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SYSTEMATIC REVIEW

Comparison of implant placement and loading protocols for single anterior maxillary implants: A systematic review and network meta-analysis

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ABSTRACT

Statement of problem. With increasing esthetic needs, patients prefer missing anterior teeth to be restored as soon as possible, but how the timing of implantation and prosthetic loading influences peri-implant tissue and the esthetic results remains unclear.

Purpose. The purpose of this systematic review and network meta-analysis of randomized controlled trials was to investigate and rank the hard-tissue and soft-tissue outcomes, esthetics, and patient satisfaction of single maxillary implant placement and loading protocols.

Material and methods. A systematic search was conducted to identify studies with at least a 1-year follow-up that compared different implant placement and loading protocols and reported on survival, marginal bone loss (MBL), soft tissue, and esthetics. A random effects model and a Bayesian approach were applied to compare protocols by using mean differences (MD) with 95% credible intervals (CrI) and surface under the cumulative ranking curve (SUCRA) values.

Results. A total of 43 articles were included, with a follow-up of 1 to 5 years. All protocols had high survival rates and no significant differences for 1-year or 2-year MBL. Immediate placement with immediate loading ranked first in pink and white esthetic scores and satisfaction and was statistically significantly better than immediate placement with delayed loading or late placement protocols in pink esthetic scores, where its advantage over late placement with late loading was also clinically relevant [MD: −1.74, CrI: −2.34 to −1.15].

Conclusions. Immediate implantation with immediate loading showed a considerable esthetic advantage over later rehabilitation, whereas only a slight difference in MBL resulted from different protocols. (J Prosthet Dent 2025;133:677-688)

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Clinical Implications

Immediate implant placement and loading performed best in pink and white esthetics and patient satisfaction and also ranked well in other aspects, whereas delayed treatments often ranked last. Immediate implant placement and loading is highly recommended when the clinical criteria are fulfilled.

Dental rehabilitation in the esthetic region is always challenging, especially when placing single maxillary anterior implant-supported crowns. Thin buccal bone and rapid bone resorption complicate correct implant positioning, prosthetic design, and supportive therapy, the basis of long-term success.[1–4] Given patient demands for excellent esthetics and short rehabilitation times, individual treatment plans must be based on the latest scientific and clinical evidence to ensure optimal outcomes. The timing of implant-prosthodontic rehabilitation may affect the amount of bone resorption and could also be crucial for soft tissue changes.[5–8] According to the 2018 Consensus report of the International Team for Implantology (ITI), the timing of implantation and loading should always be considered together and decided upon tooth extraction. Twelve implant placement and loading protocols (IPLPs) have been defined (Table 1).[9]

Although authors have emphasized that immediate implantation may preserve alveolar bone and the soft tissue contour compared with delayed implantation, mid-facial gingival recession commonly occurs, especially in patients with thin mucosal phenotypes.[8,10] However, few authors have discussed the effect of early treatment protocols, even though they may integrate the benefits of immediate and delayed protocols.[3,5] The authors are unaware of a comprehensive review that analyzed and ranked all IPLPs according to their effects on both hard and soft tissue parameters in the anterior maxilla.

Table 1. Implant placement and loading protocols. Numbers refer to timing of implant placement and letters to that of prosthetic loading[3,9]

Protocol 1A:	Immediate implantation + immediate restoration
Protocol 1B:	Immediate implantation + early loading
Protocol 1C:	Immediate implantation + conventional loading
Protocol 2A:	Early implantation with soft tissue healing + immediate restoration
Protocol 2B:	Early implantation with soft tissue healing + early loading
Protocol 2C:	Early implantation with soft tissue healing + conventional loading
Protocol 3A:	Early implantation with partial bone healing + immediate restoration
Protocol 3B:	Early implantation with partial bone healing + early loading
Protocol 3C:	Early implantation with partial bone healing + conventional loading
Protocol 4A:	Late implantation + immediate restoration
Protocol 4B:	Late implantation + early loading
Protocol 4C:	Late implantation + conventional loading

The aim of this systematic review and network meta-analysis was to compare the survival, marginal bone loss, pink and white esthetics, satisfaction, and soft-tissue outcomes of all 12 types of IPLPs for single maxillary anterior implants and to rank these protocols based on randomized controlled trials (RCTs). The null hypothesis assumed that all IPLPs have similar performances with no significant differences in any aspect investigated.

MATERIAL AND METHODS

This review followed the Cochrane Handbook and was reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines (Supplemental Table 1, available online).[11–13] The protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO) (registration number CRD42022364995).

The population was healthy adults requiring a single tooth replacement with implantation in the anterior maxilla (until the second premolars). The intervention and comparison were participants receiving treatment according to different IPLPs. The outcomes were implant survival, marginal bone loss, soft tissue changes, esthetics, and satisfaction at a minimum of a 1-year follow-up. Studies were excluded if they did not comply with this framework or included participants with acute periapical or periodontal infection, parafunctional movements, or multiple adjacent implants.

A systematic search was conducted in 7 electronic databases: MEDLINE (PubMed), Embase, Cochrane CENTRAL, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang Data, and Chinese Scientific Journal Database (VIP database) in October 2022 and last updated in January 2024. A date filter was applied for publications since January 2000. The search keys applied for the systematic search can be found in Supplemental Table 2 (available online).

Two authors (X.Q., B.V.) independently screened the search results by title, abstract, and full text; collected data in a spreadsheet (Excel; Microsoft Corp) by extracting the first author, year of publication, study population, interventions, and outcomes; and assessed risk of bias (RoB) using the Cochrane RoB 2 tool.[11] Disagreements were resolved by a third author (K.K.). The certainty of evidence was determined using the Confidence in Network Meta-Analysis (CINeMA) web application.[14,15]

Pairwise and network meta-analyses (NMAs) were conducted using random-effects models with Bayesian methods. The synthesis of each outcome began with creating a network plot to determine whether the network was fully connected. Consistency checks were excluded by the visual inspection of plots. Mean differences (MDs) with 95% credible intervals (CrIs) were calculated for continuous data. Network estimates (pooled estimates of direct and indirect data) for each intervention were ranked relative to each other. Interventions were ranked according to their posterior likelihood by calculating the surface under the cumulative ranking (SUCRA) curve values. Cumulative probabilities for each treatment were expressed as single values ranging from 0% to 100%. The higher the percentage or the SUCRA score, the more likely the intervention would be the best or one of the best. All the NMAs were consistent. All computations were performed using statistical software packages (R v4.1.1 and BUGSnet v1.1.0; R Foundation).

