Received: 24 August 2023 | Revised: 12 September 2023 | Accepted: 15 September 2023

DOI: 10.1111/prd.12534

Periodontology 2000 WILEY

REVIEW ARTICLE

Less marginal bone loss around bone-level implants restored with long abutments: A systematic review and meta-analysis

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1 | INTRODUCTION

Restoring missing teeth with dental implants has become a valid treatment alternative over conservative approaches in partially edentulous patients due to their excellent long-term survival and success rates.[1–4] However, biological complications such as peri-implantitis or marginal bone loss of 2 mm or more may affect implant survival.[1,2,5–9]

Similarly to natural teeth, supracrestal tissue attachment is formed around implants, creating a biological barrier.[10,11] The maintenance of this protective seal is crucial for the stability of peri-implant hard tissues.[12] Following implant placement and abutment insertion, physiological bone remodeling will occur to establish supracrestal tissue attachment.[10,12] Most remodeling occurs within the first year of healing, with the highest dynamics in the first 6 months.[13] As a result, the amount of marginal bone loss can determine the success of dental implants.[14] Several factors influence marginal bone loss, which can be anatomy-related,[15,16] tooth-related,[17,18] or implant-related.[16,19–26]

Implant design can be divided into one-piece (tissue-level) and two-piece (bone-level) configurations. In two-piece implants, after the connection of the prosthetic abutment, a microgap is established in the implant–abutment junction,[27] which is associated with microleakage and bacterial contamination.[28,29] Although the results are controversial, these negative factors could lead to greater marginal bone loss.[30,31] It is becoming crucial to recognize and address how implant restorative procedures may harm peri-implant tissues and explore ways to minimize this impact.[8] Several attempts have aimed to reduce the amount of marginal bone loss. A well-documented approach with bone-level implants, called platform-switching, was reported by Lazzara and Porter when a smaller diameter abutment is used on a wider implant platform.[25] However, Linkevicius et al.[16] added that when vertical mucosa height is less than 2 mm, the platform-switching concept alone will not protect against marginal bone loss. Finelle et al.[32] also added that horizontal offset plays a minimal role, while the configuration of the transmucosal component directly impacts bone remodeling.

Regarding the timing of abutment placement, recent reviews have indicated that the 'one abutment at one time' protocol may help minimize marginal bone resorption.[33–36] However, recent meta-analyses, which exclusively included non-randomized clinical trials,

have yielded conflicting results regarding whether this protocol genuinely provides benefits for crestal bone levels.[37,38]

On the other hand, several studies reported that the height of prosthetic abutment could also impact marginal bone loss,[39,40] hypothetically, through the establishment of supracrestal tissue attachment. Vervaeke et al. were probably among the first authors who concluded in a nine-year follow-up study that shorter abutments could lead to greater bone loss.[41] However, the nature of the study was a prospective case series without a control group, which lowers the level of evidence. Chen et al.[23] also examined the impact of abutment height on marginal bone loss in a meta-analysis. However, the authors included retrospective and animal studies, which downgraded the evidence level. Another systematic review of this matter concluded that the abutment height significantly impacted marginal bone loss. As such, longer abutments correlated with less bone loss.[42] However, this study included retrospective cohorts without quantitative analysis and showed a moderate-to-high risk of bias. Although a randomized clinical trial from Linkevicius et al. has found no significant difference between different abutment heights,[43] the most recent meta-analysis concluded that shorter abutments caused higher marginal bone loss.[44] This study pooled data from different follow-up times, and the authors also included data from studies with the same study group and population that had been used multiple times,[45,46] which created an important source of bias.

Therefore, the purpose of this systematic review and meta-analysis is to offer the most robust and current scientific evidence regarding the biological outcomes of bone-level implants when restored with either short or long abutments within the context of the 'one abutment at one time' protocol.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

The present systematic review and meta-analysis was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement[47] with the guidance of the Cochrane Handbook.[48] We registered the study protocol at the International Prospective Register for Systematic Reviews (PROSPERO) in May 2022 (registration number CRD42022331923).

2.2 | Search strategy

A systematic search was carried out in five medical databases: MEDLINE (PubMed), EMBASE, Web of Science, CENTRAL, and Scopus. The first search was from inception up to May 2022. An updated search was also conducted in January 2023. We used the same search term in each database: (dental implant OR dental implantation OR osseointegrated OR oral implant OR implant) AND (abutment height OR collar height OR running space OR abutment length OR collar length OR neck length OR smooth neck portion OR transmucosal height OR gingival height) AND (influence OR comparison OR difference OR different OR short OR long). During the search, we did not apply filters. An additional manual search was conducted among the reference lists of all included articles to identify further possible articles. EndNote reference management software was used to organize and manage records.[49]

2.3 | Eligibility criteria

We framed our research question following the Population, Intervention, Comparator, and Outcome (PICO) framework. Eligible randomized controlled trials and non-randomized prospective interventional studies included partially edentulous subjects in need of implant restorations and compared prosthetic rehabilitation with long (>2 mm) and short (<2 mm) abutments. The main outcome assessed was marginal bone loss. Additional outcomes were bleeding on probing and probing pocket depth.

For inclusion, studies had to fulfill the following criteria: human study, at least 20 participants treated, follow-up time of at least 6 months, any brands and kinds of titanium, bone-level, platform-switching implants, detailed reporting on biological outcomes, detailed reporting on abutment height: short abutments <2 mm, long abutments ≥2 mm, and fixed single or partial (up to 3-unit) restorations. On the other hand, we excluded studies with guided bone regeneration, tissue-level (one-piece) implants, zirconia implants, and study types like questionnaires, case reports, case series, and non-randomized retrospective studies.

