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SYSTEMATIC REVIEW

Influence of the interimplant horizontal distance on the clinical outcomes of patients rehabilitated with two adjacent implants: A systematic review and meta-analysis

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ABSTRACT

Statement of problem. The effect of the interimplant distance on bone stability, soft tissue health, and esthetic outcomes remains controversial. Closer implants may lead to greater bone loss and esthetic complications, highlighting the importance of an optimal implant placement for long-term success and patient satisfaction.

Purpose. The purpose of this systematic review was to evaluate the impact of reduced interimplant distance (<3 mm) versus increased interimplant distance (≥3 mm) on marginal bone level changes as the primary outcome. The implant survival was assessed as a secondary outcome.

Material and methods. The review, registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42024622404), followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive search of PubMed/MEDLINE, Cochrane Central Register of Controlled Trials, SCOPUS, and Web of Science was conducted, involving studies published up to January 2024.

Results. The initial search has identified 2065 studies. After removing duplicates, 1885 studies were assessed, and 1840 were excluded based on title and abstract review. A total of 45 full-text articles were retrieved and evaluated. Five studies met the inclusion criteria: 1 randomized controlled trial (RCT), 3 prospective observational studies, and 1 retrospective study. Following the risk of bias evaluation, no studies were excluded, though many were classified as medium or high risk.

Conclusions. An interimplant distance of at least 3 mm is essential for the preservation of marginal bone levels and the support of soft tissue health, emphasizing its relevance in implant planning for optimal clinical outcomes. (J Prosthet Dent xxxx;xxx:xxx-xxx)

The rehabilitation of partially and completely edentulous patients through dental implant therapy has become an integral component of modern dentistry.[1,2] Dental implants represent a reliable and frequently used solution that offers significant functional, biological, and esthetic benefits with a reported survival rate of implant-supporting fixed dental prostheses (FDPs) of 95.6% after 5 years and 93.1% after 10 years.[3–5] Optimal implant positioning is mandatory to ensure long-term success and patient satisfaction.[6,7]

The distance between adjacent implants can significantly influence lateral bone loss and the resorption of the interproximal bone peak.[8–11] Various local factors may affect interproximal crestal bone height, including implant placement depth (crestal or subcrestal),[12,13] abutment morphology and height,[14] type of surface,[15] connection types,[16] and insertion and loading protocol (immediate or delayed).[7,17]

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Clinical Implications

The findings reveal greater marginal bone loss when the distance between implants is less than 3 mm compared with 3 mm or more, while implant survival remained unaffected. Therefore, maintaining a minimum spacing of 3 mm between adjacent implants is recommended to preserve peri-implant bone.

A reduced interimplant distance has been reported to negatively impact mid-proximal crestal bone levels.[18] Maintaining a minimum interimplant distance of 3 mm has been reported to be critical for the preservation of the crestal bone, preventing lateral bone loss, and achieving favorable esthetic outcomes.[11] The interimplant distance also plays a key role in the aspect of the interproximal papilla, which is essential for natural-looking outcomes.[19] Clinical trials[20–24] have determined that when the contact point is positioned more than 6 mm coronal to the crestal bone or when the interimplant distance exceeds recommended values between 2 and 4 mm, the likelihood of papilla loss increases significantly. To address these issues, guidelines recommend positioning adjacent implants 3 to 4 mm apart. When such spacing is not feasible, alternative approaches, such as using a single implant with a cantilevered pontic, may be considered to preserve both functional and esthetic outcomes.[25]

The impact of horizontal interimplant distance remains unclear, with varying recommendations and limited consensus on its influence on clinical outcomes. With the aim of addressing this gap, this systematic review evaluated the effects of different interimplant distances on clinical outcomes in patients rehabilitated with 2 adjacent implants, focusing primarily on changes in marginal bone levels and secondarily on implant survival. The null hypothesis was that no statistically significant difference in clinical and radiographic outcomes would be found between dental implants placed less than 3 mm apart and those placed more than 3 mm apart.

MATERIAL AND METHODS

This systematic review was conducted according to the Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA) guidelines as recommended by Moher et al.[26] The protocol was designed before starting the study and was registered on the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42024622404). The Grading of Recommendations, Assessment, Development, and Evaluations approach (GRADE) was used to rate the quality of the evidence.[27]

The key question was: “Which horizontal interimplant distance provides the most predictable and favorable implant outcomes for the rehabilitation of 2 adjacent missing teeth?” Following the guidelines of Stillwell et al,[28] the systematic review and meta-analysis used the Population, Intervention, Comparison, Outcomes, and Time (PICOT) criteria to select and include the most eligible studies.[28] The population was systemically healthy and comprised adult participants with 2 adjacent missing teeth rehabilitated with 2 implants. The intervention was studies reporting data about participants with 2 adjacent implants and a horizontal interimplant distance <3 mm. The comparison was studies reporting data about participants with 2 adjacent implants and a horizontal interimplant distance ≥3 mm. The outcome was peri-implant marginal bone level (radiographically assessed) and implant survival rate, and time was studied with at least 6 months follow-up from the prosthesis delivery and implant loading.

To specifically address the central question, a selection of studies was carried out according to the following inclusion criteria: clinical human studies; randomized controlled clinical trials (RCTs), prospective or retrospective studies including at least 10 participants; at least 6 months of follow-up from the prosthesis delivery and loading; studies evaluating different horizontal interimplant distances between 2 adjacent implants; detailed information on the clinical protocol; in the case of multiple publications on the same patient cohort, only the one with the longest follow-up and/or the most comprehensive data and sufficient data reporting on the implant and prosthesis outcomes was included. Studies not fulfilling the above-listed criteria were excluded.

