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SYSTEMATIC REVIEW

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Hard and soft tissue alterations after the application of different soft tissue grafting materials during immediate dental implant placement: a systematic review and Bayesian network meta-analysis

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Abstract

Background The aim of this review is to compare the clinical outcomes of different soft tissue grafting materials (connective tissue graft (CTG), platelet-rich fibrin (L-PRF), allogenic and xenogenic substitutes) applied in immediate implant placement with each other.

Methods Through an electronic search regarding the study's main question ("In patients with non-restorable teeth, who receive immediate dental implants (P), what is the best adjunctive soft tissue grafting approach among different autogenous, allogenous, and xenogenous grafts (I), to achieve the desired hard and soft tissue structure (O), compared to sites without grafting (C)?") in PubMed, Scopus, and ISI Web of Science, randomized controlled clinical trials (RCTs) using different soft tissue grafts were identified and analyzed using a Bayesian random-effect network meta-analysis framework. The pink esthetic score (PES), marginal interproximal bone level changes (MIBL), buccal bone thickness changes (BBT), keratinized tissue width changes (KTW), soft tissue thickness changes (STT), papilla height changes (PH), midfacial gingival margin level changes (MGML) were defined as desired outcomes of the study; except for the MIBL with 12 – 24 months of follow-up, 6 – 12 months is considered for other outcomes.

Results After duplication removal, 903 studies were identified through the electronic search; from which 21 RCTs were included in the review. Among all comparisons in different outcomes, only CTG demonstrated a significantly higher gain in STT compared to not placing soft tissue graft. However, CTG in MIBL, KTW, STT, PH, and MGML, and unilayer xenogenic collagen matrix in PES were the superior treatments, according to the treatment ranking based on surface under cumulative ranking (SUCRA).

Conclusions At the time of immediate implantation, there is no significant difference between different soft tissue grafts regarding the clinical outcomes of implants. However, the utilization of CTG can be suggested in cases with thin soft tissue. The acceptable efficacy of allogenic and xenogenic materials and the non-significant difference

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between them and CTG indicate supporting evidence for the application of these materials to specific clinical situations simultaneously with immediate implantation.

Systematic review registration CRD42024568586.

Keywords Dental Implants, Implant Aesthetics, Immediate Implant Placement, Porcine-Derived Collagen Matrix, Soft Tissue Augmentation

Introduction

The immediate dental implantation experienced an upstream in its related published research after 2017 [1]. Reducing the edentulism duration and minimizing the number of surgical procedures are two main reasons for immediate implant placement popularity and application that make it a suitable treatment option for both dentists and patients [2]. There are two main aspects to every successful dental implant placement: biological and aesthetic features. The quality and harmony of the soft tissue around implants not only impact the aesthetic outcomes of dental implants but also specify health-related outcomes such as bleeding on probing [3, 4]. Soft tissue thickness can influence the biological width around dental implants. An adequate amount of soft tissue acts as a barrier against microorganisms in the mouth, facilitates oral hygiene, and guarantees aesthetics by covering the greyish color of implants and abutments [5–7].

Previously, in 2012, Hsu et al., in a decision tree and case report, suggested that soft tissue grafting can be considered in sites with less than 2 mm of keratinized mucosal width, less than 2 mm of mucosal thickness, and sites in which the implants are placed in a buccal position [8]. Moreover, a study by Kadkhodazadeh et al. offered a protocol for the efficient timing of soft tissue grafting around dental implants [9]. There are three major types of soft tissue grafts around dental implants: autogenous soft tissue grafts, such as subepithelial connective tissue graft (CTG), allogenous grafting materials, and xenogenic graft substitutes, like xenogenic collagen matrix material (XCM) or acellular dermal matrix (ADM). CTG is usually harvested from the tuberosity or hard palate; therefore, it is associated with a higher patient morbidity rate [10].

The success of autogenous grafts usually depends on patient anatomy, requires more surgeries, and can cause the patient some discomfort, while in xenogenic grafts, fewer surgeries and a faster healing process are seen. XCM acts as a space-making scaffold for new peri-implant tissue formation and holds angiogenic properties [11–13]. On the other hand, the effectiveness of xenogenic grafts is lower than autogenous grafts due to the tissue shrinkage and lower quality of attached tissues in grafts [14].

Since the benefits of different adjunctive soft tissue grafting materials in immediate implant placement have not yet been fully discovered and there is no systematic review and network meta-analysis available in the literature to evaluate the clinical outcomes of different materials used simultaneously with immediate implant placement, the present systematic review and network meta-analysis aimed to comprehensively assess the effects of different types of soft tissue grafts on different aspects of immediate implant treatment success and rank the available soft tissue graft options in the each desired outcome.

Materials and methods

Protocol

This systematic review has been conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension statement for network meta-analysis (PRISMA-NMA) guidance [15]. The protocol of this review has been prospectively registered in the PROSPERO on July 23, 2024 (CRD42024568586). The available literature has been qualitatively and quantitatively analyzed concerning the following question: "In patients with non-restorable teeth, who receive immediate dental implants (P), what is the best adjunctive soft tissue grafting approach among different autogenous, allogenous, and xenogenous grafts (I), to achieve the desired hard and soft tissue structure (O), compared to sites without grafting (C)?".

Eligibility criteria

PICO

P (Population) Human patients who need immediate dental implant placement after tooth extraction.

I (Intervention) Randomized clinical trials in which adjunctive soft tissue grafting using different autogenous, allogenous, xenogenous soft tissue grafts around immediately placed dental implants has been done.

C (Comparison) Comparison between different autogenous, allogenous, xenogenous soft tissue grafts, and No Treatment (control group).

O (Outcome) Primary outcomes: Pink Esthetic Score (PES), Marginal Interproximal Bone Level Changes

(MIBL), Buccal Bone Thickness Changes (BBT), Keratinized Tissue Width Changes (KTW), Soft Tissue Thickness Changes (STT), Papilla Height Changes (PH), Midfacial Gingival Margin Level Changes (MGML).

Secondary outcomes: Prosthetic and Surgical Complications

Inclusion criteria

- Human original studies
- Randomized clinical trials (RCTs)
- Studies used soft tissue grafts around immediately placed dental implants at the time of surgery.

Exclusion criteria

- Articles not written in English
- Observational, case report, case series.
- Studies did not compare different soft tissue grafts with each other or No Treatment; and instead, they compared soft tissue grafts with other treatment modalities for peri-implant soft tissue enhancement.

Information sources and search strategy

PubMed, Scopus, and ISI Web of Science databases have been searched electronically up to May 9, 2024 (Table 1/S1). The search was updated on September 13, 2024. All extracted records have been imported into Mendeley Reference Manager to remove the duplicates.

For further details, see Appendix S1.

Study selection and data collection process

Study selection has been carried out according to the eligibility criteria. firstly, four authors (F.R, A.Y, K.H, and A.M) were calibrated by (A.A) in terms of study selection and data extraction. three authors (F.R, A.Y, and A.M), independently, screened all records based on their titles and abstracts. Afterward, three authors (F.R, A.Y, and K.H) screened the full-text of the articles and extracted the data into the pre-designed tables (by A.A), independently. All disagreements at any stage were resolved after a discussion by the final verdict of the first author.

Data items

The following data items have been extracted into the tables for each study:

- Treatment arms and groups
- Population characteristics
- Initial ridge condition
- Placed implants' characteristics
- Follow-up period
- Implant loading details
- Missing tooth/teeth numbers
- Insertion torque
- Baseline measurements (If any were available)
- Clinical outcomes (PES, MIBL, BBT, KTW, STT, PH, and MGML)
- Prosthetic and surgical complications
- Other outcomes and observations (If any were available)

Risk of bias assessment

The Cochrane Collaboration's tool for randomized clinical trials (RoB 2) [37] has been used to assess the individual studies' risk of bias. Firstly, three authors (F.R, A.Y, and K.H) were calibrated by (A.A) in terms of utilization of the risk of bias tool in the bias assessment. Three authors (F.R, A.Y, and K.H) independently appraised all studies concerning the following domains: random sequence generation, concealment of the allocation, blinding, incomplete outcome data report, and other sources of bias. All disagreements at any stage were resolved after a discussion by the final verdict of the first author.

Statistical analysis

Due to the limited number of studies available on different treatment arms, a random-effect Bayesian network meta-analysis, considering the No Treatment group as the reference, has been conducted to compare various available treatment arms. Moreover, a traditional pairwise random-effect Bayesian meta-analysis was used, and at least two studies were available comparing two specific treatment arms. The effect measure for all outcomes was mean difference.

For the sake of transitivity and making the results of the network meta-analysis clinically interpretable, for each specific outcome, a period of follow-ups that are most frequently reported for that outcome was chosen, and reports of the shorter and longer follow-up times were disregarded from the quantitative analysis. After the data had been explored, a 6 – 12-month period was chosen for PES, BBT, KTW, STT, PH, and MGML, and a 12 – 24-month period was chosen for MIBL. Of the studies on the same populations, only one that matched the other included studies from the follow-up time perspective was chosen for each specific outcome. In cases where a study reported two follow-up time points within the specified follow-up period of an outcome, the longer one was selected for the analysis. Eventually, the exact follow-up time of the studies included in the analyses was

considered as a covariate to be tested for their significant effect and accounting for their effect if it enhanced the model fit.

All studies had a parallel design and included single implants; hence, the transitivity assumption was applicable regarding these matters. Moreover, the initial conditions of the sockets (All were non-compromised or minimally compromised) were relatively similar allowing all of the treatment arms be potentially applicable for all of the patients. The treatment arms were evaluated to be similar in terms of the patient's age and gender, whether they raised a flap or placed a flapless implant, immediate or delayed provisionalization, use of the bone graft materials, and inclusion of the defective sockets, qualitatively. By the way, it was planned to use network meta-regression to explore the effect of these covariates, if they were reported in all included studies in the analysis, to see if they have a significant effect.

The deviance information criterion (DIC) was used for model selection, as a model with lower DIC is considered better-fitted and more parsimonious. The between-study heterogeneity was evaluated using I^2. To assess the consistency assumption globally and locally, a comparison between the consistency and inconsistency models' DIC and node-splitting has been used, respectively. The node-splitting model used was introduced by van Valkenhoef et al. [38], which only split potential inconsistent loops (loops with independent indirect estimation). If there was an evident inconsistency, the source was investigated by accounting for various predictive and confounding pre-defined covariates using network meta-regression. Furthermore, to find the best-fitted model and catch as much between-study heterogeneity as possible, the predictive covariates accounted for their effect on the model to see if they could reduce the DIC value.

The sensitivity analyses in this study comprised fitting a model with a different between-study heterogeneity prior type. Moreover, if the final model accounted for the effect of a covariate, the plain model without regression was also fitted as a sensitivity analysis.

The results of the analyses are presented in the league tables (comprising both network and traditional pairwise meta-analysis results). The surface under cumulative ranking (SUCRA) was utilized to rank the treatment modalities. To assess the publication bias, the comparison-specific funnel plots were generated. The network geometry and funnel plots were produced using the STATA 15.0 software (StataCorp LP, Lakeway Drive, College Station, TX, USA). All analyses were synthesized using GeMTC [39] and Bayesmeta [40] R packages. A 95% credible interval (CrI) was used to determine the finding's significance.

For further details, see Appendix S1.

Certainty of the meta-evidence assessment

The Grades of Recommendations, Assessment, Development, and Evaluation (GRADE) approach customized for the network meta-analysis was used to assess the overall certainty and strength of the generated meta-evidence [41–43].

First, the certainty of all direct network estimations was calculated. The final certainty of the network meta-analysis evidence has been achieved considering the certainty of the direct estimates and the weight of participation of both direct and indirect estimates in the overall network meta-analysis estimation.

Results

Study selection

Figure 1 shows the flow diagram of the study. A total of 1532 records were found after the primary search, and after removing duplicates, 909 studies remained. After the primary and final screening toward the inclusion and exclusion criteria, 26 articles were included in this review. Among all these studies, 21 articles were considered for the qualitative and quantitative analysis.

Characteristics of the included studies

Among all included studies, 19, 1, 4, 1, 2, and 16 treatment arms were available on CTG, a combination of CTG with platelet-rich fibrin (L-PRF), Mucoderm, Mucograft, AlloDerm, and No Treatment, respectively. Moreover, from the included studies, two of them [27, 28] and four of them [16, 30, 32] were performed and reported on the same populations. The methodological characteristics of the included studies are summarized in Table 1.

This systematic review pooled 530 immediate implants placed. Soft tissue grafts were applied in 320 implant placements; CTG was used in 238, CTG + L-PRF was used in 6, porcine-derived collagen matrices in 51 (43 Mucoderm and 8 Mucograft), and acellular dermal matrices (AlloDerm) in 25. Furthermore, bone graft was used in 434 immediate implant placements. It was mentioned in the included studies, except Abd El-Aziz et al. study [25], that implants replaced teeth ranging from 1 to 5, maxillary anterior or premolar regions. All implant types were bone level.

Implants with different widths, ranging from 3.2 to 5 mm, and lengths, ranging from 9 to 18 mm, were employed, respectively. Nine studies did not mention the diameter width of implants [17, 20, 21, 23, 24, 27, 28, 32, 35] and nine did not mention the length of implants [17, 21, 23, 24, 27, 28, 32, 34, 35].

Sixteen studies mentioned the type of restorations used; all were non-splinted single crowns as in 11 studies were screw-retained [16, 21, 25, 27–30, 32–34, 36] and 11 studies cement-retained [16, 17, 19, 20, 22, 29–34].

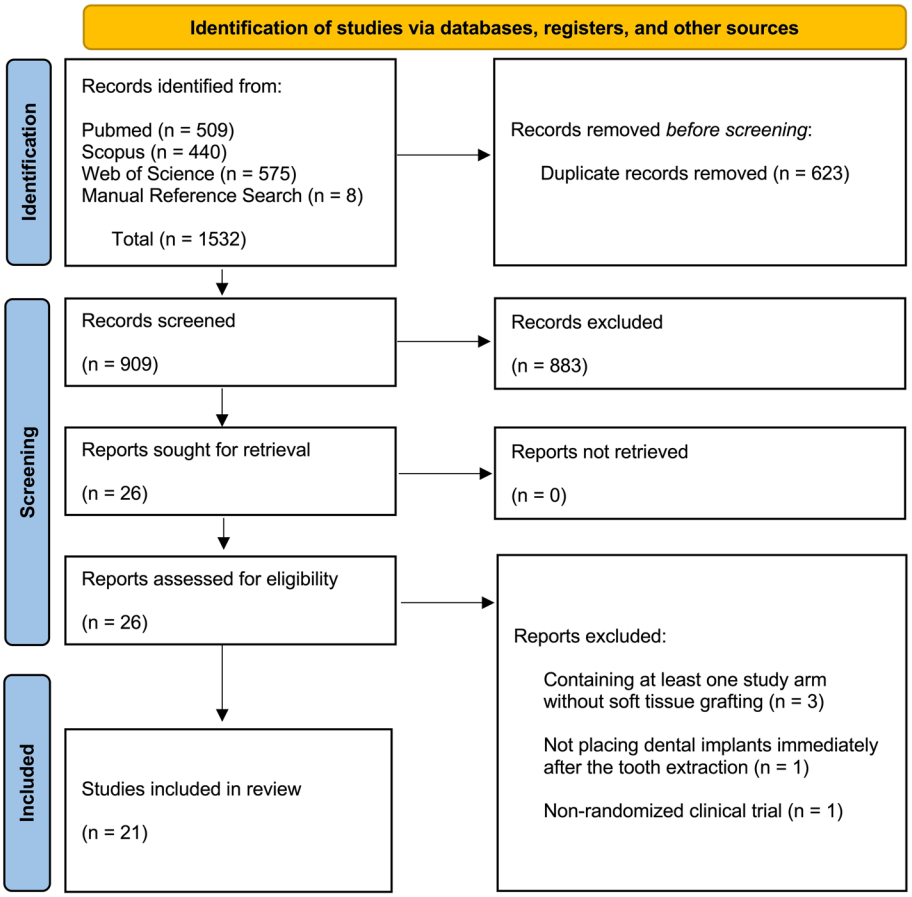

Fig. 1 PRISMA flow diagram of the study

Various follow-up periods with different onset times were observed in studies ranging from 2 weeks to 5 years.

Thirteen studies reported on the insertion torque of the implants [16–18, 20–22, 24, 29–32, 34, 36] employing different methodologies for reporting ranging between 20 to 48.55 N-cm.

Risk of bias assessment

The overall quality assessment of the studies is summarized in Fig. 2. None of the studies exhibited a high risk of bias. Randomization process was the most problematic domain among all domains due to the lack of a clear allocation concealment process, and 10 studies raised some concerns regarding this issue [16, 18, 21, 27, 28, 31–34, 36]. Five studies raised some concerns due to deviations from intended intervention (D2) [21, 28, 31, 32, 36]. There was only one study showing some concerns missing outcome data (D3) [25] and in measurement of the outcome (D4) [16]. Selection of the reported results (D5) was the only domains that raised no concerns in the included studies. In summary, among the 21 included studies, 11 showed an overall some concerns regarding bias [16, 18, 21, 25, 27, 28, 31–34, 36] While the 10 others demonstrated an overall low risk of bias [17, 19, 20, 22–24, 26, 29, 30, 35]. Moreover, an outcome specific assessment of the risk of bias are presented in the Appendix S1 as Figs. 1/S1, 2/S1, 3/S1, 4/S1, 5/S1, 6/S1, 7/S1 correspond to assessment of the risk of bias concerning studies reporting PES, MIBL, BBT, KTW, STT, PH, and MGML.

Qualitative synthesis

Table 2 summarizes the PES/WES, MIBL, BBT, KTW, STT, PH, MGML, and the complications experienced in the studies.

Twelve studies [16, 19, 20, 22–25, 27, 32–35] analyzed mean PES in using grafts and no grafts groups, reporting all studies no significant difference between them. Two studies [16, 33] reported WES points with no significant difference but a slightly lower point in CTG groups.

