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REVIEW ARTICLE

A Systematic Review of Distal Interphalangeal Joint Arthrodesis

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Abstract Arthrodesis of the distal interphalangeal joint of the hand is a reliable procedure for creating a painless stable joint. Numerous techniques are described within the literature for varying indications. We undertook a systematic review of all studies published within the English literature to provide a comparison of the different techniques. The published studies were predominantly of Level IV evidence. The most commonly employed techniques were Kirschner wire, headless compression screw and cerclage wires. There was no difference in infection rates. Headless compression screws appear to have increased union rates but are associated with complications not seen with other well-established and cheaper techniques. The screw diameter is often similar to or larger than the joint itself, which can result in penetration. Furthermore, they limit the available angle for achieving fusion. Other than in terms of union, there is insufficient evidence to show the headless compression screw is superior to other techniques.

Keywords Arthrodesis · Review · Distal interphalangeal joint · Hand · Techniques

Introduction

Arthrodesis of a finger distal interphalangeal joint (DIPJ) or a thumb interphalangeal joint (IPJ) is predominantly undertaken for a painful degenerate joint. This may be due to osteoarthritis, inflammatory arthropathy, post-traumatic condition such as chronic mallet deformity and infection. Other indications include instability or hyperextension deformity. Moberg and Henrickson stated that 'the prime requisites of a good digital arthrodesis are a painless and stable union in a proper position and in a reasonable space of time' [1]. To this end, several techniques have been described for both preparation of the bone ends and the methods of stabilization.

The bones ends can be prepared as two straight surfaces [1], chevron [2], cup and cone [3], or as a tenon [4]. The straight surfaces are simplest but do not provide highest intrinsic bony stability to the construct. The other techniques are more surgically demanding but do provide better inherent stability. Furthermore, in the cup and cone preparation, the position of arthrodesis can be adjusted following bone preparation.

Early methods of bone fixation involved the use of Kirschner wires, either two crossed [5] or one single wire and the use of a supplementary plaster cast [6]. In order to reduce the period of finger immobilisation, Tupper developed an external device though this can interfere with adjacent digits' function [7]. It has been shown that compression with a modified Charnley clamp could accelerate fusion in comparison to Kirschner wires (K wires) [8]. Various other stabilization methods have been utilised to provide compression at the arthrodesis site such as tension band wire [9], lag screw [10] and headless compression screw [11].

There is no universal agreement on the best technique. The aim of this study is to perform a systematic review on the various techniques of arthrodesis of the DIPJ of the fingers and the IPJ of the thumb with a view to elucidate the safest and most reliable technique of stabilization.

Methods

Selection Criteria

The inclusion criteria for the study were any randomized controlled trials, non-randomized or quasi-randomized

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controlled trials, prospective cohort trials and retrospective cohort studies of patients who underwent fusion of the DIPJ of the fingers or the IPJ of the thumb.

The exclusion criteria were: 1) patients undergoing revision arthrodesis; 2) studies that included arthrodesis of other joints and in combined studies where it was not possible to extract the data for the DIPJ; 3) case reports, reviews, biomechanical studies, description of technique only and animal studies; 4) studies not available in English.

Literature Search

The following sources of data were searched up to 28th February 2014: Medical Literature Analysis and Retrieval System online (MEDLINE, Bethesda, MD, USA) and the Exerpta Medica Database (EMBASE, Amsterdam, The Netherlands), The Cochrane Library and Google Scholar using the search strategy of (‘DIPJ fusion’) OR (‘DIPJ Arthrodesis’) OR (‘Distal Interphalangeal Joint Arthrodesis’) OR (‘Distal Interphalangeal Joint Fusion’) OR (‘Digital Arthrodesis’) OR (‘Digital Fusion’) OR (‘Small Joint Fusion’) OR (‘Small Joint Arthrodesis’) OR (Finger Fusion] OR (Finger Arthrodesis) OR (Thumb Fusion] or [Thumb arthrodesis], with limitation to the English language but not on the year of publication. In addition we searched the following journals using the same terms: European Journal Hand Surgery, American Journal Hand Surgery, American Journal Bone Joint Surgery, Bone Joint Journal. The bibliographies of all included papers were cross- referenced and further papers obtained where appropriate.

Data Extraction and Analysis

The titles and abstracts of the citations were screened against the eligibility criteria. The patient demographics (sample size, age, gender) surgical indication, review criteria (follow-up, loss to follow-up and methodology), study design and level of evidence, intervention (bone preparation, fixation method, treatment protocol) and assessment of outcome including all documented complications and scoring systems were extracted where the information was available. Extraction of results from graphs in trial reports was considered where data were not provided in the text or tables.

An analysis was performed using RevMan analysis software (RevMan 5.1.6) of the Cochrane Collaboration.