A systematic search was independently conducted by 2 authors (E.R., M.G.L.) across the MEDLINE, Cochrane Central Register of Controlled Trials and Trial Protocols, SCOPUS, and Web of Science databases. The search targeted peer-reviewed English publications up to January 2025 (Supplemental Data 1, available online). Additionally, a manual search was independently performed by 2 authors (P.F.M., A.S.) who reviewed the *Journal of Dental Research*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, *International Journal of Periodontics & Restorative Dentistry*, *Clinical Oral Implants Research*, and several others.

Titles and abstracts were screened by 2 reviewers (E.R., M.G.L.) to remove duplicates and irrelevant data. The full text of studies deemed eligible were analyzed by one or both reviewers and presented to the principal author (P.D.A.). Data were independently extracted by 2 authors (P.D.A., E.R.) using a spreadsheet (MS Excel; Microsoft Corp), with any disagreements resolved through discussion. A descriptive narrative table was compiled, summarizing essential study features including the reference, year, design, sample size, intervention and comparison, outcome parameters, and length of observation period.

The study quality assessment was independently conducted by 2 reviewers (M.G.L., P.F.M.), who reached conclusions through discussion. In cases of disagreement, a third investigator (P.D.A.) reviewed the study and facilitated the final decision through discussion.

The quality of nonrandomized clinical trials was evaluated using the risk of bias in nonrandomized studies - of interventions (ROBINS-I) tool; for randomized studies the risk of bias (ROB) 2 tool was used, while for retrospective study, the methodological quality was assessed using the Newcastle-Ottawa scale.[29–31] Individual studies were scrutinized, and their quality was classified as having a low, medium, or high risk of bias.

Following the Newcastle-Ottawa scale, each article was assessed based on 11 methodological quality criteria, receiving 1 point (or star) for each criterion met. Studies scoring between 9 and 11 stars (approximately ≥80% of criteria fulfilled) were considered high-quality, those scoring between 6 and 8 stars medium-quality and studies with less than 6 stars low-quality.

Implant survival was defined as the implant being present at the follow-up examination, but its condition was not specified. The changes in peri-implant marginal bone level, radiographically measured in millimeters, were described using the mean (MRAW) and the 95% confidence interval (CI). The Egger test and the funnel plots were used to assess potential publication bias. Heterogeneity was measured using the 1^2 statistics (<49%: low, 50–74%: mild, ≥75%: high). The meta-analysis used a fixed or a random effects model, based on the heterogeneity between the studies, focusing on binary and continuous data to determine the intragroup effect size. In the case of low heterogeneity (12<49%) a fixed-effects model was used; otherwise, a random-effects model was applied.

In the meta-analyses with a comparison between 2 groups, the Cohen d was used as effect size for the numeric outcome and the risk ratio for the binary one. The statistical analysis was carried out with a software program (R v.4.3.1.; R Foundation for Statistical Computing, using the “meta” and “metafor” packages), and interater agreement was assessed using Cohen kappa (α=.05).

RESULTS

The preliminary research identified 2065 studies, 1885 after the removal of duplicates. The review of titles and abstracts excluded 1840 documents; therefore, 45 full articles were retrieved and evaluated on the basis of the inclusion criteria, of which 5 studies met the inclusion criteria and were eligible for further analysis. The literature search process is articulated in the PRISMA flow chart (Fig. 1).

The main characteristics of the included studies are reported in Table 1. Among the included studies, only 1[7] was an RCT, 3[6,8,9] were prospective observational clinical studies, and 1[10] was a retrospective clinical study. The RCT involved a test (2-mm interimplant distance) and a control group (3-mm interimplant distance). Four studies[6–8,10] had at least a 1-year follow-up, while 1[9] had a follow-up ranging from 6 to 24 months. Only 1 study[7] selected the region (anterior or posterior) including only restorations on premolars, while the others used a mixed setting. None of the studies reported data about the timing of the implant insertion and loading, except Rivara et al,[7] who indicated the timing of loading (type I).

Three studies[7–9] highlight a standard implant length and a diameter ≥3.5 mm, and the others[6,10] did not include information on these parameters. Four studies[7–10] used internal connection implants; 2 of them conical, 1 with an internal hexagon, and 1 included both connections. The same 4 studies[7–10] used platform switching implants.

Two studies[7,8] involved single crowns to restore the implants, another[9] used FPDs, while the others[6,10] did not specify the type of prosthetic rehabilitation delivered. The main findings of the included studies are reported in Table 2. Given that only 1 study was a randomized clinical trial, it was treated as a nonrandomized trial and evaluated using the ROBINS-I together with the nonrandomized trials. The risk of bias evaluated with the ROBINS-I is shown in Figure 2, and 1 of the remaining studies, evaluated using the NOS, is shown in Figure 3. None of the studies were excluded because of a concerning risk of bias, although many of them were deemed to be of medium or high risk.

Five studies[6–10] analyzed the marginal bone level changes, dealing with a total of 200 treatments of 2 adjacent implants having an horizontal interimplant distance <3 mm. Funnel plot (Fig. 4) and the Egger test were used to assess the publication bias. The Egger test accepted the null hypothesis of no publication bias (P=.152). The heterogeneity test was statistically significant (Q statistic=80.66, df=4, P<.01), and the I^2 heterogeneity index was high (I^2=95%); therefore, a fixed effect model was used. The meta-analysis on the peri-implant marginal bone level changes (mm) with an interimplant distance <3 mm showed an average change from the baseline of −0.59 mm (95% CI: −0.8858; −0.2960) (Fig. 5).