Ten studies reported MIBL [16, 18–20, 23, 25, 30, 33, 35, 36]. Notably, Zuiderveld et al. [33] reported the highest median MIBL in a follow-up of 12 months gain at 0.9 mm (Interquartile Range (IQR): 0.40 – 1.2mm) in the mesial interproximal region across all of the studies,

Table 1 Design, materials and methods, and demographic information of included studies

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Zuiderveld et al., 2024 [16]	**G1:** CTG (Harvested from Tuberosity) **G2:** No graft	**G1:** 27 M: N/A F: N/A (45 ± 15.5) **G2:** 27 M: N/A F: N/A (47 ± 16.5)	N/A	**G1:** 1:1 ratio Autogenous + Xenogenous (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the buccal gap) **G2:** 1:1 ratio Autogenous + Xenogenous (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the buccal gap)	1, 12, 60 Months	Supraperiosteal envelope flap	**G1:** 27 **G2:** 27
Fernandes et al., 2023 [17]	**G1:** CTG (Harvested from the palate) **G2:** No graft	**G1:** 16 M: 3 F: 13 (44.13 ± 11.477) **G2:** 16 M: 8 F: 8 (51.25 ± 9.125)	* Sufficient apical bone * Intact socket wall	**G1:** DBBM (Symbios, Dentsply Implants) (Filling the buccal gap) **G2:** DBBM (Symbios, Dentsply Implants) (Filling the buccal gap)	1, 4, 6 Months	Flapless	**G1:** 16 **G2:** 16
Lee et al., 2023 [18]	**G1:** CTG (Harvested from palate) **G2:** ADM (AlloDerm, Biohorizons, Birmingham, AL, USA) **G3:** No graft	**G1:** 15 M: 8 F: 7 **(**61.53 ± 9.81) **G2:** 15 M: 7 F: 8 (63.53 ± 13.16) **G3:** 16 M: 7 F: 9 (58.88 ± 11.55)	* A dehiscence (≤ 3 mm in width, not present in the middle region of the buccal wall) or fenestration (≤ 3 mm in diameter) was allowed	**G1:** Xenogenous (Bio-Oss, Geistlich, Princeton, NJ, USA) (Filling the gap) **G2:** Xenogenous (Bio-Oss, Geistlich, Princeton, NJ, USA) (Filling the gap) **G3:** W/O	2 weeks, 1, 2, 3, 6, 9, 12 Months	Flapless	**G1:** 15 **G2:** 15 **G3:** 16

Table 1 (continued)

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Naiem et al., 2023 [19]	**G1:** CTG (Harvested from palate) **G2:** No graft	**G1:** 9 M:1 F: 8 33.3 ± 10.2 **G2:** 9 M: 3 F: 6 35 ± 7.6	* Buccal bone thickness > 1 mm * Sufficient apico-palatal bone in the socket	W/O	6, 9, 12, 24 Months	Modification of the conventional VIP-CT flap technique	**G1:** 9 **G2:** 9
Azaripour et al., 2023 [20]	**G1:** buccal PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** No graft	**G1:** 10 M: 5 F: 5 (45.2 ± 10.3) **G2:** 10 M: 5 F: 5 (51.8 ± 14.3)	* Sufficient bone at the site (at least 8.5 mm long and 3.75 mm wide) * Having at least 4 mm of bone apical to the tooth apex in socket * Presenting a free space of at least 3 mm between the implant's buccal site and the soft tissue in sockets missing buccal bone	**G1:** Human derived bone substitute (Puros allograft spongiosa, Zimmer Biomet) (Filling the buccal gap) **G2:** Human derived bone substitute (Puros allograft spongiosa, Zimmer Biomet) (Filling the buccal gap)	3, 6 and 12 Months	Vestibular envelope (modified tunnel technique)	**G1:** 10 **G2:** 10
Panwar et al., 2022 [21]	**G1:** ADM (AlloDerm, Biohorizons, Birmingham, AL, USA) **G2:** CTG (Harvested from palate)	**G1:** 10 M: N/A F: N/A 32.5 ± 4.7 **G2:** 10 M: N/A F: N/A 31.9 ± 4.9	* Intact socket wall	W/O	6 Months	A combination of full thickness and partial thickness flap	**G1:**10 **G2:**10
Puisys et al., 2022 [22]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG (Harvested from Tuberosiy)	**G1:** 23 M: 11 F: 12 39.8 ± 8.56 **G2:** 22 M: 9 F: 13 41.6 ± 7.66	* Class I (intact buccal wall) or class II (1/3 of buccal wall) extraction socket	**G1:** Allogenic bone (Maxgraft, Botiss Biomaterials GmbH) (Filling the gap) **G2:** Allogenic bone (Maxgraft, Botiss Biomaterials GmbH) (Filling the gap)	4, 12 Months	Subperiosteal Buccal Tunnel	**G1:** 23 **G2:** 22

Table 1 (continued)

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Sharafuddin et al., 2022 [23]	**G1:** CTG (Harvested from Palate) and L-PRF **G2:** No Graft	**G1:** 6 M: N/A F: N/A **G2:** 6 M: N/A F: N/A Ages of 18–60 in both groups	* Intact buccal/labial bone plate	W/O	0, 3, 6 months	Single Incision Technique	**G1:** 6 **G2:** 6
Abdelsamie et al., 2022 [24]	**G1:** CTG (harvested from the palate) **G2:** No graft	18 M: 2 F: 16 (32.00 ± 5.5)	* Adequate bone volume (: at least 5.7 mm in a bucco-palatal direction, 6–7 mm in a mesio-distal direction, away from the nasal floor and the maxillary sinus by 2 mm in apico-coronal dimensions) * Thick buccal bone crest > 1 mm	**G1:** Human derived bone substitute (Filling the buccal gap) **G2:** Human derived bone substitute (Filling the buccal gap)	3, 6 months	Intrasulcular (tunnel technique)	**G1:** 9 **G2:** 9
Abd El-Aziz et al., 2022 [25]	**G1:** CTG (harvested from the palate) **G2:** No graft	16 M: 1 F: 15 (N/A)	* Integrated labial/buccal bone plate	W/O	6, 8 Months	Full Thickness + Split Thickness flap in G1, Full Thickness flap in G2	**G1:** 8 **G2:** 8
Guglielmi et al., 2022 [26]	**G1:** CTG **G2:** No graft	**G1:**15 M: N/A F: N/A (53.4 ± 12.2) **G2:** 15 M: N/A F: N/A (53.4 ± 12.2)	* Dehiscence defects of the buccal bone wall < 3 mm * The distance between interdental bone crest and buccal bone crest ≤ 3 mm	W/O	6 Months	Buccal Split-Full-Split-Thickness Envelope flap	**G1:** 15 (15) **G2:** 15 (11)
Happe et al., 2022a [27]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG	**G1:** 10 M: 5 F: 5 (48.5) **G2:** 10 M: 6 F: 4 (49.4)	* Intact buccal wall after extraction	**G1:** ABBM + Collagen (Bio-Oss Collagen, Geistlich) **G2:** ABBM + Collagen (Bio-Oss Collagen, Geistlich)	12 Months	Intrasulcular with a split-thickness flap	**G1:** 10 (10) **G2:** 10 (10)

Table 1 (continued)

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Happe et al., 2022b [28]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG	**G1:** 10 M: 5 F: 5 (33–71) (48.5) **G2:** 10 M: 6 F: 4 (21–72) (49.4)	* Intact buccal wall after extraction	**G1:** 90% ABBM + 10% Collagen (Bio-Oss Collagen, Geistlich) **G2:** 90% ABBM + 10% Collagen (Bio-Oss Collagen, Geistlich)	12 Months	Intrasulcular with a split-thickness flap	**G1:** 10 (10) **G2:** 10 (10)
Ferrantino et al., 2021 [29]	**G1:** CTG (harvested from the palate/tuberosity) **G2:** No graft	**G1:** 31 M: 17 F: 14 (47.68 ± 16.50) **G2:** 28 M: 6 F: 22 (51.07 ± 14.67)	* At least 2 mm of bone apical to the socket * Intact buccal bone wall	**G1:** DBBM (Bio-Oss, Geistlich Biomaterials) (Filling the buccal gap) **G2:** DBBM (Bio-Oss, Geistlich Biomaterials) (Filling the buccal gap)	1 week, 1, 6, 12 Months	Split-thickness Flap	**G1:** 31 **G2:** 28
Zuiderveld et al., 2021 [30]	**G1:** CTG (Harvested from Tuberosity) **G2:** No graft	**G1:** 28 M: 12 F: 16 (45.3 ± 15.3) **G2:** 27 M: 12 F: 15 (47.2 ± 16.5)	* Post-extraction vertical bone defect of the buccal socket wall of < 2 mm	**G1:** Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap) **G2:** Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap)	1, 12 months	Supraperiosteal envelope flap	**G1:** 30 (28) **G2:** 30 (27)

Table 1 (continued)

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Jiang et al., 2020 [31]	**G1:** CTG **G2:** No graft	**G1:** 21 (20) M: 8 F: 12 (34.3 ± 7.0) **G2:** 21 (20) M: 11 F: 9 (37.7 ± 13.3)	* Intact buccal bone after extraction	**G1:** DBBM (Bio-Oss, Geistlich, Wolhusen, Switzerland) (Filling the gap between implant and socket wall) **G2:** DBBM (Bio-Oss, Geistlich, Wolhusen, Switzerland) (Filling the gap between implant and socket wall)	6 Months	Flapless	**G1:** 21 **G2:** 21
Van Nimwegen et al., 2018 [32]	**G1:** CTG Harvested from Tuberosity) **G2:** No Graft	**G1:** 30 M: 13 F: 17 (45.5 ± 15.5) **G2:** 30 M: 15 F: 15 (47.8 ± 16.5)	* Defects of the buccal bone wall < 5 mm in vertical direction	**G1:** 1:1 ratio Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap) **G2:** 1:1 ratio Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap)	12 months	Envelope flap	**G1:** 30 (25) **G2:** 30 (25)
Zuiderveld et al., 2018 [33]	**G1:** CTG Harvested from Tuberosity) **G2:** No Graft	**G1:** 30 M: 13 F: 17 (45.5 ± 15.5) **G2:** 30 M: 15 F: 15 (47.8 ± 16.5)	* Defects of the buccal bone wall < 5 mm in vertical direction	**G1:** 1:1 ratio Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap) **G2:** 1:1 ratio Autogenous + ABBM (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) (Filling the Buccal Gap)	1, 12 months	Supraperiosteal envelope flap	**G1:** 30 (29) **G2:** 30 (29)

Table 1 (continued)

Study	Study Groups	Sample Size (Age in Years (Mean ± SD))	Initial Ridge Condition	Bone Graft	Follow-up Time	Flap Type	Number of Implants (Number of Implants Followed-up)
Frizzera et al., 2018 [34]	**G1:** No Graft **G2:** PDCM (Mucograft, Geistlich) **G3**: CTG	**G1:** 8 M: N/A F: N/A **G2:** 8 M: N/A F: N/A **G3**: 8 M: N/A F: N/A	* Socket presenting sufficient apical bone * Facial wall defect confirmed by previous CBCT	**G1:** Bovine bone mineral containing 10% porcine collagen (Bio-Oss Collagen, Geistlich) **G2:** Bovine bone mineral containing 10% porcine collagen (Bio-Oss Collagen, Geistlich) **G3:** Bovine bone mineral containing 10% porcine collagen (Bio-Oss Collagen, Geistlich)	6,12 Months	Flapless	**G1:** 8 **G2:** 8 **G3**: 8
Migliorati et al., 2015 [35]	**G1:** CTG **G2:** No graft	**G1:** 24 **G2:** 24 M: 23 F:25 (47.5)	* Adequate Native Bone * Dehiscence defects of the facial bone wall affecting the crestal bone < 3 mm	**G1:** Xenogenous DBBM (Bio-Oss Collagen, Geistlich Pharma North America, Inc., Princeton, NJ, USA) (Filling the buccal gap) **G2:** Xenogenous DBBM (Bio-Oss Collagen, Geistlich Pharma North America, Inc., Princeton, NJ, USA) (Filling the buccal gap)	12, 24 Months	Tunnel technique	**G1:** 24 (24) **G2:** 24 (23)
Yoshino et al., 2014 [36]	**G1:** CTG (Harvested from Palate) **G2:** No Graft	**G1:** 10 **G2:** 10 M: 7 F: 13 (52.6) in both groups	Sufficient Bone Volume	**G1:** Xenograft (Bio-Oss, Osteohealth) (Filling the gap) **G2:** Xenograft (Bio-Oss, Osteohealth) (Filling the gap)	0, 3, 6, 12 months	Full-thickness envelope flap	**G1:** 10 **G2:** 10

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Zuiderveld et al., 2024 [16]	BL	**G1:** 4.3: N/A 3.5: N/A **G2:** 4.3: N/A 3.5: N/A	**G1:** 15: N/A 18: N/A **G2:** 15: N/A 18: N/A	CL (Immediate Provisional)/Both SR and CR/NSP	**Maxillary teeth:** **G1:** 1: N/A 2: N/A 3: N/A 4: N/A **G2:** 1: N/A 2: N/A 3: N/A 4: N/A	> = 45	ASC: **G1:** Type 1: N/A Type 2A: N/A **G2:** Type 1: N/A Type 2A: N/A Distance between bone and marginal mucosa (mm): **G1:** 4.7 ± 0.7 **G2:** 4.3 ± 0.9 BBT (Median (IQR)) (mm): Based on distance from the implant's neck **G1:** 0 mm: 2.14 (1.84 – 2.74) 1 mm: 2.26 (1.76 – 2.86) 2 mm: 2.68 (1.68 – 3.13) 3 mm: 2.55 (1.85 – 2.94) 4 mm: 2.43 (1.73 – 2.95) 5 mm: 2.35 (1.35 – 2.95) **G2:** 0 mm: 2.14 (1.55 – 2.69) 1 mm: 2.43 (1.59 – 2.74) 2 mm: 2.33 (1.65 – 2.78) 3 mm: 2.23 (1.63 – 2.75) 4 mm: 2.05 (1.49 – 2.69) 5 mm: 1.84 (1.25 – 2.56) PD (Mean (95% CI)) (mm): **G1:** Buccal: 2.2 (1.9 – 2.5) Mesial: 2.8 (2.5 – 3.1) Distal: 2.9 (2.5 – 3.30) Palatal: 2.6 (2.0 – 3.2) **G2:** Buccal: 2.6 (2.1 – 3.1) Mesial: 2.6 (2.3 – 2.9) Distal: 2.5 (2.1 – 2.9) Palatal: 2.2 (1.8 – 2.6)

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Fernandes et al., 2023 [17]	BL	**G1:** N/A **G2:** N/A	**G1:** N/A **G2:** N/A	CL (Delayed Provisional)/SR/NSP	**Maxillary teeth:** **G1:** 1,2: 4 4,5: 12 **G2:** 1,2: 7 4,5: 9	**G1:** 48.55 ± 12.73 **G2:** 47.50 ± 14.37	BBT (Mean ± SD) (mm): **G1:** 1.15 ± 0.59 **G2:** 1.25 ± 0.47 Gingival Biotype: **G1:** Thin: 9 Thick: 7 **G2:** Thin: 8 Thick: 8 BID (Mean ± SD) (mm): **G1:** 3.44 ± 0.629 **G2:** 3.12 ± 0.885 WKT (Mean ± SD) (mm): **G1:** 3.63 ± 0.957 **G2:** 4.13 ± 0.806

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Lee et al., 2023 [18]	BL	**G1:** 3.5: 6 4.3: 8 5: 1 **G2:** 3.5: 4 4.3: 11 5: 0 **G3:** 3.5: 7 4.3: 9 5: 0	**G1:** 10: 0 11.5: 4 13: 8 16: 3 **G2:** 10: 3 11.5: 7 13: 5 16: 0 **G3:** 10: 0 11.5: 4 13: 8 16: 4	CL (Delayed Provisional)/N/A/NSP	Maxillary Anterior or Premolar areas	> = 20	PD (Mean ± SD) (mm): **G1**: 2.28 ± 0.47 **G2**: 2.29 ± 0.38 **G3**: 2.24 ± 0.45 BOP (Mean ± SD): **G1:** 2.47 ± 1.68 **G2:** 2.60 ± 1.72 **G3:** 2.44 ± 1.59 Mean number of sites on tooth with plaque (PL): **G1:** 4.20 ± 1.66 **G2:** 4.13 ± 2.13 **G3:** 4.63 ± 1.54 WKT (Mean ± SD) (mm): **G1:** 4.70 ± 1.16 **G2:** 4.83 ± 1.32 **G3**: 4.50 ± 1.20 Buccal soft-tissue thickness (Mean ± SD) (mm): *pre-operative:* **G1:** 1.24 ± 0.25 **G2:** 1.34 ± 0.25 **G3:** 1.18 ± 0.31 *post-operative:* **G1:** 2.38 ± 0.32 **G2:** 2.57 ± 0.30 **G3:** 1.18 ± 0.31 Marginal BL (Mean ± SD) (mm): Mesial: **G1:** −0.11 ± 0.31 **G2:** −0.08 ± 0.31 **G3:** −0.31 ± 0.83 Distal: **G1:** −0.03 ± 0.10 **G2:** −0.95 ± 2.30 **G3:** −0.36 ± 1.21 * A negative value means marginal bone level is below the implant platform

