measurement of additional, non-scarred
17	influencing scar	skin/control scar	38,39,44,78,80,81	subjects ^{54,78}
18	site			- Measurement of unscarred/unaffected skin on
19	measurement			same subject as scar measurement contralaterally
20				or at anatomically similar location to provide
21				normative measurements for skin thickness
22				5,7,8,11,13,14,17,21,22,28,29,37-39,42,44,51,53,55-60,65,80,84-89
23				- Measurement of both untreated scar and
24				unaffected skin ⁸¹⁻⁸³
25				- Measurement of a control scar subjected to care
26				as usual treatment on the same individual ²⁴
27				
28		Measuring open	5	- Use of flexible transparent plastic wrap placed
29		wounds or sores in the		over the measurement area to prevent contact
30		scar		between ultrasound gel and transducer with the
31				open wound/sore ⁵
32		Operator training	5,7,11,13,15,17,19,23,26-28,30,38,39,57,60,65,71,72,86,90-92	- Trained outcome assessor ^{5,12,15,17,26,71}
33		and/or experience		- Measurements taken by radiologist/sonographer
34				27,65,72,91
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Number of

measurements per scar

4,5,7,8,10,11,19,22,24,25,30,33,36,39,43,44,46,51,53,56,59,60,65,67,78,84,91,93

- Assessors with burn experience ^{86,92}
- Ultrasound located in department of radiology ⁹⁰
- Measurements conducted by trained therapist/doctor under guidance of experienced radiologist ^{11,13,28,38}
- Measurements conducted by trained clinicians who use device regularly and received training by company representative of devices ^{7,60}
- Device-specific training provided: 1 week ¹⁹; 3 sessions of 3 hours for 3 weeks, plus 10 independent assessments of scars using study protocol ³⁹; training provided over 3 months ³⁰; physical therapist trained in ultrasound application ²³
- 3 ultrasound images taken from each patient ^{8,10,25,30,36,43,44,46,51,53,56,59,78,84}
- Clearest of 3 measurements used ¹¹
- 3 measurements in 3 locations across scar used. Individual and average measurements reported ³⁹
- Measurements performed in duplicate ^{33,93}
- Measurements taken at different points of the scar, thickest used for analysis ⁹¹
- 5 measurements of each site ^{5,22}
- 9 measurements taken, removal of maximum and minimum, 7 measurements used for average ¹⁹
- Measurements taken by 3 assessors at 3 different time points during day ^{7,60}
- Measurement of 2 sites on the same scar ²⁴
- Single ultrasound image taken for analysis ⁶⁷

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46	Use of additional measurement tools as well as ultrasound measurements	Using additional objective assessment instruments (e.g., histology, colour Doppler ultrasound, cutometer, colourimeter)	5,8-10,12,14,16,17,20-22,24-26,28,30,31,34,35,39-47,49,52,55-58,65,67-69,74-79,81-83,85-91,94-110	<ul style="list-style-type: none"> - Histology/immunohistochemistry 12,16,46,47,49,57,77,78,87,99,102,107,109 - Blood flow and blood perfusion measurement using laser Doppler perfusion imaging, flowmetry or PeriCam, and scar colour and micro-vessel percentage using dermoscopy colour and micro-vessel percentage. 34,68,69,82,83,85,86,91,98,100,107 - Oximeter⁴⁰ - Infra-red camera⁴⁰ - Measurement of scar stiffness or pliability/elasticity using elastography or cutometer^{8,14,17,20,21,24-26,28,42,45,52,56,65,81-83,85,88,89,95,97,98,100,103-105} - Measurement of sensation using Semmes-Weinstein filaments^{81-83,85} - Measurement of scar colour (including pigmentation and erythema) using spectrophotometer, colourimeter, chromameter, mexameter or Dermlite Foto IPro^{17,21,24-26,31,41,43-45,52,55,65,67,79,81,86,89,90,95-98,100-106,110} - Measurement of trans-epidermal water loss using Tewameter or scar hydration using Corneometer^{45,52,95,98} - Measurement of sebum level using sebumeter^{95,98} - Measurement of hardness using durometer⁹⁰ - Measurement of neovascularisation using echocontrastography⁵⁷ - Measurement of scar dimensions (e.g., scar height and volume) using 3D camera, 3D imaging methods, ruler or calliper^{5,9,10,22,35,74,76}
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Using subjective
assessment instruments
(e.g., clinical rating
scales, PROMs)

18,19,22,27-29,32,36,39,40,43,44,48,51,55,56,60,65,66,68-71,79-
83,85,86,90,91,93-97,99,110-114

- Measurement of skin thickness using micrometer or optical coherence tomography ^{16,30,58,75,107-109}
- Measurement of scar firmness or deformation using cicatrometer, force/torque sensor (in line with ultrasound to measure load applied) or torque meter ^{30,31,106}
- Multi-parameter skin analysis device ⁶⁵
- Measurement of erythema and elasticity using probes of DermaLab Combo ³⁹
- Multi-probe adaptor taking multiple measurements (pigmentation, erythema, trans-epidermal water loss) ⁹⁵
- PROMs:
 - Measurement of scar quality using POSAS patient report ^{7,22,29,32,44,55,60,62,63,65,74-76,81,85,94,96,105,106,113,114}
 - Subjective rating scales for scar symptoms (e.g., pain, itch) or subjective scar severity ratings ^{25,29,40,41,52,62,63,71,79,82,83,92,101,102,110,114}
 - Patient quality of life questionnaires ^{74,75,100,106}
 - Measurement of generic health-related quality of life using CHU-9D ^{62,63}
 - Measurement of scar-specific health-related quality of life using BBSIP ^{62,63}
 - subjective evaluation of response to treatment/treatment satisfaction ^{80,115}
- Clinical rating scales:
 - Measurement of scar quality using POSAS observer report ^{7,22,29,32,44,52,55,60,62,63,65,74-76,81,85,86,96,97,105,113-115}

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- Measurement of physical scar characteristics using VSS or modified versions of the VSS ^{7,17-19,27,29,32,34,36,37,39,41-43,48,55,56,60,64,65,68-71,79-85,91-94,99-102,110-112,114,116,117}
- Measurement of scar characteristics in relation to unscarred skin using Seattle Scar Scale or modified Seattle Scar Scale ⁷²
- Subjective rating scales for scar symptoms (e.g., pain, itch) as assessed by the clinician and/or researcher and/or clinical evaluation of scar severity ^{10,28,40,51,56,66,72,90,91,93,95}
- Standardised order of measurement: 3D photograph, POSAS-O, then ultrasound ⁵
- Order of device use not specified ^{34,68,69,82,83,85,86,91,98,100,107}

Determining the order
of measurement ⁵

Abbreviations: TUPS: Tissue Ultrasound Palpation System; 3D: three-dimensional; POSAS: Patient and Observer Scar Assessment Scale; CHU-9D: Child Health Utility 9D; BBSIP: Brisbane Burn Scar Impact Profile; VSS: Vancouver Scar Scale; mVSS: Modified Vancouver Scar Scale; POSAS-O: Patient and Observer Scar Assessment Scale, observer measure

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Supplement References:

1. Mokkink LB, Boers M, van der Vleuten CPM, et al. COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020;20(1):1-13. doi:10.1186/s12874-020-01179-5
2. Prinsen CAC, Vohra S, Rose MR, et al. How to select outcome measurement instruments for outcomes included in a "Core Outcome Set" - a practical guideline. *Trials*. 2016;17:urn:issn:1745-6215.
3. Proctor E, Proctor E, Silmere H, et al. Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. *Adm Policy Ment Health*. 2011;38(2):65-76. doi:10.1007/s10488-010-0319-7
4. Van den Kerckhove E, Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated measurements on post-burn scars with Dermascan C. *Skin Res Technol*. 2003;9(1):81-84. doi:10.1034/j.1600-0846.2003.00375.x
5. Simons M, Kee EG, Kimble R, Tyack Z. Ultrasound is a reproducible and valid tool for measuring scar height in children with burn scars: A cross-sectional study of the psychometric properties and utility of the ultrasound and 3D camera. *Burns*. 2017;43(5):993-1001. doi:10.1016/j.burns.2017.01.034
6. Anthonissen M, Meirte J, Moortgat P, et al. Intrarater and interrater reliability of an open 22MHz ultrasound scanning system to assess thickness and density of burn scars. *Ann Burns Fire Disasters*. 2015;28(Supplement EBA)
7. Lee KC, Bamford A, Gardiner F, et al. Investigating the intra- and inter-rater reliability of a panel of subjective and objective burn scar measurement tools. *Burns*. 2019;45(6):1311-1324. doi:10.1016/j.burns.2019.02.002
8. Guo R, Xiang X, Wang L, Zhu B, Cheng S, Qiu L. Quantitative assessment of keloids using ultrasound shear wave elastography. *Ultrasound Med Biol*. 2020;46(5):1169-1178. doi:10.1016/j.ultrasmedbio.2020.01.010
9. Schwaiger H, Reinholz M, Poetschke J, Ruzicka T, Gauglitz G. Evaluating the therapeutic success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive objective measures. *Dermatol Surg*. 2018;44(5):635-644. doi:10.1097/DSS.0000000000001427
10. Timar-Banu O, Beauregard H, Tousignant J, et al. Development of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scar in humans. *Wound Repair Regen*. 2001;9(2):123-132. doi:10.1046/j.1524-475x.2001.00123.x
11. Wang X-Q, Mill J, Kravchuk O, Kimble RM. Ultrasound assessed thickness of burn scars in association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns*. 2010;36(8):1254-1262. doi:10.1016/j.burns.2010.05.018
12. Niessen FB, Spauwen PHM, Robinson PH, Fidler, Kon M. The use of silicone occlusive sheeting (Sil-K) and silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation. *Plast Reconstr Surg*. 1998;102(6):1962-1972. doi:10.1097/00006534-199811000-00023
13. Huang P-W, Lu C-W, Chu K-T, Ho M-T. Assessing thickness of burn scars through ultrasound measurement for patients with arm burns. *J Med Biol Eng*. 2021;41(1):84-91. doi:10.1007/s40846-020-00592-x
14. Huang S-Y, Xiang X, Guo R-Q, Cheng S, Wang L-Y, Qiu L. Quantitative assessment of treatment efficacy in keloids using high-frequency ultrasound and shear wave elastography: a preliminary study. *Sci Rep*. 2020;10(1):1375-1375. doi:10.1038/s41598-020-58209-x
15. Kemp Bohan PM, Cooper LE, Lu KN, et al. Fractionated ablative carbon dioxide laser therapy decreases ultrasound thickness of hypertrophic burn scar: A prospective process improvement initiative. *Ann Plast Surg*. 2020;86(3):273-278. doi:10.1097/SAP.0000000000002517
16. Ud-Din S, Foden P, Stocking K, et al. Objective assessment of dermal fibrosis in cutaneous scarring, using optical coherence tomography, high-frequency ultrasound and immunohistomorphometry of human skin. *Br J Dermatol*. 2019;181(4):722-732. doi:10.1111/bjd.17739

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

17. Nedelec B, Correa JA, Rachelska G, Armour A, Lasalle L. Quantitative measurement of hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res.* 2008;29(3):501-511. doi:10.1097/BCR.0b013e3181710881
18. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and hypertrophic scar assessment. *Lasers Med Sci.* 2019;35(2):379-385. doi:10.1007/s10103-019-02830-4
19. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS) in objective scar evaluation. *Burns.* 2005;31(4):445-452. doi:10.1016/j.burns.2004.07.016
20. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res.* 2011;32:S167-S167.
21. Nedelec B, Correa JA, de Oliveira A, LaSalle L, Perrault I. Longitudinal burn scar quantification. *Burns.* 2014;40(8):1504-1512. doi:10.1016/j.burns.2014.03.002
22. Gee Kee EL, Kimble RM, Cuttle L, Stockton KA. Scar outcome of children with partial thickness burns: A 3 and 6 month follow up. *Burns.* 2016;42(1):97-103. doi:10.1016/j.burns.2015.06.019
23. Meirte J, Moortgat P, Anthonissen M, et al. Short-term effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an experimental study. *Burns Trauma.* 2016;4:27-27. doi:10.1186/s41038-016-0052-x
24. Nedelec B, Couture M-A, Calva V, et al. Randomized controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns.* 2019;45(1):128-139. doi:10.1016/j.burns.2018.08.018
25. Nedelec B, LaSalle L, de Oliveira A, Correa JA. Within-patient, single-blinded, randomized controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res.* 2020;41(4):761-769. doi:10.1093/jbcr/iraa057
26. Chan HH, Wong DSY, Ho WS, Lam LK, Wei W. The use of pulsed dye laser for the prevention and treatment of hypertrophic scars in Chinese persons. *Dermatol Surg.* 2004;30(7):987-994. doi:10.1111/j.1524-4725.2004.30303.x
27. Cheng W, Saing H, Zhou H, Han Y, Peh W, Tam PKH. Ultrasound assessment of scald scars in Asian children receiving pressure garment therapy. *J Pediatr Surg.* 2001;36(3):466-469. doi:10.1053/jpsu.2001.21613
28. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of postburn hypertrophic scar: A preliminary study. *Burns.* 1997;23(1):S12-S18. doi:10.1016/S0305-4179(96)00095-2
29. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective short-term outcome analysis of a prospective treatment cohort. *Burns.* 2017;43(3):573-582. doi:10.1016/j.burns.2016.09.014
30. Li JQ, Li-Tsang CWP, Huang YP, Chen Y, Zheng YP. Detection of changes of scar thickness under mechanical loading using ultrasonic measurement. *Burns.* 2012;39(1):89-97. doi:10.1016/j.burns.2012.05.009
31. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and subjective outcomes. *Ann Surg.* 2021;274(6):E574-E580. doi:10.1097/SLA.0000000000003576
32. Issler-Fisher AC, Fisher OM, Haertsch PA, Li Z, Maitz PKM. Effectiveness and safety of ablative fractional CO2 laser for the treatment of burn scars: A case-control study. *Burns.* 2021;47(4):785-795. doi:10.1016/j.burns.2020.10.002
33. Dunkin CSJ, Pleat JM, Gillespie PH, Tyler MPH, Roberts AHN, McGrouther DA. Scarring occurs at a critical depth of skin injury: Precise measurement in a graduated dermal scratch in human volunteers. *Plast Reconstr Surg.* 2007;119(6):1722-1732. doi:10.1097/01.prs.0000258829.07399.f0

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

34. Li N, Yang L, Cheng J, et al. A retrospective study to identify the optimal parameters for pulsed dye laser in the treatment of hypertrophic burn scars in Chinese children with Fitzpatrick skin types III and IV. *Lasers Med Sci.* 2021;36(8):1671-1679. doi:10.1007/s10103-021-03252-x
35. van der Veer WM, Ferreira JA, de Jong EH, Molema G, Niessen FB. Perioperative conditions affect long-term hypertrophic scar formation. *Ann Plast Surg.* 2010;65(3):321-325. doi:10.1097/SAP.0b013e3181c60f88
36. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized controlled trial. *PLoS One.* 2021;16(3):e0248799. doi:10.1371/journal.pone.0248799
37. Wood FM, Currie K, Backman B, Cena B. Current difficulties and the possible future directions in scar assessment. *Burns.* 1996;22(6):455-458. doi:10.1016/0305-4179(95)00168-9
38. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on third-degree burns through ultrasonic measurement. *J Cytol Histol.* 2017;8(5)doi:10.4172/2157-7099.1000488
39. Gankande TU, Duke JM, Danielsen PL, DeJong HM, Wood FM, Wallace HJ. Reliability of scar assessments performed with an integrated skin testing device – The DermaLab Combo. *Burns.* 2014;40(8):1521-1529. doi:10.1016/j.burns.2014.01.025
40. Berry RB, Tan OT, Cooke ED, et al. Transcutaneous oxygen tension as an index of maturity in hypertrophic scars treated by compression. *Br J Plast Surg.* 1985;38(2):163-173. doi:10.1016/0007-1226(85)90045-1
41. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its characteristics among the Chinese population. *Burns.* 2005;31(5):610-616. doi:10.1016/j.burns.2005.01.022
42. Lee SY, Cho YS, Kim L, Joo SY, Seo CH. The Intra-rater reliability and validity of ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns.* 2022;doi:10.1016/j.burns.2022.03.016
43. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic scar in a Chinese population. *Burns.* 2010;36(8):1234-1241. doi:10.1016/j.burns.2010.05.008
44. Deng H, Tan T, Luo G, Tan J, Li-Tsang CWP. Vascularity and thickness changes in immature hypertrophic scars treated with a pulsed dye laser. *Lasers Surg Med.* 2021;53(7):914-921. doi:10.1002/lsm.23366
45. Yim H, Cho YS, Seo CH, et al. The use of AlloDerm on major burn patients: AlloDerm prevents post-burn joint contracture. *Burns.* 2009;36(3):322-328. doi:10.1016/j.burns.2009.10.018
46. Agabalyan NA, Su S, Sinha S, Gabriel V. Comparison between high-frequency ultrasonography and histological assessment reveals weak correlation for measurements of scar tissue thickness. *Burns.* 2016;43(3):531-538. doi:10.1016/j.burns.2016.09.008
47. Agabalyan NA, Su S, Sinha V, Gabriel V. Evaluating high frequency ultrasonography for the non-invasive measurement of human scarring. *J Burn Care Res.* 2016;37(Supplement 183)
48. Bajouri A, Kajoor AS, Fallah N, et al. Autologous human stromal vascular fraction injection in post-burn hypertrophic scar: A double-blinded placebo-controlled clinical trial. *Bioimpacts.* 2018;8:37-38.
49. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and diagnostics. *J Dermatol Nurses Assoc.* 2020;12(2)
50. Bezugly A, Potekae N. In vivo skin morphology monitoring of patients with acne, scars and dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol.* 2014;41:4.
51. Cai L, Hu M, Lin L, Zheng T, Liu J, Li Z. Evaluation of the efficacy of triamcinolone acetonide in the treatment of keloids by high-frequency ultrasound. *Skin Res Technol.* 2020;26(4):489-493. doi:10.1111/srt.12820
52. Moortgat P, Vanhullebusch T, Anthonissen M, et al. Tension reducing taping as a mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot study. *Wound Repair Regen.* 2020;28(2):A21.

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 53. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal
4 tissue thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res.*
5 2020;41(2):421-426. doi:10.1093/jbcr/irz191
6
7 54. Avetikov DS, Bukhanchenko OP, Skikevich MG, Aipert VV, Boyko IV. Features of ultrasound
8 diagnostics of postoperative hypertrophic and keloid scars. *The New Armenian Medical Journal.*
9 2018;12(4):43-48.
10
11 55. Chae JK, Kim JH, Kim EJ, Park K. Values of a patient and observer scar assessment scale to
12 evaluate the facial skin graft scar. *Ann Dermatol.* 2016;28(5):615-623. doi:10.5021/ad.2016.28.5.615
13
14 56. Danin A, Georgesco G, Le Touze A, Penaud A, Quignon R, Zakine G. Assessment of burned
15 hands reconstructed with Integra® by ultrasonography and elastometry. *Burns.* 2012;38(7):998-
16 1004. doi:10.1016/j.burns.2012.02.017
17
18 57. Fracalvieri M, Zingarelli E, Ruka E, et al. Negative pressure wound therapy using gauze and
19 foam: histological, immunohistochemical and ultrasonography morphological analysis of the
20 granulation tissue and scar tissue. Preliminary report of a clinical study. *Int Wound J.* 2011;8(4):355-
21 364. doi:10.1111/j.1742-481X.2011.00798.x
22
23 58. Katz SM, Frank DH, Leopold GR, Wachtel TL. Objective measurement of hypertrophic burn
24 scar: A preliminary study of tonometry and ultrasonography. *Ann Plast Surg.* 1985;14(2):121-127.
25 doi:10.1097/0000637-198502000-00005
26
27 59. Kim JD, Oh SJ, Kim SG, et al. Ultrasonographic findings of re-epithelialized skin after partial-
28 thickness burns. *Burns Trauma.* 2018;6(1):21-21. doi:10.1186/s41038-018-0122-3
29
30 60. Lee KC, Bamford A, Gardiner F, et al. Burns objective scar scale (BOSS): Validation of an
31 objective measurement devices based burn scar scale panel. *Burns.* 2020;46(1):110-120.
32 doi:10.1016/j.burns.2019.05.008
33
34 61. Nicoletti G, Brenta F, Blevé M, et al. Long-term in vivo assessment of bioengineered skin
35 substitutes: a clinical study. *J Tissue Eng Regen Med.* 2015;9(4):460-468. doi:10.1002/term.1939
36
37 62. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical
38 silicone gel and pressure garment therapy for burn scar prevention and management in children 12-
39 months postburn: A parallel group randomised controlled trial. *Clin Rehabil.* 2021;35(8):1126-1141.
40 doi:10.1177/02692155211020351
41
42 63. Wiseman J, Ware RS, Simons M, et al. Effectiveness of topical silicone gel and pressure
43 garment therapy for burn scar prevention and management in children: a randomized controlled
44 trial. *Clin Rehabil.* 2020;34(1):120-131. doi:10.1177/0269215519877516
45
46 64. Źądkowski T, Nachulewicz P, Mazgaj M, et al. A new CO2 laser technique for the treatment
47 of pediatric hypertrophic burn scars: An observational study. *Medicine (Baltimore).*
48 2016;95(42):e5168-e5168. doi:10.1097/MD.0000000000005168
49
50 65. Zuccaro J, Kelly C, Perez M, Doria A, Fish JS. The effectiveness of laser therapy for
51 hypertrophic burn scars in pediatric patients: A prospective investigation. *J Burn Care Res.*
52 2021;42(5):847-856. doi:10.1093/jbcr/irab090
53
54 66. Lacarrubba F, Patania L, Perrotta R, Stracuzzi G, Nasca MR, Micali G. An open-label pilot
55 study to evaluate the efficacy and tolerability of a silicone gel in the treatment of hypertrophic scars
56 using clinical and ultrasound assessments. *J Dermatolog Treat.* 2008;19(1):50-53.
57 doi:10.1080/09546630701387009
58
59 67. Van den Kerckhove E, Stappaerts K, Fieuws S, et al. The assessment of erythema and
60 thickness on burn related scars during pressure garment therapy as a preventive measure for
hypertrophic scarring. *Burns.* 2005;31(6):696-702. doi:10.1016/j.burns.2005.04.014
68. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers
Med Sci.* 2017;33(3):497-501. doi:10.1007/s10103-017-2387-3
69. Alsharnoubi J, Shoukry KE-S, Fawzy MW, Mohamed O. Evaluation of scars in children after
treatment with low-level laser. *Lasers Med Sci.* 2018;33(9):1991-1995. doi:10.1007/s10103-018-
2572-z

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 70. Fabbrocini G, Marasca C, Ammad S, et al. Assessment of the combined efficacy of needling
4 and the use of silicone gel in the treatment of C-section and other surgical hypertrophic scars and
5 keloids. *Adv Skin Wound Care*. 2016;29(9):408-411. doi:10.1097/01.ASW.0000490028.37994.14
6
7 71. Joo SY, Lee SY, Cho YS, Seo CH. Clinical utility of extracorporeal shock wave therapy on
8 hypertrophic scars of the hand caused by burn injury: A prospective, randomized, double-blinded
9 study. *J Clin Med*. 2020;9(5):1376. doi:10.3390/jcm9051376
10
11 72. Lobos N, Wortsman X, Valenzuela F, Alonso F. Color Doppler ultrasound assessment of
12 activity in keloids. *Dermatol Surg*. 2017;43(6):817-825. doi:10.1097/DSS.0000000000001052
13
14 73. Mamdouh M, Omar GA, Hafiz HSA, Ali SM. Role of vitamin D in treatment of keloid. *J Cosmet*
15 *Dermatol*. 2022;21(1):331-336. doi:10.1111/jocd.14070
16
17 74. Reinholz M, Guertler A, Schwaiger H, Poetschke J, Gauglitz GG. Treatment of keloids using
18 5-fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating
19 therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol*.
20 2020;34(10):2436-2444. doi:10.1111/jdv.16354
21
22 75. Reinholz M, Schwaiger H, Poetschke J, et al. Objective and subjective treatment evaluation
23 of scars using optical coherence tomography, sonography, photography, and standardised
24 questionnaires. *Eur J Dermatol*. 2017;26(6):599-608. doi:10.1684/ejd.2016.2873
25
26 76. Soykan EA, Butzelaar L, de Kroon TL, et al. Minimal extracorporeal circulation (MECC) does
27 not result in less hypertrophic scar formation as compared to conventional extracorporeal
28 circulation (CECC) with dexamethasone. *Perfusion*. 2014;29(3):249-259.
29 doi:10.1177/0267659113511656
30
31 77. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix.
32 *Burns*. 2008;35(3):352-355. doi:10.1016/j.burns.2008.06.021
33
34 78. Zhidong X, Haixia L, Chao L, Yongrong L. Wavelet Bilateral Filter Algorithm-Based High-
35 Frequency Ultrasound Image Analysis on Effects of Skin Scar Repair. *Scientific programming*.
36 2021;2021doi:10.1155/2021/9573474
37
38 79. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone
39 gel dressing and pressure therapy on posttraumatic hypertrophic scars. *J Burn Care Res*.
40 2010;31(3):448-457. doi:10.1097/BCR.0b013e3181db52a7
41
42 80. Li N, Yang L, Cheng J, Han J, Hu D. Early intervention by Z-plasty combined with fractional
43 CO2 laser therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet*
44 *Surg*. 2021;74(11):3087-3093. doi:10.1016/j.bjps.2021.03.079
45
46 81. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of
47 fractional CO2 laser treatment of mature burn scars. *J Burn Care Res*. 2016;37(6):379-387.
48 doi:10.1097/BCR.0000000000000383
49
50 82. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
51 scarring. *Lasers Surg Med*. 2012;44:61.
52
53 83. Blome-Eberwein S, Blaine C, Gogal C, Eid S, Foltz C. Fractional Er:Glass photothermolysis
54 laser therapy to treat hypertrophic scarring. *J Burn Care Res*. 2011;32:S95.
55
56 84. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in
57 burn scars using high frequency ultrasound. *J Burn Care Res*. 2012;33(2)(Supplement):S105.
58
59 85. Blome-Eberwein S, Roarabaugh C, Gogal C, Eid S. Exploration of nonsurgical scar
60 modification options: Can the irregular surface of matured mesh graft scars be smoothed with
microdermabrasion? *J Burn Care Res*. 2012;33(3):e133-40.
61
62 86. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
Construct validity and predictive ability of scar thickness change. *Skin Res Technol*. 2020;26(3):369-
375. doi:10.1111/srt.12812
63
64 87. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, Bassiouny DA, Fawzy MM.
Ultrasound biomicroscopy in the diagnosis of skin diseases. *Eur J Dermatol*. 2007;17(6):469-74.
65
66 88. Zuccaro J, Perez M, Mohanta A, Fish J, Doria A. Elastography-Based Quantification of Burn
Scar Stiffness. *J Burn Care Res*. 2019;40(Supplement_1):S215-S215. doi:10.1093/jbcr/irz013.374

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
- 2
- 3
- 4 89. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, et al. Objective quantification of
- 5 hypertrophic scar and donor scar between 2 to 7 months post-burn injury. *J Burn Care Res.*
- 6 2022;43(Supplement 1):S103.
- 7 90. Engrav LH, Heimbach DM, Rivara FP, et al. 12-Year within-wound study of the effectiveness
- 8 of custom pressure garment therapy. *Burns.* 2010;36(7):975-983. doi:10.1016/j.burns.2010.04.014
- 9 91. Fraccalvieri M, Sarno A, Gasperini S, et al. Can single use negative pressure wound therapy
- 10 be an alternative method to manage keloid scarring? A preliminary report of a clinical and
- 11 ultrasound/colour-power-doppler study. *Int Wound J.* 2013;10(3):340-344. doi:10.1111/j.1742-
- 12 481X.2012.00988.x
- 13 92. Li P, Li-Tsang CWP, Deng X, et al. The recovery of post-burn hypertrophic scar in a monitored
- 14 pressure therapy intervention programme and the timing of intervention. *Burns.* 2018;44(6):1451-
- 15 1467. doi:10.1016/j.burns.2018.01.008
- 16 93. Chang C-S, Wallace CG, Hsiao Y-C, Chang C-J, Chen PK-T. Botulinum toxin to improve results
- 17 in cleft lip repair: A double-blinded, randomized, vehicle-controlled clinical trial. *PLoS One.*
- 18 2014;9(12):e115690-e115690. doi:10.1371/journal.pone.0115690
- 19 94. Blome-Eberwein S, Pagella P, Boorse D, Gogal C. Treatment of hypertrophic burn scars with
- 20 different laser modalities. *Lasers Surg Med.* 2014;46:6-7.
- 21 95. Cho YS, Jeon JH, Hong A, et al. The effect of burn rehabilitation massage therapy on
- 22 hypertrophic scar after burn: A randomized controlled trial. *Burns.* 2014;40(8):1513-1520.
- 23 doi:10.1016/j.burns.2014.02.005
- 24 96. Cooper LE, Bohan PK, Hatem VD, Carlsson AH, Cancio LC, Chan RK. Analysis of the utility of
- 25 CO2 and pulse-dye lasers in the treatment of hypertrophic burn scars. *J Burn Care Res.*
- 26 2021;42(Supplement_1):S28-S29. doi:10.1093/jbcr/irab032.041
- 27 97. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes
- 28 of burn scars treated with laser therapy. *J Burn Care Res.* 2016;37(Supplement):S106.
- 29 98. Jang KU, Lee JY, Choi JS, Seo CH. 5 FU and triamcinolone injection to the hypertrophic scar
- 30 were compared. *Burns.* 2009;35:S41-S42. doi:10.1016/j.burns.2009.06.166
- 31 99. Kim SK, Park JM, Jang YH, Son YH. Management of hypertrophic scar after burn wound using
- 32 microneedling procedure (dermastamp). *Burns.* 2009;35:S37-S37. doi:10.1016/j.burns.2009.06.146
- 33 100. Li K, Nicoli F, Cui C, et al. Treatment of hypertrophic scars and keloids using an intralesional
- 34 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive technique. *Sci Rep.*
- 35 2020;10(1):21694-21694. doi:10.1038/s41598-020-78738-9
- 36 101. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-
- 37 monitored suit in the management of post-burn hypertrophic scar: A clinical controlled study with
- 38 objective assessment. *J Burn Care Res.* 2016;37(Supplement):S199.
- 39 102. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and
- 40 related research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns).* 2010;26(6):411-5.
- 41 103. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the
- 42 efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult burn
- 43 patients. *J Am Acad Dermatol.* 2017;76(6):AB212-AB212. doi:10.1016/j.jaad.2017.04.1113
- 44 104. Nedelec B, Couture M, Calva V, et al. Randomized controlled trial of the immediate and long-
- 45 term effect of massage on adult postburn scar. *J Burn Care Res.* 2018;39(suppl_1):S57-S57.
- 46 doi:10.1093/jbcr/iry006.106
- 47 105. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report.
- 48 *Wound Repair Regen.* 2018;26(2):A28-A28.
- 49 106. Siwy KG, Lee K, Donelan MB, Anderson RR, Miletta NR. Fractionated CO2 laser and burn scar
- 50 contractures: Evaluation of post treatment scar function and appearance. *J Burn Care Res.*
- 51 2016;37:S202-S202.
- 52 107. Ud-Din S, Foden P, Douglas M, et al. A double-blind randomized controlled trial
- 53 demonstrates for the first time evidence for the role of topical epigallocatechin-3-gallate in reducing
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BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

angiogenesis, inflammation, and skin thickness in human skin scarring: A noninvasive, morphological and immu. *Wound Repair and Regeneration*. 2017;25(4):A3.

108. Ud-Din S, Foden P, Mazhari M, Al-Habba S, Baguneid M, Bayat A. Histomorphologic assessment of noninvasive quantitative imaging in progression of cutaneous healing in human skin: Dynamic optical coherence tomography versus high frequency ultrasound. *Wound Repair Regen*. 2017;25(4):A3-A4.

109. Ud-Din S, Foden P, M M, Samer A, Baguneid M, Bayat A. Quantitative index for skin fibrosis: Combined optical coherence tomography with ultrasound validated by histology and immunohistochemistry. *Wound Repair Regen*. 2018;26(4):A11-A12.

110. Li-Tsang CWP, Lau JCM, Choi J, Chan CCC, Jianan L. A prospective randomized clinical trial to investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among the Chinese population. *Burns*. 2006;32(6):678-683. doi:10.1016/j.burns.2006.01.016

111. Alshehri A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars. *Archives of the Balkan Medical Union*. 2015;50(3):364-366.

112. Cho J, Choi J, Hur J, et al. The effect of CO2 fractional laser (pixel®) on hypertrophic burn scars. *J Burn Care Res*. 2012;33(2)(Supplement):S132.

113. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn Care Res*. 2018;39(suppl_1):S219-S220. doi:10.1093/jbcr/iry006.416

114. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration matter? *Lasers Surg Med*. 2020;52(2):149-158. doi:10.1002/lsm.23166

115. Ge X, Sun Y, Lin J, Zhou F, Yao G, Su X. Effects of multiple modes of UltraPulse fractional CO2 laser treatment on extensive scarring: a retrospective study. *Lasers Med Sci*. 2021;37(3):1575-1582. doi:10.1007/s10103-021-03406-x

116. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case review. *J Burn Care Res*. 2011;32(Supplement):S169-S169.

117. Tu P, Wang Z-G, Zhang Q-X, You Y-F. High frequency ultrasound in dynamic observation on effect of local injection with diprosan for treating pathological scar. *Chinese Journal of Interventional Imaging and Therapy*. 2014;11(4):217-220.

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	3-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	5-7
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	7
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-10
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	9
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	9
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	10-11
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11 and supplementary table 1
Critical appraisal of individual	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	N/A



SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
sources of evidence§		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10-11
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	11-12
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	12-15
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Results section (11-46)
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Results section (11-46)
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	47-49
Limitations	20	Discuss the limitations of the scoping review process.	49-50
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	50-51
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	51

JB1 = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



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BMJ Open

Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence across the translational pipeline of research-to-practice

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3 Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence
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5 across the translational pipeline of research-to-practice*
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8 **Running Title:** Review of scar thickness measurement with ultrasound
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14 Brandon Meikle^{1,2**}, Megan Simons^{2,3,7}, Tamsin Mahoney⁴, Tristan Reddan^{5,6}, Bryan Dai²,
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16 Roy M Kimble^{1,2,6,7} and Zephania Tyack^{2,8}
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18
19
20
21
22

23 ¹ Centre for Children's Burns and Trauma Research, Queensland Children's Hospital,
24 Brisbane, Queensland, Australia
25
26
27

28 ² Children's Health Research Centre, Faculty of Medicine, The University of Queensland,
29 Herston, Queensland, Australia
30
31
32

33 ³ Occupational Therapy Department, Queensland Children's Hospital, Children's Health
34 Queensland Hospital and Health Service, Brisbane, Queensland, Australia
35
36
37

38 ⁴ Surgical, Treatment and Rehabilitation Services (STARS), Metro North Hospital and Health
39 Service, Brisbane, Queensland, Australia
40
41
42

43 ⁵ Medical Imaging and Nuclear Medicine, Queensland Children's Hospital and Health
44 Service, Brisbane, Queensland, Australia
45
46
47

48 ⁶ School of Clinical Sciences, Faculty of Health, Queensland University of Technology,
49 Brisbane, Queensland, Australia
50
51
52

53 ⁷ Pegg Leditschke Children's Burns Centre, Queensland Children's Hospital, Children's
54 Health Queensland Hospital and Health Service, Brisbane, Queensland, Australia
55
56
57
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59
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1
2
3 ⁸ Australian Centre for Health Service Innovation (AusHI), Centre for Healthcare
4
5 Transformation, and School of Public Health and Social Work, Queensland University of
6
7 Technology, Brisbane, Queensland, Australia
8
9

10
11 ** Corresponding author
12

13
14 E-mail: brandon.meikle@uq.net.au (BM)
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22 (ANZBA) 2022 Annual Scientific Meeting, the 2022 Centre for Children's Health Research
23
24 Symposium, Child Health Research Centre, The University of Queensland, and the 2023
25
26 British Burn Association Annual Conference.
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ABSTRACT:

Objectives: To identify the ultrasound methods used in the literature to measure traumatic scar thickness, and map gaps in the translation of these methods using evidence across the research-to-practice pipeline.

Design: Scoping review

Data Sources: Electronic database searches of Ovid MEDLINE, Embase, Cumulative Index of Nursing and Allied Health Literature (CINAHL) and Web of Science. Grey literature searches were conducted in Google. Searches were conducted from inception (date last searched 27/05/2022).

Data Extraction: Records using B-mode ultrasound to measure scar and skin thickness across the research-to-practice pipeline of evidence were included. Data was extracted from included records pertaining to: methods used; reliability and measurement error; clinical, health service, implementation and feasibility outcomes; factors influencing measurement methods; strengths and limitations; and use of measurement guidelines and/or frameworks.

Results: Of the 9309 records identified, 118 were analysed (n = 82 articles, n = 36 abstracts) encompassing 5213 participants. Reporting of methods used was poor. B-mode, including high-frequency (i.e., > 20 MHz) ultrasound was the most common type of ultrasound used (n = 72 records; 61% of records), and measurement of the combined epidermal and dermal thickness (n = 28; 24%) was more commonly measured than the epidermis or dermis alone (n = 7, 6%). Reliability of ultrasound measurement was poorly reported (n=14; 12%). The scar characteristics most commonly reported to be measured were epidermal oedema, dermal fibrosis and hair follicle density. Most records analysed (n = 115; 97%) pertained to the early stages of the research-to-practice pipeline, as part of research initiatives.

1
2
3 **Conclusions:** The lack of evaluation of measurement initiatives in routine clinical practice
4 was identified as an evidence gap. Diverse methods used in the literature identified the need
5 for greater standardisation of ultrasound thickness measurements. Findings have been used to
6 develop nine methodological considerations for practitioners to guide methods and reporting.
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13 **STRENGTHS AND LIMITATIONS OF THIS STUDY:**

- 14
15 • Use of the Australian Government Department of Health and Aged Care Medical
16 Research Future Fund research-to-practice pipeline phases to categorise records
17 allowed identification of gaps in the use of ultrasound for clinical practice.
18
19
- 20 • Clinical, health service, implementation and feasibility outcomes related to ultrasound
21 measurement in included records were summarised to determine what is needed to
22 close the research-to-practice gap for ultrasound measurement of scar thickness.
23
24
- 25 • A limitation is that only articles available in English or with an English abstract were
26 considered for inclusion and data extraction, thus findings are likely most relevant to
27 English speaking countries.
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INTRODUCTION:

Traumatic cutaneous injury, caused by sharp object penetration (e.g., surgery or vaccination) or burns (including thermal, chemical and friction) may result in the formation of

hypertrophic scarring. (1) Hypertrophic scars result from an aberrant cutaneous healing response that leads to the formation of red, raised scars, often accompanied by pruritus and skin tightening, which remain within the boundaries of the initial injury. (2-7) The sequelae of hypertrophic scars can impact on patient's physical and psychosocial quality of life. (8, 9)

A characteristic of hypertrophic scarring that both patients and clinicians have identified as being important, and which has subsequently been used as a way to measure clinical and treatment outcomes, is scar thickness. (9-17) Scar thickness can be measured both subjectively, through clinician assessment and patient-reported outcomes, or objectively, utilising medical imaging methods. (18, 19) The pathological complexity of hypertrophic scars means that they generally extend below the level of the surrounding skin, supporting the use of medical imaging modalities such as ultrasound for thickness quantification, as these are capable of providing information about subcutaneous structures and processes. (19, 20) Scar thickness measurement using ultrasound can be conducted in both clinical and research contexts. Where routine measurements like ultrasound are used to guide clinical decision-making and treatment, this practice is known as measurement-based care. (21)

Ultrasound is a safe, non-invasive and largely cost-effective (compared to other imaging modalities) imaging method with measurement utility in both adult and paediatric populations. (22-24) Modern B-mode (brightness mode) ultrasound, particularly high- (i.e., ≥ 20 MHz) or ultra-high frequency (30-100 MHz) (25) ultrasonography, allows differentiation between the epidermis and dermis, which permits quantification of skin layer-specific scar characteristics. This differentiation may allow assessors to observe and understand the pathological mechanisms of individual scars and adjust treatment protocols accordingly. (24,

1
2
3 26-31) Additionally, B-mode ultrasound is commonly used as the basis for other imaging
4
5 methods, such as colour Doppler ultrasound or elastography, which can allow quantification
6
7 of additional scar characteristics, such as their elastic properties. (26-29, 32, 33)
8
9

10
11 Despite the clinical advantages of B-mode ultrasound for scar thickness measurement,
12
13 methods are poorly reported and lack standardisation in the literature. This casts doubt on the
14
15 validity of clinical decision-making in measurement-based care initiatives (e.g., setting depth
16
17 of AFCO₂ penetration) informed by research findings (e.g., response to treatment) where
18
19 ultrasound measurements are used. (34) Lack of standardisation also makes between-study
20
21 comparison, such as systematic reviews and meta-analyses, difficult, (35) and poor
22
23 methodological reporting hampers the ability to accurately replicate findings. This scoping
24
25 review focusses on mapping and identifying gaps in ultrasound methods and evaluation
26
27 reported in the current literature along the research-to-clinical practice pipeline. (36)
28
29
30
31 Methodological considerations for people performing ultrasound scar thickness
32
33 measurements, including practitioners (herein termed assessors) using ultrasound in clinical
34
35 practice are presented based on the review findings.
36
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39 **METHODS:**

40 41 42 **Protocol Publication and Review Structure:**

43
44
45 The protocol for this review has been published *a priori*. (37) This scoping review was
46
47 conducted and is reported according to the Arksey and O'Malley (2005) (38) framework. The
48
49 steps outlined in this framework are: 1) identifying the research question; 2) identifying
50
51 relevant records; 3) selecting appropriate records; 4) charting extracted data; and 5) collating,
52
53 summarising and reporting the results. (38)
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57 **Research Question:**

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3 The primary question of this scoping review was: “What do we know and not know about the
4 measurement of traumatic cutaneous scar thickness using ultrasound?” This question was
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6 measurement of traumatic cutaneous scar thickness using ultrasound?” This question was
7
8 addressed through exploration of: methods used; reliability and measurement error; clinical,
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10 health service, implementation and feasibility outcomes; factors influencing ultrasound
11
12 imaging and measurement methods; strengths and limitations of measurement methods; and
13
14 use of measurement guidelines and/or frameworks. While the focus of this review was the
15
16 measurement of traumatic cutaneous scar thickness with ultrasound, methods used to measure
17
18 the thickness of unscarred skin were reported where these were used in combination with
19
20 measurement of scar thickness (e.g., as control or comparator measurements).
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23

24 **Identifying Relevant Records:**

25
26
27 A standardised search strategy was developed and piloted with the assistance of a medical
28
29 librarian using the concepts ‘ultrasound’, ‘skin’, ‘thickness’ and ‘measure’, with associated
30
31 terms and truncations (supplementary box 1). Ovid MEDLINE, Embase, Cumulative Index of
32
33 Nursing and Allied Health Literature (CINAHL) and Web of Science electronic databases
34
35 were searched from conception to identify original studies (date last searched 27th May
36
37 2022).
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42 The phrase ‘ultrasound scar thickness measurement’ was used to conduct additional searches
43
44 in 1) Google Scholar, and 2) Google to identify original studies in grey literature, and studies
45
46 not identified in database searches. Title and abstract searches in Google Scholar and Google
47
48 were limited to the first 200 results. (39)
49
50

51 **Record Selection:**

52
53 Following de-duplication, six reviewers screened records using Covidence (Veritas Health
54
55 Innovation, Melbourne, Australia; available at www.covidence.org) for eligibility according
56
57 to the inclusion criteria (Table 1). Both peer-reviewed journal articles and abstracts were
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59
60

1
2
3 included to ensure that all the available and most recent methodological information was
4
5 obtained. (40) Data collected from peer-reviewed journal articles was considered the primary
6
7 source of data, with information from abstracts used to confirm or extend the journal data.
8
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10 The inclusion of abstracts will assist future authors to further investigate the information
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12 presented as full texts may become available. During both title and abstract and full text
13
14 screening, one researcher (BM) screened all records as a single reviewer, while other
15
16 researchers (MS, TM, TR, BD and ZT) screened records as a second reviewer. Conflicts were
17
18 resolved through discussion between at least two authors to reach agreement. A third author
19
20 was used as a tiebreaker where agreement could not be reached.
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25 **Table 1. Inclusion and exclusion criteria for studies included in the scoping review.**

Inclusion	Exclusion
<ul style="list-style-type: none"> • Traumatic scars measured with ultrasound based on B-mode ultrasound (including high-frequency, ultra-high-frequency and Doppler) • Measurements taken of living, human individuals • Measurement of traumatic cutaneous scarring arising from penetration of the skin with sharp objects (including surgery or vaccination), or as a result of burns, (including thermal, chemical or friction) • Articles written in English, or with English abstracts 	<ul style="list-style-type: none"> • Reviews, discussion papers, opinion pieces • Measurement of non-traumatic scars (e.g., acne scars). Non-traumatic scars measured along with burn scars were included • Measurement of skin thickness in non-traumatic conditions (e.g., diabetes) • Measurement of skin thickness where there is no cutaneous involvement in the trauma (e.g., traumatic brain injury) • Measurement using A-mode ultrasound

48 **Charting the Data:**

49
50
51 The data extraction table was developed in Microsoft Excel and piloted by two authors (BM
52
53 and ZT) through independent extraction and comparison of data from two records. The table
54
55 was then modified to include the scar characteristics (e.g., fibrosis, oedema) measured,
56
57 measurer/assessor training, the number of measurements taken and funding sources
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3 (Supplementary Table 1). Full text data extraction was completed by four authors (BM, MS,
4
5 TM and ZT). An additional author (BD) independently extracted data from five randomly
6
7 selected records, which was compared to data extracted by other authors. Minimal differences
8
9 between data extracted by the independent author and that by other authors were observed,
10
11 thus further independent extraction was not performed. As is typical in scoping reviews, the
12
13 certainty or quality of evidence was not appraised. (38)
14
15

16
17 The research-to-practice pipeline published by the Australian Government Department of
18
19 Health and Aged Care Medical Research Future Fund (figure 1) was used to categorise each
20
21 included record based on their stated aims into one of the four phases. (36) Studies related to
22
23 phase 1 of this pipeline, basic research, were only included in this review when data on scar
24
25 or skin thickness pertained to human participants (table 1). Phase 2 of this pipeline included
26
27 randomised controlled trials, while phase 3 included pragmatic and observational studies
28
29 conducted outside randomised controlled trials. The final phase of this pipeline (phase 4)
30
31 indicates initiatives used in routine clinical practice.
32
33

34
35 Where clinical (e.g., treatment satisfaction, scar symptoms), health service (e.g., efficiency,
36
37 safety, effectiveness, equity, patient-centredness and timeliness) and implementation (e.g.,
38
39 acceptability, adoption, appropriateness, fidelity, cost, penetration and sustainability)
40
41 outcomes were addressed, they were reported and defined according to Proctor *et al.* (41).
42
43 For example, in the context of this scoping review, acceptability is defined as the level to
44
45 which ultrasound is palatable amongst stakeholders (e.g., assessors), appropriateness is the
46
47 perceived fit of ultrasound within regular clinical practice, and fidelity is the degree to which
48
49 ultrasound is used in the way it was initially described. (41) Measurement instrument-specific
50
51 feasibility outcomes defined by Prinsen *et al.* (42) are reported in the current review. These
52
53 outcomes included ease of administration, standardisation, completion time, instrument cost
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55 and availability, and ease of score calculation. (42) Reliability and measurement error were
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1
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3 defined according to COnsensus-based Standards for the selection of health Measurement
4 INstruments (COSMIN) tools. (43, 44) Measurements with an intraclass correlation
5 coefficient (ICC) of 0.7 or greater were considered reliable. (44) Measurement error was
6 assessed by comparing the reported standard error of the measurement (SEM) with the
7 reported smallest detectable change (SDC). Where the reported measurement error was
8 smaller than the reported smallest detectable change, it was interpreted as indicating real
9 change or variance can be detected, and that change or variance is not a result of error. (44)

19 **Patient and Public Involvement**

20 There was no patient and/or public involvement in the design, conduct, reporting or
21 dissemination of information in this scoping review.