2.4 | Selection of studies

After removing duplicates, records were inspected by two review authors (PT and ES) independently, based on the titles and abstracts of the papers. Afterward, full texts were also assessed by the same two authors. On each level, Cohen's Kappa (κ) coefficient was calculated. Furthermore, the reference lists of the eligible articles were hand-searched for additional potential studies. Finally, disagreements between review authors were solved by discussion or by involving a third reviewer (KM).

2.5 | Data extraction

Two authors (PT and ES) independently extracted data. Any disagreements were resolved by discussion until consensus was reached or by consulting a third author (KM). We extracted the following data: first author, year of publication, study design, study setting, number of participants, number of implants planned, number of implants at the end of the study, mean age

of participants, implant type, surgical site, 'one abutment at one time' protocol, restoration type, type of fixation, loading protocol, level of implant placement, follow-up time, and outcome parameters. None of the studies reporting on multiple interventions in one participant reported the intracluster correlation coefficient (ICC). If data were given in independent groups, for example, thin and thick mucosa, we calculated their common mean and standard deviation (SD) using the appropriate formula. However, if data were given in dependent groups, for example, mesial and distal measurement, the average standard deviation was used as pooled standard deviation, which is an upper boundary estimate for the true standard deviation, assuming a positive correlation between the measurements.

2.6 | Quality assessment

The quality of each included study was assessed by two reviewers (PT and ES) independently using the Cochrane Risk of Bias Tool 2 for randomized clinical trials and ROBINS-I for non-randomized trials.[50] If needed, a third reviewer author (KM) was also involved in the decision-making.

2.7 | Statistical analysis

The statistical analyses were made with R.[51] For calculations and plots, we used the *meta*[52] and *dmetar*[53] packages. In the case of marginal bone loss and probing pocket depth, we calculated pooled mean difference (MD) with 95% confidence intervals (CI). We analyzed bleeding on probing as a binary variable, calculating pooled risk ratios (RR) with 95% CI. The Mantel–Haenszel method was used for pooling, and the exact Mantel–Haenszel method (no continuity correction) was used to handle zero cell counts. In each case, we applied the random-effects meta-analysis model with the Hartung-Knapp adjustment to prevent false-positive findings. If it was applicable, we reported the 95% summary prediction interval (PI). We used forest plots to summarize results graphically. To estimate τ^2, we used the REML method and Q profile method for calculating the CI of τ^2.[54] Statistical heterogeneity across trials was assessed using the Cochrane Q test and I^2 values.[55]

2.8 | Handling of correlated data

In the case of studies with multiple interventions in the same subjects,[40,55–58] we performed a sample size correction following the recommendations of Higgins et al.[48] We performed two calculations with two values of the intracluster correlation coefficient: one for ICC = 0, which means full independence, and one for ICC = 0.5, which means considerable dependence. Both results are presented on the forest plots. For the detailed description of sample size correction, see Supplementary Methods in Appendix S1.

2.9 | Certainty of evidence

We assessed the certainty of evidence using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach.[59]

3 | RESULTS

3.1 | Screening process

The systematic search resulted in 4055 articles after duplicate removal. After title and abstract evaluation, 16 records were selected ($\kappa = 0.91$). Finally, full-text selection revealed eight eligible articles ($\kappa = 0.97$). Finally, the hand search of reference lists did not bring any more results (Figure 1). Reasons for exclusion are detailed in Table S1.

3.2 | Included studies

Eight studies were included in the systematic review,[40,43,46,55–58,60] out of which seven were included in the meta-analysis.[40,46,55–58,60] Seven of the included studies were randomized clinical trials, and one was a non-randomized prospective interventional study.[58] All implants were titanium, bone-level, platform-switched, and placed epi- or subcrestally without the need for hard or soft tissue augmentation. Healing periods ranged from 2 to 4 months in all studies. Only two studies followed the two-stage protocol with submerged healing before inserting healing abutments.[46,58] Three studies reported 6-month[40,46,56] and seven studies reported 12-month follow-up data.[43,46,55–58,60] The 'one abutment at one time' protocol was applied in five studies.[40,43,55–57] All included studies investigated bone-level changes, five studies investigated sulcus bleeding,[43,46,55,57,60] and two studies investigated pocket depths.[55,60] The extended summary of study characteristics is given in Table 1.

3.3 | Quality assessment

The overall risk of bias was low for three randomized clinical trials,[46,55,57] while the other three showed some concerns[40,56,60] due to missing pre-specified analysis plans (Figure S1). For the non-randomized study,[58] the risk of bias was moderate (Table S2).

3.4 | Marginal bone loss at 6 months

Three studies with 174 implants overall were included in this analysis. According to the random-effects model, the long abutment group showed less (0.63 mm) marginal bone loss at 6-month follow-up (ICC = 0.5, MD 0.63, 95% CI: [−0.16; 1.42] $I^2 = 93.99\%$, $p < 0.001$; Figure 2). The certainty of evidence was moderate (Table S3). As forest plots shown in Figure 2, there was almost no difference between the calculations based on the corrected sample sizes of the related