Four studies[6–8,10] analyzed the marginal bone level changes and dealt with a total of 80 treatments of 2 adjacent implants having an horizontal interimplant distance ≥3 mm. The Egger test and the funnel plot were used to assess the presence of publication bias. The

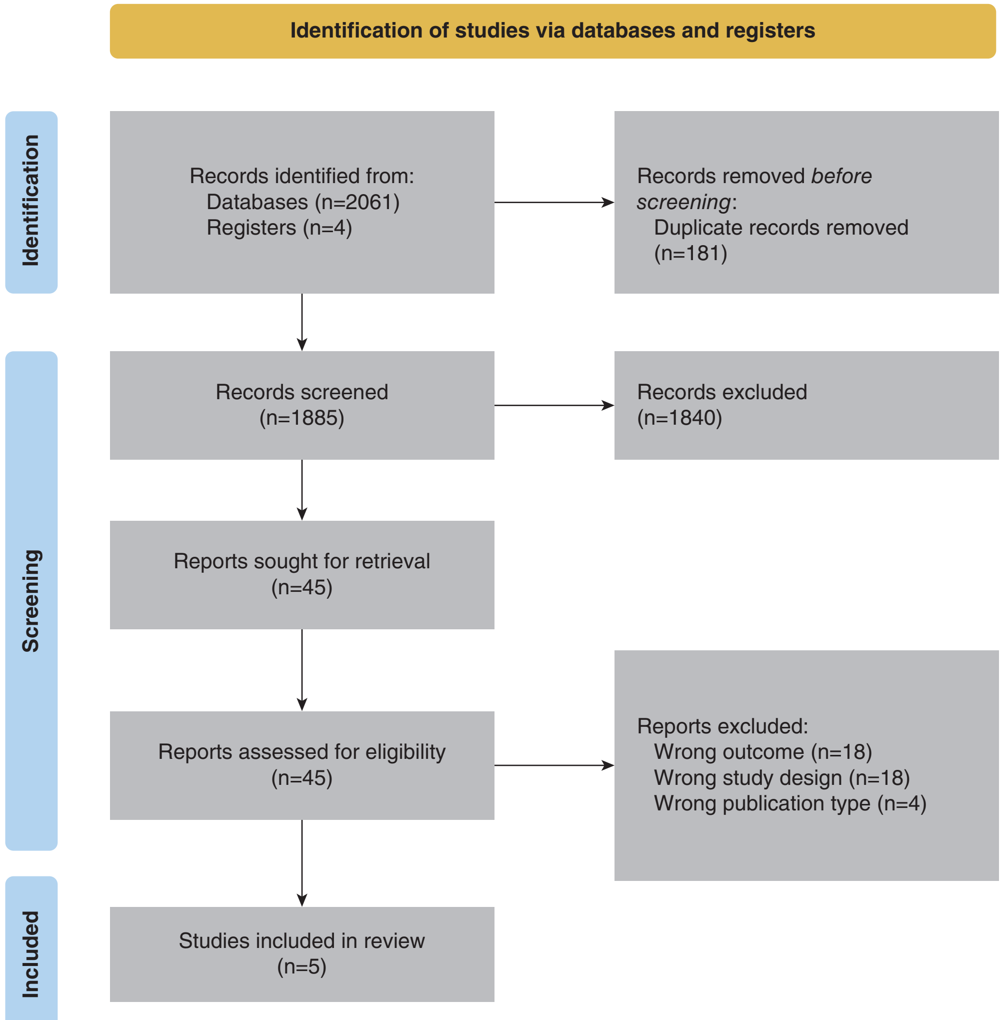

Figure 1. Flowchart of study according to 2020 PRISMA checklist.

Table 1. Main characteristics of included studies

Author, Year	Study Design	Country	Setting	Number of Participants	Number of Implants	Implant Type	Platform Switching	Previous or Simultaneous Bone Regeneration
Tarnow et al, 2000	Retrospective study	USA	University Dental Hospital	36	72	NR*	no	NR*
Rodríguez-Ciurana et al, 2009	Prospective study	Spain	Private practice	37	82	Prevail e XP di Biomet/3i	yes	no
Jo et al, 2014	Retrospective study	Korea	University Dental Hospital	25	50	Osseospeed,GS III, Implantium, Superline, TS III	yes	no
Koutouzis et al, 2015	Prospective study	USA	University Dental Hospital	30	60	Astra, OsseospeedDentsply	yes	no
Rivara et al, 2020	RCT	Italy	University Dental Hospital	30	60	Nobel Replace CC TiUnite, Nobel Biocare	yes	no

*NR, not reported

Egger test rejected the null hypothesis of no publication bias (P=.012), and, based on the funnel plot analysis, the study by Tarnow et al[6] was removed from the meta-analysis. (Fig. 6) The heterogeneity test was not statistically significant (Q statistic=2.15 df=2, P=.342), and the I^2 heterogeneity index was low (I^2=6.8). The meta-analysis on the peri-implant marginal bone level changes (mm) with an interimplant distance ≥3 mm showed an average change from the baseline of −0.25 mm (95% CI: −0.34; −0.17) (Fig. 7).