The proportion with a 95% confidence interval (CI) was used for the measurement of the effect size for cumulating implant survival rates. As considerable between-study heterogeneity was assumed in all cases, effect sizes were pooled with a random-effects model. Between-study heterogeneity was described by the Higgins and Thompson I^2 statistics.[16] All statistical analyses were performed with the meta (v6.2.1) package for basic meta-analysis calculations and plots and the dmetar (v0.0.9000) package for additional influential analysis calculations and plots in R (v4.1.2; R Foundation).[17–19] The inverse variance method was used to pool proportions. A Hartung-Knapp adjustment was applied for CIs.[20,21] The Clopper-Pearson method was used for the CI of proportion calculation of individual studies.[22] For a cell count of 0, the individual study proportion with 95% CI was calculated by adding 0.01 as a continuity correction.

RESULTS

Forty-three articles were selected (Fig. 1). The characteristics of each study are included in Supplemental Tables 3 and 4 (available online).[23–65]

The results of study-level and domain-level RoB are shown in Supplemental Figure 1–8 (available online). Most studies carried no risk, whereas some studies raised some concerns, mainly because of missing outcome data, possible selection of data, and the randomization process. The certainty of evidence was often moderate to low due to imprecision, heterogeneity, and incoherence (Supplemental Tables 5–10, available online).

Thirty-three studies were analyzed for 1-year implant survival (IS), but an NMA was not feasible because of the low number of implant failures; thus, for this outcome only, cumulated IS rates with 95% CI were calculated for each protocol by using a proportional meta-analysis.[23,25–32,35–41,45,46,48–62,64,65] Survival rates were 1A (N=762) =91% (CI: 86%, 94%), 1C (N=477) =96% (CI: 92%, 98%), 2C (N=45) =100% (CI: 100%, 100%), 3C (N=168) =100% (CI: 100%, 100%), 4A (N=178) =96%

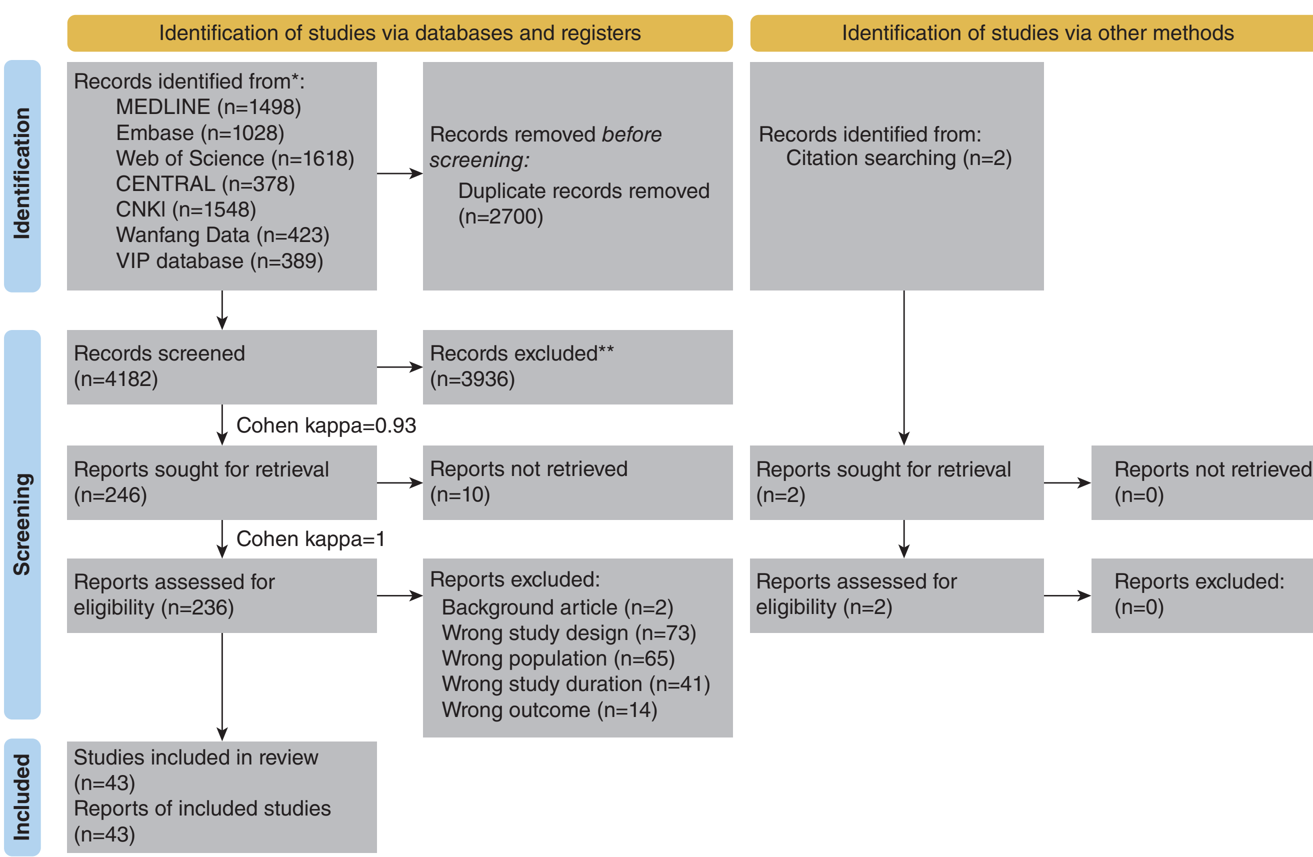


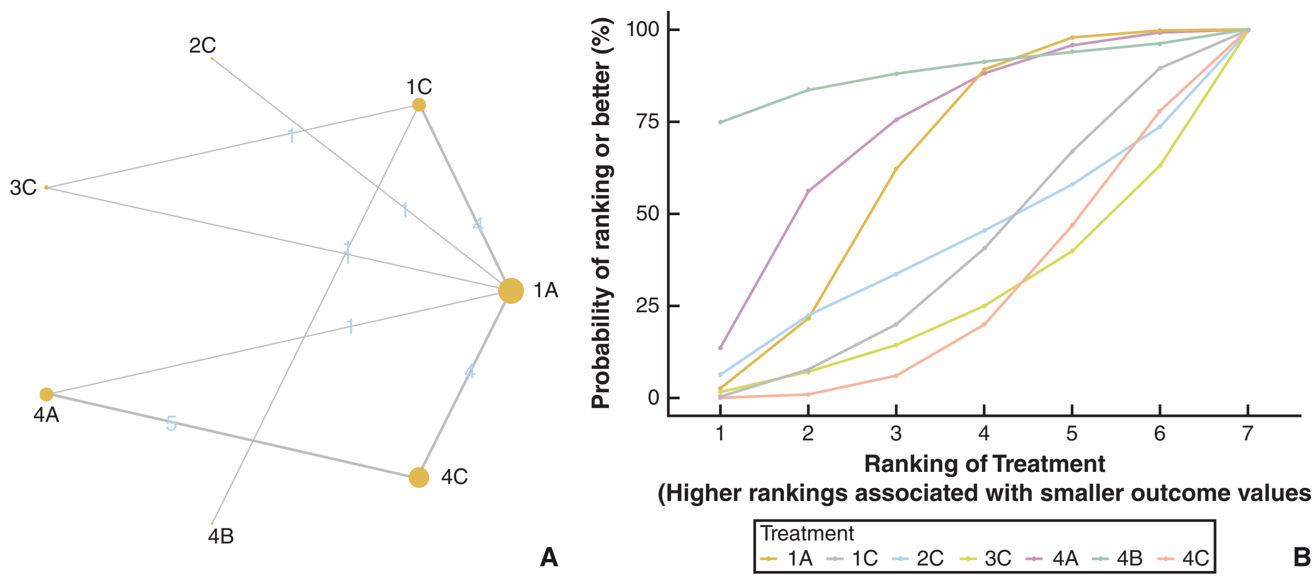
Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 flowchart of study selection process.