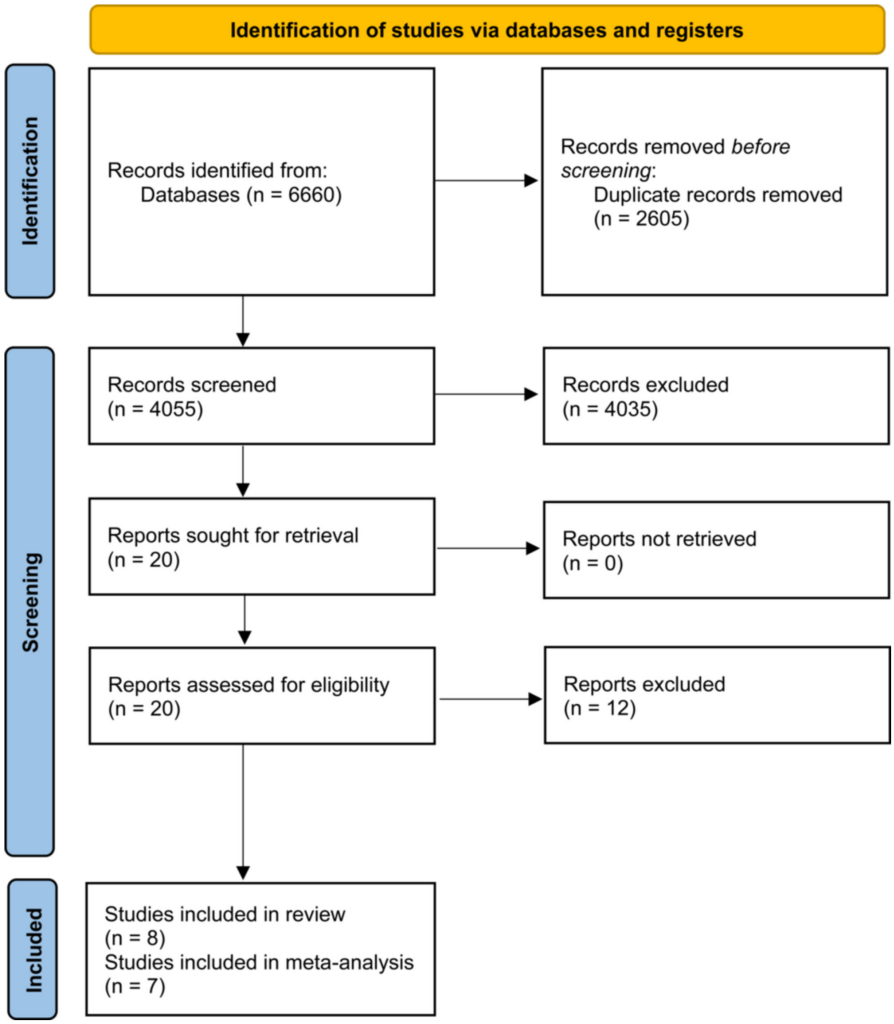

FIGURE 1 Flowchart of the selection process based on PRISMA 2020 statement.

articles. ICC = 0 and ICC = 0.5 calculations showed no difference in pooled values ($p = 0.980$).

3.5 | Marginal bone loss at 1 year

Overall, 384 implants from six studies were included in this analysis. The long abutment group exhibited less (0.26 mm) marginal bone loss at 1-year follow-up (ICC = 0.5, MD 0.26, 95% CI: [−0.02; 0.53] $I^2 = 73.25\%$, $p = 0.002$; Figure 3). The certainty of evidence was high (Table S3). There was almost no difference between the calculations based on the corrected sample sizes of the related articles, as forest plots shown in Figure 3. ICC = 0 and ICC = 0.5 calculations resulted in less than 0.1 difference in pooled values ($p = 0.948$).

3.6 | Subgroup analysis of the 'one abutment at one time' protocol

Subgroup analysis of six studies revealed no difference in marginal bone loss at 1-year follow-up, when definitive abutments were placed immediately after implant placement ($p = 0.973$; Figure 4 with ICC = 0.5 and Figure S2 with ICC = 0 calculations).

3.7 | Leave-one-out analysis of marginal bone loss

Omitting the article of Spinato et al. (2017), thus including only randomized clinical trials in this analysis, random-effects meta-analysis resulted in less (0.26 mm) marginal bone loss in the long abutment group at 1-year follow-up (ICC = 0.5, MD 0.26, 95% CI: [−0.12; 0.65] $I^2 = 77\%$; Figure S3).

3.8 | Bleeding on probing

Four studies with 256 implants overall were included in this analysis. We found no difference in bleeding on probing between abutment heights at 1-year follow-up (ICC = 0.5, RR 0.97, 95% CI: [0.76; 1.23] $I^2 = 0\%$, $p = 0.927$; Figure 5). The certainty of evidence is moderate (Table S3). As the forest plots shown in Figure 5, there was almost no difference between the calculations based on the corrected sample sizes of the related articles. ICC = 0 and ICC = 0.5

TABLE 1 Basic characteristics of the included studies.