Results

The literature search yielded 2940 articles; 2908 were excluded because they did not fulfil the selection criteria. 32 studies (1125 digits) were included for further analysis. Figure 1 shows a flowchart of how these studies were selected.

Table 1 shows the details of the studies included based on the surgical techniques. Our analysis revealed 7 groups based on the surgical intervention as follows: eight K-wire studies (389 joints), four interosseous wire studies (114 joints), three headed screw studies (47 joints), 13 headless compression screw studies (492 joints), three absorbable rod studies (37 joints), one plate fixation study (15 joints) and three external fixation studies (31 joints). There were two studies (6 %) with level 3 and the remainder (94 %) with level 4 evidence.

Out of total 1125 joints, 607 joints were followed-up for 6 weeks to 50 months but no follow-up period was stated for the remaining 518 joints. Union was assessed by clinical assessment alone in one study (3 %), radiological assessment alone in three studies (9 %), by both radiological and clinical assessment in 14 studies (44 %) with the remaining 14 studies not stating how union was assessed (44 %). A follow-up protocol was described in 8 studies (25 %), which consisted of fixed time intervals until fusion occurred.

None of the studies provided a list of assessed complications. Three studies simply stated that no complications were seen. In assessing each complication, we included data where the complication was specifically mentioned.

Table 2 shows the overall union rates, time to union, infection rates and other complications between the different surgical techniques. The number of joints in each group is shown in the brackets.

Due to the quality of the data available, only two outcome measures (union rate and infection rate) were amenable for

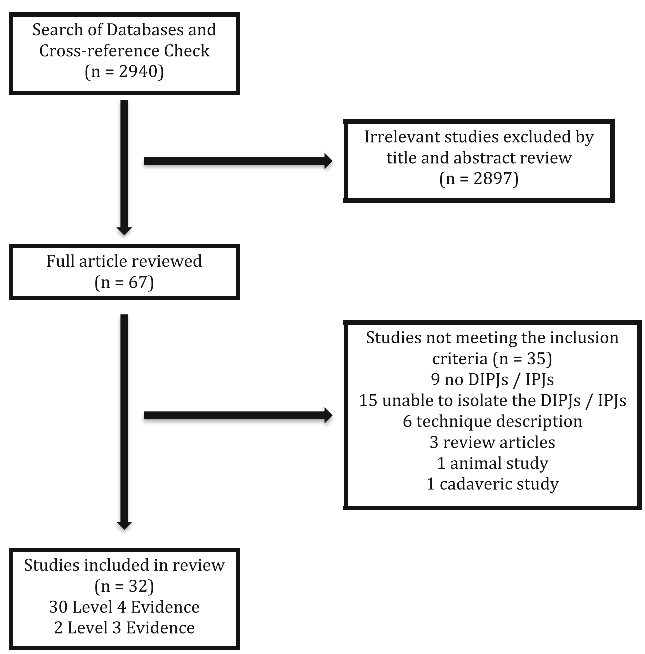


Fig. 1 Flowchart illustrating the selection of studies included in the systematic review

Table 1 Details of the studies included in the review, including level of evidence, demographic details, method of bone preparation, fixation method, treatment and follow-up protocol