(CI: 93%, 98%), and 4C (N=517) =98% (CI: 94%, 99%) (Supplemental Figs. 9–14, available online).

Eighteen studies (N=1055)[25,27,30–32,35–37,39–41,49,52,55–57,59,63,65] were analyzed for 1-year marginal bone losses (MBLs) by comparing 7 protocols (Supplemental Figs. 15, 16, available online). The SUCRA values for each protocol in descending order were 4B=88.16%, 4A=71.5%, 1A=62.26%, 2C=39.95%, 1C=37.56%, 4C=25.36%, and 3C=25.18% (Fig. 2). Five studies (N=209) were synthesized for 2-year MBLs by comparing 5 protocols.[23,27,29,31,38] The SUCRA values were 2A=67.26%, 1C=58.49%, 1A=58.14%, 4A=44.31%, and 4C=21.79% (Fig. 3). No statistically or clinically significant differences were reported among protocols at 1 or 2 years.

Separate data of 1-year mid-facial, mesial, and distal soft tissue recession (STR) were available for quantitative synthesis (Fig. 4, Supplemental Figs. 17–19, available online). Six studies (N=262) were synthesized for mid-facial STR by comparing 5 protocols.[26,27,30,32,35–37,39–41] SUCRA values were 2C=73.2%, 1A=63.64%, 4B=50.45%, 1C=37.64%, and 3C=25.07%. The same 5 studies (N=212) were synthesized for mesial and distal STR, by comparing 4 protocols. For mesial STR, SUCRA values were 4B=63.05%, 1C=55.21%, 3C=44.91%, and 1A=36.83%. SUCRA values for distal STR were 1A=56.85%, 4B=53.08%, 3C=50.17%, and 1C=39.91%. No statistically or clinically significant differences were reported among protocols.

Twenty-two studies (N=1665) were analyzed for 1-year pink esthetic score (PES), by comparing 8 protocols (Supplemental Fig. 20, available online).[26,32,35,39–41,47–58,60–62,65] SUCRA values were 1A=89.61%, 2C=76.71%, 3A=64.77%, 1C=52.21%, 4B=47.58%, 4A=34.4%, 4C=23.67%, and 3C=11.05%.

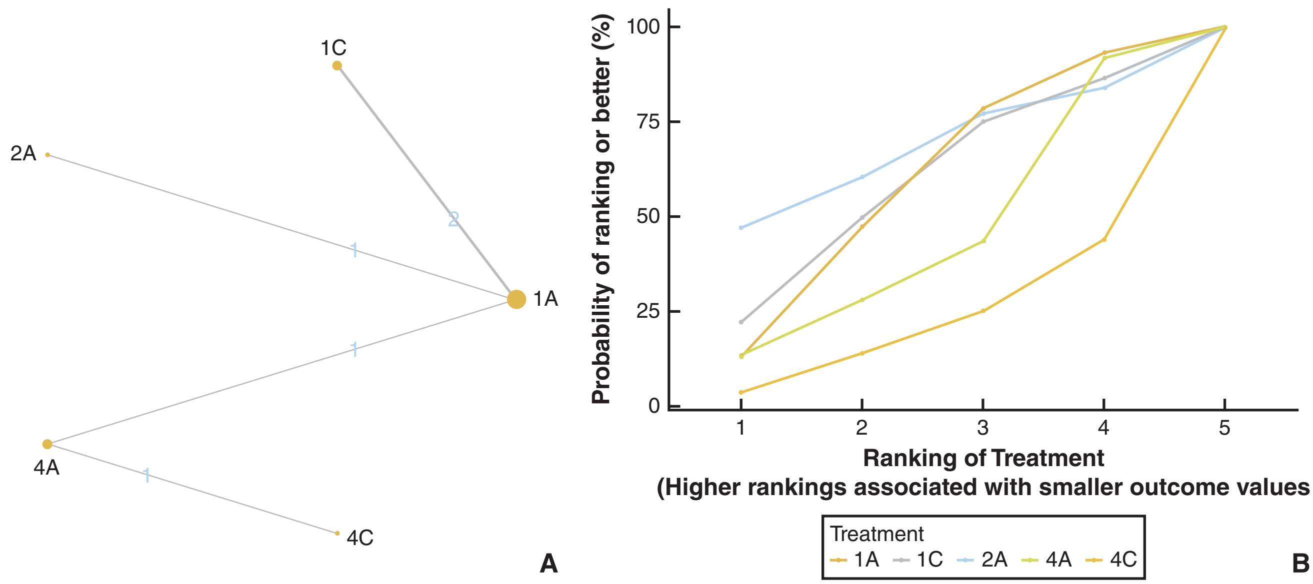


Treatment

Comparator	4B	4A	1A	2C	1C	4C	3C
4B		0.32 (−0.47, 1.14)	0.38 (−0.34, 1.14)	0.48 (−0.39, 1.37)	0.49 (−0.20, 1.18)	0.54 (−0.23, 1.34)	0.57 (−0.23, 1.37)
4A	−0.32 (−1.14, 0.47)		0.06 (−0.21, 0.33)	0.16 (−0.40, 0.70)	0.16 (−0.21, 0.53)	0.21 (−0.00, 0.42)	0.25 (−0.21, 0.69)
1A	−0.38 (−1.14, 0.34)	−0.06 (−0.33, 0.21)		0.10 (−0.39, 0.57)	0.11 (−0.15, 0.36)	0.16 (−0.05, 0.36)	0.19 (−0.19, 0.54)
2C	−0.48 (−1.37, 0.39)	−0.16 (−0.70, 0.40)	−0.10 (−0.57, 0.39)		0.00 (−0.54, 0.54)	0.05 (−0.45, 0.59)	0.08 (−0.52, 0.68)
1C	−0.49 (−1.18, 0.20)	−0.16 (−0.53, 0.21)	−0.11 (−0.36, 0.15)	−0.00 (−0.54, 0.54)		0.05 (−0.28, 0.38)	0.08 (−0.29, 0.45)
4C	−0.54 (−1.34, 0.23)	−0.21 (−0.42, 0.00)	−0.16 (−0.36, 0.05)	−0.05 (−0.59, 0.45)	−0.05 (−0.38, 0.28)		0.03 (−0.39, 0.44)
3C	−0.57 (−1.37, 0.23)	−0.25 (−0.69, 0.21)	−0.19 (−0.54, 0.19)	−0.08 (−0.68, 0.52)	−0.08 (−0.45, 0.29)	−0.03 (−0.44, 0.39)	

C

Figure 2. A, 1-year marginal bone loss (MBL) network diagram. Nodes indicate investigated protocols, and edge thickness refers proportionally to number of studies included. B, 1-year MBL SUCRA curves. X axis shows number of possible rankings matching number of protocols analyzed. Y axis indicates probability (%) to reach given rank or higher. C, 1-year MBL league plot showing mean differences and credible intervals in mm between protocols ordered from best to worst starting at top-left corner. Values above and below gray grids show same differences in opposite direction. No significant differences observed.