Study					Population		Implant						
Author	Year	Design	Setting	ICC	Mean age (years)	No. of subjects	No. at beginning	No. at the end	System	Platform	Type	Material	Connection type
Linkevicius et al.[43]	2022	RCT	University	Not needed	46	60	60	55	T6, NucleOSS	PS	Bone-level	Titanium	Internal conical
Munoz et al.[55]	2021	RCT	University	Applied but nr	1 mm: 56.5 3 mm: 53.8	69	112	99	Vega, Klockner Implant System	PS	Bone-level	Titanium	Internal hexagon
Borges et al.[60]	2021	RCT	Private center	Not needed	1 mm: 67 2 mm: 62	33	68	59	OsseoSpeed, Astratech	PS	Bone-level	Titanium	Internal conical
Spinato et al.[46]	2019	RCT	Private center	Not needed	51.3	70	70	66	Shape1BC, Lugano	PS	Bone-level	Titanium	Internal hexagon
Pico et al.[56]	2019	RCT	University	Not applied	1 mm: 55.6 3 mm: 52.3	33	66	66	BioniQ, LASAK	PS	Bone-level	titanium	Internal conical
Borges et al.[57]	2018	RCT	Private center	Not applied	1 mm: 67 2 mm: 62	33	68	63	OsseoSpeed, Astratech	PS	Bone-level	Titanium	Internal conical
Blanco et al.[40]	2018	RCT	University	Not applied	1 mm: 55.8 3 mm: 52.3	22	44	42	BioniQ, LASAK	PS	Bone-level	Titanium	Internal conical
Spinato et al.[58]	2017	NRT	Private center	Not applied	<1.6 mm: 56.9 >2.4 mm: 52.2	93	110	110	Shape-1, hybrid	PS	Bone-level	Titanium	Internal hexagon

Study		Implant placement level	Surgical site	Soft or hard tissue augmentation	Loading protocol	Restorations	Follow-up months	Abutment height (short)	Abutment height (long)	OAOT protocol	Outcomes
Author	Year										
Linkevicius et al.[43]	2022	Epicrestal	Posterior	No	Conventional	Screw-retained single unit	12	0.7 mm	2.4 mm	–	MBL, PPD, BOP, PI
Munoz et al.[55]	2021	Subcrestal	Posterior	No	Conventional	Screw-retained single or multi-unit	12	1 mm	3 mm	Applied	MBL, VMT, PPD, BOP
Borges et al.[60]	2021	Epi- or subcrestal	Posterior	No	Conventional	Screw-retained splinted crowns	1, 4, 12, 36	1 mm	2 mm	Applied	MBL, BOP, KM
Spinato et al.[46]	2019	Epicrestal	Posterior	No	Conventional	Screw-retained single unit	4, 6, 12	1 mm	3 mm	–	MBL, mPI, mSBI, VMT
Pico et al.[56]	2019	Epi- or subcrestal	Posterior	No	Conventional	Screw-retained multi-unit	3, 6, 12	1 mm	3 mm	Applied	IPBL
Borges et al.[57]	2018	Epi- or subcrestal	Posterior	No	Conventional	Screw-retained splinted crowns	1, 4, 12	1 mm	2 mm	Applied	MBL, KM, BOP
Blanco et al.[40]	2018	Epicrestal	Nr	No	Conventional	Screw-retained bridges	3, 6	1 mm	3 mm	Applied	MBL
Spinato et al.[58]	2017	Epicrestal	Nr	No	Conventional	Cement-retained single or multi-unit	12	<1.6 mm	>2.4 mm	–	MBL

Abbreviations: BOP, bleeding on probing; ICC, intracluster correlation coefficient; IPBL, interproximal bone level; KM, keratinized mucosa; MBL, marginal bone loss; MC, metal-ceramic; mPI, modified plaque index; mSBI, modified sulcus bleeding index; MZ, monolithic zirconia; nr, not reported; NRT, non-randomized trial; OAOT, one abutment at one time; PI, plaque index; PPD, probing pocket depth; RCT, randomized controlled trial; VMT, vertical mucosal thickness.