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Naiem et al., 2023 [19]	BL	**G1:** 3.5: N/A 4: N/A 4.5: N/A **G2:** 3.5: N/A 4: N/A 4.5: N/A	**G1:** 10: N/A 11.5: N/A **G2:** 10: N/A 11.5: N/A	CL (Delayed Provisional)/SR/NSP	**Maxillary teeth:** **G1:** 1: 0 2: 3 3: 0 4: 3 5: 3 **G2:** 1: 2 2: 1 3: 1 4: 2 5: 3	N/A	BBT (Median (IQR)) (mm): **G1:** 0 mm: 0.9 (0.6–1.1) 2 mm: 1.2 (1.2–1.7) 4 mm: 1 (0.8–1.5) 6 mm: 0.8 (0.7–1.4) **G2:** 0 mm: 0.88 (0.69–1.11) 2 mm: 1.03 (1–1.5) 4 mm: 0.97 (0.8–1.1) 6 mm: 0.8 (0.69–0.9) Marginal BL (Mean ± SD) (mm): **G1:** 0.43 ± 0.37 **G2:** 0.98 ± 1.18 WKT (Mean ± SD) (mm): **G1:** 6.29 ± 1.70 **G2:** 6.38 ± 1.60
Azaripour et al., 2023 [20]	BL	**G1:** N/A **G2:** N/A	**G1:** 11: 1 13: 4 15: 5 **G2:** 11: 1 13: 3 15: 6	CL (Immediate Provisional)/SR/NSP	**G1:** Maxillary incisor: 7 Maxillary premolar: 2 Mandibular premolar: 1 **G2:** Maxillary incisor: 7 Maxillary premolar: 2 Mandibular premolar: 1	> = 30	Keratinized Mucosa Height (Mean ± SD) (mm): **G1:** 5.2 ± 1.4 **G2:** 6 ± 2.1 Marginal BL (Mean ± SD) (mm): measured from the coronal margin of the implant collar and the most coronal point of visible bone to implant contact **G1:** 0 **G2:** 0 WKT (Mean ± SD) (mm): **G1:** 5.2 ± 1.4 **G2:** 6.0 ± 2.1
Panwar et al., 2022 [21]	BL	N/A	N/A	CL (Delayed Provisional) /CR/NSP	Maxillary Anterior (single rooted tooth)	> = 35	GT (Mean ± SD) (mm): **G1:** 0.500 ± 0.0943 **G2:** 0.450 ± 0.108 WKT (Mean ± SD) (mm): **G1:** 3.20 ± 0.4216 **G2:** 2.8 ± 0.788 Gingival Biotype: **G1:** Thin: 10 **G2:** Thin: 10

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Puisys et al., 2022 [22]	BL	3.75 mm	**G1:** 12: N/A 14: N/A **G2:** 12: N/A 14: N/A	CL (Immediate Provisional)/SR/NSP	**Maxillary teeth:** **G1:** 1: 15 2: 7 3: 1 **G2:** 1: 14 2: 7 3: 1	30	Gingival Biotype: **G1:** Thin: 11 Thick: 12 **G2:** Thin: 13 Thick: 9
Sharafuddin et al., 2022 [23]	BL	**G1:** N/A **G2:** N/A	**G1:** N/A **G2:** N/A	CL (Delayed Provisional)/ N/A/N/A	Anterior or Premolar regions	N/A	WKT (Mean ± SD) (mm): G1: *6.83* ± 1.83 G2: *6.50* ± 2.17 Tissue Biotype (Mean ± SD) (mm): **G1:** 1.00 ± 0.00 **G2:** 0.83 ± 0.26 PES: **G1**: N/A **G2**: N/A CBL: **G1**: N/A **G2**: N/A
Abdelsamie et al., 2022 [24]	N/A	**G1:** N/A **G2:** N/A	**G1:** N/A **G2:** N/A	CL (Delayed Provisional)/N/A/NSP	**Maxillary teeth:** 1: 4 2: 3 3: 3 4: 4 5: 4	> = 30	Facial gingival level (Mean ± SD) (mm): **G1:** 2.97 ± 0.4 **G2:** 3.00 ± 0.8 Tissue Biotype (Mean ± SD) (mm): **G1:** 2.07 ± 0.6 **G2:** 1.81 ± 0.4 WKT (Mean ± SD) (mm): **G1:** 6.31 ± 0.5 **G2:** 6.67 ± 1.5

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Abd El-Aziz et al., 2022 [25]	BL	**G1:** 3.2: N/A 3.5: N/A **G2:** 3.2: N/A 3.5: N/A	**G1:** 10: 1 11: N/A 13: N/A 15: N/A **G2:** 11: N/A 13: N/A 15: N/A	CL (Delayed Provisional)/CR/NSP	Maxillary anterior area and pre-molars	N/A	Tissue Biotype (Mean ± SD) (mm): **G1:** 0.60 ± 0.22 **G2:** 0.92 ± 0.38 WKT (Mean ± SD) (mm): **G1:** 5.60 ± 1.08 **G2:** 6.17 ± 1.60
Guglielmi et al., 2022 [26]	BL	**G1:** 3.8: 12 4.5: 3 **G2:** 3.8: 8 4.5: 3	**G1:** 9: 0 11: 6 13: 7 15: 2 **G2:** 9: 2 11: 6 13: 3 15: 0	CL (Delayed Provisional)/N/A/N/A	**Maxillary and Mandibular teeth:** **G1:** 1, 2, 3: 3 4, 5: 12 (Maxillary: 13, Mandibular: 2) **G2:** 1, 2, 3: 0 4, 5: 11 (Maxillary: 9, Mandibular: 2)	N/A	Buccal Bone Thickness (Mean ± SD) (mm): 2 mm: **G1:** 0.84 ± 0.39 **G2:** 1.03 ± 0.49
Happe et al., 2022a [27]	BL	**G1:** N/A **G2:** N/A	**G1:** N/A **G2:** N/A	CL (Immediate Provisional)/CR/N/A	**Maxillary teeth:** **G1:** 1: N/A 2: N/A 3: N/A **G2:** 1: N/A 2: N/A 3: N/A	N/A	N/A

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Happe et al., 2022b [28]	BL	**G1:** N/A **G2:** N/A	**G1:** N/A **G2:** N/A	CL (Immediate Provisional)/CR/N/A	**Maxillary teeth:** **G1:** 1: N/A 2: N/A 3: N/A **G2:** 1: N/A 2: N/A 3: N/A	N/A	Gingival Biotype: **G1:** Thin: 4 Thick: 6 **G2:** Thin: 2 Thick: 8
Ferrantino et al., 2021 [29]	BL	**G1:** 4.2: 13 3.75: 18 **G2:** 4.2: 22 3.75: 6	**G1:** 11.5: 4 13: 16 16: 11 **G2:** 11.5: 3 13: 17 16: 8	CL (Immediate Provisional)/Both SR and CR/NSP	**Maxillary and Mandibular teeth:** **G1:** 1/2: 4 3: 4 4: 11 5: 12 (Maxillary: N/A, Mandibular: N/A) **G2:** 1/2: 4 3: 4 4: 9 5: 11 (Maxillary: N/A, Mandibular: N/A)	> 35	Apico-coronal (A-C) implant position (Mean ± SD) (mm): (Considering the buccal bone crest as reference) **G1:** − 1.10 ± 0.79 **G2:** − 1.39 ± 0.99 GAP (Mean ± SD) (mm): **G1:** 2.02 ± 1.16 **G2:** 2.54 ± 0.84 Bone quality **G1:** Type 1: 0 Type 2: 9 Type 3: 18 Type 4: 4 **G2:** Type 1: 1 Type 2: 8 Type 3: 15 Type 4: 4
Zuiderveld et al., 2021 [30]	BL	**G1:** 3.5: 11 4.3: 17 **G2:** 3.5: 12 4.3: 15	**G1:** 15: 5 18: 23 **G2:** 15: 7 18: 20	CL (Immediate Provisional)/Both SR and CR/NSP	**Maxillary teeth:** **G1:** 1: 16 2: 9 3: 1 4: 2 **G2:** 1: 11 2: 8 3: 7 4: 1	> = 45	BBT (Mean ± SD) (mm): **G1:** 2.38 ± 0.81 **G2:** 2.28 ± 0.92 MBML: **G1:** N/A **G2:** N/A Gingival Biotype: **G1:** Thin: 18 Thick: 10 **G2:** Thin: 13 Thick: 14 Preoperative Bone Defect (Mean ± SD) (mm): **G1:** 4.6 ± 0.68 **G2:** 4.2 ± 0.88

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Jiang et al., 2020 [31]	BL	**G1:** 3.5 **G2:** 3.5	**G1:** 13:1 15: 14 18: 5 **G2:** 13:1 15: 9 18: 10	IL (Immediate Provisional)/ SR /NSP	**Maxillary teeth:** **G1:** 1: 16 2: 4 **G2:** 1: 18 2: 2	> 35	BBT (Mean ± SD) (mm): **G1:** 0.54 ± 0.20 **G2:** 0.69 ± 0.30 Initial Socket Width (Mean ± SD) (mm): **G1:** 7.10 ± 0.73 **G2:** 7.43 ± 0.85 The central point of implant platform to the outer surface of the buccal plate (Mean ± SD) (mm): **G1:** 4.79 ± 0.61 **G2:** 4.98 ± 0.57 BPP (Mean ± SD) (mm): **G1:** 67.58 ± 5.24% **G2:** 67.20 ± 4.56%
Van Nimwegen et al., 2018 [32]	N/A	N/A	N/A	CL (Immediate Provisional)/Both SR and CR/NSP	**Maxillary teeth:** **G1:** 1: 16 2: 9 3: 3 4: 2 **G2:** 1: 12 2: 10 3: 7 4: 1	> = 45	Gingival Biotype: **G1:** Thin: 20 Thick: 10 **G2:** Thin: 15 Thick: 15 MBML: **G1:** N/A **G2:** N/A

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Zuiderveld et al., 2018 [33]	BL	**G1:** 3.5: 11 4.3: 19 **G2:** 3.5: 14 4.3: 16	**G1:** 15: 5 18: 25 **G2:** 15: 7 18: 23	CL (Immediate Provisional)/Both SR and CR/NSP	**Maxillary teeth:** **G1:** 1: 16 2: 9 3: 3 4: 2 **G2:** 1: 12 2: 10 3: 7 4: 1	N/A	Gingival Biotype: **G1:** Thin: 20 Thick: 10 **G2:** Thin: 15 Thick: 15 Bone Defect (Mean ± SD) (mm): **G1:** 4.7 ± 0.66 **G2:** 4.3 ± 0.87 MBML: **G1:** N/A **G2:** N/A Probing Pocket Depth (before extraction- to the tooth) (Mean ± SD) (mm): **G1:** Mesial: 2.8 ± 0.9 Mid-buccal: 2.2 ± 0.9 Distal: 2.0 ± 1.0 Palatal: 2.6 ± 1.6 **G2:** Mesial: 2.6 ± 0.9 Mid-buccal: 2.6 ± 1.4 Distal: 2.5 ± 1.1 Palatal: 2.2 ± 1.0 PIS before extraction- to the tooth) (mesial/distal) **G1:** Score 0: 0%/3.4% Score 1: 13.8%/6.9% Score 2: 37.9%/34.5% Score 3: 48.3%/55.2% Score 4: 0%/0% **G2:** Score 0: 3.6%/3.6% Score 1: 17.9%/14.3% Score 2: 39.3%/46.4% Score 3: 39.3%/35.7% Score 4: 0%/0% Satisfaction (Median (IQR)) **G1:** 5.3 (3.9–6.8) **G2:** 5.5 (3.8–7.0) Total OHIP score (Median (IQR)) **G1:** 10.0 (6.0–16.0) **G2:** 10.0 (5.3–19.8)

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Frizzera et al., 2018 [34]	BL	**G1:** 3.5 **G2:** 3.5 **G3:** 3.5	**G1:** N/A **G2:** N/A **G3:** N/A	CL (Immediate Provisional)/CR and SR/NSP	**Maxillary teeth:** **G1:** 1: N/A 2: N/A **G2:** 1: N/A 2: N/A **G3:** 1: N/A 2: N/A	> 32	Gingival biotype: **G1:** Thick: 3 Thin: 5 **G2:** Thick: 4 Thin: 4 **G3:** Thick: 3 Thin: 5 FBD% (Mean ± SD) (mm): **G1:** 63.25 ± 32.93 **G2:** 60.5 ± 28.15 **G3**: 56.86 ± 31.94 FRD (Mean ± SD) (mm): **G1:** 7.72 ± 0.96 **G2:** 7.66 ± 1.29 **G3:** 7.72 ± 0.82 STT (Mean ± SD) (mm): **G1:** 1 ± 0.18 **G2:** 0.98 ± 0.21 **G3:** 0.98 ± 0.29 PES (Mean ± SD): **G1:** 10.75 ± 2.05 **G2:** 10.63 ± 1.84 **G3:** 9.37 ± 1.9 Modified PES (Mean ± SD): **G1:** 7 ± 1.73 **G2:** 7.75 ± 0.70 **G3:** 7 ± 1.41

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Migliorati et al., 2015 [35]	BL	N/A	N/A	CL (Delayed Provisional)/N/A/N/A	**Maxillary teeth:** 1: 7 2: 14 3: 12 4: 15	N/A	GT (Mean ± SD) (mm): **G1:** Thin: 0.8 ± 0.2 Thick: 1.6 ± 0.6 Mean: 1.1 ± 0.6 **G2:** Thin: 0.8 ± 0.5 Thick: 1.6 ± 0.6 Mean: 1.2 ± 0.5 KM (Mean ± SD) (mm): **G1:** Thin: 2.6 ± 0.9 Thick: 4.2 ± 1.2 Mean: 3.3 ± 1.2 **G2:** Thin: 3.5 ± 0.9 Thick: 5.1 ± 0.6 Mean: 4.3 ± 1.1

Table 1 (continued)

Study	Type of Implants	Implants Diameter (mm)	Implants Length (mm)	Final Loading (Provisional Crown)/Crown Retention/Splint or Non-splint	Tooth Number	Insertion Torque (N cm)	Baseline Measurements
Yoshino et al., 2014 [36]	BL	3.3: 5 4.1: 14 4.8: 1 in both groups	**G1:** 14: 10 **G2:** 14: 10	CL (Immediate Provisional)/CR/NSP	**Maxillary teeth:** 1: 13 2: 2 3: 3 4: 2 in both groups	> = 25	Gingival Biotype (before extraction): **G1:** Thin: 0 Thick: 10 **G2:** Thin: 3 Thick: 7 ISQ (immediately after implant placement- to implant): **G1:** 61.7 ± 2.8 **G2:** 65.6 ± 5.6 PIS (immediately after implant placement- to implant) (mesial/distal) **G1:** Score 0: 4/3 Score 1: 1/2 Score 2: 2/2 Score 3: 3/3 Score 4: 0/0 **G2:** Score 0: 2/2 Score 1: 3/4 Score 2: 1/1 Score 3: 4/3 Score 4: 0/0

HUs Hounsfield Units, *RCT* Randomized Clinical Trial, *M* Male, *F* Female, *BL* Bone Level, *TL* Tissue Level, *IL* Immediate Loading, *EL* Early Loading, *DL* Delayed Loading, *CL* Conventional Loading, *SP* Splinted Prosthesis, *NSP* Non-Splinted Prosthesis, *SR* Screw-retained, *CR* Cement-retained, *ISQ* Implant Stability Quotient, *CBCT* Cone beam Computed Tomography, *OPG* Orthopantogram, *PA* Periapical X-ray, *PD* Pocket Depth, *BBT* Buccal Bone Thickness, *ASC* Alveolar Socket Classification, *CI* Confidence Interval, *SD* Standard Deviation, *IQR* Interquartile Range, *W/O* Without Grafting Material, *N/A* Not Available, *PIS* Papilla Index Score, *WKT* Width of Keratinized Tissue, *PES* Pink Esthetic Score, *CBL* Crestal Bone Level, *MBML* Mid-Buccal Mucosa Level, *DBBM* deproteinized bovine bone mineral, *GT* Gingival Tissue Thickness, *ABBM* Anorganic Bovine Bone Mineral, *ADM* Acellular Dermal Matrix, *BID* Buccal Implant Distance, *PDCM* Porcine-Derived Collagen Matrix. GAP Bucco-lingual distance between the buccal bone crest and the buccal implant surface, *STGS* Soft Tissue Graft Substitute, *CTG* Connective Tissue Graft, *BPP* Bucco-Palatal Position of placed implant in relation to the socket, *FRD* Format of Ridge Defect, *FBD%* Percentage of Facial Bone Defect, *KM* Keratinized Mucosa

Fig. 2 Summary of the included studies' overall risk of bias

Table 2 Outcomes reported in the included studies

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Zuiderveld et al., 2024 [16]	**G1:** CTG **G2:** No Graft	***(Mean (95% CI))*** 12 Months: *PES:* **G1:** 6.4 (5.8 – 6.9) **G2:** 6.8 (6.3 – 7.4) *WES:* **G1:** 6.9 (6.1 – 7.6) **G2:** 7.4 (6.9 – 7.9) *PES/WES:* **G1:** 13.2 (12.1 – 14.4) **G2:** 14.2 (13.3 – 15.1) ***60 Months:*** *PES:* **G1:** 6.2 (5.5 – 6.8) **G2:** 6.4 (5.7 – 7.1) *WES:* **G1:** 7.6 (6.9 – 8.2) **G2:** 8.0 (7.5 – 8.5) *PES/WES:* **G1:** 14.4 (13.4 – 15.5) **G2:** 13.7 (12.6 – 14.8)	***(Mean (95% CI))*** 1 – 60 Months: **G1:** Mesial: −0.49 (−0.80 – −0.20) Distal: −0.10 (−0.30 – 0.10) **G2:** Mesial: 0.01 (−0.40 – 0.40) Distal: −0.09 (−0.30 – 0.30)	***(Median (IQR))*** 60 Months: Based on distance from the implant's neck **G1:** 0 mm: 0.64 (0.34 – 1.64) 1 mm: 1.63 (0.56 – 2.26) 2 mm: 1.57 (1.17 – 2.47) 3 mm: 2.05 (1.19 – 2.54) 4 mm: 2.03 (1.15 – 2.43) 5 mm: 1.85 (0.95 – 2.44) **G2:** 0 mm: 1.29 (0.64 – 1.73) 1 mm: 2.03 (1.33 – 2.33) 2 mm: 2.13 (1.45 – 2.57) 3 mm: 2.05 (1.18 – 2.50) 4 mm: 1.95 (1.13 – 2.55) 5 mm: 1.65 (0.99 – 2.35)	N/A	N/A	***Mucosal Level (Mean (95% CI)) (mm):*** 0 – 60 Months: **G1:** Mid-buccal: 0.1 (−0.4 – 0.5) Mesial: −0.3 (−0.7 – 0.1) Distal: −0.4 (−0.9 – 0.0) **G2:** Mid-buccal: −0.6 (−1.1 – −0.1) Mesial: −0.5 (−0.8 – −0.2) Distal: −0.7 (−1.0 – −0.4)	**G1:** 1 implant loss during osseointegration **G2:** 1 implant loss during osseointegration	***PD (Mean (95% CI)) (mm):*** 12 Months: **G1:** Buccal: 2.3 (2.0 – 2.6) Mesial: 2.8 (2.4 – 3.2) Distal: 2.9 (2.6 – 3.3) Palatal: 2.2 (1.9 – 2.5) **G2:** Buccal: 2.5 (2.0 – 2.9) Mesial: 3.0 (2.7 – 3.3) Distal: 2.9 (2.4 – 3.4) Palatal: 2.3 (2.0 – 2.6) ***60 Months:*** **G1:** Buccal: 1.8 (1.6 – 2.0) Mesial: 2.2 (1.9 – 2.5) Distal: 1.9 (1.6 – 2.2) Palatal: 1.9 (1.7 – 2.1) **G2:** Buccal: 1.7 (1.4 – 2.0) Mesial: 2.1 (1.8 – 2.4) Distal: 2.2 (1.8 – 2.6) Palatal: 2.0 (1.7 – 2.3) ***BoP:*** **G1:** Point Bleeding: 3 Patients Confluent Bleeding: 1 Patient **G2:** Point Bleeding: 1 Patient