Treatment

Comparator	2A	1C	1A	4A	4C
2A		0.08 (−0.56, 0.71)	0.08 (−0.47, 0.63)	0.20 (−0.56, 0.94)	0.29 (−0.50, 1.06)
1C	−0.08 (−0.71, 0.56)		0.00 (−0.27, 0.28)	0.13 (−0.46, 0.71)	0.21 (−0.41, 0.83)
1A	−0.08 (−0.63, 0.47)	−0.00 (−0.28, 0.27)		0.13 (−0.40, 0.64)	0.21 (−0.35, 0.74)
4A	−0.20 (−0.94, 0.56)	−0.13 (−0.71, 0.46)	−0.13 (−0.64, 0.40)		0.08 (−0.14, 0.29)
4C	−0.29 (−1.06, 0.50)	−0.21 (−0.83, 0.41)	−0.21 (−0.74, 0.35)	−0.08 (−0.29, 0.14)	

C

Figure 3. A, Two-year marginal bone loss (MBL) network diagram. Nodes indicate investigated protocols, and edge thickness refers proportionally to number of studies included. B, 2-year MBL SUCRA curve. X axis shows number of possible rankings matching number of protocols analyzed. Y axis indicates probability (%) to reach given rank or higher. C, 2-year MBL league plot showing mean differences and credible intervals in mm between protocols ordered from best to worst starting at top-left corner. Values above and below gray grids show same differences in opposite direction. No significant differences observed.

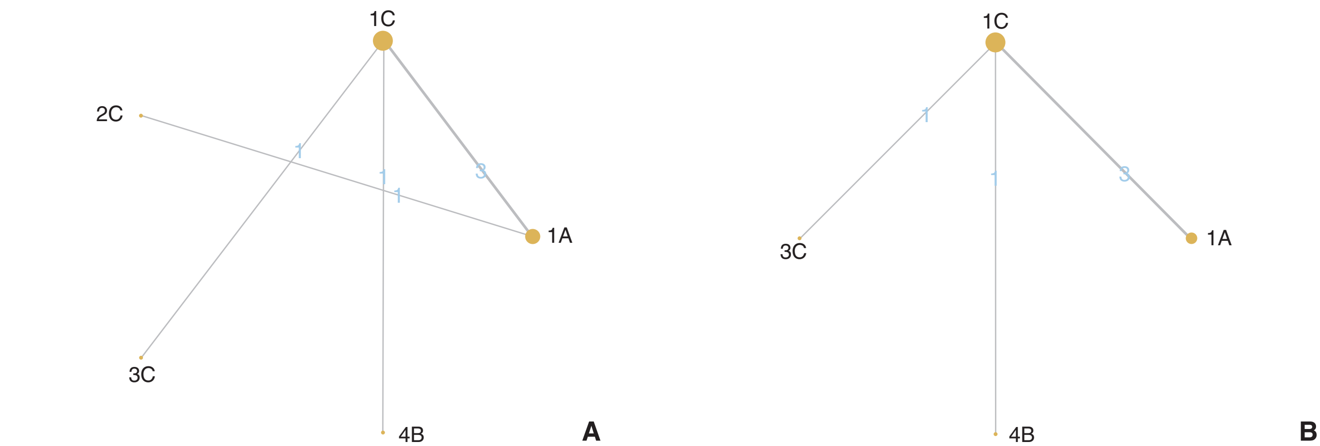
Differences among protocols 1A-1C [MD: −1.11, CrI: −1.91 to −0.25], 1A–4A [MD: −1.53, CrI: −2.65 to −0.32], 1A-4C [MD: −1.74, CrI: −2.34 to −1.15], and 1A-3C [MD: −2.17, CrI: −3.37 to −0.93] were statistically significant (the CrI does not contain the null effect). The clinical significance threshold was 1; thus, only the difference in protocols 1A-4C was clinically relevant considering the whole CrI (Fig. 5).

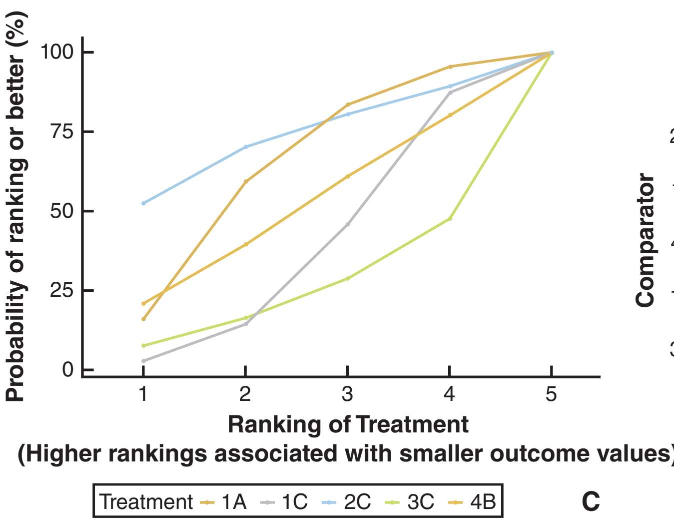
Four studies (N=310) were analyzed for 1-year white esthetic score (WES), by comparing 4 protocols (Supplemental Fig. 21, available online).[40,41,62,65] The difference between 1A-4C [MD: −1.41, CrI: −2.66 to −0.15] was statistically significant but not clinically relevant (Supplemental Fig. 22, available online).

Thirteen studies (N=982) were analyzed for 1-year satisfaction measured with a visual analog scale (VAS), comparing 6 protocols (Supplemental Fig. 23, available online).[32,35,40,41,47,48,50,53,55,56,60,61,65] SUCRA values were 1A=84.85%, 3C=51.81%, 4A=48.74%, 1C=40.59%, 4C=37.27%, and 3A=36.75%. Though protocol 1A was much more likely to be ranked first, no statistically significant differences were found among the protocols (Fig. 6).