26 **RESULTS:**

27
28 Electronic database searches identified 9309 records. After removal of 3703 duplicate
29 records, the titles and abstracts of 5606 records were screened for relevance according to the
30 inclusion criteria (Table 1). Following full-text screening, 104 records proceeded to data
31 extraction. Searches in Google and Google Scholar identified an additional 14 records,
32 providing a total of 118 records for data extraction. Search and screening results are
33 presented according to the Preferred Reporting Items for Systematic reviews and Meta-
34 Analyses (PRISMA) flow diagram (supplementary figure 1). (45)

46 **Record Characteristics:**

47
48 Of the 118 records included in this review, 82 were journal articles (69%) and 36 were
49 abstracts (31%) (Table 2), representing a total of 5213 participants (range 1-438; mode 20
50 participants per record). Adults aged 18 years and older were most commonly targeted in
51 articles (n = 43 articles; 52% of articles), (17, 26, 29, 46-85) while most abstracts did not
52 report the age group measured (n = 25 abstracts; 69% of abstracts). (86-110) The most
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3 common scar type measured was burn scars in both journal articles (n = 43 articles; 52% of
4 articles), (17, 22-24, 27, 47, 57-59, 61, 62, 64-67, 71-75, 81, 82, 84, 111-130) and abstracts (n
5 = 23 abstracts; 64% of abstracts) (28, 30, 86-88, 91-94, 96, 98, 102-106, 131-135) (Table 2).
6
7
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10 Most identified articles used ultrasound measurement of scar thickness as part of research
11 initiatives, and were categorised as either phase 2 (n = 50 articles; 61% of articles) (17, 22,
12 26, 31, 46-49, 51-56, 61, 63-65, 67, 69-71, 74-76, 78, 81, 83, 84, 111, 112, 114, 115, 117,
13 124-127, 129, 130, 136-145) or phase 3 (n = 30 articles; 37% of articles). (23, 24, 27, 29, 50,
14 57-60, 62, 66, 68, 72, 73, 77, 79, 80, 82, 85, 116, 118, 120-123, 128, 146-149) on the
15 research-to-practice pipeline. (36) Phase 2 was also the most common phase represented by
16 abstracts (n = 21; 58% of abstracts), (86, 88, 91, 93, 95, 97, 99-104, 106-108, 131-134, 150,
17 151) followed by phase 3 (n = 15 abstracts; 42% of abstracts). (28, 30, 87, 89, 90, 94, 96, 98,
18 105, 109, 110, 135, 152-154) Phase 4 was addressed by two articles (2% of articles) (113,
19 119) and one abstract (2% of abstracts), (92) which used ultrasound to measure treatment
20 response to an intervention already used in routine clinical practice, including compression
21 garments (113, 119) and CO₂ fractional laser. (92) No records pertained to phase 1.
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Table 2. Summary of characteristics of records included in this review*

Characteristic	Category	Number of Records (Translational Pipeline Phase 2*)	Number of Records (Translational Pipeline Phase 3*)	Number of Records (Translational Pipeline Phase 4*)
<i>Journal Articles</i>				
Funding Source	Commercial	2	1	1
	Non-commercial	23	13	0
Population Type	Commercial & Non-commercial	2	1	1
	No funding	6	3	0
	Not reported	16	12	0
	Adult	27	16	0
	Paediatric	6	4	0
	Paediatric and Adult	13	7	2
Scar Aetiology	Not reported	3	3	0
	Burn	22	18	1
	Surgical†	5	2	0
	Mixed	10	3	0
	Not specified	12	7	0
<i>Abstracts</i>				
Funding Source	Commercial	0	0	0
	Non-commercial	3	1	0
	Commercial & Non-commercial	0	0	0
	No funding	0	0	0
	Not reported	17	14	1
Population Type	Adult	1	2	0
	Paediatric	0	3	0
	Paediatric and Adult	4	1	0
	Not reported	15	9	1
Scar Aetiology	Burn	12	10	1
	Surgical†	1	2	0
	Mixed	2	1	0
	Not specified	5	2	0

Legend: Paediatric: measurement of patients under the age of 18; Adult: measurement of patients aged 18 years or older; Burn: scars caused by thermal, chemical or friction injury; Surgical: scars caused by surgical procedures (including biopsies); Mixed: scars of included record were of mixed origin (e.g., burn and acne)

Footnotes: *Stage in the research to clinical practice translational pipeline, as defined by the Australian Government Department of Health and Aged Care (36); †Type of surgery defined in supplementary table 2

* A breakdown of each characteristic per record is presented in Supplementary Table 2

1 **Methods used to measure traumatic cutaneous scar thickness:**

2 B-mode, including high-frequency (i.e., ≥ 20 MHz) B-mode ultrasound was the most
3 commonly reported ultrasound type used in both articles (n = 56; 68% of articles) (17, 22-24,
4 26, 29, 31, 46-49, 53, 54, 56, 57, 59, 60, 64, 65, 67, 69-78, 80-82, 84, 85, 111, 112, 114, 116-
5 118, 120, 122, 123, 126-130, 138, 139, 141, 142, 144-146, 149), while most abstracts did not
6 report the type of ultrasound used (n = 22; 61% of abstracts) (86, 87, 92-98, 101, 103, 105,
7 106, 108, 131-134, 150-153) (Table 3). Specialised B-mode ultrasound devices, including the
8 Tissue Ultrasound Palpation System (TUPS; a B-mode ultrasound transducer in-series with a
9 load cell to allow measured compression of the skin), (68, 99, 100, 124) and colour Doppler
10 ultrasound, (52, 149) were used in six records (Table 3).

12 **Table 3. Summary of measurement methods used in included record***

Characteristic	Parameters	Number of Records
<i>Journal Articles</i>		
Ultrasound Type	B-mode	24
	Midrange	2
	High-frequency	29
	Other	4
	Not reported	22
Measurement Parameters	Epidermal	0
	Dermal	4
	Epidermal & dermal	2
	Combined epidermal & dermal	32
	Other	3
Scar characteristic measured	Not reported	40
	Fibrosis	27
	Oedema	1
	Fibrosis & oedema	10
	Other	1
	Not reported	42
<i>Abstracts</i>		
Ultrasound Type	B-mode	3
	Midrange	0
	High-frequency	9
	Other	3
	Not reported	21
Measurement Parameters	Epidermal	0
	Dermal	1
	Epidermal & dermal	4
	Combined epidermal & dermal	1
	Other	1
Scar characteristic measured	Not reported	29
	Fibrosis	2
	Oedema	0
	Fibrosis & oedema	0
	Other	0
	Not reported	34

Legend: B-mode: brightness-mode ultrasound (<20 MHz); High-frequency: High-frequency B-mode ultrasound (>20 MHz); Other: fields are expanded with additional detail in supplementary table 3

13 *A full summary of each included record is available in supplementary table 3

1
2
3 14 The type of scar and skin thickness measurement (i.e., thickness of the dermis, epidermis, or
4
5 15 combined epidermal and dermal measurement) was reported in 39 records (33%) (Table 3).
6
7 16 Where reported, combined measurement of epidermal and dermal thickness was the most
8
9 17 common method used in articles (n = 32; 76% of articles reporting skin measurement type).
10
11 18 (17, 22-24, 27, 29, 50, 53, 56-58, 60, 64-66, 70, 72-77, 80-82, 114, 116, 118, 122, 126, 127,
12
13 19 130, 139, 146, 148) Separate epidermal and/or dermal thickness measurements were reported
14
15 20 in seven journal articles (17% of articles reporting skin thickness measurement type). (26, 47,
16
17 21 48, 52, 53, 71, 118) Of these records, two authors provided a rationale for this decision: each
18
19 22 skin layer provided different information on the scar; (26) or responded differently to
20
21 23 treatment. (67, 71) Most abstracts did not report the type of skin measurement used (n = 30;
22
23 24 83% of abstracts). (28, 30, 91-101, 103-110, 131-134, 150-154)
24
25 25 Three articles (4% of articles) (47, 110, 111) and one abstract (3% of abstracts) (28) directly
26
27 26 reported that fibrosis was the scar characteristic targeted by the measurement. One of these
28
29 27 records also quantified hair follicle density to assess the difference between scarred and
30
31 28 unscarred skin. (47) An additional 25 articles (30% of articles) (17, 46, 52, 53, 56, 63-65, 67,
32
33 29 70, 79, 80, 83, 84, 112, 120, 123, 125-127, 140, 142, 145, 148, 149, 155) and one abstract
34
35 30 (3% of abstracts) (110) made indirect reference (i.e., within the introduction or discussion) to
36
37 31 the measurement of fibrosis. Ten journal articles (12%) made indirect reference to the
38
39 32 measurement of both oedema and fibrosis, (31, 54, 55, 71, 74, 76-78, 138, 144) and one
40
41 33 record made indirect reference to the measurement of oedema. (59)
42
43 34 Additional objective and/or subjective measurement methods were employed alongside
44
45 35 ultrasound measurement in 72 articles (88% of articles) (17, 22, 24, 26, 29, 31, 46-53, 55-57,
46
47 36 60-70, 72-81, 83-85, 111-122, 124-130, 136-142, 144, 145, 147-149) and 31 abstracts (86%
48
49 37 of abstracts) (86, 88, 89, 91-95, 97-110, 131-134, 150, 151, 153, 154) (Supplementary Table
50
51 38 4). All three phase 4 studies involving implementation in routine clinical practice utilised
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1
2
3 39 additional measurements. (92, 113, 119) The additional objective measurements used in
4
5 40 included records were elastography (elasticity), cutometric assessment (pliability) and
6
7 41 Doppler ultrasound (vascularity). The additional subjective measurements were conducted
8
9 42 using clinician-based rating scales (e.g., Vancouver Scar Scale or modified Vancouver Scar
10
11 43 Scale) or Patient Reported Outcome Measures. The Vancouver Scar Scale was used in 35
12
13 44 articles (43% of articles) (17, 31, 46, 47, 49, 50, 52, 55, 57, 61-64, 66-70, 73, 85, 111, 112,
14
15 45 114, 116, 118, 121, 124, 128, 130, 136-138, 140-142) and 11 abstracts (31% of abstracts) (88,
16
17 46 91, 92, 98-100, 107, 134, 150, 151, 153). Patient-reported outcome measures (PROMs) were
18
19 47 used in 27 articles (33% of articles) and 11 abstracts (31% of abstracts). (46, 53, 56, 57, 60,
20
21 48 72-75, 85, 91, 94, 97, 101-106, 111, 112, 114, 115, 117, 118, 120, 122, 129, 131-133, 138,
22
23 49 140, 141, 148, 150, 151, 153, 154) Of the records that reported using PROMs, the most
24
25 50 commonly used was the patient report of the Patient and Observer Scar Assessment Scale
26
27 51 (POSAS), used in 17 articles (63% of articles reporting use of PROMs) (17, 22, 46, 50, 53,
28
29 52 61, 62, 64, 76, 77, 79, 114, 121, 125-127, 147) and 8 abstracts (73% of abstracts reporting use
30
31 53 of PROMs) (91, 93, 102, 104, 106, 132, 153) (Supplementary Table 4). In most cases,
32
33 54 additional measurement methods were used to supplement ultrasound thickness
34
35 55 measurements as research outcomes. In some records (n = 16; 14% of records), however,
36
37 56 ultrasound was compared with histology, POSAS, dermoscopy, VSS and modified VSS,
38
39 57 clinical assessment, modified Seattle Scar Scale, high-definition optical coherence
40
41 58 tomography, 3D camera, immunohistochemistry, and immunohistomorphometry. (17, 24, 26,
42
43 59 29, 31, 50, 51, 64, 73, 77, 86, 95, 110, 120, 124, 149) Where the effectiveness of ultrasound
44
45 60 was judged against other methods, it was only found to be inadequate against histology. (26,
46
47 61 86)
48
49
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56
57 62 Methods used to relocate the scar for repeated measurements were reported in 34 records
58
59 63 (29%) (Supplementary Table 3). The most common relocation method was tracing the outline
60

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3 64 or boundaries of the scar on a transparent or translucent sheet (n = 14 articles; 35% of articles
4
5 65 reporting scar relocation), (23, 49, 65, 74, 81, 115, 116, 120, 124, 125, 153) occasionally
6
7
8 66 including prominent or bony landmarks close to the scar. (23, 24, 72, 73, 123) Photographs (n
9
10 67 = 10 articles; 25% of articles reporting relocation and n = 1 abstract) and linear measurements
11
12 68 from defined points or anatomical landmarks on or around the scar (n = 4 articles; 10% of
13
14 69 articles reporting relocation) were also used for scar relocation. The ‘worst’ or ‘thickest’ part
15
16 70 of the scar, as determined by patients or assessors, was chosen as the measurement site in 14
17
18 71 journal articles (35% of journal articles reporting relocation) (23, 31, 52, 54, 57, 61, 62, 67,
19
20 72 126, 127, 138, 141, 148, 155) and one abstract. (105)

23
24 73 Measurement of unscarred skin, either contralateral or adjacent to the scar, was performed in
25
26 74 32 articles (39% of articles%) (17, 22-24, 27, 29, 46-48, 50, 51, 53, 56-60, 64, 72, 73, 80, 81,
27
28 75 85, 114, 118, 120-122, 128, 145, 146, 148) and 7 abstracts (19% of abstracts) (28, 94, 95,
29
30 76 150, 151, 153, 154) These measurements were primarily used as controls or comparators to
31
32 77 scar measurements (n = 27, 69% of records reporting unscarred skin measurement). (17, 22,
33
34 78 23, 28, 29, 47, 48, 51, 53, 56-60, 64, 67, 73, 80, 85, 95, 118, 120, 122, 128, 146, 148, 153,
35
36 79 154) Additionally, four records (10% of records reporting unscarred skin measurement)
37
38 80 evaluating treatment efficacy measured both unaffected skin thickness and the thickness of a
39
40 81 ‘control’ or untreated scar. (46, 74, 94, 114) All instances where additional ultrasound
41
42 82 measurements were taken of unscarred skin or untreated scars were reported as part of
43
44 83 research initiatives aligning with phases 2 and 3 of the research-to-practice pipeline (figure
45
46 84 1). (36)

85 **Reliability and measurement error**

54
55 86 Reliability was calculated for both scarred and unscarred skin in 13 articles (16% of articles)
56
57 87 and two abstracts (5% of abstracts), and was generally considered acceptable (Supplementary
58
59
60

1
2
3 88 Table 5). This included inter-rater reliability (n = 5; 4% of articles), (54, 64, 73, 120, 137)
4
5 89 intra-rater reliability (n = 3; 4% of journal articles), (22, 23, 65) and both inter- and intra-rater
6
7 90 reliability (n = 7; 6%; including 2 abstracts) (17, 24, 57, 82, 87, 105, 124). The intraclass
8
9 91 correlation coefficient (ICC) was the most commonly reported reliability statistic (n = 10; 8%
10
11 92 of records, including one abstract), (17, 24, 57, 64, 65, 73, 82, 87, 120, 124) where it was
12
13 93 reported for both scar and unscarred skin measurements in four articles (5% of articles). (17,
14
15 94 24, 57, 73) The reported combined thickness (i.e., epidermal and dermal) ICCs for inter-rater
16
17 95 reliability of scarred skin ranged from 0.82 to 0.985, while the inter-rater ICC for the
18
19 96 measurement of unscarred skin ranged from 0.33 to 0.98, with one of the four records
20
21 97 reporting an ICC below the threshold value of 0.7 (ICC = 0.33) (24) and one record simply
22
23 98 reported that the inter-rater ICC for scarred skin was “acceptable to high”. (64) The reported
24
25 99 intra-rater reliability for combined thickness measurements of scarred skin ranged from 0.89
26
27 100 to 0.983, and for unscarred skin ranged from 0.61 to 0.982, with one record reporting an ICC
28
29 101 below the threshold of 0.7 (ICC = 0.61). (24) One record reported both the inter- and intra-
30
31 102 rater ICCs for individual epidermal (inter-rater ICC = 0.297; intra-rater ICC = 0.809) and
32
33 103 dermal (inter-rater ICC = 0.991; intra-rater ICC = 0.991) scar thickness measurement. (87)
34
35 104 Four articles (5% of articles) reporting reliability used Pearson’s R, an undisclosed method,
36
37 105 or description (e.g., high) as detailed in supplementary table 2. (22, 54, 105, 137)
38
39 106 Measurement error for inter-rater and intra-rater reliability of combined, epidermal or dermal
40
41 107 thickness was reported in four articles (5% of articles) and one abstract using standard error
42
43 108 of the measurement (SEM). The inter-rater SEM for the combined epidermal and dermal
44
45 109 thickness of scarred skin ranged from 0.11 mm to 0.5 mm, and the intra-rater SEMs ranged
46
47 110 from 0.18 to 0.52 mm. Individual records reported SEM values for unscarred skin, and
48
49 111 separate epidermal and dermal measurements, available in Supplementary Table 5. (17, 23,
50
51 112 24, 82, 87) Only one record reported calculation of the smallest detectable change (SDC). In
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3 113 that record the inter-and intra-rater SDC was calculated for both scarred and unscarred skin.
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5 114 The scarred skin SDCs were 1.4 mm (inter-rater) and 0.6 mm (intra-rater), and unscarred skin
6
7
8 115 SDCs were 0.8 mm (inter-rater) and 0.5 mm (intra-rater). (24) The reported SEMs were all
9
10 116 close to or below the largest SDC value reported. This finding may indicate that ultrasound
11
12 117 can detect true variance in scar thickness above measurement error for traumatic scar and skin
13
14
15 118 thickness.

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18 119 Of the records that reported reliability and measurement error, measurements were taken by
19
20 120 practitioners with varying clinical expertise and roles within the treating team. These
21
22 121 included therapists, nurses and doctors, sometimes under the supervision of trained
23
24 122 radiologists. One record reported that 3 assessors received 3 hours of training, and conducted
25
26
27 123 10 assessments using the study protocol before the study began. (57)

28
29
30 124 **Clinical, health service, implementation and feasibility outcomes:**

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32
33 125 No record specifically investigated clinical, health service, implementation or feasibility
34
35 126 outcomes of ultrasound as a measurement-based-care initiative. Ultrasound was used to
36
37 127 assess the clinical outcomes of scar treatment initiatives in all included records. Clinical,
38
39 128 health service, implementation and feasibility outcomes related to ultrasound measurement
40
41
42 129 were, however, reported in 53 journal articles (17, 22-24, 26, 27, 31, 46-48, 50, 51, 54, 56-61,
43
44 130 63-66, 69-75, 77, 80, 82, 113-116, 119, 120, 122-124, 128, 129, 138, 142-144, 148, 149, 155)
45
46 131 and 14 abstracts (28, 86, 87, 89, 90, 95, 96, 102, 105, 107, 109, 110, 152, 153) that focused
47
48
49 132 on scar treatments.

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51
52 133 The clinical outcome of patient satisfaction related to ultrasound measurement was only
53
54 134 reported in one journal article. Whilst patient satisfaction was not directly measured in that
55
56 135 record, a proxy measure of satisfaction was reported by the authors stating that no paediatric
57
58
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60

136 patient or their caregiver refused ultrasound measurement once the purpose was explained.

137 (24)

138 Timeliness was the only reported health service outcome, reported as the time required to
139 take ultrasound measurements. Where reported in three journal articles, this was short, taking
140 between one to five minutes. (24, 27, 122)

141 The most common implementation outcomes reported in the identified records were fidelity,
142 acceptability and appropriateness. Fidelity to the measurement method was reported through
143 the use of experienced or trained assessors (n = 6 journal articles; n = 1 abstract), (24, 57, 58,
144 87, 142, 144, 148) and/or utilising the same assessor/s for all measurement sessions (n = 5
145 journal articles; 6% of included journal articles). (24, 61, 138, 144, 148) Differences between
146 intended and actual measurement methods were not discussed. The training and/or experience
147 of the assessors was discussed in 24 records (23 journal articles and 1 abstract), (17, 23, 24,
148 27, 51, 56-59, 63-66, 71, 73, 115, 116, 120, 123, 124, 138, 144, 149, 153) where
149 measurements were either taken by a clinician (n = 13; 54% of records reporting training),
150 (17, 23, 24, 58, 59, 64-67, 71, 120, 124, 141) members of the research team (n = 6; 25% of
151 records reporting training), (57, 63, 73, 115, 123, 144) or by specialist sonographers and/or
152 radiologists (n = 5, including one abstract; 21% of records reporting training). (56, 116, 138,
153 149, 153) Only one record reported on fidelity in the context of routine clinical practice. In
154 this instance, ultrasound was conducted in the department of radiology, however the role or
155 training of the staff was not reported. (119)

156 The acceptability and appropriateness of the ultrasound methods used in individual records
157 were generally based on author opinion and outlined in the discussion. Acceptability was
158 reported in 26 records (23 journal articles and 3 abstracts), (17, 22-24, 26-28, 31, 57, 64, 70,
159 74, 75, 77, 80, 82, 86, 96, 116, 119, 120, 122, 124, 143, 149, 155) including for paediatric

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2
3 160 populations, where one record reported potential difficulty in measuring this population, (22)
4
5 161 contrasting that which reported that measurement was acceptable to both children and their
6
7 162 caregivers. (24) One record reported acceptability where the intervention being analysed by
8
9 163 ultrasound was already part of routine clinical practice. In this instance, the authors
10
11 164 referenced additional publications which stated that ultrasound had an accuracy of 0.5 mm,
12
13 165 which was judged by the authors to be sufficient for assessment of scar thickness. (24, 27,
14
15 166 119, 122) Potential difficulty was identified in the measurement of open wounds, (24) and
16
17 167 traditionally hard-to-reach areas (such as the axillae or groin). (22)
18
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21

22 168 The appropriateness of the ultrasound methods was reported in 35 journal articles (43% of
23
24 169 included journal articles) (22, 24, 26, 27, 31, 46-48, 50, 54, 57, 60, 61, 64-66, 69, 72-75, 77,
25
26 170 80, 82, 113, 114, 116, 119, 120, 122, 124, 128, 148, 149, 155) and 11 abstracts (31% of
27
28 171 included abstracts) (86, 87, 89, 90, 95, 102, 105, 107, 109, 110, 152), where it was generally
29
30 172 addressed in the discussion. Of these records, two (4% of records reporting appropriateness)
31
32 173 determined that ultrasound was not appropriate for scar measurement. The first stated that it
33
34 174 was too inaccurate and complex; (86) and the second, which reported on initiatives within
35
36 175 routine clinical practice, determined that the minimum resolution of the Dasonography
37
38 176 ultrasonic scanner (Nuclear Enterprises, Edinburgh, UK) precluded its use in scars thinner
39
40 177 than 3mm. (113)
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46 178 The feasibility of ultrasound was reported in 12 journal articles (15% of included journal
47
48 179 articles). (22, 24, 26, 46, 57, 70, 80, 119, 120, 124, 129) Five records considered ultrasound
49
50 180 not feasible for scar measurements. The rationale presented included high-frequency 20 MHz
51
52 181 ultrasound having an inadequate penetration depth; (26, 57) and ultrasound measurement and
53
54 182 training of investigators requiring too much time (as reported in one record in phase 4 of the
55
56 183 research-to-practice pipeline). (22, 119, 120) Another factor identified as precluding
57
58 184 feasibility was the inability to consistently relocate the measurement site. (24) Conversely,
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2
3 185 one record reported ultrasound to be feasible in combination with Vancouver Scar Scale
4
5 186 (VSS) measurement, (70) and another stated that ultrasound was able to distinguish between
6
7 187 subcutaneous fat and muscle, which was interpreted by the authors of that record to mean that
8
9 188 skin thickness measurements were accurate. (129) The majority (n = 11; 92%) of the records
10
11 189 reporting feasibility were research initiatives in phase 2 or 3 of the research to practice
12
13 190 pipeline. One record examined feasibility in the context of routine clinical practice (i.e.,
14
15 191 phase 4; figure 1), (119) where it was determined that ultrasound was not suitable for use in
16
17 192 their twelve-year longitudinal study due to changes in staff, equipment and software over
18
19 193 such a long time period, which introduced additional variables to the measurement process
20
21
22 194 that were impossible to control. (119)

27 195 **Factors influencing ultrasound images and measurement methods:**

28
29
30 196 The only factor that was reported to influence the imaging and measurement methods was the
31
32 197 measurement of scars with open wounds. This was reported in one record, which determined
33
34 198 that ultrasound and ultrasound gel was unsuitable in this instance. The authors of that record
35
36 199 suggested the use of a flexible transparent plastic wrap, which is placed over the
37
38
39 200 measurement area prior to measurement with ultrasound. (24)

42 201 **Reported strengths and limitations of the measurement methods:**

43
44
45 202 The safety, practicality, objectivity, versatility, reliability and non-invasive nature of
46
47 203 ultrasound were all reported as strengths of the measurement method. (22, 27-29, 47, 50, 57,
48
49 204 61, 64, 77, 78, 80, 82, 87, 89, 95, 96, 105, 107, 109, 119, 123, 124, 129, 139, 148) When
50
51 205 compared to other subjective or clinical measurement methods (e.g., VSS) and 3D camera,
52
53 206 ultrasound was viewed as the superior measurement method of scar and skin thickness, due to
54
55 207 its improved accuracy, greater sensitivity to change and objectivity. (24, 64, 73, 116, 120)
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58 208 The ability of ultrasound to differentiate between scarred and unscarred skin was also
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3 209 highlighted (n = 4; 3%), (47, 60, 72, 122) as was the versatility of ultrasound in its ability to
4
5 210 measure a variety of anatomical areas and be used with child participants (i.e., <18 years) (n
6
7 211 = 2; 2%). (22, 149)
8
9

10 212 The poor correlation between ultrasound and histological thickness measurements, (86) and
11
12 213 the established inverse relationship between ultrasound penetration depth and the resolution
13
14 214 of superficial structures were identified as limitations of ultrasound in the measurement of
15
16 215 scar thickness. (26, 27, 77, 80, 89, 113, 149) This may be an evidence gap worth exploring in
17
18 216 more depth. One record, reporting on a longitudinal study that was conducted over twelve
19
20 217 years, reported that the continuous development of ultrasound software and hardware over
21
22 218 that time limited the usefulness of ultrasound. (119) Despite being reported elsewhere as
23
24 219 acceptable (i.e., between one to five minutes (24, 27, 122)), one record reported that the time-
25
26 220 consuming nature of measurement and the requirement for assessors to be trained in the
27
28 221 operation of, and techniques required for, ultrasonography was a limitation of the method.
29
30 222 (120) Methodologically, concerns were raised around the pressure caused by application of
31
32 223 the ultrasound transducer to the skin, and how that may influence thickness measurement.
33
34 224 (61, 62, 123, 124) The size of the transducer head relative to the size of scars was also
35
36 225 considered a potential limitation, as multiple measurements are required for quantification of
37
38 226 larger scars. (57) Finally, it was recognised that there may be a difference between changes to
39
40 227 the scar that can be measured by ultrasound, and what is felt and/or experienced by the
41
42 228 patient. (75, 80, 126, 127) It was suggested that changes that are detectable by ultrasound
43
44 229 may be smaller than those able to be detected by patients. In patients with burn scars, a
45
46 230 minimum change in scar thickness of between 1 to 6 mm measured by ultrasound, has been
47
48 231 reported to be required before a patient may report noticing any difference to their scar
49
50 232 thickness. (24, 75) While further research is required to allow generalisation of these findings
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3 233 to other scar aetiologies, this indicates that a holistic approach to scar thickness using the
4
5 234 patient's opinion as well as objective measurement through ultrasound may be beneficial.
6
7

8 **235 Guidelines or frameworks used to guide the measurement methods:**
9

10
11 236 No records reported using any guidelines or frameworks to inform their measurement
12
13 237 methods. One record utilised suggestions from The American Wound Healing Society to
14
15 238 support the measurement of contralateral, unscarred skin thickness on the same individual as
16
17 239 a control or comparator. (75)
18
19

20
21 **240 Methodological Considerations:**
22

23
24 241 Based on the ultrasound methods and outcomes identified in this review, a list of
25
26 242 methodological considerations have been compiled (Supplementary Table 6). These are
27
28 243 intended to guide the decision-making and methodological reporting of researchers and/or
29
30 244 clinicians undertaking scar or skin thickness ultrasound measurement.
31
32

33
34 **245 DISCUSSION:**
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36
37 246 This review mapped the methods used in the published literature to measure traumatic scar
38
39 247 thickness using ultrasound across the research-to-practice translational pipeline. No record
40
41 248 reported their methods with sufficient detail to allow them to be independently replicated.
42
43 249 Overall, there was a lack of consistent rationale underpinning which skin layers (i.e.,
44
45 250 epidermis, dermis and combined) were measured, and little consideration was given to the
46
47 251 training and experience required by assessors. The included records mainly aligned with the
48
49 252 second and third phases of the research-to-practice pipeline (figure 1), with only three records
50
51 253 (2 articles and 1 abstract) reporting the use of ultrasound in routine clinical practice (phase 4).
52
53 254 (92, 113, 119). The paucity of records aligning with phase four studies (use in clinical
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55 255 practice) suggests a translational gap from research to regular clinical practice. There are two
56
57 256 likely explanations for this: 1) that ultrasound is most commonly used as an outcome measure
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3 257 for research initiatives and is not regularly used to evaluate care once treatments are
4
5 258 implemented into routine clinical practice; or 2) that use of ultrasound in routine clinical
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8 259 practice is not reported or evaluated, as routine clinical practice is rarely published.
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11 260 Searching of grey literature was conducted in an attempt to identify clinical practice
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13 261 documents, however none were located. Surveys of health service departments may be the
14
15 262 best method of identifying ultrasound methods used in regular clinical practice as part of
16
17 263 future research. While some records reported using additional subjective and objective
18
19 264 measurement methods in addition to ultrasound, none used these methods to determine the
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21 265 criterion validity of the ultrasound for scar thickness measurement. This is another evidence
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23 266 gap that should be addressed.
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27 267 While efforts have been made to standardise ultrasound measurement procedures elsewhere
28
29 268 in dermatology (including tumours, cancers, vascular anomalies, and systemic sclerosis (34,
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31 269 35)), this same effort has not yet extended to the measurement of traumatic scarring.
32
33 270 Methodological standardisation has the potential to increase confidence in the use of
34
35 271 ultrasound as the basis of measurement-based care initiatives for clinical decision-making,
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37 272 allowing patient care and scar treatments to be tailored towards individual needs. (62, 147,
38
39 273 156) Standardising the core methodological components of ultrasound measurement of scar
40
41 274 thickness, or at the very least, creating a standardised framework for methodological
42
43 275 decision-making, may support implementation of ultrasound measurement into routine
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45 276 clinical practice, supported by strategies to overcome barriers to implementation at local sites.
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47 277 (157)
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53 278 This review identified novel insights into the identification of the composition of cutaneous
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55 279 scars using ultrasound, and highlighted the apparent lack of consistent understanding of, or
56
57 280 rationale behind, what scar thickness characteristics were being measured. Fibrosis is
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3 281 generally understood to be the primary cause of scar thickness through the deposition of
4
5 282 excessive extracellular matrix proteins such as collagen. (158, 159) This has been confirmed
6
7 283 through histological analysis, which has shown the presence of excess collagen and other
8
9 284 extracellular matrix proteins in the dermis of hypertrophic scars. (160, 161) An additional
10
11 285 method for assessing the effects of scarring on the dermis, as identified by one record in this
12
13 286 review, (47) is through quantification of the presence and density of hair follicles. This
14
15 287 quantification may serve as a method of differentiation between scarred and physiological
16
17 288 skin, and may also serve as a measure of skin function. (47) What is less understood, and
18
19 289 perhaps largely overlooked, is the function of the epidermis in scar thickness. In the one
20
21 290 record identified in this review that directly report the measurement of the epidermis, the
22
23 291 authors noted that the measurement quantified the presence of oedema. (55) This was further
24
25 292 supported by two records that noted that the epidermis and dermis responded differently to
26
27 293 treatment, (67, 71) indicating that there is likely a difference in the composition of the scar
28
29 294 between these skin layers. Cutaneous oedema has been observed using high-frequency
30
31 295 ultrasound in other pathologies, including atopic dermatitis and skin ageing, where it is
32
33 296 characterised by the presence of a sub-epidermal low echogenic band (SLEB), a hyperechoic
34
35 297 band at the dermoepidermal junction. (162) Understanding the interplay between epidermal
36
37 298 oedema, dermal fibrosis and the presence and density of hair follicles may result in an
38
39 299 increased understanding of the mechanisms and treatment responses of cutaneous scarring.
40
41 300 With better understanding, more targeted scar treatments that inform a greater understanding
42
43 301 of scar responsivity may arise.

44
45 302 Another important, but potential limiting factor for the use of ultrasound to measure scar
46
47 303 thickness raised in this review is the training and/or experience required of assessors, and the
48
49 304 ramifications this likely has on the reliability of measurements and interpretation. (163) This
50
51 305 review identified 24 records where assessor experience was discussed, however none made
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2
3 306 any recommendations on the optimal training and/or experience. Identifying the training
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5 307 requirements of assessors may prove an important step towards more widespread
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7
8 308 implementation of reliable ultrasound scar thickness measurement in research trials and as the
9
10 309 basis for measurement-based care in routine clinical practice. (164) A panel of
11
12 310 dermatological and ultrasound experts has previously recommended that a physician with a
13
14 311 minimum of 300 examinations per year should hold responsibility for ultrasound
15
16 312 measurements. (34) It has also been suggested that training existing members of clinical
17
18 313 teams and standardising measurement method/s may be the most effective way to achieve
19
20 314 minimum reliability standards under clinical conditions. This could allow measurement to be
21
22 315 reliably conducted within an outpatient clinic setting by a number of healthcare providers
23
24 316 assisting workflow, negating the requirement for patients to wait for an experienced
25
26 317 radiographer. (24, 164) In the current review, reliability estimates were generally acceptable
27
28 318 but were tested under research conditions. The diverse experience and expertise of assessors,
29
30 319 where reported for the reliability estimates, means that the acceptable reliability results
31
32 320 should be generalisable to most clinical teams, as therapists, doctors and nurses were all
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34 321 included. The cumulative sample size of all reliability studies also supports this
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36 322 generalisation; however each team should perform their own reliability estimates before
37
38 323 conducting ultrasound thickness measurements.
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45 324 **Study Limitations:**

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48 325 Only articles available in English or with an English abstract were considered for inclusion
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50 326 and data extraction, which may have resulted in the omission of eligible information. Data
51
52 327 extraction was completed on the English abstracts of two non-English articles that were
53
54 328 available electronically, however the non-English articles themselves were not available to
55
56 329 the authors, and thus could not be analysed. Based on the number of records included in this
57
58 330 review, however, it is unlikely that this would have impacted the review findings. It is
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3 331 acknowledged that methods reported in included abstracts may not be fully reproducible, due
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5 332 to their brevity. Thus, findings were reported separately to articles. An additional limitation
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7
8 333 was that authors of included records were not contacted to provide clarification or further
9
10 334 information, as this was not feasible given the number of results identified. It should also be
11
12 335 acknowledged that the included records were not designed to align with the specific aims of
13
14 336 this review, which likely explains some of the lack of reporting on outcomes of interest in our
15
16
17 337 review, particularly clinical, health service and implementation outcomes. Furthermore, as
18
19 338 this review relied on published information (including grey literature), routine practices
20
21 339 employed within organisations may not have been considered and unpublished industry
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23
24 340 sponsored reports may not have been identified.

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26
27 341 It is also important to consider the limitations of ultrasound itself for the holistic
28
29 342 quantification of cutaneous scarring. Ultrasound transducers are generally small, meaning
30
31 343 that it is difficult to assess the entirety of a scar, necessitating multiple measurements. (165)
32
33 344 Additionally, thickness is often not the only scar parameter of clinical or research interest. It
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35
36 345 has therefore been recommended that multi-modal measurement techniques are employed,
37
38 346 which include both subjective and objective measurements. (166, 167) However, use of these
39
40 347 methods may be challenging in routine clinical practice, due to the length of time and training
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43 348 required. Thus, feasibility and implementation outcomes are of importance in evaluating
44
45 349 measurement-based care initiatives involving ultrasound alone or multimodal measurement
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47
48 350 tools in scar care practice – a field in its infancy based on this review.

351 **Future Directions:**

352 It is intended that the results of this review will be used to inform the creation of a Delphi
353 consensus study, leading to the formation of a guideline for the measurement of traumatic
354 scar thickness using ultrasound. This guideline can then be used by researchers and clinicians

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2
3 355 to standardise the measurement of scars. In preparation for this study, we have provided a list
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5 356 of methodological considerations for assessors or practitioners when planning to conduct scar
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7 357 thickness measurements with ultrasound (Supplementary Table 6). Future research could also
8
9 358 investigate aspects that were beyond the scope of this review including factors influencing
10
11 359 the implementation of ultrasound-based care initiatives, strategies to support implementation,
12
13 360 and how research-based initiatives could be applied in practice. Further studies are needed
14
15 361 that compare SDCs to SEMs to interpret reliability estimates to confirm our interpretation
16
17 362 that ultrasound may have the ability to detect true change or variance in scar thickness above
18
19 363 measurement error, which was based on the SDC reported by a single study. Our
20
21 364 interpretation is supported by mostly acceptable reliability estimates of ultrasound thickness
22
23 365 for other cutaneous conditions. (168, 169) Additional investigations should also be conducted
24
25 366 to determine the criterion validity of ultrasound as a measure for scar thickness.
26
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29

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39
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41

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43
44
45 372 The authors declare no competing interests. The research presented in this publication was
46
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48
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60

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2
3 379 **AUTHOR CONTRIBUTIONS**
4

5 380 BM and ZT conceived the project after identifying this area as a knowledge gap in existing
6
7 381 literature. BM developed the research questions and study methodology, conducted the
8
9 382 literature search, screened all articles and extracted data. Record screening and data
10
11 383 extraction was completed by BM, MS, TM, and TR, with additional extraction completed by
12
13 384 BD to assess consistency. MS, TM, TR and RK provided advice to BM on the clinical
14
15 385 implications of ultrasound measurement. MS, RK and ZT contributed to the supervision of
16
17 386 BM as a PhD student. BM drafted the paper, and ZT and MS provided critical appraisal of
18
19 387 the drafted manuscript, with further advice provided by TM, TR, BD and RK.
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24 388 **DATA SHARING STATEMENT:**
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26 389 Not applicable
27

28 390 **ETHICS APPROVAL STATEMENT:**
29

30 391 This study does not involve human participants. No ethics approval was required.
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33 392 **FIGURE LEGENDS:**
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35 393 **Figure 1: Research to clinical practice pipeline.**
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References:

1. Jagdeo J, Shumaker PR. Traumatic scarring. *JAMA Dermatol (Patient Page)*. 2017;153(3):364-398.
2. Lawrence WJ, Mason TS, Schomer BK, Klein BM. Epidemiology and Impact of Scarring After Burn Injury: A Systematic Review of the Literature. *Journal of Burn Care & Research*. 2012;33(1):136-46.
3. Bayat A, McGrouther DA, Ferguson MWJ. Skin scarring. *BMJ*. 2003;326(7380):88-92.
4. Lee H, Jang Y. Recent Understandings of Biology, Prophylaxis and Treatment Strategies for Hypertrophic Scars and Keloids. *Int J Mol Sci*. 2018;19(3).
5. Rabello FB, Souza CD, Farina Júnior JA. Update on hypertrophic scar treatment. *Clinics*. 2014;69(8):565-73.
6. English RS, Shenefelt PD. *Keloids and Hypertrophic Scars*. Boston, MA, USA: Blackwell Science Inc; 1999. p. 631-8.
7. Niessen BF, Spauwen HMP, Schalkwijk HMJ, Kon HMM. On the Nature of Hypertrophic Scars and Keloids: A Review. *Plastic and Reconstructive Surgery*. 1999;104(5):1435-58.
8. Simons M, Price N, Kimble R, Tyack Z. Patient experiences of burn scars in adults and children and development of a health-related quality of life conceptual model: A qualitative study. *Burns*. 2016;42(3):620-32.
9. Tyack Z, Ziviani J, Kimble R, Plaza A, Jones A, Cuttle L, et al. Measuring the impact of burn scarring on health-related quality of life: Development and preliminary content validation of the Brisbane Burn Scar Impact Profile (BBSIP) for children and adults. *Burns*. 2015;41(7):1405-19.
10. Sullivan T, Smith J, Kermode J, McIver E, Courtemanche DJ. Rating the burn scar. *J Burn Care Rehabil*. 1990;11(3):256-60.
11. Draaijers JL, Tempelman RHF, Botman AMY, Tuinebreijer EW, Middelkoop WE, Kreis PMR, et al. The patient and observer scar assessment scale: A reliable and feasible tool for scar evaluation. *Plast Reconstr Surg*. 2004;113(7):1960-5.
12. Tyack Z, Wasiak J, Spinks A, Kimble R, Simons M. A guide to choosing a burn scar rating scale for clinical or research use. *Burns*. 2013;39(7):1341-50.
13. Gold HM, McGuire AM, Mustoe AT, Pusic AA, Sachdev AM, Waibel AJ, et al. Updated international clinical recommendations on scar management: Part 2 - Algorithms for scar prevention and treatment. *Dermatol Surg*. 2014;40(8):825-31.
14. Jones LL, Calvert M, Moiemmen N, Deeks JJ, Bishop J, Kinghorn P, et al. Outcomes important to burns patients during scar management and how they compare to the concepts captured in burn-specific patient reported outcome measures. *Burns*. 2017;43(8):1682-92.
15. McGarry S, Elliott C, McDonald A, Valentine J, Wood F, Girdler S. Paediatric burns: From the voice of the child. *Burns*. 2014;40(4):606-15.
16. Bloemen MCT, van Der Veer WM, Ulrich MMW, van Zuijlen PPM, Niessen FB, Middelkoop E. Prevention and curative management of hypertrophic scar formation. *Burns*. 2009;35(4):463-75.
17. Lee KC, Bamford A, Gardiner F, Agovino A, ter Horst B, Bishop J, et al. Investigating the intra- and inter-rater reliability of a panel of subjective and objective burn scar measurement tools. *Burns*. 2019;45(6):1311-24.
18. Brusselaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S. Burn Scar Assessment: A Systematic Review of Different Scar Scales. *Journal of Surgical Research*. 2010;164(1):e115-e23.
19. Brusselaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S. Burn scar assessment: A systematic review of objective scar assessment tools. *Burns*. 2010;36(8):1157-64.
20. Hambleton J, Shakespeare PG, Pratt BJ. The progress of hypertrophic scars monitored by ultrasound measurements of thickness. *Burns*. 1992;18(4):301-7.

- 1
2
3 444 21. Sonsbeek AMSv, Hutschemaekers GJM, Veerman JW, Vermulst AA, Tiemens BG. The results
4 445 of clinician-focused implementation strategies on uptake and outcomes of Measurement-Based Care
5 446 (MBC) in general mental health care. *BMC Health Serv Res.* 2023;23(1):326-.
- 6 447 22. Gee Kee EL, Kimble RM, Cuttle L, Stockton KA. Scar outcome of children with partial
7 448 thickness burns: A 3 and 6 month follow up. *Burns.* 2016;42(1):97-103.
- 8 449 23. Wang X-Q, Mill J, Kravchuk O, Kimble RM. Ultrasound assessed thickness of burn scars in
9 450 association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns.*
10 451 2010;36(8):1254-62.
- 11 452 24. Simons M, Kee EG, Kimble R, Tyack Z. Ultrasound is a reproducible and valid tool for
12 453 measuring scar height in children with burn scars: A cross-sectional study of the psychometric
13 454 properties and utility of the ultrasound and 3D camera. *Burns.* 2017;43(5):993-1001.
- 14 455 25. Izzetti R, Vitali S, Aringhieri G, Nisi M, Oranges T, Dini V, et al. Ultra-high frequency
15 456 ultrasound, a promising diagnostic technique: review of the literature and single-center experience.
16 457 *Can Assoc Radiol J.* 2021;72(3):418-31.
- 17 458 26. Agabalyan NA, Su S, Sinha S, Gabriel V. Comparison between high-frequency
18 459 ultrasonography and histological assessment reveals weak correlation for measurements of scar
19 460 tissue thickness. *Burns.* 2016;43(3):531-8.
- 20 461 27. Kim JD, Oh SJ, Kim SG, Ahn SV, Jang YJ, Yang BS, et al. Ultrasonographic findings of re-
21 462 epithelialized skin after partial-thickness burns. *Burns Trauma.* 2018;6(1):21-.
- 22 463 28. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in
23 464 burn scars using high frequency ultrasound. *J Burn Care Res.* 2012;33(2):S105.
- 24 465 29. Ud-Din S, Foden P, Stocking K, Mazhari M, Al-Habba S, Baguneid M, et al. Objective
25 466 assessment of dermal fibrosis in cutaneous scarring, using optical coherence tomography,
26 467 high-frequency ultrasound and immunohistomorphometry of human skin. *Br J Dermatol.*
27 468 2019;181(4):722-32.
- 28 469 30. Du Y-C, Lin C-M, Chen Y-F, Chen C-L, Chen T. Implementation of a burn scar assessment
29 470 system by ultrasound techniques. *Conf Proc IEEE Eng Med Biol Soc.* 2006:2328-31.
- 30 471 31. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and
31 472 hypertrophic scar assessment. *Lasers Med Sci.* 2019;35(2):379-85.
- 32 473 32. Jasaitiene D, Valiukeviciene S, Linkeviciute G, Raisutis R, Jasiuniene E, Kazys R. Principles of
33 474 high-frequency ultrasonography for investigation of skin pathology. *J Eur Acad Dermatol Venereol.*
34 475 2011;25(4):375-82.
- 35 476 33. Rodríguez Bandera AI, Sebaratnam DF, Feito Rodríguez M, Lucas Laguna R. Cutaneous
36 477 ultrasound and its utility in pediatric dermatology. Part I: Lumps, bumps, and inflammatory
37 478 conditions. *Pediatr Dermatol.* 2020;37(1):29-39.
- 38 479 34. Wortsman X, Alfageme F, Roustan G, Arias-Santiago S, Martorell A, Catalano O, et al.
39 480 Guidelines for performing dermatologic ultrasound examinations by the DERMUS Group. *J*
40 481 *Ultrasound Med.* 2016;35(3):577-80.
- 41 482 35. Vanhaecke A, Cutolo M, Heeman L, Vilela V, Deschepper E, Melsens K, et al. High frequency
42 483 ultrasonography: Reliable tool to measure skin fibrosis in SSC? A systematic literature review and
43 484 additional pilot study. *Rheumatology (Oxford).* 2022;61(1):42-52.
- 44 485 36. Australian Government Department of Health and Aged Care Medical Research Future Fund.
45 486 Research Translation Australia2022 [Available from: <https://www.health.gov.au/our-work/medical-research-future-fund/mrff-research-themes/research-translation#what-is-the-research-pipeline>.
46 487
- 47 488 37. Meikle B, Kimble RM, Tyack Z. Ultrasound measurements of pathological and physiological
48 489 skin thickness: A scoping review protocol. *BMJ Open.* 2022;12(1):e056720-e.
- 49 490 38. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res*
50 491 *Methodol.* 2005;8(1):19-32.
- 51 492 39. Haddaway NR, Collins AM, Coughlin D, Kirk S. The role of google scholar in evidence reviews
52 493 and its applicability to grey literature searching. *PLoS One.* 2015;10(9):e0138237-e.