The comparison of the marginal bone level changes between the 2 previously mentioned groups was based

Table 2. Main findings of included studies

Author, Year	Conclusions
Tarnow et al, 2000	Bone loss around implants exhibits lateral component. Implants spaced more than 3 mm apart showed bone loss of 0.45 mm, while those with 3 mm or less of distance between them experienced crestal bone loss of 1.04 mm.
Rodríguez-Ciurana et al, 2009	Platform-switching technique found more effective than traditional implant restorations in preserving peri-implant bone and maintaining interproximal bone peak. In narrow edentulous areas where implants placed less than 3 mm apart (ranging from 1.5 to 3 mm), platform-switched implants contribute to preservation of bone peak.
Jo et al, 2014	Average horizontal and vertical marginal bone loss in group 1 (≤ 3 mm)–0.18 ±0.25 mm and –0.15 ±0.18 mm, respectively, while in group 2 (>3 mm),–0.17 ±0.31 mm and –0.11 ±0.33 mm, respectively. Interimplant distance did not influence crestal bone loss in implants with internal connections and platform switching.
Koutouzis et al, 2015	Interimplant distance does not elevate risk of bone loss during functional loading, as long as implants feature internal conical connection and platform-switching design.
Rivara et al, 2020	Thirty patients received 2 immediately loaded implants in premolar region, with implants placed 2 mm apart (test group) or 3 mm apart (control group). No significant differences observed between groups in terms of soft tissue esthetics or bone level changes over a 12-month period.

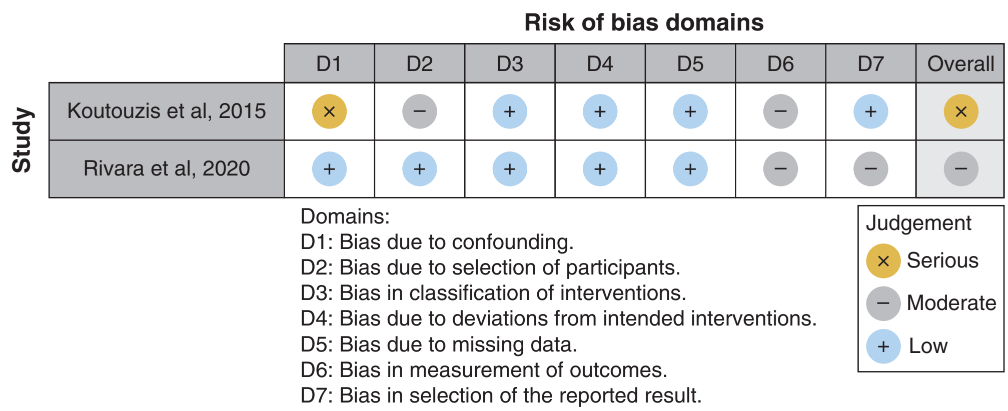

Figure 2. Risk of bias assessment for nonrandomized clinical trials using ROBINS-I tool.

on 4 studies and 80 treatments (Table 3). The Egger test accepted the null hypothesis of no publication bias (P=.392) (Fig. 8). The heterogeneity test was not statistically significant (Q statistic=3.22, df =3, P=.359), and the I^2 heterogeneity index was low (I^2=6.8). The overall effect size of the Cohen d was −0.40 (95% CI: −0.72; −0.08); as a result, a significant difference (P=.01) of the mean marginal bone level changes was found between the 2 groups even if this difference was slight (Fig. 9).

The comparison of the implant survival rate between the 2 groups was based on 4 studies and 118 treatments (Table 3). The Egger test could not be performed because of the lack of heterogeneity in the data (τ^2=0). This aspect has indicated that the variability among studies was fully explained by within-study variance, leaving no residual heterogeneity to assess funnel plot asymmetry. The heterogeneity test was not statistically significant (Q statistic=0, df=3, P>.99), and the I^2 heterogeneity index was low (I^2=0). As the overall Risk Ratio was 1.00 (95% CI: −0.96; 1.04), no significant difference (P>.999) in the number of surviving implants was found between the 2 groups. (Fig. 10) The quality of the obtained evidence was evaluated following the GRADE approach and is described in Table 4. The available evidence strongly supported the advantages of placing implants at a distance of 3 mm or above when the outcome of interest is the marginal bone level, and bone resorption as a slight difference was noted; the same cannot be stated when observing implant survival which was similar between the 2 groups, possibly as a consequence of the short follow-up in most studies.

DISCUSSION

The null hypothesis that no difference would be found in marginal bone loss between an interimplant distance of <3 mm and ≥3 mm was rejected, as the meta-analysis identified significant differences (P<.05). The findings consistently suggested that reduced interimplant distances (<3 mm) were associated with increased marginal bone loss. Previous studies by Tarnow et al[6] and Rodríguez-Ciurana et al[9] identified a critical threshold of 3 mm, beyond which both bone stability and esthetic outcomes improved significantly. Indeed, Tarnow et al[6] reported a mean marginal bone loss of 1.04 ±0.78 mm for distances <3 mm compared with 0.45 ±0.7 mm for distances ≥3 mm, while Rodríguez-Ciurana et al[9] reported slightly higher bone loss for narrower spacing, potentially because of differences in the follow-up durations or implant surface treatments. Rivara et al[7] reported a mean marginal bone loss of −0.74 ±0.79 mm for distances <3 mm. Findings of studies by Koutouzis et al[8] and Jo et al[10] reported fewer pronounced differences between interimplant distances.