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Fernandes et al., 2023 [17]	**G1:** CTG **G2:** No Graft	N/A	N/A	N/A	N/A	**G1:** Thin: 9 Thick: 7 **G2:** Thin: 8 Thick: 8	***Midfacial Mucosa Height Variation (Mean ± SD (95% CI)) (mm):*** 0–12 Months: **G1:** −0.38 ± 0.446 **G2:** −0.60 ± 0.723 ***Papilla Height Variation (Mean ± SD (95% CI)) (mm):*** 0–12 Months: **G1:** −0.10 ± 0.554 Mesial: −0.07 ± 0.544 Distal: −0.13 ± 0.688 **G2:** −0.34 ± 0.358 Mesial: −0.29 ± 0.369 Distal: −0.38 ± 0.498	None	***Buccal Volume Variation (Mean ± SD (95% CI)) (mm):*** 0–1 Month: **G1:** −4.35 ± 2.257 **G2:** −5.59 ± 5.006 ***0–4 Months:*** **G1:** −7.38 ± 4.021 **G2:** −6.98 ± 5.544 ***0–12 Months:*** **G1:** -9.69 ± 4.744 **G2:** -9.78 ± 4.594 ***Total Volume Variation (Mean ± SD (95% CI)) (mm):*** 0–1 Month: **G1:** −4.26 ± 2.869 **G2:** −4.69 ± 4.461 ***0–4 Months:*** **G1:** −5.38 ± 2.761 **G2:** -6.85 ± 4.371 ***0–12 Months:*** **G1:** -6.71 ± 3.470 **G2:** -8.36 ± 3.080 ***BID (Mean ± SD (95% CI)) (mm):*** **G1:** 3.44 ± 0.629 **G2:** 3.12 ± 0.885 ***VAS (Mean ± SD (95% CI)):*** **G1:** 2.38 ± 1.025 **G2:** 2.00 ± 0.730

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Lee et al., 2023 [18]	**G1:** CTG **G2:** ADM (AlloDerm, Biohorizons, Birmingham, AL, USA) **G3:** No Graft	N/A	***Change (Mean ± SD (95% CI))*** Marginal ***0–6 Months***: **G1:** Mesial: −0.45 ± 0.78 Distal: −0.19 ± 0.62 **G2:** Mesial: −0.70 ± 0.90 Distal: −0.27 ± 2.63 **G3:** Mesial: −0.37 ± 1.05 Distal: −0.40 ± 1.69 ***0–12 Months:*** **G1:** Mesial: −0.52 ± 0.80 Distal: −0.44 ± 0.72 **G2:** Mesial: −0.69 ± 0.74 Distal: −0.39 ± 2.24 **G3:** Mesial: −0.99 ± 1.30 Distal: −0.90 ± 1.74	N/A	***KTW Change (Mean ± SD (95% CI)):*** 0–3 Months: **G1:** 0.30 ± 0.84 **G2:** −0.07 ± 1.13 **G3:** 0.34 ± 0.60 ***0–6 Months:*** **G1:** 0.27 ± 0.73 **G2:** −0.47 ± 1.06 **G3:** 0.37 ± 0.85 ***0–12 Months:*** **G1:** −0.18 ± 1.07 **G2:** −0.80 ± 1.11 **G3:** −0.18 ± 0.91	Changes ***(Mean ± SD (95% CI)) (mm):*** 0–3 Months: **G1:** 0.94 ± 0.25 **G2:** 1.00 ± 0.56 **G3:** 0.21 ± 0.26 ***0–6 Months***: **G1:** 0.86 ± 0.25 **G2:** 0.97 ± 0.47 **G3:** 0.14 ± 0.14 ***0–12 Months:*** **G1:** 0.80 ± 0.26 **G2:** 0.86 ± 0.36 **G3:** 0.20 ± 0.17	***Mucosal Level Change (Mean ± SD (95% CI))*** 0–3 Months: **G1:** Mesial: −0.47 ± 0.61 Mid: 0.1 ± 0.81 Distal: −0.33 ± 0.70 **G2:** Mesial: −0.7 ± 1.26 Mid: −0.23 ± 0.62 Distal: −0.53 ± 0.44 **G3:** Mesial: −0.59 ± 0.58 Mid: −0.09 ± 0.93 Distal: −0.44 ± 0.57 ***0–6 Months:*** **G1:** Mesial: −0.47 ± 0.61 Mid: 0.2 ± 0.90 Distal: −0.23 ± 0.62 **G2:** Mesial: −0.9 ± 1.24 Mid: −0.37 ± 1.03 Distal: −0.70 ± 0.92 **G3:** Mesial: −0.67 ± 0.70 Mid: 0.3 ± 0.94 Distal: −0.43 ± 0.94 ***0–12 Months:*** **G1:** Mesial: −0.29 ± 0.51 Mid: −0.07 ± 1.00 Distal: −0.25 ± 0.58 **G2:** Mesial: −0.90 ± 1.31 Mid: −0.67 ± 0.96 Distal: −0.70 ± 0.80 **G3:** Mesial: −0.64 ± 0.50 Mid: −0.18 ± 1.08 Distal: −0.39 ± 0.63	**G1:** 1 implant restored 3 months following immediate implant replacement 1 implant required non-surgical debridement because of observed peri-implant mucosal inflammation **G2:** 1 did not complete the 12-month visit due to the contact loss 2 implants required non-surgical debridement because of observed peri-implant mucosal inflammation **G3:** 1 did not complete the 12-month visit due to the contact loss 1 implant required non-surgical debridement because of observed peri-implant mucosal inflammation	***PD (Mean ± SD (95% CI)) (mm):*** 3 Months: **G1:** 2.43 ± 0.39 **G2:** 2.20 ± 0.42 **G3:** 2.56 ± 0.51 ***6 Months:*** **G1:** 2.61 ± 0.42 **G2:** 2.20 ± 0.35 **G3:** 2.29 ± 0.44 ***12 Months:*** **G1:** 2.75 ± 0.45 **G2:** 2.41 ± 0.55 **G3:** 2.67 ± 0.56 ***BOP (Mean number ± SD (95% CI)):*** 3 Months: **G1:** 1.87 ± 1.77 **G2:** 1.67 ± 1.68 **G3:** 2.25 ± 1.84 ***6 Months:*** **G1:** 1.53 ± 1.51 **G2:** 1.20 ± 1.42 **G3:** 1.50 ± 1.15 ***12 Months:*** **G1:** 1.53 ± 1.41 **G2:** 1.33 ± 1.35 **G3:** 1.69 ± 1.08 ***PL (Mean number ± SD (95% CI)):*** 3 Months: **G1:** 4.00 ± 2.07 **G2:** 2.87 ± 1.96 **G3:** 3.81 ± 2.51 ***6 Months:*** **G1:** 2.93 ± 2.28 **G2:** 2.93 ± 2.28 **G3:** 2.44 ± 1.79 ***12 Months:*** **G1:** 1.87 ± 2.00 **G2:** 1.67 ± 1.95 **G3:** 1.31 ± 1.30

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Naiem et al., 2023 [19]	**G1:** CTG **G2:** No Graft	***(Mean ± SD (95% CI))*** *PES:* ***6 Months:*** **G1:** 11.7 ± 1.7 **G2:** 12.4 ± 1.6 ***9 Months:*** **G1:** 12.4 ± 1.6 **G2:** 12.8 ± 0.8 ***12 Months:*** **G1:** 12.4 ± 2.2 **G2:** 12.7 ± 1.2 ***24 Months:*** **G1:** 12.0 ± 3.2 Mesial papilla: 1.9 ± 0.2 Distal papilla: 1.6 ± 0.5 Gingival level: 1.6 ± 0.6 Contour: 1.6 ± 0.6 Alveolar process deficiency: 1.5 ± 0.7 Color: 1.7 ± 0.6 Texture: 1.8 ± 0.6 **G2:** 12.9 ± 1.3 Mesial papilla: 1.9 ± 0.4 Distal papilla: 1.9 ± 0.2 Gingival level: 1.9 ± 0.2 Contour: 1.9 ± 0.4 Alveolar process deficiency: 1.6 ± 0.4 Color: 1.5 ± 0.5 Texture: 2.0 ± 0	***(Mean ± SD (95% CI))*** *Marginal Proximal:* ***24 Months:*** **G1:** 0.43 ± 0.41 **G2:** 0.39 ± 0.43	***Changes (Mean ± SD (95% CI))*** 4 Months: **G1:** 0 mm: − 1.83 ± 2.13 2 mm: − 1.37 ± 0.7 4 mm: − 1.22 ± 0.88 6 mm: − 0.78 ± 1.36 **G2:** 0 mm: − 0.71 ± 1.11 2 mm: − 1.2 ± 1.47 4 mm: − 0.63 ± 0.66 6 mm: − 0.58 ± 0.76 ***9 Months:*** **G1:** 0 mm: − 1.34 ± 2.29 2 mm: − 1.26 ± 1.43 4 mm: − 1.23 ± 1.3 6 mm: − 0.5 ± 1.1 **G2:** 0 mm: − 1.15 ± 0.91 2 mm: − 1.23 ± 1.41 4 mm: − 0.69 ± 0.64 6 mm: − 0.9 ± 0.82 ***12 Months:*** **G1:** 0 mm: − 1.11 ± 1.96 2 mm: − 1.19 ± 1.32 4 mm: − 1.1 ± 0.89 6 mm: − 0.64 ± 0.72 **G2:** 0 mm: − 1.2 ± 1.17 2 mm: − 1.33 ± 1.67 4 mm: − 0.54 ± 0.83 6 mm: − 0.8 ± 0.84 ***24 Months:*** **G1:** 0 mm: − 2.17 ± 2.39 2 mm: − 2.03 ± 1.57 4 mm: − 1.5 ± 0.86 6 mm: − 1 ± 0.95 **G2:** 0 mm: − 1.28 ± 1.22 2 mm: − 1.09 ± 1.3 4 mm: − 0.78 ± 0.8 6 mm: − 1.1 ± 0.88	***(Mean ± SD (95% CI)):*** 24 Months: **G1:** 5.79 ± 2.04 **G2:** 5.86 ± 0.63	N/A	N/A	**G1:** None **G2:** 1 Implant demonstrated early failure	***Sounding Device Changes (Mean ± SD (95% CI)):*** 24 Months: **G1:** 0 mm: − 2.17 ± 2.39 2 mm: − 2.03 ± 1.57 4 mm: − 1.5 ± 0.86 6 mm: − 1 ± 0.95 **G2:** 0 mm: − 1.28 ± 1.22 2 mm: − 1.09 ± 1.3 4 mm: − 0.78 ± 0.8 6 mm: − 1.1 ± 0.88

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Azaripour et al., 2023 [20]	**G1:** buccal PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** No Graft	***(Mean ± SD)*** PES: 3 Months: **G1:** 12.0 ± 1.7 Mesial Papilla: 1.5 ± 0.52 Distal Papilla:1.7 ± 0.48 Soft Tissue Level: 1.6 ± 0.51 Soft Tissue Contour: 1.7 ± 0.48 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 1.9 ± 0.31 Soft Tissue Texture: 1.6 ± 0.51 **G2:** 12.7 ± 1.4 Mesial Papilla: 1.7 ± 0.48 Distal Papilla:1.7 ± 0.48 Soft Tissue Level: 1.9 ± 0.31 Soft Tissue Contour: 1.8 ± 0.42 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 1.8 ± 0.42 Soft Tissue Texture: 1.8 ± 0.42 ***6 Months:*** **G1:** 12.5 ± 1.5 Mesial Papilla: 1.5 ± 0.52 Distal Papilla:1.9 ± 0.31 Soft Tissue Level: 1.8 ± 0.42 Soft Tissue Contour: 1.6 ± 0.51 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 2.0 ± 0.0 Soft Tissue Texture: 1.7 ± 0.48 **G2:** 13.0 ± 1.3 Mesial Papilla: 1.7 ± 0.48 Distal Papilla:1.8 ± 0.42 Soft Tissue Level: 1.9 ± 0.31 Soft Tissue Contour: 1.8 ± 0.42 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 1.9 ± 0.31 Soft Tissue Texture: 1.8 ± 0.42 ***12 Months:*** **G1:** 12.8 ± 1.4 Mesial Papilla: 1.6 ± 0.51 Distal Papilla:1.9 ± 0.31 Soft Tissue Level: 1.9 ± 0.31 Soft Tissue Contour: 1.8 ± 0.42 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 1.8 ± 0.42 Soft Tissue Texture: 1.8 ± 0.42 **G2:** 13.3 ± 0.82 Mesial Papilla: 1.9 ± 0.31 Distal Papilla:1.8 ± 0.42 Soft Tissue Level: 1.9 ± 0.31 Soft Tissue Contour: 1.9 ± 0.31 Alveolar Process Deficiencies: 2.0 ± 0.0 Soft Tissue Color: 2.0 ± 0.0 Soft Tissue Texture: 1.8 ± 0.42	***(Mean ± SD)*** Marginal ***3 Months:*** **G1:** 0.32 ± 0.54 **G2:** 0.07 ± 0.23 ***6 Months:*** **G1:** 0.34 ± 0.55 **G2:** 0.19 ± 0.33 ***12 Months:*** **G1:** 0.29 ± 0.51 **G2:** 0.12 ± 0.28	N/A	***12 Months:*** **G1:** 5.3 ± 1.7 **G2:** 5.9 ± 2.2 ***(Mean change ± SD (95% CI))*** 0–12 Months: **G1:** 0.1 ± 0.56 **G2:** −0.1 ± 0.31	N/A	N/A	None	***Mean Volume Changes (Mean ± SD) (mm^3)*** 3 Months: **G1:** 4.31 ± 2.7 **G2:** 5.16 ± 3.4 ***6 Months:*** **G1:** 6.21 ± 2.9 **G2:** 7.22 ± 3.9 ***12 Months:*** **G1:** 6.21 ± 3.0 **G2:** 7.31 ± 3.9

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Panwar et al., 2022 [21]	**G1:** ADM (AlloDerm, Biohorizons, Birmingham, AL, USA) **G2:** CTG	N/A	N/A	N/A	***(Mean ± SD (95% CI)):*** 6 Months: **G1:** 2.950 ± 0.28 **G2:** 3.4 ± 0.864 Change of KWT ***(Mean ± SD (95% CI)):*** 0–6 Months: **G1:** −0.250 ± 0.2635 **G2:** 0.65 ± 0.411	***6 Months:*** **G1:** Thin: 10 **G2:** Thin: 10 ***(Mean ± SD (95% CI)) (mm):*** 6 Months: **G1:** 0.56 ± 0.1075 **G2:** 0.570 ± 0.082 Changes ***(Mean ± SD (95% CI)) (mm):*** 0–6 Months: **G1:** 0.06 ± 0.069 **G2:** 0.12 ± 0.07	***Papillary Height Change (Mean ± SD) (mm):*** 0–6 Months: **G1:** Mesial: −0.25 ± 0.25 Distal: −0.45 ± 0.37 **G2:** Mesial: −0.06 ± 0.44 Distal: −0.22 ± 0.25	None	***Implant Success Rate:*** **G1:** 100% **G2:** 100%
Puisys et al., 2022 [22]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG	***(Mean ± SD (95% CI))*** *PES:* ***4 Months:*** **G1:** 12.1 ± 1.28 Mesial papilla: 1.7 ± 0.47 Distal papilla: 1.5 ± 0.51 Soft Tissue level: 1.9 ± 0.34 Contour: 1.8 ± 0.43 Alveolar process deficiency: 2.0 ± 0.21 Color: 2 ± 0.21 Texture: 1.8 ± 0.39 **G2:** 12.5 ± 1.37 Mesial papilla: 1.6 ± 0.58 Distal papilla: 1.4 ± 0.58 Soft Tissue level: 2.0 ± 0 Contour: 1.8 ± 0.42 Alveolar process deficiency: 1.5 ± 0.51 Color: 2 ± 0.21 Texture: 1.7 ± 0.45 ***12 Months:*** **G1:** 12.1 ± 1.39 Mesial papilla: 1.7 ± 0.47 Distal papilla: 1.6 ± 0.66 Soft Tissue level: 2.0 ± 0 Contour: 1.9 ± 0.35 Alveolar process deficiency: 2.0 ± 0 Color: 2 ± 0.21 Texture: 1.9 ± 0.29 **G2:** 12.9 ± 1.27 Mesial papilla: 1.7 ± 0.57 Distal papilla: 1.5 ± 0.6 Soft Tissue level: 2.0 ± 0 Contour: 1.8 ± 0.39 Alveolar process deficiency: 1.5 ± 0.51 Color: 1.8 ± 0.42 Texture: 1.7 ± 0.45	N/A	N/A	N/A	**G1:** Thin: 11 Thick: 12 **G2:** Thin: 13 Thick: 9	N/A	None	***Crestal Bone Stability (Mean number ± SD (95% CI)) Mesial/Distal:*** 4 Months: **G1:** 0.4 ± 0.41/ 0.4 ± 0.48 **G2:** 0.3 ± 0.39/ 0.4 ± 0.46 ***Prosthetic Delivery:*** **G1:** 0.4 ± 0.32/ 0.4 ± 0.33 **G2:** 0.3 ± 0.35/ 0.5 ± 0.44 ***12 Months:*** **G1:** 0.1 ± 0.21/ 0.2 ± 0.26 **G2:** 0.2 ± 0.22/ 0.2 ± 0.17