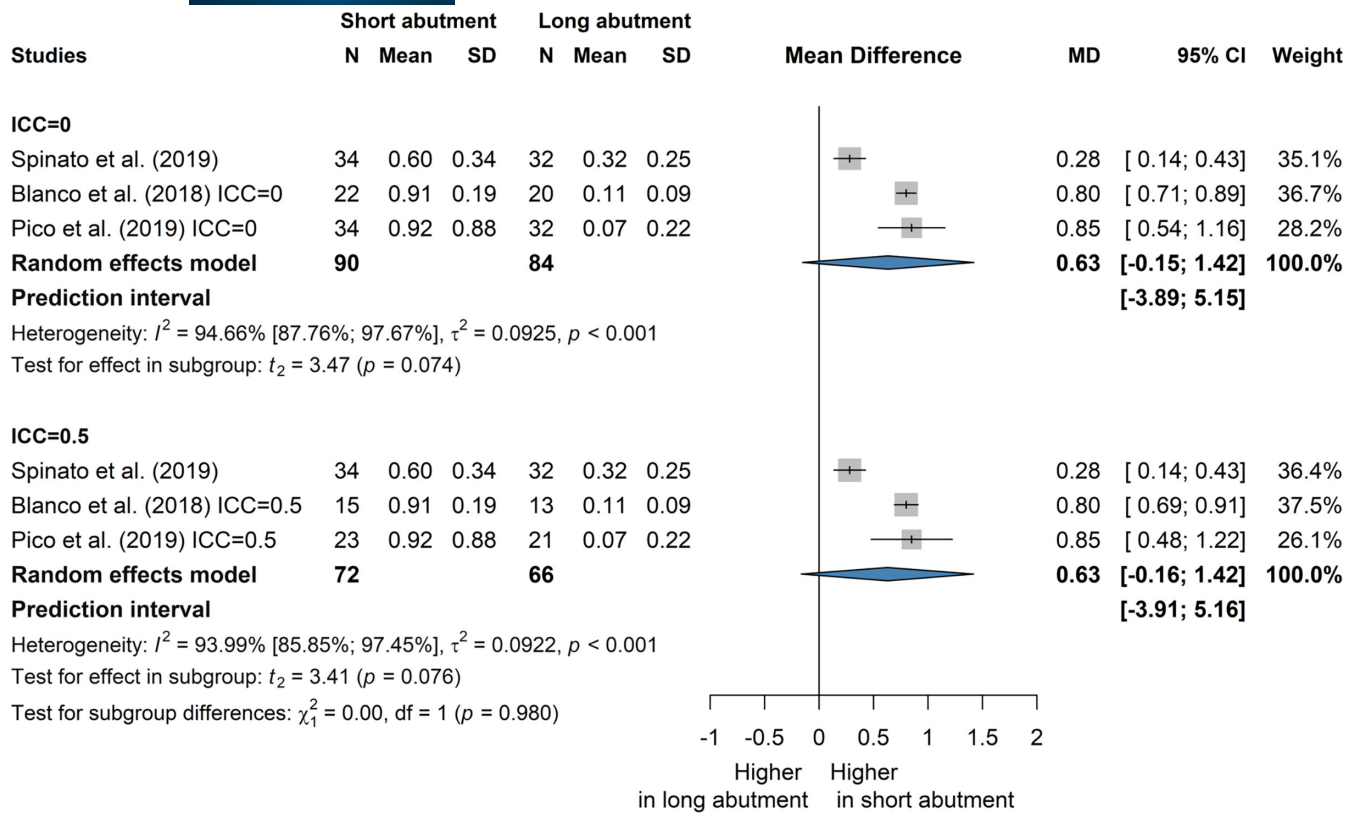

FIGURE 2 Forest plot shows less marginal bone loss with long abutments at 6-month follow-up.

calculations resulted in less than 0.1 difference in pooled values ($p = 0.950$).

3.9 | Probing pocket depth

Overall, 154 implants from two studies were included in this analysis. There was no difference in probing pocket depth between abutment heights at 1-year follow-up (ICC = 0.5, MD −0.05, 95% CI: [−1.11; 1.01] $I^2 = 0\%$, $p = 0.650$; Figure 6). The certainty of evidence was moderate (Table S3). There was almost no difference between the calculations based on the corrected sample sizes of the related articles, as the forest plots shown in Figure 6. ICC = 0 and ICC = 0.5 calculations resulted in less than 0.1 difference in pooled values ($p = 0.933$).

4 | DISCUSSION

This systematic review and meta-analysis aimed to assess the biological outcomes of bone-level implants when restored with various abutment heights, within the framework of the 'one abutment at one time' protocol.

In dental implantology, bone remodeling around implants is crucial for osseointegration.[61] The majority of this occurs within the first year after implant placement. The rate of bone turnover is highest during the first 6 months and then gradually declines over time.[13,62,63] Besides the different surgical techniques, implant designs, and surfaces, Donos et al. mention the importance of immune-inflammatory cells for the maturation of the bone matrix.[64] Immune cells like neutrophils, monocytes, and macrophages stimulate collagen deposition in the early stages. Long-term bone remodeling shows that bone matures and gains resistance to deformation, but osteocyte density decreases, emphasizing the importance of both early and long-term remodeling for implant stability.[61] For this reason, it is essential to separately assess marginal bone loss at different time points, as the marginal bone loss rate within the first year can serve as a reliable predictor of long-term implant failure.[13] Our findings align with these assertions, as the results revealed a significant disparity in marginal bone loss at the 6-month follow-up, which corroborates the notion of substantial bone remodeling during this period.

In our study, concerning early marginal bone loss, our analysis unveiled slightly higher bone levels in the long abutment group. Although these findings did not reach statistical significance, they did indicate less bone loss in this group at both the 6- and 12-month follow-up intervals, and these measurements held clinical relevance. One possible explanation could be attributed to the establishment of soft tissue architecture and the management of abutment-crown microgaps. When utilizing a short abutment in cases with a thin phenotype, there might not be enough vertical mucosal thickness to facilitate the formation of soft tissue architecture. Consequently, marginal bone loss could occur as a means to establish the necessary vertical dimensions for STA.[65]

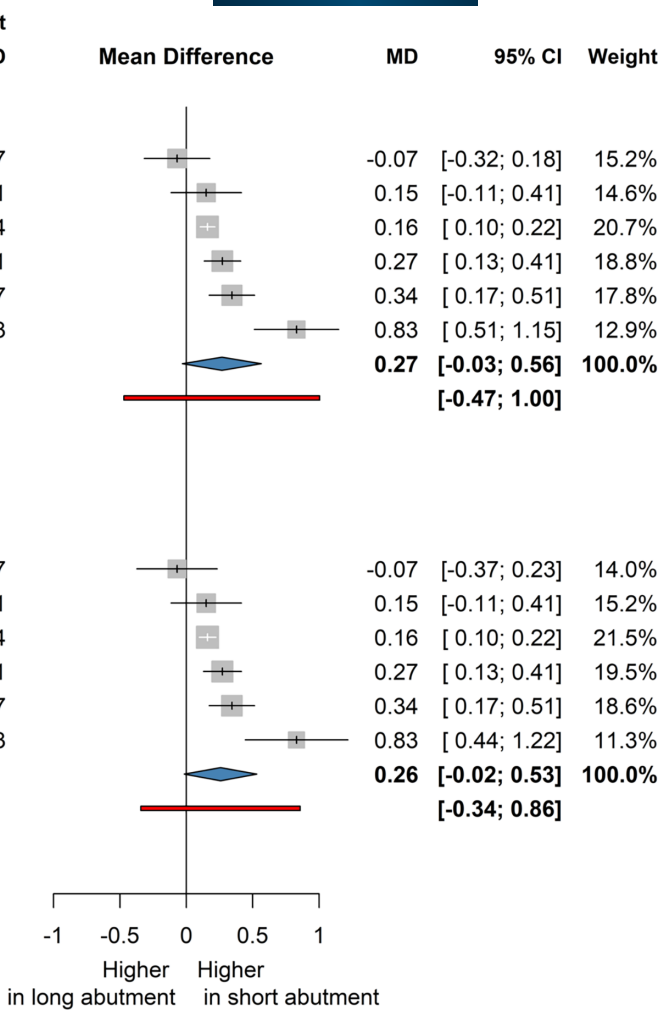

FIGURE 3 Forest plot shows less marginal bone loss with long abutments at 1-year follow-up.