- 1
2
3 494 40. Pieper D, Puljak L. Language restrictions in systematic reviews should not be imposed in the
4 495 search strategy but in the eligibility criteria if necessary. *J Clin Epidemiol*. 2021;132:146-7.
- 5 496 41. Proctor E, Proctor E, Silmere H, Silmere H, Raghavan R, Raghavan R, et al. Outcomes for
6 497 Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda.
7 498 *Adm Policy Ment Health*. 2011;38(2):65-76.
- 8 499 42. Prinsen CAC, Vohra S, Rose MR, Boers M, Tugwell P, Clarke M, et al. How to select outcome
9 500 measurement instruments for outcomes included in a "Core Outcome Set" - a practical guideline.
10 501 *Trials*. 2016;17:urn:issn:1745-6215.
- 11 502 43. Mookink LB, Boers M, van der Vleuten CPM, Bouter LM, Alonso J, Patrick DL, et al. COSMIN
12 503 Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome
13 504 measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020;20(1):1-13.
- 14 505 44. Terwee CB, Bot SDM, de Boer MR, van der Windt DAWM, Knol DL, Dekker J, et al. Quality
15 506 criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol*.
16 507 2007;60(1):34-42.
- 17 508 45. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA
18 509 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71-n.
- 19 510 46. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of
20 511 fractional CO2 laser treatment of mature burn scars. *J Burn Care Res*. 2016;37(6):379-87.
- 21 512 47. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal
22 513 tissue thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res*.
23 514 2020;41(2):421-6.
- 24 515 48. Cai L, Hu M, Lin L, Zheng T, Liu J, Li Z. Evaluation of the efficacy of triamcinolone acetonide in
25 516 the treatment of keloids by high-frequency ultrasound. *Skin Res Technol*. 2020;26(4):489-93.
- 26 517 49. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic
27 518 scar in a Chinese population. *Burns*. 2010;36(8):1234-41.
- 28 519 50. Chae JK, Kim JH, Kim EJ, Park K. Values of a patient and observer scar assessment scale to
29 520 evaluate the facial skin graft scar. *Ann Dermatol*. 2016;28(5):615-23.
- 30 521 51. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
31 522 Construct validity and predictive ability of scar thickness change. *Skin Res Technol*. 2020;26(3):369-
32 523 75.
- 33 524 52. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following
34 525 intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized
35 526 controlled trial. *PLoS One*. 2021;16(3):e0248799.
- 36 527 53. Deng H, Tan T, Luo G, Tan J, Li-Tsang CWP. Vascularity and thickness changes in immature
37 528 hypertrophic scars treated with a pulsed dye laser. *Lasers Surg Med*. 2021;53(7):914-21.
- 38 529 54. Dunkin CSJ, Pleat JM, Gillespie PH, Tyler MPH, Roberts AHN, McGrouther DA. Scarring occurs
39 530 at a critical depth of skin injury: Precise measurement in a graduated dermal scratch in human
40 531 volunteers. *Plast Reconstr Surg*. 2007;119(6):1722-32.
- 41 532 55. Fabbrocini G, Marasca C, Ammad S, Brazzini B, Izzo R, Donnarumma M, et al. Assessment of
42 533 the combined efficacy of needling and the use of silicone gel in the treatment of C-section and other
43 534 surgical hypertrophic scars and keloids. *Adv Skin Wound Care*. 2016;29(9):408-11.
- 44 535 56. Fracalvieri M, Zingarelli E, Ruka E, Antoniotti U, Coda R, Sarno A, et al. Negative pressure
45 536 wound therapy using gauze and foam: histological, immunohistochemical and ultrasonography
46 537 morphological analysis of the granulation tissue and scar tissue. Preliminary report of a clinical study.
47 538 *Int Wound J*. 2011;8(4):355-64.
- 48 539 57. Gankande TU, Duke JM, Danielsen PL, DeJong HM, Wood FM, Wallace HJ. Reliability of scar
49 540 assessments performed with an integrated skin testing device – The DermaLab Combo. *Burns*.
50 541 2014;40(8):1521-9.
- 51 542 58. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on
52 543 third-degree burns through ultrasonic measurement. *J Cytol Histol*. 2017;8(5).
- 53
54
55
56
57
58
59
60

- 1
2
3 544 59. Huang P-W, Lu C-W, Chu K-T, Ho M-T. Assessing thickness of burn scars through ultrasound
4 545 measurement for patients with arm burns. *J Med Biol Eng.* 2021;41(1):84-91.
- 5 546 60. Huang S-Y, Xiang X, Guo R-Q, Cheng S, Wang L-Y, Qiu L. Quantitative assessment of
6 547 treatment efficacy in keloids using high-frequency ultrasound and shear wave elastography: a
7 548 preliminary study. *Sci Rep.* 2020;10(1):1375-.
- 8 549 61. Issler-Fisher AC, Fisher OM, Haertsch PA, Li Z, Maitz PKM. Effectiveness and safety of
9 550 ablative fractional CO2 laser for the treatment of burn scars: A case-control study. *Burns.*
10 551 2021;47(4):785-95.
- 11 552 62. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with
12 553 laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration
13 554 matter? *Lasers Surg Med.* 2020;52(2):149-58.
- 14 555 63. Joo SY, Lee SY, Cho YS, Seo CH. Clinical utility of extracorporeal shock wave therapy on
15 556 hypertrophic scars of the hand caused by burn injury: A prospective, randomized, double-blinded
16 557 study. *J Clin Med.* 2020;9(5):1376.
- 17 558 64. Lee KC, Bamford A, Gardiner F, Agovino A, ter Horst B, Bishop J, et al. Burns objective scar
18 559 scale (BOSS): Validation of an objective measurement devices based burn scar scale panel. *Burns.*
19 560 2020;46(1):110-20.
- 20 561 65. Li JQ, Li-Tsang CWP, Huang YP, Chen Y, Zheng YP. Detection of changes of scar thickness
21 562 under mechanical loading using ultrasonic measurement. *Burns.* 2012;39(1):89-97.
- 22 563 66. Li P, Li-Tsang CWP, Deng X, Wang X, Wang H, Zhang Y, et al. The recovery of post-burn
23 564 hypertrophic scar in a monitored pressure therapy intervention programme and the timing of
24 565 intervention. *Burns.* 2018;44(6):1451-67.
- 25 566 67. Li N, Yang L, Cheng J, Han J, Hu D. Early intervention by Z-plasty combined with fractional
26 567 CO2 laser therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet*
27 568 *Surg.* 2021;74(11):3087-93.
- 28 569 68. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its
29 570 characteristics among the Chinese population. *Burns.* 2005;31(5):610-6.
- 30 571 69. Li-Tsang CWP, Lau JCM, Choi J, Chan CCC, Jianan L. A prospective randomized clinical trial to
31 572 investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among
32 573 the Chinese population. *Burns.* 2006;32(6):678-83.
- 33 574 70. Mamdouh M, Omar GA, Hafiz HSA, Ali SM. Role of vitamin D in treatment of keloid. *J Cosmet*
34 575 *Dermatol.* 2022;21(1):331-6.
- 35 576 71. Meirte J, Moortgat P, Anthonissen M, Maertens K, Lafaire C, De Cuyper L, et al. Short-term
36 577 effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an
37 578 experimental study. *Burns Trauma.* 2016;4:27-.
- 38 579 72. Nedelec B, Correa JA, de Oliveira A, LaSalle L, Perrault I. Longitudinal burn scar
39 580 quantification. *Burns.* 2014;40(8):1504-12.
- 40 581 73. Nedelec B, Correa JA, Rachelska G, Armour A, Lasalle L. Quantitative measurement of
41 582 hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res.* 2008;29(3):501-11.
- 42 583 74. Nedelec B, Couture M-A, Calva V, Poulin C, Chouinard A, Shashoua D, et al. Randomized
43 584 controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns.*
44 585 2019;45(1):128-39.
- 45 586 75. Nedelec B, LaSalle L, de Oliveira A, Correa JA. Within-patient, single-blinded, randomized
46 587 controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the
47 588 treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res.* 2020;41(4):761-9.
- 48 589 76. Reinholz M, Guertler A, Schwaiger H, Poetschke J, Gauglitz GG. Treatment of keloids using
49 590 5-fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating
50 591 therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol.*
51 592 2020;34(10):2436-44.
- 52
53
54
55
56
57
58
59
60

- 1
2
3 593 77. Reinholz M, Schwaiger H, Poetschke J, Epple A, Ruzicka T, Von Braunmühl T, et al. Objective
4 594 and subjective treatment evaluation of scars using optical coherence tomography, sonography,
5 595 photography, and standardised questionnaires. *Eur J Dermatol.* 2017;26(6):599-608.
6 596 78. Schwaiger H, Reinholz M, Poetschke J, Ruzicka T, Gauglitz G. Evaluating the therapeutic
7 597 success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive
8 598 objective measures. *Dermatol Surg.* 2018;44(5):635-44.
9 599 79. Soykan EA, Butzelaar L, de Kroon TL, Beelen RHJ, Ulrich MMW, van der Molens ABM, et al.
10 600 Minimal extracorporeal circulation (MECC) does not result in less hypertrophic scar formation as
11 601 compared to conventional extracorporeal circulation (CECC) with dexamethasone. *Perfusion.*
12 602 2014;29(3):249-59.
13 603 80. Timar-Banu O, Beauregard H, Tousignant J, Lassonde M, Harris P, Viau G, et al. Development
14 604 of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scars in
15 605 humans. *Wound Repair Regen.* 2001;9(2):123-32.
16 606 81. Van den Kerckhove E, Stappaerts K, Fieuws S, Laperre J, Massage P, Flour M, et al. The
17 607 assessment of erythema and thickness on burn related scars during pressure garment therapy as a
18 608 preventive measure for hypertrophic scarring. *Burns.* 2005;31(6):696-702.
19 609 82. Van den Kerckhove E, Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated
20 610 measurements on post-burn scars with Dermascan C. *Skin Res Technol.* 2003;9(1):81-4.
21 611 83. van der Veer WM, Ferreira JA, de Jong EH, Molema G, Niessen FB. Perioperative conditions
22 612 affect long-term hypertrophic scar formation. *Ann Plast Surg.* 2010;65(3):321-5.
23 613 84. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix.
24 614 *Burns.* 2008;35(3):352-5.
25 615 85. Lee SY, Cho YS, Kim L, Joo SY, Seo CH. The Intra-rater reliability and validity of
26 616 ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns.* 2022.
27 617 86. Agabalyan NA, Su S, Sinha V, Gabriel V. Evaluating high frequency ultrasonography for the
28 618 non-invasive measurement of human scarring. *J Burn Care Res.* 2016;37.
29 619 87. Anthonissen M, Meirte J, Moortgat P, Temmerman S, Lafaie C, De Cuyper L, et al. Intrarater
30 620 and interrater reliability of an open 22MHz ultrasound scanning system to assess thickness and
31 621 density of burn scars. *Ann Burns Fire Disasters.* 2015;28.
32 622 88. Bajouri A, Kajoor AS, Fallah N, Latifi NA, Ghasimi M, Bagheri T, et al. Autologous human
33 623 stromal vascular fraction injection in post-burn hypertrophic scar: A double-blinded placebo-
34 624 controlled clinical trial. *Bioimpacts.* 2018;8:37-8.
35 625 89. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and
36 626 diagnostics. *J Dermatol Nurses Assoc.* 2020;12(2).
37 627 90. Bezugly A, Potekae N. In vivo skin morphology monitoring of patients with acne, scars and
38 628 dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol.* 2014;41:4.
39 629 91. Blome-Eberwein S, Pagella P, Boorse D, Gogal C. Treatment of hypertrophic burn scars with
40 630 different laser modalities. *Lasers Surg Med.* 2014;46:6-7.
41 631 92. Cho J, Choi J, Hur J, Ko J, Seo D, Lee J, et al. The effect of CO2 fractional laser (pixel®) on
42 632 hypertrophic burn scars. *J Burn Care Res.* 2012;33(2):S132.
43 633 93. Cooper LE, Bohan PK, Hatem VD, Carlsson AH, Cancio LC, Chan RK. Analysis of the utility of
44 634 CO2 and pulse-dye lasers in the treatment of hypertrophic burn scars. *J Burn Care Res.*
45 635 2021;42(Supplement_1):S28-S9.
46 636 94. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, Couture M-A, Réadaptation M, Calva V, et al.
47 637 Objective quantification of hypertrophic scar and donor scar between 2 to 7 months post-burn
48 638 injury. *J Burn Care Res.* 2022;43:S103.
49 639 95. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, Bassiouny DA, Fawzy MM.
50 640 Ultrasound biomicroscopy in the diagnosis of skin diseases. *Eur J Dermatol.* 2007;17(6):469-74.
51 641 96. George R, Siordia H, Buhler J, Thompson S, Cancio L, Chan R. The use of high frequency
52 642 ultrasound to monitor treatment of hypertrophic burn scars with fractionated ablative CO2 laser
53 643 therapy. *J Burn Care Res.* 2019;40(Supplement_1):S135-S.

- 1
2
3 644 97. Jang KU, Lee JY, Choi JS, Seo CH. 5 FU and triamcinolone injection to the hypertrophic scar
4 645 were compared. *Burns*. 2009;35:S41-S2.
- 5 646 98. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-
6 647 monitored suit in the management of post-burn hypertrophic scar: A clinical controlled study with
7 648 objective assessment. *J Burn Care Res*. 2016;37:S199.
- 8 649 99. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case
9 650 review. *J Burn Care Res*. 2011;32:S169-S.
- 10 651 100. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and
11 652 related research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns)*. 2010;26(6):411-5.
- 12 653 101. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the
13 654 efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult burn
14 655 patients. *J Am Acad Dermatol*. 2017;76(6):AB212-AB.
- 15 656 102. Moortgat P, Vanhullebusch T, Anthonissen M, Meirte J, Lafaire C, De Cuyper L, et al. Tension
16 657 reducing taping as a mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot
17 658 study. *Wound Repair Regen*. 2020;28(2):A21.
- 18 659 103. Nedelec B, Couture M, Calva V, Chouinard A, Shashoua D, Gauthier N, et al. Randomized
19 660 controlled trial of the immediate and long-term effect of massage on adult postburn scar. *J Burn
20 661 Care Res*. 2018;39(suppl_1):S57-S.
- 21 662 104. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report.
22 663 *Wound Repair Regen*. 2018;26(2):A28-A.
- 23 664 105. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res*.
24 665 2011;32:S167-S.
- 25 666 106. Siwy KG, Lee K, Donelan MB, Anderson RR, Miletta NR. Fractionated CO2 laser and burn scar
26 667 contractures: Evaluation of post treatment scar function and appearance. *J Burn Care Res*.
27 668 2016;37:S202-S.
- 28 669 107. Tu P, Wang Z-G, Zhang Q-X, You Y-F. High frequency ultrasound in dynamic observation on
29 670 effect of local injection with diprospan for treating pathological scar. *Chinese Journal of
30 671 Interventional Imaging and Therapy*. 2014;11(4):217-20.
- 31 672 108. Ud-Din S, Foden P, Douglas M, Mazhari M, Al-Habba S, Baguneid M, et al. A double-blind
32 673 randomized controlled trial demonstrates for the first time evidence for the role of topical
33 674 epigallocatechin-3-gallate in reducing angiogenesis, inflammation, and skin thickness in human skin
34 675 scarring: A noninvasive, morphological and immu. *Wound Repair and Regeneration*. 2017;25(4):A3.
- 35 676 109. Ud-Din S, Foden P, Mazhari M, Al-Habba S, Baguneid M, Bayat A. Histomorphologic assessment
36 677 of noninvasive quantitative imaging in progression of cutaneous healing in human skin: Dynamic
37 678 optical coherence tomography versus high frequency ultrasound. *Wound Repair Regen*.
38 679 2017;25(4):A3-A4.
- 39 680 110. Ud-Din S, Foden P, M M, Samer A, Baguneid M, Bayat A. Quantitative index for skin fibrosis:
40 681 Combined optical coherence tomography with ultrasound validated by histology and
41 682 immunohistochemistry. *Wound Repair Regen*. 2018;26(4):A11-A2.
- 42 683 111. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers
43 684 Med Sci*. 2017;33(3):497-501.
- 44 685 112. Alsharnoubi J, Shoukry KE-S, Fawzy MW, Mohamed O. Evaluation of scars in children after
45 686 treatment with low-level laser. *Lasers Med Sci*. 2018;33(9):1991-5.
- 46 687 113. Berry RB, Tan OT, Cooke ED, Gaylarde PM, Bowcock SA, Lamberty BGH, et al.
47 688 Transcutaneous oxygen tension as an index of maturity in hypertrophic scars treated by
48 689 compression. *Br J Plast Surg*. 1985;38(2):163-73.
- 49 690 114. Blome-Eberwein S, Roarabaugh C, Gogal C, Eid S. Exploration of nonsurgical scar
50 691 modification options: Can the irregular surface of matured mesh graft scars be smoothed with
51 692 microdermabrasion? *J Burn Care Res*. 2012;33(3):e133-40.
- 52 693 115. Chan HH, Wong DSY, Ho WS, Lam LK, Wei W. The use of pulsed dye laser for the prevention
53 694 and treatment of hypertrophic scars in Chinese persons. *Dermatol Surg*. 2004;30(7):987-94.

- 1
2
3 695 116. Cheng W, Saing H, Zhou H, Han Y, Peh W, Tam PKH. Ultrasound assessment of scald scars in
4 696 Asian children receiving pressure garment therapy. *J Pediatr Surg*. 2001;36(3):466-9.
- 5 697 117. Cho YS, Jeon JH, Hong A, Yang HT, Yim H, Cho YS, et al. The effect of burn rehabilitation
6 698 massage therapy on hypertrophic scar after burn: A randomized controlled trial. *Burns*.
7 699 2014;40(8):1513-20.
- 8 700 118. Danin A, Georgesco G, Le Touze A, Penaud A, Quignon R, Zakine G. Assessment of burned
9 701 hands reconstructed with Integra® by ultrasonography and elastometry. *Burns*. 2012;38(7):998-
10 702 1004.
- 11 703 119. Engrav LH, Heimbach DM, Rivara FP, Moore ML, Wang J, Carrougher GJ, et al. 12-Year
12 704 within-wound study of the effectiveness of custom pressure garment therapy. *Burns*.
13 705 2010;36(7):975-83.
- 14 706 120. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of
15 707 postburn hypertrophic scar: A preliminary study. *Burns*. 1997;23(1):S12-S8.
- 16 708 121. Issler-Fisher AC, Fisher OM, Smialkowski AO, Li F, van Schalkwyk CP, Haertsch P, et al.
17 709 Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective
18 710 short-term outcome analysis of a prospective treatment cohort. *BURNS*. 2016;43(3):573-82.
- 19 711 122. Katz SM, Frank DH, Leopold GR, Wachtel TL. Objective measurement of hypertrophic burn
20 712 scar: A preliminary study of tonometry and ultrasonography. *Ann Plast Surg*. 1985;14(2):121-7.
- 21 713 123. Kemp Bohan PM, Cooper LE, Lu KN, Raper DM, Batchinsky M, Carlsson AH, et al.
22 714 Fractionated ablative carbon dioxide laser therapy decreases ultrasound thickness of hypertrophic
23 715 burn scar: A prospective process improvement initiative. *Ann Plast Surg*. 2020;86(3):273-8.
- 24 716 124. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS)
25 717 in objective scar evaluation. *Burns*. 2005;31(4):445-52.
- 26 718 125. Miletta N, Siwy K, Hivnor C, Clark J, Shofner J, Zurakowski D, et al. Fractional ablative laser
27 719 therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and
28 720 subjective outcomes. *Ann Surg*. 2021;274(6):E574-E80.
- 29 721 126. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical
30 722 silicone gel and pressure garment therapy for burn scar prevention and management in children 12-
31 723 months postburn: A parallel group randomised controlled trial. *Clin Rehabil*. 2021;35(8):1126-41.
- 32 724 127. Wiseman J, Ware RS, Simons M, McPhail S, Kimble R, Dotta A, et al. Effectiveness of topical
33 725 silicone gel and pressure garment therapy for burn scar prevention and management in children: a
34 726 randomized controlled trial. *Clin Rehabil*. 2020;34(1):120-31.
- 35 727 128. Wood FM, Currie K, Backman B, Cena B. Current difficulties and the possible future
36 728 directions in scar assessment. *Burns*. 1996;22(6):455-8.
- 37 729 129. Yim H, Cho YS, Seo CH, Lee BC, Ko JH, Kim D, et al. The use of AlloDerm on major burn
38 730 patients: AlloDerm prevents post-burn joint contracture. *Burns*. 2009;36(3):322-8.
- 39 731 130. Żądkowski T, Nachulewicz P, Mazgaj M, Woźniak M, Cielecki C, Wieczorek AP, et al. A new
40 732 CO2 laser technique for the treatment of pediatric hypertrophic burn scars: An observational study.
41 733 *Medicine (Baltimore)*. 2016;95(42):e5168-e.
- 42 734 131. Cho J, Jang Y, Hur J, Ko J, Seo D, Lee J, et al. Effectiveness of emu oil on burn scar. *J Burn Care*
43 735 *Res*. 2012;33(2):S71.
- 44 736 132. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn*
45 737 *Care Res*. 2018;39(suppl_1):S219-S20.
- 46 738 133. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes
47 739 of burn scars treated with laser therapy. *J Burn Care Res*. 2016;37:S106.
- 48 740 134. Kim SK, Park JM, Jang YH, Son YH. Management of hypertrophic scar after burn wound using
49 741 microneedling procedure (dermastamp). *Burns*. 2009;35:S37-S.
- 50 742 135. Zuccaro J, Fish JS, Kelly C. The effectiveness of laser therapy for hypertrophic burn scars in
51 743 pediatric patients: A prospective investigation. *Journal of Burn Care and Research*. 2021;42(S1):S24.
- 52
53
54
55
56
57
58
59
60

- 1
2
3 744 136. Alshehari A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid
4 745 injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars. Archives
5 746 of the Balkan Medical Union. 2015;50(3):364-6.
- 6 747 137. Chang C-S, Wallace CG, Hsiao Y-C, Chang C-J, Chen PK-T. Botulinum toxin to improve results
7 748 in cleft lip repair: A double-blinded, randomized, vehicle-controlled clinical trial. PLoS One.
8 749 2014;9(12):e115690-e.
- 9 750 138. Fraccalvieri M, Sarno A, Gasperini S, Zingarelli E, Fava R, Salomone M, et al. Can single use
10 751 negative pressure wound therapy be an alternative method to manage keloid scarring? A
11 752 preliminary report of a clinical and ultrasound/colour-power-doppler study. Int Wound J.
12 753 2013;10(3):340-4.
- 13 754 139. Lacarrubba F, Patania L, Perrotta R, Stracuzzi G, Nasca MR, Micali G. An open-label pilot
14 755 study to evaluate the efficacy and tolerability of a silicone gel in the treatment of hypertrophic scars
15 756 using clinical and ultrasound assessments. J Dermatolog Treat. 2008;19(1):50-3.
- 16 757 140. Li K, Nicoli F, Cui C, Xi WJ, Al-Mousawi A, Zhang Z, et al. Treatment of hypertrophic scars and
17 758 keloids using an intralesional 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive
18 759 technique. Sci Rep. 2020;10(1):21694-.
- 19 760 141. Li N, Yang L, Cheng J, Han J, Yang X, Zheng Z, et al. A retrospective study to identify the
20 761 optimal parameters for pulsed dye laser in the treatment of hypertrophic burn scars in Chinese
21 762 children with Fitzpatrick skin types III and IV. Lasers Med Sci. 2021;36(8):1671-9.
- 22 763 142. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone
23 764 gel dressing and pressure therapy on posttraumatic hypertrophic scars. J Burn Care Res.
24 765 2010;31(3):448-57.
- 25 766 143. Nicoletti G, Brenta F, Blevé M, Pellegatta T, Malovini A, Faga A, et al. Long-term in vivo
26 767 assessment of bioengineered skin substitutes: a clinical study. J Tissue Eng Regen Med.
27 768 2015;9(4):460-8.
- 28 769 144. Niessen FB, Spauwen PHM, Robinson PH, Fidler, Kon M. The use of silicone occlusive
29 770 sheeting (Sil-K) and silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation.
30 771 Plast Reconstr Surg. 1998;102(6):1962-72.
- 31 772 145. Zhidong X, Haixia L, Chao L, Yongrong L. Wavelet Bilateral Filter Algorithm-Based High-
32 773 Frequency Ultrasound Image Analysis on Effects of Skin Scar Repair. Scientific programming.
33 774 2021;2021.
- 34 775 146. Avetnikov DS, Bukhanchenko OP, Skikevich MG, Aipert VV, Boyko IV. Features of ultrasound
35 776 diagnostics of postoperative hypertrophic and keloid scars. The New Armenian Medical Journal.
36 777 2018;12(4):43-8.
- 37 778 147. Ge X, Sun Y, Lin J, Zhou F, Yao G, Su X. Effects of multiple modes of UltraPulse fractional CO2
38 779 laser treatment on extensive scarring: a retrospective study. Lasers Med Sci. 2021;37(3):1575-82.
- 39 780 148. Guo R, Xiang X, Wang L, Zhu B, Cheng S, Qiu L. Quantitative assessment of keloids using
40 781 ultrasound shear wave elastography. Ultrasound Med Biol. 2020;46(5):1169-78.
- 41 782 149. Lobos N, Wortsman X, Valenzuela F, Alonso F. Color Doppler ultrasound assessment of
42 783 activity in keloids. Dermatol Surg. 2017;43(6):817-25.
- 43 784 150. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
44 785 scarring. Lasers Surg Med. 2012;44:61.
- 45 786 151. Blome-Eberwein S, Blaine C, Gogal C, Eid S, Foltz C. Fractional Er:Glass photothermolysis
46 787 laser therapy to treat hypertrophic scarring. J Burn Care Res. 2011;32:S95.
- 47 788 152. Timina I, Sharobaro V, Trykova I. A potential of the high-frequency ultrasonic investigation in
48 789 the differential diagnostics of scars. Ultraschall Med. 2013;34(S 01).
- 49 790 153. Zuccaro J, Kelly C, Perez M, Doria A, Fish JS. The effectiveness of laser therapy for
50 791 hypertrophic burn scars in pediatric patients: A prospective investigation. J Burn Care Res.
51 792 2021;42(5):847-56.
- 52 793 154. Zuccaro J, Perez M, Mohanta A, Fish J, Doria A. Elastography-Based Quantification of Burn
53 794 Scar Stiffness. J Burn Care Res. 2019;40(Supplement_1):S215-S.

- 1
2
3 795 155. Issler-Fisher AC, Fisher OM, Smialkowski AO, Li F, van Schalkwyk CP, Haertsch P, et al.
4 796 Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective
5 797 short-term outcome analysis of a prospective treatment cohort. *Burns*. 2017;43(3):573-82.
6 798 156. Jameson JL, Longo DL. Precision medicine — personalized, problematic, and promising. *N*
7 799 *Engl J Med*. 2015;372(23):2229-34.
8 800 157. Robinson T, Bailey C, Morris H, Burns P, Melder A, Croft C, et al. Bridging the research-
9 801 practice gap in healthcare: A rapid review of research translation centres in England and Australia.
10 802 *Health research policy and systems*. 2020;18(1):1-117.
11 803 158. Wynn T. Cellular and molecular mechanisms of fibrosis. In: Altmann DM, Douek DC, editors.
12 804 Chichester, UK: John Wiley & Sons, Ltd.; 2008. p. 199-210.
13 805 159. Willenborg S, Eming SA. Cellular networks in wound healing. *Science*. 2018;362(6417):891-2.
14 806 160. Kwan P, Desmouliere A, Tredget EE. Molecular and cellular basis of hypertrophic scarring. In:
15 807 Herndon DN, editor. *Total Burn Care*. 5 ed. China: Elsevier; 2018. p. 455-65.
16 808 161. Hellström M, Hellström S, Engström-Laurent A, Bertheim U. The structure of the basement
17 809 membrane zone differs between keloids, hypertrophic scars and normal skin: A possible background
18 810 to an impaired function. *J Plast Reconstr Aesthet Surg*. 2014;67(11):1564-72.
19 811 162. Nicolescu AC, Ionescu S, Ancuta I, Popa V-T, Lupu M, Soare C, et al. Subepidermal Low-
20 812 Echogenic Band—Its Utility in Clinical Practice: A Systematic Review. *Diagnostics (Basel)*.
21 813 2023;13(5):970.
22 814 163. Laverde-Saad A, Simard A, Nassim D, Jfri A, Alajmi A, O'Brien E, et al. Performance of
23 815 ultrasound for identifying morphological characteristics and thickness of cutaneous basal cell
24 816 carcinoma: A systematic review. *Dermatology*. 2022;1-19.
25 817 164. Russell FM, Herbert A, Ferre RM, Zakeri B, Echeverria V, Peterson D, et al. Development and
26 818 implementation of a point of care ultrasound curriculum at a multi-site institution. *Ultrasound J*.
27 819 2021;13(1):9-.
28 820 165. Perry DM, McGrouther DA, Bayat A. Current Tools for Noninvasive Objective Assessment of
29 821 Skin Scars. *Plastic and Reconstructive Surgery*. 2010;126(3):912-23.
30 822 166. Powers PS, Sarkar S, Goldgof DB, Cruse CW, Tsap LV. Scar assessment: current problems and
31 823 future solutions. *The Journal of burn care & rehabilitation*. 1999;20(1 Pt 1):54-60.
32 824 167. Nguyen DQA, Potokar T, Price P. A review of current objective and subjective scar
33 825 assessment tools. *Journal of Wound Care*. 2008;17(3):101-6.
34 826 168. Li H, Furst DE, Jin H, Sun C, Wang X, Yang L, et al. High-frequency ultrasound of the skin in
35 827 systemic sclerosis: an exploratory study to examine correlation with disease activity and to define
36 828 the minimally detectable difference. *Arthritis Res Ther*. 2018;20(1):181-.
37 829 169. Santiago T, Santos E, Ruaro B, Lepri G, Green L, Wildt M, et al. Ultrasound and elastography
38 830 in the assessment of skin involvement in systemic sclerosis: A systematic literature review focusing
39 831 on validation and standardization – WSF Skin Ultrasound Group. *Semin Arthritis Rheum*.
40 832 2022;52:151954-.

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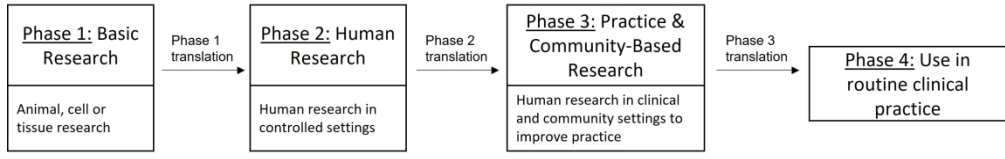


Figure 1: Research to clinical practice pipeline.

275x42mm (330 x 330 DPI)

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

Supplementary Box 1. Full search strategy for Ovid MEDLINE.

((ultrasound.ti,ab. OR ultra sound.ti,ab. OR sonograph*.ti,ab. OR ultrasonic.ti,ab. OR high-frequency.ti,ab. OR high frequency.ti,ab. OR hfus.ti,ab. OR ultrasonog*.ti,ab. OR exp Ultrasonography/)

AND

((skin.ti,ab. OR epiderm*.ti,ab. OR derm*.ti,ab. OR cutaneous.ti,ab OR scar*.ti,ab OR keloid*.ti,ab OR cicatri*.ti,ab OR exp Skin/ OR exp Dermatology/ OR exp Cicatrix/)

AND

(thickness*.ti,ab. OR thicken*.ti,ab. OR depth.ti,ab. OR volume.ti,ab. OR height.ti,ab. OR vancouver scar scale.ti,ab)

ADJ10

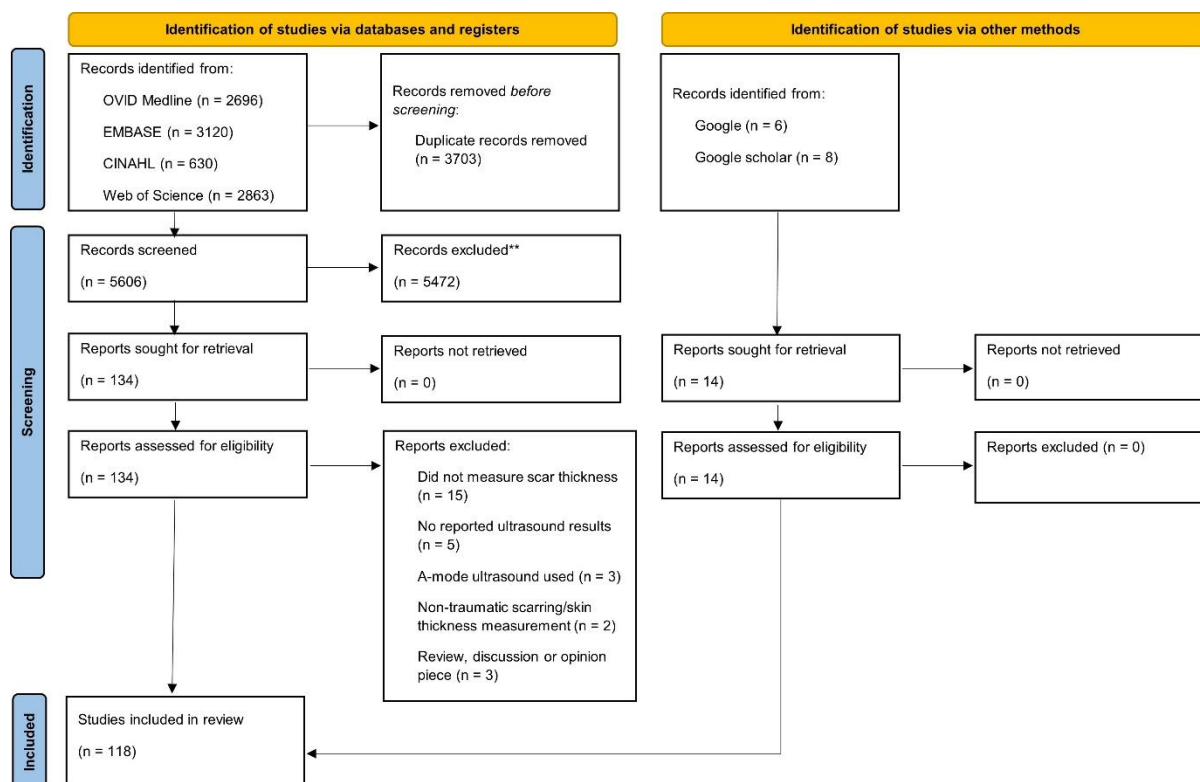
(measure*.ti,ab. OR quantif*.ti,ab. OR calculat*.ti,ab OR estimat*.ti,ab OR assess*.ti,ab. OR determin*.ti,ab. OR evaluat*.ti,ab OR imag*.ti,ab OR exam*.ti,ab)))

NOT (exp animals/ NOT exp humans/)

Legend: ab, abstract (searches the abstract of the publication); adj10, adjacency (search terms must be located within 10 words of one another); exp, explode (used to include all subheadings when searching MeSH headings); ti, title (searches the title of the publication)

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Supplementary Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram for this study.



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Supplementary Table 1: Extraction categories and fields

Extraction category	Extraction field	
Publication details	First author	
	Year of publication	
	Title of publication	
	Country (first author)	
	Country (study)	
	Country (recruited)	
	Publication type (e.g., peer-reviewed journal article, abstract)	
	Journal name	
	Corresponding author contact details	
	Funding source (e.g., commercial, non-commercial)	
	Use of scar thickness measurement (e.g., longitudinal study, response to treatment)	
	Study details	Aim/objective
		Research questions
		Target population/topics
Study design (e.g., RCT, mixed methods)		
Data and analysis (i.e., statistical methods)		
Removal of scar treatments before ultrasound measurement (e.g., length of time before measurement)		
Reason for measurement (e.g., research, clinical initiative)		
Inclusion/exclusion criteria		
Dates of data collection		
Ultrasound thickness collection methods (e.g., direct collection, collected from medical records)		
Contralateral/unaffected/comparator skin thickness measurement		
Other methods used		
Use of guidelines/frameworks for measurement methods		
How previously published methods/guidelines were used		
Research pipeline stage		
Participant details		Setting (e.g., inpatient/outpatient clinics)
	Scar type (e.g., burn scar, surgical scar)	
	Number of participants	
	Population type (e.g., adult/paediatric)	
Ultrasound methods	Gender ratio	
	Patient involvement in thickness determination	
	How patients were involved in thickness determination	
	Ultrasound mode	
	Device name and manufacturer	
	Frequency used	
	Number of measurements taken	
	What did researchers report they were measuring (e.g., fibrosis, oedema)	
	Anatomical locations/functional measurement units measured	
	Patient orientation	
Psychometric properties*	Ultrasound transducer orientation	
	Methods used to prevent skin compression	
	Measurement site relocation strategies	
	Type of skin measurement (i.e., epidermis/dermis/combined)	
Feasibility† outcomes	Measurer training	
	Reliability	
	Measurement error	
	Time taken for measurement	

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1	
2	
3	Availability of measurement method
4	Ease of administration
5	Number of steps required
6	Number of people required to conduct measurements
7	Considerations for special populations
8	Implementation [‡] outcomes
9	Acceptability
10	Adoption
11	Appropriateness
12	Cost
13	Feasibility
14	Fidelity
15	Sustainability
16	Strengths and limitations of
17	measurement methods
18	Strengths
19	Limitations
20	Barriers
21	Enablers
22	Findings
23	Ultrasound-related findings

*Psychometric properties as outlined in the COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments¹

[†]Feasibility outcomes as per Prinsen *et al.*²

[‡]Implementation outcomes as per Proctor *et al.*³

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Supplementary Table 2. Characteristics of records included in this review. Studies are listed alphabetically by author within the translational pipeline phase.

First Author (year)	Country of Publication	Funding Sources	Sample Size (n)	Population Type	Scar Aetiology	Translational Pipeline Phase*
<i>Journal articles</i>						
Agabalyan (2017)	Canada	Non-commercial	10	Adult	Not specified	2
Alsharnoubi (2018)	Egypt	No funding	15	Paediatric	Burn	2
Alsharnoubi (2018)	Egypt	Not reported	15	Paediatric	Burn	2
Alshehari (2015)	Egypt	Not reported	30	Not reported	Mixed	2
Blome-Eberwein (2012)	United States	Non-commercial	16	Paediatric & adult	Burn	2
Blome-Eberwein (2016)	United States	Not reported	36	Adult	Not specified	2
Blome-Eberwein (2019)	United States	Non-commercial	19	Adult	Burn	2
Cai (2019)	China	Non-commercial	51	Adult	Not specified	2
Candy (2010)	Hong Kong	Not reported	17	Adult	Not specified	2
Chan (2004)	China	Non-commercial	56	Paediatric & adult	Burn	2
Chang (2014)	Taiwan	Non-commercial	60	Paediatric & adult	Surgical (cleft lip repair)	2
Cho (2014)	Korea	Non-commercial	146	Not reported	Burn	2
Deng (2019)	China	Not reported	20	Adult	Not specified	2
Deng (2021)	China	No funding	31	Adult	Not specified	2
Deng (2021)	Hong Kong and China	Non-commercial	45	Adult	Not specified	2
Dunkin (2007)	England	Non-commercial	113	Adult	Surgical (dermal scratch)	2
Elrefaie (2020)	Not specified	Not reported	22	Paediatric & adult	Not specified	2
Fabbrocini (2016)	Not specified	Not reported	20	Adult	Mixed	2
Fracalvieri (2011)	Italy	No funding	5	Adult	Mixed	2
Fracalvieri (2013)	Italy	Not reported	3	Paediatric & adult	Mixed	2
Gee Kee (2016)	Australia	Commercial	43	Paediatric	Burn	2
Issler-Fisher (2021)	Australia	Commercial	187	Adult	Burn	2
Joo (2020)	Korea	Non-commercial	48	Adult	Not specified	2
Lacarrubba (2008)	Not specified	Not reported	8	Paediatric & adult	Mixed	2

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1							
2							
3	Lau (2005)	Hong Kong	Not reported	100	Paediatric & adult	Burn	2
4	Lee (2019)	United Kingdom	Non-commercial	55	Adult	Burn	2
5	Lee (2020)	United Kingdom	Non-commercial	55	Adult	Burn	2
6	Li (2013)	China	Non-commercial	7	Adult	Burn	2
7	Li (2020)	China	Not reported	21	Paediatric & adult	Mixed	2
8	Li (2021)	China	Non-commercial	165	Paediatric	Mixed	2
9	Li (2021)	China	Non-commercial	105	Adult	Burn	2
10	Li (2021)	China	Non-commercial	105	Adult	Burn	2
11	Li-Tsang (2006)	Not specified	Non-commercial	45	Adult	Not specified	2
12	Li-Tsang (2010)	China	Non-commercial	104	Paediatric & adult	Mixed	2
13	Mamdouh (2021)	Egypt	Not reported	40	Adult	Not specified	2
14	Meirte (2016)	Belgium	Non-commercial	9	Adult	Burn	2
15	Miletta (2021)	United States	Non-commercial	29	Paediatric & adult	Burn	2
16	Nedelec (2019)	Canada	Non-commercial	70	Adult	Burn	2
17	Nedelec (2020)	Canada	Non-commercial	51	Adult	Burn	2
18	Nicoletti (2015)	Italy	Not reported	27	Paediatric & adult	Surgical (scar reconstruction)	2
19							
20							
21	Niessen (1998)	The Netherlands	Commercial & Non-commercial	145	Paediatric & adult	Surgical (breast reduction)	2
22							
23							
24	Reinholz (2020)	Germany	No funding	25	Adult	Mixed	2
25	Schwaiger (2018)	Germany	No funding	15	Adult	Mixed	2
26	van den Kerckhove (2005)	Belgium	Not reported	60	Adult	Burn	2
27							
28	van der Veer (2010)	The Netherlands	Non-commercial	44	Adult	Surgical (cardiothoracic surgery)	2
29							
30							
31							
32	Wang (2009)	China	Non-commercial	22	Adult	Burn	2
33	Wiseman (2020, 2021)	Australia	Commercial & Non-commercial	153	Paediatric	Burn	2
34							
35	Xuan (2021)	Not specified	Not reported	72	Not reported	Not specified	2
36	Yim (2010)	Korea	No funding	31	Paediatric & adult	Burn	2
37	Zadkowski (2016)	Not specified	Not reported	47	Paediatric	Burn	2
38	Avetikov (2018)	Not specified	Not reported	50	Paediatric & adult	Not specified	3
39							
40							
41							
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1							
2							
3	Chae (2016)	Korea	Non-commercial	23	Adult	Not specified	3
4	Cheng (2001)	Hong Kong	Not reported	58	Paediatric	Burn	3
5	Danin (2012)	France	Not reported	22	Paediatric & adult	Burn	3
6	Fong (1997)	Not specified	Not reported	16	Paediatric & adult	Burn	3
7	Gankande (2014)	Australia	Non-commercial	30	Adult	Burn	3
8	Ge (2022)	China	Not reported	21	Paediatric & adult	Mixed	3
9	Guo (2020)	China	Non-commercial	87	Paediatric & adult	Not specified	3
10	Huang (2017)	Taiwan	Not reported	1	Adult	Burn	3
11	Huang (2020)	China	Non-commercial	43	Adult	Not specified	3
12	Huang (2021)	Taiwan	Not reported	5	Adult	Burn	3
13	Issler-Fisher (2017)	Australia	No funding	47	Paediatric & adult	Burn	3
14	Issler-Fisher (2020)	Australia	No funding	78	Adult	Burn	3
15	Katz (1985)	United States	Not reported	4	Not reported	Burn	3
16	Kemp Bohan (2021)	United States	No funding	21	Not reported	Burn	3
17	Kim (2018)	Not specified	Not reported	148	Not reported	Burn	3
18	Li (2018)	China	Non-commercial	34	Adult	Burn	3
19	Li-Tsang (2005)	China	Non-commercial	101	Adult	Surgical	3
20						(orthopaedic	
21						surgery)	
22							
23							
24							
25	Lobos (2017)	Not specified	Not reported	35	Paediatric & adult	Not specified	3
26	Nedelec (2008)	Canada	Non-commercial	32	Adult	Burn	3
27	Nedelec (2014)	Not specified	Non-commercial	46	Adult	Burn	3
28	Reinholz (2016)	Not specified	Commercial	8	Adult	Not specified	3
29	Simons (2017)	Australia	Non-commercial	49	Paediatric	Burn	3
30	Soykan (2014)	The Netherlands	Non-commercial	87	Adult	Surgical	3
31						(cardiothoracic	
32						surgery)	
33							
34	Timar-Banu (2011)	Canada	Non-commercial	30	Adult	Mixed	3
35	Ud-Din (2019)	United Kingdom	Non-commercial	62	Adult	Not specified	3
36	van den Kerckhove	Not specified	Not reported	6	Adult	Burn	3
37	(2003)						
38							
39							
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1							
2							
3	Wang (2010)	Australia	Commercial & Non-commercial	21	Paediatric	Burn	3
4							
5	Wood (1996)	Not specified	Not reported	1	Paediatric	Burn	3
6	Yeol Lee (2022)	Korea	Non-commercial	16	Adult	Mixed	3
7							
8	Berry (1985)	Not specified	Commercial	16	Paediatric & adult	Burn	4
9	Engrav (2010)	Not specified	Commercial & Non-commercial	67	Paediatric & adult	Burn	4
10							
11	<i>Abstracts</i>						
12	Agabalyan (2016)	Not specified	Non-commercial	10	Not reported	Burn	2
13	Bajouri (2018)	Not specified	Not reported	20	Not reported	Burn	2
14	Blome-Eberwein (2011, 2012)	Not specified	Not reported	16	Paediatric & adult	Mixed	2
15							
16	Blome-Eberwein (2014)	Not specified	Not reported	66	Not reported	Burn	2
17	Cho (2012)	Not specified	Not reported	60	Paediatric & adult	Burn	2
18	Comstock (2018)	Not specified	Not reported	1	Adult	Burn	2
19	Cooper (2021)	Not specified	Not reported	25	Not reported	Burn	2
20	El-Zawhary (2007)	Not specified	Not reported	57	Not reported	Mixed	2
21	Jacobs (2016)	Not specified	Not reported	6	Paediatric & adult	Burn	2
22	Jang (2009)	Not specified	Not reported	20	Not reported	Not specified	2
23	Kim (2009)	Not specified	Not reported	5	Paediatric & adult	Burn	2
24	Li-Tsang (2010)	Not specified	Not reported	45	Not reported	Not specified	2
25	Li-Tsang (2011)	Not specified	Not reported	4	Not reported	Not specified	2
26	Maari (2017)	Not specified	Non-commercial	12	Not reported	Not specified	2
27	Moortgat (2020)	Not specified	Not reported	10	Not reported	Burn	2
28	Nedelec (2018)	Not specified	Not reported	60	Not reported	Burn	2
29	Peters (2018)	Not specified	Not reported	5	Not reported	Burn	2
30	Siwy (2016)	Not specified	Non-commercial	15	Not reported	Burn	2
31	Tu (2014)	Not specified	Not reported	59	Not reported	Not specified	2
32	Ud-Din (2017)	Not specified	Not reported	20	Not reported	Surgical (tissue biopsies)	2
33							
34	Anthonissen (2015)	Not specified	Not reported	N.R.	Not reported	Burn	3
35	Bezugly (2014)	Not specified	Not reported	103	Not reported	Mixed	3
36							
37							
38							
39							
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43							
44							
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1							
2							
3	Bezugly (2019)	Not specified	Not reported	438	Not reported	Not specified	3
4	Blome-Eberwein (2012)	Not specified	Not reported	19	Adult	Burn	3
5	Du (2006)	Not specified	Not reported	1	Adult	Burn	3
6	Edgear-Lacoursière	Canada	Not reported	44	Not reported	Burn	3
7	(2022)						
8	George (2019)	Not specified	Not reported	11	Not reported	Burn	3
9	Li (2016)	Not specified	Not reported	34	Not reported	Burn	3
10	Seo (2011)	Korea	Not reported	48	Not reported	Burn	3
11	Timina (2013)	Not specified	Not reported	49	Paediatric & adult	Not specified	3
12	Ud-Din (2017)	Not specified	Not reported	20	Not reported	Surgical (tissue biopsies)	3
13							
14	Ud-Din (2018)	Not specified	Not reported	62	Not reported	Surgical (tissue biopsies)	3
15							
16	Zuccaro (2019)	Canada	Not reported	13	Paediatric	Burn	3
17	Zuccaro (2021)	Not specified	Not reported	20	Paediatric	Burn	3
18	Zuccaro (2021)	Canada	Non-commercial	20	Paediatric	Burn	3
19	Cho (2012)	Not specified	Not reported	30	Not reported	Burn	4

Legend: Paediatric: measurement of patients under the age of 18; Adult: measurement of patients aged 18 years or older; N.R.: Not reported; Burn: scars caused by thermal, chemical or friction injury; Surgical: scars caused by surgical procedures (including biopsies); Mixed: participant scars caused by mixed trauma (e.g., burn and acne)

Footnotes: *Stage in the research to clinical practice translational pipeline, based on the Australian Government Department of Health and Aged Care⁴

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Supplementary Table 3. Measurement methods used in included records.

First Author (year)	Ultrasound Type	Ultrasound Frequency (MHz)	Measurement Parameters	Scar Characteristic Measured	Scar Relocation
<i>Journal articles</i>					
Agabalyan (2017)	High-frequency	20	Epidermal, dermal & combined	N.R.	Not relevant – single measurement
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis	N.R.
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis [†]	N.R.
Alshehari (2015)	N.R.	N.R.	Maximum elevation above normal skin	N.R.	N.R.
Avetikov (2018)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Berry (1985)	N.R.	N.R.	N.R.	N.R.	N.R. [‡]
Blome- Eberwein (2012)	B-mode	N.R.	Combined epidermal & dermal [§]	N.R.	N.R. [‡]
Blome- Eberwein (2016)	High-frequency	50	N.R.	Fibrosis [†]	N.R. [‡]
Blome- Eberwein (2019)	High-frequency	35	Dermal	Fibrosis, hair follicle density	N.R.
Cai (2019)	High-frequency	50	Dermal	N.R.	N.R. [‡]
Candy (2010)	B-mode	N.R.	N.R.	N.R.	Scar boundaries traced
Chae (2016)	N.R.	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Chang (2014)	N.R.	12	N.R.	N.R.	N.R.