Seven studies (N=462) were analyzed for 1-year change in peri-implant probing depth (PPDc), comparing 6 protocols (Supplemental Figs. 24, 25, available online).[39–41,45,48,51,53] Another 7 studies (N=517) were analyzed for 1-year bleeding index (BI), comparing 6 protocols (Supplemental Figs. 26, 27, available online).[30,32,39,40,51,61,62]

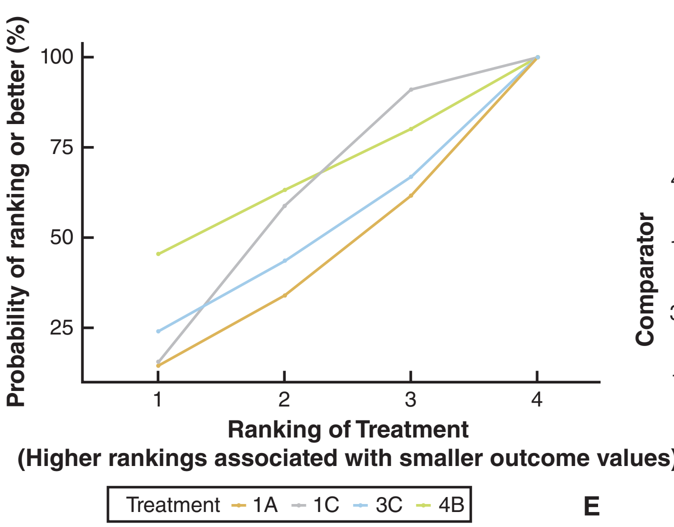
Some studies used cone beam computed tomography (CBCT) to measure buccal bone thickness (BBT) and mid-facial MBL, the results of which are shown in Table 2. Quantitative analyses of these outcomes were





D

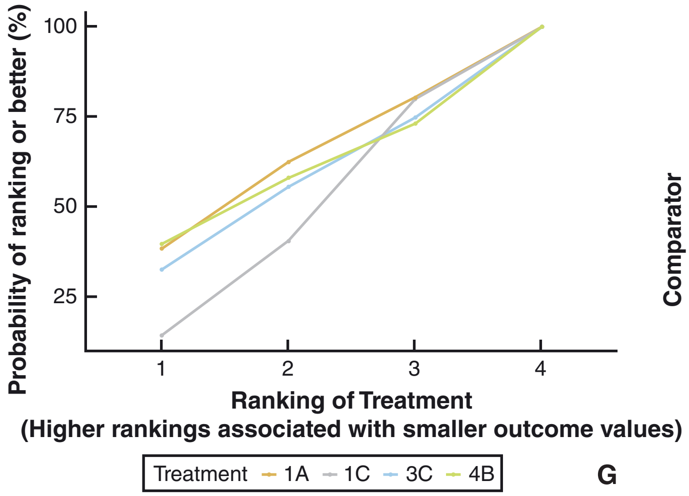
Comparator \ Treatment	2C	1A	4B	1C	3C
2C		0.20 (−0.93, 1.29)	0.33 (−1.31, 1.98)	0.43 (−0.83, 1.67)	0.63 (−0.97, 2.26)
1A	−0.20 (−1.29, 0.93)		0.13 (−1.09, 1.27)	0.23 (−0.41, 0.85)	0.43 (−0.74, 1.60)
4B	−0.33 (−1.98, 1.31)	−0.13 (−1.27, 1.09)		−0.11 (−0.88, 1.14)	0.30 (−1.11, 1.74)
1C	−0.43 (−1.67, 0.83)	−0.23 (−0.85, 0.41)	−0.11 (−1.14, 0.88)		0.19 (−0.79, 1.22)
3C	−0.63 (−2.26, 0.97)	−0.43 (−1.60, 0.74)	−0.30 (−1.74, 1.11)	−0.19 (−1.22, 0.79)	



F

Comparator \ Treatment	4B	1C	3C	1A
4B		0.09 (−0.78, 0.97)	0.16 (−1.01, 1.39)	0.20 (−0.85, 1.22)
1C	−0.09 (−0.97, 0.78)		0.07 (−0.78, 0.91)	0.11 (−0.47, 0.63)
3C	−0.16 (−1.39, 1.01)	−0.07 (−0.91, 0.78)		0.04 (−0.98, 1.02)
1A	−0.20 (−1.22, 0.85)	−0.11 (−0.63, 0.47)	−0.04 (−1.02, 0.98)	

Figure 4. A, One-year mid-facial soft tissue recession (STR) network diagram. Nodes indicate investigated protocols, and edge thickness refers proportionally to number of studies included. B, 1-year mesial and distal STR network diagram. C, 1-year mid-facial STR SUCRA curve. X axis shows number of possible rankings matching number of protocols analyzed. Y axis indicates probability (%) to reach given rank or higher. D, 1-year mid-facial STR league plot showing mean differences and credible intervals in mm between protocols ordered from best to worst starting at top-left corner. Values above and below gray grids show same differences in opposite direction. No significant differences observed. E, 1-year mesial STR SUCRA curve. F, 1-year mesial STR league plot. No significant differences observed. G, 1-year distal STR SUCRA curve. H) 1-year distal STR league plot. No significant differences observed.



G

Comparator \ Treatment	1A	4B	3C	1C
1A		0.02 (−0.63, 0.70)	0.03 (−0.63, 0.68)	0.06 (−0.33, 0.46)
4B	−0.02 (−0.70, 0.63)		0.01 (−0.76, 0.74)	0.04 (−0.50, 0.59)
3C	−0.03 (−0.68, 0.63)	−0.01 (−0.74, 0.76)		0.03 (−0.49, 0.54)
1C	0.06 (−0.46, 0.33)	−0.04 (−0.59, 0.50)	−0.03 (−0.54, 0.49)	

H

Figure 4. (*continued*)

not possible. Four studies reported on the BBT of various protocols,[24,27,43,51] whereas buccal MBL was only measured by Chan and Bushari et al[24,27] and Liu et al.[51]

Four studies with 3-year follow-up compared protocols 1C-3C, 1A-1C, 1A-4C, and 4A-4C.[28,31,45,63] Only Crespi et al[28] reported 4-year results, comparing 1A-1C. The longest reported follow-up was 5 years in 4 studies, comparing 1C-3C, 1A-1C, and 4A-4C.[33,34,42,44]

Tonetti et al[45] (1C protocol), Zhang et al[63] (1A), Gjelvold et al[34] (4C), and den Hartog et al[33] (4A) each reported 1 implant failure, whereas others found no failure at 3 to 5 years of follow-up, resulting in high medium-to-long-term survival rates. Low (≤1 mm) MBL was measured in all studies.[33,34,42,44] Gjelvold et al[34,35] even reported lower 5-year MBLs (4A=0.50 ±0.73, 4C=0.54 ±0.65) than at 1 year (4A=0.57 ±0.52, 4C=0.69 ±0.57).