When a short abutment is used with a thick soft tissue phenotype, the microgap and inflammatory infiltration are positioned closer to the bone crest, potentially leading to increased bone resorption.[40,66,67] It is worth noting that our results, showing no significant difference, diverge from those of previous meta-analyses. This divergence could be attributed to the more sophisticated statistical methodology we employed in our study.[23,43]

Due to the limited data set size, a meta-analysis of late marginal bone loss could not be conducted in the present study. Only one trial could be included with a 3-year follow-up period.[60] In that study, no significant difference was reported for marginal bone loss between short and long abutments at long-term follow-up. Previously, Vervaeke et al.[41] also found no significant difference in long-term peri-implant bone loss with different abutment heights during their 9-year prospective case series.

A subgroup analysis revealed no significant difference in marginal bone loss when definitive abutments were inserted immediately after implant placement. Despite the few studies in this analysis, it is interesting to see such controversy in the literature. Canullo et al.[68] reported that the 'one abutment at one time' method might be able to minimize marginal bone loss. In a recent meta-analysis using data from four studies, significantly greater bone loss was also reported with multiple abutment placements.[38] Borges et al. investigated the concept alongside abutment height with a 3-year follow-up. They concluded that long definitive abutments inserted immediately after surgery offer a favorable treatment option regarding the maintenance of crestal bone.[60] Other systematic reviews concluded insufficient evidence in this regard.[69,70] These findings support the assumption that further investigations are needed to draw solid conclusions from this as-yet controversial concept.

Key elements of assessing soft tissue health are bleeding of probing and probing pocket depth, indicating inflammation and attachment loss.[71] Our analysis showed no difference in bleeding of probing or probing pocket depth between study groups. Our results suggest that abutment height alone may not have an influence on soft tissue health, but prosthetic factors and individual oral hygiene routines could have.[72–74] Previous meta-analyses could not investigate this outcome due to the scarce amount of data available.[23,44]

Several factors, both clinical and anatomical, influence the choice of abutment height, including implant depth and angulation, interocclusal space, and soft tissue height.[75] Previously, it seemed that mucosa thickness was also a significant factor in maintaining crestal bone