Another systematic review,[32] which exclusively examined animal studies, addressed the impact of interimplant distance on implant success. According to the

Tarnow et al, 2000	Cardaropoli et al, 2002	Rodríguez-Ciurana et al, 2009	Jo et al, 2014	
				Sample size calculation
				Representativeness of the population included
				Clear definition of the protocols followed
				Calibration of the prosthodontist/assessor
				Description of clear inclusion/exclusion criteria
				Comparability of patients on the basis of the study design
				Management of potential confounders
				Assessment of Outcome
				Appropriate protocol of data collection
				Appropriateness of statistical analysis
				Unit of analysis reported in the statistical analysis
6	6	7	6	**Total**

Figure 3. Appraisal of quality of included articles using Newcastle-Ottawa scale.

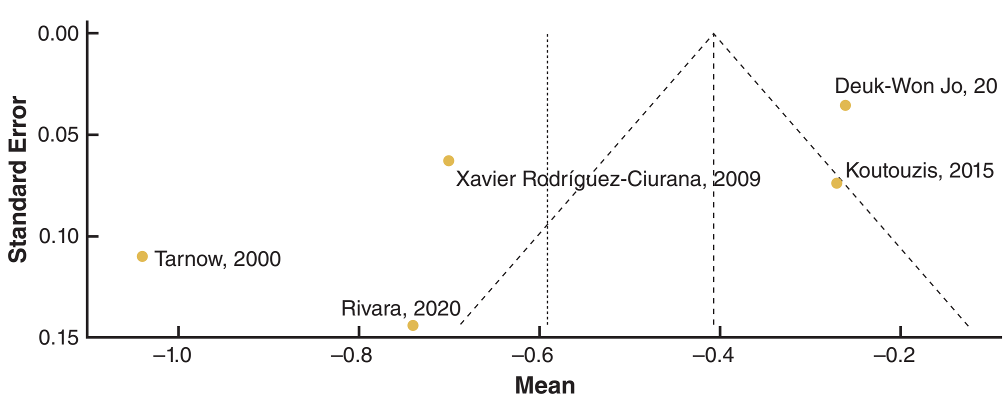

Figure 4. Funnel plot illustrating distribution of publication bias risk based on sample sizes from studies evaluating peri-implant marginal bone loss (MBL) where horizontal interimplant distance < 3 mm.

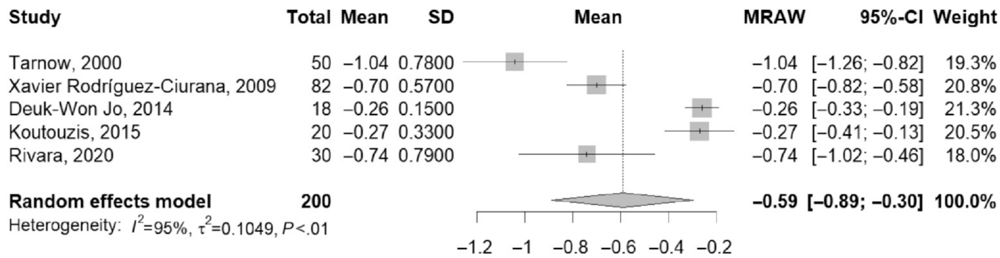

Figure 5. Forest plot showing changes in peri-implant marginal bone level (MBL) in studies analyzing implants with horizontal interimplant distance <3 mm.

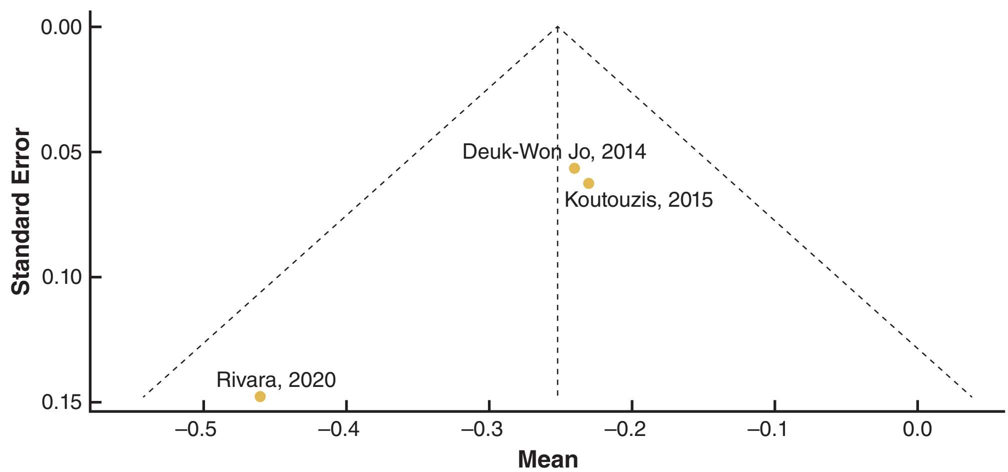

Figure 6. Funnel plot illustrating distribution of publication bias risk based on sample size from studies evaluating peri-implant marginal bone loss (MBL) in case of horizontal interimplant distance ≥3 mm.

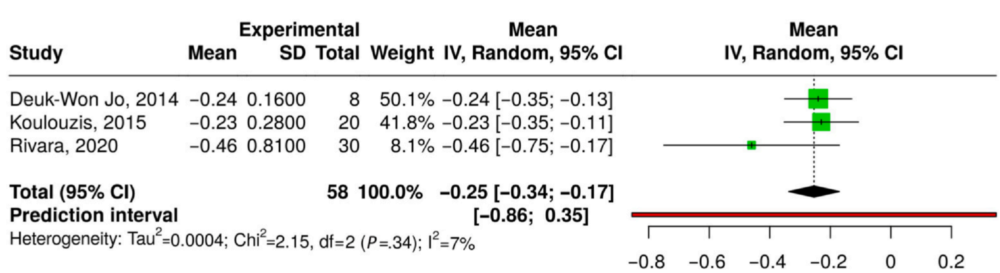

Figure 7. Forest plot showing changes in peri-implant marginal bone level (MBL) in studies analyzing implants with horizontal interimplant distance ≥3 mm.