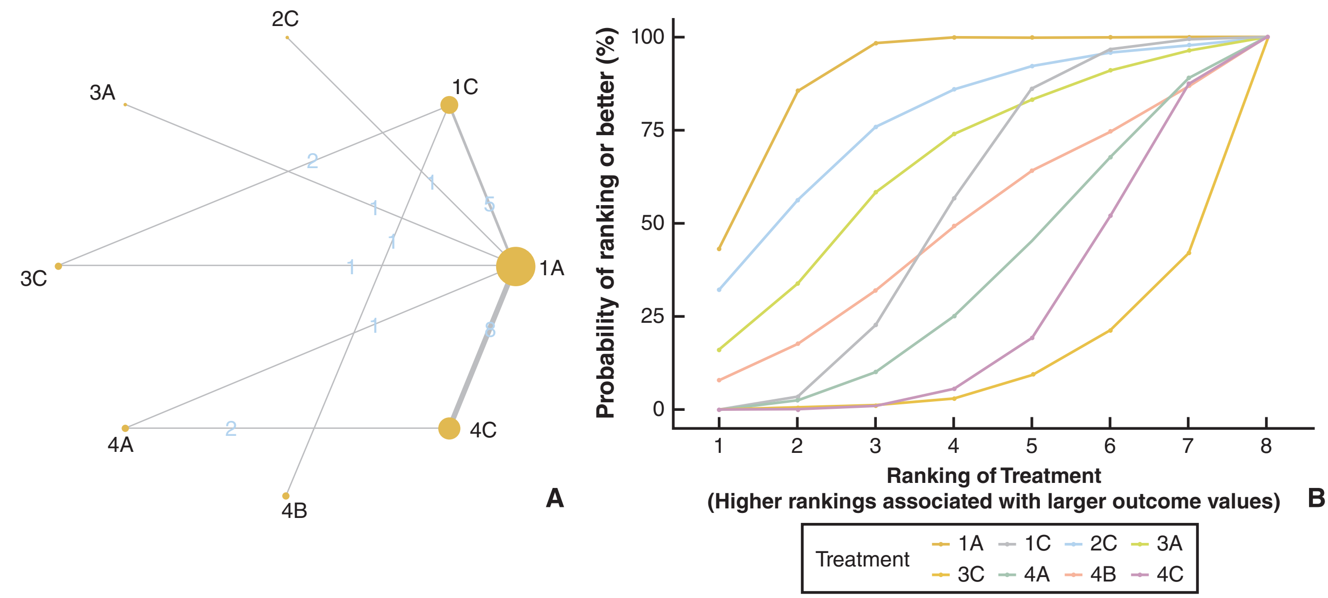
DISCUSSION

The authors are unaware of a previous NMA to rank IPLPs. Survival rates were above 96% for all included protocols except for protocol 1A (91%), the reason for which remains to be investigated. However, protocol 1A generally ranked high in other aspects, with significant advantage in esthetics, especially over protocol 4C. Thus, the null hypothesis that all IPLPs have similar performances with no significant differences in any aspect investigated was rejected.

The cumulated IS rates were found to be generally lower than in previous systematic reviews, especially for protocol 1A. As most failures occurred in the first year, only short-term IS was analyzed.[66] The 1A protocol requires careful patient selection and is technique-sensitive, influenced by several surgical and prosthetic factors such as pre-extraction gingival levels, phenotype, intact bone walls with ≥1 mm buccal bone, and correct implant 3D positioning with >2 mm jumping gap filled with biomaterial.[10,67] Zhou et al[3] calculated a cumulative IS rate of 97.5% (range: 69.2 to 100%), whereas Pommer et al[5] obtained an IS of 99.6% at 3 to 5 years (95% CI: 98.5 to 100%). These differences can be explained by Zhou et al[3] and Pommer et al[5] considering different study types and follow-up ranges, whereas, in the present study, RCTs with short-term follow-up were analyzed.

Although most studies measured interproximal MBLs, data were not reported separately for mesial and distal sites; thus, only mean interproximal MBLs could be analyzed at the 1-year and 2-year follow-up. Different studies were included for the 1-year and 2-year analyses, which could cause incoherence in the rankings; therefore, no tendencies could be derived for longer-term MBL. Interestingly, protocol 4B performed the best at 1 year, but only based on 1 analysis by Cardaropoli et al,[25] where 0.17 mm bone growth was measured compared with the 0.31 bone loss in protocol 1C. Bone grafting was applied in both interventions; however, the implant was placed at the crestal level for 4B but subcrestally for 1C to compensate for postextraction healing.

Zhou et al[3] stated 4A and 1C to be scientifically and clinically valid treatment options based on IS. Recently, MBL has gained importance in evaluating protocol validity. In the present study, 4B was followed by protocols 4A, then 1A. Protocol 1C only ranked as one of the last protocols before 3C and 4C, showing that immediate loading may be a more favorable treatment regarding MBL, though no significant differences were observed. Nearly all studies took the timing of implant placement as baseline, in which case, the true effect of placement timing on postextraction healing cannot be examined in protocols later than immediate implantation. Only Lu et al[52] and Zhou et al[65] set the baseline at the time of tooth extraction, which should be the most appropriate method of detecting true differences among the protocols. Medium- to long-term follow-up showed promising MBLs. Gjelvold et al[34,35] showed bone growth at 5 years compared with at 1 year in both protocols 4A and 4C.