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Sharafuddin et al., 2022 [23]	**G1:** CTG and L-PRF **G2:** No Graft	***(Mean ± SD (95% CI))*** 6 Months: *PES:* **G1:** 12.17 ± 1.72 **G2:** 10.67 ± 1.37	***(Mean ± SD (95% CI))*** 1–6 Months: Buccal Crestal **G1:** 0.36 ± 1.78 **G2:** 0.48 ± 1.49	N/A	***(Mean ± SD (95% CI))*** 3 Months: **G1:** 7.33 ± 2.16 **G2:** 5.50 ± 2.26 ***6 Months:*** **G1:** 7.33 ± 2.16 **G2:** 5.33 ± 2.42 Change of % KTW: ***1–3 Months:*** **G1:** 7.43 ± 12.63 **G2:** 15.42 ± 18.60 ***3–6 Months:*** **G1:** 00.00 ± 00.00 **G2:** −4.17 ± 10.21 ***1–6 Months:*** **G1:** 5.71 ± 12.36 **G2:** −30.62 ± 35.88	***(Mean ± SD (95% CI)) (mm)*** 3 Months: **G1:** 1.92 ± 1.07 **G2:** 0.83 ± 0.26 ***6 Months:*** **G1:** 1.75 ± 0.69 **G2:** 0.83 ± 0.26 Change of % tissue biotype: ***0–3 Months:*** **G1:** 91.67 ± 60.85 **G2:** 00.00 ± 00.00 ***3–6 Months:*** **G1:** −4.17 ± 10.21 **G2:** 00.00 ± 00.00 ***0–6 Months:*** **G1:** 75.00 ± 69.82 **G2:** 0.00 ± 00.00	N/A	N/A	***Patient Satisfaction (Mean ± SD (95% CI))*** 6 Months: **G1:** 3.89 ± 1.23 **G2:** 4.72 ± 0.70
Abdelsamie et al., 2022 [24]	**G1:** CTG **G2:** No Graft	***(Mean ± SD)*** 6 Months: *PES:* **G1:** 13.17 ± 0.4 **G2:** 10.5 ± 2.1	N/A	N/A	***(Mean ± SD (95% CI))*** 3 Months: **G1:** 5.75 ± 0.7 **G2:** 6.56 ± 1.4 ***6 Months:*** **G1:** 5.58 ± 0.8 **G2:** 6.50 ± 1.4 ***%changes (Mean ± SD (95% CI))*** 0–3 Months **G1:** 9.00 ± 1.1 **G2:** 1.43 ± 0.07 ***0–6 Months*** **G1:** 11.79 ± 3.1 **G2:** 2.27 ± 0.5	***(Mean ± SD (95% CI)) (mm)*** 3 Months: **G1:** 4.04 ± 0.5 **G2:** 1.81 ± 0.4 ***6 Months:*** **G1:** 4.33 ± 0.5 **G2:** 1.83 ± 0.4 ***% changes (Mean ± SD (95% CI))*** 0–3 Months **G1:** 124.65 ± 29.8 **G2:** 0.00 ± 0.00 ***0–6 Months*** **G1:** 109.11 ± 26.9 **G2:** 0.93 ± 0.1	***Facial Gingival Level (Mean ± SD (95% CI)) (mm)*** 3 Months: **G1:** 3.05 ± 1.0 **G2:** 3.44 ± 0.8 ***6 Months:*** **G1:** 3.06 ± 0.9 **G2:** 3.72 ± 0.9 ***Changes of Facial Gingival Level (% changes) (Mean ± SD (95% CI))*** 0–3 Months: **G1:** 4.21 ± 0.2 **G2:** 14.77 ± 2.6 ***0–6 Months:*** **G1:** 4.93 ± 0.2 **G2:** 25.17 ± 8.2	N/A	N/A
Abd El-Aziz et al., 2022 [25]	**G1:** CTG **G2:** No Graft	***(Median (IQR))*** 8 Months: *PES:* **G1:** 13.00 (0.00) **G2:** 10.50 (1.00)	***Buccal Crestal (Mean ± SD (95% CI))*** 0–6 Months: **G1:** −0.62 ± 0.87 **G2:** −1.19 ± 1.48	N/A	***(Mean ± SD (95% CI)) (mm)*** 6 Months: **G1:** 6.50 ± 0.94 **G2:** 4.75 ± 1.84 ***0–6 Months:*** **G1:** 0.90 ± 0.82 **G2:** −1.42 ± 0.49	***(Mean ± SD (95% CI)) (mm)*** 6 Months: **G1:** 3.90 ± 1.08 **G2:** 0.92 ± 0.38 ***0–6 Months:*** **G1:** 3.30 ± 0.97 **G2:** 0.00 ± 0.00	N/A	**G1:** 1 implant loss during osseointegration **G2:** 1 implant loss during osseointegration	***(Median (IQR))*** Patient Satisfaction Score 6 Months: **G1:** 100 (0.00) **G2:** 100 (1.50)

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Guglielmi et al., 2022 [26]	**G1:** CTG **G2:** No Graft	N/A	N/A	N/A	***(Mean ± SD (95% CI)) (mm)*** 6 Months: **G1:** 4.53 ± 1.36 **G2:** 3.64 ± 1.29 ***0–6 Months:*** **G1:** 0.6 ± 1.71 **G2:** 0.14 ± 1.28	N/A	N/A	N/A	***Soft Tissue Volume Increase (Mean ± SD (95% CI)) (mm^3):*** **G1:** 6.76 ± 8.94 **G2:** 0.16 ± 0.49 ***Horizontal Buccal Gap (S-IC) (Mean ± SD (95% CI)) (mm):*** **G1:** 2.73 ± 0.90 **G2:** 2.59 ± 0.77 ***VBBR (Mean ± SD (95% CI)) (mm):*** **G1:** −0.66 ± 0.53 **G2:** −0.66 ± 0.75 ***HBBR (Mean ± SD (95% CI)) (mm):*** **G1:** −1.36 ± 1.17 1 mm: −1.36 ± 1.17 2 mm: −0.89 ± 0.70 3 mm: −0.73 ± 0.53 4 mm: −0.69 ± 0.39 5 mm: −0.66 ± 0.45 **G2:** −1.59 ± 0.54 1 mm: −1.59 ± 0.63 2 mm: −1.13 ± 0.47 3 mm: −0.96 ± 0.44 4 mm: −0.79 ± 0.40 5 mm: −0.7 ± 0.40 ***ORR (Mean ± SD (95% CI)) (mm):*** **G1:** 1 mm: −1.16 ± 0.5 2 mm: −1.03 ± 0.66 3 mm: −0.95 ± 0.6 4 mm: −1.05 ± 0.68 5 mm: −0.94 ± 0.56 **G2:** 1 mm: −2.09 ± 0.53 2 mm: −1.66 ± 0.79 3 mm: −1.45 ± 0.89 4 mm: −1.13 ± 0.69 5 mm: −1.06 ± 0.58 ***VAS (Mean ± SD (95% CI)):*** **G1:** 2.73 ± 1.62 **G2:** 1.07 ± 0.70

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Happe et al., 2022a [27]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG	N/A	N/A	N/A	N/A	N/A	N/A	**G1:** 1 superficial necrosis up to 2 weeks and tissue healing delay **G2:** 2 superficial necrosis up to 2 weeks	***Change of Soft Tissue Volume (Mean ± SD (95% CI)) (mm^3)*** **12 Months:** **G1:** −27.7 ± 19.24 **G2:** −18.3 ± 13.82 ***The ratio of volume change to the measured area (Mean ± SD (95% CI)) (mm^3/mm^2)*** **G1:** −0.23 ± 0.128 **G2:** −0.22 ± 0.116 **The linear change of the ridge *(Mean ± SD (95% CI))* (mm)** **G1:** −0.55 ± 0.330 **G2:** −0.60 ± 0.491 ***VAS score (Mean ± SD (95% CI))*** **1 week:** **G1:** 1.30 ± 1.41 **G2:** 4.00 ± 2.90 **2 weeks:** **G1:** 0.00 ± 0.0 **G2:** 0.5 ± 0.85
Happe et al., 2022b [28]	**G1:** PDCM (Mucoderm, Botiss Biomaterials GmbH) **G2:** CTG	***(Mean (95% CI))*** 12 Months: *PES:* **G1:** 11.4 ± 1.4 **G2:** 10.7 ± 1.5 *WES:* **G1:** N/A **G2:** N/A *PES/WES:* **G1:** N/A **G2:** N/A	N/A	N/A	N/A	**G1:** Thick: 8 Thin: 2 **G2:** Thick: 6 Thin: 4	N/A	**G1:** 1 superficial necrosis up to 2 weeks and tissue healing delay **G2:** 2 superficial necrosis up to 2 weeks	***Color Difference of the Peri-implant Mucosa (mm):*** 12 Months: **G1:** 4.06 ± 1.6 **G2:** 3.58 ± 1.36
Ferrantino et al., 2021 [29]	**G1:** CTG **G2:** No Graft	N/A	N/A	N/A	N/A	N/A	N/A	**G1:** 1 implant loss due to loss of retention of the implant-supported restoration **G2:** 1 implant loss due to loss of retention of the implant-supported restoration	***ICAI (Mean ± SD (95% CI))*** 12 Months: **G1:** 4.69 ± 2.53 **G2:** 3.45 ± 2.42 ***ICAI–mucosa (Mean ± SD (95% CI))*** 12 Months: **G1:** 1.77 ± 0.73 **G2:** 2.27 ± 1.95 ***ICAI–crown (Mean ± SD (95% CI))*** 12 Months: **G1:** 2.92 ± 2.36 **G2:** 1.18 ± 0.87

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Zuiderveld et al., 2021 [30]	**G1:** CTG **G2:** No Graft	N/A	***(Mean ± SD (95% CI))*** 1–12 Months: Marginal **G1: -**0.05 ± 0.33 **G2: -**0.01 ± 0.38	***(Mean ± SD (95% CI))*** 1 Month: **G1:** 1.62 ± 0.74 **G2:** 2.00 ± 0.90 ***12 Months:*** **G1:** 1.57 ± 0.80 **G2:** 1.83 ± 0.94 ***0–12 Months:*** Based on distance from the implant's neck **G1:** −0.84 ± 0.61 0 mm: −1.21 ± 1.07 1 mm: −0.80 ± 0.86 2 mm: −0.81 ± 0.77 3 mm: −0.72 ± 0.63 4 mm: −0.69 ± 0.59 5 mm: −0.65 ± 0.63 **G2:** −0.46 ± 0.54 0 mm: −0.91 ± 0.77 1 mm: −0.42 ± 0.57 2 mm: −0.37 ± 0.62 3 mm: −0.31 ± 0.63 4 mm: −0.35 ± 0.69 5 mm: −0.37 ± 0.63	N/A	***Gingival Biotype:*** **Baseline** **G1:** Thin: 18 Thick: 10 **G2:** Thin: 13 Thick: 14	***Mucosal Level (Mean ± SD (95% CI))*** 1–12 Months: Mid-buccal **G1:** 0.07 ± 0.85 (−0.25 to 0.40) **G2:** −0.52 ± 1.16 (−0.98 to −0.07)	**G1:** 1 implant loss during osseointegration, 1 excluded due to scatter artefacts in CBCT **G2:** 1 implant loss during osseointegration, 2 excluded due to scatter artefacts in CBCT	-
Jiang et al., 2020 [31]	**G1:** CTG **G2:** No graft	N/A	N/A	***(Mean ± SD (95% CI))*** Based on distance from the implant's shoulder ***6 Months:*** **G1:** 0 mm: 2.56 ± 0.50 **G2:** 0 mm: 2.72 ± 0.73	N/A	N/A	***Midfacial Gingival Margin Level (Mean ± SD (95% CI)) (mm):*** 6 Months: **G1**: 0.63 ± 0.53 **G2**: 0.63 ± 0.55 ***Midfacial Gingival Margin Level Changes (Mean ± SD (95% CI)) (mm):*** 0–6 Months: **G1: -**0.16 ± 0.60 **G2: -**0.26 ± 0.54	**G1:** 1 loosening of the provisional restoration around 3–6 weeks post-surgery **G2:** 2 loosening of the provisional restoration around 3–6 weeks post-surgery	***BPR % (Mean ± SD (95% CI)):*** 6 Months: **G1:** 92.8 ± 27.8% **G2:** 77.5 ± 44.5%

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Frizzera et al., 2019 [34]	**G1:** No Graft **G2:** PDCM (Mucograft, Geistlich) **G3**: CTG	***(Mean ± SD (95% CI))*** 12 Months: *PES:* **G1:** 9.87 ± 1.64 **G2:** 10 ± 1.3 **G3:** 10.75 ± 1.38 *WES:* N/A *PES/WES:* N/A	N/A	***(Mean ± SD (95% CI))*** Based on distance from the implant's neck ***6 Months:*** **G1:** 0 mm: 1.22 ± 0.85 1 mm: 1.58 ± 0.87 3 mm: 1.79 ± 0.88 5 mm: 2.07 ± 0.73 7 mm: 2.10 ± 1.34 **G2:** 0 mm: 1.35 ± 1.38 1 mm: 1.48 ± 1.13 3 mm: 1.55 ± 1.17 5 mm: 1.69 ± 1.12 7 mm: 2.01 ± 1.44 **G3:** 0 mm: 1.04 ± 1.01 1 mm: 1.54 ± 1.06 3 mm: 1.63 ± 0.91 5 mm: 1.90 ± 1.03 7 mm: 2.25 ± 1.32 ***12 Months:*** **G1:** 0 mm: 1.28 ± 0.92 1 mm: 1.70 ± 0.86 3 mm: 1.62 ± 0.80 5 mm: 1.57 ± 0.94 7 mm: 1.69 ± 1.22 **G2:** 0 mm: 1.14 ± 1.34 1 mm: 1.26 ± 1.16 3 mm: 1.40 ± 1.05 5 mm: 1.53 ± 1.13 7 mm: 2.03 ± 1.25 **G3:** 0 mm: 1.06 ± 1.87 1 mm: 1.45 ± 1.06 3 mm: 1.51 ± 0.87 5 mm: 1.72 ± 0.95 7 mm: 2.05 ± 1.41	N/A	***STT ((Mean ± SD (95% CI)) (mm):*** 6 Months: **G1:** 2.04 ± 0.43 **G2:** 2.05 ± 0.41 **G3**: 2.82 ± 0.40 ***12 Months:*** **G1:** 2.11 ± 0.60 **G2:** 2.10 ± 0.54 **G3:** 3.04 ± 0.61	***Migration of Mesial Papilla (Mean ± SD (95% CI)) (mm):*** 0–6 Months: **G1:** -0.64 ± 0.41 **G2:** -0.39 ± 0.45 **G3:** -0.53 ± 0.28 ***0–12 Months:*** **G1:** -0.36 ± 0.7 **G2:** -0.41 ± 0.47 **G3:** -0.56 ± 0.57 ***Migration of Distal Papilla (Mean ± SD (95% CI)) (mm):*** 0–6 Months: **G1:** -0.69 ± 0.62 **G2:** -0.64 ± 0.80 **G3:** -0.44 ± 0.79 ***0–12 Months:*** **G1:** -0.74 ± 0.68 **G2:** -0.52 ± 0.67 **G3:** -0.47 ± 0.53	**G1:** 1 inflammed tissue containing biomaterial particle after 6 months **G2:** 2 facial peri-implant tissues inflammation **G3:** 1 provisional loosening after 4 months	***Modified PES (Mean ± SD (95% CI)):*** 12 Months **G1:** 6.62 ± 1.59 **G2:** 7.12 ± 0.99 **G3:** 7.87 ± 0.99 ***DIPBIC ((Mean ± SD (95% CI)) (mm):*** 12months: **G1:** −0.35 ± 3.69 **G2:** −0.28 ± 2.51 **G3:** −0.55 ± 3.51 ***MPR (Mean ± SD (95% CI)) (mm):*** 6 Months: **G1:** 0.41 ± 0.40 **G2:** 0.14 ± 0.37 **G3:** −0.41 ± 0.75 ***12 Months:*** **G1:** 0.72 ± 0.57 **G2:** 0.42 ± 0.60 **G3:** −0.04 ± 0.3

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Van Nimwegen et al., 2018 [32]	**G1:** CTG **G2:** No Graft	(Mean ± SD (95% CI)) ***12 Months:*** *PES:* **G1:** 11.28 ± 1.67 Mesial Papilla: 1.48 ± 0.51 Distal Papilla:1.48 ± 0.65 Level Gingival Margin: 1.80 ± 0.50 Contour: 1.40 ± 0.71 Alveolar Process: 1.48 ± 0.65 Color: 1.84 ± 0.37 Texture: 1.80 ± 0.50 **G2:** 11.36 ± 1.65 Mesial Papilla: 1.44 ± 0.51 Distal Papilla: 1.68 ± 0.48 Level Gingival Margin: 1.44 ± 0.71 Contour: 1.60 ± 0.58 Alveolar Process: 1.24 ± 0.72 Color: 1.96 ± 0.20 Texture: 2.00 ± 0.00	N/A	N/A	N/A	***Mucosal Thickness Change (Mean ± SD (95% CI))*** 0–12 Months: **G1:** −0.68 ± 0.59 **G2:** −0.49 ± 0.54	***Change in Mid-facial Mucosa Level (Mean ± SD (95% CI))*** 1–12 Months: Mid-facial **G1:** + 0.20 ± 0.70 **G2:** −0.48 ± 1.13	**G1:** 1 implant loss during osseointegration, 4 excluded due to irregularities in stone casts **G2:** 1 implant loss during osseointegration, 4 excluded due to irregularities in stone casts	***Survival Rate:*** 0–12 Months **G1:** 96.7% **G2:** 96.7% ***Volumetric Changes (mm^2)*** 0–12 Months **G1:** 11.97 ± 4.43 **G2:** 13.45 ± 3.56 ***Volumetric Changes (mm^3)*** 0–12 Months **G1:** 9.32 ± 7.19 **G2:** 7.77 ± 7.26 ***Mid-facial PD (Mean (95% CI)) (mm):*** 12 Months: **G1:** 2.28 ± 0.79 **G2:** 2.44 ± 1.19 ***Patient Satisfaction (Mean ± SD (95% CI))*** 12 Months: **G1:** Color of Peri-implant Mucosa: 8.37 ± 2.20 Shape of Peri-implant Mucosa: 8.27 ± 2.25 Total Score: 8.38 ± 2.28 **G2:** Color of Peri-implant Mucosa: 8.70 ± 1.76 Shape of Peri-implant Mucosa: 8.18 ± 2.38 Total Score: 8.84 ± 1.23