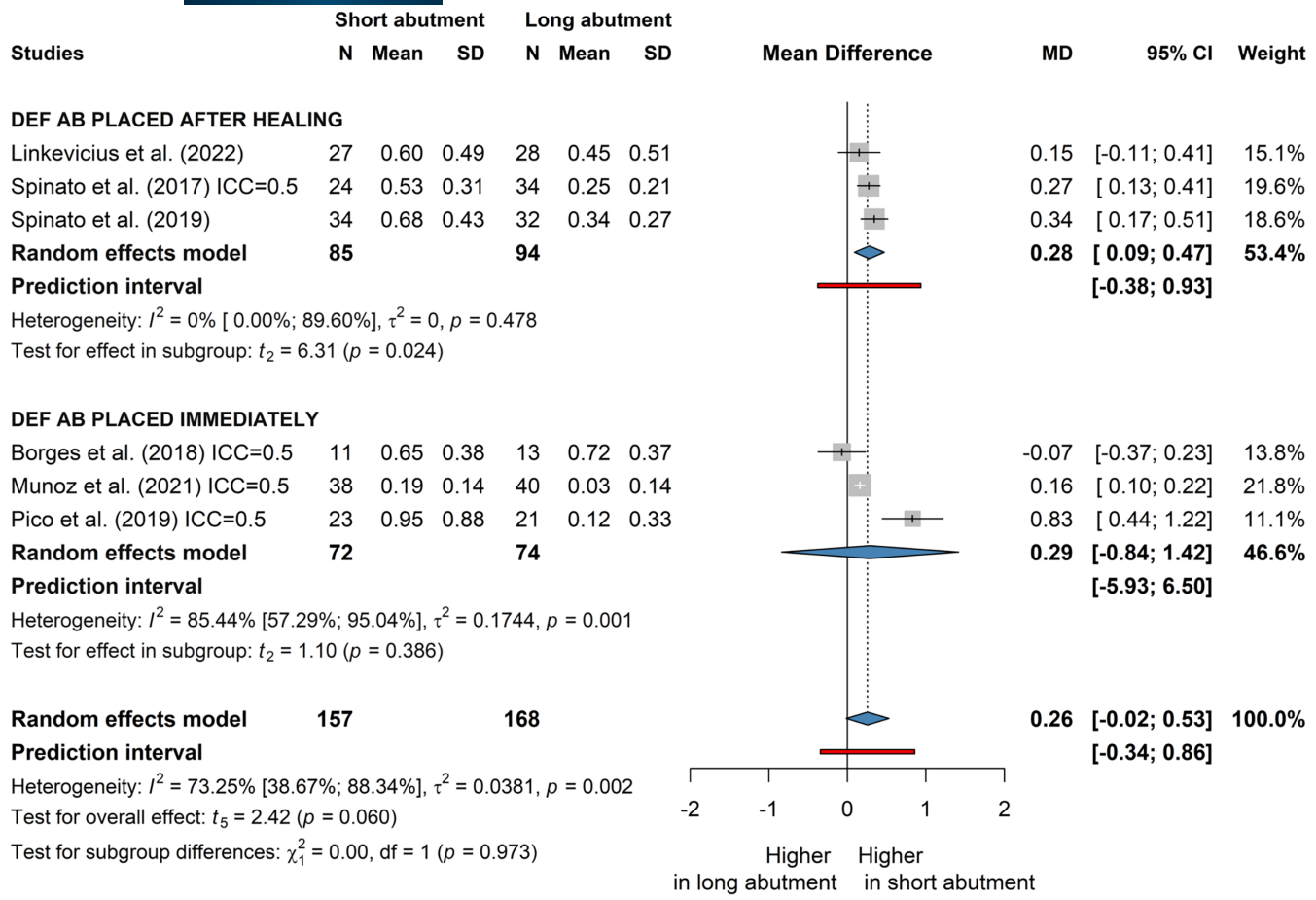

FIGURE 4 Forest plot shows no difference in marginal bone loss between subgroups of 'one abutment at one time' and conventional placement protocols at 1-year follow-up (ICC = 0.5).

levels.[12] Linkevicius et al. suggested that initial mucosa thickness influences crestal bone changes.[16] Also, a meta-analysis in 2016 stated that implants placed in thicker peri-implant soft tissue areas had significantly less marginal bone loss than those with thinner mucosa.[65] Nonetheless, it must be noted that these studies did not consider abutment height. In our study, two of the included trials investigated marginal bone loss of different abutment heights in relation to vertical mucosal thickness.[46,55] Contrary to previous findings, both of these studies confirmed that the amount of marginal bone loss was not correlated with vertical mucosal thickness. Therefore, this controversial question should be further analyzed in future studies.

4.1 | Strengths and limitations

The strengths of the present meta-analysis were the pre-established and published methodologies, with a more refined statistical analysis, and the inclusion of seven randomized clinical trials. The included studies showed low to moderate risk of bias, and GRADE assessment indicated high to moderate certainty of evidence.

The present study has several limitations as well: (1) relatively few studies were available for most of our analyses, mainly having short-term follow-ups; (2) high statistical heterogeneity, which may be due to the low number of studies available; and (3) differences in study characteristics, such as restoration and retention types, follow-up periods, implant connection types, implant placement levels, and soft tissue phenotypes.

4.2 | Clinical and research implications

The usefulness of immediate implementation of scientific results has been previously shown.[76,77] Clinicians may prioritize the use of long abutments when restoring dental implants as they can help reduce bone loss and maintain more stable tissues, which may lead to more predictable long-term outcomes. These advantages may make long abutments a preferred choice for implant restorations whenever possible in clinical practice.

Nevertheless, further research is needed to understand the long-term implications of different abutment heights. More homogeneous study designs are needed in terms of implant placement levels, abutment designs, and restoration types with longer follow-ups, and preferably split-mouth trials. Moreover, further research should also focus on the 'one abutment at one time' protocol as well as follow-ups on vertical mucosal thickness in order to eliminate any controversies around their influential effects.