Paper Type and Name	Level of Evidence	Joint No	Sex	Age	Follow up Period	Follow Up Protocol	Fusion Position	Bone End Preparation	Bone Grafting	Period of Immobilisation
Headless Compression Screw										
Konan [12]	Level IV	38	9 M 26 F	59 (30–83)	minimum 6 months	Stated	0	flat	none	Splint for 6 weeks
Song [13]	Level IV	23	6 M 16 F	54 (22–77)	not stated	Stated	0–10	flat	none	None
Brutus [14]	Level IV	27	10 M, 12 F	47 (38–60)	minimum 3 months	Stated	0–10	flat	none	Splinting for 2–4 weeks
Iwamoto [15]	Level IV	28	2 M 21 F	65 (58–74)	minimum 6 months	Stated	0–10	flat	none	Splint for 2 weeks
Cox [16]	Level IV	48	5 M, 24 F	59 (35–80)	12 months (2–50)	Not stated	zero	flat	none	6 weeks
Villani [17]	Level IV	102	3 M, 56 F	61 (43–80)	minimum of 7 months	Not stated	0	flat	none	4–8 weeks
Ruchelsman [18]	Level IV	2	1 M 1 F	27, 79	minimum 6 weeks	Not stated	0	flat	none	initially!
Matsumoto [19]	Level IV	89	3 M, 57 F	62 (36–89)	minimum 5 months	Not stated	0	flat	none	Splint for 6 weeks
El-Hadidi [20]	Level IV	13	8 M, 5 F	26 (15–51)	minimum 3 years	Not stated	0	flat	none	none stated
Faithfull [11]	Level IV	11	Not Stated	Not Stated	Not Stated	Not stated		flat	none	None
Kocak [21]	Level IV	64	M 17 34 F	57 (19–89)	minimum 3 months	Not stated	0	cup and cone	none	Splint for 2 days
Lamas-Gomez [22]	Level IV	20	6 M 14 F	53 (22–73)	minimum 6 months	Not stated	10	flat	none	10 days
Stern [23]	Level III	27	Not Calculable	Not Calculable	Not Calculable	Not stated	Not Stated	flat	none	Not Stated
Headless Compression Screw Total	1 Level III, 12 Level IV	492	Not Calculable	Not Calculable	Variable	Variable	Up to 10°	Variable	None	Variable
K-wire Studies										
Carroll [3]	Level IV	79	not stated	not stated	not stated	Not stated	25	cup and cone	none	6 weeks
Engel [24]	Level III	15	not stated	not stated	not stated	Stated	0	cup and cone	none	4–12 weeks
Moberg [1]	Level IV	21	not stated	not stated	not stated	Not stated	Not stated	flat	Yes	not stated
Pribyl [2]	Level IV	4	Not able to separate	not able to separate	not stated	Not stated	not stated	chevron	none	until fusion occurred
Burton [25]	Level IV	59	Not able to separate	not able to separate	not stated	Stated	10–20	flat	Yes	3–5 weeks
Stern [23]	Level III	111	Not able to separate	not able to separate		Not stated	Not stated	flat	not stated	not stated
Lewis [4]	Level IV	57	Not able to separate	not able to separate	until fusion occurred	Stated	Not stated	tenon	none	Splint for 6 weeks
K-Wire Total	2 Level III, 5 Level IV	346	Not Calculable	Not Calculable	Variable	Variable	Up to 25°	Variable	Variable	Variable
Headed Screw Studies										
Engel [24]	Level III	15	not stated	not stated	not stated	Stated	0	not stated	none	1 week
Olivier [26]	Level IV	18	Not able to separate	48 (15–72)	minimum 6 months	Not stated	0	Flat	Bone chips	4 weeks
Teoh [27]	Level IV	14	15 M 7 F	35.4 (19–64)	minimum 2 months	Not stated	25	flat	none	None
Headed Screw Total	1 Level III, 2 Level IV	47	Not Calculable	Not Calculable	Variable	Variable	Up to 25°	Variable	Variable	Variable

Table 1 (continued)

Paper Type and Name	Level of Evidence	Joint No	Sex	Age	Follow up Period	Follow Up Protocol	Fusion Position	Bone End Preparation	Bone Grafting	Period of Immobilisation
Plate Study										
Mantovani [28]	1 Level IV	15	8 M, 3 F	41 (23–73)	minimum 18 months	Not Stated	0–5	Flat	None	1 week
Interosseous Wire Studies										
Stern [23]	Level III	43	Not able to separate	not able to separate	not able to separate	Not Stated	Not stated	flat	not stated	not stated
Shanker [29]	Level IV	37	Not able to separate	not able to separate	not able to separate	Not Stated	Not stated	flat	none	None
Lister [30]	Level IV	33	Not able to separate	not able to separate	not stated	Not Stated	not stated	variable	none	not stated
Stahl [31]	Level IV	20	Not able to separate	not able to separate	minimum 18 months	Not Stated	Not stated	flat	none	4–6 days
Zavitsanos [32]	Level IV	24	not stated	58 (29–78)	minimum 18 weeks	Not Stated	0	flat	none	not stated
Interosseous Wire Total	1 Level III, 4 Level IV	114	Not calculable	Not Calculable	Variable	Not Stated	Not stated	Variable	None	Variable
External Fixator Studies										
Leonard [33]	Level IV	16	Not able to separate	22–65	not stated	Not stated	Not stated	ball and socket	none	6 weeks whilst ex-fix on!
Seitz [34]	Level IV	4	3 M, 1 F	54 (47–66)	not stated	Stated	not stated	cup and cone	none	4–6 weeks (Ex-FIX in situ)
Wexler [35]	Level IV	11	Not able to separate	not able to separate	not stated	Not stated	not stated	flat	none	4 weeks
Ex Fix Total	3 Level IV	31	Not Calculable	Not Calulable	not stated	Variable	Not stated	Variable	None	4–6 weeks
Resorbable pegs Studies										
Sabbagh [36]	Level IV	15	Not able to separate	not able to separate	minimum 2 years	Not stated	30–50	flat	none	2 weeks
Arata [37]	Level IV	16	11 M 5 F	49 (21–64)	minimum 2 months	Stated	0–20	flat	none	3 weeks
Harrison [38]	Level IV	6	not stated	not stated	not stated	Not stated	not stated	flat	none	14 days
Resorbable pegs total	3 Level IV	37	Not Calculable	Not Calculable	Variable	Variable	Up to 50°	Flat	None	up to 3 weeks