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1						
2						
3	Chan (2004)	N.R.	N.R.	N.R.	N.R.	Tracing
4	Cheng (2001)	B-mode	5-10	Combined epidermal & dermal	N.R.	Tracing & cutting out paper
5						Photographs
6						
7	Cho (2014)	High-frequency	7.5	N.R.	N.R.	N.R.
8	Danin (2012)	B-mode	20	Epidermal & dermal	N.R.	N.R.
9	Deng (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
10	Deng (2021)	Colour Doppler	4-15	Dermal	Fibrosis [†]	N.R.
11	Deng (2021)	B-mode	8-12	Epidermal & dermal	Fibrosis [†]	Photographs
12	Dunkin (2007)	High-frequency	N.R.	N.R.	Fibrosis & oedema [†]	Measurements taken at set
13						linear distances along scar
14						
15	Elrefaie (2020)	High-frequency	13	N.R.	Fibrosis & oedema [†]	N.R. [‡]
16						
17	Engrav (2010)	N.R.	N.R.	N.R.	N.R.	N.R.
18	Fabbrocini	N.R.	N.R.	N.R.	Fibrosis & oedema [†]	N.R. [‡]
19	(2016)					
20	Fong (1997)	B-mode	7.5	N.R.	Fibrosis [†]	Tracing
21	Fraccalvieri	High-frequency	7-10	N.R.	Fibrosis & oedema [†]	N.R.
22	(2013)		& 10-13			
23	Fraccalvieri	High-frequency	10-13	Combined epidermal & dermal	Fibrosis [†]	N.R.
24	(2011)					
25	Gankande	High-frequency	20	Combined epidermal & dermal	N.R.	Scar marked & photographed
26	(2014)					
27	Ge (2022)	N.R.	N.R.	N.R.	N.R.	N.R.
28	Gee Kee	B-mode	8-18	Combined epidermal & dermal	N.R.	Transducer in centre of
29	(2016)					original burn site where no
30						scar present
31						
32						
33	Guo (2020)	N.R.	2-15	Combined epidermal & dermal ^c	Fibrosis [†]	Thickest site on peripheral
34			& 4-15			regions
35	Huang (2017)	N.R.	N.R.	Combined epidermal & dermal	N.R.	Marked & linear
36						measurements from bony
37						landmarks
38						
39						
40						
41						
42						
43						
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45						
46						

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1						
2						
3	Huang (2021)	B-mode	5-12	N.R.	Oedema [†]	Not relevant – single measurement
4						
5	Huang (2020)	B-mode	5-12	Combined epidermal & dermal	N.R.	N.R.
6	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	Photograph & measurement of thickest area
7	(2021)					
8	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	N.R.
9	(2020)					
10	Issler-Fisher	N.R.	N.R.	N.R.	Fibrosis [†]	Scar mapped with drawing
11	(2017)					Thickest area measured
12	Joo (2020)	N.R.	N.R.	N.R.	Fibrosis [†]	N.R.
13	Katz (1985)	B-mode	10	Combined epidermal & dermal	N.R.	N.R.
14	Kemp Bohan	High-frequency	12	N.R.	Fibrosis [†]	Tracing – thickest area & adjacent landmarks marked
15	(2021)					
16	Kim (2018)	N.R.	22	Combined epidermal & dermal	N.R.	Not relevant – single measurement
17						
18	Lacarrubba	B-mode	20	Combined epidermal & dermal	N.R.	N.R.
19	(2008)					
20	Lau (2005)	Tissue Ultrasound Palpation System	5 (burn) & 10 (surgical)	N.R.	N.R.	Tracing – most severe/prominent site
21						
22	Lee (2020)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Not relevant – single measurement
23						
24	Lee (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Marked with pen
25	Li (2013)	High-frequency	12	Combined epidermal & dermal	Fibrosis [†]	Tracing
26	Li (2020)	N.R.	10	N.R.	Fibrosis [†]	N.R.
27	Li (2021)	High-frequency	20	N.R.	N.R.	Thickest area
28	Li (2021)	High-frequency	20	N.R. [§]	Fibrosis [†]	Thickest area
29	Li (2018)	N.R.	N.R.	Combined epidermal & dermal	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound Palpation System	N.R.	N.R.	N.R.	N.R.
31	(2005)					
32	Li-Tsang	B-mode	N.R.	N.R.	N.R.	N.R. [‡]
33	(2006)					
34						
35						
36						
37						
38						
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1						
2						
3	Li-Tsang	B-mode	N.R.	N.R.	Fibrosis [†]	N.R.
4	(2010)					
5	Lobos (2017)	B-mode & colour	18	N.R.	Fibrosis [†]	Not relevant – single
6		Doppler				measurement
7	Mamdouh	High-frequency	N.R.	Combined epidermal & dermal [§]	Fibrosis [†]	N.R.
8	(2021)					
9	Meirte (2016)	High-frequency	22	Dermal	Fibrosis &	Marked with surgical pen, including boundaries of probe. Photograph of body position & probe location Tracing – worst scar
10				oedema [†]		
11	Miletta (2021)	N.R.	50	N.R.	Fibrosis [†]	
12	Nedelec (2014)	High-frequency	20	Combined epidermal & dermal	N.R.	
13						Tracing including notable
14						landmarks. Measurement site
15	Nedelec (2008)	High-frequency	20	Combined epidermal & dermal	N.R.	circled. Photograph
16						Tracing including notable
17						landmarks. Measurement site
18						circled. Photograph
19	Nedelec (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis &	Tracing. Hole cut over
20					oedema [†]	measurement area
21	Nedelec (2020)	High-frequency	20	Combined epidermal & dermal	N.R.	Photograph
22	Nicoletti	N.R.	22	Epidermis to fascia	N.R.	N.R.
23	(2015)					
24	Niessen (1998)	B-mode	N.R.	N.R.	Fibrosis &	3cm border marked with tape
25					oedema [†]	– measurements lateral
26	Reinholz	B-mode	11	Combined epidermal & dermal	Fibrosis &	N.R.
27	(2020)				oedema [†]	
28	Reinholz	B-mode	11	Combined epidermal & dermal [§]	Fibrosis &	N.R.
29	(2016)				oedema [†]	
30	Schwaiger	B-mode	11	N.R.	Fibrosis &	N.R.
31	(2018)				oedema [†]	
32	Simons (2017)	B-mode	8-18	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical
33						landmarks
34						
35						
36						
37						
38						
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1						
2						
3	Soykan (2014)	N.R.	3-9	N.R.	Fibrosis [†]	N.R.
4	Timar-Banu	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	N.R.
5	(2001)					
6	Ud-Din (2019)	High-frequency	50	Combined epidermal & dermal	Fibrosis	Defined anatomical location
7	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test sites marked.
8	Kerckhove					Thermoplastic splints created
9	(2003)					with space for transducer
10	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test site boundaries marked
11	Kerckhove					& traced
12	(2005)					
13	van der Veer	N.R.	7.5	N.R.	Fibrosis [†]	Standardised linear
14	(2010)					measurement points
15	Wang (2009)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.
16	Wang (2010)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical
17						landmarks
18	Wiseman	B-mode	N.R.	Combined epidermal & dermal	Fibrosis [†]	Centrally site of interest
19	(2020, 2021)					
20	Wood (1996)	B-mode	7 & 10	N.R.	N.R.	Transducer affixed to
21						tracking arm
22	Xuan (2021)	High-frequency	20	N.R.	Fibrosis [†]	N.R.
23	Yeol Lee	B-mode	7-16	N.R.	N.R.	N.R.
24	(2022)					
25	Yim (2010)	High-frequency	12	N.R.	N.R.	N.R.
26	Zadkowski	B-mode	N.R.	Combined epidermal & dermal	N.R.	N.R.
27	(2016)					
28	<i>Abstracts</i>					
29						
30	Agabalyan	N.R.	20	Epidermal, dermal & combined	N.R.	N.R.
31	(2016)					
32	Anthonissen	N.R.	22	Epidermal & dermal	N.R.	N.R.
33	(2015)					
34	Bajouri (2018)	High-frequency	N.R.	Epidermal & dermal	N.R.	N.R.
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3	Bezugly (2019)	High-frequency	22, 33 & 75	Epidermal & dermal	N.R.	N.R.
4	Bezugly (2014)	High-frequency	33 & 75	Epidermal & dermal	N.R.	N.R.
5	Blome-	N.R.	N.R.	N.R.	N.R.	N.R.
6	Eberwein					
7	(2011, 2012)					
8	Blome-	High-frequency	N.R.	N.R.	Fibrosis	N.R.
9	Eberwein					
10	(2012)					
11	Blome-	High-frequency	N.R.	N.R.	N.R.	N.R.
12	Eberwein					
13	(2014)					
14	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
15	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
16	Comstock	N.R.	N.R.	N.R.	N.R.	N.R.
17	(2018)					
18	Cooper (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
19	Du (2006)	B-mode	15	N.R.	N.R.	N.R.
20	Edgar-	N.R.	N.R.	N.R.	N.R.	N.R.
21	Lacoursière					
22	(2022)					
23	El-Zawhary	N.R.	N.R.	N.R.	N.R.	N.R.
24	(2007)					
25	George (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
26	Jacobs (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
27	Jang (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
28	Kim (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
29	Li (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
31	(2011)	Palpation System				
32	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
33	(2010)	Palpation System				
34	Maari (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
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3	Moortgat	High-frequency	N.R.	Dermal	N.R.	N.R.
4	(2020)					
5	Nedelec (2018)	N.R.	N.R.	N.R.	N.R.	N.R.
6	Peters (2018)	High-frequency	22	N.R.	N.R.	N.R.
7	Seo (2011)	N.R.	7.5	N.R.	N.R.	Thickest point
8	Siwy (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
9	Timina (2013)	N.R.	20-40	N.R.	N.R.	N.R.
10	Tu (2014)	High-frequency	N.R.	N.R.	N.R.	N.R.
11		ultrasound				
12		biomicroscopy				
13						
14	Ud-Din (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
15	Ud-Din (2017)	High-frequency	50	N.R.	N.R.	N.R.
16	Ud-Din (2018)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.
17	Zuccaro (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
18	Zuccaro (2019)	B-mode	N.R.	N.R.	N.R.	N.R.
19	Zuccaro (2021)	B-mode	6-18	Combined epidermal & dermal	N.R.	Scar outlined &
20						photographed
21						
22						

Legend: Scar relocation: Methods used by assessors to relocate the measured scar for sequential measurements; B-mode: brightness-mode ultrasound (< 20 MHz); High-frequency: high-frequency B-mode ultrasound (> 20 MHz); N.R.: Not reported

Footnotes: [†]Indirect reference made in record (e.g. in introduction or discussion); [‡]Photographs taken of the scar but not specified whether used for relocation; [§]Not stated in methods, so images provided in record used by authors of this review to provide subjective judgement

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Supplementary Table 4. Additional measurement methods used alongside ultrasound in included studies

First author (year)	Objective measurement methods	Clinician-based rating scale	PROM
<i>Journal articles</i>			
Agabalyan (2017)	Histology	-	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alshehari (2015)	-	VSS	-
Avetikov (2018)	-	-	-
Berry (1985)	Transcutaneous oxygen measurement	Scar redness and hypertrophy rating scale (0-5 Likert scale)	Scar redness and hypertrophy rating scale (0-5 Likert scale)
Blome-Eberwein (2012)	Doppler flowmeter – vascularity	VSS	POSAS-P
	Cutometer – pliability	POSAS-O	
	Semmes-Weinstein monofilament		
	Aesthesiometer testing set – sensation		
Blome-Eberwein (2016)	Cutometer – pliability	VSS	POSAS-P
	Dermaspectrometer – colour	POSAS-O	
	Semmes-Weinstein Aesthesiometer		
	Monofilament Testing Set – sensation		
Blome-Eberwein (2019)	-	VSS	-
Cai (2019)	-	Clinical evaluation	-
Candy (2010)	Spectrocolorimeter – colour	VSS	-
Chae (2016)	Spectrophotometer – pigmentation	VSS	POSAS-P
		POSAS-O	
Chang (2014)	-	VSS	-
		Photographic evaluation (0-10 VAS)	
Chan (2004)	Cutometer – viscoelasticity Spectrophotometer – pigmentation	-	-
Cheng (2001)	-	VSS	-
Cho (2014)	Mexameter – colour	Treatment efficacy (0-10 VAS)	Itching scale (0-4 Likert scale)

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3		Tewameter – trans-epidermal water		
4		loss		
5		Sebumeter – sebum		
6		Cutometer – elasticity		
7	Danin (2012)	Cutometer – elasticity	VSS	-
8	Deng (2019)	DermaLab Combo – colour	POSAS-O	-
9		Dermoscopy – vascularity		
10	Deng (2021)	-	VSS	-
11	Deng (2021)	Doppler – blood perfusion	POSAS-O	POSAS-P
12		Dermlite Foto IPro – erythema		
13	Dunkin (2007)	-	-	-
14	Elrefaie (2020)	Ultrasound – echogenicity, compressibility & vascularity	VSS	-
15	Engrav (2010)	Durometer – hardness	Clinical appearance based on photographs	-
16		Chromameter – colour	mVSS (vascularity, pigmentation, pliability)	-
17	Fabbrocini (2016)	-	Clinical rating – colour change, consistent itch, hypersensitivity, blistering	-
18	Fong (1997)	Cutometer – elasticity	VSS	-
19		Colour power Doppler – vascularisation	Visual analogue scale – pain and itch	-
20	Fraccalvieri (2013)			
21		Histology	-	-
22	Fraccalvieri (2011)	Echocontrastography – neovascularisation		
23		DermLab combo – erythema & elasticity	mVSS (some participants)	-
24	Gankande (2014)			
25	Ge (2022)	-	POSAS-O	POSAS-P
26			Subjective reports on patient range of movement	
27	Gee Kee (2016)	3D photography – thickness	POSAS-O	POSAS-P
28	Guo (2020)	Ultrasound – blood flow grade	-	-
29		Shear wave elastography – scar stiffness		
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3	Huang (2017)	-	-	-
4	Huang (2021)	-	-	-
5	Huang (2020)	Shear wave elastography – scar stiffness	-	-
6				
7	Issler-Fisher (2021)	-	VSS	POSAS-P
8			POSAS-O	
9	Issler-Fisher (2020)	-	VSS	POSAS-P
10			POSAS-O	Patient pain & itch scales
11	Issler-Fisher (2017)	-	VSS	POSAS-P
12			POSAS-O	Patient pain, itch & quality of life rating scales
13				
14	Joo (2020)	-	VSS	Pain severity (0-10 VAS)
15	Katz (1985)	Cicatrometer – firmness	-	-
16	Kemp Bohan (2021)	-	-	-
17	Kim (2018)	-	-	-
18	Lacarrubba (2008)	-	Clinical evaluation of lesion size	-
19	Lau (2005)	-	VSS	-
20	Lee (2020)	-	mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
21			POSAS-O	
22				
23	Lee (2019)	-	mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
24			POSAS-O	
25				
26				
27	Li (2013)	Micrometer – tissue thickness	-	-
28		Force/torque sensor – load applied to scar		
29				
30	Li (2020)	Cutometer – elasticity	VSS	Quality of life questionnaire
31		Mexameter – colour		
32		PeriCam PSI system and mexameter – blood supply		
33				
34	Li (2021)	Laser Doppler flowmetry – perfusion	VSS	-
35	Li (2018)	Spectrocolourimeter – scar colour	VSS	Pain & itch (0-10 VAS)
36	Li (2021)	-	VSS	Treatment satisfaction
37	Li-Tsang (2005)	Spectrocolourimeter – scar colour	VSS	Pain & itch (VAS scale not specified)
38	Li-Tsang (2006)	Spectrocolorimeter – colour	VSS	Pain & itch (VAS)
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3	Li-Tsang (2010)	Spectrocolorimeter – colour	VSS (pliability)	Pain & itch (10-point VAS)
4	Lobos (2017)	-	Modified Seattle Scar Scale	-
5			Clinical opinion	
6	Mamdouh (2021)	-	VSS	Patient satisfaction (VAS)
7	Meirte (2016)	-	-	-
8	Miletta (2021)	Colourmeter – scar colour	Unclear, likely POSAS-O	Unclear, likely POSAS-P
9		Dermal torque meter – scar compliance		Short Form 36 Quality of Life Survey
10				
11	Nedelec (2014)	Cutometer – elasticity	-	-
12		Mexameter – colour		
13	Nedelec (2008)	Cutometer – elasticity	mVSS	-
14		Mexameter – colour		
15	Nedelec (2019)	Cutometer – elasticity	-	-
16		Mexameter – colour		
17	Nedelec (2020)	Cutometer – elasticity	-	Pain & itch (10cm line VAS)
18		Mexameter – colour		
19	Nicoletti (2015)	-	-	-
20	Niessen (1998)	Histology	-	-
21	Reinholz (2020)	3D topographic imaging device	POSAS-O	Dermatology Quality of Life Index
22				POSAS-P
23	Reinholz (2016)	Optical coherence tomography – thickness	POSAS-O	Dermatology Quality of Life Index
24				POSAS-P
25	Schwaiger (2018)	3D topographic imaging device	-	-
26	Simons (2017)	3D camera – scar height	POSAS-O	-
27	Soykan (2014)	Slide calliper – dimensions	POSAS-O	POSAS-P
28	Timar-Banu (2001)	Metric ruler – dimensions	Validated 3-point scoring system for redness, hardness, itching & pain	-
29				
30	Ud-Din (2019)	Optical coherence tomography – thickness	-	-
31		Histology		
32	van den Kerckhove (2005)	Chromameter – erythema	-	-
33	van der Veer (2010)	Slide calliper – dimensions	-	-
34	Wang (2009)	Histology	-	-
35	Wang (2010)	-	-	-
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3	Wiseman (2020, 2021)	-	POSAS-O	POSAS-P
4				Numeric rating scale for itch
5				Toronto Paediatric Itch Scale
6				CH-9D
7				BBSIP
8	Wood (1996)	-	VSS	-
9	Xuan (2021)	Histology	-	-
10	Yeol Lee (2022)	Cutometer – elasticity	mVSS	-
11		Elastography		
12	Yim (2010)	Cutometer – elasticity	-	-
13		Tewameter – trans-epidermal water		
14		loss		
15		Mexameter – colour		
16	Zadkowski (2016)	-	VSS	-
17	<hr/>			
18	<i>Abstracts</i>			
19	<hr/>			
20	Agabalyan (2016)	Histology	-	-
21	Bajouri (2018)	-	VSS	-
22	Bezugly (2019)	Clinical or histopathological	-	-
23		diagnosis		
24	Bezugly (2014)	-	-	-
25	Blome-Eberwein (2011, 2012)	Doppler vascularity, elasticity and	VSS	Pain and itching scale (0-10 Likert
26		sensation		scale)
27	Blome-Eberwein (2012)	-	-	-
28	Blome-Eberwein (2014)	Doppler flowmeter – vascularity	VSS	POSAS-P
29		Cutometer – pliability		
30		Semmes-Weinstein monofilament		
31		aesthesiometer testing set – sensation		
32	Cho (2012)	-	VSS	-
33	Cho (2012)	CK-MPA Multi-Probe adaptor –	-	-
34		pigmentation, erythema and trans-		
35		epidermal water loss		
36		Cutometer – elasticity		
37	Comstock (2018)	Computer-based tools – Thickness &	Unclear, likely POSAS-O	Unclear, likely POSAS-P
38		pliability		
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Cooper (2021)	Colorimeter – pigmentation	Unclear, likely POSAS-O	Unclear, likely POSAS-P
Du (2006)	-	-	-
Edgar-Lacoursière (2022)	Cutometer – elasticity	-	-
	Mexameter – colour		
El-Zawhary (2007)	Histology	-	-
George (2019)	-	-	-
Jacobs (2016)	Cutometer – pliability	POSAS-O	-
	Colorimeter – colour		
Jang (2009)	Mexameter – pigmentation	-	-
	Tewameter – trans-epidermal water loss		
	Sebumeter – sebum		
	Cutometer – elasticity		
	Laser Doppler – perfusion		
Kim (2009)	Histology	VSS	-
Li (2016)	Spectrocolourimeter – scar colour	VSS	Patient report of pain & itch
Li-Tsang (2011)	-	VSS (thickness, pliability and pigmentation)	-
Li-Tsang (2010)	Histology	VSS	Self-report questionnaire
	Spectrocolourimeter – scar colour		
Maari (2017)	Cutometer – elasticity	-	-
	Mexameter – pigmentation		
Moortgat (2020)	Cutometer – elasticity	Unclear, likely POSAS-O	Unclear, likely POSAS-P
	Chromameter – colour		
	Tewameter – trans-epidermal water loss		
	Corneometer – hydration		
Nedelec (2018)	Cutometer – elasticity	-	-
	Mexameter – colour		
Peters (2018)	Cutometer – elasticity	POSAS-O	POSAS-P
	Colourimeter – colour		
Seo 2011	Cutometer – elasticity		
Siwy (2016)	Colourimeter – colour	-	SF-36 Quality of Life Measurement
	Torque meter – pliability & elasticity		POSAS-P
Timina (2013)	-	-	-

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1				
2				
3	Tu (2014)	-	VSS	-
4	Ud-Din (2017)	Laser perfusion imaging	-	-
5		Optical coherence tomography –		
6		thickness		
7		Histology		
8	Ud-Din (2017)	Optical coherence tomography –	-	-
9		thickness		
10	Ud-Din (2018)	Optical coherence tomography –	-	-
11		thickness		
12		Histology		
13	Zuccaro (2021)	Multi-parameter skin analysis device	VSS	Unclear, likely POSAS-P
14			Unclear, likely POSAS-O	
15	Zuccaro (2019)	Acoustic radiation force impulse	-	-
16		ultrasound elastography		
17	Zuccaro (2021)	Acoustic radiation force impulse –	VSS	POSAS-P
18		stiffness	POSAS-O (did not include	
19		DermLab Combo elasticity probe –	surface area and relief subscales)	
20		elasticity		
21		DermLab Combo colour probe –		
22		colour		

Legend: (m)VSS: (Modified) Vancouver Scar Scale; POSAS: Patient and Observer Scar Assessment Scale (POSAS-O: POSAS observer scale; POSAS-P: POSAS patient scale); VAS: Visual Analogue Scale; CHU-9D: Child Health Utility-9D; BBSIP: Brisbane Burn Scar Impact Profile

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Supplementary Table 5: Reliability of ultrasound methods reported in each included study

First Author (year)	Reliability Test & Measurement Error	Reliability & Measurement Error Test Statistics & Details
<i>Inter-rater reliability</i>		
Anthonissen (2015)	ICC; SEM	Epidermal – 0.297; 0.02mm Dermal – 0.991; 0.13mm
Chang (2014)	Pearson correlation	R=0.90, p<0.001
Dunkin (2007)	N.R.	N.R.
Fong (1997)	ICC	0.93, p=0.146
Gankande (2014)	ICC (95% CI)	<u>Individual site:</u> Rater 1 vs rater 2 ‘Best scar’ – 0.95 (0.92, 0.96) ‘Worst scar’ – 0.95 (0.91, 0.97) ‘Normal skin’ – 0.94 (0.91, 0.96) Rater 1 vs rater 3: ‘Best scar’ – 0.86 (0.78, 0.91) ‘Worst scar’ – 0.91 (0.85, 0.95) ‘Normal skin’ – 0.92 (0.88, 0.95) Rater 2 vs rater 3: ‘Best scar’ – 0.93 (0.89, 0.95) ‘Worst scar’ – 0.96 (0.92, 0.97) ‘Normal skin’ – 0.95 (0.92, 0.97) <u>Average site:</u> Rater 1 vs rater 2 ‘Best scar’ – 0.97 (0.94, 0.99) ‘Worst scar’ – 0.98 (0.96, 0.99) ‘Normal skin’ – 0.97 (0.93, 0.98) Rater 1 vs rater 3 ‘Best scar’ – 0.90 (0.77, 0.95) ‘Worst scar’ – 0.97 (0.91, 0.98) ‘Normal skin’ – 0.96 (0.92, 0.98) Rater 2 vs rater 2 ‘Best scar’ – 0.95 (0.88, 0.98) ‘Worst scar’ – 0.98 (0.94, 0.99) ‘Normal skin’ – 0.98 (0.97, 0.99)
Lau (2005)	ICC	0.84, p<0.01
Lee (2020)	ICC	“Acceptable to high”
Lee (2019)	ICC (95% CI); SEM	<u>Scar:</u> Single: 0.957 (0.934-0.973) Average: 0.985 (0.977-0.991) SEM: 0.10 mm <u>Unscarred skin:</u> Single: 0.967 (0.949-0.980) Average: 0.989 (0.982-0.993) SEM: 0.04 mm
Nedelec (2008)	ICC (95% CI)	Most severe scar: 0.90 (0.84-0.95) Less severe scar: 0.91 (0.85-0.95) Donor site: 0.89 (0.82-0.94) Normal skin: 0.85 (0.75-0.92)
Seo (2011)	N.R.	“High”
Simons (2017)	ICC (95% CI); SEM	Scar: 0.82 (0.7-0.89); 0.05 cm Normal skin: 0.33 (0.08-0.54); 0.03 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	<u>One day:</u> 0.88 (0.81-0.95); 0.29 mm

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		<u>Day-to-day:</u>
		0.94 (0.90-0.98); 0.21mm
<hr/>		
<i>Intra-rater reliability</i>		
<hr/>		
Anthonissen (2015)	ICC; SEM	Epidermal – 0.809; 0.01mm Dermal – 0.991; 0.13mm
Gankande (2014)	ICC (95% CI)	‘Best scar’ – 0.97 (0.89, 0.94) ‘Worst scar’ – 0.92 (0.88, 0.95) ‘Normal skin’ – 0.86 (0.81, 0.89)
Gee Kee (2016)	N.R.	N.R.
Lau (2005)	ICC	Intra-rater: 0.98, p<0.01
Lee (2019)	ICC (95% CI)	<u>Scar:</u> Single: 0.951 (0.871-0.987) Average: 0.983 (0.953-0.966) SEM: 0.10 mm
		<u>Unscarred skin:</u> Single: 0.948 (0.881-0.976) Average: 0.982 (0.954-0.993) SEM: 0.04 mm
Li (2013)	ICC	0.89
Seo (2011)	N.R.	“High”
Simons (2017)	ICC (95% CI); SEM	Scar: 0.95 (0.91-0.97); 0.02 cm Normal skin: 0.61 (0.41-0.75); 0.02 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	0.98 (0.97-0.99); 0.11mm
Wang (2010)	SE	Peak: 0.032 3 months: 0.018 6 months: 0.399 9 months: 0.353
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Abbreviations used in tables: N.R.: Not reported; ICC: Intraclass Correlation Coefficient; 95% CI: 95% Confidence Interval; SEM: Standard Error of Measurement; SE: Standard Error		
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Summary of findings for measurement error:

The reported inter-rater SEM measurements for the combined (i.e., epidermal and dermal) thickness measurement of scars was reported in two records as 0.11 mm⁵ and 0.5 mm.⁶ The inter-rater SEM for the combined thickness measurement of unscarred skin was also calculated in one record (SEM = 0.3 mm).⁶ The inter-rater SEM was calculated in one record for the measurement of epidermal (SEM = 0.02 mm) and dermal (0.13) measurements⁷, and one record reported only the dermal SEM for scar thickness (SEM = 0.1 mm) and unscarred skin (0.04 mm).⁸ The intra-rater SEM for the combined thickness measurement of scarred skin ranged from 0.18 mm to 0.52 mm, and was measured at 0.2 mm for unscarred skin in one record.⁶ One record reported the intra-rater SEM for epidermal (0.01 mm) and dermal (0.12 mm),⁷ and one record reported the intra-rater SEM for dermal scar (0.1 mm) and unscarred skin (0.04).⁸

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Supplementary Table 6. Methodological considerations for researchers and/or clinicians undertaking measurement of scar thickness using ultrasound.

Consideration	Details & examples of considerations	Publications in our review addressing the consideration	Details reported in included review records
Preventing skin compression during measurement	Using standoff methods (e.g., ultrasound gel, water bath) to prevent transducer touching the skin	6,9-13	- Use of ultrasound gel to prevent contact between ultrasound transducer and skin surface to minimise compression applied by direct application of transducer ^{6,9-12}
	Application of minimal pressure by transducer	14-18	- Silicone pad placed underneath transducer ¹³ - Transducer held to maintain minimal pressure on scar ^{14,15,17} - Training users to apply minimal force on transducer to prevent scar or skin distortion ^{16,18}
	Deliberately compressing skin to quantify scar compressibility	19-21	- Measurement of thickness with and without compression with transducer ^{19,21} - Thickness measurements taken using TUPS, which uses controlled and metered compression during measurement ²⁰
Orienting the patient	Orienting the patient during measurement (e.g., upright, supine, prone or seated)	8,18,22	- Patient supine throughout measurement to allow measurement to be taken in the same position ^{8,18,22}
	Maintaining patient stillness during measurement	9	- Patients asked to hold breath during measurement of scars on the chest to allow shear-wave ultrasound ⁹
Placing ultrasound transducer	Orientating ultrasound transducer [e.g., vertical (superior to inferior/cranial to caudal), horizontal (medial to lateral)]	23	- Direction of transducer recorded to ensure consistency ²³

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4		Orienting the	9,15,17,18,22,24-26
5		transducer in relation to	
6		the scar (e.g.,	
7		perpendicular)	
8		Measuring	6
9		difficult/tight areas	
10		(e.g., axillae or other	
11		joints)	
12		Mapping measurement	6,12,16,18,20,22,27-32
13	Relocating	area (e.g., tracing,	
14	scars for	schematic diagram)	
15	longitudinal		
16	measurement		
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24		Photographing	24,26,33
25		measurement area	
26			
27		Measuring specific scar	6,8,9,13,19-21,23,30,33-37
28		locations (e.g., centre	
29		of scar, worst area of	
30		scar, counting	
31		transducer lengths)	
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- Transducer oriented perpendicular to the skin surface to provide optimal image^{9,15,18,22,24-26}

- Exclusion of fingers and toes in paediatric measurements due to size of measurement area and thin skin⁶

- Scars traced using translucent paper^{18,20,22,27,29,31,32}

- Scars and surrounding anatomical landmarks traced using translucent paper¹⁶

- Scar mapped on transparent paper, which was then cut out²⁸

- Scar mapped with drawing, no elaboration provided³⁰

- Scars traced using Visitrak (Smith & Nephew Medical Limited, England)^{6,12}

- Assessed area marked and photograph taken in initial consultation^{24,33}

- Photographs of scars taken²⁶

- Measurement taken at standardised transducer lengths along surgically created scars of pre-specified dimensions³⁴

- Measurements taken at thickest/most severe point^{19-21,30,33,35,37}, as determined by the patient and/or clinician⁸

- Transducer placed on thickest site on peripheral regions⁹

- Transducer placed on area initially identified to have greatest burn depth²³

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Conducting linear measurements from nearby anatomical landmarks

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Acclimatising scar to measurement conditions

Removing scar treatments prior to ultrasound measurement

8,12,20,22,24-26,28,29,39,40

Acclimatising patient to room prior to measurement

5,18,22,29,41-46

- Measurement area selected by the measurer with -selected area marked with tape ¹³
- Measurements taken at set linear distances from cranial/caudal border of linear sternal scar ³⁶
- Linear measurements from anatomical landmark to measurement site ¹⁷
- Transducer placement mapped in 3-dimensional space using a surgical precision tracking arm ³⁸
- Pressure garments removed 10 minutes before measurement ²⁸
- Pressure garments removed 15 minutes before measurement to regain original (uncompressed) scar thickness or to reduce blanching effects on measurement ^{20,40}
- Pressure garments/gels/moisturisers removed 20 minutes before measurement ^{8,22,29}
- Pressure garments removed 30 minutes before measurement ^{12,25,26,39}
- Sequential measurement of scars following direct treatment with vacuum massage at 5, 30, 60 and 120 minutes to monitor effect of treatment ²⁴
- Patients rested for minimum 5 minutes before measurement ^{5,18,22}
- Scar exposed to room conditions for 10 minutes ²⁹ to allow equilibrium to be reached with surrounding environment ⁴¹
- Patients resting in room with constant temperature for 15 mins ⁴² to allow scar to stabilise ⁴⁴

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4				- Patients rested for 20 minutes prior to measurement ^{29,45}
5				- Patients resting for 10 minutes before repeated measurements taken ⁴³
6				- Patients wait in testing room holding position for 5 min before measurement to stabilise cutaneous blood flow ⁵
7				- Patients allowed to adapt in controlled room to exclude external variables ⁴⁶
8				- Patients remained supine for at least 5 minutes before measurement to avoid artefacts on Doppler imaging ¹³
9				- Patients allowed to acclimatise to room and assumed a supine position for a minimum of 10 minutes before measurements of biophysical parameters ¹¹
10				- Measurement of epidermal, dermal and combined epidermal and dermal thickness to allow comparison with histological measurement ^{47,48}
11				- Measurement of the epidermal and dermal thickness ^{45,49} , combined with layer acoustic density ⁷
12				- Measurement of the epidermal, dermal and subcutaneous thickness, combined with acoustic density ^{50,51}
13				- Measurement of dermal thickness as treatment thought to affect/target the dermis ^{24,37,52-54}
14				- Combined epidermal and dermal thickness measurement to provide information on the full thickness of the scar
15				5,6,8,11,12,15,17,18,22,23,26,28,35,40,55-68
16		Maintaining patient position before measurement	11,13	
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22	Measuring different skin layers	Measuring epidermis and/or dermis individually	7,24,37,45,47-54	
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36		Measuring both epidermis/dermis combined (no	5,6,8,11,12,15,17,18,22,23,26,28,35,40,55-68	
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1				
2				
3		individual		
4		measurement)		
5	Measurement	Measuring	8,10,11,13,14,16,17,24,25,29-32,34,36,37,45,54,58,60,61,63,64,69-82	- Measurement of fibrosis or collagen
6	objective	fibrosis/oedema/hair		architecture ^{8,11,17,24,29-32,34,36,37,45,54,58,61,63,64,69,70,72-}
7		follicles		74,77-79,82
8				- Measurement of inflammation/oedema ¹⁴
9				- Quantification of the sub epidermal low
10				echogenic band, indicating oedema ⁶⁰
11				- Measurement of both fibrosis and oedema
12				10,13,16,25,58,71,75,76,80,81
13				- Measurement of the presence and density of
14				hair follicles to differentiate scarred and
15				unscarred skin ⁵⁴
16	Factors	Measuring contralateral	9,14,15,23,29,30,52,55-58,83-88	- Measurement of additional, non-scarred
17	influencing scar	skin/control scar	6,8,12,18,22,25,38,43,54,59-61,66,89,90	subjects ^{55,79}
18	site		39,40,45,79,81,82	- Measurement of unscarred/unaffected skin on
19	measurement			same subject as scar measurement contralaterally
20				or at anatomically similar location to provide
21				normative measurements for skin thickness
22				6,8,9,12,14,15,18,22,23,29,30,38-40,43,45,52,54,56-61,66,81,85-90
23				- Measurement of both untreated scar and
24				unaffected skin ⁸²⁻⁸⁴
25				- Measurement of a control scar subjected to care
26				as usual treatment on the same individual ²⁵
27				
28		Measuring open	6	- Use of flexible transparent plastic wrap placed
29		wounds or sores in the		over the measurement area to prevent contact
30		scar		between ultrasound gel and transducer with the
31				open wound/sore ⁶
32		Operator training	6,8,12,14,16,18,20,24,27-29,31,39,40,58,61,66,72,73,87,91-93	- Trained outcome assessor ^{6,13,16,18,27,72}
33		and/or experience		- Measurements taken by radiologist/sonographer
34				28,66,73,92
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Number of

measurements per scar

5,6,8,9,11,12,20,23,25,26,31,34,37,40,44,45,47,52,54,57,60,61,66,68,79,85,92,94

- Assessors with burn experience ^{87,93}
- Ultrasound located in department of radiology ⁹¹
- Measurements conducted by trained therapist/doctor under guidance of experienced radiologist ^{12,14,29,39}
- Measurements conducted by trained clinicians who use device regularly and received training by company representative of devices ^{8,61}
- Device-specific training provided: 1 week ²⁰; 3 sessions of 3 hours for 3 weeks, plus 10 independent assessments of scars using study protocol ⁴⁰; training provided over 3 months ³¹; physical therapist trained in ultrasound application ²⁴
- 3 ultrasound images taken from each patient ^{9,11,26,31,37,44,45,47,52,54,57,60,79,85}
- Clearest of 3 measurements used ¹²
- 3 measurements in 3 locations across scar used. Individual and average measurements reported ⁴⁰
- Measurements performed in duplicate ^{34,94}
- Measurements taken at different points of the scar, thickest used for analysis ⁹²
- 5 measurements of each site ^{6,23}
- 9 measurements taken, removal of maximum and minimum, 7 measurements used for average ²⁰
- Measurements taken by 3 assessors at 3 different time points during day ^{8,61}
- Measurement of 2 sites on the same scar ²⁵
- Single ultrasound image taken for analysis ⁶⁸

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<p>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46</p>	<p>Use of additional measurement tools as well as ultrasound measurements</p>	<p>Using additional objective assessment instruments (e.g., histology, colour Doppler ultrasound, cutometer, colourimeter)</p>	<p>6,9-11,13,15,17,18,21-23,25-27,29,31,32,35,36,40-48,50,53,56-59,66,68-70,75- 80,82-84,86-92,95-111</p>	<p>- Histology/immunohistochemistry 13,17,47,48,50,58,78,79,88,100,103,108,110</p> <p>- Blood flow and blood perfusion measurement using laser Doppler perfusion imaging, flowmetry or PeriCam, and scar colour and micro-vessel percentage using dermoscopy colour and micro-vessel percentage. 35,69,70,83,84,86,87,92,99,101,108</p> <p>- Oximeter⁴¹</p> <p>- Infra-red camera⁴¹</p> <p>- Measurement of scar stiffness or pliability/elasticity using elastography or cutometer^{9,15,18,21,22,25-27,29,43,46,53,57,66,82- 84,86,89,90,96,98,99,101,104-106}</p> <p>- Measurement of sensation using Semmes- Weinstein filaments^{82-84,86}</p> <p>- Measurement of scar colour (including pigmentation and erythema) using spectrophotometer, colourimeter, chromameter, mexameter or Dermlite Foto IPro^{18,22,25- 27,32,42,44-46,53,56,66,68,80,82,87,90,91,96-99,101-107,111}</p> <p>- Measurement of trans-epidermal water loss using Tewameter or scar hydration using Corneometer^{46,53,96,99}</p> <p>- Measurement of sebum level using sebumeter 96,99</p> <p>- Measurement of hardness using durometer⁹¹</p> <p>- Measurement of neovascularisation using echocontrastography⁵⁸</p> <p>- Measurement of scar dimensions (e.g., scar height and volume) using 3D camera, 3D imaging methods, ruler or calliper^{6,10,11,23,36,75,77}</p>
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Using subjective
assessment instruments
(e.g., clinical rating
scales, PROMs)

19,20,23,28-30,33,37,40,41,44,45,49,52,56,57,61,66,67,69-72,80-
84,86,87,91,92,94-98,100,111-115

- Measurement of skin thickness using
micrometer or optical coherence tomography
17,31,59,76,108-110

- Measurement of scar firmness or deformation
using cicatrometer, force/torque sensor (in line
with ultrasound to measure load applied) or
torque meter ^{31,32,107}

- Multi-parameter skin analysis device ⁶⁶

- Measurement of erythema and elasticity using
probes of DermaLab Combo ⁴⁰

- Multi-probe adaptor taking multiple
measurements (pigmentation, erythema, trans-
epidermal water loss) ⁹⁶

PROMs:

- Measurement of scar quality using POSAS
patient report <sup>8,23,30,33,45,56,61,63,64,66,75-
77,82,86,95,97,106,107,114,115</sup>

- Subjective rating scales for scar symptoms
(e.g., pain, itch) or subjective scar severity
ratings ^{26,30,41,42,53,63,64,72,80,83,84,93,102,103,111,115}

- Patient quality of life questionnaires ^{75,76,101,107}

- Measurement of generic health-related quality
of life using CHU-9D ^{63,64}

- Measurement of scar-specific health-related
quality of life using BBSIP ^{63,64}

- subjective evaluation of response to
treatment/treatment satisfaction ^{81,116}

Clinical rating scales:

- Measurement of scar quality using POSAS
observer report <sup>8,23,30,33,45,53,56,61,63,64,66,75-
77,82,86,87,97,98,106,114-116</sup>

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Determining the order
of measurement ⁶

- Measurement of physical scar characteristics using VSS or modified versions of the VSS ^{8,18-20,28,30,33,35,37,38,40,42-44,49,56,57,61,65,66,69-72,80-86,92-95,100-103,111-113,115,117,118}
- Measurement of scar characteristics in relation to unscarred skin using Seattle Scar Scale or modified Seattle Scar Scale ⁷³
- Subjective rating scales for scar symptoms (e.g., pain, itch) as assessed by the clinician and/or researcher and/or clinical evaluation of scar severity ^{11,29,41,52,57,67,73,91,92,94,96}
- Standardised order of measurement: 3D photograph, POSAS-O, then ultrasound ⁶
- Order of device use not specified ^{35,69,70,83,84,86,87,92,99,101,108}

Abbreviations: TUPS: Tissue Ultrasound Palpation System; 3D: three-dimensional; POSAS: Patient and Observer Scar Assessment Scale; CHU-9D: Child Health Utility 9D; BBSIP: Brisbane Burn Scar Impact Profile; VSS: Vancouver Scar Scale; mVSS: Modified Vancouver Scar Scale; POSAS-O: Patient and Observer Scar Assessment Scale, observer measure

Supplement References:

1. Mokkink LB, Boers M, van der Vleuten CPM, et al. COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020;20(1):1-13. doi:10.1186/s12874-020-01179-5
2. Prinsen CAC, Vohra S, Rose MR, et al. How to select outcome measurement instruments for outcomes included in a "Core Outcome Set" - a practical guideline. *Trials*. 2016;17:urn:issn:1745-6215.
3. Proctor E, Proctor E, Silmere H, et al. Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. *Adm Policy Ment Health*. 2011;38(2):65-76. doi:10.1007/s10488-010-0319-7
4. Australian Government Department of Health and Aged Care Medical Research Future Fund. Research Translation. Accessed 29/05/2023, <https://www.health.gov.au/our-work/medical-research-future-fund/mrff-research-themes/research-translation#what-is-the-research-pipeline>
5. Van den Kerckhove E, Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated measurements on post-burn scars with Dermascan C. *Skin Res Technol*. 2003;9(1):81-84. doi:10.1034/j.1600-0846.2003.00375.x
6. Simons M, Kee EG, Kimble R, Tyack Z. Ultrasound is a reproducible and valid tool for measuring scar height in children with burn scars: A cross-sectional study of the psychometric properties and utility of the ultrasound and 3D camera. *Burns*. 2017;43(5):993-1001. doi:10.1016/j.burns.2017.01.034
7. Anthonissen M, Meirte J, Moortgat P, et al. Intrarater and interrater reliability of an open 22MHz ultrasound scanning system to assess thickness and density of burn scars. *Ann Burns Fire Disasters*. 2015;28(Supplement EBA)
8. Lee KC, Bamford A, Gardiner F, et al. Investigating the intra- and inter-rater reliability of a panel of subjective and objective burn scar measurement tools. *Burns*. 2019;45(6):1311-1324. doi:10.1016/j.burns.2019.02.002
9. Guo R, Xiang X, Wang L, Zhu B, Cheng S, Qiu L. Quantitative assessment of keloids using ultrasound shear wave elastography. *Ultrasound Med Biol*. 2020;46(5):1169-1178. doi:10.1016/j.ultrasmedbio.2020.01.010
10. Schwaiger H, Reinholz M, Poetschke J, Ruzicka T, Gauglitz G. Evaluating the therapeutic success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive objective measures. *Dermatol Surg*. 2018;44(5):635-644. doi:10.1097/DSS.0000000000001427
11. Timar-Banu O, Beauregard H, Tousignant J, et al. Development of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scars in humans. *Wound Repair Regen*. 2001;9(2):123-132. doi:10.1046/j.1524-475x.2001.00123.x
12. Wang X-Q, Mill J, Kravchuk O, Kimble RM. Ultrasound assessed thickness of burn scars in association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns*. 2010;36(8):1254-1262. doi:10.1016/j.burns.2010.05.018
13. Niessen FB, Spauwen PHM, Robinson PH, Fidler, Kon M. The use of silicone occlusive sheeting (Sil-K) and silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation. *Plast Reconstr Surg*. 1998;102(6):1962-1972. doi:10.1097/00006534-199811000-00023
14. Huang P-W, Lu C-W, Chu K-T, Ho M-T. Assessing thickness of burn scars through ultrasound measurement for patients with arm burns. *J Med Biol Eng*. 2021;41(1):84-91. doi:10.1007/s40846-020-00592-x
15. Huang S-Y, Xiang X, Guo R-Q, Cheng S, Wang L-Y, Qiu L. Quantitative assessment of treatment efficacy in keloids using high-frequency ultrasound and shear wave elastography: a preliminary study. *Sci Rep*. 2020;10(1):1375-1375. doi:10.1038/s41598-020-58209-x
16. Kemp Bohan PM, Cooper LE, Lu KN, et al. Fractionated ablative carbon dioxide laser therapy decreases ultrasound thickness of hypertrophic burn scar: A prospective process improvement initiative. *Ann Plast Surg*. 2020;86(3):273-278. doi:10.1097/SAP.0000000000002517

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17. Ud-Din S, Foden P, Stocking K, et al. Objective assessment of dermal fibrosis in cutaneous scarring, using optical coherence tomography, high-frequency ultrasound and immunohistomorphometry of human skin. *Br J Dermatol*. 2019;181(4):722-732. doi:10.1111/bjd.17739
18. Nedelec B, Correa JA, Rachelska G, Armour A, Lasalle L. Quantitative measurement of hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res*. 2008;29(3):501-511. doi:10.1097/BCR.0b013e3181710881
19. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and hypertrophic scar assessment. *Lasers Med Sci*. 2019;35(2):379-385. doi:10.1007/s10103-019-02830-4
20. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS) in objective scar evaluation. *Burns*. 2005;31(4):445-452. doi:10.1016/j.burns.2004.07.016
21. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res*. 2011;32:S167-S167.
22. Nedelec B, Correa JA, de Oliveira A, LaSalle L, Perrault I. Longitudinal burn scar quantification. *Burns*. 2014;40(8):1504-1512. doi:10.1016/j.burns.2014.03.002
23. Gee Kee EL, Kimble RM, Cuttle L, Stockton KA. Scar outcome of children with partial thickness burns: A 3 and 6 month follow up. *Burns*. 2016;42(1):97-103. doi:10.1016/j.burns.2015.06.019
24. Meirte J, Moortgat P, Anthonissen M, et al. Short-term effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an experimental study. *Burns Trauma*. 2016;4:27-27. doi:10.1186/s41038-016-0052-x
25. Nedelec B, Couture M-A, Calva V, et al. Randomized controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns*. 2019;45(1):128-139. doi:10.1016/j.burns.2018.08.018
26. Nedelec B, LaSalle L, de Oliveira A, Correa JA. Within-patient, single-blinded, randomized controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res*. 2020;41(4):761-769. doi:10.1093/jbcr/iraa057
27. Chan HH, Wong DSY, Ho WS, Lam LK, Wei W. The use of pulsed dye laser for the prevention and treatment of hypertrophic scars in Chinese persons. *Dermatol Surg*. 2004;30(7):987-994. doi:10.1111/j.1524-4725.2004.30303.x
28. Cheng W, Saing H, Zhou H, Han Y, Peh W, Tam PKH. Ultrasound assessment of scald scars in Asian children receiving pressure garment therapy. *J Pediatr Surg*. 2001;36(3):466-469. doi:10.1053/jpsu.2001.21613
29. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of postburn hypertrophic scar: A preliminary study. *Burns*. 1997;23(1):S12-S18. doi:10.1016/S0305-4179(96)00095-2
30. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective short-term outcome analysis of a prospective treatment cohort. *Burns*. 2017;43(3):573-582. doi:10.1016/j.burns.2016.09.014
31. Li JQ, Li-Tsang CWP, Huang YP, Chen Y, Zheng YP. Detection of changes of scar thickness under mechanical loading using ultrasonic measurement. *Burns*. 2012;39(1):89-97. doi:10.1016/j.burns.2012.05.009
32. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and subjective outcomes. *Ann Surg*. 2021;274(6):E574-E580. doi:10.1097/SLA.0000000000003576
33. Issler-Fisher AC, Fisher OM, Haertsch PA, Li Z, Maitz PKM. Effectiveness and safety of ablative fractional CO2 laser for the treatment of burn scars: A case-control study. *Burns*. 2021;47(4):785-795. doi:10.1016/j.burns.2020.10.002

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34. Dunkin CSJ, Pleat JM, Gillespie PH, Tyler MPH, Roberts AHN, McGrouther DA. Scarring occurs at a critical depth of skin injury: Precise measurement in a graduated dermal scratch in human volunteers. *Plast Reconstr Surg*. 2007;119(6):1722-1732. doi:10.1097/01.prs.0000258829.07399.f0
35. Li N, Yang L, Cheng J, et al. A retrospective study to identify the optimal parameters for pulsed dye laser in the treatment of hypertrophic burn scars in Chinese children with Fitzpatrick skin types III and IV. *Lasers Med Sci*. 2021;36(8):1671-1679. doi:10.1007/s10103-021-03252-x
36. van der Veer WM, Ferreira JA, de Jong EH, Molema G, Niessen FB. Perioperative conditions affect long-term hypertrophic scar formation. *Ann Plast Surg*. 2010;65(3):321-325. doi:10.1097/SAP.0b013e3181c60f88
37. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized controlled trial. *PLoS One*. 2021;16(3):e0248799. doi:10.1371/journal.pone.0248799
38. Wood FM, Currie K, Backman B, Cena B. Current difficulties and the possible future directions in scar assessment. *Burns*. 1996;22(6):455-458. doi:10.1016/0305-4179(95)00168-9
39. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on third-degree burns through ultrasonic measurement. *J Cytol Histol*. 2017;8(5)doi:10.4172/2157-7099.1000488
40. Gankande TU, Duke JM, Danielsen PL, DeJong HM, Wood FM, Wallace HJ. Reliability of scar assessments performed with an integrated skin testing device – The DermaLab Combo. *Burns*. 2014;40(8):1521-1529. doi:10.1016/j.burns.2014.01.025
41. Berry RB, Tan OT, Cooke ED, et al. Transcutaneous oxygen tension as an index of maturity in hypertrophic scars treated by compression. *Br J Plast Surg*. 1985;38(2):163-173. doi:10.1016/0007-1226(85)90045-1
42. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its characteristics among the Chinese population. *Burns*. 2005;31(5):610-616. doi:10.1016/j.burns.2005.01.022
43. Lee SY, Cho YS, Kim L, Joo SY, Seo CH. The Intra-rater reliability and validity of ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns*. 2022;doi:10.1016/j.burns.2022.03.016
44. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic scar in a Chinese population. *Burns*. 2010;36(8):1234-1241. doi:10.1016/j.burns.2010.05.008
45. Deng H, Tan T, Luo G, Tan J, Li-Tsang CWP. Vascularity and thickness changes in immature hypertrophic scars treated with a pulsed dye laser. *Lasers Surg Med*. 2021;53(7):914-921. doi:10.1002/lsm.23366
46. Yim H, Cho YS, Seo CH, et al. The use of AlloDerm on major burn patients: AlloDerm prevents post-burn joint contracture. *Burns*. 2009;36(3):322-328. doi:10.1016/j.burns.2009.10.018
47. Agabalyan NA, Su S, Sinha S, Gabriel V. Comparison between high-frequency ultrasonography and histological assessment reveals weak correlation for measurements of scar tissue thickness. *Burns*. 2016;43(3):531-538. doi:10.1016/j.burns.2016.09.008
48. Agabalyan NA, Su S, Sinha V, Gabriel V. Evaluating high frequency ultrasonography for the non-invasive measurement of human scarring. *J Burn Care Res*. 2016;37(Supplement 183)
49. Bajouri A, Kajoor AS, Fallah N, et al. Autologous human stromal vascular fraction injection in post-burn hypertrophic scar: A double-blinded placebo-controlled clinical trial. *Bioimpacts*. 2018;8:37-38.
50. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and diagnostics. *J Dermatol Nurses Assoc*. 2020;12(2)
51. Bezugly A, Potekae N. In vivo skin morphology monitoring of patients with acne, scars and dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol*. 2014;41:4.
52. Cai L, Hu M, Lin L, Zheng T, Liu J, Li Z. Evaluation of the efficacy of triamcinolone acetonide in the treatment of keloids by high-frequency ultrasound. *Skin Res Technol*. 2020;26(4):489-493. doi:10.1111/srt.12820

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 53. Moortgat P, Vanhullebusch T, Anthonissen M, et al. Tension reducing taping as a
4 mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot study. *Wound Repair*
5 *Regen.* 2020;28(2):A21.
6
7 54. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal
8 tissue thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res.*
9 2020;41(2):421-426. doi:10.1093/jbcr/irz191
10
11 55. Avetikov DS, Bukhanchenko OP, Skikevich MG, Aipert VV, Boyko IV. Features of ultrasound
12 diagnostics of postoperative hypertrophic and keloid scars. *The New Armenian Medical Journal.*
13 2018;12(4):43-48.
14
15 56. Chae JK, Kim JH, Kim EJ, Park K. Values of a patient and observer scar assessment scale to
16 evaluate the facial skin graft scar. *Ann Dermatol.* 2016;28(5):615-623. doi:10.5021/ad.2016.28.5.615
17
18 57. Danin A, Georgesco G, Le Touze A, Penaud A, Quignon R, Zakine G. Assessment of burned
19 hands reconstructed with Integra® by ultrasonography and elastometry. *Burns.* 2012;38(7):998-
20 1004. doi:10.1016/j.burns.2012.02.017
21
22 58. Fraccalvieri M, Zingarelli E, Ruka E, et al. Negative pressure wound therapy using gauze and
23 foam: histological, immunohistochemical and ultrasonography morphological analysis of the
24 granulation tissue and scar tissue. Preliminary report of a clinical study. *Int Wound J.* 2011;8(4):355-
25 364. doi:10.1111/j.1742-481X.2011.00798.x
26
27 59. Katz SM, Frank DH, Leopold GR, Wachtel TL. Objective measurement of hypertrophic burn
28 scar: A preliminary study of tonometry and ultrasonography. *Ann Plast Surg.* 1985;14(2):121-127.
29 doi:10.1097/0000637-198502000-00005
30
31 60. Kim JD, Oh SJ, Kim SG, et al. Ultrasonographic findings of re-epithelialized skin after partial-
32 thickness burns. *Burns Trauma.* 2018;6(1):21-21. doi:10.1186/s41038-018-0122-3
33
34 61. Lee KC, Bamford A, Gardiner F, et al. Burns objective scar scale (BOSS): Validation of an
35 objective measurement devices based burn scar scale panel. *Burns.* 2020;46(1):110-120.
36 doi:10.1016/j.burns.2019.05.008
37
38 62. Nicoletti G, Brenta F, Blevé M, et al. Long-term in vivo assessment of bioengineered skin
39 substitutes: a clinical study. *J Tissue Eng Regen Med.* 2015;9(4):460-468. doi:10.1002/term.1939
40
41 63. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical
42 silicone gel and pressure garment therapy for burn scar prevention and management in children 12-
43 months postburn: A parallel group randomised controlled trial. *Clin Rehabil.* 2021;35(8):1126-1141.
44 doi:10.1177/02692155211020351
45
46 64. Wiseman J, Ware RS, Simons M, et al. Effectiveness of topical silicone gel and pressure
47 garment therapy for burn scar prevention and management in children: a randomized controlled
48 trial. *Clin Rehabil.* 2020;34(1):120-131. doi:10.1177/0269215519877516
49
50 65. Żądkowski T, Nachulewicz P, Mazgaj M, et al. A new CO2 laser technique for the treatment
51 of pediatric hypertrophic burn scars: An observational study. *Medicine (Baltimore).*
52 2016;95(42):e5168-e5168. doi:10.1097/MD.00000000000005168
53
54 66. Zuccaro J, Kelly C, Perez M, Doria A, Fish JS. The effectiveness of laser therapy for
55 hypertrophic burn scars in pediatric patients: A prospective investigation. *J Burn Care Res.*
56 2021;42(5):847-856. doi:10.1093/jbcr/irab090
57
58 67. Lacarrubba F, Patania L, Perrotta R, Stracuzzi G, Nasca MR, Micali G. An open-label pilot
59 study to evaluate the efficacy and tolerability of a silicone gel in the treatment of hypertrophic scars
60 using clinical and ultrasound assessments. *J Dermatolog Treat.* 2008;19(1):50-53.
doi:10.1080/09546630701387009
61
62 68. Van den Kerckhove E, Stappaerts K, Fieuws S, et al. The assessment of erythema and
63 thickness on burn related scars during pressure garment therapy as a preventive measure for
64 hypertrophic scarring. *Burns.* 2005;31(6):696-702. doi:10.1016/j.burns.2005.04.014
65
66 69. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers*
67 *Med Sci.* 2017;33(3):497-501. doi:10.1007/s10103-017-2387-3