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Zuiderveld et al., 2018 [33]	**G1:** CTG **G2:** No Graft	***(Mean ± SD (95% CI))*** 12 Months: *PES:* **G1:** 6.4 ± 1.5 Mesial Papilla: 1.5 ± 0.5 Distal Papilla: 1.4 ± 0.5 Curvature of facial mucosa: 1.3 ± 0.7 Level of facial mucosa: 1.2 ± 0.5 Root convexity/ soft tissue color and texture: 0.9 ± 0.7 **G2:** 6.8 ± 1.5 Mesial Papilla: 1.5 ± 0.5 Distal Papilla: 1.6 ± 0.5 Curvature of facial mucosa: 1.5 ± 0.5 Level of facial mucosa: 1.2 ± 0.5 Root convexity/ soft tissue color and texture: 1.1 ± 0.6 *WES:* **G1:** 6.9 ± 1.9 Tooth form: 1.2 ± 0.6 Outline/volume: 1.7 ± 0.5 Color: 1.3 ± 0.5 Surface texture: 1.3 ± 0.5 Translucency/characterization: 1.3 ± 0.6 **G2:** 7.4 ± 1.3 Tooth form: 1.2 ± 0.4 Outline/volume: 1.5 ± 0.5 Color: 1.6 ± 0.5 Surface texture: 1.6 ± 0.5 Translucency/characterization: 1.5 ± 0.5 *PES/WES:* **G1:** 13.2 ± 2.9 **G2:** 14.2 ± 2.4	***(Median (IQR))*** 1–12 Months: **G1:** Mesial: 0.8 (0.0–1.5) Distal: 0.3 (0.0–1.1) **G2:** Mesial: 0.9 (0.2–1.2) Distal: 0.5 (0.0–1.2) ***0–12 Months:*** **G1:** Mesial: 0.9 (0.4–1.2) Distal: 0.8 (0.0–1.1) **G2:** Mesial: 0.8 (0.5–1.2) Distal: 0.8 (0.0–1.1)	N/A	N/A	N/A	***Gingival Level (Mean ± SD (95% CI))*** 0–1 Months **G1:** Mid-buccal: 0.1 ± 0.9 Mesial: −0.4 ± 0.7 Distal: −0.4 ± 0.6 **G2:** Mid-buccal: −0.5 ± 1.0 Mesial: −0.3 ± 0.8 Distal: −0.6 ± 0.7 ***1–12 Months*** **G1:** Mid-buccal: 0.0 ± 0.3 Mesial: 0.2 ± 0.4 Distal: −0.1 ± 0.5 **G2:** Mid-buccal: 0.0 ± 0.3 Mesial: −0.1 ± 0.5 Distal: −0.0 ± 0.4 ***0–12 Months*** **G1:** Mid-buccal: 0.1 ± 0.8 Mesial: −0.3 ± 0.7 Distal: −0.4 ± 0.7 **G2:** Mid-buccal: −0.5 ± 1.1 Mesial: −0.4 ± 1.0 Distal: −0.6 ± 0.6 ***PIS (Mesial/Distal)*** 1 Month: **G1:** Score 0: 0%/0% Score 1: 10.3%/10.3% Score 2: 37.9%/31.0% Score 3: 51.7%/58.6% Score 4: 0%/0% **G2:** Score 0: 0%/0% Score 1: 13.8%/3.4% Score 2: 34.5%/37.9% Score 3: 51.7%/58.6% Score 4: 0%/0% ***12 Months:*** **G1:** Score 0: 0%/0% Score 1: 6.9%/6.9% Score 2: 27.6%/24.1% Score 3: 65.5%/69.0% Score 4: 0%/0% **G2:** Score 0: 0%/0% Score 1: 10.3%/6.9% Score 2: 41.4%/27.6% Score 3: 48.3%/65.5% Score 4: 0%/0%	**G1:** 1 implant loss during osseointegration **G2:** 1 implant loss during osseointegration	***Survival Rate:*** 12 Months **G1:** 96.7% **G2:** 96.7% ***PD (Mean ± SD (95% CI)) (mm):*** 1 Months: **G1:** Mesial: 3.1 ± 1.4 Mid-buccal: 2.6 ± 1.1 Distal: 3.0 ± 1.0 Palatal: 2.4 ± 0.7 **G2:** Mesial: 3.0 ± 1.2 Mid-buccal: 2.2 ± 1.1 Distal: 2.0 ± 1.4 Palatal: 2.3 ± 0.7 ***12 Months:*** **G1:** Mesial: 2.8 ± 1.1 Mid-buccal: 2.3 ± 0.9 Distal: 2.9 ± 0.9 Palatal: 2.2 ± 0.7 **G2:** Mesial: 3.0 ± 0.9 Mid-buccal: 2.5 ± 1.2 Distal: 2.9 ± 1.4 Palatal: 2.3 ± 0.8 ***Total OHIP score*** 1 Month: **G1:** 3.0 (1.0–9.0) **G2:** 6.0 (0.8–1.0) ***12 Months:*** **G1:** 2.0 (1.0–5.0) **G2:** 2.0 (0.0–6.0)

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
Migliorati et al., 2015 [35]	**G1:** CTG **G2:** No Graft	***(Mean ± SD (95% CI))*** *PES:* 7.15 ± 1.75 **G1**: Optimum: 66.6% Good: 12.5% Sufficient: 20.8% **G2:** Optimum: 17.3% Good: 21.7% Sufficient: 48.5% Poor: 17.3% *WES:* 7.98 ± 0.99	***Bone Loss (Mean ± SD (95% CI))*** 12 Months: **G1:** Mesial: −0.03 ± 0.13 Distal: 0.035 ± 0.05 Overall: 0.001 ± 0.092 **G2:** Mesial: −0.14 ± 0.105 Distal: −0.13 ± 0.11 Overall: −0.136 ± 0.107 ***24 Months:*** **G1:** Mesial: −0.115 ± 0.16 Distal: −0.005 ± 0.021 Overall: −0.06 ± 0.091 **G2:** Mesial: −0.165 ± 0.055 Distal: −0.167 ± 0.072 Overall: −0.166 ± 0.063	N/A	***(Mean ± SD (95% CI)) (mm)*** 12 Months: **G1:** 3.0 ± 1.2 In thin biotype: 2.4 ± 0.7 In thick biotype: 4.0 ± 1.1 **G2:** 3.7 ± 1.1 In thin biotype: 2.9 ± 0.8 In thick biotype: 4.6 ± 0.6 ***24 Months:*** **G1:** 2.9 ± 1.2 In thin biotype: 2.3 ± 0.7 In thick biotype: 4.0 ± 1.0 **G2:** 3.6 ± 1.2 In thin biotype: 2.7 ± 0.8 In thick biotype: 4.5 ± 0.6	***(Mean ± SD (95% CI)) (mm)*** 12 Months: **G1:** 1.8 ± 0.8 In thin biotype: 1.3 ± 0.4 In thick biotype: 2.5 ± 0.7 **G2:** 1.1 ± 0.5 In thin biotype: 0.8 ± 0.5 In thick biotype: 1.5 ± 0.5 ***24 Months:*** **G1:** 1.5 ± 0.8 In thin biotype: 1.00 ± 0.3 In thick biotype: 2.2 ± 0.7 **G2:** 1.0 ± 0.5 In thin biotype: 0.7 ± 0.5 In thick biotype: 1.4 ± 0.5	***Papilla Highness (Mean ± SD (95% CI)) (mm):*** 12 Months: **G1:** Mesial: 3.3 ± 1.1 Distal: 2.6 ± 0.6 **G2:** Mesial: 3.3 ± 0.9 Distal: 2.6 ± 0.6 ***24 Months:*** **G1:** Mesial: 3.6 ± 1.1 Distal: 2.9 ± 0.5 **G2:** Mesial: 3.6 ± 0.5 Distal: 2.8 ± 0.7	None	***PD (Mean ± SD (95% CI)) (mm):*** 12 Months: **G1:** 3.3 ± 0.4 **G2:** 3.1 ± 1 ***24 Months:*** **G1:** 3.4 ± 0.5 **G2:** 3.2 ± 0.5 ***BOP (Mean number ± SD (95% CI)):*** 12 Months: **G1:** 0.4 ± 0.3 **G2:** 0.4 ± 0.4 ***24 Months:*** **G1:** 0.2 ± 0.3 **G2:** 0.4 ± 0.4 ***PL (Mean number ± SD (95% CI)):*** 12 Months: **G1:** 0.1 ± 0.2 **G2:** 0.1 ± 0.2 ***24 Months:*** **G1:** 0.1 ± 0.2 **G2:** 0.1 ± 0.2
Yoshino et al., 2014 [36]	**G1:** CTG **G2:** No Graft	N/A	***(Mean ± SD (95% CI))*** Marginal ***0–3 Months:*** **G1:** -0.01 ± 0.06 **G2:** -0.13 ± 0.29 ***0–6 Months:*** **G1:** -0.09 ± 0.12 **G2:** -0.12 ± 0.40 ***0–12 Months:*** **G1:** -0.01 ± 0.27 **G2:** -0.14 ± 0.53 ***3–6 Months:*** **G1:** -0.08 ± 0.11 **G2:** 0.01 ± 0.17 ***3–12 Months:*** **G1:** 0.00 ± 0.26 **G2:** -0.02 ± 0.31 ***6–12 Months:*** **G1:** 0.09 ± 0.24 **G2:** -0.02 ± 0.28	N/A	N/A	***Gingival Biotype:*** **Baseline** **G1:** Thin: 0 Thick: 10 **G2:** Thin: 3 Thick: 7	***Facial Gingival Level (Mean ± SD (95% CI))*** 0–3 Months: **G1:** -0.4 ± 0.46 **G2:** -0.8 ± 0.59 ***0–6 Months:*** **G1:** -0.4 ± 0.52 **G2:** -0.75 ± 0.54 ***0–12 Months:*** **G1:** -0.25 ± 0.35 **G2:** -0.7 ± 0.48 ***3–6 Months:*** **G1:** 0.0 ± 0.24 **G2:** 0.05 ± 0.28 ***3–12 Months:*** **G1:** 0.15 ± 0.24 **G2:** 0.1 ± 0.39 ***6–12 Months:*** **G1:** 0.15 ± 0.24 **G2:** 0.05 ± 0.28 ***PIS (Mesial/Distal)*** 3 Months: **G1:** Score 0: 1/2 Score 1: 2/2 Score 2: 7/4 Score 3: 0/2 Score 4: 0/0	**Prosthetic Complications:** * inadequate resistance and retention form of the provisional abutment * Fracture of the provisional abutment Peri-implantitis: * Fistula Tract due to residual flowable composite resin * Exudate around the gingiva margin of one implant All complications were resolved	***Survival Rate:*** 12 Months **G1:** 100% **G2:** 100% ***ISQ (Mean ± SD (95% CI))*** 6 Months: **G1:** 75.2 ± 6.1 **G2:** 76.6 ± 4.9 ***mPI/mBI*** 3 Months: **G1:** Score 0: 4/4 Score 1: 5/4 Score 2: 1/2 Score 3: 0/0 **G2:** Score 0: 4/9 Score 1: 6/1 Score 2: 0/0 Score 3: 0/0

Table 2 (continued)

Study	Study Groups	PES, WES, PES/WES	Bone Level (mm)	BBT (mm)	KTW (mm)	Soft Tissue Phenotype	Mucosal Level (mm) Gingival Level (mm) Papillary Index Score	Complications	Other Observations
							G2: Score 0: 0/1 Score 1: 2/3 Score 2: 6/6 Score 3: 2/0 Score 4: 0/0 ***6 Months:*** **G1:** Score 0: 1/1 Score 1: 2/2 Score 2: 4/2 Score 3: 3/5 Score 4: 0/0 **G2:** Score 0: 0/1 Score 1: 2/2 Score 2: 5/7 Score 3: 3/0 Score 4: 0/0 ***12 Months:*** **G1:** Score 0: 1/1 Score 1: 2/1 Score 2: 3/3 Score 3: 4/5 Score 4: 0/0 **G2:** Score 0: 0/0 Score 1: 1/3 Score 2: 4/5 Score 3: 5/2 Score 4: 0/0		***6 Months:*** **G1:** Score 0: 5/6 Score 1: 5/4 Score 2: 0/0 Score 3: 0/0 **G2:** Score 0: 8/10 Score 1: 2/0 Score 2: 0/0 Score 3: 0/0 ***12 Months:*** **G1:** Score 0: 8/7 Score 1: 2/3 Score 2: 0/0 Score 3: 0/0 **G2:** Score 0: 8/10 Score 1: 2/0 Score 2: 0/0 Score 3: 0/0

HUs Hounsfield Unit, *BoP* Bleeding on Probing, *PES* Pink Esthetic Score, *WES* White Esthetic Score, *KTW* Keratinized Tissue Width, *BBT* Buccal Bone Thickness, *PD* Pocket Depth, *SD* Standard Deviation, *CI* Confidence Interval, *IQR* Interquartile Range, *W/O* Without, *N/A* Not Available, *ICAI* Implant Crown Aesthetic Index, *BRP* Buccal Plate Resorption Ratio, *ORR* Osseus Ridge Resorption, *VBBR* Vertical Buccal Bone Resorption, *HBBR* Horizontal Buccal Bone Resorption, *CTG* Connective Tissue Graft, *MPR* Marginal Peri-implant Recession, *STT* Soft Tissue Thickness, *DIPBIC* Distance between Implant Platform and the first Bone to Implant Contact, *PL* Plaque Index, *PDCM* Porcine-Derived Collagen Matrix, *BID* Buccal Implant Distance, *mPI* Modified Plaque Index, *mBI* Modified Bleeding Index

achieved through the CTG as the grafting material. In contrast, Abd El-Aziz et al. [25] documented the lowest mean change in a follow-up of 6 months at −1.19 ± 1.48 mm in buccal crestal region without any grafting materials. Among the studies using grafting material, six studies [16, 18, 25, 30, 35, 36] presented a decrease in mean (or median) MIBL despite using CTG as grafting material, and Lee et al. [18] reported mean MIBL of −0.69 ± 0.74 mm in mesial and −0.39 ± 2.24 mm in the distal region with AlloDerm as grafting material in a 12 months follow-up.

Five studies [16, 19, 30, 31, 34] reported BBT changes Jiang et al. [31] mentioned the highest BBT of 2.72 ± 0.73 mm based on the 0 mm distance from the implant's shoulder with no grafting material in a 6-month follow-up. Contrary, a decrease in BBT was documented in 2 studies [19, 30], reporting the most decreasing change of −2.17 ± 2.39 mm based on the 0 mm distance from the implant's shoulder with CTG as grafting material in a 24 months follow-up [19].

KTW was presented by nine studies [18–21, 23–26, 35]. Sharafuddin et al. [23] reported the highest value change of 15.42 ± 18.60 mm without any grafting material in a 3-month follow-up. However, the lowest value change of −30.62 ± 35.88 mm without any grafting material was reported in Sharafuddin et al. [23] study in a 6-month follow-up. Two studies reported decreased KTW in immediate implant placements with AlloDerm as grafting material [18, 21] in which the lowest rate was reported as −0.47 ± 1.06 mm [18].

Seven studies reported implant loss due to failure in osseointegration [16, 19, 25, 29, 30, 32, 33].

Quantitative synthesis

The transitivity assessment has been qualitatively appraised as described in "Certainty of the meta-evidence assessment" section. The potential covariates (the patient's age and gender, whether a study raised a flap or flapless, immediate or delayed provisionalization, use of the bone graft materials, and inclusion of the defective sockets) were distributed similarly between different treatment arms qualitatively; however, all expect for patient's age and gender, were considered to be tested as predictive covariates for their effects on the final estimation in the model.

Individual outcome measures

The detailed results of the network meta-analysis for the estimation of each PES, MIBL, BBT, KTW, STT, PH, and MGML outcomes are reported in appendices S3, S4, S5, S6, S7, S8, and S9, respectively.

For further details, see Appendix S2.