Table 2 Details of the outcomes from each study, including union, infection, malunion and complications

Paper	Union Rate	Malunion	Infection	Nail Abnormality	Metalwork Prominence	Metalwork removal	Cold intolerance	Skin Necrosis	PIPJ stiffness	Fractures	Screw Cut out	Amputation	Paraesthesia
Headless Compression Screw Studies													
Konan [12]	38/38	Not stated	1/38	0/38	0/38	3/38	Not stated	not stated	Not stated	2/38	2/38	none	not stated
Song [13]	23/23	Not stated	0/23	0/23	0/23	0/23	Not stated	0/23	0/23	0/23	0/23	not stated	0/23
Brutus [14]	23/27	Not stated	4/27	3/27	0/27	3/27	not stated	1/27	not stated	not stated	0/27	none	not sstated
Iwamoto [15]	27/28	Not stated	2/28	0/28	0/28	1/28	not stated	0/28	not stated	1/28	0/28	none	0/28
Cox [16]	45/48	0/43	Not stated	0/48	0/48	not stated	not stated	0/48	Not stated	1/48	0/48	none	not stated
Villani [17]	102/102	0/102	0/102	0/102	2/102	4/102	0/102	0/102	Not stated	0/102	0/102	none	not stated
Ruchelsman [18]	2/2	Not stated	Not stated	Not stated	Not stated	Not stated	not stated	not stated	not stated	not stated	not stated	none	not stated
Matsumoto [19]	86/89	Not stated	0/89	0/89	1/89	not stated	0/89	0/89	Not stated	not stated	not stated	none	0/89
El-Hadidi [20]	12/13	Not stated	0/13	0/13	1/13	1/13	2/13	0/13	Not stated	not stated	1/13	none	not stated
Faithfull 1984	11/11	Not stated	0/11	0/11	0/11	0/11	Not stated	0/11	Not stated	0/11	not stated	none	not stated
Kocak [21]	61/64	Not stated	1/64	not stated	5/64	5/64	not stated	not stated	Not stated	Not stated	not stated	none	not stated
Lamas-Gomez [22]	19/20	0/20	0/20	0/20	0/20	0/20	0/20	1/20	0/20	not stated	not stated	1/20 due to pulp necrosis	not stated
Stern [23]	24/27	1/27	2/27	Not stated	2/27	not stated	2/27	4/27	0/27	not stated	not stated	none	3/27
Headless Compression Screw Total	473/492 (96.1%)	1/192 (0.5%)	10/ 442 (2.3%)	3/399 (0.8%)	11/490 (2.2%)	17/326 (5.2%)	4/191 (2.1%)	6/377 (1.6%)_	0/70	4/250 (1.6%)	3/279 (1.1%)	1/492 (0.2%)	3/167 (1.8%)
K-wire Studies													
Carroll [3]	72/79	Not stated	0/79	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated
Engel [24] not stated	12/15 not stated	not		calculable	1/15	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated
Moberg [1] not stated	17/21 not stated	not		calculable	1/21	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated
Pribyl [2] not stated	4/4	0/4	Not	calculable	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated
Burton [25] not stated	59/59 not stated	not		calculable	0/59	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated
Stern [23]	98/111	4/111	6/111	not stated	0/111	not stated	2/111	3/111	2/111	not stated	not stated	not stated	2/111
Lewis [4]	55/57	Not stated	0/57	0/57	not stated	not stated	not stated	0/57	not stated	not stated	not stated	not stated	not stated
K-Wire Total	317/346 (91.6%)	4/115 (3.5%)	8/342 (2.3%)	0/57	0/111	None	2/111 (1.8%)	3/168 (1.8%)	2/111 (1.8%)	none	n/a	none	2/111 (1.8%)
Headed Screw Studies													
Engel [24]	12/15	not stated	0/15	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated	not stated

Table 2 (continued)