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 70. Alsharnoubi J, Shoukry KE-S, Fawzy MW, Mohamed O. Evaluation of scars in children after
4 treatment with low-level laser. *Lasers Med Sci*. 2018;33(9):1991-1995. doi:10.1007/s10103-018-
5 2572-z
- 6 71. Fabbrocini G, Marasca C, Ammad S, et al. Assessment of the combined efficacy of needling
7 and the use of silicone gel in the treatment of C-section and other surgical hypertrophic scars and
8 keloids. *Adv Skin Wound Care*. 2016;29(9):408-411. doi:10.1097/01.ASW.0000490028.37994.14
- 9 72. Joo SY, Lee SY, Cho YS, Seo CH. Clinical utility of extracorporeal shock wave therapy on
10 hypertrophic scars of the hand caused by burn injury: A prospective, randomized, double-blinded
11 study. *J Clin Med*. 2020;9(5):1376. doi:10.3390/jcm9051376
- 12 73. Lobos N, Wortsman X, Valenzuela F, Alonso F. Color Doppler ultrasound assessment of
13 activity in keloids. *Dermatol Surg*. 2017;43(6):817-825. doi:10.1097/DSS.0000000000001052
- 14 74. Mamdouh M, Omar GA, Hafiz HSA, Ali SM. Role of vitamin D in treatment of keloid. *J Cosmet*
15 *Dermatol*. 2022;21(1):331-336. doi:10.1111/jocd.14070
- 16 75. Reinholz M, Guertler A, Schwaiger H, Poetschke J, Gauglitz GG. Treatment of keloids using 5-
17 fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating
18 therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol*.
19 2020;34(10):2436-2444. doi:10.1111/jdv.16354
- 20 76. Reinholz M, Schwaiger H, Poetschke J, et al. Objective and subjective treatment evaluation
21 of scars using optical coherence tomography, sonography, photography, and standardised
22 questionnaires. *Eur J Dermatol*. 2017;26(6):599-608. doi:10.1684/ejd.2016.2873
- 23 77. Soykan EA, Butzelaar L, de Kroon TL, et al. Minimal extracorporeal circulation (MECC) does
24 not result in less hypertrophic scar formation as compared to conventional extracorporeal
25 circulation (CECC) with dexamethasone. *Perfusion*. 2014;29(3):249-259.
26 doi:10.1177/0267659113511656
- 27 78. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix.
28 *Burns*. 2008;35(3):352-355. doi:10.1016/j.burns.2008.06.021
- 29 79. Zhidong X, Haixia L, Chao L, Yongrong L. Wavelet Bilateral Filter Algorithm-Based High-
30 Frequency Ultrasound Image Analysis on Effects of Skin Scar Repair. *Scientific programming*.
31 2021;2021doi:10.1155/2021/9573474
- 32 80. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone
33 gel dressing and pressure therapy on posttraumatic hypertrophic scars. *J Burn Care Res*.
34 2010;31(3):448-457. doi:10.1097/BCR.0b013e3181db52a7
- 35 81. Li N, Yang L, Cheng J, Han J, Hu D. Early intervention by Z-plasty combined with fractional
36 CO2 laser therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet*
37 *Surg*. 2021;74(11):3087-3093. doi:10.1016/j.bjps.2021.03.079
- 38 82. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of
39 fractional CO2 laser treatment of mature burn scars. *J Burn Care Res*. 2016;37(6):379-387.
40 doi:10.1097/BCR.0000000000000383
- 41 83. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
42 scarring. *Lasers Surg Med*. 2012;44:61.
- 43 84. Blome-Eberwein S, Blaine C, Gogal C, Eid S, Foltz C. Fractional Er:Glass photothermolysis
44 laser therapy to treat hypertrophic scarring. *J Burn Care Res*. 2011;32:S95.
- 45 85. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in
46 burn scars using high frequency ultrasound. *J Burn Care Res*. 2012;33(2)(Supplement):S105.
- 47 86. Blome-Eberwein S, Roarabaugh C, Gogal C, Eid S. Exploration of nonsurgical scar
48 modification options: Can the irregular surface of matured mesh graft scars be smoothed with
49 microdermabrasion? *J Burn Care Res*. 2012;33(3):e133-40.
- 50 87. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
51 Construct validity and predictive ability of scar thickness change. *Skin Res Technol*. 2020;26(3):369-
52 375. doi:10.1111/srt.12812
- 53
54
55
56
57
58
59
60

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
- 2
- 3
- 4 88. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, Bassiouny DA, Fawzy MM. Ultrasound biomicroscopy in the diagnosis of skin diseases. *Eur J Dermatol*. 2007;17(6):469-74.
- 5
- 6 89. Zuccaro J, Perez M, Mohanta A, Fish J, Doria A. Elastography-Based Quantification of Burn Scar Stiffness. *J Burn Care Res*. 2019;40(Supplement_1):S215-S215. doi:10.1093/jbcr/irz013.374
- 7
- 8 90. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, et al. Objective quantification of hypertrophic scar and donor scar between 2 to 7 months post-burn injury. *J Burn Care Res*. 2022;43(Supplement 1):S103.
- 9
- 10
- 11 91. Engrav LH, Heimbach DM, Rivara FP, et al. 12-Year within-wound study of the effectiveness of custom pressure garment therapy. *Burns*. 2010;36(7):975-983. doi:10.1016/j.burns.2010.04.014
- 12
- 13 92. Fracalvieri M, Sarno A, Gasperini S, et al. Can single use negative pressure wound therapy be an alternative method to manage keloid scarring? A preliminary report of a clinical and ultrasound/colour-power-doppler study. *Int Wound J*. 2013;10(3):340-344. doi:10.1111/j.1742-481X.2012.00988.x
- 14
- 15
- 16
- 17
- 18 93. Li P, Li-Tsang CWP, Deng X, et al. The recovery of post-burn hypertrophic scar in a monitored pressure therapy intervention programme and the timing of intervention. *Burns*. 2018;44(6):1451-1467. doi:10.1016/j.burns.2018.01.008
- 19
- 20
- 21 94. Chang C-S, Wallace CG, Hsiao Y-C, Chang C-J, Chen PK-T. Botulinum toxin to improve results in cleft lip repair: A double-blinded, randomized, vehicle-controlled clinical trial. *PLoS One*. 2014;9(12):e115690-e115690. doi:10.1371/journal.pone.0115690
- 22
- 23
- 24
- 25 95. Blome-Eberwein S, Pagella P, Boorse D, Gogal C. Treatment of hypertrophic burn scars with different laser modalities. *Lasers Surg Med*. 2014;46:6-7.
- 26
- 27 96. Cho YS, Jeon JH, Hong A, et al. The effect of burn rehabilitation massage therapy on hypertrophic scar after burn: A randomized controlled trial. *Burns*. 2014;40(8):1513-1520. doi:10.1016/j.burns.2014.02.005
- 28
- 29
- 30 97. Cooper LE, Bohan PK, Hatem VD, Carlsson AH, Cancio LC, Chan RK. Analysis of the utility of CO2 and pulse-dye lasers in the treatment of hypertrophic burn scars. *J Burn Care Res*. 2021;42(Supplement_1):S28-S29. doi:10.1093/jbcr/irab032.041
- 31
- 32
- 33 98. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes of burn scars treated with laser therapy. *J Burn Care Res*. 2016;37(Supplement):S106.
- 34
- 35
- 36 99. Jang KU, Lee JY, Choi JS, Seo CH. 5 FU and triamcinolone injection to the hypertrophic scar were compared. *Burns*. 2009;35:S41-S42. doi:10.1016/j.burns.2009.06.166
- 37
- 38 100. Kim SK, Park JM, Jang YH, Son YH. Management of hypertrophic scar after burn wound using microneedling procedure (dermastamp). *Burns*. 2009;35:S37-S37. doi:10.1016/j.burns.2009.06.146
- 39
- 40 101. Li K, Nicoli F, Cui C, et al. Treatment of hypertrophic scars and keloids using an intralesional 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive technique. *Sci Rep*. 2020;10(1):21694-21694. doi:10.1038/s41598-020-78738-9
- 41
- 42
- 43 102. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-monitored suit in the management of post-burn hypertrophic scar: A clinical controlled study with objective assessment. *J Burn Care Res*. 2016;37(Supplement):S199.
- 44
- 45
- 46 103. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and related research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns)*. 2010;26(6):411-5.
- 47
- 48 104. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult burn patients. *J Am Acad Dermatol*. 2017;76(6):AB212-AB212. doi:10.1016/j.jaad.2017.04.1113
- 49
- 50
- 51 105. Nedelec B, Couture M, Calva V, et al. Randomized controlled trial of the immediate and long-term effect of massage on adult postburn scar. *J Burn Care Res*. 2018;39(suppl_1):S57-S57. doi:10.1093/jbcr/iry006.106
- 52
- 53
- 54
- 55 106. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report. *Wound Repair Regen*. 2018;26(2):A28-A28.
- 56
- 57
- 58
- 59
- 60

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 107. Siwy KG, Lee K, Donelan MB, Anderson RR, Miletta NR. Fractionated CO2 laser and burn scar
4 contractures: Evaluation of post treatment scar function and appearance. *J Burn Care Res.*
5 2016;37:S202-S202.
6
7 108. Ud-Din S, Foden P, Douglas M, et al. A double-blind randomized controlled trial
8 demonstrates for the first time evidence for the role of topical epigallocatechin-3-gallate in reducing
9 angiogenesis, inflammation, and skin thickness in human skin scarring: A noninvasive, morphological
10 and immu. *Wound Repair and Regeneration.* 2017;25(4):A3.
11 109. Ud-Din S, Foden P, Mazhari M, Al-Habba S, Baguneid M, Bayat A. Histomorphologic assessment
12 of noninvasive quantitative imaging in progression of cutaneous healing in human skin: Dynamic
13 optical coherence tomography versus high frequency ultrasound. *Wound Repair Regen.*
14 2017;25(4):A3-A4.
15 110. Ud-Din S, Foden P, M M, Samer A, Baguneid M, Bayat A. Quantitative index for skin fibrosis:
16 Combined optical coherence tomography with ultrasound validated by histology and
17 immunohistochemistry. *Wound Repair Regen.* 2018;26(4):A11-A12.
18 111. Li-Tsang CWP, Lau JCM, Choi J, Chan CCC, Jianan L. A prospective randomized clinical trial to
19 investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among
20 the Chinese population. *Burns.* 2006;32(6):678-683. doi:10.1016/j.burns.2006.01.016
21 112. Alshehari A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid
22 injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars. *Archives*
23 *of the Balkan Medical Union.* 2015;50(3):364-366.
24 113. Cho J, Choi J, Hur J, et al. The effect of CO2 fractional laser (pixel®) on hypertrophic burn
25 scars. *J Burn Care Res.* 2012;33(2)(Supplement):S132.
26 114. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn*
27 *Care Res.* 2018;39(suppl_1):S219-S220. doi:10.1093/jbcr/iry006.416
28 115. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with
29 laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration
30 matter? *Lasers Surg Med.* 2020;52(2):149-158. doi:10.1002/lsm.23166
31 116. Ge X, Sun Y, Lin J, Zhou F, Yao G, Su X. Effects of multiple modes of UltraPulse fractional CO2
32 laser treatment on extensive scarring: a retrospective study. *Lasers Med Sci.* 2021;37(3):1575-1582.
33 doi:10.1007/s10103-021-03406-x
34 117. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case
35 review. *J Burn Care Res.* 2011;32(Supplement):S169-S169.
36 118. Tu P, Wang Z-G, Zhang Q-X, You Y-F. High frequency ultrasound in dynamic observation on
37 effect of local injection with diprospan for treating pathological scar. *Chinese Journal of*
38 *Interventional Imaging and Therapy.* 2014;11(4):217-220.
39
40
41
42
43
44
45
46
47
48
49
50
51
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Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	3-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	5-7
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	7
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-10
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	9
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	9
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	10-11
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11 and supplementary table 1
Critical appraisal of individual	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	N/A



SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
sources of evidence§		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10-11
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	11-12
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	12-15
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Results section (11-46)
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Results section (11-46)
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	47-49
Limitations	20	Discuss the limitations of the scoping review process.	49-50
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	50-51
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	51

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



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Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence across the translational pipeline of research-to-practice

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Complete List of Authors:	Meikle, Brandon; Queensland Children's Hospital, Centre for Children's Burns and Trauma Research; The University of Queensland Faculty of Medicine, Children's Health Research Centre Simons, Megan; Queensland Children's Hospital, Occupational Therapy; The University of Queensland, Children's Health Research Centre Mahoney, Tamsin; Metro North Hospital and Health Service, Surgical, Treatment and Rehabilitation Services (STARS) Reddan, Tristan; Children's Health Queensland Hospital and Health Service, Medical Imaging and Nuclear Medicine; Queensland University of Technology, School of Clinical Sciences, Faculty of Health Dai, Bryan; The University of Queensland Kimble, Roy; Children's Health Queensland Hospital and Health Service, Pegg Leditschke Children's Burns Centre; The University of Queensland, Faculty of Medicine Tyack, Zephaniah; The University of Queensland, Children's Health Research Centre, Faculty of Medicine; Queensland University of Technology, Australian Centre for Health Service Innovation (AusHI), Centre for Healthcare Transformation, and School of Public Health and Social Work
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3 Ultrasound measurement of traumatic scar and skin thickness: A scoping review of evidence
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5 across the translational pipeline of research-to-practice*
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8 **Running Title:** Review of scar thickness measurement with ultrasound
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14 Brandon Meikle^{1,2**}, Megan Simons^{2,3,7}, Tamsin Mahoney⁴, Tristan Reddan^{5,6}, Bryan Dai²,
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16 Roy M Kimble^{1,2,6,7} and Zephania Tyack^{2,8}
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18
19
20
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22

23 ¹ Centre for Children's Burns and Trauma Research, Queensland Children's Hospital,
24 Brisbane, Queensland, Australia
25
26
27

28 ² Children's Health Research Centre, Faculty of Medicine, The University of Queensland,
29 Herston, Queensland, Australia
30
31
32

33 ³ Occupational Therapy Department, Queensland Children's Hospital, Children's Health
34 Queensland Hospital and Health Service, Brisbane, Queensland, Australia
35
36
37

38 ⁴ Surgical, Treatment and Rehabilitation Services (STARS), Metro North Hospital and Health
39 Service, Brisbane, Queensland, Australia
40
41
42

43 ⁵ Medical Imaging and Nuclear Medicine, Queensland Children's Hospital and Health
44 Service, Brisbane, Queensland, Australia
45
46
47

48 ⁶ School of Clinical Sciences, Faculty of Health, Queensland University of Technology,
49 Brisbane, Queensland, Australia
50
51
52

53 ⁷ Pegg Leditschke Children's Burns Centre, Queensland Children's Hospital, Children's
54 Health Queensland Hospital and Health Service, Brisbane, Queensland, Australia
55
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57
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2
3 ⁸ Australian Centre for Health Service Innovation (AusHI), Centre for Healthcare
4
5 Transformation, and School of Public Health and Social Work, Queensland University of
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7 Technology, Brisbane, Queensland, Australia
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10
11 ** Corresponding author
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13
14 E-mail: brandon.meikle@uq.net.au (BM)
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22 (ANZBA) 2022 Annual Scientific Meeting, the 2022 Centre for Children's Health Research
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24 Symposium, Child Health Research Centre, The University of Queensland, and the 2023
25
26 British Burn Association Annual Conference.
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ABSTRACT:

Objectives: To identify the ultrasound methods used in the literature to measure traumatic scar thickness, and map gaps in the translation of these methods using evidence across the research-to-practice pipeline.

Design: Scoping review

Data Sources: Electronic database searches of Ovid MEDLINE, Embase, Cumulative Index of Nursing and Allied Health Literature (CINAHL) and Web of Science. Grey literature searches were conducted in Google. Searches were conducted from inception (date last searched 27/05/2022).

Data Extraction: Records using B-mode ultrasound to measure scar and skin thickness across the research-to-practice pipeline of evidence were included. Data was extracted from included records pertaining to: methods used; reliability and measurement error; clinical, health service, implementation and feasibility outcomes; factors influencing measurement methods; strengths and limitations; and use of measurement guidelines and/or frameworks.

Results: Of the 9309 records identified, 118 were analysed (n = 82 articles, n = 36 abstracts) encompassing 5213 participants. Reporting of methods used was poor. B-mode, including high-frequency (i.e., > 20 MHz) ultrasound was the most common type of ultrasound used (n = 72 records; 61% of records), and measurement of the combined epidermal and dermal thickness (n = 28; 24%) was more commonly measured than the epidermis or dermis alone (n = 7, 6%). Reliability of ultrasound measurement was poorly reported (n=14; 12%). The scar characteristics most commonly reported to be measured were epidermal oedema, dermal fibrosis and hair follicle density. Most records analysed (n = 115; 97%) pertained to the early stages of the research-to-practice pipeline, as part of research initiatives.

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3 **Conclusions:** The lack of evaluation of measurement initiatives in routine clinical practice
4 was identified as an evidence gap. Diverse methods used in the literature identified the need
5 for greater standardisation of ultrasound thickness measurements. Findings have been used to
6 develop nine methodological considerations for practitioners to guide methods and reporting.
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13 **STRENGTHS AND LIMITATIONS OF THIS STUDY:**

- 14
15 • Use of the Australian Government Department of Health and Aged Care Medical
16 Research Future Fund research-to-practice pipeline phases to categorise records
17 allowed identification of gaps in the use of ultrasound for clinical practice.
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- 20 • Clinical, health service, implementation and feasibility outcomes related to ultrasound
21 measurement in included records were summarised to determine what is needed to
22 close the research-to-practice gap for ultrasound measurement of scar thickness.
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- 25 • A limitation is that only articles available in English or with an English abstract were
26 considered for inclusion and data extraction, thus findings are likely most relevant to
27 English speaking countries.
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INTRODUCTION:

Traumatic cutaneous injury, caused by sharp object penetration (e.g., surgery or vaccination) or burns (including thermal, chemical and friction) may result in the formation of

hypertrophic scarring. (1) Hypertrophic scars result from an aberrant cutaneous healing response that leads to the formation of red, raised scars, often accompanied by pruritus and skin tightening, which remain within the boundaries of the initial injury. (2-7) The sequelae of hypertrophic scars can impact on patient's physical and psychosocial quality of life. (8, 9)

A characteristic of hypertrophic scarring that both patients and clinicians have identified as being important, and which has subsequently been used as a way to measure clinical and treatment outcomes, is scar thickness. (9-17) Scar thickness can be measured both subjectively, through clinician assessment and patient-reported outcomes, or objectively, utilising medical imaging methods. (18, 19) The pathological complexity of hypertrophic scars means that they generally extend below the level of the surrounding skin, supporting the use of medical imaging modalities such as ultrasound for thickness quantification, as these are capable of providing information about subcutaneous structures and processes. (19, 20) Scar thickness measurement using ultrasound can be conducted in both clinical and research contexts. Where routine measurements like ultrasound are used to guide clinical decision-making and treatment, this practice is known as measurement-based care. (21)

Ultrasound is a safe, non-invasive and largely cost-effective (compared to other imaging modalities) imaging method with measurement utility in both adult and paediatric populations. (22-24) Modern B-mode (brightness mode) ultrasound, particularly high- (i.e., ≥ 20 MHz) or ultra-high frequency (30-100 MHz) (25) ultrasonography, allows differentiation between the epidermis and dermis, which permits quantification of skin layer-specific scar characteristics. This differentiation may allow assessors to observe and understand the pathological mechanisms of individual scars and adjust treatment protocols accordingly. (24,

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3 26-31) Additionally, B-mode ultrasound is commonly used as the basis for other imaging
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5 methods, such as colour Doppler ultrasound or elastography, which can allow quantification
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7 of additional scar characteristics, such as their elastic properties. (26-29, 32, 33)
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11 Despite the clinical advantages of B-mode ultrasound for scar thickness measurement,
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13 methods are poorly reported and lack standardisation in the literature. This casts doubt on the
14
15 validity of clinical decision-making in measurement-based care initiatives (e.g., setting depth
16
17 of AFCO₂ penetration) informed by research findings (e.g., response to treatment) where
18
19 ultrasound measurements are used. (34) Lack of standardisation also makes between-study
20
21 comparison, such as systematic reviews and meta-analyses, difficult, (35) and poor
22
23 methodological reporting hampers the ability to accurately replicate findings. This scoping
24
25 review focusses on mapping and identifying gaps in ultrasound methods and evaluation
26
27 reported in the current literature along the research-to-clinical practice pipeline. (36)
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31 Methodological considerations for people performing ultrasound scar thickness
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33 measurements, including practitioners (herein termed assessors) using ultrasound in clinical
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35 practice are presented based on the review findings.
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39 **METHODS:**

40 41 42 **Protocol Publication and Review Structure:**

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45 The protocol for this review has been published *a priori*. (37) This scoping review was
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47 conducted and is reported according to the Arksey and O'Malley (2005) (38) framework. The
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49 steps outlined in this framework are: 1) identifying the research question; 2) identifying
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51 relevant records; 3) selecting appropriate records; 4) charting extracted data; and 5) collating,
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53 summarising and reporting the results. (38)
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57 **Research Question:**

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3 The primary question of this scoping review was: “What do we know and not know about the
4 measurement of traumatic cutaneous scar thickness using ultrasound?” This question was
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6 measurement of traumatic cutaneous scar thickness using ultrasound?” This question was
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8 addressed through exploration of: methods used; reliability and measurement error; clinical,
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10 health service, implementation and feasibility outcomes; factors influencing ultrasound
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12 imaging and measurement methods; strengths and limitations of measurement methods; and
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14 use of measurement guidelines and/or frameworks. While the focus of this review was the
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16 measurement of traumatic cutaneous scar thickness with ultrasound, methods used to measure
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18 the thickness of unscarred skin were reported where these were used in combination with
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20 measurement of scar thickness (e.g., as control or comparator measurements).
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24 **Identifying Relevant Records:**

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27 A standardised search strategy was developed and piloted with the assistance of a medical
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29 librarian using the concepts ‘ultrasound’, ‘skin’, ‘thickness’ and ‘measure’, with associated
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31 terms and truncations (supplementary box 1). Ovid MEDLINE, Embase, Cumulative Index of
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33 Nursing and Allied Health Literature (CINAHL) and Web of Science electronic databases
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35 were searched from conception to identify original studies (date last searched 27th May
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37 2022).
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42 The phrase ‘ultrasound scar thickness measurement’ was used to conduct additional searches
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44 in 1) Google Scholar, and 2) Google to identify original studies in grey literature, and studies
45
46 not identified in database searches. Title and abstract searches in Google Scholar and Google
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48 were limited to the first 200 results. (39)
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51 **Record Selection:**

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53 Following de-duplication, six reviewers screened records using Covidence (Veritas Health
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55 Innovation, Melbourne, Australia; available at www.covidence.org) for eligibility according
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57 to the inclusion criteria (Table 1). Both peer-reviewed journal articles and abstracts were
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3 included to ensure that all the available and most recent methodological information was
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5 obtained. (40) Data collected from peer-reviewed journal articles was considered the primary
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7 source of data, with information from abstracts used to confirm or extend the journal data.
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10 The inclusion of abstracts will assist future authors to further investigate the information
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12 presented as full texts may become available. During both title and abstract and full text
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14 screening, one researcher (BM) screened all records as a single reviewer, while other
15
16 researchers (MS, TM, TR, BD and ZT) screened records as a second reviewer. Conflicts were
17
18 resolved through discussion between at least two authors to reach agreement. A third author
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20 was used as a tiebreaker where agreement could not be reached.
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25 **Table 1. Inclusion and exclusion criteria for studies included in the scoping review.**

Inclusion	Exclusion
<ul style="list-style-type: none"> • Traumatic scars measured with ultrasound based on B-mode ultrasound (including high-frequency, ultra-high-frequency and Doppler) • Measurements taken of living, human individuals • Measurement of traumatic cutaneous scarring arising from penetration of the skin with sharp objects (including surgery or vaccination), or as a result of burns, (including thermal, chemical or friction) • Articles written in English, or with English abstracts 	<ul style="list-style-type: none"> • Reviews, discussion papers, opinion pieces • Measurement of non-traumatic scars (e.g., acne scars). Where non-traumatic scars measured along with burn scars, these were included • Measurement of skin thickness in non-traumatic conditions (e.g., diabetes) • Measurement of skin thickness where there is no cutaneous involvement in the trauma (e.g., traumatic brain injury) • Measurement using A-mode ultrasound

48 **Charting the Data:**

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51 The data extraction table was developed in Microsoft Excel and piloted by two authors (BM
52
53 and ZT) through independent extraction and comparison of data from two records. The table
54
55 was then modified to include the scar characteristics (e.g., fibrosis, oedema) measured,
56
57 measurer/assessor training, the number of measurements taken and funding sources
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3 (Supplementary Table 1). Full text data extraction was completed by four authors (BM, MS,
4
5 TM and ZT). An additional author (BD) independently extracted data from five randomly
6
7 selected records, which was compared to data extracted by other authors. Minimal differences
8
9 between data extracted by the independent author and that by other authors were observed,
10
11 thus further independent extraction was not performed. As is typical in scoping reviews, the
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13 certainty or quality of evidence was not appraised. (38)
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17 The research-to-practice pipeline published by the Australian Government Department of
18
19 Health and Aged Care Medical Research Future Fund (figure 1) was used to categorise each
20
21 included record based on their stated aims into one of the four phases. (36) Studies related to
22
23 phase 1 of this pipeline, basic research, were only included in this review when data on scar
24
25 or skin thickness pertained to human participants (table 1). Phase 2 of this pipeline included
26
27 randomised controlled trials, while phase 3 included pragmatic and observational studies
28
29 conducted outside randomised controlled trials. The final phase of this pipeline (phase 4)
30
31 indicates initiatives used in routine clinical practice.
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35 Where clinical (e.g., treatment satisfaction, scar symptoms), health service (e.g., efficiency,
36
37 safety, effectiveness, equity, patient-centredness and timeliness) and implementation (e.g.,
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39 acceptability, adoption, appropriateness, fidelity, cost, penetration and sustainability)
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41 outcomes were addressed, they were reported and defined according to Proctor *et al.* (41).
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43 For example, in the context of this scoping review, acceptability is defined as the level to
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45 which ultrasound is palatable amongst stakeholders (e.g., assessors), appropriateness is the
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47 perceived fit of ultrasound within regular clinical practice, and fidelity is the degree to which
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49 ultrasound is used in the way it was initially described. (41) Measurement instrument-specific
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51 feasibility outcomes defined by Prinsen *et al.* (42) are reported in the current review. These
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53 outcomes included ease of administration, standardisation, completion time, instrument cost
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55 and availability, and ease of score calculation. (42) Reliability and measurement error were
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3 defined according to COnsensus-based Standards for the selection of health Measurement
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INstruments (COSMIN) tools. (43, 44) Measurements with an intraclass correlation coefficient (ICC) of 0.7 or greater were considered reliable. (44) Measurement error was assessed by comparing the reported standard error of the measurement (SEM) with the reported smallest detectable change (SDC). Where the reported measurement error was smaller than the reported smallest detectable change, it was interpreted as indicating real change or variance can be detected, and that change or variance is not a result of error. (44)

Patient and Public Involvement

There was no patient and/or public involvement in the design, conduct, reporting or dissemination of information in this scoping review.

RESULTS:

Electronic database searches identified 9309 records. After removal of 3703 duplicate records, the titles and abstracts of 5606 records were screened for relevance according to the inclusion criteria (Table 1). Following full-text screening, 104 records proceeded to data extraction. Searches in Google and Google Scholar identified an additional 14 records, providing a total of 118 records for data extraction. Search and screening results are presented according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram (supplementary figure 1). (45)

Record Characteristics:

Of the 118 records included in this review, 82 were journal articles (69%) and 36 were abstracts (31%) (Table 2), representing a total of 5213 participants (range 1-438; mode 20 participants per record). Adults aged 18 years and older were the most highly represented age group reported in articles (n = 43 articles; 52% of articles), (17, 26, 29, 46-85) while most abstracts did not report the age group measured (n = 25 abstracts; 69% of abstracts). (86-110)

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3 The most common scar type measured was burn scars in both journal articles (n = 43 articles;
4 52% of articles), (17, 22-24, 27, 47, 57-59, 61, 62, 64-67, 71-75, 81, 82, 84, 111-130) and
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7 abstracts (n = 23 abstracts; 64% of abstracts) (28, 30, 86-88, 91-94, 96, 98, 102-106, 131-
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10 135) (Table 2). Most identified articles used ultrasound measurement of scar thickness as part
11
12 of research initiatives, and were categorised as either phase 2 (n = 50 articles; 61% of
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14 articles) (17, 22, 26, 31, 46-49, 51-56, 61, 63-65, 67, 69-71, 74-76, 78, 81, 83, 84, 111, 112,
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17 114, 115, 117, 124-127, 129, 130, 136-145) or phase 3 (n = 30 articles; 37% of articles). (23,
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19 24, 27, 29, 50, 57-60, 62, 66, 68, 72, 73, 77, 79, 80, 82, 85, 116, 118, 120-123, 128, 146-149)
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21 on the research-to-practice pipeline. (36) Phase 2 was also the most common phase
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23 represented by abstracts (n = 21; 58% of abstracts), (86, 88, 91, 93, 95, 97, 99-104, 106-108,
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25 131-134, 150, 151) followed by phase 3 (n = 15 abstracts; 42% of abstracts). (28, 30, 87, 89,
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27 90, 94, 96, 98, 105, 109, 110, 135, 152-154) Phase 4 was addressed by two articles (2% of
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29 articles) (113, 119) and one abstract (2% of abstracts), (92) which used ultrasound to measure
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31 treatment response to an intervention already used in routine clinical practice, including
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33 compression garments (113, 119) and CO₂ fractional laser. (92) No records pertained to
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38 phase 1.
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Table 2. Summary of characteristics of records included in this review*

Characteristic	Category	Number of Records (Translational Pipeline Phase 2*)	Number of Records (Translational Pipeline Phase 3*)	Number of Records (Translational Pipeline Phase 4*)
<i>Journal Articles</i>				
Funding Source	Commercial	2	1	1
	Non-commercial	23	13	0
Population Type	Commercial & Non-commercial	2	1	1
	No funding	6	3	0
	Not reported	16	12	0
	Adult	27	16	0
	Paediatric	6	4	0
	Paediatric and Adult	13	7	2
Scar Aetiology	Not reported	3	3	0
	Burn	22	18	1
	Surgical†	5	2	0
	Mixed	10	3	0
	Not specified	12	7	0
<i>Abstracts</i>				
Funding Source	Commercial	0	0	0
	Non-commercial	3	1	0
	Commercial & Non-commercial	0	0	0
	No funding	0	0	0
	Not reported	17	14	1
Population Type	Adult	1	2	0
	Paediatric	0	3	0
	Paediatric and Adult	4	1	0
	Not reported	15	9	1
Scar Aetiology	Burn	12	10	1
	Surgical†	1	2	0
	Mixed	2	1	0
	Not specified	5	2	0

Legend: Paediatric: measurement of patients under the age of 18; Adult: measurement of patients aged 18 years or older; Burn: scars caused by thermal, chemical or friction injury; Surgical: scars caused by surgical procedures (including biopsies); Mixed: scars of included record were of mixed origin (e.g., burn and acne)

Footnotes: *Stage in the research to clinical practice translational pipeline, as defined by the Australian Government Department of Health and Aged Care (36); †Type of surgery defined in supplementary table 2

* A breakdown of each characteristic per record is presented in Supplementary Table 2

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2
3 **1 Methods used to measure traumatic cutaneous scar thickness:**
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6 2 B-mode, including high-frequency B-mode ultrasound (i.e., ≥ 20 MHz) was the most
7
8 3 commonly reported ultrasound type in the included articles (n = 56; 68% of articles) (17, 22-
9
10 4 24, 26, 29, 31, 46-49, 53, 54, 56, 57, 59, 60, 64, 65, 67, 69-78, 80-82, 84, 85, 111, 112, 114,
11
12 5 116-118, 120, 122, 123, 126-130, 138, 139, 141, 142, 144-146, 149), while most abstracts did
13
14 6 not report the type of ultrasound used (n = 22; 61% of abstracts) (86, 87, 92-98, 101, 103,
15
16 7 105, 106, 108, 131-134, 150-153) (Table 3). Specialised B-mode ultrasound devices,
17
18 8 including the Tissue Ultrasound Palpation System (TUPS; a B-mode ultrasound transducer
19
20 9 in-series with a load cell to allow measured compression of the skin), (68, 99, 100, 124) and
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22 10 colour Doppler ultrasound, (52, 149) were used in six records (Table 3).
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12 **Table 3. Summary of measurement methods used in included record***

Characteristic	Parameters	Number of Records
<i>Journal Articles</i>		
Ultrasound Type	B-mode	24
	Midrange	2
	High-frequency	29
	Other	4
	Not reported	22
Measurement Parameters	Epidermal	0
	Dermal	4
	Epidermal & dermal	2
	Combined epidermal & dermal	32
	Other	3
Scar characteristic measured	Not reported	40
	Fibrosis	27
	Oedema	1
	Fibrosis & oedema	10
	Other	1
	Not reported	42
<i>Abstracts</i>		
Ultrasound Type	B-mode	3
	Midrange	0
	High-frequency	9
	Other	3
	Not reported	21
Measurement Parameters	Epidermal	0
	Dermal	1
	Epidermal & dermal	4
	Combined epidermal & dermal	1
	Other	1
Scar characteristic measured	Not reported	29
	Fibrosis	2
	Oedema	0
	Fibrosis & oedema	0
	Other	0
	Not reported	34

Legend: B-mode: brightness-mode ultrasound (<20 MHz); High-frequency: High-frequency B-mode ultrasound (>20 MHz); Other: fields are expanded with additional detail in supplementary table 3

13 *A full summary of each included record is available in supplementary table 3

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2
3 14 The type of scar and skin thickness measurement (i.e., thickness of the dermis, epidermis, or
4
5 15 combined epidermal and dermal measurement) was reported in 39 records (33%) (Table 3).
6
7 16 Where reported, combined measurement of epidermal and dermal thickness was the most
8
9 17 common method used in articles (n = 32; 76% of articles reporting skin measurement type).
10
11 18 (17, 22-24, 27, 29, 50, 53, 56-58, 60, 64-66, 70, 72-77, 80-82, 114, 116, 118, 122, 126, 127,
12
13 19 130, 139, 146, 148) Separate epidermal and/or dermal thickness measurements were reported
14
15 20 in seven journal articles (17% of articles reporting skin thickness measurement type). (26, 47,
16
17 21 48, 52, 53, 71, 118) Of these records, two authors provided a rationale for this decision: each
18
19 22 skin layer provided different information on the scar; (26) or responded differently to
20
21 23 treatment. (67, 71) Most abstracts did not report the type of skin measurement used (n = 30;
22
23 24 83% of abstracts). (28, 30, 91-101, 103-110, 131-134, 150-154)
24
25 25 Three articles (4% of articles) (47, 110, 111) and one abstract (3% of abstracts) (28) directly
26
27 26 reported that fibrosis was the scar characteristic targeted by the measurement. One of these
28
29 27 records also quantified hair follicle density to assess the difference between scarred and
30
31 28 unscarred skin. (47) An additional 25 articles (30% of articles) (17, 46, 52, 53, 56, 63-65, 67,
32
33 29 70, 79, 80, 83, 84, 112, 120, 123, 125-127, 140, 142, 145, 148, 149, 155) and one abstract
34
35 30 (3% of abstracts) (110) made indirect reference (i.e., within the introduction or discussion) to
36
37 31 the measurement of fibrosis. Ten journal articles (12%) made indirect reference to the
38
39 32 measurement of both oedema and fibrosis, (31, 54, 55, 71, 74, 76-78, 138, 144) and one
40
41 33 record made indirect reference to the measurement of oedema. (59)
42
43 34 Additional objective and/or subjective measurement methods were employed alongside
44
45 35 ultrasound measurement in 72 articles (88% of articles) (17, 22, 24, 26, 29, 31, 46-53, 55-57,
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47 36 60-70, 72-81, 83-85, 111-122, 124-130, 136-142, 144, 145, 147-149) and 31 abstracts (86%
48
49 37 of abstracts) (86, 88, 89, 91-95, 97-110, 131-134, 150, 151, 153, 154) (Supplementary Table
50
51 38 4). All three phase 4 studies involving implementation in routine clinical practice utilised
52
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1
2
3 39 additional measurements. (92, 113, 119) The additional objective measurements used in
4
5 40 included records were elastography (elasticity), cutometric assessment (pliability) and
6
7 41 Doppler ultrasound (vascularity). The additional subjective measurements were conducted
8
9 42 using clinician-based rating scales (e.g., Vancouver Scar Scale or modified Vancouver Scar
10
11 43 Scale) or Patient Reported Outcome Measures. The Vancouver Scar Scale was used in 35
12
13 44 articles (43% of articles) (17, 31, 46, 47, 49, 50, 52, 55, 57, 61-64, 66-70, 73, 85, 111, 112,
14
15 45 114, 116, 118, 121, 124, 128, 130, 136-138, 140-142) and 11 abstracts (31% of abstracts) (88,
16
17 46 91, 92, 98-100, 107, 134, 150, 151, 153). Patient-reported outcome measures (PROMs) were
18
19 47 used in 27 articles (33% of articles) and 11 abstracts (31% of abstracts). (46, 53, 56, 57, 60,
20
21 48 72-75, 85, 91, 94, 97, 101-106, 111, 112, 114, 115, 117, 118, 120, 122, 129, 131-133, 138,
22
23 49 140, 141, 148, 150, 151, 153, 154) Of the records that reported using PROMs, the most
24
25 50 commonly used was the patient report of the Patient and Observer Scar Assessment Scale
26
27 51 (POSAS), used in 17 articles (63% of articles reporting use of PROMs) (17, 22, 46, 50, 53,
28
29 52 61, 62, 64, 76, 77, 79, 114, 121, 125-127, 147) and 8 abstracts (73% of abstracts reporting use
30
31 53 of PROMs) (91, 93, 102, 104, 106, 132, 153) (Supplementary Table 4). In most cases,
32
33 54 additional measurement methods were used to supplement ultrasound thickness
34
35 55 measurements as research outcomes. In some records (n = 16; 14% of records), however,
36
37 56 ultrasound was compared with histology, POSAS, dermoscopy, VSS and modified VSS,
38
39 57 clinical assessment, modified Seattle Scar Scale, high-definition optical coherence
40
41 58 tomography, 3D camera, immunohistochemistry, and immunohistomorphometry. (17, 24, 26,
42
43 59 29, 31, 50, 51, 64, 73, 77, 86, 95, 110, 120, 124, 149) Where the effectiveness of ultrasound
44
45 60 was judged against other methods, it was only found to be inadequate against histology. (26,
46
47 61 86)
48
49
50
51
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54
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56
57 62 Methods used to relocate the scar for repeated measurements were reported in 34 records
58
59 63 (29%) (Supplementary Table 3). The most common relocation method was tracing the outline
60

1
2
3 64 or boundaries of the scar on a transparent or translucent sheet (n = 14 articles; 35% of articles
4
5 65 reporting scar relocation), (23, 49, 65, 74, 81, 115, 116, 120, 124, 125, 153) occasionally
6
7
8 66 including prominent or bony landmarks close to the scar. (23, 24, 72, 73, 123) Photographs (n
9
10 67 = 10 articles; 25% of articles reporting relocation and n = 1 abstract) and linear measurements
11
12 68 from defined points or anatomical landmarks on or around the scar (n = 4 articles; 10% of
13
14 69 articles reporting relocation) were also used for scar relocation. The ‘worst’ or ‘thickest’ part
15
16 70 of the scar, as determined by patients or assessors, was chosen as the measurement site in 14
17
18 71 journal articles (35% of journal articles reporting relocation) (23, 31, 52, 54, 57, 61, 62, 67,
19
20 72 126, 127, 138, 141, 148, 155) and one abstract. (105)

23
24 73 Measurement of unscarred skin, either contralateral or adjacent to the scar, was performed in
25
26 74 32 articles (39% of articles%) (17, 22-24, 27, 29, 46-48, 50, 51, 53, 56-60, 64, 72, 73, 80, 81,
27
28 75 85, 114, 118, 120-122, 128, 145, 146, 148) and 7 abstracts (19% of abstracts) (28, 94, 95,
29
30 76 150, 151, 153, 154) These measurements were primarily used as controls or comparators to
31
32 77 scar measurements (n = 27, 69% of records reporting unscarred skin measurement). (17, 22,
33
34 78 23, 28, 29, 47, 48, 51, 53, 56-60, 64, 67, 73, 80, 85, 95, 118, 120, 122, 128, 146, 148, 153,
35
36 79 154) Additionally, four records (10% of records reporting unscarred skin measurement)
37
38 80 evaluating treatment efficacy measured both unaffected skin thickness and the thickness of a
39
40 81 ‘control’ or untreated scar. (46, 74, 94, 114) All instances where additional ultrasound
41
42 82 measurements were taken of unscarred skin or untreated scars were reported as part of
43
44 83 research initiatives aligning with phases 2 and 3 of the research-to-practice pipeline (figure
45
46 84 1). (36)

85 **Reliability and measurement error**

55
56 86 Reliability was calculated for both scarred and unscarred skin in 13 articles (16% of articles)
57
58 87 and two abstracts (5% of abstracts), and was generally considered acceptable (Supplementary
59
60

1
2
3 88 Table 5). This included inter-rater reliability (n = 5; 4% of articles), (54, 64, 73, 120, 137)
4
5 89 intra-rater reliability (n = 3; 4% of journal articles), (22, 23, 65) and both inter- and intra-rater
6
7 90 reliability (n = 7; 6%; including 2 abstracts) (17, 24, 57, 82, 87, 105, 124). The intraclass
8
9 91 correlation coefficient (ICC) was the most commonly reported reliability statistic (n = 10; 8%
10
11 92 of records, including one abstract), (17, 24, 57, 64, 65, 73, 82, 87, 120, 124) where it was
12
13 93 reported for both scar and unscarred skin measurements in four articles (5% of articles). (17,
14
15 94 24, 57, 73) The reported combined thickness (i.e., epidermal and dermal) ICCs for inter-rater
16
17 95 reliability of scarred skin ranged from 0.82 to 0.985, while the inter-rater ICC for the
18
19 96 measurement of unscarred skin ranged from 0.33 to 0.98, with one of the four records
20
21 97 reporting an ICC below the threshold value of 0.7 (ICC = 0.33) (24) and one record simply
22
23 98 reported that the inter-rater ICC for scarred skin was “acceptable to high”. (64) The reported
24
25 99 intra-rater reliability for combined thickness measurements of scarred skin ranged from 0.89
26
27 100 to 0.983, and for unscarred skin ranged from 0.61 to 0.982, with one record reporting an ICC
28
29 101 below the threshold of 0.7 (ICC = 0.61). (24) One record reported both the inter- and intra-
30
31 102 rater ICCs for individual epidermal (inter-rater ICC = 0.297; intra-rater ICC = 0.809) and
32
33 103 dermal (inter-rater ICC = 0.991; intra-rater ICC = 0.991) scar thickness measurement. (87)
34
35 104 Four articles (5% of articles) reporting reliability used Pearson’s R, an undisclosed method,
36
37 105 or description (e.g., high) as detailed in supplementary table 2. (22, 54, 105, 137)
38
39
40 106 Measurement error for inter-rater and intra-rater reliability of combined, epidermal or dermal
41
42 107 thickness was reported in four articles (5% of articles) and one abstract using standard error
43
44 108 of the measurement (SEM). The inter-rater SEM for the combined epidermal and dermal
45
46 109 thickness of scarred skin ranged from 0.11 mm to 0.5 mm, and the intra-rater SEMs ranged
47
48 110 from 0.18 to 0.52 mm. Individual records reported SEM values for unscarred skin, and
49
50 111 separate epidermal and dermal measurements, available in Supplementary Table 5. (17, 23,
51
52 112 24, 82, 87) Only one record reported calculation of the smallest detectable change (SDC). In
53
54
55
56
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1
2
3 113 that record the inter-and intra-rater SDC was calculated for both scarred and unscarred skin.
4
5 114 The scarred skin SDCs were 1.4 mm (inter-rater) and 0.6 mm (intra-rater), and unscarred skin
6
7
8 115 SDCs were 0.8 mm (inter-rater) and 0.5 mm (intra-rater). (24) The reported SEMs were all
9
10 116 close to or below the largest SDC value reported. This finding may indicate that ultrasound
11
12 117 can detect true variance in scar thickness above measurement error for traumatic scar and skin
13
14
15 118 thickness.

16
17
18 119 Of the records that reported reliability and measurement error, measurements were taken by
19
20 120 practitioners with varying clinical expertise and roles within the treating team. These
21
22 121 included therapists, nurses and doctors, sometimes under the supervision of trained
23
24 122 radiologists. One record reported that 3 assessors received 3 hours of training, and conducted
25
26
27 123 10 assessments using the study protocol before the study began. (57)

28
29
30 124 **Clinical, health service, implementation and feasibility outcomes:**

31
32
33 125 No record specifically investigated clinical, health service, implementation or feasibility
34
35 126 outcomes of ultrasound as a measurement-based-care initiative. Ultrasound was used to
36
37 127 assess the clinical outcomes of scar treatment initiatives in all included records. Clinical,
38
39 128 health service, implementation and feasibility outcomes related to ultrasound measurement
40
41
42 129 were, however, reported in 53 journal articles (17, 22-24, 26, 27, 31, 46-48, 50, 51, 54, 56-61,
43
44 130 63-66, 69-75, 77, 80, 82, 113-116, 119, 120, 122-124, 128, 129, 138, 142-144, 148, 149, 155)
45
46 131 and 14 abstracts (28, 86, 87, 89, 90, 95, 96, 102, 105, 107, 109, 110, 152, 153) that focused
47
48
49 132 on scar treatments.

50
51
52 133 The clinical outcome of patient satisfaction related to ultrasound measurement was only
53
54 134 reported in one journal article. Whilst patient satisfaction was not directly measured in that
55
56 135 record, a proxy measure of satisfaction was reported by the authors stating that no paediatric
57
58
59
60

1
2
3 136 patient or their caregiver refused ultrasound measurement once the purpose was explained.