Table 3. Summary of peri-implant marginal bone level (MBL) and implant survival of studies included

Author, Year	Change of Marginal Bone Level in mm (Mean ±SD)		Implant Survival (%)		Follow-up
	Test Group	Control Group	Test Group	Control Group	
Tarnow et al, 2000	−1.04 ±0.78	−0.45 ±0.7	100%	100%	1 to 3 years from implant exposure
Rodríguez-Ciurana et al, 2009	−0.7 ±0.57	A	100%	A	6 to 24 months
Jo et al, 2014	−0.26 ±0.15	−0.24 ±0.16	100%	100%	mean 19.3 months
Koutouzis et al, 2015	−0.27 ±0.33	−0.23 ±0.28	100%	100%	2 years from implant placement
Rivara et al, 2020	−0.74 ±0.79	−0.46 ±0.81	100%	100%	1 year

results of the 4 studies analyzed, no significant relationship was found between interproximal crestal bone height (ICBH) and interimplant distance. However, a preclinical study conducted on dogs suggested that, while interimplant distance did not influence vertical bone loss (VBL), it did have an effect on horizontal

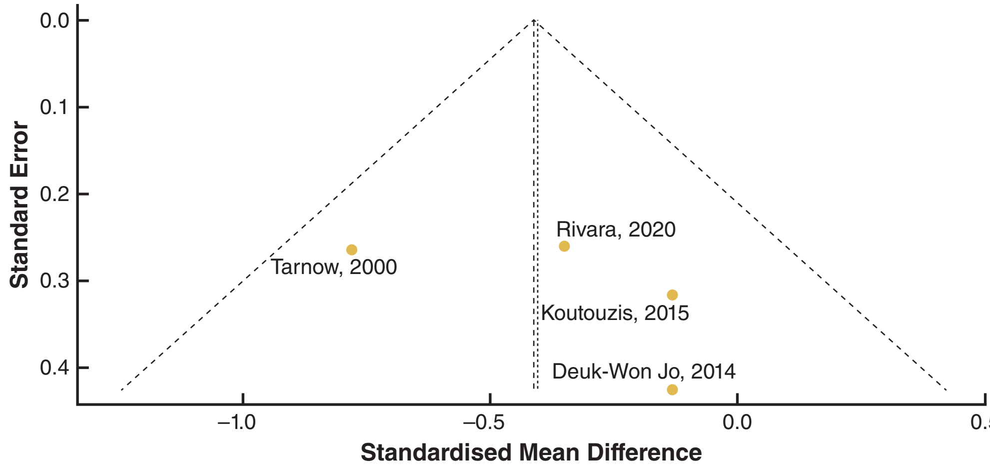

Figure 8. Funnel plot illustrating distribution of publication bias risk based on sample size from studies comparing peri-implant marginal bone loss (MBL) in case of a horizontal interimplant distance<3 mm and ≥3 mm.

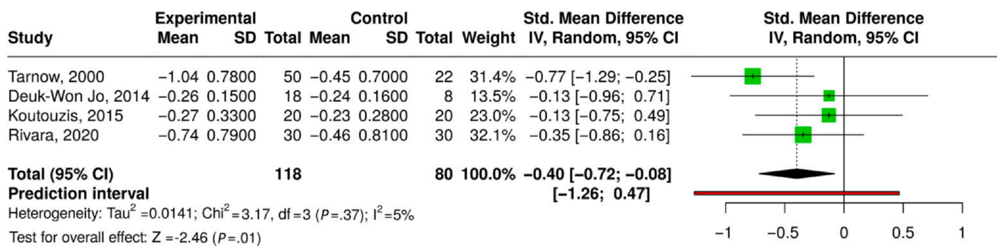

Figure 9. Forest plot of studies comparing peri-implant marginal bone loss (MBL) in case of a horizontal interimplant distance <3 mm and ≥3 mm.

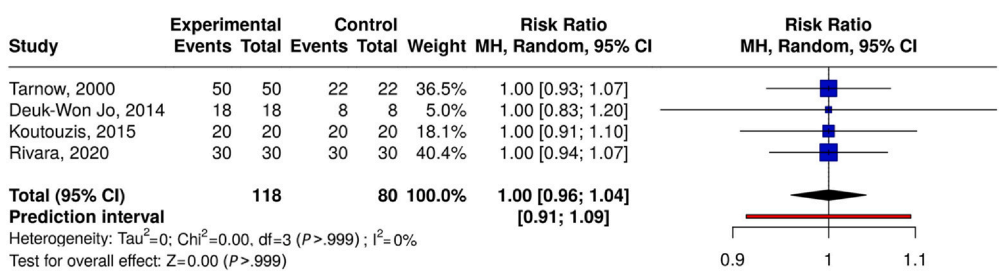

Figure 10. Forest plot of implant survival in studies comparing a horizontal interimplant distance of <3 mm and ≥3 mm. Risk ratio (RR) and confidence intervals (CIs) are shown for each study. Vertical line at a risk ratio of 1 indicates no difference between groups.