Paper	Union Rate	Malunion	Infection	Nail Abnormality	Metalwork Prominence	Metalwork removal	Cold intolerance	Skin Necrosis	PIPJ stiffness	Fractures	Screw Cut out	Amputation	Paraesthesia
Olivier [26]	18/18	Not stated	2/18	1/18	0/18	2/18	Not stated	0/18	Not stated	Not stated	not stated	Not stated	not stated
Teoh [27]	14/14	0/14	0/14	not stated	0/14	0/14	not stated	0/14	not stated	not stated	not stated	not stated	not stated
Headed Screw Total	44/47 (93.6%)	0/14	2/47 (4.3%)	1/18 (5.6%)	0/32	2/32 (6.25%)	not stated	0/32	not stated	not stated	not stated	not stated	not stated
Plate Study													
Mantovani [28]	15/15	0/15	0%	0/15	2/15	2/15	Not stated	0/15	0/15	0/15	N/A	not stated	0/15
Interosseous Wire Studies													
Stern [23]	38/43	1/43	4/43	not stated	0/43	not stated	2/43	1/43	3/43	not stated	n/a	not stated	0/43
Shanker [29]	32/37	Not stated	Not	calculable	Not							calculable	Not
calculable	Not calculable	Not		calculable	not stated	not stated	not stated	n/a	not stated	not stated			
Lister [30]	30/33	Not stated	0/33	not stated	3/33	3/33	not stated	not stated	not stated	not stated	n/a	not stated	not stated
Stahl [31]	20/20	Not stated	0/20	Not calculable	Not							calculable	Not
calculable	Not calculable	Not calculale	Not stated	Not stated	n/a	not stated	not stated						
Zavitsanos [32]	23/24	0/24	1/24	0/24	2/24	2/24	not stated	0/24	0/24	not stated	N/A	not stated	not stated
Interosseous Wire Total	143/157 (91.1%)	1/67 (1.5%)	5/120 (4.2%)	0/24	5/100 (5%)	5/57 (8.8%)	2/43 (4.7%)	1/67 (1.5%)	3/67 (4.5%)	not stated	n/a	not stated	0/43
External Fixator Studies													
Leonard [33]	15/16	Not stated	0/16	not stated	N/a	N/A	Not stated	not stated	not stated	not stated	N/A	not stated	not stated
Seitz [34]	3/4	0/4	0/4	0/4	0/4	N/A	Not stated	not stated	not stated	0/4	N/A	not stated	not stated
Wexler [35]	Not calculable	2/11	0/11	not calculable	not							calculable	N/A
Not stated	0/11	not stated	not stated	N/A	not stated	not stated							
Ex Fix Total	18/20 (90%)	2/15 (13.3%)	0%	0/4	0/4	N/A	not stated	0/11	not stated	0/4	n/a	not stated	not stated
Resorbable pegs Studies													
Sabbagh [36]	not able to separate	Not stated	3/15	Not calculable	N/A	N/A	not stated	not stated	Not stated	Not stated	N/A	not stated	not stated
Arata [37]	16/16	0/16	0/16	0/16	N/A	N/A	not stated	0/16	not stated	0/16	N/A	not stated	not stated
Harrison [38]	6/6	Not stated	Not stated	not stated	N/A	N/A	not stated	not stated	Not stated	Not stated	N/A	not stated	not stated
Resorbable pegs total	22/22	0/16	3/37 (8.1%)	0/16	N/a	N/A	not stated	0/22	0/6	0/22			0/6

further analysis in order to generate odds ratios of occurrence among the three most commonly employed techniques (Kirschner wire, headless compression screw and cerclage wires). These are shown in Figs. 2 and 3. The rates of non-union and infection were compared using Fisher Exact test and the results are shown in Table 3.

A patient rated outcome score was reported in 4 studies. Only one paper reported the time of return to work. No analyses were possible in either of these parameters.

Discussion

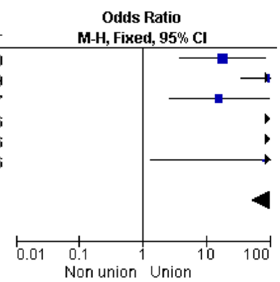
A wide range of surgical techniques have been described for achieving arthrodesis of the DIPJ. Literature search revealed that the published studies are predominantly case series of Level 4 evidence, which highlights a lack of good quality data to guide surgical choice. Nevertheless, the majority of joints were fused with Kirschner wires, interosseous wiring or headless compression screws. Each of these three techniques has over 100 joints when the results from studies were collated. We have, therefore, performed statistical analysis of these three techniques. The results however should be interpreted with caution due to the levels of evidence of the studies as well as the heterogeneous mix of patients in terms of age and surgical indications. It is notable that of the 12 papers published within the last 10 years which had been included in our review, 9 of them reported the results of headless compression screws. None of the studies reported the use of Kirschner wires since 1996. This may represent a shift amongst hand surgeons to using headless compression screws or a publication bias.