4
5 137 (24)

6
7
8 138 Timeliness was the only reported health service outcome, reported as the time required to

9
10 139 take ultrasound measurements. Where reported in three journal articles, this was short, taking

11
12
13 140 between one to five minutes. (24, 27, 122)

14
15
16 141 The most common implementation outcomes reported in the identified records were fidelity,

17
18 142 acceptability and appropriateness. Fidelity to the measurement method was reported through

19
20 143 the use of experienced or trained assessors (n = 6 journal articles; n = 1 abstract), (24, 57, 58,

21
22 144 87, 142, 144, 148) and/or utilising the same assessor/s for all measurement sessions (n = 5

23
24 145 journal articles; 6% of included journal articles). (24, 61, 138, 144, 148) Differences between

25
26 146 intended and actual measurement methods were not discussed. The training and/or experience

27
28 147 of the assessors was discussed in 24 records (23 journal articles and 1 abstract), (17, 23, 24,

29
30 148 27, 51, 56-59, 63-66, 71, 73, 115, 116, 120, 123, 124, 138, 144, 149, 153) where

31
32 149 measurements were either taken by a clinician (n = 13; 54% of records reporting training),

33
34 150 (17, 23, 24, 58, 59, 64-67, 71, 120, 124, 141) members of the research team (n = 6; 25% of

35
36 151 records reporting training), (57, 63, 73, 115, 123, 144) or by specialist sonographers and/or

37
38 152 radiologists (n = 5, including one abstract; 21% of records reporting training). (56, 116, 138,

39
40 153 149, 153) Only one record reported on fidelity in the context of routine clinical practice. In

41
42 154 this instance, ultrasound was conducted in the department of radiology, however the role or

43
44 155 training of the staff was not reported. (119)

45
46 156 The acceptability and appropriateness of the ultrasound methods used in individual records

47
48 157 were generally based on author opinion and outlined in the discussion. Acceptability was

49
50 158 reported in 26 records (23 journal articles and 3 abstracts), (17, 22-24, 26-28, 31, 57, 64, 70,

51
52 159 74, 75, 77, 80, 82, 86, 96, 116, 119, 120, 122, 124, 143, 149, 155) including for paediatric

1
2
3 160 populations, where one record reported potential difficulty in measuring this population, (22)
4
5 161 contrasting that which reported that measurement was acceptable to both children and their
6
7 162 caregivers. (24) One record reported acceptability where the intervention being analysed by
8
9 163 ultrasound was already part of routine clinical practice. In this instance, the authors
10
11 164 referenced additional publications which stated that ultrasound had an accuracy of 0.5 mm,
12
13 165 which was judged by the authors to be sufficient for assessment of scar thickness. (24, 27,
14
15 166 119, 122) Potential difficulty was identified in the measurement of open wounds, (24) and
16
17 167 traditionally hard-to-reach areas (such as the axillae or groin). (22)
18
19
20
21

22 168 The appropriateness of the ultrasound methods was reported in 35 journal articles (43% of
23
24 169 included journal articles) (22, 24, 26, 27, 31, 46-48, 50, 54, 57, 60, 61, 64-66, 69, 72-75, 77,
25
26 170 80, 82, 113, 114, 116, 119, 120, 122, 124, 128, 148, 149, 155) and 11 abstracts (31% of
27
28 171 included abstracts) (86, 87, 89, 90, 95, 102, 105, 107, 109, 110, 152), where it was generally
29
30 172 addressed in the discussion. Of these records, two (4% of records reporting appropriateness)
31
32 173 determined that ultrasound was not appropriate for scar measurement. The first stated that it
33
34 174 was too inaccurate and complex; (86) and the second, which reported on initiatives within
35
36 175 routine clinical practice, determined that the minimum resolution of the Dasonography
37
38 176 ultrasonic scanner (Nuclear Enterprises, Edinburgh, UK) precluded its use in scars thinner
39
40 177 than 3mm. (113)
41
42
43
44
45

46 178 The feasibility of ultrasound was reported in 12 journal articles (15% of included journal
47
48 179 articles). (22, 24, 26, 46, 57, 70, 80, 119, 120, 124, 129) Five records considered ultrasound
49
50 180 not feasible for scar measurements. The rationale presented included high-frequency 20 MHz
51
52 181 ultrasound having an inadequate penetration depth; (26, 57) and ultrasound measurement and
53
54 182 training of investigators requiring too much time (as reported in one record in phase 4 of the
55
56 183 research-to-practice pipeline). (22, 119, 120) Another factor identified as precluding
57
58 184 feasibility was the inability to consistently relocate the measurement site. (24) Conversely,
59
60

1
2
3 185 one record reported ultrasound to be feasible in combination with Vancouver Scar Scale
4
5 186 (VSS) measurement, (70) and another stated that ultrasound was able to distinguish between
6
7 187 subcutaneous fat and muscle, which was interpreted by the authors of that record to mean that
8
9 188 skin thickness measurements were accurate. (129) The majority (n = 11; 92%) of the records
10
11 189 reporting feasibility were research initiatives in phase 2 or 3 of the research to practice
12
13 190 pipeline. One record examined feasibility in the context of routine clinical practice (i.e.,
14
15 191 phase 4; figure 1), (119) where it was determined that ultrasound was not suitable for use in
16
17 192 their twelve-year longitudinal study due to changes in staff, equipment and software over
18
19 193 such a long time period, which introduced additional variables to the measurement process
20
21
22 194 that were impossible to control. (119)

25 26 27 195 **Factors influencing ultrasound images and measurement methods:**

28
29
30 196 The only factor that was reported to influence the imaging and measurement methods was the
31
32 197 measurement of scars with open wounds. This was reported in one record, which determined
33
34 198 that ultrasound and ultrasound gel was unsuitable in this instance. The authors of that record
35
36 199 suggested the use of a flexible transparent plastic wrap, which is placed over the
37
38
39 200 measurement area prior to measurement with ultrasound. (24)

40 41 42 201 **Reported strengths and limitations of the measurement methods:**

43
44
45 202 The safety, practicality, objectivity, versatility, reliability and non-invasive nature of
46
47 203 ultrasound were all reported as strengths of the measurement method. (22, 27-29, 47, 50, 57,
48
49 204 61, 64, 77, 78, 80, 82, 87, 89, 95, 96, 105, 107, 109, 119, 123, 124, 129, 139, 148) When
50
51 205 compared to other subjective or clinical measurement methods (e.g., VSS) and 3D camera,
52
53 206 ultrasound was viewed as the superior measurement method of scar and skin thickness, due to
54
55 207 its improved accuracy, greater sensitivity to change and objectivity. (24, 64, 73, 116, 120)
56
57
58 208 The ability of ultrasound to differentiate between scarred and unscarred skin was also
59
60

1
2
3 209 highlighted (n = 4; 3%), (47, 60, 72, 122) as was the versatility of ultrasound in its ability to
4
5 210 measure a variety of anatomical areas and be used with child participants (i.e., <18 years) (n
6
7 211 = 2; 2%). (22, 149)
8
9

10 212 The poor correlation between ultrasound and histological thickness measurements, (86) and
11
12 213 the established inverse relationship between ultrasound penetration depth and the resolution
13
14 214 of superficial structures were identified as limitations of ultrasound in the measurement of
15
16 215 scar thickness. (26, 27, 77, 80, 89, 113, 149) This may be an evidence gap worth exploring in
17
18 216 more depth. One record, reporting on a longitudinal study that was conducted over twelve
19
20 217 years, reported that the continuous development of ultrasound software and hardware over
21
22 218 that time limited the usefulness of ultrasound. (119) Despite being reported elsewhere as
23
24 219 acceptable (i.e., between one to five minutes (24, 27, 122)), one record reported that the time-
25
26 220 consuming nature of measurement and the requirement for assessors to be trained in the
27
28 221 operation of, and techniques required for, ultrasonography was a limitation of the method.
29
30 222 (120) Methodologically, concerns were raised around the pressure caused by application of
31
32 223 the ultrasound transducer to the skin, and how that may influence thickness measurement.
33
34 224 (61, 62, 123, 124) The size of the transducer head relative to the size of scars was also
35
36 225 considered a potential limitation, as multiple measurements are required for quantification of
37
38 226 larger scars. (57) Finally, it was recognised that there may be a difference between changes to
39
40 227 the scar that can be measured by ultrasound, and what is felt and/or experienced by the
41
42 228 patient. (75, 80, 126, 127) It was suggested that changes that are detectable by ultrasound
43
44 229 may be smaller than those able to be detected by patients. In patients with burn scars, a
45
46 230 minimum change in scar thickness of between 1 to 6 mm measured by ultrasound, has been
47
48 231 reported to be required before a patient may report noticing any difference to their scar
49
50 232 thickness. (24, 75) While further research is required to allow generalisation of these findings
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1
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3 233 to other scar aetiologies, this indicates that a holistic approach to scar thickness using the
4
5 234 patient's opinion as well as objective measurement through ultrasound may be beneficial.
6
7

8 **235 Guidelines or frameworks used to guide the measurement methods:**
9

10
11 236 No records reported using any guidelines or frameworks to inform their measurement
12
13 237 methods. One record utilised suggestions from The American Wound Healing Society to
14
15 238 support the measurement of contralateral, unscarred skin thickness on the same individual as
16
17 239 a control or comparator. (75)
18
19

20
21 **240 Methodological Considerations:**
22

23
24 241 Based on the ultrasound methods and outcomes identified in this review, a list of
25
26 242 methodological considerations have been compiled (Supplementary Table 6). These are
27
28 243 intended to guide the decision-making and methodological reporting of researchers and/or
29
30 244 clinicians undertaking scar or skin thickness ultrasound measurement.
31
32

33
34 **245 DISCUSSION:**
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36
37 246 This review mapped the methods used in the published literature to measure traumatic scar
38
39 247 thickness using ultrasound across the research-to-practice translational pipeline. No record
40
41 248 reported their methods with sufficient detail to allow them to be independently replicated.
42
43 249 Overall, there was a lack of consistent rationale underpinning which skin layers (i.e.,
44
45 250 epidermis, dermis and combined) were measured, and little consideration was given to the
46
47 251 training and experience required by assessors. The included records mainly aligned with the
48
49 252 second and third phases of the research-to-practice pipeline (figure 1), with only three records
50
51 253 (2 articles and 1 abstract) reporting the use of ultrasound in routine clinical practice (phase 4).
52
53 254 (92, 113, 119). The paucity of records aligning with phase four studies (use in clinical
54
55 255 practice) suggests a translational gap from research to regular clinical practice. There are two
56
57 256 likely explanations for this: 1) that ultrasound is most commonly used as an outcome measure
58
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1
2
3 257 for research initiatives and is not regularly used to evaluate care once treatments are
4
5 258 implemented into routine clinical practice; or 2) that use of ultrasound in routine clinical
6
7
8 259 practice is not reported or evaluated, as routine clinical practice is rarely published.
9

10
11 260 Searching of grey literature was conducted in an attempt to identify clinical practice
12
13 261 documents, however none were located. Surveys of health service departments may be the
14
15 262 best method of identifying ultrasound methods used in regular clinical practice as part of
16
17 263 future research. While some records reported using additional subjective and objective
18
19 264 measurement methods in addition to ultrasound, none used these methods to determine the
20
21 265 criterion validity of the ultrasound for scar thickness measurement. This is another evidence
22
23 266 gap that should be addressed.
24
25
26

27 267 While efforts have been made to standardise ultrasound measurement procedures elsewhere
28
29 268 in dermatology (including tumours, cancers, vascular anomalies, and systemic sclerosis (34,
30
31 269 35)), this same effort has not yet extended to the measurement of traumatic scarring.
32
33 270 Methodological standardisation has the potential to increase confidence in the use of
34
35 271 ultrasound as the basis of measurement-based care initiatives for clinical decision-making,
36
37 272 allowing patient care and scar treatments to be tailored towards individual needs. (62, 147,
38
39 273 156) Standardising the core methodological components of ultrasound measurement of scar
40
41 274 thickness, or at the very least, creating a standardised framework for methodological
42
43 275 decision-making, may support implementation of ultrasound measurement into routine
44
45 276 clinical practice, supported by strategies to overcome barriers to implementation at local sites.
46
47 277 (157)
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53 278 This review identified novel insights into the identification of the composition of cutaneous
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55 279 scars using ultrasound, and highlighted the apparent lack of consistent understanding of, or
56
57 280 rationale behind, what scar thickness characteristics were being measured. Fibrosis is
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1
2
3 281 generally understood to be the primary cause of scar thickness through the deposition of
4
5 282 excessive extracellular matrix proteins such as collagen. (158, 159) This has been confirmed
6
7 283 through histological analysis, which has shown the presence of excess collagen and other
8
9 284 extracellular matrix proteins in the dermis of hypertrophic scars. (160, 161) An additional
10
11 285 method for assessing the effects of scarring on the dermis, as identified by one record in this
12
13 286 review, (47) is through quantification of the presence and density of hair follicles. This
14
15 287 quantification may serve as a method of differentiation between scarred and physiological
16
17 288 skin, and may also serve as a measure of skin function. (47) What is less understood, and
18
19 289 perhaps largely overlooked, is the function of the epidermis in scar thickness. In the one
20
21 290 record identified in this review that directly report the measurement of the epidermis, the
22
23 291 authors noted that the measurement quantified the presence of oedema. (55) This was further
24
25 292 supported by two records that noted that the epidermis and dermis responded differently to
26
27 293 treatment, (67, 71) indicating that there is likely a difference in the composition of the scar
28
29 294 between these skin layers. Cutaneous oedema has been observed using high-frequency
30
31 295 ultrasound in other pathologies, including atopic dermatitis and skin ageing, where it is
32
33 296 characterised by the presence of a sub-epidermal low echogenic band (SLEB), a hyperechoic
34
35 297 band at the dermoepidermal junction. (162) Understanding the interplay between epidermal
36
37 298 oedema, dermal fibrosis and the presence and density of hair follicles may result in an
38
39 299 increased understanding of the mechanisms and treatment responses of cutaneous scarring.
40
41 300 With better understanding, more targeted scar treatments that inform a greater understanding
42
43 301 of scar responsivity may arise.

44
45 302 Another important, but potential limiting factor for the use of ultrasound to measure scar
46
47 303 thickness raised in this review is the training and/or experience required of assessors, and the
48
49 304 ramifications this likely has on the reliability of measurements and interpretation. (163) This
50
51 305 review identified 24 records where assessor experience was discussed, however none made
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2
3 306 any recommendations on the optimal training and/or experience. Identifying the training
4
5 307 requirements of assessors may prove an important step towards more widespread
6
7
8 308 implementation of reliable ultrasound scar thickness measurement in research trials and as the
9
10 309 basis for measurement-based care in routine clinical practice. (164) A panel of
11
12 310 dermatological and ultrasound experts has previously recommended that a physician with a
13
14 311 minimum of 300 examinations per year should hold responsibility for ultrasound
15
16 312 measurements. (34) It has also been suggested that training existing members of clinical
17
18 313 teams and standardising measurement method/s may be the most effective way to achieve
19
20 314 minimum reliability standards under clinical conditions. This could allow measurement to be
21
22 315 reliably conducted within an outpatient clinic setting by a number of healthcare providers
23
24 316 assisting workflow, negating the requirement for patients to wait for an experienced
25
26 317 radiographer. (24, 164) In the current review, reliability estimates were generally acceptable
27
28 318 but were tested under research conditions. The diverse experience and expertise of assessors,
29
30 319 where reported for the reliability estimates, means that the acceptable reliability results
31
32 320 should be generalisable to most clinical teams, as therapists, doctors and nurses were all
33
34 321 included. The cumulative sample size of all reliability studies also supports this
35
36 322 generalisation; however each team should perform their own reliability estimates before
37
38 323 conducting ultrasound thickness measurements.
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45 324 **Study Limitations:**

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47
48 325 Only articles available in English or with an English abstract were considered for inclusion
49
50 326 and data extraction, which may have resulted in the omission of eligible information. Data
51
52 327 extraction was completed on the English abstracts of two non-English articles that were
53
54 328 available electronically, however the non-English articles themselves were not available to
55
56 329 the authors, and thus could not be analysed. Based on the number of records included in this
57
58 330 review, however, it is unlikely that this would have impacted the review findings. It is
59
60

1
2
3 331 acknowledged that methods reported in included abstracts may not be fully reproducible, due
4
5 332 to their brevity. Thus, findings were reported separately to articles. An additional limitation
6
7
8 333 was that authors of included records were not contacted to provide clarification or further
9
10 334 information, as this was not feasible given the number of results identified. It should also be
11
12 335 acknowledged that the included records were not designed to align with the specific aims of
13
14 336 this review, which likely explains some of the lack of reporting on outcomes of interest in our
15
16 337 review, particularly clinical, health service and implementation outcomes. Furthermore, as
17
18 338 this review relied on published information (including grey literature), routine practices
19
20 339 employed within organisations may not have been considered and unpublished industry
21
22 340 sponsored reports may not have been identified.
23
24
25

26
27 341 It is also important to consider the limitations of ultrasound itself for the holistic
28
29 342 quantification of cutaneous scarring. Ultrasound transducers are generally small, meaning
30
31 343 that it is difficult to assess the entirety of a scar, necessitating multiple measurements. (165)
32
33 344 Additionally, thickness is often not the only scar parameter of clinical or research interest. It
34
35 345 has therefore been recommended that multi-modal measurement techniques are employed,
36
37 346 which include both subjective and objective measurements. (166, 167) However, use of these
38
39 347 methods may be challenging in routine clinical practice, due to the length of time and training
40
41 348 required. Thus, feasibility and implementation outcomes are of importance in evaluating
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43 349 measurement-based care initiatives involving ultrasound alone or multimodal measurement
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45 350 tools in scar care practice – a field in its infancy based on this review.
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50 351 **Future Directions:**

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53 352 It is intended that the results of this review will be used to inform the creation of a Delphi
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55 353 consensus study, leading to the formation of a guideline for the measurement of traumatic
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57 354 scar thickness using ultrasound. This guideline can then be used by researchers and clinicians
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3 355 to standardise the measurement of scars. In preparation for this study, we have provided a list
4
5 356 of methodological considerations for assessors or practitioners when planning to conduct scar
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7 357 thickness measurements with ultrasound (Supplementary Table 6). Future research could also
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9 358 investigate aspects that were beyond the scope of this review including factors influencing
10
11 359 the implementation of ultrasound-based care initiatives, strategies to support implementation,
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13 360 and how research-based initiatives could be applied in practice. Further studies are needed
14
15 361 that compare SDCs to SEMs to interpret reliability estimates to confirm our interpretation
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17 362 that ultrasound may have the ability to detect true change or variance in scar thickness above
18
19 363 measurement error, which was based on the SDC reported by a single study. Our
20
21 364 interpretation is supported by mostly acceptable reliability estimates of ultrasound thickness
22
23 365 for other cutaneous conditions. (168, 169) Additional investigations should also be conducted
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25 366 to determine the criterion validity of ultrasound as a measure for scar thickness.
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49 374 University of Queensland.
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3 379 **AUTHOR CONTRIBUTIONS**
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5 380 BM and ZT conceived the project after identifying this area as a knowledge gap in existing
6
7 381 literature. BM developed the research questions and study methodology, conducted the
8
9 382 literature search, screened all articles and extracted data. Record screening and data
10
11 383 extraction was completed by BM, MS, TM, and TR, with additional extraction completed by
12
13 384 BD to assess consistency. MS, TM, TR and RK provided advice to BM on the clinical
14
15 385 implications of ultrasound measurement. MS, RK and ZT contributed to the supervision of
16
17 386 BM as a PhD student. BM drafted the paper, and ZT and MS provided critical appraisal of
18
19 387 the drafted manuscript, with further advice provided by TM, TR, BD and RK.
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24 388 **DATA SHARING STATEMENT:**
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26 389 Not applicable
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28 390 **ETHICS APPROVAL STATEMENT:**
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30 391 This study does not involve human participants. No ethics approval was required.
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33 392 **FIGURE LEGENDS:**
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35 393 **Figure 1: Research to clinical practice pipeline.**
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58
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References:

1. Jagdeo J, Shumaker PR. Traumatic scarring. *JAMA Dermatol (Patient Page)*. 2017;153(3):364-398.
2. Lawrence WJ, Mason TS, Schomer BK, Klein BM. Epidemiology and Impact of Scarring After Burn Injury: A Systematic Review of the Literature. *Journal of Burn Care & Research*. 2012;33(1):136-46.
3. Bayat A, McGrouther DA, Ferguson MWJ. Skin scarring. *BMJ*. 2003;326(7380):88-92.
4. Lee H, Jang Y. Recent Understandings of Biology, Prophylaxis and Treatment Strategies for Hypertrophic Scars and Keloids. *Int J Mol Sci*. 2018;19(3).
5. Rabello FB, Souza CD, Farina Júnior JA. Update on hypertrophic scar treatment. *Clinics*. 2014;69(8):565-73.
6. English RS, Shenefelt PD. *Keloids and Hypertrophic Scars*. Boston, MA, USA: Blackwell Science Inc; 1999. p. 631-8.
7. Niessen BF, Spauwen HMP, Schalkwijk HMJ, Kon HMM. On the Nature of Hypertrophic Scars and Keloids: A Review. *Plastic and Reconstructive Surgery*. 1999;104(5):1435-58.
8. Simons M, Price N, Kimble R, Tyack Z. Patient experiences of burn scars in adults and children and development of a health-related quality of life conceptual model: A qualitative study. *Burns*. 2016;42(3):620-32.
9. Tyack Z, Ziviani J, Kimble R, Plaza A, Jones A, Cuttle L, et al. Measuring the impact of burn scarring on health-related quality of life: Development and preliminary content validation of the Brisbane Burn Scar Impact Profile (BBSIP) for children and adults. *Burns*. 2015;41(7):1405-19.
10. Sullivan T, Smith J, Kermode J, McIver E, Courtemanche DJ. Rating the burn scar. *J Burn Care Rehabil*. 1990;11(3):256-60.
11. Draaijers JL, Tempelman RHF, Botman AMY, Tuinebreijer EW, Middelkoop WE, Kreis PMR, et al. The patient and observer scar assessment scale: A reliable and feasible tool for scar evaluation. *Plast Reconstr Surg*. 2004;113(7):1960-5.
12. Tyack Z, Wasiak J, Spinks A, Kimble R, Simons M. A guide to choosing a burn scar rating scale for clinical or research use. *Burns*. 2013;39(7):1341-50.
13. Gold HM, McGuire AM, Mustoe AT, Pusic AA, Sachdev AM, Waibel AJ, et al. Updated international clinical recommendations on scar management: Part 2 - Algorithms for scar prevention and treatment. *Dermatol Surg*. 2014;40(8):825-31.
14. Jones LL, Calvert M, Moiemmen N, Deeks JJ, Bishop J, Kinghorn P, et al. Outcomes important to burns patients during scar management and how they compare to the concepts captured in burn-specific patient reported outcome measures. *Burns*. 2017;43(8):1682-92.
15. McGarry S, Elliott C, McDonald A, Valentine J, Wood F, Girdler S. Paediatric burns: From the voice of the child. *Burns*. 2014;40(4):606-15.
16. Bloemen MCT, van Der Veer WM, Ulrich MMW, van Zuijlen PPM, Niessen FB, Middelkoop E. Prevention and curative management of hypertrophic scar formation. *Burns*. 2009;35(4):463-75.
17. Lee KC, Bamford A, Gardiner F, Agovino A, ter Horst B, Bishop J, et al. Investigating the intra- and inter-rater reliability of a panel of subjective and objective burn scar measurement tools. *Burns*. 2019;45(6):1311-24.
18. Brusselaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S. Burn Scar Assessment: A Systematic Review of Different Scar Scales. *Journal of Surgical Research*. 2010;164(1):e115-e23.
19. Brusselaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S. Burn scar assessment: A systematic review of objective scar assessment tools. *Burns*. 2010;36(8):1157-64.
20. Hambleton J, Shakespeare PG, Pratt BJ. The progress of hypertrophic scars monitored by ultrasound measurements of thickness. *Burns*. 1992;18(4):301-7.

- 1
2
3 444 21. Sonsbeek AMSv, Hutschemaekers GJM, Veerman JW, Vermulst AA, Tiemens BG. The results
4 445 of clinician-focused implementation strategies on uptake and outcomes of Measurement-Based Care
5 446 (MBC) in general mental health care. *BMC Health Serv Res.* 2023;23(1):326-
6 447 22. Gee Kee EL, Kimble RM, Cuttle L, Stockton KA. Scar outcome of children with partial
7 448 thickness burns: A 3 and 6 month follow up. *Burns.* 2016;42(1):97-103.
8 449 23. Wang X-Q, Mill J, Kravchuk O, Kimble RM. Ultrasound assessed thickness of burn scars in
9 450 association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns.*
10 451 2010;36(8):1254-62.
11 452 24. Simons M, Kee EG, Kimble R, Tyack Z. Ultrasound is a reproducible and valid tool for
12 453 measuring scar height in children with burn scars: A cross-sectional study of the psychometric
13 454 properties and utility of the ultrasound and 3D camera. *Burns.* 2017;43(5):993-1001.
14 455 25. Izzetti R, Vitali S, Aringhieri G, Nisi M, Oranges T, Dini V, et al. Ultra-high frequency
15 456 ultrasound, a promising diagnostic technique: review of the literature and single-center experience.
16 457 *Can Assoc Radiol J.* 2021;72(3):418-31.
17 458 26. Agabalyan NA, Su S, Sinha S, Gabriel V. Comparison between high-frequency
18 459 ultrasonography and histological assessment reveals weak correlation for measurements of scar
19 460 tissue thickness. *Burns.* 2016;43(3):531-8.
20 461 27. Kim JD, Oh SJ, Kim SG, Ahn SV, Jang YJ, Yang BS, et al. Ultrasonographic findings of re-
21 462 epithelialized skin after partial-thickness burns. *Burns Trauma.* 2018;6(1):21-
22 463 28. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in
23 464 burn scars using high frequency ultrasound. *J Burn Care Res.* 2012;33(2):S105.
24 465 29. Ud-Din S, Foden P, Stocking K, Mazhari M, Al-Habba S, Baguneid M, et al. Objective
25 466 assessment of dermal fibrosis in cutaneous scarring, using optical coherence tomography,
26 467 high-frequency ultrasound and immunohistomorphometry of human skin. *Br J Dermatol.*
27 468 2019;181(4):722-32.
28 469 30. Du Y-C, Lin C-M, Chen Y-F, Chen C-L, Chen T. Implementation of a burn scar assessment
29 470 system by ultrasound techniques. *Conf Proc IEEE Eng Med Biol Soc.* 2006:2328-31.
30 471 31. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and
31 472 hypertrophic scar assessment. *Lasers Med Sci.* 2019;35(2):379-85.
32 473 32. Jasaitiene D, Valiukeviciene S, Linkeviciute G, Raisutis R, Jasiuniene E, Kazys R. Principles of
33 474 high-frequency ultrasonography for investigation of skin pathology. *J Eur Acad Dermatol Venereol.*
34 475 2011;25(4):375-82.
35 476 33. Rodríguez Bandera AI, Sebaratnam DF, Feito Rodríguez M, Lucas Laguna R. Cutaneous
36 477 ultrasound and its utility in pediatric dermatology. Part I: Lumps, bumps, and inflammatory
37 478 conditions. *Pediatr Dermatol.* 2020;37(1):29-39.
38 479 34. Wortsman X, Alfageme F, Roustan G, Arias-Santiago S, Martorell A, Catalano O, et al.
39 480 Guidelines for performing dermatologic ultrasound examinations by the DERMUS Group. *J*
40 481 *Ultrasound Med.* 2016;35(3):577-80.
41 482 35. Vanhaecke A, Cutolo M, Heeman L, Vilela V, Deschepper E, Melsens K, et al. High frequency
42 483 ultrasonography: Reliable tool to measure skin fibrosis in SSC? A systematic literature review and
43 484 additional pilot study. *Rheumatology (Oxford).* 2022;61(1):42-52.
44 485 36. Australian Government Department of Health and Aged Care Medical Research Future Fund.
45 486 Research Translation Australia2022 [Available from: <https://www.health.gov.au/our-work/medical-research-future-fund/mrff-research-themes/research-translation#what-is-the-research-pipeline>.
46 487 37. Meikle B, Kimble RM, Tyack Z. Ultrasound measurements of pathological and physiological
47 488 skin thickness: A scoping review protocol. *BMJ Open.* 2022;12(1):e056720-e.
48 489 38. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res*
49 490 *Methodol.* 2005;8(1):19-32.
50 491 39. Haddaway NR, Collins AM, Coughlin D, Kirk S. The role of google scholar in evidence reviews
51 492 and its applicability to grey literature searching. *PLoS One.* 2015;10(9):e0138237-e.
52 493
53
54
55
56
57
58
59
60

- 1
2
3 494 40. Pieper D, Puljak L. Language restrictions in systematic reviews should not be imposed in the
4 495 search strategy but in the eligibility criteria if necessary. *J Clin Epidemiol*. 2021;132:146-7.
- 5 496 41. Proctor E, Proctor E, Silmere H, Silmere H, Raghavan R, Raghavan R, et al. Outcomes for
6 497 Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda.
7 498 *Adm Policy Ment Health*. 2011;38(2):65-76.
- 8 499 42. Prinsen CAC, Vohra S, Rose MR, Boers M, Tugwell P, Clarke M, et al. How to select outcome
9 500 measurement instruments for outcomes included in a "Core Outcome Set" - a practical guideline.
10 501 *Trials*. 2016;17:urn:issn:1745-6215.
- 11 502 43. Mookink LB, Boers M, van der Vleuten CPM, Bouter LM, Alonso J, Patrick DL, et al. COSMIN
12 503 Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome
13 504 measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020;20(1):1-13.
- 14 505 44. Terwee CB, Bot SDM, de Boer MR, van der Windt DAWM, Knol DL, Dekker J, et al. Quality
15 506 criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol*.
16 507 2007;60(1):34-42.
- 17 508 45. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA
18 509 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71-n.
- 19 510 46. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of
20 511 fractional CO2 laser treatment of mature burn scars. *J Burn Care Res*. 2016;37(6):379-87.
- 21 512 47. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal
22 513 tissue thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res*.
23 514 2020;41(2):421-6.
- 24 515 48. Cai L, Hu M, Lin L, Zheng T, Liu J, Li Z. Evaluation of the efficacy of triamcinolone acetonide in
25 516 the treatment of keloids by high-frequency ultrasound. *Skin Res Technol*. 2020;26(4):489-93.
- 26 517 49. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic
27 518 scar in a Chinese population. *Burns*. 2010;36(8):1234-41.
- 28 519 50. Chae JK, Kim JH, Kim EJ, Park K. Values of a patient and observer scar assessment scale to
29 520 evaluate the facial skin graft scar. *Ann Dermatol*. 2016;28(5):615-23.
- 30 521 51. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
31 522 Construct validity and predictive ability of scar thickness change. *Skin Res Technol*. 2020;26(3):369-
32 523 75.
- 33 524 52. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following
34 525 intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized
35 526 controlled trial. *PLoS One*. 2021;16(3):e0248799.
- 36 527 53. Deng H, Tan T, Luo G, Tan J, Li-Tsang CWP. Vascularity and thickness changes in immature
37 528 hypertrophic scars treated with a pulsed dye laser. *Lasers Surg Med*. 2021;53(7):914-21.
- 38 529 54. Dunkin CSJ, Pleat JM, Gillespie PH, Tyler MPH, Roberts AHN, McGrouther DA. Scarring occurs
39 530 at a critical depth of skin injury: Precise measurement in a graduated dermal scratch in human
40 531 volunteers. *Plast Reconstr Surg*. 2007;119(6):1722-32.
- 41 532 55. Fabbrocini G, Marasca C, Ammad S, Brazzini B, Izzo R, Donnarumma M, et al. Assessment of
42 533 the combined efficacy of needling and the use of silicone gel in the treatment of C-section and other
43 534 surgical hypertrophic scars and keloids. *Adv Skin Wound Care*. 2016;29(9):408-11.
- 44 535 56. Fracalvieri M, Zingarelli E, Ruka E, Antoniotti U, Coda R, Sarno A, et al. Negative pressure
45 536 wound therapy using gauze and foam: histological, immunohistochemical and ultrasonography
46 537 morphological analysis of the granulation tissue and scar tissue. Preliminary report of a clinical study.
47 538 *Int Wound J*. 2011;8(4):355-64.
- 48 539 57. Gankande TU, Duke JM, Danielsen PL, DeJong HM, Wood FM, Wallace HJ. Reliability of scar
49 540 assessments performed with an integrated skin testing device – The DermaLab Combo. *Burns*.
50 541 2014;40(8):1521-9.
- 51 542 58. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on
52 543 third-degree burns through ultrasonic measurement. *J Cytol Histol*. 2017;8(5).
- 53
54
55
56
57
58
59
60

- 1
2
3 544 59. Huang P-W, Lu C-W, Chu K-T, Ho M-T. Assessing thickness of burn scars through ultrasound
4 545 measurement for patients with arm burns. *J Med Biol Eng.* 2021;41(1):84-91.
- 5 546 60. Huang S-Y, Xiang X, Guo R-Q, Cheng S, Wang L-Y, Qiu L. Quantitative assessment of
6 547 treatment efficacy in keloids using high-frequency ultrasound and shear wave elastography: a
7 548 preliminary study. *Sci Rep.* 2020;10(1):1375-.
- 8 549 61. Issler-Fisher AC, Fisher OM, Haertsch PA, Li Z, Maitz PKM. Effectiveness and safety of
9 550 ablative fractional CO2 laser for the treatment of burn scars: A case-control study. *Burns.*
10 551 2021;47(4):785-95.
- 11 552 62. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with
12 553 laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration
13 554 matter? *Lasers Surg Med.* 2020;52(2):149-58.
- 14 555 63. Joo SY, Lee SY, Cho YS, Seo CH. Clinical utility of extracorporeal shock wave therapy on
15 556 hypertrophic scars of the hand caused by burn injury: A prospective, randomized, double-blinded
16 557 study. *J Clin Med.* 2020;9(5):1376.
- 17 558 64. Lee KC, Bamford A, Gardiner F, Agovino A, ter Horst B, Bishop J, et al. Burns objective scar
18 559 scale (BOSS): Validation of an objective measurement devices based burn scar scale panel. *Burns.*
19 560 2020;46(1):110-20.
- 20 561 65. Li JQ, Li-Tsang CWP, Huang YP, Chen Y, Zheng YP. Detection of changes of scar thickness
21 562 under mechanical loading using ultrasonic measurement. *Burns.* 2012;39(1):89-97.
- 22 563 66. Li P, Li-Tsang CWP, Deng X, Wang X, Wang H, Zhang Y, et al. The recovery of post-burn
23 564 hypertrophic scar in a monitored pressure therapy intervention programme and the timing of
24 565 intervention. *Burns.* 2018;44(6):1451-67.
- 25 566 67. Li N, Yang L, Cheng J, Han J, Hu D. Early intervention by Z-plasty combined with fractional
26 567 CO2 laser therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet*
27 568 *Surg.* 2021;74(11):3087-93.
- 28 569 68. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its
29 570 characteristics among the Chinese population. *Burns.* 2005;31(5):610-6.
- 30 571 69. Li-Tsang CWP, Lau JCM, Choi J, Chan CCC, Jianan L. A prospective randomized clinical trial to
31 572 investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among
32 573 the Chinese population. *Burns.* 2006;32(6):678-83.
- 33 574 70. Mamdouh M, Omar GA, Hafiz HSA, Ali SM. Role of vitamin D in treatment of keloid. *J Cosmet*
34 575 *Dermatol.* 2022;21(1):331-6.
- 35 576 71. Meirte J, Moortgat P, Anthonissen M, Maertens K, Lafaire C, De Cuyper L, et al. Short-term
36 577 effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an
37 578 experimental study. *Burns Trauma.* 2016;4:27-.
- 38 579 72. Nedelec B, Correa JA, de Oliveira A, LaSalle L, Perrault I. Longitudinal burn scar
39 580 quantification. *Burns.* 2014;40(8):1504-12.
- 40 581 73. Nedelec B, Correa JA, Rachelska G, Armour A, Lasalle L. Quantitative measurement of
41 582 hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res.* 2008;29(3):501-11.
- 42 583 74. Nedelec B, Couture M-A, Calva V, Poulin C, Chouinard A, Shashoua D, et al. Randomized
43 584 controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns.*
44 585 2019;45(1):128-39.
- 45 586 75. Nedelec B, LaSalle L, de Oliveira A, Correa JA. Within-patient, single-blinded, randomized
46 587 controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the
47 588 treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res.* 2020;41(4):761-9.
- 48 589 76. Reinholz M, Guertler A, Schwaiger H, Poetschke J, Gauglitz GG. Treatment of keloids using
49 590 5-fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating
50 591 therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol.*
51 592 2020;34(10):2436-44.
- 52
53
54
55
56
57
58
59
60

- 1
2
3 593 77. Reinholz M, Schwaiger H, Poetschke J, Epple A, Ruzicka T, Von Braunmühl T, et al. Objective
4 594 and subjective treatment evaluation of scars using optical coherence tomography, sonography,
5 595 photography, and standardised questionnaires. *Eur J Dermatol.* 2017;26(6):599-608.
- 6 596 78. Schwaiger H, Reinholz M, Poetschke J, Ruzicka T, Gauglitz G. Evaluating the therapeutic
7 597 success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive
8 598 objective measures. *Dermatol Surg.* 2018;44(5):635-44.
- 9 599 79. Soykan EA, Butzelaar L, de Kroon TL, Beelen RHJ, Ulrich MMW, van der Molens ABM, et al.
10 600 Minimal extracorporeal circulation (MECC) does not result in less hypertrophic scar formation as
11 601 compared to conventional extracorporeal circulation (CECC) with dexamethasone. *Perfusion.*
12 602 2014;29(3):249-59.
- 13 603 80. Timar-Banu O, Beaugregard H, Tousignant J, Lassonde M, Harris P, Viau G, et al. Development
14 604 of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scars in
15 605 humans. *Wound Repair Regen.* 2001;9(2):123-32.
- 16 606 81. Van den Kerckhove E, Stappaerts K, Fieuws S, Laperre J, Massage P, Flour M, et al. The
17 607 assessment of erythema and thickness on burn related scars during pressure garment therapy as a
18 608 preventive measure for hypertrophic scarring. *Burns.* 2005;31(6):696-702.
- 19 609 82. Van den Kerckhove E, Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated
20 610 measurements on post-burn scars with Dermascan C. *Skin Res Technol.* 2003;9(1):81-4.
- 21 611 83. van der Veer WM, Ferreira JA, de Jong EH, Molema G, Niessen FB. Perioperative conditions
22 612 affect long-term hypertrophic scar formation. *Ann Plast Surg.* 2010;65(3):321-5.
- 23 613 84. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix.
24 614 *Burns.* 2008;35(3):352-5.
- 25 615 85. Lee SY, Cho YS, Kim L, Joo SY, Seo CH. The Intra-rater reliability and validity of
26 616 ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns.* 2022.
- 27 617 86. Agabalyan NA, Su S, Sinha V, Gabriel V. Evaluating high frequency ultrasonography for the
28 618 non-invasive measurement of human scarring. *J Burn Care Res.* 2016;37.
- 29 619 87. Anthonissen M, Meirte J, Moortgat P, Temmerman S, Lafaire C, De Cuyper L, et al. Intrarater
30 620 and interrater reliability of an open 22MHz ultrasound scanning system to assess thickness and
31 621 density of burn scars. *Ann Burns Fire Disasters.* 2015;28.
- 32 622 88. Bajouri A, Kajoor AS, Fallah N, Latifi NA, Ghasimi M, Bagheri T, et al. Autologous human
33 623 stromal vascular fraction injection in post-burn hypertrophic scar: A double-blinded placebo-
34 624 controlled clinical trial. *Bioimpacts.* 2018;8:37-8.
- 35 625 89. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and
36 626 diagnostics. *J Dermatol Nurses Assoc.* 2020;12(2).
- 37 627 90. Bezugly A, Potekae N. In vivo skin morphology monitoring of patients with acne, scars and
38 628 dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol.* 2014;41:4.
- 39 629 91. Blome-Eberwein S, Pagella P, Boorse D, Gogal C. Treatment of hypertrophic burn scars with
40 630 different laser modalities. *Lasers Surg Med.* 2014;46:6-7.
- 41 631 92. Cho J, Choi J, Hur J, Ko J, Seo D, Lee J, et al. The effect of CO2 fractional laser (pixel®) on
42 632 hypertrophic burn scars. *J Burn Care Res.* 2012;33(2):S132.
- 43 633 93. Cooper LE, Bohan PK, Hatem VD, Carlsson AH, Cancio LC, Chan RK. Analysis of the utility of
44 634 CO2 and pulse-dye lasers in the treatment of hypertrophic burn scars. *J Burn Care Res.*
45 635 2021;42(Supplement_1):S28-S9.
- 46 636 94. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, Couture M-A, Réadaptation M, Calva V, et al.
47 637 Objective quantification of hypertrophic scar and donor scar between 2 to 7 months post-burn
48 638 injury. *J Burn Care Res.* 2022;43:S103.
- 49 639 95. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, Bassiouny DA, Fawzy MM.
50 640 Ultrasound biomicroscopy in the diagnosis of skin diseases. *Eur J Dermatol.* 2007;17(6):469-74.
- 51 641 96. George R, Siordia H, Buhler J, Thompson S, Cancio L, Chan R. The use of high frequency
52 642 ultrasound to monitor treatment of hypertrophic burn scars with fractionated ablative CO2 laser
53 643 therapy. *J Burn Care Res.* 2019;40(Supplement_1):S135-S.

- 1
2
3 644 97. Jang KU, Lee JY, Choi JS, Seo CH. 5 FU and triamcinolone injection to the hypertrophic scar
4 645 were compared. *Burns*. 2009;35:S41-S2.
- 5 646 98. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-
6 647 monitored suit in the management of post-burn hypertrophic scar: A clinical controlled study with
7 648 objective assessment. *J Burn Care Res*. 2016;37:S199.
- 8 649 99. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case
9 650 review. *J Burn Care Res*. 2011;32:S169-S.
- 10 651 100. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and
11 652 related research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns)*. 2010;26(6):411-5.
- 12 653 101. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the
13 654 efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult burn
14 655 patients. *J Am Acad Dermatol*. 2017;76(6):AB212-AB.
- 15 656 102. Moortgat P, Vanhullebusch T, Anthonissen M, Meirte J, Lafaire C, De Cuyper L, et al. Tension
16 657 reducing taping as a mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot
17 658 study. *Wound Repair Regen*. 2020;28(2):A21.
- 18 659 103. Nedelec B, Couture M, Calva V, Chouinard A, Shashoua D, Gauthier N, et al. Randomized
19 660 controlled trial of the immediate and long-term effect of massage on adult postburn scar. *J Burn
20 661 Care Res*. 2018;39(suppl_1):S57-S.
- 21 662 104. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report.
22 663 *Wound Repair Regen*. 2018;26(2):A28-A.
- 23 664 105. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res*.
24 665 2011;32:S167-S.
- 25 666 106. Siwy KG, Lee K, Donelan MB, Anderson RR, Miletta NR. Fractionated CO2 laser and burn scar
26 667 contractures: Evaluation of post treatment scar function and appearance. *J Burn Care Res*.
27 668 2016;37:S202-S.
- 28 669 107. Tu P, Wang Z-G, Zhang Q-X, You Y-F. High frequency ultrasound in dynamic observation on
29 670 effect of local injection with diprosan for treating pathological scar. *Chinese Journal of
30 671 Interventional Imaging and Therapy*. 2014;11(4):217-20.
- 31 672 108. Ud-Din S, Foden P, Douglas M, Mazhari M, Al-Habba S, Baguneid M, et al. A double-blind
32 673 randomized controlled trial demonstrates for the first time evidence for the role of topical
33 674 epigallocatechin-3-gallate in reducing angiogenesis, inflammation, and skin thickness in human skin
34 675 scarring: A noninvasive, morphological and immu. *Wound Repair and Regeneration*. 2017;25(4):A3.
- 35 676 109. Ud-Din S, Foden P, Mazhari M, Al-Habba S, Baguneid M, Bayat A. Histomorphologic assessment
36 677 of noninvasive quantitative imaging in progression of cutaneous healing in human skin: Dynamic
37 678 optical coherence tomography versus high frequency ultrasound. *Wound Repair Regen*.
38 679 2017;25(4):A3-A4.
- 39 680 110. Ud-Din S, Foden P, M M, Samer A, Baguneid M, Bayat A. Quantitative index for skin fibrosis:
40 681 Combined optical coherence tomography with ultrasound validated by histology and
41 682 immunohistochemistry. *Wound Repair Regen*. 2018;26(4):A11-A2.
- 42 683 111. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers
43 684 Med Sci*. 2017;33(3):497-501.
- 44 685 112. Alsharnoubi J, Shoukry KE-S, Fawzy MW, Mohamed O. Evaluation of scars in children after
45 686 treatment with low-level laser. *Lasers Med Sci*. 2018;33(9):1991-5.
- 46 687 113. Berry RB, Tan OT, Cooke ED, Gaylarde PM, Bowcock SA, Lamberty BGH, et al.
47 688 Transcutaneous oxygen tension as an index of maturity in hypertrophic scars treated by
48 689 compression. *Br J Plast Surg*. 1985;38(2):163-73.
- 49 690 114. Blome-Eberwein S, Roarabaugh C, Gogal C, Eid S. Exploration of nonsurgical scar
50 691 modification options: Can the irregular surface of matured mesh graft scars be smoothed with
51 692 microdermabrasion? *J Burn Care Res*. 2012;33(3):e133-40.
- 52 693 115. Chan HH, Wong DSY, Ho WS, Lam LK, Wei W. The use of pulsed dye laser for the prevention
53 694 and treatment of hypertrophic scars in Chinese persons. *Dermatol Surg*. 2004;30(7):987-94.

- 1
2
3 695 116. Cheng W, Saing H, Zhou H, Han Y, Peh W, Tam PKH. Ultrasound assessment of scald scars in
4 696 Asian children receiving pressure garment therapy. *J Pediatr Surg*. 2001;36(3):466-9.
- 5 697 117. Cho YS, Jeon JH, Hong A, Yang HT, Yim H, Cho YS, et al. The effect of burn rehabilitation
6 698 massage therapy on hypertrophic scar after burn: A randomized controlled trial. *Burns*.
7 699 2014;40(8):1513-20.
- 8 700 118. Danin A, Georgesco G, Le Touze A, Penaud A, Quignon R, Zakine G. Assessment of burned
9 701 hands reconstructed with Integra® by ultrasonography and elastometry. *Burns*. 2012;38(7):998-
10 702 1004.
- 11 703 119. Engrav LH, Heimbach DM, Rivara FP, Moore ML, Wang J, Carrougher GJ, et al. 12-Year
12 704 within-wound study of the effectiveness of custom pressure garment therapy. *Burns*.
13 705 2010;36(7):975-83.
- 14 706 120. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of
15 707 postburn hypertrophic scar: A preliminary study. *Burns*. 1997;23(1):S12-S8.
- 16 708 121. Issler-Fisher AC, Fisher OM, Smialkowski AO, Li F, van Schalkwyk CP, Haertsch P, et al.
17 709 Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective
18 710 short-term outcome analysis of a prospective treatment cohort. *BURNS*. 2016;43(3):573-82.
- 19 711 122. Katz SM, Frank DH, Leopold GR, Wachtel TL. Objective measurement of hypertrophic burn
20 712 scar: A preliminary study of tonometry and ultrasonography. *Ann Plast Surg*. 1985;14(2):121-7.
- 21 713 123. Kemp Bohan PM, Cooper LE, Lu KN, Raper DM, Batchinsky M, Carlsson AH, et al.
22 714 Fractionated ablative carbon dioxide laser therapy decreases ultrasound thickness of hypertrophic
23 715 burn scar: A prospective process improvement initiative. *Ann Plast Surg*. 2020;86(3):273-8.
- 24 716 124. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS)
25 717 in objective scar evaluation. *Burns*. 2005;31(4):445-52.
- 26 718 125. Miletta N, Siwy K, Hivnor C, Clark J, Shofner J, Zurakowski D, et al. Fractional ablative laser
27 719 therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and
28 720 subjective outcomes. *Ann Surg*. 2021;274(6):E574-E80.
- 29 721 126. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical
30 722 silicone gel and pressure garment therapy for burn scar prevention and management in children 12-
31 723 months postburn: A parallel group randomised controlled trial. *Clin Rehabil*. 2021;35(8):1126-41.
- 32 724 127. Wiseman J, Ware RS, Simons M, McPhail S, Kimble R, Dotta A, et al. Effectiveness of topical
33 725 silicone gel and pressure garment therapy for burn scar prevention and management in children: a
34 726 randomized controlled trial. *Clin Rehabil*. 2020;34(1):120-31.
- 35 727 128. Wood FM, Currie K, Backman B, Cena B. Current difficulties and the possible future
36 728 directions in scar assessment. *Burns*. 1996;22(6):455-8.
- 37 729 129. Yim H, Cho YS, Seo CH, Lee BC, Ko JH, Kim D, et al. The use of AlloDerm on major burn
38 730 patients: AlloDerm prevents post-burn joint contracture. *Burns*. 2009;36(3):322-8.
- 39 731 130. Żądkowski T, Nachulewicz P, Mazgaj M, Woźniak M, Cielecki C, Wiczorek AP, et al. A new
40 732 CO2 laser technique for the treatment of pediatric hypertrophic burn scars: An observational study.
41 733 *Medicine (Baltimore)*. 2016;95(42):e5168-e.
- 42 734 131. Cho J, Jang Y, Hur J, Ko J, Seo D, Lee J, et al. Effectiveness of emu oil on burn scar. *J Burn Care*
43 735 *Res*. 2012;33(2):S71.
- 44 736 132. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn*
45 737 *Care Res*. 2018;39(suppl_1):S219-S20.
- 46 738 133. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes
47 739 of burn scars treated with laser therapy. *J Burn Care Res*. 2016;37:S106.
- 48 740 134. Kim SK, Park JM, Jang YH, Son YH. Management of hypertrophic scar after burn wound using
49 741 microneedling procedure (dermastamp). *Burns*. 2009;35:S37-S.
- 50 742 135. Zuccaro J, Fish JS, Kelly C. The effectiveness of laser therapy for hypertrophic burn scars in
51 743 pediatric patients: A prospective investigation. *Journal of Burn Care and Research*. 2021;42(S1):S24.
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58
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2
3 744 136. Alshehari A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid
4 745 injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars. Archives
5 746 of the Balkan Medical Union. 2015;50(3):364-6.
- 6 747 137. Chang C-S, Wallace CG, Hsiao Y-C, Chang C-J, Chen PK-T. Botulinum toxin to improve results
7 748 in cleft lip repair: A double-blinded, randomized, vehicle-controlled clinical trial. PLoS One.
8 749 2014;9(12):e115690-e.
- 9 750 138. Fraccalvieri M, Sarno A, Gasperini S, Zingarelli E, Fava R, Salomone M, et al. Can single use
10 751 negative pressure wound therapy be an alternative method to manage keloid scarring? A
11 752 preliminary report of a clinical and ultrasound/colour-power-doppler study. Int Wound J.
12 753 2013;10(3):340-4.
- 13 754 139. Lacarrubba F, Patania L, Perrotta R, Stracuzzi G, Nasca MR, Micali G. An open-label pilot
14 755 study to evaluate the efficacy and tolerability of a silicone gel in the treatment of hypertrophic scars
15 756 using clinical and ultrasound assessments. J Dermatolog Treat. 2008;19(1):50-3.
- 16 757 140. Li K, Nicoli F, Cui C, Xi WJ, Al-Mousawi A, Zhang Z, et al. Treatment of hypertrophic scars and
17 758 keloids using an intralesional 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive
18 759 technique. Sci Rep. 2020;10(1):21694-.
- 19 760 141. Li N, Yang L, Cheng J, Han J, Yang X, Zheng Z, et al. A retrospective study to identify the
20 761 optimal parameters for pulsed dye laser in the treatment of hypertrophic burn scars in Chinese
21 762 children with Fitzpatrick skin types III and IV. Lasers Med Sci. 2021;36(8):1671-9.
- 22 763 142. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone
23 764 gel dressing and pressure therapy on posttraumatic hypertrophic scars. J Burn Care Res.
24 765 2010;31(3):448-57.
- 25 766 143. Nicoletti G, Brenta F, Blevé M, Pellegatta T, Malovini A, Faga A, et al. Long-term in vivo
26 767 assessment of bioengineered skin substitutes: a clinical study. J Tissue Eng Regen Med.
27 768 2015;9(4):460-8.
- 28 769 144. Niessen FB, Spauwen PHM, Robinson PH, Fidler, Kon M. The use of silicone occlusive
29 770 sheeting (Sil-K) and silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation.
30 771 Plast Reconstr Surg. 1998;102(6):1962-72.
- 31 772 145. Zhidong X, Haixia L, Chao L, Yongrong L. Wavelet Bilateral Filter Algorithm-Based High-
32 773 Frequency Ultrasound Image Analysis on Effects of Skin Scar Repair. Scientific programming.
33 774 2021;2021.
- 34 775 146. Avetnikov DS, Bukhanchenko OP, Skikevich MG, Aipert VV, Boyko IV. Features of ultrasound
35 776 diagnostics of postoperative hypertrophic and keloid scars. The New Armenian Medical Journal.
36 777 2018;12(4):43-8.
- 37 778 147. Ge X, Sun Y, Lin J, Zhou F, Yao G, Su X. Effects of multiple modes of UltraPulse fractional CO2
38 779 laser treatment on extensive scarring: a retrospective study. Lasers Med Sci. 2021;37(3):1575-82.
- 39 780 148. Guo R, Xiang X, Wang L, Zhu B, Cheng S, Qiu L. Quantitative assessment of keloids using
40 781 ultrasound shear wave elastography. Ultrasound Med Biol. 2020;46(5):1169-78.
- 41 782 149. Lobos N, Wortsman X, Valenzuela F, Alonso F. Color Doppler ultrasound assessment of
42 783 activity in keloids. Dermatol Surg. 2017;43(6):817-25.
- 43 784 150. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
44 785 scarring. Lasers Surg Med. 2012;44:61.
- 45 786 151. Blome-Eberwein S, Blaine C, Gogal C, Eid S, Foltz C. Fractional Er:Glass photothermolysis
46 787 laser therapy to treat hypertrophic scarring. J Burn Care Res. 2011;32:S95.
- 47 788 152. Timina I, Sharobaro V, Trykova I. A potential of the high-frequency ultrasonic investigation in
48 789 the differential diagnostics of scars. Ultraschall Med. 2013;34(S 01).
- 49 790 153. Zuccaro J, Kelly C, Perez M, Doria A, Fish JS. The effectiveness of laser therapy for
50 791 hypertrophic burn scars in pediatric patients: A prospective investigation. J Burn Care Res.
51 792 2021;42(5):847-56.
- 52 793 154. Zuccaro J, Perez M, Mohanta A, Fish J, Doria A. Elastography-Based Quantification of Burn
53 794 Scar Stiffness. J Burn Care Res. 2019;40(Supplement_1):S215-S.