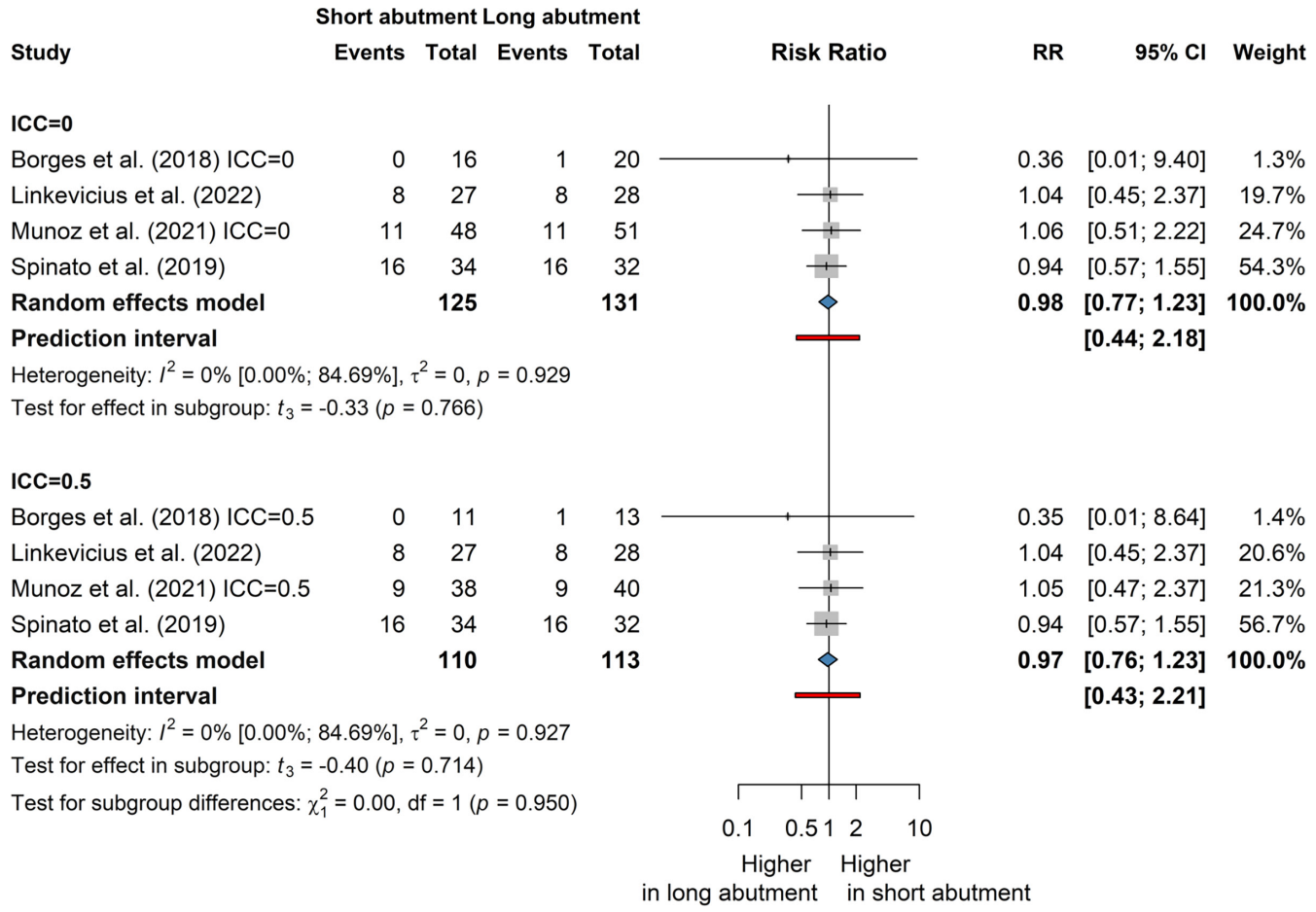

FIGURE 5 Forest plot shows no difference in bleeding on probing between different abutment heights at 1-year follow-up.

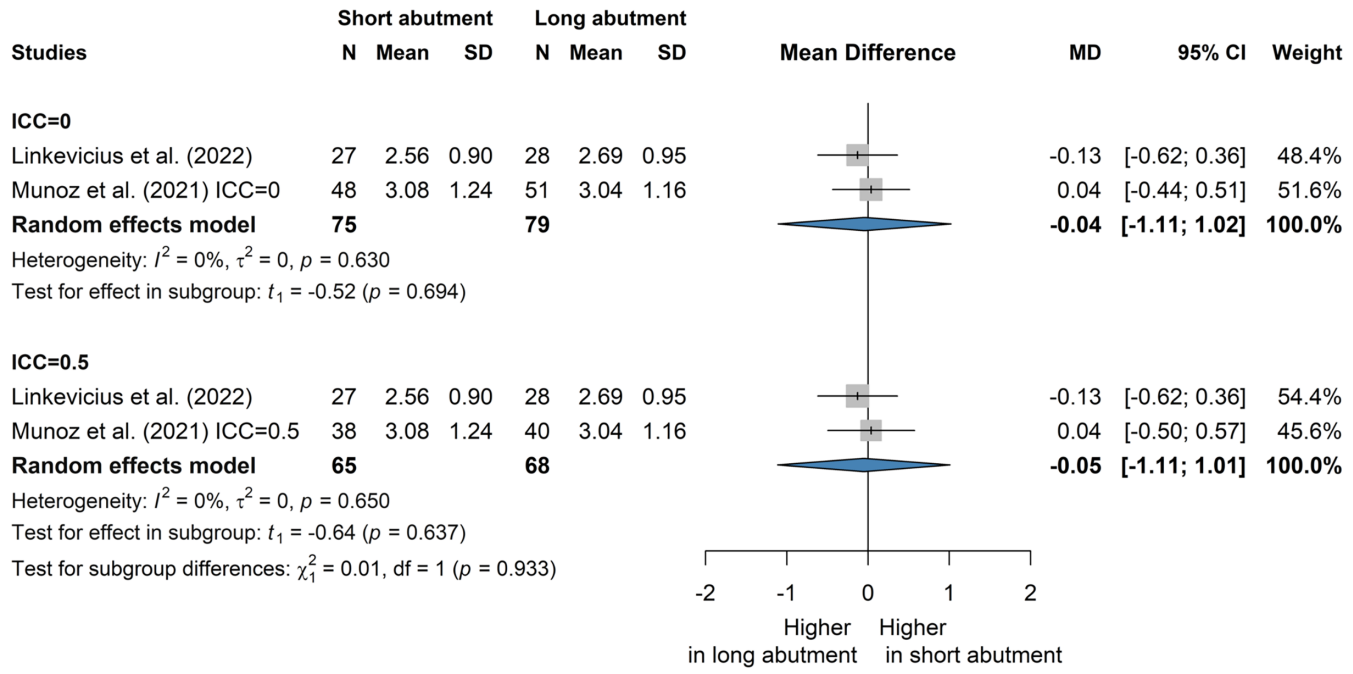

FIGURE 6 Forest plot shows no difference in probing pocket depth between different abutment heights at 1-year follow-up.

5 | CONCLUSIONS

It can be tentatively concluded that longer abutments for bone-level implants appear to be a favorable treatment option for reducing early marginal bone loss. In the context of a short-term follow-up period, the timing of the abutment connection may not exert a significant influence on biological outcomes. However, additional research is required to substantiate these findings.

ACKNOWLEDGMENTS

This study was supported by the Centre for Translational Medicine, Semmelweis University.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Tajti P, Solyom E, Váncsa S, et al. Less marginal bone loss around bone-level implants restored with long abutments: A systematic review and meta-analysis. *Periodontol 2000*. 2023;00:1-12. doi:10.1111/prd.12534