Fig. 2 The Forest plots with Odds Ratios for K-wires, Cerclage wires and Headless Compression Screw respectively

K-wire

Study or Subgroup	union Events	union Total	non union Events	non union Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Moberg 1960	17	21	4	21	36.2%	18.06 [3.87, 84.28]	1960
Carrol 1969	72	79	7	79	29.4%	105.80 [35.31, 317.00]	1969
Engel 1977	12	15	3	15	28.5%	16.00 [2.67, 95.75]	1977
Lewis 1986	55	57	2	57	3.3%	756.25 [102.83, 5561.67]	1986
Burton 1986	59	59	0	59	0.2%	14161.00 [276.41, 725495.96]	1986
Pribyl 1996	4	4	0	4	2.4%	81.00 [1.30, 5046.33]	1996
Total (95% CI)		**235**		**235**	**100.0%**	**97.37 [50.40, 188.09]**	
Total events	219		16				

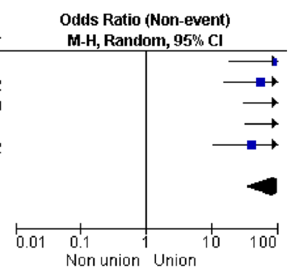
Heterogeneity: Chi² = 18.74, df = 5 (P = 0.002); I² = 73%
Test for overall effect: Z = 13.63 (P < 0.00001)



Cerclage Wire

Study or Subgroup	nonnion Events	nonnion Total	union Events	union Total	Weight	Odds Ratio (Non-event) M-H, Random, 95% CI	Year
Lister 1978	3	33	30	33	22.7%	100.00 [18.67, 535.70]	
Stern 1992	5	43	38	43	31.4%	57.76 [15.45, 215.92]	1992
Zavitsanos 1999	1	24	23	24	9.7%	529.00 [31.17, 8976.92]	1999
Stahl 2001	0	20	20	20	5.2%	1681.00 [31.81, 88839.63]	2001
Shanker 2002	5	37	32	37	31.0%	40.96 [10.80, 155.32]	2002
Total (95% CI)		**157**		**157**	**100.0%**	**86.81 [34.06, 221.22]**	
Total events	14		143				

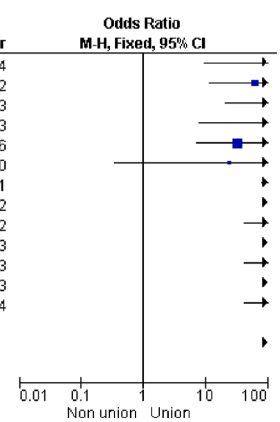
Heterogeneity: Tau² = 0.27; Chi² = 5.26, df = 4 (P = 0.26); I² = 24%
Test for overall effect: Z = 9.35 (P < 0.00001)



Headless Compression Screw

Study or Subgroup	union Events	union Total	non union Events	non union Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Faithful 1984	11	11	0	11	1.3%	529.00 [9.65, 29005.06]	1984
Stern 1992	24	27	3	27	20.3%	64.00 [11.72, 349.42]	1992
Lamas-Gomez 2003	19	20	1	20	3.0%	361.00 [21.01, 6202.41]	2003
El-hadidi 2003	12	13	1	13	4.7%	144.00 [8.04, 2578.09]	2003
Brutus 2006	23	27	4	27	36.1%	33.06 [7.37, 148.41]	2006
Ruchelsman 2010	2	2	0	2	5.1%	25.00 [0.34, 1831.59]	2010
Kocak 2011	61	64	3	64	8.6%	413.44 [80.27, 2129.64]	2011
Villani 2012	102	102	0	102	0.1%	42025.00 [825.96, 2138247.44]	2012
Song 2012	23	23	0	23	0.6%	2209.00 [42.05, 116041.72]	2012
Matsumoto 2013	86	89	3	89	6.2%	821.78 [161.34, 4185.77]	2013
Iwamoto 2013	27	28	1	28	2.2%	729.00 [43.34, 12263.03]	2013
Konan 2013	38	38	0	38	0.4%	5929.00 [114.70, 306480.92]	2013
Cox 2014	45	48	3	48	11.4%	225.00 [43.09, 1174.84]	2014
Total (95% CI)		**492**		**492**	**100.0%**	**277.62 [153.08, 503.50]**	
Total events	473		19				

Heterogeneity: Chi² = 24.20, df = 12 (P = 0.02); I² = 50%
Test for overall effect: Z = 18.52 (P < 0.00001)