- 1
2
3 795 155. Issler-Fisher AC, Fisher OM, Smialkowski AO, Li F, van Schalkwyk CP, Haertsch P, et al.
4 796 Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective
5 797 short-term outcome analysis of a prospective treatment cohort. *Burns*. 2017;43(3):573-82.
6 798 156. Jameson JL, Longo DL. Precision medicine — personalized, problematic, and promising. *N*
7 799 *Engl J Med*. 2015;372(23):2229-34.
8 800 157. Robinson T, Bailey C, Morris H, Burns P, Melder A, Croft C, et al. Bridging the research-
9 801 practice gap in healthcare: A rapid review of research translation centres in England and Australia.
10 802 *Health research policy and systems*. 2020;18(1):1-117.
11 803 158. Wynn T. Cellular and molecular mechanisms of fibrosis. In: Altmann DM, Douek DC, editors.
12 804 Chichester, UK: John Wiley & Sons, Ltd.; 2008. p. 199-210.
13 805 159. Willenborg S, Eming SA. Cellular networks in wound healing. *Science*. 2018;362(6417):891-2.
14 806 160. Kwan P, Desmouliere A, Tredget EE. Molecular and cellular basis of hypertrophic scarring. In:
15 807 Herndon DN, editor. *Total Burn Care*. 5 ed. China: Elsevier; 2018. p. 455-65.
16 808 161. Hellström M, Hellström S, Engström-Laurent A, Bertheim U. The structure of the basement
17 809 membrane zone differs between keloids, hypertrophic scars and normal skin: A possible background
18 810 to an impaired function. *J Plast Reconstr Aesthet Surg*. 2014;67(11):1564-72.
19 811 162. Nicolescu AC, Ionescu S, Ancuta I, Popa V-T, Lupu M, Soare C, et al. Subepidermal Low-
20 812 Echogenic Band—Its Utility in Clinical Practice: A Systematic Review. *Diagnostics (Basel)*.
21 813 2023;13(5):970.
22 814 163. Laverde-Saad A, Simard A, Nassim D, Jfri A, Alajmi A, O'Brien E, et al. Performance of
23 815 ultrasound for identifying morphological characteristics and thickness of cutaneous basal cell
24 816 carcinoma: A systematic review. *Dermatology*. 2022;1-19.
25 817 164. Russell FM, Herbert A, Ferre RM, Zakeri B, Echeverria V, Peterson D, et al. Development and
26 818 implementation of a point of care ultrasound curriculum at a multi-site institution. *Ultrasound J*.
27 819 2021;13(1):9-.
28 820 165. Perry DM, McGrouther DA, Bayat A. Current Tools for Noninvasive Objective Assessment of
29 821 Skin Scars. *Plastic and Reconstructive Surgery*. 2010;126(3):912-23.
30 822 166. Powers PS, Sarkar S, Goldgof DB, Cruse CW, Tsap LV. Scar assessment: current problems and
31 823 future solutions. *The Journal of burn care & rehabilitation*. 1999;20(1 Pt 1):54-60.
32 824 167. Nguyen DQA, Potokar T, Price P. A review of current objective and subjective scar
33 825 assessment tools. *Journal of Wound Care*. 2008;17(3):101-6.
34 826 168. Li H, Furst DE, Jin H, Sun C, Wang X, Yang L, et al. High-frequency ultrasound of the skin in
35 827 systemic sclerosis: an exploratory study to examine correlation with disease activity and to define
36 828 the minimally detectable difference. *Arthritis Res Ther*. 2018;20(1):181-.
37 829 169. Santiago T, Santos E, Ruaro B, Lepri G, Green L, Wildt M, et al. Ultrasound and elastography
38 830 in the assessment of skin involvement in systemic sclerosis: A systematic literature review focusing
39 831 on validation and standardization – WSF Skin Ultrasound Group. *Semin Arthritis Rheum*.
40 832 2022;52:151954-.

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6
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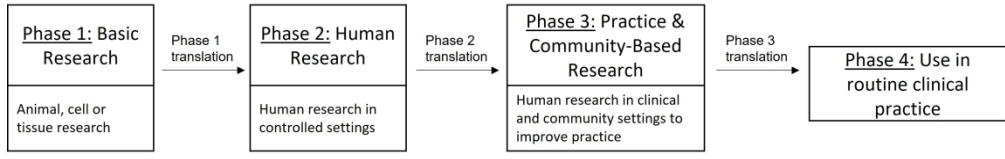


Figure 1: Research to clinical practice pipeline.

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Supplementary Box 1. Full search strategy for Ovid MEDLINE.

((ultrasound.ti,ab. OR ultra sound.ti,ab. OR sonograph*.ti,ab. OR ultrasonic.ti,ab. OR high-frequency.ti,ab. OR high frequency.ti,ab. OR hfus.ti,ab. OR ultrasonog*.ti,ab. OR exp Ultrasonography/)

AND

((skin.ti,ab. OR epiderm*.ti,ab. OR derm*.ti,ab. OR cutaneous.ti,ab OR scar*.ti,ab OR keloid*.ti,ab OR cicatri*.ti,ab OR exp Skin/ OR exp Dermatology/ OR exp Cicatrix/)

AND

(thickness*.ti,ab. OR thicken*.ti,ab. OR depth.ti,ab. OR volume.ti,ab. OR height.ti,ab. OR vancouver scar scale.ti,ab)

ADJ10

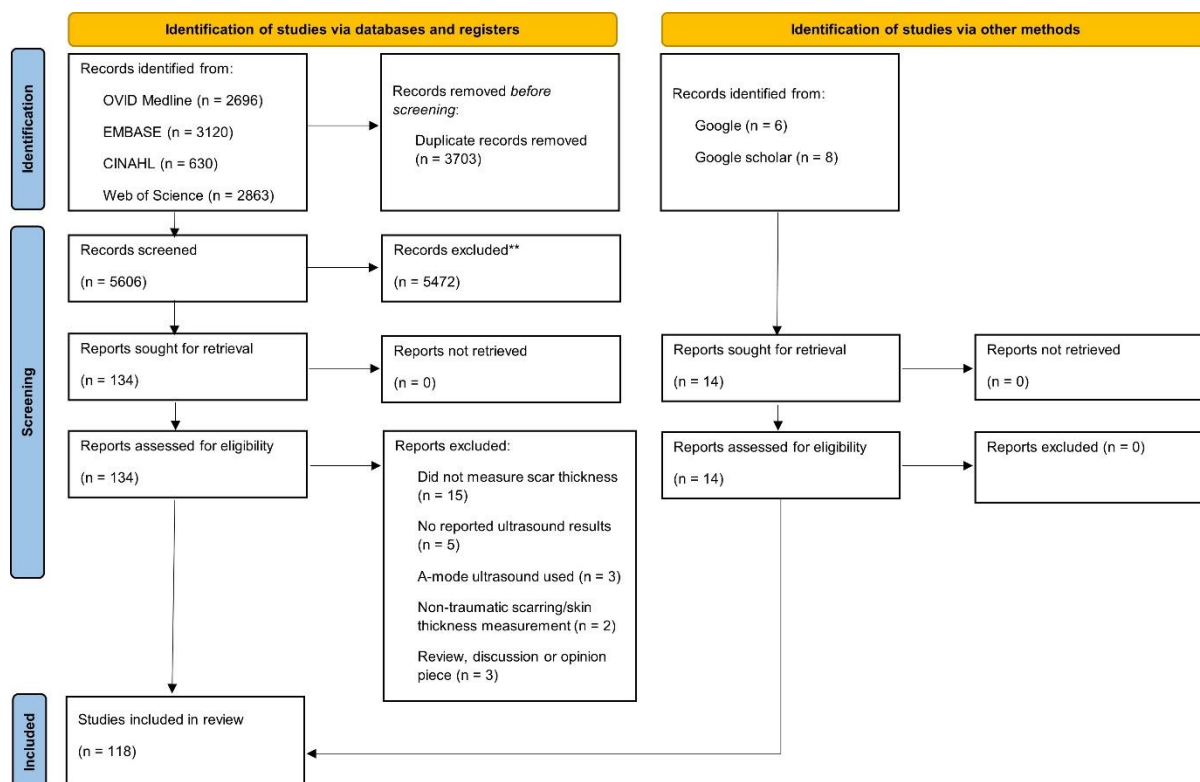
(measure*.ti,ab. OR quantif*.ti,ab. OR calculat*.ti,ab OR estimat*.ti,ab OR assess*.ti,ab. OR determin*.ti,ab. OR evaluat*.ti,ab OR imag*.ti,ab OR exam*.ti,ab)))

NOT (exp animals/ NOT exp humans/)

Legend: ab, abstract (searches the abstract of the publication); adj10, adjacency (search terms must be located within 10 words of one another); exp, explode (used to include all subheadings when searching MeSH headings); ti, title (searches the title of the publication)

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Supplementary Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram for this study.



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Supplementary Table 1: Extraction categories and fields

Extraction category	Extraction field	
Publication details	First author	
	Year of publication	
	Title of publication	
	Country (first author)	
	Country (study)	
	Country (recruited)	
	Publication type (e.g., peer-reviewed journal article, abstract)	
	Journal name	
	Corresponding author contact details	
	Funding source (e.g., commercial, non-commercial)	
	Use of scar thickness measurement (e.g., longitudinal study, response to treatment)	
	Study details	Aim/objective
		Research questions
		Target population/topics
Study design (e.g., RCT, mixed methods)		
Data and analysis (i.e., statistical methods)		
Removal of scar treatments before ultrasound measurement (e.g., length of time before measurement)		
Reason for measurement (e.g., research, clinical initiative)		
Inclusion/exclusion criteria		
Dates of data collection		
Ultrasound thickness collection methods (e.g., direct collection, collected from medical records)		
Contralateral/unaffected/comparator skin thickness measurement		
Other methods used		
Use of guidelines/frameworks for measurement methods		
How previously published methods/guidelines were used		
Research pipeline stage		
Participant details		Setting (e.g., inpatient/outpatient clinics)
	Scar type (e.g., burn scar, surgical scar)	
	Number of participants	
	Population type (e.g., adult/paediatric)	
	Gender ratio	
Ultrasound methods	Patient involvement in thickness determination	
	How patients were involved in thickness determination	
	Ultrasound mode	
	Device name and manufacturer	
	Frequency used	
	Number of measurements taken	
	What did researchers report they were measuring (e.g., fibrosis, oedema)	
	Anatomical locations/functional measurement units measured	
	Patient orientation	
	Ultrasound transducer orientation	
Methods used to prevent skin compression		
Psychometric properties*	Measurement site relocation strategies	
	Type of skin measurement (i.e., epidermis/dermis/combined)	
	Measurer training	
	Reliability	
Feasibility† outcomes	Measurement error	
	Time taken for measurement	

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1	
2	
3	Availability of measurement method
4	Ease of administration
5	Number of steps required
6	Number of people required to conduct measurements
7	Considerations for special populations
8	Implementation [‡] outcomes
9	Acceptability
10	Adoption
11	Appropriateness
12	Cost
13	Feasibility
14	Fidelity
15	Sustainability
16	Strengths and limitations of
17	measurement methods
18	Strengths
19	Limitations
20	Barriers
21	Enablers
22	Findings
23	Ultrasound-related findings

*Psychometric properties as outlined in the COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments¹

†Feasibility outcomes as per Prinsen *et al.*²

‡Implementation outcomes as per Proctor *et al.*³

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Supplementary Table 2. Characteristics of records included in this review. Studies are listed alphabetically by author within the translational pipeline phase.

First Author (year)	Country of Publication	Funding Sources	Sample Size (n)	Population Type	Scar Aetiology	Translational Pipeline Phase*
<i>Journal articles</i>						
Agabalyan (2017)	Canada	Non-commercial	10	Adult	Not specified	2
Alsharnoubi (2018)	Egypt	No funding	15	Paediatric	Burn	2
Alsharnoubi (2018)	Egypt	Not reported	15	Paediatric	Burn	2
Alshehari (2015)	Egypt	Not reported	30	Not reported	Mixed	2
Blome-Eberwein (2012)	United States	Non-commercial	16	Paediatric & adult	Burn	2
Blome-Eberwein (2016)	United States	Not reported	36	Adult	Not specified	2
Blome-Eberwein (2019)	United States	Non-commercial	19	Adult	Burn	2
Cai (2019)	China	Non-commercial	51	Adult	Not specified	2
Candy (2010)	Hong Kong	Not reported	17	Adult	Not specified	2
Chan (2004)	China	Non-commercial	56	Paediatric & adult	Burn	2
Chang (2014)	Taiwan	Non-commercial	60	Paediatric & adult	Surgical (cleft lip repair)	2
Cho (2014)	Korea	Non-commercial	146	Not reported	Burn	2
Deng (2019)	China	Not reported	20	Adult	Not specified	2
Deng (2021)	China	No funding	31	Adult	Not specified	2
Deng (2021)	Hong Kong and China	Non-commercial	45	Adult	Not specified	2
Dunkin (2007)	England	Non-commercial	113	Adult	Surgical (dermal scratch)	2
Elrefaie (2020)	Not specified	Not reported	22	Paediatric & adult	Not specified	2
Fabbrocini (2016)	Not specified	Not reported	20	Adult	Mixed	2
Fracalvieri (2011)	Italy	No funding	5	Adult	Mixed	2
Fracalvieri (2013)	Italy	Not reported	3	Paediatric & adult	Mixed	2
Gee Kee (2016)	Australia	Commercial	43	Paediatric	Burn	2
Issler-Fisher (2021)	Australia	Commercial	187	Adult	Burn	2
Joo (2020)	Korea	Non-commercial	48	Adult	Not specified	2
Lacarrubba (2008)	Not specified	Not reported	8	Paediatric & adult	Mixed	2

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1							
2							
3	Lau (2005)	Hong Kong	Not reported	100	Paediatric & adult	Burn	2
4	Lee (2019)	United Kingdom	Non-commercial	55	Adult	Burn	2
5	Lee (2020)	United Kingdom	Non-commercial	55	Adult	Burn	2
6	Li (2013)	China	Non-commercial	7	Adult	Burn	2
7	Li (2020)	China	Not reported	21	Paediatric & adult	Mixed	2
8	Li (2021)	China	Non-commercial	165	Paediatric	Mixed	2
9	Li (2021)	China	Non-commercial	105	Adult	Burn	2
10	Li (2021)	China	Non-commercial	105	Adult	Burn	2
11	Li-Tsang (2006)	Not specified	Non-commercial	45	Adult	Not specified	2
12	Li-Tsang (2010)	China	Non-commercial	104	Paediatric & adult	Mixed	2
13	Mamdouh (2021)	Egypt	Not reported	40	Adult	Not specified	2
14	Meirte (2016)	Belgium	Non-commercial	9	Adult	Burn	2
15	Miletta (2021)	United States	Non-commercial	29	Paediatric & adult	Burn	2
16	Nedelec (2019)	Canada	Non-commercial	70	Adult	Burn	2
17	Nedelec (2020)	Canada	Non-commercial	51	Adult	Burn	2
18	Nicoletti (2015)	Italy	Not reported	27	Paediatric & adult	Surgical (scar reconstruction)	2
19							
20							
21	Niessen (1998)	The Netherlands	Commercial & Non-commercial	145	Paediatric & adult	Surgical (breast reduction)	2
22							
23							
24	Reinholz (2020)	Germany	No funding	25	Adult	Mixed	2
25	Schwaiger (2018)	Germany	No funding	15	Adult	Mixed	2
26	van den Kerckhove (2005)	Belgium	Not reported	60	Adult	Burn	2
27							
28	van der Veer (2010)	The Netherlands	Non-commercial	44	Adult	Surgical (cardiothoracic surgery)	2
29							
30							
31							
32	Wang (2009)	China	Non-commercial	22	Adult	Burn	2
33	Wiseman (2020, 2021)	Australia	Commercial & Non-commercial	153	Paediatric	Burn	2
34							
35	Xuan (2021)	Not specified	Not reported	72	Not reported	Not specified	2
36	Yim (2010)	Korea	No funding	31	Paediatric & adult	Burn	2
37	Zadkowski (2016)	Not specified	Not reported	47	Paediatric	Burn	2
38	Avetikov (2018)	Not specified	Not reported	50	Paediatric & adult	Not specified	3
39							
40							
41							
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1							
2							
3	Chae (2016)	Korea	Non-commercial	23	Adult	Not specified	3
4	Cheng (2001)	Hong Kong	Not reported	58	Paediatric	Burn	3
5	Danin (2012)	France	Not reported	22	Paediatric & adult	Burn	3
6	Fong (1997)	Not specified	Not reported	16	Paediatric & adult	Burn	3
7	Gankande (2014)	Australia	Non-commercial	30	Adult	Burn	3
8	Ge (2022)	China	Not reported	21	Paediatric & adult	Mixed	3
9	Guo (2020)	China	Non-commercial	87	Paediatric & adult	Not specified	3
10	Huang (2017)	Taiwan	Not reported	1	Adult	Burn	3
11	Huang (2020)	China	Non-commercial	43	Adult	Not specified	3
12	Huang (2021)	Taiwan	Not reported	5	Adult	Burn	3
13	Issler-Fisher (2017)	Australia	No funding	47	Paediatric & adult	Burn	3
14	Issler-Fisher (2020)	Australia	No funding	78	Adult	Burn	3
15	Katz (1985)	United States	Not reported	4	Not reported	Burn	3
16	Kemp Bohan (2021)	United States	No funding	21	Not reported	Burn	3
17	Kim (2018)	Not specified	Not reported	148	Not reported	Burn	3
18	Li (2018)	China	Non-commercial	34	Adult	Burn	3
19	Li-Tsang (2005)	China	Non-commercial	101	Adult	Surgical	3
20						(orthopaedic	
21						surgery)	
22							
23							
24							
25	Lobos (2017)	Not specified	Not reported	35	Paediatric & adult	Not specified	3
26	Nedelec (2008)	Canada	Non-commercial	32	Adult	Burn	3
27	Nedelec (2014)	Not specified	Non-commercial	46	Adult	Burn	3
28	Reinholz (2016)	Not specified	Commercial	8	Adult	Not specified	3
29	Simons (2017)	Australia	Non-commercial	49	Paediatric	Burn	3
30	Soykan (2014)	The Netherlands	Non-commercial	87	Adult	Surgical	3
31						(cardiothoracic	
32						surgery)	
33							
34	Timar-Banu (2011)	Canada	Non-commercial	30	Adult	Mixed	3
35	Ud-Din (2019)	United Kingdom	Non-commercial	62	Adult	Not specified	3
36	van den Kerckhove	Not specified	Not reported	6	Adult	Burn	3
37	(2003)						
38							
39							
40							
41							
42							
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1							
2							
3	Wang (2010)	Australia	Commercial & Non-commercial	21	Paediatric	Burn	3
4							
5	Wood (1996)	Not specified	Not reported	1	Paediatric	Burn	3
6	Yeol Lee (2022)	Korea	Non-commercial	16	Adult	Mixed	3
7							
8	Berry (1985)	Not specified	Commercial	16	Paediatric & adult	Burn	4
9	Engrav (2010)	Not specified	Commercial & Non-commercial	67	Paediatric & adult	Burn	4
10							
11	<i>Abstracts</i>						
12	Agabalyan (2016)	Not specified	Non-commercial	10	Not reported	Burn	2
13	Bajouri (2018)	Not specified	Not reported	20	Not reported	Burn	2
14	Blome-Eberwein (2011, 2012)	Not specified	Not reported	16	Paediatric & adult	Mixed	2
15							
16	Blome-Eberwein (2014)	Not specified	Not reported	66	Not reported	Burn	2
17	Cho (2012)	Not specified	Not reported	60	Paediatric & adult	Burn	2
18	Comstock (2018)	Not specified	Not reported	1	Adult	Burn	2
19	Cooper (2021)	Not specified	Not reported	25	Not reported	Burn	2
20	El-Zawhary (2007)	Not specified	Not reported	57	Not reported	Mixed	2
21	Jacobs (2016)	Not specified	Not reported	6	Paediatric & adult	Burn	2
22	Jang (2009)	Not specified	Not reported	20	Not reported	Not specified	2
23	Kim (2009)	Not specified	Not reported	5	Paediatric & adult	Burn	2
24	Li-Tsang (2010)	Not specified	Not reported	45	Not reported	Not specified	2
25	Li-Tsang (2011)	Not specified	Not reported	4	Not reported	Not specified	2
26	Maari (2017)	Not specified	Non-commercial	12	Not reported	Not specified	2
27	Moortgat (2020)	Not specified	Not reported	10	Not reported	Burn	2
28	Nedelec (2018)	Not specified	Not reported	60	Not reported	Burn	2
29	Peters (2018)	Not specified	Not reported	5	Not reported	Burn	2
30	Siwy (2016)	Not specified	Non-commercial	15	Not reported	Burn	2
31	Tu (2014)	Not specified	Not reported	59	Not reported	Not specified	2
32	Ud-Din (2017)	Not specified	Not reported	20	Not reported	Surgical (tissue biopsies)	2
33							
34	Anthonissen (2015)	Not specified	Not reported	N.R.	Not reported	Burn	3
35	Bezugly (2014)	Not specified	Not reported	103	Not reported	Mixed	3
36							
37							
38							
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1							
2							
3	Bezugly (2019)	Not specified	Not reported	438	Not reported	Not specified	3
4	Blome-Eberwein (2012)	Not specified	Not reported	19	Adult	Burn	3
5	Du (2006)	Not specified	Not reported	1	Adult	Burn	3
6	Edgear-Lacoursière	Canada	Not reported	44	Not reported	Burn	3
7	(2022)						
8	George (2019)	Not specified	Not reported	11	Not reported	Burn	3
9	Li (2016)	Not specified	Not reported	34	Not reported	Burn	3
10	Seo (2011)	Korea	Not reported	48	Not reported	Burn	3
11	Timina (2013)	Not specified	Not reported	49	Paediatric & adult	Not specified	3
12	Ud-Din (2017)	Not specified	Not reported	20	Not reported	Surgical (tissue biopsies)	3
13							
14	Ud-Din (2018)	Not specified	Not reported	62	Not reported	Surgical (tissue biopsies)	3
15							
16	Zuccaro (2019)	Canada	Not reported	13	Paediatric	Burn	3
17	Zuccaro (2021)	Not specified	Not reported	20	Paediatric	Burn	3
18	Zuccaro (2021)	Canada	Non-commercial	20	Paediatric	Burn	3
19	Cho (2012)	Not specified	Not reported	30	Not reported	Burn	4

Legend: Paediatric: measurement of patients under the age of 18; Adult: measurement of patients aged 18 years or older; N.R.: Not reported; Burn: scars caused by thermal, chemical or friction injury; Surgical: scars caused by surgical procedures (including biopsies); Mixed: participant scars caused by mixed trauma (e.g., burn and acne)

Footnotes: *Stage in the research to clinical practice translational pipeline, based on the Australian Government Department of Health and Aged Care⁴

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Supplementary Table 3. Measurement methods used in included records.

First Author (year)	Ultrasound Type	Ultrasound Frequency (MHz)	Measurement Parameters	Scar Characteristic Measured	Scar Relocation
<i>Journal articles</i>					
Agabalyan (2017)	High-frequency	20	Epidermal, dermal & combined	N.R.	Not relevant – single measurement
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis	N.R.
Alsharnoubi (2018)	Midrange ultrasound	N.R.	N.R.	Fibrosis [†]	N.R.
Alshehari (2015)	N.R.	N.R.	Maximum elevation above normal skin	N.R.	N.R.
Avetikov (2018)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Berry (1985)	N.R.	N.R.	N.R.	N.R.	N.R. [‡]
Blome- Eberwein (2012)	B-mode	N.R.	Combined epidermal & dermal [§]	N.R.	N.R. [‡]
Blome- Eberwein (2016)	High-frequency	50	N.R.	Fibrosis [†]	N.R. [‡]
Blome- Eberwein (2019)	High-frequency	35	Dermal	Fibrosis, hair follicle density	N.R.
Cai (2019)	High-frequency	50	Dermal	N.R.	N.R. [‡]
Candy (2010)	B-mode	N.R.	N.R.	N.R.	Scar boundaries traced
Chae (2016)	N.R.	N.R.	Combined epidermal & dermal	N.R.	Not relevant – single measurement
Chang (2014)	N.R.	12	N.R.	N.R.	N.R.

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1						
2						
3	Chan (2004)	N.R.	N.R.	N.R.	N.R.	Tracing
4	Cheng (2001)	B-mode	5-10	Combined epidermal & dermal	N.R.	Tracing & cutting out paper
5						Photographs
6						
7	Cho (2014)	High-frequency	7.5	N.R.	N.R.	N.R.
8	Danin (2012)	B-mode	20	Epidermal & dermal	N.R.	N.R.
9	Deng (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
10	Deng (2021)	Colour Doppler	4-15	Dermal	Fibrosis [†]	N.R.
11	Deng (2021)	B-mode	8-12	Epidermal & dermal	Fibrosis [†]	Photographs
12	Dunkin (2007)	High-frequency	N.R.	N.R.	Fibrosis & oedema [†]	Measurements taken at set
13						linear distances along scar
14						
15	Elrefaie (2020)	High-frequency	13	N.R.	Fibrosis & oedema [†]	N.R. [‡]
16						
17	Engrav (2010)	N.R.	N.R.	N.R.	N.R.	N.R.
18	Fabbrocini	N.R.	N.R.	N.R.	Fibrosis & oedema [†]	N.R. [‡]
19	(2016)					
20	Fong (1997)	B-mode	7.5	N.R.	Fibrosis [†]	Tracing
21	Fraccalvieri	High-frequency	7-10	N.R.	Fibrosis & oedema [†]	N.R.
22	(2013)		& 10-13			
23	Fraccalvieri	High-frequency	10-13	Combined epidermal & dermal	Fibrosis [†]	N.R.
24	(2011)					
25	Gankande	High-frequency	20	Combined epidermal & dermal	N.R.	Scar marked & photographed
26	(2014)					
27	Ge (2022)	N.R.	N.R.	N.R.	N.R.	N.R.
28	Gee Kee	B-mode	8-18	Combined epidermal & dermal	N.R.	Transducer in centre of
29	(2016)					original burn site where no
30						scar present
31						
32						
33	Guo (2020)	N.R.	2-15	Combined epidermal & dermal ^c	Fibrosis [†]	Thickest site on peripheral
34			& 4-15			regions
35	Huang (2017)	N.R.	N.R.	Combined epidermal & dermal	N.R.	Marked & linear
36						measurements from bony
37						landmarks
38						
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1						
2						
3	Huang (2021)	B-mode	5-12	N.R.	Oedema [†]	Not relevant – single measurement
4						
5	Huang (2020)	B-mode	5-12	Combined epidermal & dermal	N.R.	N.R.
6	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	Photograph & measurement of thickest area
7	(2021)					
8	Issler-Fisher	N.R.	N.R.	N.R.	N.R.	N.R.
9	(2020)					
10	Issler-Fisher	N.R.	N.R.	N.R.	Fibrosis [†]	Scar mapped with drawing
11	(2017)					Thickest area measured
12	Joo (2020)	N.R.	N.R.	N.R.	Fibrosis [†]	N.R.
13	Katz (1985)	B-mode	10	Combined epidermal & dermal	N.R.	N.R.
14	Kemp Bohan	High-frequency	12	N.R.	Fibrosis [†]	Tracing – thickest area & adjacent landmarks marked
15	(2021)					
16	Kim (2018)	N.R.	22	Combined epidermal & dermal	N.R.	Not relevant – single measurement
17						
18	Lacarrubba	B-mode	20	Combined epidermal & dermal	N.R.	N.R.
19	(2008)					
20	Lau (2005)	Tissue Ultrasound Palpation System	5 (burn) & 10 (surgical)	N.R.	N.R.	Tracing – most severe/prominent site
21						
22	Lee (2020)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Not relevant – single measurement
23						
24	Lee (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	Marked with pen
25	Li (2013)	High-frequency	12	Combined epidermal & dermal	Fibrosis [†]	Tracing
26	Li (2020)	N.R.	10	N.R.	Fibrosis [†]	N.R.
27	Li (2021)	High-frequency	20	N.R.	N.R.	Thickest area
28	Li (2021)	High-frequency	20	N.R. [§]	Fibrosis [†]	Thickest area
29	Li (2018)	N.R.	N.R.	Combined epidermal & dermal	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound Palpation System	N.R.	N.R.	N.R.	N.R.
31	(2005)					
32	Li-Tsang	B-mode	N.R.	N.R.	N.R.	N.R. [‡]
33	(2006)					
34						
35						
36						
37						
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1						
2						
3	Li-Tsang	B-mode	N.R.	N.R.	Fibrosis [†]	N.R.
4	(2010)					
5	Lobos (2017)	B-mode & colour	18	N.R.	Fibrosis [†]	Not relevant – single
6		Doppler				measurement
7	Mamdouh	High-frequency	N.R.	Combined epidermal & dermal [§]	Fibrosis [†]	N.R.
8	(2021)					
9	Meirte (2016)	High-frequency	22	Dermal	Fibrosis &	Marked with surgical pen, including boundaries of probe. Photograph of body position & probe location Tracing – worst scar
10				oedema [†]		
11	Miletta (2021)	N.R.	50	N.R.	Fibrosis [†]	
12	Nedelec (2014)	High-frequency	20	Combined epidermal & dermal	N.R.	
13						Tracing including notable
14						landmarks. Measurement site
15	Nedelec (2008)	High-frequency	20	Combined epidermal & dermal	N.R.	circled. Photograph
16						Tracing including notable
17						landmarks. Measurement site
18						circled. Photograph
19	Nedelec (2019)	High-frequency	20	Combined epidermal & dermal	Fibrosis &	Tracing. Hole cut over
20					oedema [†]	measurement area
21	Nedelec (2020)	High-frequency	20	Combined epidermal & dermal	N.R.	Photograph
22	Nicoletti	N.R.	22	Epidermis to fascia	N.R.	N.R.
23	(2015)					
24	Niessen (1998)	B-mode	N.R.	N.R.	Fibrosis &	3cm border marked with tape
25					oedema [†]	– measurements lateral
26	Reinholz	B-mode	11	Combined epidermal & dermal	Fibrosis &	N.R.
27	(2020)				oedema [†]	
28	Reinholz	B-mode	11	Combined epidermal & dermal [§]	Fibrosis &	N.R.
29	(2016)				oedema [†]	
30	Schwaiger	B-mode	11	N.R.	Fibrosis &	N.R.
31	(2018)				oedema [†]	
32	Simons (2017)	B-mode	8-18	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical
33						landmarks
34						
35						
36						
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1						
2						
3	Soykan (2014)	N.R.	3-9	N.R.	Fibrosis [†]	N.R.
4	Timar-Banu	High-frequency	20	Combined epidermal & dermal	Fibrosis [†]	N.R.
5	(2001)					
6	Ud-Din (2019)	High-frequency	50	Combined epidermal & dermal	Fibrosis	Defined anatomical location
7	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test sites marked.
8	Kerckhove					Thermoplastic splints created
9	(2003)					with space for transducer
10	van den	High-frequency	20	Combined epidermal & dermal	N.R.	Test site boundaries marked
11	Kerckhove					& traced
12	(2005)					
13	van der Veer	N.R.	7.5	N.R.	Fibrosis [†]	Standardised linear
14	(2010)					measurement points
15	Wang (2009)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.
16	Wang (2010)	B-mode	N.R.	Combined epidermal & dermal	N.R.	Tracing – scar & anatomical
17						landmarks
18	Wiseman	B-mode	N.R.	Combined epidermal & dermal	Fibrosis [†]	Centrally site of interest
19	(2020, 2021)					
20	Wood (1996)	B-mode	7 & 10	N.R.	N.R.	Transducer affixed to
21						tracking arm
22	Xuan (2021)	High-frequency	20	N.R.	Fibrosis [†]	N.R.
23	Yeol Lee	B-mode	7-16	N.R.	N.R.	N.R.
24	(2022)					
25	Yim (2010)	High-frequency	12	N.R.	N.R.	N.R.
26	Zadkowski	B-mode	N.R.	Combined epidermal & dermal	N.R.	N.R.
27	(2016)					
28	<i>Abstracts</i>					
29						
30	Agabalyan	N.R.	20	Epidermal, dermal & combined	N.R.	N.R.
31	(2016)					
32	Anthonissen	N.R.	22	Epidermal & dermal	N.R.	N.R.
33	(2015)					
34	Bajouri (2018)	High-frequency	N.R.	Epidermal & dermal	N.R.	N.R.
35						
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1						
2						
3	Bezugly (2019)	High-frequency	22, 33 & 75	Epidermal & dermal	N.R.	N.R.
4	Bezugly (2014)	High-frequency	33 & 75	Epidermal & dermal	N.R.	N.R.
5	Blome-	N.R.	N.R.	N.R.	N.R.	N.R.
6	Eberwein					
7	(2011, 2012)					
8	Blome-	High-frequency	N.R.	N.R.	Fibrosis	N.R.
9	Eberwein					
10	(2012)					
11	Blome-	High-frequency	N.R.	N.R.	N.R.	N.R.
12	Eberwein					
13	(2014)					
14	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
15	Cho (2012)	N.R.	N.R.	N.R.	N.R.	N.R.
16	Comstock	N.R.	N.R.	N.R.	N.R.	N.R.
17	(2018)					
18	Cooper (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
19	Du (2006)	B-mode	15	N.R.	N.R.	N.R.
20	Edgar-	N.R.	N.R.	N.R.	N.R.	N.R.
21	Lacoursière					
22	(2022)					
23	El-Zawhary	N.R.	N.R.	N.R.	N.R.	N.R.
24	(2007)					
25	George (2019)	N.R.	N.R.	N.R.	N.R.	N.R.
26	Jacobs (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
27	Jang (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
28	Kim (2009)	N.R.	N.R.	N.R.	N.R.	N.R.
29	Li (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
30	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
31	(2011)	Palpation System				
32	Li-Tsang	Tissue Ultrasound	N.R.	N.R.	N.R.	N.R.
33	(2010)	Palpation System				
34	Maari (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
35						
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1						
2						
3	Moortgat	High-frequency	N.R.	Dermal	N.R.	N.R.
4	(2020)					
5	Nedelec (2018)	N.R.	N.R.	N.R.	N.R.	N.R.
6	Peters (2018)	High-frequency	22	N.R.	N.R.	N.R.
7	Seo (2011)	N.R.	7.5	N.R.	N.R.	Thickest point
8	Siwy (2016)	N.R.	N.R.	N.R.	N.R.	N.R.
9	Timina (2013)	N.R.	20-40	N.R.	N.R.	N.R.
10	Tu (2014)	High-frequency	N.R.	N.R.	N.R.	N.R.
11		ultrasound				
12		biomicroscopy				
13						
14	Ud-Din (2017)	N.R.	N.R.	N.R.	N.R.	N.R.
15	Ud-Din (2017)	High-frequency	50	N.R.	N.R.	N.R.
16	Ud-Din (2018)	High-frequency	N.R.	N.R.	Fibrosis [†]	N.R.
17	Zuccaro (2021)	N.R.	N.R.	N.R.	N.R.	N.R.
18	Zuccaro (2019)	B-mode	N.R.	N.R.	N.R.	N.R.
19	Zuccaro (2021)	B-mode	6-18	Combined epidermal & dermal	N.R.	Scar outlined &
20						photographed
21						
22						

Legend: Scar relocation: Methods used by assessors to relocate the measured scar for sequential measurements; B-mode: brightness-mode ultrasound (< 20 MHz); High-frequency: high-frequency B-mode ultrasound (> 20 MHz); N.R.: Not reported

Footnotes: [†]Indirect reference made in record (e.g. in introduction or discussion); [‡]Photographs taken of the scar but not specified whether used for relocation; [§]Not stated in methods, so images provided in record used by authors of this review to provide subjective judgement

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Supplementary Table 4. Additional measurement methods used alongside ultrasound in included studies

First author (year)	Objective measurement methods	Clinician-based rating scale	PROM
<i>Journal articles</i>			
Agabalyan (2017)	Histology	-	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alsharnoubi (2018)	Laser Doppler perfusion	VSS	-
Alshehari (2015)	-	VSS	-
Avetikov (2018)	-	-	-
Berry (1985)	Transcutaneous oxygen measurement	Scar redness and hypertrophy rating scale (0-5 Likert scale)	Scar redness and hypertrophy rating scale (0-5 Likert scale)
Blome-Eberwein (2012)	Doppler flowmeter – vascularity Cutometer – pliability Semmes-Weinstein monofilament Aesthesiometer testing set – sensation	VSS POSAS-O	POSAS-P
Blome-Eberwein (2016)	Cutometer – pliability Dermaspectrometer – colour Semmes-Weinstein Aesthesiometer Monofilament Testing Set – sensation	VSS POSAS-O	POSAS-P
Blome-Eberwein (2019)	-	VSS	-
Cai (2019)	-	Clinical evaluation	-
Candy (2010)	Spectrocolorimeter – colour	VSS	-
Chae (2016)	Spectrophotometer – pigmentation	VSS POSAS-O	POSAS-P
Chang (2014)	-	VSS Photographic evaluation (0-10 VAS)	-
Chan (2004)	Cutometer – viscoelasticity Spectrophotometer – pigmentation	-	-
Cheng (2001)	-	VSS	-
Cho (2014)	Mexameter – colour	Treatment efficacy (0-10 VAS)	Itching scale (0-4 Likert scale)

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3		Tewameter – trans-epidermal water		
4		loss		
5		Sebumeter – sebum		
6		Cutometer – elasticity		
7	Danin (2012)	Cutometer – elasticity	VSS	-
8	Deng (2019)	DermaLab Combo – colour	POSAS-O	-
9		Dermoscopy – vascularity		
10	Deng (2021)	-	VSS	-
11	Deng (2021)	Doppler – blood perfusion	POSAS-O	POSAS-P
12		Dermlite Foto IPro – erythema		
13	Dunkin (2007)	-	-	-
14	Elrefaie (2020)	Ultrasound – echogenicity, compressibility & vascularity	VSS	-
15	Engrav (2010)	Durometer – hardness	Clinical appearance based on photographs	-
16		Chromameter – colour	mVSS (vascularity, pigmentation, pliability)	-
17	Fabbrocini (2016)	-	Clinical rating – colour change, consistent itch, hypersensitivity, blistering	-
18	Fong (1997)	Cutometer – elasticity	VSS	-
19			Visual analogue scale – pain and itch	-
20	Fraccalvieri (2013)	Colour power Doppler – vascularisation	VSS	-
21				
22	Fraccalvieri (2011)	Histology	-	-
23		Echocontrastography – neovascularisation		
24	Gankande (2014)	DermLab combo – erythema & elasticity	mVSS (some participants)	-
25	Ge (2022)	-	POSAS-O	POSAS-P
26			Subjective reports on patient range of movement	
27	Gee Kee (2016)	3D photography – thickness	POSAS-O	POSAS-P
28	Guo (2020)	Ultrasound – blood flow grade	-	-
29		Shear wave elastography – scar stiffness		
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3	Huang (2017)	-	-	-
4	Huang (2021)	-	-	-
5	Huang (2020)	Shear wave elastography – scar stiffness	-	-
6				
7	Issler-Fisher (2021)	-	VSS	POSAS-P
8			POSAS-O	
9	Issler-Fisher (2020)	-	VSS	POSAS-P
10			POSAS-O	Patient pain & itch scales
11	Issler-Fisher (2017)	-	VSS	POSAS-P
12			POSAS-O	Patient pain, itch & quality of life rating scales
13				
14	Joo (2020)	-	VSS	Pain severity (0-10 VAS)
15	Katz (1985)	Cicatrometer – firmness	-	-
16	Kemp Bohan (2021)	-	-	-
17	Kim (2018)	-	-	-
18	Lacarrubba (2008)	-	Clinical evaluation of lesion size	-
19	Lau (2005)	-	VSS	-
20	Lee (2020)	-	mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
21			POSAS-O	
22				
23	Lee (2019)	-	mVSS (height, pliability, vascularity, pigmentation)	POSAS-P
24			POSAS-O	
25				
26				
27	Li (2013)	Micrometer – tissue thickness	-	-
28		Force/torque sensor – load applied to scar		
29				
30	Li (2020)	Cutometer – elasticity	VSS	Quality of life questionnaire
31		Mexameter – colour		
32		PeriCam PSI system and mexameter – blood supply		
33				
34	Li (2021)	Laser Doppler flowmetry – perfusion	VSS	-
35	Li (2018)	Spectrocolourimeter – scar colour	VSS	Pain & itch (0-10 VAS)
36	Li (2021)	-	VSS	Treatment satisfaction
37	Li-Tsang (2005)	Spectrocolourimeter – scar colour	VSS	Pain & itch (VAS scale not specified)
38	Li-Tsang (2006)	Spectrocolorimeter – colour	VSS	Pain & itch (VAS)
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3	Li-Tsang (2010)	Spectrocolorimeter – colour	VSS (pliability)	Pain & itch (10-point VAS)
4	Lobos (2017)	-	Modified Seattle Scar Scale	-
5			Clinical opinion	
6	Mamdouh (2021)	-	VSS	Patient satisfaction (VAS)
7	Meirte (2016)	-	-	-
8	Miletta (2021)	Colourmeter – scar colour	Unclear, likely POSAS-O	Unclear, likely POSAS-P
9		Dermal torque meter – scar compliance		Short Form 36 Quality of Life Survey
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11	Nedelec (2014)	Cutometer – elasticity	-	-
12		Mexameter – colour		
13	Nedelec (2008)	Cutometer – elasticity	mVSS	-
14		Mexameter – colour		
15	Nedelec (2019)	Cutometer – elasticity	-	-
16		Mexameter – colour		
17	Nedelec (2020)	Cutometer – elasticity	-	Pain & itch (10cm line VAS)
18		Mexameter – colour		
19	Nicoletti (2015)	-	-	-
20	Niessen (1998)	Histology	-	-
21	Reinholz (2020)	3D topographic imaging device	POSAS-O	Dermatology Quality of Life Index
22				POSAS-P
23	Reinholz (2016)	Optical coherence tomography – thickness	POSAS-O	Dermatology Quality of Life Index
24				POSAS-P
25	Schwaiger (2018)	3D topographic imaging device	-	-
26	Simons (2017)	3D camera – scar height	POSAS-O	-
27	Soykan (2014)	Slide calliper – dimensions	POSAS-O	POSAS-P
28	Timar-Banu (2001)	Metric ruler – dimensions	Validated 3-point scoring system for redness, hardness, itching & pain	-
29				
30	Ud-Din (2019)	Optical coherence tomography – thickness	-	-
31		Histology		
32	van den Kerckhove (2005)	Chromameter – erythema	-	-
33	van der Veer (2010)	Slide calliper – dimensions	-	-
34	Wang (2009)	Histology	-	-
35	Wang (2010)	-	-	-
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3	Wiseman (2020, 2021)	-	POSAS-O	POSAS-P
4				Numeric rating scale for itch
5				Toronto Paediatric Itch Scale
6				CH-9D
7				BBSIP
8	Wood (1996)	-	VSS	-
9	Xuan (2021)	Histology	-	-
10	Yeol Lee (2022)	Cutometer – elasticity	mVSS	-
11		Elastography		
12	Yim (2010)	Cutometer – elasticity	-	-
13		Tewameter – trans-epidermal water		
14		loss		
15		Mexameter – colour		
16	Zadkowski (2016)	-	VSS	-
17	<hr/>			
18	<i>Abstracts</i>			
19	<hr/>			
20	Agabalyan (2016)	Histology	-	-
21	Bajouri (2018)	-	VSS	-
22	Bezugly (2019)	Clinical or histopathological	-	-
23		diagnosis		
24	Bezugly (2014)	-	-	-
25	Blome-Eberwein (2011, 2012)	Doppler vascularity, elasticity and	VSS	Pain and itching scale (0-10 Likert
26		sensation		scale)
27	Blome-Eberwein (2012)	-	-	-
28	Blome-Eberwein (2014)	Doppler flowmeter – vascularity	VSS	POSAS-P
29		Cutometer – pliability		
30		Semmes-Weinstein monofilament		
31		aesthesiometer testing set – sensation		
32	Cho (2012)	-	VSS	-
33	Cho (2012)	CK-MPA Multi-Probe adaptor –	-	-
34		pigmentation, erythema and trans-		
35		epidermal water loss		
36		Cutometer – elasticity		
37	Comstock (2018)	Computer-based tools – Thickness &	Unclear, likely POSAS-O	Unclear, likely POSAS-P
38		pliability		
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Cooper (2021)	Colorimeter – pigmentation	Unclear, likely POSAS-O	Unclear, likely POSAS-P
Du (2006)	-	-	-
Edgar-Lacoursière (2022)	Cutometer – elasticity	-	-
	Mexameter – colour		
El-Zawhary (2007)	Histology	-	-
George (2019)	-	-	-
Jacobs (2016)	Cutometer – pliability	POSAS-O	-
	Colorimeter – colour		
Jang (2009)	Mexameter – pigmentation	-	-
	Tewameter – trans-epidermal water loss		
	Sebumeter – sebum		
	Cutometer – elasticity		
	Laser Doppler – perfusion		
Kim (2009)	Histology	VSS	-
Li (2016)	Spectrocolourimeter – scar colour	VSS	Patient report of pain & itch
Li-Tsang (2011)	-	VSS (thickness, pliability and pigmentation)	-
Li-Tsang (2010)	Histology	VSS	Self-report questionnaire
	Spectrocolourimeter – scar colour		
Maari (2017)	Cutometer – elasticity	-	-
	Mexameter – pigmentation		
Moortgat (2020)	Cutometer – elasticity	Unclear, likely POSAS-O	Unclear, likely POSAS-P
	Chromameter – colour		
	Tewameter – trans-epidermal water loss		
	Corneometer – hydration		
Nedelec (2018)	Cutometer – elasticity	-	-
	Mexameter – colour		
Peters (2018)	Cutometer – elasticity	POSAS-O	POSAS-P
	Colourimeter – colour		
Seo 2011	Cutometer – elasticity		
Siwy (2016)	Colourimeter – colour	-	SF-36 Quality of Life Measurement
	Torque meter – pliability & elasticity		POSAS-P
Timina (2013)	-	-	-

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3	Tu (2014)	-	VSS	-
4	Ud-Din (2017)	Laser perfusion imaging	-	-
5		Optical coherence tomography –		
6		thickness		
7		Histology		
8	Ud-Din (2017)	Optical coherence tomography –	-	-
9		thickness		
10	Ud-Din (2018)	Optical coherence tomography –	-	-
11		thickness		
12		Histology		
13	Zuccaro (2021)	Multi-parameter skin analysis device	VSS	Unclear, likely POSAS-P
14			Unclear, likely POSAS-O	
15	Zuccaro (2019)	Acoustic radiation force impulse	-	-
16		ultrasound elastography		
17	Zuccaro (2021)	Acoustic radiation force impulse –	VSS	POSAS-P
18		stiffness	POSAS-O (did not include	
19		DermLab Combo elasticity probe –	surface area and relief subscales)	
20		elasticity		
21		DermLab Combo colour probe –		
22		colour		
23				

Legend: (m)VSS: (Modified) Vancouver Scar Scale; POSAS: Patient and Observer Scar Assessment Scale (POSAS-O: POSAS observer scale; POSAS-P: POSAS patient scale); VAS: Visual Analogue Scale; CHU-9D: Child Health Utility-9D; BBSIP: Brisbane Burn Scar Impact Profile

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Supplementary Table 5: Reliability of ultrasound methods reported in each included study

First Author (year)	Reliability Test & Measurement Error	Reliability & Measurement Error Test Statistics & Details
<i>Inter-rater reliability</i>		
Anthonissen (2015)	ICC; SEM	Epidermal – 0.297; 0.02mm Dermal – 0.991; 0.13mm
Chang (2014)	Pearson correlation	R=0.90, p<0.001
Dunkin (2007)	N.R.	N.R.
Fong (1997)	ICC	0.93, p=0.146
Gankande (2014)	ICC (95% CI)	<u>Individual site:</u> Rater 1 vs rater 2 'Best scar' – 0.95 (0.92, 0.96) 'Worst scar' – 0.95 (0.91, 0.97) 'Normal skin' – 0.94 (0.91, 0.96) Rater 1 vs rater 3: 'Best scar' – 0.86 (0.78, 0.91) 'Worst scar' – 0.91 (0.85, 0.95) 'Normal skin' – 0.92 (0.88, 0.95) Rater 2 vs rater 3: 'Best scar' – 0.93 (0.89, 0.95) 'Worst scar' – 0.96 (0.92, 0.97) 'Normal skin' – 0.95 (0.92, 0.97) <u>Average site:</u> Rater 1 vs rater 2 'Best scar' – 0.97 (0.94, 0.99) 'Worst scar' – 0.98 (0.96, 0.99) 'Normal skin' – 0.97 (0.93, 0.98) Rater 1 vs rater 3 'Best scar' – 0.90 (0.77, 0.95) 'Worst scar' – 0.97 (0.91, 0.98) 'Normal skin' – 0.96 (0.92, 0.98) Rater 2 vs rater 2 'Best scar' – 0.95 (0.88, 0.98) 'Worst scar' – 0.98 (0.94, 0.99) 'Normal skin' – 0.98 (0.97, 0.99)
Lau (2005)	ICC	0.84, p<0.01
Lee (2020)	ICC	"Acceptable to high"
Lee (2019)	ICC (95% CI); SEM	<u>Scar:</u> Single: 0.957 (0.934-0.973) Average: 0.985 (0.977-0.991) SEM: 0.10 mm <u>Unscarred skin:</u> Single: 0.967 (0.949-0.980) Average: 0.989 (0.982-0.993) SEM: 0.04 mm
Nedelec (2008)	ICC (95% CI)	Most severe scar: 0.90 (0.84-0.95) Less severe scar: 0.91 (0.85-0.95) Donor site: 0.89 (0.82-0.94) Normal skin: 0.85 (0.75-0.92)
Seo (2011)	N.R.	"High"
Simons (2017)	ICC (95% CI); SEM	Scar: 0.82 (0.7-0.89); 0.05 cm Normal skin: 0.33 (0.08-0.54); 0.03 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	<u>One day:</u> 0.88 (0.81-0.95); 0.29 mm

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		<u>Day-to-day:</u>
		0.94 (0.90-0.98); 0.21mm
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<i>Intra-rater reliability</i>		
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Anthonissen (2015)	ICC; SEM	Epidermal – 0.809; 0.01mm Dermal – 0.991; 0.13mm
Gankande (2014)	ICC (95% CI)	‘Best scar’ – 0.97 (0.89, 0.94) ‘Worst scar’ – 0.92 (0.88, 0.95) ‘Normal skin’ – 0.86 (0.81, 0.89)
Gee Kee (2016)	N.R.	N.R.
Lau (2005)	ICC	Intra-rater: 0.98, p<0.01
Lee (2019)	ICC (95% CI)	<u>Scar:</u> Single: 0.951 (0.871-0.987) Average: 0.983 (0.953-0.966) SEM: 0.10 mm
		<u>Unscarred skin:</u> Single: 0.948 (0.881-0.976) Average: 0.982 (0.954-0.993) SEM: 0.04 mm
Li (2013)	ICC	0.89
Seo (2011)	N.R.	“High”
Simons (2017)	ICC (95% CI); SEM	Scar: 0.95 (0.91-0.97); 0.02 cm Normal skin: 0.61 (0.41-0.75); 0.02 cm
Van Den Kerckhove (2003)	ICC (95% CI); SEM	0.98 (0.97-0.99); 0.11mm
Wang (2010)	SE	Peak: 0.032 3 months: 0.018 6 months: 0.399 9 months: 0.353
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Abbreviations used in tables: N.R.: Not reported; ICC: Intraclass Correlation Coefficient; 95% CI: 95% Confidence Interval; SEM: Standard Error of Measurement; SE: Standard Error		
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Summary of findings for measurement error:

The reported inter-rater SEM measurements for the combined (i.e., epidermal and dermal) thickness measurement of scars was reported in two records as 0.11 mm⁵ and 0.5 mm.⁶ The inter-rater SEM for the combined thickness measurement of unscarred skin was also calculated in one record (SEM = 0.3 mm).⁶ The inter-rater SEM was calculated in one record for the measurement of epidermal (SEM = 0.02 mm) and dermal (0.13) measurements⁷, and one record reported only the dermal SEM for scar thickness (SEM = 0.1 mm) and unscarred skin (0.04 mm).⁸ The intra-rater SEM for the combined thickness measurement of scarred skin ranged from 0.18 mm to 0.52 mm, and was measured at 0.2 mm for unscarred skin in one record.⁶ One record reported the intra-rater SEM for epidermal (0.01 mm) and dermal (0.12 mm),⁷ and one record reported the intra-rater SEM for dermal scar (0.1 mm) and unscarred skin (0.04).⁸

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Supplementary Table 6. Methodological considerations for researchers and/or clinicians undertaking measurement of scar thickness using ultrasound.