Treatment

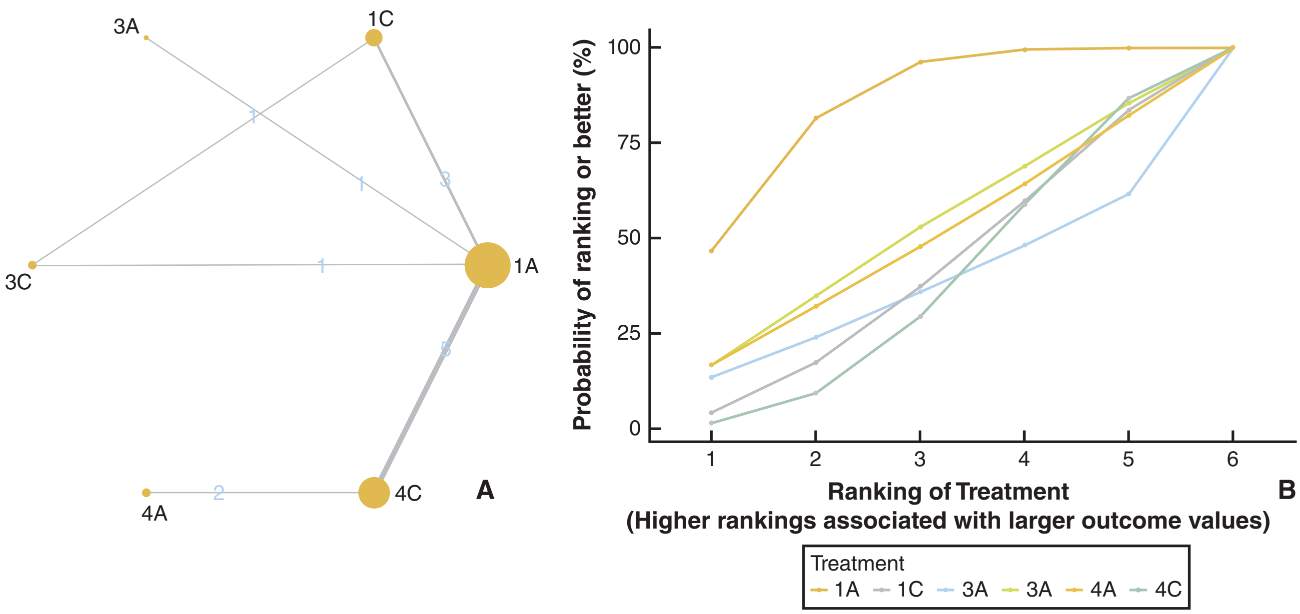
Comparator	1A	2C	3A	1C	4B	4A	4C	3C
1A		−0.26 (−2.00, 1.64)	−0.65 (−2.34, 1.06)	**−1.11** (−1.91, −0.25)	−1.18 (−3.20, −0.91)	**−1.53** (−2.65, −0.32)	**−1.74** (−2.34, −1.15)	**−2.17** (−3.37, −0.93)
2C	0.26 (−1.64, 2.00)		−0.39 (−2.86, 2.13)	−0.84 (−2.95, 1.10)	−0.92 (−3.65, 1.90)	−1.27 (−3.56, 0.82)	−1.48 (−3.44, 0.35)	−1.91 (−4.20, 0.33)
3A	0.65 (−1.06, 2.34)	0.39 (−2.13, 2.86)		−0.45 (−2.32, 1.31)	−0.53 (−3.11, 2.08)	−0.88 (−2.90, 1.14)	−1.09 (−2.90, 0.68)	−1.52 (−3.53, 0.66)
1C	**1.11** (0.25, 1.91)	0.84 (−1.10, 2.95)	0.45 (−1.31, 2.32)		−0.08 (−1.91, 1.87)	−0.43 (−1.86, 1.03)	−0.64 (−1.73, 0.40)	−1.07 (−2.18, 0.07)
4B	1.18 (−0.91, 3.20)	0.92 (−1.90, 3.65)	0.53 (−2.08, 3.11)	0.08 (−1.87, 1.91)		−0.35 (−2.70, 2.02)	−0.56 (−2.72, 1.45)	−0.99 (−3.19, 1.23)
4A	**1.53** (0.32, 2.65)	1.27 (−0.82, 3.56)	0.88 (−1.14, 2.90)	0.43 (−1.03, 1.86)	0.35 (−2.02, 2.70)		−0.21 (−1.33, 0.93)	−0.65 (−2.29, 1.06)
4C	**1.74** (1.15, 2.34)	1.48 (−0.35, 3.44)	1.09 (−0.68, 2.90)	0.64 (−0.40, 1.73)	0.56 (−1.45, 2.72)	0.21 (−0.93, 1.33)		−0.43 (−1.74, 0.98)
3C	**2.17** (0.93, 3.37)	1.91 (−0.33, 4.20)	1.52 (−0.66, 3.53)	1.07 (−0.07, 2.18)	0.99 (−1.23, 3.19)	0.64 (−1.06, 2.29)	0.43 (−0.98, 1.74)	

C

Figure 5. A, One-year pink esthetic score (PES) network diagram. Nodes indicate investigated protocols, and edge thickness refers proportionally to number of studies included. B, 1-year PES SUCRA curve. X axis shows number of possible rankings matching number of protocols analyzed. Y axis indicates probability (%) to reach given rank or higher. C, 1-year PES league plot showing mean differences and credible intervals in mm between protocols ordered from best to worst starting at top-left corner. Values above and below gray grids show same differences in opposite direction. Double asterisks indicate statistically significant differences.

Few studies have reported on mid-facial MBL or BBT, both measurable only on CBCT scans. Slagter et al[43] only evaluated the top 5-mm section from the implant platform. Liu et al[51] measured BBT at 1 mm apical to the platform, at mid-implant level, and at 1 mm coronal to the apex of the implant, and also measured mid-facial MBL. Chan et al[27] also measured mid-facial MBL as well as BBT at 0, 2, 4, 6, and 8 mm above platform level. No analysis was possible because of the low number of rather heterogeneously measured data.

Both Liu et al[51] and Slagter et al[43] compared protocols 1C and 3C. Liu et al[51] reported that the BBT reduction was around 0.6 mm (1C) and 0.56 mm (3C), and Slagter et al[43] reported approximately 0.04 mm (1C) and 0.07 mm (3C); however, the within study differences between compared protocols were minimal. Interstudy differences may therefore be attributed to study designs, materials, and methods. Slagter et al[43] included patients with buccal bone defect sizes of ≥5 mm and used autogenous bone and soft tissue grafts in both protocols, whereas Liu et al[51] reported no information on buccal defect sizes and applied only guided bone regeneration for intervention 3C. There was no information on phenotype, abutment design, and whether there was veneering in the subgingival region.



Comparator \ Treatment	1A	3C	4A	1C	4C	3A
1A		−8.27 (−33.08, 15.77)	−9.56 (−36.86, 17.06)	−11.30 (−29.16, 6.17)	−11.99 (−26.42, 2.84)	−14.29 (−48.11, 18.97)
3C	8.27 (−15.77, 33.08)		−1.29 (−38.64, 34.94)	−3.03 (−27.49, 22.26)	−3.71 (−32.04, 25.16)	−6.02 (−47.30, 34.79)
4A	9.56 (−17.06, 36.86)	1.29 (−34.94, 38.64)		−1.74 (−33.24, 31.18)	−2.42 (−25.53, 21.15)	−4.73 (−50.39, 37.81)
1C	11.30 (−6.17, 29.16)	3.03 (−22.26, 27.49)	1.74 (−31.18, 33.24)		−0.69 (−23.75, 22.69)	−2.99 (−40.91, 35.88)
4C	11.99 (−2.84, 26.42)	3.71 (−25.16, 32.04)	2.42 (−21.15, 25.53)	0.69 (−22.69, 23.75)		−2.31 (−39.36, 34.46)
3A	14.29 (−18.97, 48.11)	6.02 (−0.34, 47.30)	4.73 (−37.81, 50.39)	2.99 (−35.88, 40.91)	2.31 (−34.46, 39.36)	

C

Figure 6. A, One-year visual analog scale (VAS) network diagram. Nodes indicate investigated protocols, and edge thickness refers proportionally to number of studies included. B, 1-year VAS SUCRA curve. X axis shows number of possible rankings matching number of protocols analyzed. Y axis indicates probability (%) to reach given rank or higher. C, 1-year VAS league plot showing mean differences and credible intervals in mm between protocols ordered from best to worst starting at top-left corner. Values above and below gray grids show same differences in opposite direction. No significant differences observed.