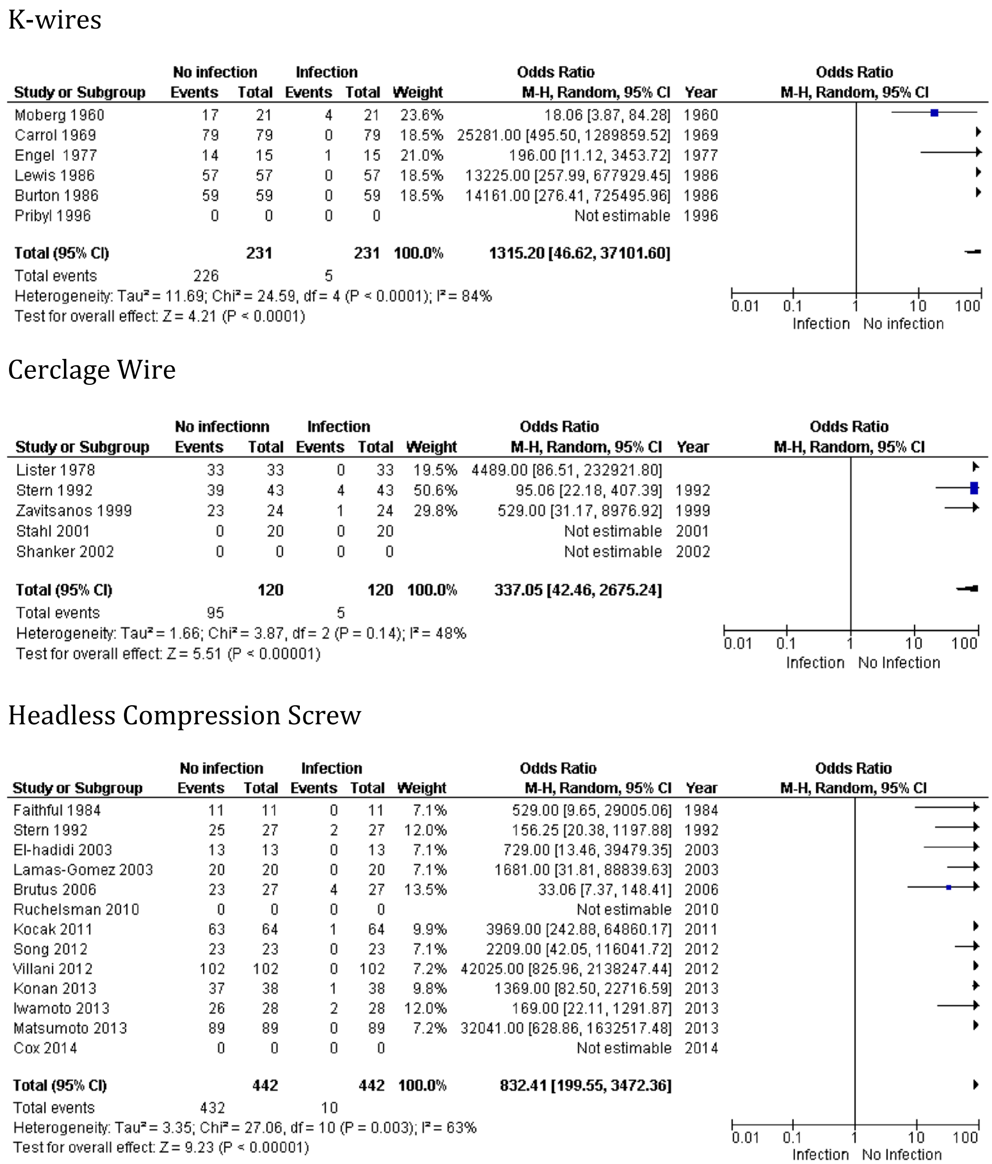


Fig. 3 Forest Plots and Odds Ratios for Infection using K-wires, Cerclage wire and Headless Compression Screws respectively

The odds ratios showed strong trends towards both union and no infection in all three techniques. In comparing the techniques with each other there was also no difference in the infection rates but there was a statistically increased rate of union with the headless compression screw when compared to either the K-wire ($p<0.01$) or cerclage wire ($p=0.02$). There was no statistically significant difference in the union rates between the K-wires or cerclage wire. However, whilst headless compression screws appear to achieve a higher rate of union there are a number of complications unique to this technique such as 1 % nail abnormalities, 1 % fracture and 1 % screw cut through. Further surgery to remove the screw was required in 5 % of cases, compared with 9 % for cerclage wires, whilst the K-wires can easily be removed in the outpatient setting.

Whilst the surgeon tends to view union and no infection as the main desirable outcomes, there is no comparable patient reported outcome data to show advantage of one technique over another. The cost of a headless compression screw is significantly greater than that for a K-wire (for instance, £205 compared with £8 in our hospital). However headless compression screw may facilitate earlier mobilization and potentially earlier return to work when compared to the wires. The potential savings thus may offset the increased cost of a screw. The risk reward balance of these different techniques and costs to the patient and the healthcare system should be borne in mind when deciding on the choice of implant.