Consideration	Details & examples of considerations	Publications in our review addressing the consideration	Details reported in included review records
Preventing skin compression during measurement	Using standoff methods (e.g., ultrasound gel, water bath) to prevent transducer touching the skin	6,9-13	- Use of ultrasound gel to prevent contact between ultrasound transducer and skin surface to minimise compression applied by direct application of transducer ^{6,9-12}
	Application of minimal pressure by transducer	14-18	- Silicone pad placed underneath transducer ¹³ - Transducer held to maintain minimal pressure on scar ^{14,15,17} - Training users to apply minimal force on transducer to prevent scar or skin distortion ^{16,18}
	Deliberately compressing skin to quantify scar compressibility	19-21	- Measurement of thickness with and without compression with transducer ^{19,21} - Thickness measurements taken using TUPS, which uses controlled and metered compression during measurement ²⁰
Orienting the patient	Orienting the patient during measurement (e.g., upright, supine, prone or seated)	8,18,22	- Patient supine throughout measurement to allow measurement to be taken in the same position ^{8,18,22}
	Maintaining patient stillness during measurement	9	- Patients asked to hold breath during measurement of scars on the chest to allow shear-wave ultrasound ⁹
Placing ultrasound transducer	Orientating ultrasound transducer [e.g., vertical (superior to inferior/cranial to caudal), horizontal (medial to lateral)]	23	- Direction of transducer recorded to ensure consistency ²³

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13	Relocating	9,15,17,18,22,24-26	
14	scars for		
15	longitudinal		
16	measurement		
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Orienting the transducer in relation to the scar (e.g., perpendicular)

9,15,17,18,22,24-26

- Transducer oriented perpendicular to the skin surface to provide optimal image^{9,15,18,22,24-26}

Measuring difficult/tight areas (e.g., axillae or other joints)

6

- Exclusion of fingers and toes in paediatric measurements due to size of measurement area and thin skin⁶

Mapping measurement area (e.g., tracing, schematic diagram)

6,12,16,18,20,22,27-32

- Scars traced using translucent paper^{18,20,22,27,29,31,32}

- Scars and surrounding anatomical landmarks traced using translucent paper¹⁶

- Scar mapped on transparent paper, which was then cut out²⁸

- Scar mapped with drawing, no elaboration provided³⁰

- Scars traced using Visitrak (Smith & Nephew Medical Limited, England)^{6,12}

- Assessed area marked and photograph taken in initial consultation^{24,33}

- Photographs of scars taken²⁶

- Measurement taken at standardised transducer lengths along surgically created scars of pre-specified dimensions³⁴

- Measurements taken at thickest/most severe point^{19-21,30,33,35,37},

as determined by the patient and/or clinician⁸

- Transducer placed on thickest site on peripheral regions⁹

- Transducer placed on area initially identified to have greatest burn depth²³

Photographing measurement area

24,26,33

Measuring specific scar locations (e.g., centre of scar, worst area of scar, counting transducer lengths)

6,8,9,13,19-21,23,30,33-37

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Conducting linear measurements from nearby anatomical landmarks

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Removing scar treatments prior to ultrasound measurement

8,12,20,22,24-26,28,29,39,40

Acclimatising scar to measurement conditions

Acclimatising patient to room prior to measurement

5,18,22,29,41-46

- Measurement area selected by the measurer with -selected area marked with tape ¹³
- Measurements taken at set linear distances from cranial/caudal border of linear sternal scar ³⁶
- Linear measurements from anatomical landmark to measurement site ¹⁷
- Transducer placement mapped in 3-dimensional space using a surgical precision tracking arm ³⁸
- Pressure garments removed 10 minutes before measurement ²⁸
- Pressure garments removed 15 minutes before measurement to regain original (uncompressed) scar thickness or to reduce blanching effects on measurement ^{20,40}
- Pressure garments/gels/moisturisers removed 20 minutes before measurement ^{8,22,29}
- Pressure garments removed 30 minutes before measurement ^{12,25,26,39}
- Sequential measurement of scars following direct treatment with vacuum massage at 5, 30, 60 and 120 minutes to monitor effect of treatment ²⁴
- Patients rested for minimum 5 minutes before measurement ^{5,18,22}
- Scar exposed to room conditions for 10 minutes ²⁹ to allow equilibrium to be reached with surrounding environment ⁴¹
- Patients resting in room with constant temperature for 15 mins ⁴² to allow scar to stabilise ⁴⁴

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4				- Patients rested for 20 minutes prior to measurement ^{29,45}
5				- Patients resting for 10 minutes before repeated measurements taken ⁴³
6				- Patients wait in testing room holding position for 5 min before measurement to stabilise cutaneous blood flow ⁵
7				- Patients allowed to adapt in controlled room to exclude external variables ⁴⁶
8				- Patients remained supine for at least 5 minutes before measurement to avoid artefacts on Doppler imaging ¹³
9				- Patients allowed to acclimatise to room and assumed a supine position for a minimum of 10 minutes before measurements of biophysical parameters ¹¹
10				- Measurement of epidermal, dermal and combined epidermal and dermal thickness to allow comparison with histological measurement ^{47,48}
11				- Measurement of the epidermal and dermal thickness ^{45,49} , combined with layer acoustic density ⁷
12				- Measurement of the epidermal, dermal and subcutaneous thickness, combined with acoustic density ^{50,51}
13				- Measurement of dermal thickness as treatment thought to affect/target the dermis ^{24,37,52-54}
14				- Combined epidermal and dermal thickness measurement to provide information on the full thickness of the scar
15				5,6,8,11,12,15,17,18,22,23,26,28,35,40,55-68
16		Maintaining patient position before measurement	11,13	
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22	Measuring different skin layers	Measuring epidermis and/or dermis individually	7,24,37,45,47-54	
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36		Measuring both epidermis/dermis combined (no	5,6,8,11,12,15,17,18,22,23,26,28,35,40,55-68	
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3		individual		
4		measurement)		
5	Measurement	Measuring	8,10,11,13,14,16,17,24,25,29-32,34,36,37,45,54,58,60,61,63,64,69-82	- Measurement of fibrosis or collagen
6	objective	fibrosis/oedema/hair		architecture ^{8,11,17,24,29-32,34,36,37,45,54,58,61,63,64,69,70,72-}
7		follicles		74,77-79,82
8				- Measurement of inflammation/oedema ¹⁴
9				- Quantification of the sub epidermal low
10				echogenic band, indicating oedema ⁶⁰
11				- Measurement of both fibrosis and oedema
12				10,13,16,25,58,71,75,76,80,81
13				- Measurement of the presence and density of
14				hair follicles to differentiate scarred and
15				unscarred skin ⁵⁴
16	Factors	Measuring contralateral	9,14,15,23,29,30,52,55-58,83-88	- Measurement of additional, non-scarred
17	influencing scar	skin/control scar	6,8,12,18,22,25,38,43,54,59-61,66,89,90	subjects ^{55,79}
18	site		39,40,45,79,81,82	- Measurement of unscarred/unaffected skin on
19	measurement			same subject as scar measurement contralaterally
20				or at anatomically similar location to provide
21				normative measurements for skin thickness
22				6,8,9,12,14,15,18,22,23,29,30,38-40,43,45,52,54,56-61,66,81,85-90
23				- Measurement of both untreated scar and
24				unaffected skin ⁸²⁻⁸⁴
25				- Measurement of a control scar subjected to care
26				as usual treatment on the same individual ²⁵
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28		Measuring open	6	- Use of flexible transparent plastic wrap placed
29		wounds or sores in the		over the measurement area to prevent contact
30		scar		between ultrasound gel and transducer with the
31				open wound/sore ⁶
32		Operator training	6,8,12,14,16,18,20,24,27-29,31,39,40,58,61,66,72,73,87,91-93	- Trained outcome assessor ^{6,13,16,18,27,72}
33		and/or experience		- Measurements taken by radiologist/sonographer
34				28,66,73,92
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Number of

measurements per scar

5,6,8,9,11,12,20,23,25,26,31,34,37,40,44,45,47,52,54,57,60,61,66,68,79,85,92,94

- Assessors with burn experience ^{87,93}
- Ultrasound located in department of radiology ⁹¹
- Measurements conducted by trained therapist/doctor under guidance of experienced radiologist ^{12,14,29,39}
- Measurements conducted by trained clinicians who use device regularly and received training by company representative of devices ^{8,61}
- Device-specific training provided: 1 week ²⁰; 3 sessions of 3 hours for 3 weeks, plus 10 independent assessments of scars using study protocol ⁴⁰; training provided over 3 months ³¹; physical therapist trained in ultrasound application ²⁴
- 3 ultrasound images taken from each patient ^{9,11,26,31,37,44,45,47,52,54,57,60,79,85}
- Clearest of 3 measurements used ¹²
- 3 measurements in 3 locations across scar used. Individual and average measurements reported ⁴⁰
- Measurements performed in duplicate ^{34,94}
- Measurements taken at different points of the scar, thickest used for analysis ⁹²
- 5 measurements of each site ^{6,23}
- 9 measurements taken, removal of maximum and minimum, 7 measurements used for average ²⁰
- Measurements taken by 3 assessors at 3 different time points during day ^{8,61}
- Measurement of 2 sites on the same scar ²⁵
- Single ultrasound image taken for analysis ⁶⁸

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<p>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46</p>	<p>Use of additional measurement tools as well as ultrasound measurements</p>	<p>Using additional objective assessment instruments (e.g., histology, colour Doppler ultrasound, cutometer, colourimeter)</p>	<p>6,9-11,13,15,17,18,21-23,25-27,29,31,32,35,36,40-48,50,53,56-59,66,68-70,75-80,82-84,86-92,95-111</p>	<p>- Histology/immunohistochemistry 13,17,47,48,50,58,78,79,88,100,103,108,110</p> <p>- Blood flow and blood perfusion measurement using laser Doppler perfusion imaging, flowmetry or PeriCam, and scar colour and micro-vessel percentage using dermoscopy colour and micro-vessel percentage. 35,69,70,83,84,86,87,92,99,101,108</p> <p>- Oximeter⁴¹</p> <p>- Infra-red camera⁴¹</p> <p>- Measurement of scar stiffness or pliability/elasticity using elastography or cutometer^{9,15,18,21,22,25-27,29,43,46,53,57,66,82-84,86,89,90,96,98,99,101,104-106}</p> <p>- Measurement of sensation using Semmes-Weinstein filaments^{82-84,86}</p> <p>- Measurement of scar colour (including pigmentation and erythema) using spectrophotometer, colourimeter, chromameter, mexameter or Dermlite Foto IPro^{18,22,25-27,32,42,44-46,53,56,66,68,80,82,87,90,91,96-99,101-107,111}</p> <p>- Measurement of trans-epidermal water loss using Tewameter or scar hydration using Corneometer^{46,53,96,99}</p> <p>- Measurement of sebum level using sebumeter^{96,99}</p> <p>- Measurement of hardness using durometer⁹¹</p> <p>- Measurement of neovascularisation using echocontrastography⁵⁸</p> <p>- Measurement of scar dimensions (e.g., scar height and volume) using 3D camera, 3D imaging methods, ruler or calliper^{6,10,11,23,36,75,77}</p>
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Using subjective
assessment instruments
(e.g., clinical rating
scales, PROMs)

19,20,23,28-30,33,37,40,41,44,45,49,52,56,57,61,66,67,69-72,80-
84,86,87,91,92,94-98,100,111-115

- Measurement of skin thickness using
micrometer or optical coherence tomography
17,31,59,76,108-110

- Measurement of scar firmness or deformation
using cicatrometer, force/torque sensor (in line
with ultrasound to measure load applied) or
torque meter ^{31,32,107}

- Multi-parameter skin analysis device ⁶⁶

- Measurement of erythema and elasticity using
probes of DermaLab Combo ⁴⁰

- Multi-probe adaptor taking multiple
measurements (pigmentation, erythema, trans-
epidermal water loss) ⁹⁶

PROMs:

- Measurement of scar quality using POSAS
patient report <sup>8,23,30,33,45,56,61,63,64,66,75-
77,82,86,95,97,106,107,114,115</sup>

- Subjective rating scales for scar symptoms
(e.g., pain, itch) or subjective scar severity
ratings ^{26,30,41,42,53,63,64,72,80,83,84,93,102,103,111,115}

- Patient quality of life questionnaires ^{75,76,101,107}

- Measurement of generic health-related quality
of life using CHU-9D ^{63,64}

- Measurement of scar-specific health-related
quality of life using BBSIP ^{63,64}

- subjective evaluation of response to
treatment/treatment satisfaction ^{81,116}

Clinical rating scales:

- Measurement of scar quality using POSAS
observer report <sup>8,23,30,33,45,53,56,61,63,64,66,75-
77,82,86,87,97,98,106,114-116</sup>

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Determining the order
of measurement ⁶

- Measurement of physical scar characteristics using VSS or modified versions of the VSS ^{8,18-20,28,30,33,35,37,38,40,42-44,49,56,57,61,65,66,69-72,80-86,92-95,100-103,111-113,115,117,118}
- Measurement of scar characteristics in relation to unscarred skin using Seattle Scar Scale or modified Seattle Scar Scale ⁷³
- Subjective rating scales for scar symptoms (e.g., pain, itch) as assessed by the clinician and/or researcher and/or clinical evaluation of scar severity ^{11,29,41,52,57,67,73,91,92,94,96}
- Standardised order of measurement: 3D photograph, POSAS-O, then ultrasound ⁶
- Order of device use not specified ^{35,69,70,83,84,86,87,92,99,101,108}

Abbreviations: TUPS: Tissue Ultrasound Palpation System; 3D: three-dimensional; POSAS: Patient and Observer Scar Assessment Scale; CHU-9D: Child Health Utility 9D; BBSIP: Brisbane Burn Scar Impact Profile; VSS: Vancouver Scar Scale; mVSS: Modified Vancouver Scar Scale; POSAS-O: Patient and Observer Scar Assessment Scale, observer measure

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

Supplement References:

1. Mokkink LB, Boers M, van der Vleuten CPM, et al. COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. *BMC Med Res Methodol*. 2020;20(1):1-13. doi:10.1186/s12874-020-01179-5
2. Prinsen CAC, Vohra S, Rose MR, et al. How to select outcome measurement instruments for outcomes included in a "Core Outcome Set" - a practical guideline. *Trials*. 2016;17:urn:issn:1745-6215.
3. Proctor E, Proctor E, Silmere H, et al. Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. *Adm Policy Ment Health*. 2011;38(2):65-76. doi:10.1007/s10488-010-0319-7
4. Australian Government Department of Health and Aged Care Medical Research Future Fund. Research Translation. Accessed 29/05/2023, <https://www.health.gov.au/our-work/medical-research-future-fund/mrff-research-themes/research-translation#what-is-the-research-pipeline>
5. Van den Kerckhove E, Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated measurements on post-burn scars with Dermascan C. *Skin Res Technol*. 2003;9(1):81-84. doi:10.1034/j.1600-0846.2003.00375.x
6. Simons M, Kee EG, Kimble R, Tyack Z. Ultrasound is a reproducible and valid tool for measuring scar height in children with burn scars: A cross-sectional study of the psychometric properties and utility of the ultrasound and 3D camera. *Burns*. 2017;43(5):993-1001. doi:10.1016/j.burns.2017.01.034
7. Anthonissen M, Meirte J, Moortgat P, et al. Intrarater and interrater reliability of an open 22MHz ultrasound scanning system to assess thickness and density of burn scars. *Ann Burns Fire Disasters*. 2015;28(Supplement EBA)
8. Lee KC, Bamford A, Gardiner F, et al. Investigating the intra- and inter-rater reliability of a panel of subjective and objective burn scar measurement tools. *Burns*. 2019;45(6):1311-1324. doi:10.1016/j.burns.2019.02.002
9. Guo R, Xiang X, Wang L, Zhu B, Cheng S, Qiu L. Quantitative assessment of keloids using ultrasound shear wave elastography. *Ultrasound Med Biol*. 2020;46(5):1169-1178. doi:10.1016/j.ultrasmedbio.2020.01.010
10. Schwaiger H, Reinholz M, Poetschke J, Ruzicka T, Gauglitz G. Evaluating the therapeutic success of keloids treated with cryotherapy and intralesional corticosteroids using noninvasive objective measures. *Dermatol Surg*. 2018;44(5):635-644. doi:10.1097/DSS.0000000000001427
11. Timar-Banu O, Beauregard H, Tousignant J, et al. Development of noninvasive and quantitative methodologies for the assessment of chronic ulcers and scars in humans. *Wound Repair Regen*. 2001;9(2):123-132. doi:10.1046/j.1524-475x.2001.00123.x
12. Wang X-Q, Mill J, Kravchuk O, Kimble RM. Ultrasound assessed thickness of burn scars in association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns*. 2010;36(8):1254-1262. doi:10.1016/j.burns.2010.05.018
13. Niessen FB, Spauwen PHM, Robinson PH, Fidler, Kon M. The use of silicone occlusive sheeting (Sil-K) and silicone occlusive gel (epiderm) in the prevention of hypertrophic scar formation. *Plast Reconstr Surg*. 1998;102(6):1962-1972. doi:10.1097/00006534-199811000-00023
14. Huang P-W, Lu C-W, Chu K-T, Ho M-T. Assessing thickness of burn scars through ultrasound measurement for patients with arm burns. *J Med Biol Eng*. 2021;41(1):84-91. doi:10.1007/s40846-020-00592-x
15. Huang S-Y, Xiang X, Guo R-Q, Cheng S, Wang L-Y, Qiu L. Quantitative assessment of treatment efficacy in keloids using high-frequency ultrasound and shear wave elastography: a preliminary study. *Sci Rep*. 2020;10(1):1375-1375. doi:10.1038/s41598-020-58209-x
16. Kemp Bohan PM, Cooper LE, Lu KN, et al. Fractionated ablative carbon dioxide laser therapy decreases ultrasound thickness of hypertrophic burn scar: A prospective process improvement initiative. *Ann Plast Surg*. 2020;86(3):273-278. doi:10.1097/SAP.0000000000002517

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

17. Ud-Din S, Foden P, Stocking K, et al. Objective assessment of dermal fibrosis in cutaneous scarring, using optical coherence tomography, high-frequency ultrasound and immunohistomorphometry of human skin. *Br J Dermatol*. 2019;181(4):722-732. doi:10.1111/bjd.17739
18. Nedelec B, Correa JA, Rachelska G, Armour A, Lasalle L. Quantitative measurement of hypertrophic scar: Interrater reliability and concurrent validity. *J Burn Care Res*. 2008;29(3):501-511. doi:10.1097/BCR.0b013e3181710881
19. Elrefaie AM, Salem RM, Faheem MH. High-resolution ultrasound for keloids and hypertrophic scar assessment. *Lasers Med Sci*. 2019;35(2):379-385. doi:10.1007/s10103-019-02830-4
20. Lau JCM, Li-Tsang CWP, Zheng YP. Application of tissue ultrasound palpation system (TUPS) in objective scar evaluation. *Burns*. 2005;31(4):445-452. doi:10.1016/j.burns.2004.07.016
21. Seo C. Dynamic burn scar elasticity evaluation using ultrasonography. *J Burn Care Res*. 2011;32:S167-S167.
22. Nedelec B, Correa JA, de Oliveira A, LaSalle L, Perrault I. Longitudinal burn scar quantification. *Burns*. 2014;40(8):1504-1512. doi:10.1016/j.burns.2014.03.002
23. Gee Kee EL, Kimble RM, Cuttle L, Stockton KA. Scar outcome of children with partial thickness burns: A 3 and 6 month follow up. *Burns*. 2016;42(1):97-103. doi:10.1016/j.burns.2015.06.019
24. Meirte J, Moortgat P, Anthonissen M, et al. Short-term effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an experimental study. *Burns Trauma*. 2016;4:27-27. doi:10.1186/s41038-016-0052-x
25. Nedelec B, Couture M-A, Calva V, et al. Randomized controlled trial of the immediate and long-term effect of massage on adult postburn scar. *Burns*. 2019;45(1):128-139. doi:10.1016/j.burns.2018.08.018
26. Nedelec B, LaSalle L, de Oliveira A, Correa JA. Within-patient, single-blinded, randomized controlled clinical trial to evaluate the efficacy of triamcinolone acetonide injections for the treatment of hypertrophic scar in adult burn survivors. *J Burn Care Res*. 2020;41(4):761-769. doi:10.1093/jbcr/iraa057
27. Chan HH, Wong DSY, Ho WS, Lam LK, Wei W. The use of pulsed dye laser for the prevention and treatment of hypertrophic scars in Chinese persons. *Dermatol Surg*. 2004;30(7):987-994. doi:10.1111/j.1524-4725.2004.30303.x
28. Cheng W, Saing H, Zhou H, Han Y, Peh W, Tam PKH. Ultrasound assessment of scald scars in Asian children receiving pressure garment therapy. *J Pediatr Surg*. 2001;36(3):466-469. doi:10.1053/jpsu.2001.21613
29. Fong SSL, Hung LK, Cheng JCY. The cutometer and ultrasonography in the assessment of postburn hypertrophic scar: A preliminary study. *Burns*. 1997;23(1):S12-S18. doi:10.1016/S0305-4179(96)00095-2
30. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective short-term outcome analysis of a prospective treatment cohort. *Burns*. 2017;43(3):573-582. doi:10.1016/j.burns.2016.09.014
31. Li JQ, Li-Tsang CWP, Huang YP, Chen Y, Zheng YP. Detection of changes of scar thickness under mechanical loading using ultrasonic measurement. *Burns*. 2012;39(1):89-97. doi:10.1016/j.burns.2012.05.009
32. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and subjective outcomes. *Ann Surg*. 2021;274(6):E574-E580. doi:10.1097/SLA.0000000000003576
33. Issler-Fisher AC, Fisher OM, Haertsch PA, Li Z, Maitz PKM. Effectiveness and safety of ablative fractional CO2 laser for the treatment of burn scars: A case-control study. *Burns*. 2021;47(4):785-795. doi:10.1016/j.burns.2020.10.002

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

34. Dunkin CSJ, Pleat JM, Gillespie PH, Tyler MPH, Roberts AHN, McGrouther DA. Scarring occurs at a critical depth of skin injury: Precise measurement in a graduated dermal scratch in human volunteers. *Plast Reconstr Surg*. 2007;119(6):1722-1732. doi:10.1097/01.prs.0000258829.07399.f0
35. Li N, Yang L, Cheng J, et al. A retrospective study to identify the optimal parameters for pulsed dye laser in the treatment of hypertrophic burn scars in Chinese children with Fitzpatrick skin types III and IV. *Lasers Med Sci*. 2021;36(8):1671-1679. doi:10.1007/s10103-021-03252-x
36. van der Veer WM, Ferreira JA, de Jong EH, Molema G, Niessen FB. Perioperative conditions affect long-term hypertrophic scar formation. *Ann Plast Surg*. 2010;65(3):321-325. doi:10.1097/SAP.0b013e3181c60f88
37. Deng K, Xiao H, Liu X, Ogawa R, Xu X, Liu Y. Strontium-90 brachytherapy following intralesional triamcinolone and 5-fluorouracil injections for keloid treatment: A randomized controlled trial. *PLoS One*. 2021;16(3):e0248799. doi:10.1371/journal.pone.0248799
38. Wood FM, Currie K, Backman B, Cena B. Current difficulties and the possible future directions in scar assessment. *Burns*. 1996;22(6):455-458. doi:10.1016/0305-4179(95)00168-9
39. Huang P-W, Lu C-W, Liu H-L. Fitted pressure garment of assessment of scar thickness on third-degree burns through ultrasonic measurement. *J Cytol Histol*. 2017;8(5)doi:10.4172/2157-7099.1000488
40. Gankande TU, Duke JM, Danielsen PL, DeJong HM, Wood FM, Wallace HJ. Reliability of scar assessments performed with an integrated skin testing device – The DermaLab Combo. *Burns*. 2014;40(8):1521-1529. doi:10.1016/j.burns.2014.01.025
41. Berry RB, Tan OT, Cooke ED, et al. Transcutaneous oxygen tension as an index of maturity in hypertrophic scars treated by compression. *Br J Plast Surg*. 1985;38(2):163-173. doi:10.1016/0007-1226(85)90045-1
42. Li-Tsang CWP, Lau JCM, Chan CCH. Prevalence of hypertrophic scar formation and its characteristics among the Chinese population. *Burns*. 2005;31(5):610-616. doi:10.1016/j.burns.2005.01.022
43. Lee SY, Cho YS, Kim L, Joo SY, Seo CH. The Intra-rater reliability and validity of ultrasonography in the evaluation of hypertrophic scars caused by burns. *Burns*. 2022;doi:10.1016/j.burns.2022.03.016
44. Candy LHY, Cecilia L-TWP, Ping ZY. Effect of different pressure magnitudes on hypertrophic scar in a Chinese population. *Burns*. 2010;36(8):1234-1241. doi:10.1016/j.burns.2010.05.008
45. Deng H, Tan T, Luo G, Tan J, Li-Tsang CWP. Vascularity and thickness changes in immature hypertrophic scars treated with a pulsed dye laser. *Lasers Surg Med*. 2021;53(7):914-921. doi:10.1002/lsm.23366
46. Yim H, Cho YS, Seo CH, et al. The use of AlloDerm on major burn patients: AlloDerm prevents post-burn joint contracture. *Burns*. 2009;36(3):322-328. doi:10.1016/j.burns.2009.10.018
47. Agabalyan NA, Su S, Sinha S, Gabriel V. Comparison between high-frequency ultrasonography and histological assessment reveals weak correlation for measurements of scar tissue thickness. *Burns*. 2016;43(3):531-538. doi:10.1016/j.burns.2016.09.008
48. Agabalyan NA, Su S, Sinha V, Gabriel V. Evaluating high frequency ultrasonography for the non-invasive measurement of human scarring. *J Burn Care Res*. 2016;37(Supplement 183)
49. Bajouri A, Kajoor AS, Fallah N, et al. Autologous human stromal vascular fraction injection in post-burn hypertrophic scar: A double-blinded placebo-controlled clinical trial. *Bioimpacts*. 2018;8:37-38.
50. Bezugly A. Noninvasive skin pathology evaluation: High-frequency ultrasound imaging and diagnostics. *J Dermatol Nurses Assoc*. 2020;12(2)
51. Bezugly A, Potekae N. In vivo skin morphology monitoring of patients with acne, scars and dermal fillers, with 22 and 75 MHz high frequency ultrasound. *J Dermatol*. 2014;41:4.
52. Cai L, Hu M, Lin L, Zheng T, Liu J, Li Z. Evaluation of the efficacy of triamcinolone acetonide in the treatment of keloids by high-frequency ultrasound. *Skin Res Technol*. 2020;26(4):489-493. doi:10.1111/srt.12820

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 53. Moortgat P, Vanhullebusch T, Anthonissen M, et al. Tension reducing taping as a
4 mechanotherapy for hypertrophic burn scars: Preliminary results from a pilot study. *Wound Repair*
5 *Regen.* 2020;28(2):A21.
6
7 54. Blome-Eberwein SA, Roarabaugh C, Gogal C. Assessment of hair density and sub-epidermal
8 tissue thickness in burn scars using high-definition ultrasound imaging. *J Burn Care Res.*
9 2020;41(2):421-426. doi:10.1093/jbcr/irz191
10
11 55. Avetikov DS, Bukhanchenko OP, Skikevich MG, Aipert VV, Boyko IV. Features of ultrasound
12 diagnostics of postoperative hypertrophic and keloid scars. *The New Armenian Medical Journal.*
13 2018;12(4):43-48.
14
15 56. Chae JK, Kim JH, Kim EJ, Park K. Values of a patient and observer scar assessment scale to
16 evaluate the facial skin graft scar. *Ann Dermatol.* 2016;28(5):615-623. doi:10.5021/ad.2016.28.5.615
17
18 57. Danin A, Georgesco G, Le Touze A, Penaud A, Quignon R, Zakine G. Assessment of burned
19 hands reconstructed with Integra® by ultrasonography and elastometry. *Burns.* 2012;38(7):998-
20 1004. doi:10.1016/j.burns.2012.02.017
21
22 58. Fraccalvieri M, Zingarelli E, Ruka E, et al. Negative pressure wound therapy using gauze and
23 foam: histological, immunohistochemical and ultrasonography morphological analysis of the
24 granulation tissue and scar tissue. Preliminary report of a clinical study. *Int Wound J.* 2011;8(4):355-
25 364. doi:10.1111/j.1742-481X.2011.00798.x
26
27 59. Katz SM, Frank DH, Leopold GR, Wachtel TL. Objective measurement of hypertrophic burn
28 scar: A preliminary study of tonometry and ultrasonography. *Ann Plast Surg.* 1985;14(2):121-127.
29 doi:10.1097/0000637-198502000-00005
30
31 60. Kim JD, Oh SJ, Kim SG, et al. Ultrasonographic findings of re-epithelialized skin after partial-
32 thickness burns. *Burns Trauma.* 2018;6(1):21-21. doi:10.1186/s41038-018-0122-3
33
34 61. Lee KC, Bamford A, Gardiner F, et al. Burns objective scar scale (BOSS): Validation of an
35 objective measurement devices based burn scar scale panel. *Burns.* 2020;46(1):110-120.
36 doi:10.1016/j.burns.2019.05.008
37
38 62. Nicoletti G, Brenta F, Blevé M, et al. Long-term in vivo assessment of bioengineered skin
39 substitutes: a clinical study. *J Tissue Eng Regen Med.* 2015;9(4):460-468. doi:10.1002/term.1939
40
41 63. Wiseman J, Simons M, Kimble R, Ware RS, McPhail SM, Tyack Z. Effectiveness of topical
42 silicone gel and pressure garment therapy for burn scar prevention and management in children 12-
43 months postburn: A parallel group randomised controlled trial. *Clin Rehabil.* 2021;35(8):1126-1141.
44 doi:10.1177/02692155211020351
45
46 64. Wiseman J, Ware RS, Simons M, et al. Effectiveness of topical silicone gel and pressure
47 garment therapy for burn scar prevention and management in children: a randomized controlled
48 trial. *Clin Rehabil.* 2020;34(1):120-131. doi:10.1177/0269215519877516
49
50 65. Żądkowski T, Nachulewicz P, Mazgaj M, et al. A new CO2 laser technique for the treatment
51 of pediatric hypertrophic burn scars: An observational study. *Medicine (Baltimore).*
52 2016;95(42):e5168-e5168. doi:10.1097/MD.00000000000005168
53
54 66. Zuccaro J, Kelly C, Perez M, Doria A, Fish JS. The effectiveness of laser therapy for
55 hypertrophic burn scars in pediatric patients: A prospective investigation. *J Burn Care Res.*
56 2021;42(5):847-856. doi:10.1093/jbcr/irab090
57
58 67. Lacarrubba F, Patania L, Perrotta R, Stracuzzi G, Nasca MR, Micali G. An open-label pilot
59 study to evaluate the efficacy and tolerability of a silicone gel in the treatment of hypertrophic scars
60 using clinical and ultrasound assessments. *J Dermatolog Treat.* 2008;19(1):50-53.
doi:10.1080/09546630701387009
61
62 68. Van den Kerckhove E, Stappaerts K, Fieuws S, et al. The assessment of erythema and
63 thickness on burn related scars during pressure garment therapy as a preventive measure for
64 hypertrophic scarring. *Burns.* 2005;31(6):696-702. doi:10.1016/j.burns.2005.04.014
65
66 69. Alsharnoubi J, Mohamed O, Fawzy M. Photobiomodulation effect on children's scars. *Lasers*
67 *Med Sci.* 2017;33(3):497-501. doi:10.1007/s10103-017-2387-3

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 70. Alsharnoubi J, Shoukry KE-S, Fawzy MW, Mohamed O. Evaluation of scars in children after
4 treatment with low-level laser. *Lasers Med Sci*. 2018;33(9):1991-1995. doi:10.1007/s10103-018-
5 2572-z
- 6 71. Fabbrocini G, Marasca C, Ammad S, et al. Assessment of the combined efficacy of needling
7 and the use of silicone gel in the treatment of C-section and other surgical hypertrophic scars and
8 keloids. *Adv Skin Wound Care*. 2016;29(9):408-411. doi:10.1097/01.ASW.0000490028.37994.14
- 9 72. Joo SY, Lee SY, Cho YS, Seo CH. Clinical utility of extracorporeal shock wave therapy on
10 hypertrophic scars of the hand caused by burn injury: A prospective, randomized, double-blinded
11 study. *J Clin Med*. 2020;9(5):1376. doi:10.3390/jcm9051376
- 12 73. Lobos N, Wortsman X, Valenzuela F, Alonso F. Color Doppler ultrasound assessment of
13 activity in keloids. *Dermatol Surg*. 2017;43(6):817-825. doi:10.1097/DSS.0000000000001052
- 14 74. Mamdouh M, Omar GA, Hafiz HSA, Ali SM. Role of vitamin D in treatment of keloid. *J Cosmet*
15 *Dermatol*. 2022;21(1):331-336. doi:10.1111/jocd.14070
- 16 75. Reinholz M, Guertler A, Schwaiger H, Poetschke J, Gauglitz GG. Treatment of keloids using 5-
17 fluorouracil in combination with crystalline triamcinolone acetonide suspension: evaluating
18 therapeutic effects by using non-invasive objective measures. *J Eur Acad Dermatol Venereol*.
19 2020;34(10):2436-2444. doi:10.1111/jdv.16354
- 20 76. Reinholz M, Schwaiger H, Poetschke J, et al. Objective and subjective treatment evaluation
21 of scars using optical coherence tomography, sonography, photography, and standardised
22 questionnaires. *Eur J Dermatol*. 2017;26(6):599-608. doi:10.1684/ejd.2016.2873
- 23 77. Soykan EA, Butzelaar L, de Kroon TL, et al. Minimal extracorporeal circulation (MECC) does
24 not result in less hypertrophic scar formation as compared to conventional extracorporeal
25 circulation (CECC) with dexamethasone. *Perfusion*. 2014;29(3):249-259.
26 doi:10.1177/0267659113511656
- 27 78. Wang G-Q, Xia Z-F. Transplantation of epidermis of scar tissue on acellular dermal matrix.
28 *Burns*. 2008;35(3):352-355. doi:10.1016/j.burns.2008.06.021
- 29 79. Zhidong X, Haixia L, Chao L, Yongrong L. Wavelet Bilateral Filter Algorithm-Based High-
30 Frequency Ultrasound Image Analysis on Effects of Skin Scar Repair. *Scientific programming*.
31 2021;2021doi:10.1155/2021/9573474
- 32 80. Li-Tsang CWP, Zheng YP, Lau JCM. A randomized clinical trial to study the effect of silicone
33 gel dressing and pressure therapy on posttraumatic hypertrophic scars. *J Burn Care Res*.
34 2010;31(3):448-457. doi:10.1097/BCR.0b013e3181db52a7
- 35 81. Li N, Yang L, Cheng J, Han J, Hu D. Early intervention by Z-plasty combined with fractional
36 CO2 laser therapy as a potential treatment for hypertrophic burn scars. *J Plast Reconstr Aesthet*
37 *Surg*. 2021;74(11):3087-3093. doi:10.1016/j.bjps.2021.03.079
- 38 82. Blome-Eberwein S, Gogal C, Weiss MJ, Boorse D, Pagella P. Prospective evaluation of
39 fractional CO2 laser treatment of mature burn scars. *J Burn Care Res*. 2016;37(6):379-387.
40 doi:10.1097/BCR.0000000000000383
- 41 83. Blome-Eberwein S. Fractional Er:Glass photothermolysis laser therapy to treat hypertrophic
42 scarring. *Lasers Surg Med*. 2012;44:61.
- 43 84. Blome-Eberwein S, Blaine C, Gogal C, Eid S, Foltz C. Fractional Er:Glass photothermolysis
44 laser therapy to treat hypertrophic scarring. *J Burn Care Res*. 2011;32:S95.
- 45 85. Blome-Eberwein S, Gogal C, Folz C. Assessment of hair density and sub-epidermal tissue in
46 burn scars using high frequency ultrasound. *J Burn Care Res*. 2012;33(2)(Supplement):S105.
- 47 86. Blome-Eberwein S, Roarabaugh C, Gogal C, Eid S. Exploration of nonsurgical scar
48 modification options: Can the irregular surface of matured mesh graft scars be smoothed with
49 microdermabrasion? *J Burn Care Res*. 2012;33(3):e133-40.
- 50 87. Deng H, Li-Tsang CWP, Li J. Measuring vascularity of hypertrophic scars by dermoscopy:
51 Construct validity and predictive ability of scar thickness change. *Skin Res Technol*. 2020;26(3):369-
52 375. doi:10.1111/srt.12812
- 53
54
55
56
57
58
59
60

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 88. El-Zawahry MBM, El-Cheweikh HMAE-H, Ramadan SA-E-R, Bassiouny DA, Fawzy MM. Ultrasound biomicroscopy in the diagnosis of skin diseases. *Eur J Dermatol*. 2007;17(6):469-74.
- 4 89. Zuccaro J, Perez M, Mohanta A, Fish J, Doria A. Elastography-Based Quantification of Burn Scar Stiffness. *J Burn Care Res*. 2019;40(Supplement_1):S215-S215. doi:10.1093/jbcr/irz013.374
- 5 90. Edger-Lacoursière Z, de Oliveira A, Marois-Pagé E, et al. Objective quantification of
6 hypertrophic scar and donor scar between 2 to 7 months post-burn injury. *J Burn Care Res*.
7 2022;43(Supplement 1):S103.
- 8 91. Engrav LH, Heimbach DM, Rivara FP, et al. 12-Year within-wound study of the effectiveness
9 of custom pressure garment therapy. *Burns*. 2010;36(7):975-983. doi:10.1016/j.burns.2010.04.014
- 10 92. Fracalvieri M, Sarno A, Gasperini S, et al. Can single use negative pressure wound therapy
11 be an alternative method to manage keloid scarring? A preliminary report of a clinical and
12 ultrasound/colour-power-doppler study. *Int Wound J*. 2013;10(3):340-344. doi:10.1111/j.1742-
13 481X.2012.00988.x
- 14 93. Li P, Li-Tsang CWP, Deng X, et al. The recovery of post-burn hypertrophic scar in a monitored
15 pressure therapy intervention programme and the timing of intervention. *Burns*. 2018;44(6):1451-
16 1467. doi:10.1016/j.burns.2018.01.008
- 17 94. Chang C-S, Wallace CG, Hsiao Y-C, Chang C-J, Chen PK-T. Botulinum toxin to improve results
18 in cleft lip repair: A double-blinded, randomized, vehicle-controlled clinical trial. *PLoS One*.
19 2014;9(12):e115690-e115690. doi:10.1371/journal.pone.0115690
- 20 95. Blome-Eberwein S, Pagella P, Boorse D, Gogal C. Treatment of hypertrophic burn scars with
21 different laser modalities. *Lasers Surg Med*. 2014;46:6-7.
- 22 96. Cho YS, Jeon JH, Hong A, et al. The effect of burn rehabilitation massage therapy on
23 hypertrophic scar after burn: A randomized controlled trial. *Burns*. 2014;40(8):1513-1520.
24 doi:10.1016/j.burns.2014.02.005
- 25 97. Cooper LE, Bohan PK, Hatem VD, Carlsson AH, Cancio LC, Chan RK. Analysis of the utility of
26 CO2 and pulse-dye lasers in the treatment of hypertrophic burn scars. *J Burn Care Res*.
27 2021;42(Supplement_1):S28-S29. doi:10.1093/jbcr/irab032.041
- 28 98. Jacobs M, Roggy D, Sood R. A preliminary report of a prospective study evaluating outcomes
29 of burn scars treated with laser therapy. *J Burn Care Res*. 2016;37(Supplement):S106.
- 30 99. Jang KU, Lee JY, Choi JS, Seo CH. 5 FU and triamcinolone injection to the hypertrophic scar
31 were compared. *Burns*. 2009;35:S41-S42. doi:10.1016/j.burns.2009.06.166
- 32 100. Kim SK, Park JM, Jang YH, Son YH. Management of hypertrophic scar after burn wound using
33 microneedling procedure (dermastamp). *Burns*. 2009;35:S37-S37. doi:10.1016/j.burns.2009.06.146
- 34 101. Li K, Nicoli F, Cui C, et al. Treatment of hypertrophic scars and keloids using an intralesional
35 1470 nm bare-fibre diode laser: a novel efficient minimally-invasive technique. *Sci Rep*.
36 2020;10(1):21694-21694. doi:10.1038/s41598-020-78738-9
- 37 102. Li P, Li-Tsang CWP. Clinical effectiveness and intervention timing of smart pressure-
38 monitored suit in the management of post-burn hypertrophic scar: A clinical controlled study with
39 objective assessment. *J Burn Care Res*. 2016;37(Supplement):S199.
- 40 103. Li-Tsang CWP, Feng B-B, Li K-C. Pressure therapy of hypertrophic scars after burns and
41 related research. *Zhonghua Shao Shang Za Zh (Chinese Journal of Burns)*. 2010;26(6):411-5.
- 42 104. Maari C. Randomized, controlled, within-patient, single-blinded pilot study to evaluate the
43 efficacy of the ablative fractional CO2 laser in the treatment of hypertrophic scars in adult burn
44 patients. *J Am Acad Dermatol*. 2017;76(6):AB212-AB212. doi:10.1016/j.jaad.2017.04.1113
- 45 105. Nedelec B, Couture M, Calva V, et al. Randomized controlled trial of the immediate and long-
46 term effect of massage on adult postburn scar. *J Burn Care Res*. 2018;39(suppl_1):S57-S57.
47 doi:10.1093/jbcr/iry006.106
- 48 106. Peters EP, Moortgat P. Electronic micro-needling on mature burn scars: A case series report.
49 *Wound Repair Regen*. 2018;26(2):A28-A28.
- 50
51
52
53
54
55
56
57
58
59
60

BM, MS, TM, TR, BD, RK, ZT – Ultrasound Scoping Review: Supplement

- 1
2
3 107. Siwy KG, Lee K, Donelan MB, Anderson RR, Miletta NR. Fractionated CO2 laser and burn scar
4 contractures: Evaluation of post treatment scar function and appearance. *J Burn Care Res.*
5 2016;37:S202-S202.
6
7 108. Ud-Din S, Foden P, Douglas M, et al. A double-blind randomized controlled trial
8 demonstrates for the first time evidence for the role of topical epigallocatechin-3-gallate in reducing
9 angiogenesis, inflammation, and skin thickness in human skin scarring: A noninvasive, morphological
10 and immu. *Wound Repair and Regeneration.* 2017;25(4):A3.
11 109. Ud-Din S, Foden P, Mazhari M, Al-Habba S, Baguneid M, Bayat A. Histomorphologic assessment
12 of noninvasive quantitative imaging in progression of cutaneous healing in human skin: Dynamic
13 optical coherence tomography versus high frequency ultrasound. *Wound Repair Regen.*
14 2017;25(4):A3-A4.
15 110. Ud-Din S, Foden P, M M, Samer A, Baguneid M, Bayat A. Quantitative index for skin fibrosis:
16 Combined optical coherence tomography with ultrasound validated by histology and
17 immunohistochemistry. *Wound Repair Regen.* 2018;26(4):A11-A12.
18 111. Li-Tsang CWP, Lau JCM, Choi J, Chan CCC, Jianan L. A prospective randomized clinical trial to
19 investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among
20 the Chinese population. *Burns.* 2006;32(6):678-683. doi:10.1016/j.burns.2006.01.016
21 112. Alshehari A, Wahdan W, Maamoun MI. Comparative study between intralesional steroid
22 injection and silicone sheet versus silicone sheet alone in the treatment of pathologic scars. *Archives*
23 *of the Balkan Medical Union.* 2015;50(3):364-366.
24 113. Cho J, Choi J, Hur J, et al. The effect of CO2 fractional laser (pixel®) on hypertrophic burn
25 scars. *J Burn Care Res.* 2012;33(2)(Supplement):S132.
26 114. Comstock J, Sood R. Can mature facial scars benefit from a transparent face mask? *J Burn*
27 *Care Res.* 2018;39(suppl_1):S219-S220. doi:10.1093/jbcr/iry006.416
28 115. Issler-Fisher AC, Fisher OM, Haertsch P, Li Z, Maitz PKM. Ablative fractional resurfacing with
29 laser-facilitated steroid delivery for burn scar management: Does the depth of laser penetration
30 matter? *Lasers Surg Med.* 2020;52(2):149-158. doi:10.1002/lsm.23166
31 116. Ge X, Sun Y, Lin J, Zhou F, Yao G, Su X. Effects of multiple modes of UltraPulse fractional CO2
32 laser treatment on extensive scarring: a retrospective study. *Lasers Med Sci.* 2021;37(3):1575-1582.
33 doi:10.1007/s10103-021-03406-x
34 117. Li-Tsang CWP. The effect of a new silicone padding (SPMP) in management of keloids: Case
35 review. *J Burn Care Res.* 2011;32(Supplement):S169-S169.
36 118. Tu P, Wang Z-G, Zhang Q-X, You Y-F. High frequency ultrasound in dynamic observation on
37 effect of local injection with diprosan for treating pathological scar. *Chinese Journal of*
38 *Interventional Imaging and Therapy.* 2014;11(4):217-220.
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Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	3-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	5-7
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	7
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-10
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	9
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	9
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	10-11
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11 and supplementary table 1
Critical appraisal of individual	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe	N/A



SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
sources of evidence§		the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10-11
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	11-12
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	12-15
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Results section (11-46)
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Results section (11-46)
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	47-49
Limitations	20	Discuss the limitations of the scoping review process.	49-50
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	50-51
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	51

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



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