Pink esthetic score

Figure 3A elicits the geometry of the overall network of the studies reporting PES included in the network meta-analysis. A global inconsistency has been observed in the plain model (Table 1/S3), which is resolved by fixed-effect accounting for the effect of follow-up time in the

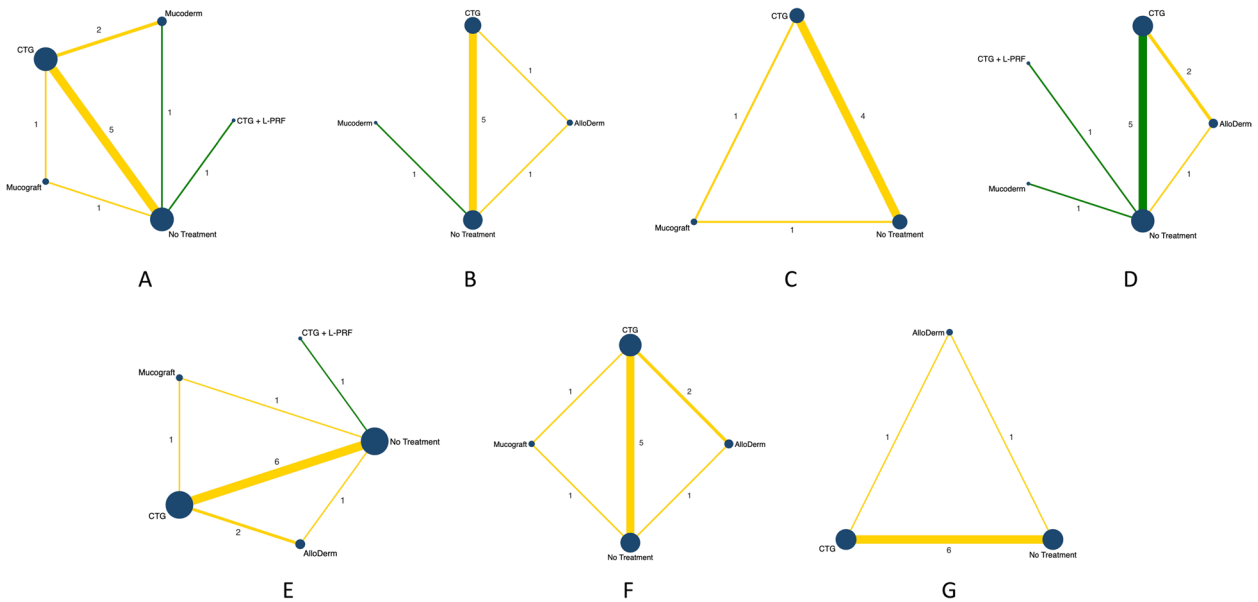

Fig. 3 Network map of studies concerning each desired outcome: Pink Esthetic Score (**A**), Marginal Interproximal Bone Level Changes (**B**), Buccal Bone Thickness Changes (**C**), Keratinized Tissue Width Changes (**D**), Soft Tissue Thickness Changes (**E**), Papilla Height Changes (**F**), Midfacial Gingival Margin Level Changes (**G**). The size of nodes, size of edges, and color of the edges represent the number of studies on treatment arms, the number of studies comparing two treatment arms, and the mode of the risk of bias of studies comparing two treatment arms

final model (Table 4/S3). The network meta-regression showed that the follow-up time has a significant effect on the estimation of PES in both fixed- (−2.68 [95% CrI: −4.68, −0.65]) and random-effect (for CTG: −2.69 [95% CrI: −4.68, −0.60]). No significant effect was observed among other predictive and confounder variables. There was not a significant sign of loop inconsistency according to the node-splitting. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 3). The treatment ranking according to the SUCRA value was as follows: Mucoderm (0.81) – CTG (0.67) – Mucograft (0.52) – No Treatment (0.27) – CTG + L-PRF (0.24). Figure 4A shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Marginal interproximal bone level changes

Figure 3B elicits the geometry of the overall network of the studies reporting MIBL included in the network meta-analysis. No global inconsistency has been observed in the plain model (Table 1/S4). No significant effect was observed among the predictive and confounder variables. There was no potential inconsistent loop to be investigated in the network geometry. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 12 – 24 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 4). The treatment ranking according to the SUCRA value was as follows: CTG (0.59) – AlloDerm (0.56) – Mucoderm (0.50) – No Treatment (0.35). Figure 4B shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Table 3 The results of the comparisons of the pink esthetic score between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis				
CTG	-	0.76 [−3.65, 5.15]	-	−1.08 [−3.21, 1.06]
1.35 [−1.79, 4.44]	**CTG + L-PRF**	-	**-**	-
−0.37 [−1.64, 0.93]	−1.72 [−5.09, 1.70]	**Mucoderm**	-	-
0.29 [−1.75, 2.35]	−1.05 [−4.78, 2.72]	0.66 [−1.68, 3.00]	**Mucograft**	**-**
0.78 [−0.13, 1.69]	−0.56 [−3.53, 2.44]	1.15 [−0.25, 2.53]	0.49 [−1.57, 2.55]	**No Treatment**
Network Meta-analysis				

The values in the square brackets demonstrate the 95% credible interval

Buccal bone thickness changes

Figure 3C elicits the geometry of the overall network of the studies reporting BBT included in the network meta-analysis. No global inconsistency has been observed in the plain model (Table 1/S5). No significant effect was observed among the predictive and confounder variables. There was no potential inconsistent loop to be investigated in the network geometry. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 5). The treatment ranking according to the SUCRA value was as follows: No Treatment (0.57) – Mucograft (0.48) – CTG (0.45). Figure 4C shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Keratinized tissue width changes

Figure 3D elicits the geometry of the overall network of the studies reporting KTW included in the network meta-analysis. No global inconsistency has been observed in the plain model (Table 1/S6). No significant effect was observed among the predictive and confounder variables. There was not a significant sign of loop inconsistency according to the node-splitting. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 6). The treatment ranking according to the SUCRA value was as follows: CTG (0.67) – CTG + L-PRF (0.5) – Mucoderm (0.64) – AlloDerm (0.27) – No Treatment (0.27). Figure 4D shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Soft tissue thickness changes

Figure 3E elicits the geometry of the overall network of the studies reporting STT included in the

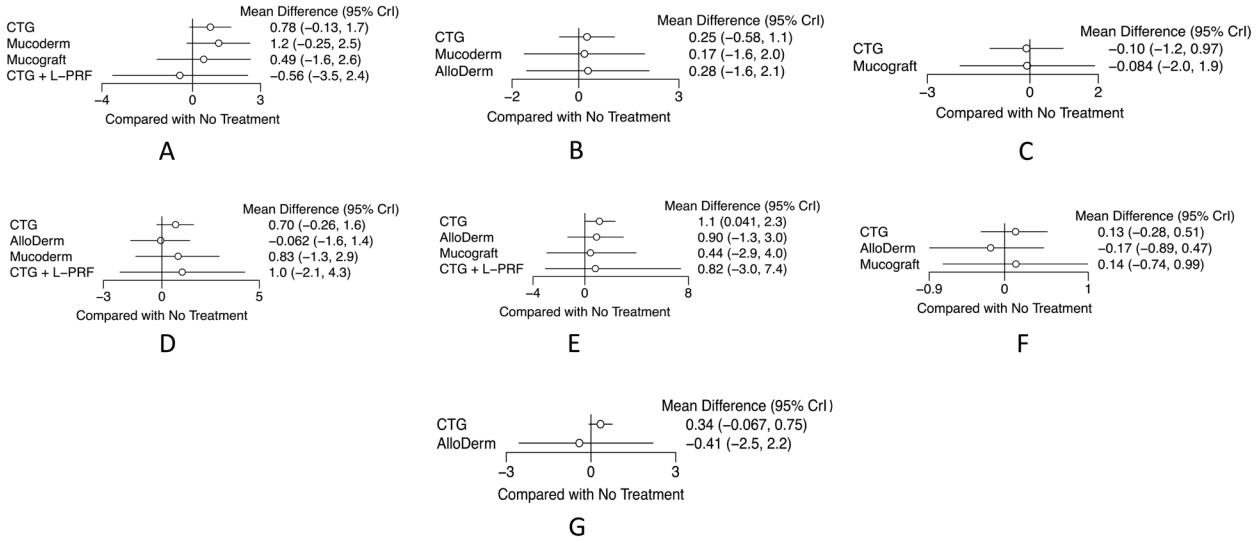

Fig. 4 Forest plots of the results of quantitative network meta-analysis of the included studies concerning each desired outcome: Pink Esthetic Score (**A**), Marginal Interproximal Bone Level Changes (**B**), Buccal Bone Thickness Changes (**C**), Keratinized Tissue Width Changes (**D**), Soft Tissue Thickness Changes (**E**), Papilla Height Changes (**F**), Midfacial Gingival Margin Level Changes (**G**)

Table 4 The results of the comparisons of the marginal interproximal bone level change between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis			
AlloDerm	-	-	-
0.03 [−1.79, 1.86]	**CTG**	-	−0.16 [−0.49, 0.11]
0.11 [−2.47, 2.69]	0.07 [−1.88, 2.05]	**Mucoderm**	-
0.28 [−1.57, 2.11]	0.25 [−0.58, 1.07]	0.17 [−1.64, 1.97]	**No Treatment**
Network Meta-analysis			

The values in the square brackets demonstrate the 95% credible interval

Table 5 The results of the comparisons of the buccal bone thickness changes between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis		
CTG	-	0.10 [−0.80, 1.00]
0.01 [−2.12, 2.13]	**Mucograft**	-
−0.08 [−1.26, 1.08]	−0.10 [−2.19, 2.02]	**No Treatment**
Network Meta-analysis		

The values in the square brackets demonstrate the 95% credible interval

network meta-analysis. A global inconsistency has been observed in the plain model (Table 1/S7), which is resolved by random-effect accounting for the effect of baseline soft tissue thickness value in the final model (Table 4/S7). No significant effect was observed among other predictive and confounder variables. There was not a significant sign of loop inconsistency according to the node-splitting. The funnel plot did not show an observable sign of publication bias. Only the adjunctive application of CTG showed a significantly higher amount of STT after 6 – 12 months of follow-up compared to No Treatment (1.13 mm [95% CrI: 0.04, 2.34]). The other comparisons did not demonstrate any significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 7). The treatment ranking according to the SUCRA value was as follows: CTG (0.69) – AlloDerm (0.63) – CTG + L-PRF (0.58) – Mucograft (0.42) – No Treatment (0.19). Figure 4E shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Papilla height changes

Figure 3F elicits the geometry of the overall network of the studies reporting PH included in the network

Table 6 The results of the comparisons of the keratinized tissue width changes between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis				
AlloDerm	0.79 [−3.35, 4.87]	-	-	-
−0.77 [−2.12, 0.58]	**CTG**	-	-	−0.53 [−2.16, 1.12]
−1.10 [−4.78, 2.50]	−0.34 [−3.76, 3.01]	**CTG + L-PRF**	-	-
−0.90 [−3.36, 1.61]	−0.13 [−2.39, 2.15]	0.22 [−3.79, 4.26]	**Mucoderm**	**-**
−0.06 [−1.60, 1.43]	0.70 [−0.26, 1.63]	1.04 [−2.15, 4.25]	0.83 [−1.34, 2.94]	**No Treatment**
Network Meta-analysis				

The values in the square brackets demonstrate the 95% credible interval

Table 7 The results of the comparisons of the soft tissue thickness changes between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis				
AlloDerm	0.01 [−3.53, 3.53]	-	-	-
−0.21 [−2.59, 1.78]	**CTG**	-	**-**	−1.10 [−2.74, 0.54]
0.05 [−6.37, 4.35]	0.31 [−6.28, 4.42]	**CTG + L-PRF**	-	-
0.46 [−3.77, 4.36]	0.69 [−2.80, 4.11]	0.41 [−5.02, 7.60]	**Mucograft**	**-**
0.90 [−1.32, 2.97]	**1.13 [0.04, 2.34] ***	0.82 [−3.05, 7.39]	0.44 [−3.96, 2.92]	**No Treatment**
Network Meta-analysis				

The values in the square brackets demonstrate the 95% credible interval

* Sign indicates a significant difference in a comparison upon considering a 95% credible interval

meta-analysis. No global inconsistency has been observed in the plain model (Table 1/S8). No significant effect was observed among the predictive and confounder variables. There was not a significant sign of loop inconsistency according to the node-splitting. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 8). The

Table 8 The results of the comparisons of the papilla height changes between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis			
AlloDerm	0.35 [−3.72, 4.46]	-	-
−0.30 [−0.94, 0.28]	**CTG**	-	−0.15 [−0.43, 0.14]
−0.31 [−1.38, 0.70]	−0.00 [−0.86, 0.84]	**Mucograft**	-
−0.17 [−0.89, 0.47]	0.13 [−0.28, 0.51]	0.14 [−0.74, 0.99]	**No Treatment**
Network Meta-analysis			

The values in the square brackets demonstrate the 95% credible interval

treatment ranking according to the SUCRA value was as follows: CTG (0.73) – Mucograft (0.65) – No Treatment (0.43) – AlloDerm (0.19). Figure 4F shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Midfacial gingival margin level changes

Figure 3G elicits the geometry of the overall network of the studies reporting MGML included in the network meta-analysis. No global inconsistency has been observed in the plain model (Table 1/S9). No significant effect was observed among the predictive and confounder variables. There was no potential inconsistent loop to be investigated in the network geometry. The funnel plot did not show an observable sign of publication bias. There was no significant difference between treatment arms after 6 – 12 months of follow-up according to both network and traditional pair-wise meta-analysis (Table 9). The treatment ranking according to the SUCRA value was as follows: CTG (0.91) – No Treatment (0.39) – AlloDerm (0.20). Figure 4G shows the forest plot of the comparison between each treatment arm and the No Treatment group. The sensitivity analysis results were not significantly different from the main results.

Certainty of the meta-evidence assessment

A summary of the GRADE assessment regarding each outcome and each comparison is demonstrated in Table 10. The problematic domains were the within study bias and imprecision causing the certainty of the meta-evidence to be down-graded. Only meta-evidence receiving a high certainty in this study were CTG vs. No

Table 9 The results of the comparisons of the midfacial gingival margin level changes between treatments using network meta-analysis (lower-left side) and pair-wise meta-analysis (upper-right side), where at least two studies were present, summarized in the league table. In the league table, each value represents the result of the comparison between its column treatment against its row treatment

Pair-wise Meta-analysis		
AlloDerm	-	-
−0.75 [−2.89, 1.85]	**CTG**	**−0.33 [−0.63, −0.04]***
−0.41 [−2.54, 2.20]	0.34 [−0.07, 0.75]	**No Treatment**
Network Meta-analysis		

The values in the square brackets demonstrate the 95% credible interval

Treatment in the KTW and Mucoderm vs. No Treatment in the MIBL. Overall, in different outcomes, 18, 16, and 12 comparisons received a low, moderate, and very low certainty.

Discussion

Interpretation of the results

This review aimed to evaluate the effect of different adjunctive soft tissue grafts on the clinical outcomes of immediately placed implants. Figure 5 elicits the SUCRA values of each treatment modality regarding each of the outcomes.

Despite the fact that there are some available decision trees in the literature regarding the application of soft tissue grafting around immediately placed dental implants, still there is no widely accepted guideline and consensus on the subject, especially for the sockets with minimally hard and soft tissue deficiencies in which it is not clear that soft tissue grafting with different materials are beneficial or have any differences regarding the implant-related clinical outcomes. Since most of the studies in the present review evaluated the effect using different soft tissue grafts on the aforementioned condition and compared them with not placing any grafts, the results of this study can be considered beneficial to the available literature.

The esthetic outcomes of an immediately placed implant can be dependent on the location of the tooth, mucosal margin position, soft tissue phenotype, and spatial position of the placed implant in relation to the available hard and soft tissue [44]. Moreover, planning for a provisional restoration showed a beneficial effect on the emergence profile of the soft tissue and, consequently, a superior esthetic outcome [34]. In the present review, it was tried to investigate and account for the effect of these factors even though they were qualitatively similar in the included studies. Nonetheless, except for the follow-up time, other tested covariates did not show a significant effect on all outcomes. This result could be because of the relatively limited number of studies reporting each outcome, as the regression analyses could be heavily associated with the number of observations, in our case, studies.

The long-term stability and health of the restorations supported by the implants are associated with the quantity of the peri-implant keratinized mucosal width and thickness. It has been shown that a keratinized tissue width higher than 2 mm can reduce the chance of soft tissue inflammation and recession, bacterial plaque aggregation, and hygiene maintenance. On the other hand, more than 2 mm of soft tissue thickness demonstrated a protective influence on the peri-implant marginal bone [5, 45–48]. According to the SUCRA values and rankings, our analyses illustrated that CTG, compared to other treatments, could be associated with a higher STT after 6 – 12 months and, consequently, a higher MIBL after 12 – 24 months. Mucograft, on the other hand, demonstrated a weak performance among graft materials regarding the STT, which might be attributed to its higher rate of thickness loss and maintained space, consequently [49]. Interestingly, a higher BBT was achieved after 6 – 12 months in No Treatment had been applied. This outcome could be attributed to less soft tissue manipulation when the implants are placed without soft tissue grafting. Coherently, Kuebler and Noelken, in 2024, evaluated the effect of adjunctive CTG grafting alongside bone grafting in immediate implant placement and demonstrated that sockets grafted with CTG and bone grafts experienced higher PES, lower recession, but thinner buccal bone wall [50].

The findings of the present study were in convergence with similar reviews. In 2024, Tommasato et al., in a systematic review, for non-immediately placed implants, compared the effect of autogenous and collagen matrices on the outcomes of peri-implant soft tissue augmentation [45]. With an insistence on the CTG as superior material in most outcomes and free gingival graft (FGG) in increasing the keratinized tissue width after six months, their frequentist network meta-analysis revealed the efficacy of the autogenous grafts (FGG and CTG) is higher than that of xenogenous soft tissue grafts. However, except for the keratinized tissue width increasing after six months, they did not find any other significant differences between different treatment modalities in other outcomes. Coherently, our findings suggest that CTG possessed a higher efficacy in improving MIBL, KTW, STT, PH, and MGML than other treatments. In the Tommasato et al. study, all available xenogenic, as well as allogenic, substitutes were combined together; however,

Table 10 The summary of GRADE assessment for meta-evidence certainty regarding each pair of comparison and each desired outcome

	PES	**MIBL**	**BBT**	**KTW**	**STT**	**PH**	**MGML**
Importance for Clinical Decision Making	**9 Critical**	**4 Important**	**4 Important**	**5 Important**	**6 Important**	**7 Critical**	**8 Critical**
AlloDerm vs. CTG	-	Within study bias: Some concerns	-	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns
		Reporting bias: No concerns		Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns
		Indirectness: No concerns		Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns
		Imprecision: No concerns		Imprecision: No concerns	Imprecision: Some concerns	Imprecision: No concerns	Imprecision: Major concerns
		Heterogeneity: No concerns		Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns
		Incoherence: No concerns		Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns
		Overall: Moderate		**Overall: Moderate**	**Overall: Low**	**Overall: Moderate**	**Overall: Very low**
AlloDerm vs. CTG + L-PRF	-	-	-	Within study bias: Some concerns	Within study bias: Some concerns	-	-
				Reporting bias: No concerns	Reporting bias: No concerns		
				Indirectness: No concerns	Indirectness: No concerns		
				Imprecision: Major concerns	Imprecision: Major concerns		
				Heterogeneity: No concerns	Heterogeneity: No concerns		
				Incoherence: No concerns	Incoherence: No concerns		
				Overall: Very low	**Overall: Very low**		
AlloDerm vs. Mucoderm	-	Within study bias: Some concerns	-	Within study bias: Some concerns	-	-	-
		Reporting bias: No concerns		Reporting bias: No concerns			
		Indirectness: No concerns		Indirectness: No concerns			
		Imprecision: Major concerns		Imprecision: Some concerns			
		Heterogeneity: No concerns		Heterogeneity: No concerns			
		Incoherence: No concerns		Incoherence: No concerns			
		Overall: Very low		**Overall: Low**			

Table 10 (continued)