Table 4. Quality of obtained evidence following the GRADE approach

Outcome	Number of Participants (Studies)	Certainty of the Evidence	Relative Effect (95% CI)	Strength of Recommendation	Interpretation Findings	Comments
MBL (measured in mm)	198 implants(5)	Moderate (⊕⊕⊕O)	−0.41 (−0.71;0.12)	↑↑	Implant positioned at distance of more than 3 mm have lower risk of bone loss, even if this difference small. Still, as this might play role in developing further peri-implantitis advisable to place implants at adequate distance if possible.[a]	N/A
Implant survival	198 implants (3)	Low (⊕⊕OO)	1.01(−0.97; 1.05)	↑↓	The risk of implant failure between implant placed within 3 mm or 3 mm or more is the same; henceforth, it can be postulated that the distance between implants does not play a role in their survival. Similarly, the included short follow-ups and the experimental setting might have covered any existent difference[a]	N/A

CI, confidence interval; MBL, marginal bone loss.

[a] Most of included articles observational studies, mainly retrospective.

interimplant bone loss (IHBL).[18] These findings collectively emphasized the need for further well-designed studies to better define the optimal interimplant distance and its comprehensive impact on implant success, peri-implant health, and long-term outcomes, as well as soft tissue parameters and esthetics.

The present review identified notable trends in other clinical outcomes. Even though the implant survival rate was 100% in both the control and test groups, reduced interimplant distances were associated with deeper probing depths and increased bleeding, suggesting compromised soft tissue health. Koutouzis et al[8] reported data related to BoP in terms of percentage (%), with the minimum rate for the 4-mm interimplant distance group (17.90%), and the maximum for the 3-mm interimplant distance group (34.20%). No significant differences were observed in the implant survival rates across varying interimplant distances, indicating that while reduced space may challenge biological outcomes, implant stability is still maintained, at least on a short-term follow-up. However, technical complications such as screw loosening were more frequently reported in patients with closer implant placement, likely due to prosthetic compromises.

Wider interimplant distances (≥4 mm) were consistently associated with improved papillary filling and esthetic scores, particularly in the anterior maxilla. This aspect underscores the role of spacing in preserving soft tissue contours and achieving harmonious gingival esthetics.[22,33,34] In high-risk scenarios, clinicians may consider additional measures, such as increasing the interimplant distance and using soft tissue augmentation procedures to enhance peri-implant papilla volume and stability.[35,36] Tarnow et al[6] also revealed that when the distance from the base of the proximal contact to the crest of the bone was 3, 4, or 5 mm, the papilla was present nearly 100% of the time. However, when the distance increased up to 10 mm, the papilla was predominantly absent.[20]

The implants in 4[7–10] of the 5 articles in the present study used the platform-switching technique, but 1 did not[6] and reported higher levels of bone loss around implants when compared with the other implants. A statistical analysis could not be provided given the scarcity of the results, but this may indicate that platform switching plays a major role in controlling marginal bone loss.

The current available literature on interimplant distance remains scarce; key factors such as the depth of implant insertion, connection types, platform switching, type of abutment, available space, and implant diameter have seldom been taken into consideration. Moreover, data on critical peri-implant parameters such as probing pocket depth, bleeding on probing and interimplant papilla, as well as esthetic outcomes and the prevalence of technical complications in relation to interimplant distance remain limited, leaving a crucial gap in our understanding of the biological and technical interplay at these sites.

Limitations of the study included the clinical heterogeneity regarding the jaw (maxillary or mandibular), the region rehabilitated (anterior or posterior), the depth of implant insertion, the type of connection and implant surface, the presence of platform switching, the type of abutment, the different available space and implant diameter, the timing of implant insertion and loading, the type of prosthetic rehabilitation, and the emergence angle and profile. Long-term, randomized comparative trials are necessary to further clarify the clinical and radiographic outcomes associated with various interimplant distances.

CONCLUSIONS

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

1. Even if no differences in terms of implant survival were observed between the 2 groups, maintaining an interimplant distance of at least 3 mm was statistically significant for the preservation of the peri-implant bone in a short-term follow-up.
2. Using the platform switching technique could reduce the minimum required distance.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2025.06.004.

REFERENCES

1. Howe MS, Keys W, Richards D. Long-term (10-year) dental implant survival: A systematic review and sensitivity meta-analysis. *J Dent*. 2019;84:9–21.
2. Buser D, Janner SF, Wittneben JG, et al. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: A retrospective study in 303 partially edentulous patients. *Clin Implant Dent Relat Res*. 2012;14:839–851.
3. Jung RE, Zembic A, Pjetursson BE, et al. Systematic review of the survival rate and the incidence of biological, technical, and aesthetic complications of single crowns on implants reported in longitudinal studies with a mean follow-up of 5 years. *Clin Oral Implants Res*. 2012;23:2–21.
4. Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. *Periodontol 2000*. 2017;73:7–21.
5. Zitzmann NU, Marinello CP, Schärer P. Esthetic and functional rehabilitation of a completely edentulous patient with a full-arch implant-supported prosthesis: 1-Year results. *J Prosthet Dent*. 2001;85:577–585.
6. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol*. 2000;71:2060–2063.
7. Rivara F, Macaluso GM, Toffoli A, et al. The effect of a 2-mm inter-implant distance on esthetic outcomes in immediately non-occlusally loaded platform shifted implants in healed ridges: 12-Month results of a randomized clinical trial. *Clin Implant Dent Relat Res*. 2020;22:486–496.