The headless compression screws have been grouped together for the purposes of this review though they vary in shape and size. The Acutrak™ screw has a conical shape with threads along its length, which has been purported to reduce pistoning and increase the surface area for bone purchase [39]. They have also been reported to provide greater compression than Herbert™ screws [40] but there has been no clinical correlation to support one over another. It is also important

Table 3 Fisher exact method results showing differences in infection and union rates between the three main methods

Technique	Infection Rate		P-value compared to Technique			Union rate		P-value compared to Technique		
	Not Infected	Infected	K-wire	Cerclage	Headless Compression	Union	Non-Union	K-wire	Cerclage	Headless Compression
K-wire	342	8	N/A	0.35	1	346	29	N/A	0.86	<0.01
Cerclage	115	5	0.35	N/A	0.34	143	14	0.85	N/A	0.02
Headless Compression	432	10	1	0.34	N/A	473	19	<0.01	0.02	N/A

to note that the screw diameter varies between designs from 2.5 mm for the Acutrak™ screw up to 4.1 mm for the Twinfix™ screw. The average lateral diameter for the distal phalanx also varies in diameter from 3.17 mm in the middle finger to 2.64 mm in the little finger [13]. Mintalucci et al. have found similar problems with a mismatch between the phalangeal and screws sizes [40]. They compared the anteroposterior and lateral dimensions of the phalanx with 16 different headless compression screws and found a mismatch occurred in 66 % index, 53 % middle, 49 % ring and 72 % of little fingers [40]. Indeed they found that only one of these screws, the Acutrak Fusion™, had a compatibility of over 90 % for all DIP joints. This means that in some instances it may not be possible to place a screw without cortical penetration whilst in other cases there is only a very small margin for error. Careful assessment should be made of the size of the phalanx particularly the little finger and if in doubt use a different technique [14, 40]. This is supported by Wyrsch who reported dorsal cortex penetration in 25 out of 30 cadaveric specimens [41]. Conversely, it has also been suggested that headless compression screws should not be used in the phalanges of the thumb as the intramedullary cavity is too wide for adequate purchase [17]. Further studies are required to ascertain whether there is an optimum screw to phalanx diameter ratio. As the diameter of the little phalanx is smaller than that of the index or middle fingers it may be that cortical penetration and nail deformities are higher in this finger, though it has not been possible to establish this from our review as most studies failed to comment on the specific digit the complications occurred in.

There is a wide variety of the optimum angle of fusion within the literature. It has been postulated that most surgeons would fuse the joint in full extension because it is adequate for most work of the hand [24]. Whilst full extension may be cosmetically acceptable this may have an impact on function. For instance in the presence of restricted flexion in the proximal interphalangeal and metacarpophalangeal joints a greater angle of fusion may be required in the DIPJ to optimize function [42, 43]. Straub recommended fusing the joint in the position it would normal rest in, as such the flexion would increase (from radial to ulnar digits) from approximately 10° in the index finger to 40° in the little finger [44]. It would seem sensible to assess the mobility in the proximal joints prior to deciding on the fusion angle. It is important to appreciate that the angle of fusion with retrograde headless compression screw is generally limited to 0–10°. If the screw is placed in an antegrade manner across the joint a greater angle can be achieved but there may be only minimal purchase for the proximal part of the screw within the middle phalanx [24]. It is easier to achieve a greater angle by using other techniques such as Kirschner wires [24].

The success of arthrodesis will be determined not just on surgical technique but also on patient factors, in particular the indication for surgery. Most studies have included multiple indications from traumatic to inflammatory and non-inflammatory arthritis. The soft-tissue envelope, bone stock and bone quality can differ considerably between these conditions. Complication rates of 40 % have been reported in patients with psoriatic arthropathy [23]. Bone stock rather than the fixation method was the greatest determinant of successful arthrodesis in these patients [23]. In addition, in patients with poor bone stock, K-wires have been preferred to screw stabilization due to the poor purchase of the screw into the bone [45]. In the presence of any irregularity use of bone graft (from the condyles, distal radius or iliac crest) has been recommended.

When determining the fixation method of DIPJ arthrodesis, we recommend the following considerations:

1. What is the desired angle of arthrodesis? If greater than 10° of flexion is required then do not use a compression screw.
2. Assess the bone stock and quality. If the bone stock is poor, consider supplemental use of bone graft. Consider whether the bone is of sufficient quality to support compression with either the wire or screw.
3. What is the size of the distal phalanx in relation to the metalwork? Be aware of the diameter of the screw or wire.

Conclusion

With the limited evidence of the studies available, the three most commonly reported techniques for DIPJ fusion in the hand are Kirschner wire, headless compression screw and cerclage wire. There is insufficient evidence to support any particular technique. The technique with the least reported complications appears to be Kirschner wires. Further level one studies with well-matched controls taking into considerations of surgical indications, specific digit, bone preparation techniques, immobilization period, union time, complications and patient reported outcomes, are required.

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