	PES	MIBL	BBT	KTW	STT	PH	MGML
Importance for Clinical Decision Making	**9 Critical**	**4 Important**	**4 Important**	**5 Important**	**6 Important**	**7 Critical**	**8 Critical**
AlloDerm vs. Mucograft	-	-	-	-	Within study bias: Some concerns	Within study bias: Some concerns	-
					Reporting bias: No concerns	Reporting bias: No concerns	
					Indirectness: No concerns	Indirectness: No concerns	
					Imprecision: Major concerns	Imprecision: Some concerns	
					Heterogeneity: No concerns	Heterogeneity: No concerns	
					Incoherence: No concerns	Incoherence: No concerns	
					Overall: Very low	**Overall: Low**	
AlloDerm vs. No Treatment	-	Within study bias: Some concerns	-	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns
		Reporting bias: No concerns		Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns
		Indirectness: No concerns		Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns
		Imprecision: Some concerns		Imprecision: No concerns	Imprecision: Some concerns	Imprecision: No concerns	Imprecision: Major concerns
		Heterogeneity: No concerns		Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns
		Incoherence: No concerns		Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns
		Overall: Low		**Overall: Moderate**	**Overall: Low**	**Overall: Moderate**	**Overall: Verry low**
CTG vs. CTG + L-PRF	Within study bias: Some concerns	-	-	Within study bias: No concerns	Within study bias: Some concerns	-	-
	Reporting bias: No concerns			Reporting bias: No concerns	Reporting bias: No concerns		
	Indirectness: No concerns			Indirectness: No concerns	Indirectness: No concerns		
	Imprecision: Some concerns			Imprecision: Major concerns	Imprecision: Major concerns		
	Heterogeneity: No concerns			Heterogeneity: No concerns	Heterogeneity: No concerns		
	Incoherence: No concerns			Incoherence: No concerns	Incoherence: No concerns		
	Overall: Low			**Overall: Low**	**Overall: Very low**		

Table 10 (continued)

	PES	MIBL	BBT	KTW	STT	PH	MGML
Importance for Clinical Decision Making	**9 Critical**	**4 Important**	**4 Important**	**5 Important**	**6 Important**	**7 Critical**	**8 Critical**
CTG vs. Mucoderm	Within study bias: Some concerns	Within study bias: Some concerns	-	Within study bias: No concerns	-	-	-
	Reporting bias: No concerns	Reporting bias: No concerns		Reporting bias: No concerns			
	Indirectness: No concerns	Indirectness: No concerns		Indirectness: No concerns			
	Imprecision: No concerns	Imprecision: Some concerns		Imprecision: Major concerns			
	Heterogeneity: No concerns	Heterogeneity: No concerns		Heterogeneity: No concerns			
	Incoherence: No concerns	Incoherence: No concerns		Incoherence: No concerns			
	Overall: Moderate	**Overall: Low**		**Overall: Low**			
CTG vs. Mucograft	Within study bias: Some concerns	-	Within study bias: Some concerns	-	Within study bias: Some concerns	Within study bias: Some concerns	-
	Reporting bias: No concerns		Reporting bias: No concerns		Reporting bias: No concerns	Reporting bias: No concerns	
	Indirectness: No concerns		Indirectness: No concerns		Indirectness: No concerns	Indirectness: No concerns	
	Imprecision: Some concerns		Imprecision: Major concerns		Imprecision: Major concerns	Imprecision: No concerns	
	Heterogeneity: No concerns		Heterogeneity: No concerns		Heterogeneity: No concerns	Heterogeneity: No concerns	
	Incoherence: No concerns		Incoherence: No concerns		Incoherence: No concerns	Incoherence: No concerns	
	Overall: Low		**Overall: Very low**		**Overall: Very low**	**Overall: Moderate**	
CTG vs. No Treatment	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: No concerns	Within study bias: Some concerns	Within study bias: Some concerns	Within study bias: Some concerns
	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns	Reporting bias: No concerns
	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns	Indirectness: No concerns
	Imprecision: No concerns	Imprecision: No concerns	Imprecision: No concerns	Imprecision: No concerns	Imprecision: No concerns	Imprecision: No concerns	Imprecision: No concerns
	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns	Heterogeneity: No concerns
	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns	Incoherence: No concerns
	Overall: Moderate	**Overall: Moderate**	**Overall: Moderate**	**Overall: High**	**Overall: Moderate**	**Overall: Moderate**	**Overall: Moderate**

Table 10 (continued)

	PES	MIBL	BBT	KTW	STT	PH	MGML
Importance for Clinical Decision Making	**9 Critical**	**4 Important**	**4 Important**	**5 Important**	**6 Important**	**7 Critical**	**8 Critical**
CTG + L-PRF vs. Mucoderm	Within study bias: No concerns	-	-	Within study bias: No concerns	-	-	-
	Reporting bias: No concerns			Reporting bias: No concerns			
	Indirectness: No concerns			Indirectness: No concerns			
	Imprecision: Some concerns			Imprecision: Major concerns			
	Heterogeneity: No concerns			Heterogeneity: No concerns			
	Incoherence: No concerns			Incoherence: No concerns			
	Overall: Moderate			**Overall: Low**			
CTG + L-PRF vs. Mucograft	Within study bias: Some concerns	-	-	-	Within study bias: Some concerns	-	-
	Reporting bias: No concerns				Reporting bias: No concerns		
	Indirectness: No concerns				Indirectness: No concerns		
	Imprecision: Major concerns				Imprecision: Major concerns		
	Heterogeneity: No concerns				Heterogeneity: No concerns		
	Incoherence: No concerns				Incoherence: No concerns		
	Overall: Very low				**Overall: Very low**		
CTG + L-PRF vs. No Treatment	Within study bias: No concerns	-	-	Within study bias: No concerns	Within study bias: No concerns	-	-
	Reporting bias: No concerns			Reporting bias: No concerns	Reporting bias: No concerns		
	Indirectness: No concerns			Indirectness: No concerns	Indirectness: No concerns		
	Imprecision: Major concerns			Imprecision: Major concerns	Imprecision: Major concerns		
	Heterogeneity: No concerns			Heterogeneity: No concerns	Heterogeneity: No concerns		
	Incoherence: No concerns			Incoherence: No concerns	Incoherence: No concerns		
	Overall: Low			**Overall: Low**	**Overall: Low**		

Table 10 (continued)

	PES	MIBL	BBT	KTW	STT	PH	MGML
Importance for Clinical Decision Making	**9 Critical**	**4 Important**	**4 Important**	**5 Important**	**6 Important**	**7 Critical**	**8 Critical**
Mucoderm vs. Mucograft	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: Some concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Low**	-	-	-	-	-	-
Mucoderm vs. No Treatment	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: Some concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Low**	Within study bias: No concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: No concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: High**	-	Within study bias: No concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: Some concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Moderate**	-	-	-
Mucograft vs. No Treatment	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: Some concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Low**	-	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No Concerns Imprecision: Major concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Very low**	-	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: Major concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Very low**	Within study bias: Some concerns Reporting bias: No concerns Indirectness: No concerns Imprecision: No concerns Heterogeneity: No concerns Incoherence: No concerns **Overall: Moderate**	-

CTG Connective Tissue Graft, *MIBL* Marginal Interproximal Bone Level Changes, *BBT* Buccal Bone Thickness Changes, *KTW* Keratinized Tissue Width Changes, *STT* Soft Tissue Thickness Changes, *PH* Papilla Height Changes, *MGML* Midfacial Gingival Margin Level Changes

their various structure, porosity, number of layers, origin of collagens, and thickness, which are critical properties for the regeneration process, can cause inaccuracies in the conclusion.

Torra-Moneny et al., in a systematic review and meta-analysis in 2024, assessed the impact of the application of CTG on the peri-implant soft tissue of the immediate implants compared to no grafting modality [44]. In

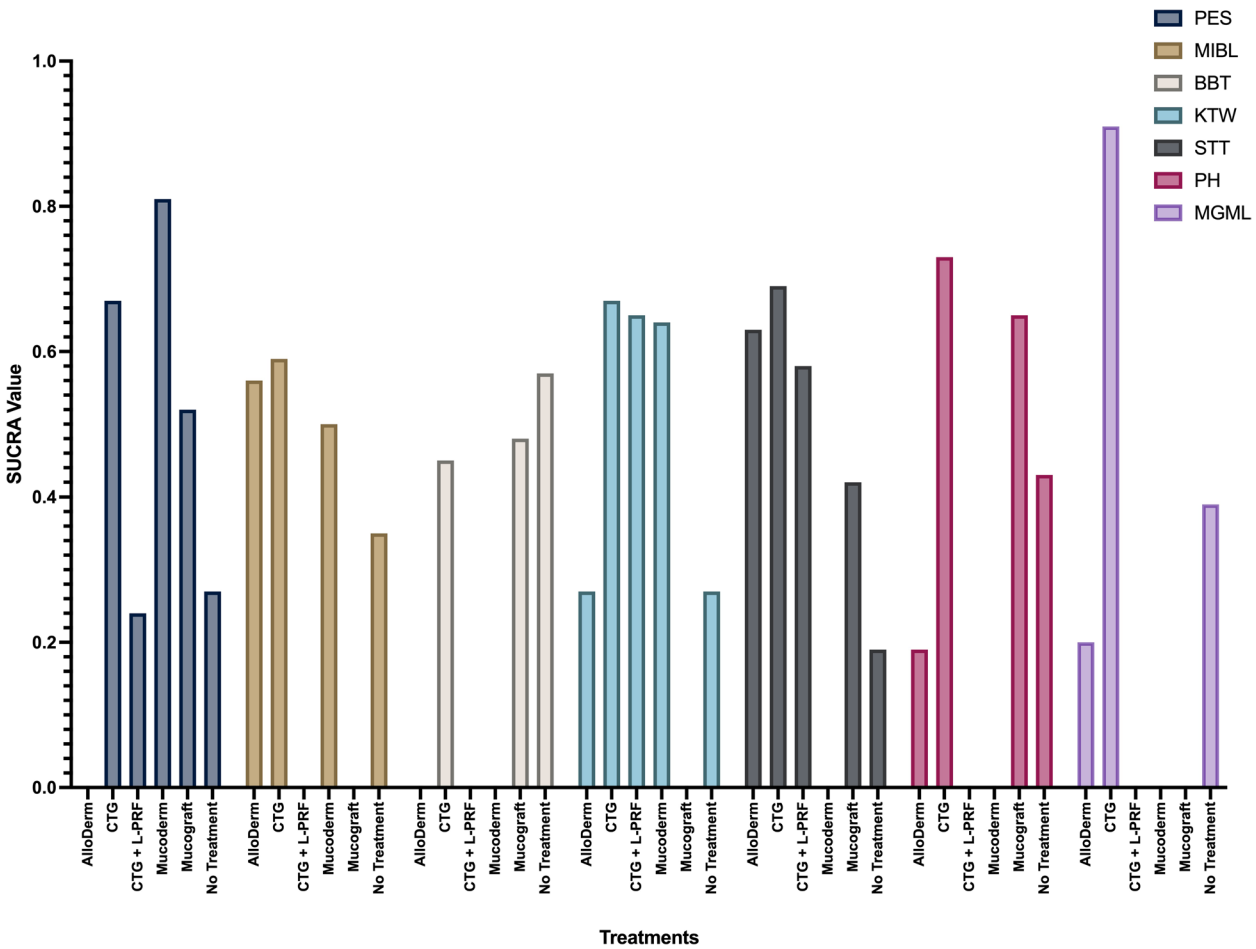

Fig. 5 Summary of the surface under cumulative ranking (SUCRA) values of each treatment modality in each outcome. Pink Esthetic Score = PES; Marginal Interproximal Bone Level Changes = MIBL; Buccal Bone Thickness Changes = BBT; Keratinized Tissue Width Changes = KTW; Soft Tissue Thickness Changes = STT; Papilla Height Changes = PH; Midfacial Gingival Margin Level Changes = MGML

agreement with our findings, they suggest that there is no significant difference in the buccal gingival margin level between the application of CTG and No Treatment.

Although CTG is highly effective, they come with several significant drawbacks. For instance, they often require longer surgical procedures and can cause complications at the donor site, potentially leading to additional surgeries. These issues can result in considerable postoperative pain and discomfort for patients [51], especially those concerned about surgical complications. Additionally, the availability of CTGs may be limited for larger surgical areas, which could discourage patients from starting or continuing treatments involving CTG. Despite the fact that the application of CTG showed superior efficacy in the improvement of the MIBL, KTW, STT, PH, and MGML, Mucoderm demonstrated higher, but relatively comparable to CTG, amounts of achieved PES, as a comprehensive outcome of an immediately placed implant, after 6 – 12 months. Moreover, based on the presence of no statistically significant difference between different types of grafts, a clinical recommendation needs to be supported by a richer literature, and therefore, more clinical investigations should be conducted on this subject. Hence, according to current evidence, the utilization of allogeneic and xenogeneic soft tissue grafts may be deemed appropriate for individuals exhibiting mild to moderate soft tissue deficiencies, those demonstrating limited compliance, or patients who exhibit apprehension regarding potential postoperative discomfort, adverse events, or morbidity.

Eventually, the findings regarding CTG+L-PRF and Mucograft treatment modalities may not be completely relied on because there is only one study available on them. Moreover, a caution should be made regarding the

evidence graded with low and very low certainty as they are limited by imprecision or bias and are more likely to be changed with emerging of new studies in the field.

Limitations and recommendations for future studies

Since to the authors knowledge there is no review comprehensively comparing different soft tissue grafting materials regarding the clinical outcomes of immediately placed implants, this study can be considered novel and can contribute the expansion of the available literature. However, the present systematic review has its limitations. First, the imprecision of some of the comparisons due to the lack of a reliable number of studies comparing those treatment arms affected the certainty and quality of the generated meta-evidence. Although most of the included studies have an overall low risk of bias, an unclear risk of bias affected the certainty of comparisons between AlloDerm and CTG or No Treatment in KTW, STT, and PH outcomes. Moreover, a comprehensive comparison between all available treatment modalities could not be achieved, as it is demonstrated in Table 4 that many of the cells are not filled, because the included studies on different treatment arms are not distributed balanced. Furthermore, the reports on the different outcomes are mostly within a short-term follow-up time, which negatively influences the generalizability of the results. Eventually, despite the fact that the follow-up time was considered as a potential covariate in the regression models and also has been restricted to a limited period to satisfy the assumption of transitivity, still this network meta-analysis has this limitation that the included studies have different follow-up times which may violate the transitivity; thus, the results should be interpretated with cautions.

It would be beneficial to the literature if future studies focus on the mentioned missing comparisons between available treatment arms in the different outcomes. Furthermore, higher follow-up time periods (longer than 12 months) will enable future evidence with more power and certainty. Finally, based on the current literature, allogenic and xenogenic soft tissue substitutes showed no significant difference compared to the autogenous grafts, and they are attributed to less post-operative pain and discomfort; hence, to recommend the CTG as a gold standard, further investigation seems to be necessary for a more comprehensive conclusion with higher certainty, and making clinical recommendation instead of suggestions.

Conclusion

Considering the limitations of the present review, the following conclusions can be drawn:

- There was not any significant difference between different autogenous, allogenous, and xenogenous soft tissue grafts regarding any of the investigated implant-related clinical outcomes, However, based on the treatment rankings, although CTG illustrated higher efficacy in the improvement of most of the immediate implant clinical outcomes (MIBL, KTW, STT, PH, and MGML), Mucoderm superiorly, but relatively comparable to CTG, enhanced the most important outcome of an immediately placed implant (PES). Hence, no clinical recommendation can be drawn based on the current literature, and the use of CTG can be only a suggestion. Nonetheless, since the current evidence shows no significant difference between different graft types, allogeneic and xenogeneic soft tissue grafts, especially xenogenic collagen matrices, may be suitable for patients with mild soft tissue thickness loss, limited compliance, or major concerns about postoperative complications and morbidity.
- The application of CTG showed significantly higher amounts of soft tissue thickness gain compared to the not applying any soft tissue grafts after 6 – 12 months and can be suggested for the clinical scenario, especially in cases with a thin soft tissue thickness. However, based on the treatment rankings, adjunctive soft tissue grafting intervention, except for BBT, demonstrated higher efficacy in the improvement of clinical outcomes of the immediately placed implants compared to No Treatment in 6 – 12 months (12 – 24 months for MIBL).
- The PES score of the immediately placed implants decreases between 6 – 12 months of follow-up regardless of the grafting with different materials or non-grafting approach.

Abbreviations

CTG	Connective Tissue Graft
PRF	Platelet-rich Fibrin
XCM	Xenogenic Collagen Matrix Material
ADM	Acellular Dermal Matrix
PES	Pink Esthetic Score
MIBL	Marginal Interproximal Bone Level Changes
BBT	Buccal Bone Thickness Changes
KTW	Keratinized Tissue Width Changes
STT	Soft Tissue Thickness Changes
PH	Papilla Height Changes
MGML	Midfacial Gingival Margin Level Changes
RCT	Randomized Clinical Trial
DIC	Deviance Information Criterion
SUCRA	Surface Under Cumulative Ranking
GRADE	The Grades of Recommendations, Assessment, Development, and Evaluation

Supplementary Information

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Supplementary Material 1.
Supplementary Material 2.
Supplementary Material 3.
Supplementary Material 4.
Supplementary Material 5.
Supplementary Material 6.
Supplementary Material 7.
Supplementary Material 8.
Supplementary Material 9.

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Authors' contributions
Ali Azadi: Conceptualization/Methodology/Formal Analysis/Investigation/Visualization/Software/Project Administration/Writing – Original draft preparation/Writing – Review and editing. Fatemeh Rezaei: Investigation/Validation/Writing – Original draft preparation/Writing – Review and editing. Atoosa Yazdani: Investigation/Validation/Writing – Original draft preparation/Writing – Review and editing. Kimia Hejazi: Investigation/Validation/Writing – Original draft preparation/Writing – Review and editing. Aryousha Moallem Savasari: Investigation/Validation/Writing – Original draft preparation/Writing – Review and editing. Mahdi Kadkhodazadeh: Conceptualization/Supervision/Investigation/Writing – Original draft preparation/Writing – Review and editing. Reza Amid: Conceptualization/Supervision/Investigation/Writing – Original draft preparation/Writing – Review and editing.

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Data availability
The data that support the findings of this study are available from the corresponding author.

Declarations

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Not applicable.

Consent for publication
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Competing interests
The authors declare no competing interests.

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