Table 2. Buccal marginal bone loss (MBL) and buccal bone thickness (BBT) (mean ±standard deviation) at first two time points reported for 1A, 1C, and 3C protocols[24,27,43,51]

Study	Measurement	Time of Measurement	Measured Dimensions (mm)		
			1A	1C	3C
Chan 2019, Bushahri 2021	BBT (platform level)	4 months	2.3 ±1.4	2.5 ±1.2	-
		30 months	1.83 ±1.04	2.04 ±0.92	-
	Buccal MBL	12 months	0.3 ±0.4	0.7 ±0.6	-
		30 months	1.89 ±1.02	1.88 ±0.61	-
Liu 2016	BBT (1 mm apical to the platform)	0 month	-	1.33 ±0.32	1.27 ±0.25
		12 months	-	0.73 ±0.38	0.71 ±0.34
	Buccal MBL	0 month	-	-0.44 ±0.31	-0.42 ±0.50
		12 months	-	1.30 ±0.50	-0.31 ±0.42
Slagter 2017 (<5 mm defect)	BBT (1 mm apical to the platform)	1 month	2.05 ±0.80	1.39 ±0.94	-
		12 months	1.94 ±0.79	1.37 ±0.78	-
Slagter 2017 (>5 mm defect)	BBT (1 mm apical to the platform)	1 month	-	1.29 ±0.60	0.88 ±0.57
		12 months	-	1.25 ±0.53	0.81 ±0.46

Two reports were available for 1-year mid-facial MBL for protocol 1C, where Liu et al[51] reported a mean MBL of around 1.74 mm, and Chan et al[27] reported only 0.7 mm. Large differences were observed, with Chan et al[27] only achieving an MBL similar to that of the 1-year report of Liu et al[51] at their 30-month follow-up (1.88 mm). The differences may be explained by the fact that Chan et al[27] performed allogenic bone grafting, whereas Liu et al[51] used no grafting.

As thin buccal bone, fast bundle bone resorption, and soft tissue recession are major concerns in implant treatment in the anterior maxilla, it is advisable to standardize and perform such measurements in further studies to obtain evidence that aids in clinical decision-making.[1,4,68,69]

The protocols were similar regarding STR but achieved different rankings at mesial, mid-facial, and distal sites. Most data were available for mid-facial recession, where the rankings were 2C, 1A, 4B, 1C, and 3C in descending order. Immediate implantation has often been associated with higher mid-facial bone loss, which explains increased STR.[70,71] Interestingly, 1A ranked first at the distal papilla but showed greater recession at the mesial papilla where it ranked last. The difference could have been the effect of the position and gingival level of the failing tooth, the quality and quantity of interproximal bone in both vertical and horizontal dimensions toward the neighboring teeth, and 3D implant positioning, as well as oral hygiene, but no data were available to analyze the effect these variables.[10,72–74] STR can worsen esthetics, satisfaction, and can indicate MBL underneath, the analysis of which would require data on the same measuring points from the same studies.[75,76]

PPD change also indicates bone loss and a deep PPD that is bleeding or purulent could be a sign of peri-implantitis.[75,76] As pockets deeper than 4 mm were not reported, PPD change was analyzed instead of PPD. The 3A protocol ranked first with a mean difference of >1 mm from the following protocols 4C, 1C, 3C, 2C, and 1A, which showed small differences from each other; only 1A was significantly worse than 3A but had no clinical relevance because of wide CrI. Increased probing depth in 1A may have been associated with postextraction healing.[70,71]

Bleeding is a definitive indicator of inflammation, either peri-implantitis if bone loss is present or peri-implant mucositis if no bone loss is present.[76] In the analysis of BI, there were no statistically significant differences among the protocols. Though both PPDc and BI were compared, the examined populations were not the same, and these parameters may only be evaluated as indicators of peri-implantitis when investigated together.[75,76] Peri-implant inflammation cannot be attributed to timing protocols alone, as it is greatly associated with individual oral hygiene, measurable with plaque indices, missing from most reports, and not available for analysis.[75]

Esthetics and patient satisfaction are key indicators of success in the anterior region. For both PES and WES, protocol 1A ranked first with a statistically significant advantage, especially over late placement. Immediate implantation and loading allowed patients to preserve their original and natural soft tissue profile, resulting in significantly higher PES and WES.[10,28,77] Higher patient satisfaction was also found with protocol 1A. Though mean differences were not statistically significant, the SUCRA values showed an extremely high probability for 1A (84.85%) to rank best, with 33.04% advantage over the second protocol (51.81%). Both esthetics and immediate rehabilitation may contribute to the higher satisfaction observed in the present study and in the literature.[77]

The authors are unaware of a previous NMA reviewing IPLPs, analyzing several protocols (1A, 1C, 2A, 2C, 3A, 3C, 4A, 4B, 4C), including only RCTs with samples across America, Asia, and Europe based on data from English and Chinese language databases. This study focused not only on implant survival and MBLs but also on soft tissue parameters, esthetics, and patient satisfaction.

Although a few RCTs with long-term (3 to 5 years) follow-up were included, only 1-year and 2-year follow-ups had sufficient data available for qualitative analysis. Even for short-term analyses, the strength of evidence and networks was weak because of the low number of studies, and therefore subset analyses were not possible. Parameters such as the definitive restoration material and retention method, abutment height and connection, flap design, mucosal phenotype of the patient, and application of either hard or soft tissue grafts were rarely mentioned, all of which could have affected the outcomes. Missing and possibly selected outcome data, imprecision, heterogeneity, and incoherence were also reasons for the reduced strength of the evidence.

If conditions are met, applying 1A protocol in the anterior maxillary region could result in improved esthetics (PES, WES) and patient satisfaction. With recent systematic reviews of the ITI proving high survivability, this review could also contribute to acknowledging the 1A protocol as a scientifically and clinically validated treatment option.[3,67,78,79]

Well-designed RCTs with standardized methodology, larger sample sizes, and long-term follow-up focusing on patient phenotype, implant placement position, hard or soft tissue grafting, buccal bone dimensions, and soft tissue parameters are needed for stronger clinical recommendations.

CONCLUSIONS

Based on the findings of this systematic review and network meta-analysis, the following conclusions were drawn:

1. Immediate implant placement with immediate loading (1A) shows a considerable advantage in

terms of esthetics and promising benefits in patient satisfaction over later rehabilitation, whereas minor differences were monitored on MBLs around anterior maxillary single implants treated with different protocols.

2. Further studies are needed to determine the long-term effects of different implant placement and loading protocols.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2024.05.033.

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