8. Koutouzis T, Neiva R, Lipton D, Lundgren T. The effect of interimplant distance on peri-implant bone and soft tissue dimensional changes: A nonrandomized, prospective, 2-year follow-up study. *Int J Oral Maxillofac Implants*. 2015;30:900–908.
9. Rodríguez-Ciurana X, Vela-Nebot X, Segalà-Torres M, et al. The effect of interimplant distance on the height of the interimplant bone crest when using platform-switched implants. *Int J Periodontics Restorative Dent*. 2009;29:141–151.
10. Jo DW, Yi YJ, Kwon MJ, Kim YK. Correlation between interimplant distance and crestal bone loss in internal connection implants with platform switching. *Int J Oral Maxillofac Implants*. 2014;29:296–302.
11. Ramanauskaite A, Sader R. Esthetic complications in implant dentistry. *Periodontol 2000*. 2022;88:73–85.
12. Valles C, Rodríguez-Ciurana X, Clementini M, et al. Influence of subcrestal implant placement compared with equicrestal position on the peri-implant hard and soft tissues around platform-switched implants: A systematic review and meta-analysis. *Clin Oral Investig*. 2018;22:555–570.
13. Degidi M, Perrotti V, Shibli JA, et al. Equicrestal and subcrestal dental implants: A histologic and histomorphometric evaluation of nine retrieved human implants. *J Periodontol*. 2011;82:708–715.
14. Canullo L, Fedele GR, Iannello G, Jepsen S. Platform switching and marginal bone-level alterations: The results of a randomized-controlled trial. *Clin Oral Implants Res*. 2010;21:115–121.
15. Bartold PM, Kuliwaba JS, Lee V, et al. Influence of surface roughness and shape on microdamage of the osseous surface adjacent to titanium dental implants. *Clin Oral Implants Res*. 2011;22:613–618.
16. Lee JH, Kim JC, Kim HY, Yeo IL. Influence of connections and surfaces of dental implants on marginal bone loss: A retrospective study over 7 to 19 years. *Int J Oral Maxillofac Implants*. 2020;35:1195–1202.
17. Kupershmidt I, Levin L, Schwartz-Arad D. Inter-implant bone height changes in anterior maxillary immediate and non-immediate adjacent dental implants. *J Periodontol*. 2007;78:991–996.
18. Scarano A, Assenza B, Piattelli M, et al. Interimplant distance and crestal bone resorption: A histologic study in the canine mandible. *Clin Implant Dent Relat Res*. 2004;6:150–156.
19. Ramanauskaite A, Roccuzzo A, Schwarz F. A systematic review on the influence of the horizontal distance between two adjacent implants inserted in the anterior maxilla on the inter-implant mucosa fill. *Clin Oral Implants Res*. 2018;29:62–70.
20. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol*. 1992;63:995–996.
21. Degidi M, Novaes Jr AB, Nardi D, et al. Outcome analysis of immediately placed, immediately restored implants in the esthetic area: The clinical relevance of different interimplant distances. *J Periodontol*. 2008;79:1056–1061.
22. Choquet V, Hermans M, Adriaenssens P, et al. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol*. 2001;72:1364–1371.
23. Gastaldo JF, Cury PR, Sendyk WR. Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. *J Periodontol*. 2004;75:1242–1246.
24. Roccuzzo M, Roccuzzo A, Ramanuskaite A. Papilla height in relation to the distance between bone crest and interproximal contact point at single-tooth implants: A systematic review. *Clin Oral Implants Res*. 2018;29:50–61.
25. Jung RE, Heitz-Mayfield L, Schwarz F. Groups of the 2nd Osteology Foundation Consensus Meeting. Evidence-based knowledge on the aesthetics and maintenance of peri-implant soft tissues: Osteology Foundation Consensus Report Part 3-Aesthetics of peri-implant soft tissues. *Clin Oral Implants Res*. 2018;29:14–17.
26. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4(1).
27. Piggott T, Morgan RL, Cuello-Garcia CA, et al. Grading of recommendations assessment, development, and evaluations (GRADE) notes: Extremely serious, GRADE's terminology for rating down by three levels. *J Clin Epidemiol*. 2020;120:116–120.
28. Stillwell SB, Fineout-Overholt E, Melnyk BM, Williamson KM. Evidence-based practice, step by step: asking the clinical question: A key step in evidence-based practice. *Am J Nurs*. 2010;110:58–61.
29. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. 2016;355:i4919.
30. Sterne JAC, Savović J, Page MJ, et al. Rob 2: A revised tool for assessing risk of bias in randomized trials. *BMJ*. 2019;366:l4898.
31. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol*. 2010;25:603–605.
32. Al Amri MD. Influence of interimplant distance on the crestal bone height around dental implants: A systematic review and meta-analysis. *J Prosthet Dent*. 2016;115:278–282. .e1.
33. Su H, Gonzalez-Martin O, Weisgold A, Lee E. Considerations of implant abutment and crown contour: Critical contour and subcritical contour. *Int J Periodontics Restorative Dent*. 2010;30:335–343.
34. Choquet V, Hermans M, Adriaenssens P, et al. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. *Clin Oral Implants Res*. 2001;12:346–350.
35. Buser D, Martin W, Belser UC. Optimizing esthetics for implant restorations in the anterior maxilla: Anatomic and surgical considerations. *Int J Oral Maxillofac Implants*. 2004;19:43–61.
36. Puisys A, Linkevicius T. The influence of mucosal tissue thickening on crestal bone stability around bone-level implants. A prospective controlled clinical trial. *Clin Oral Implants Res*. 2015;26:123–129.

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