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SYSTEMATIC REVIEW

Influence of abutment height on peri-implant marginal bone loss: A systematic review and meta-analysis

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ABSTRACT

Statement of problem. Whether abutment height can influence peri-implant marginal bone loss has not yet been determined.

Purpose. The purpose of this systematic review and meta-analysis was to investigate the early and late marginal bone loss around implants with long and short abutment height.

Material and methods. Electronic (PubMed, EMBASE, and Cochrane) and hand literature searches were performed to identify articles published up to May 2018. A random-effects model was used to analyze the weighted mean difference of marginal bone loss between the long and short groups. Potential confounding factors, including implant/abutment connection, healing, and cement- or screw-retained restoration type, were investigated using meta-regression.

Results. Fourteen studies fulfilled the inclusion criteria, and 8 were further included in the meta-analysis. Around bone-level implants with a long abutment, marginal bone loss can be reduced significantly in both the early (−0.52 mm; 95% confidence interval [CI]: −0.79 to −0.24; *P*=.001) and late (−0.53 mm; 95% CI: −1.03 to −0.02; *P*=.041) period. Among tissue-level implants, however, and compared with the short-abutment group, more bone loss was found during the early stage in the long abutment (weighted mean difference: 0.28 mm; 95% CI: 0.03 to 0.54; *P*=.031). Meta-regression failed to find any association between confounding factors and early bone loss around bone-level implants.

Conclusions. Within the limitation of this systematic review and meta-analysis, abutment height can influence early bone loss around bone-level implants. However, the evidence is insufficient to determine its impact on late bone loss around bone-level implants and early and late bone loss around tissue-level implants. (J Prosthet Dent 2019;122:14-21)

Marginal bone loss has been one of the criteria to define implant success.[1] Early bone loss, considered to be mainly physiological,[2] happens rapidly during the early healing phase from implant installation to 1 year after loading.[3] Progressive bone loss is often regarded as the first step before peri-implantitis, which may be triggered by early bone loss.[4]

Peri-implant marginal bone loss can be influenced by surgical trauma,[5] implant position,[6] occlusal overload,[7] implant-abutment connection type,[8] plaque accumulation,[9] and biologic width reformation.[10] Similar to natural teeth, supracrestal tissue attachment exists around dental implants, providing a biologic seal against the invasion of bacterial pathogens and the ingress of food debris into the implant-tissue interface.[11] Abutment height has been reported to impact peri-implant marginal bone loss.[12,13] Theoretically, the selection of abutment height could influence the space for biologic width re-establishment, the width of the gap between the abutment/crown and bone, and the location of the subgingival crown margin. Some studies[12-19]

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Clinical Implications

An increased abutment height (greater than 2 mm) is recommended to minimize early marginal bone loss around bone-level implants. Whether the choice of abutment height can influence late bone loss around bone-level implants and early and late bone loss around tissue-level implants is unclear.

reported reduced bone loss with increased abutment height (greater than 2 mm). However, some studies reported that implants with a shorter collar not only had no additional bone resorption[20,21] but also had improved clinical performance.[22,23] However, the authors are unaware of a systematic review concerning the association between abutment height and marginal bone loss. Therefore, the purpose of this systematic review and meta-analysis was to examine the impact of abutment height on early and late marginal bone loss around dental implants.

MATERIAL AND METHODS

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[24] with its protocol registered (CRD42018085026) in the International Prospective Register of Systematic Reviews (PROSPERO). The focus question was developed considering the Population, Intervention, Comparison, and Outcome (PICO) elements[25] (Table 1). To minimize bias from combining the bone loss value of various follow-up times, bone resorption was divided into early (≤12 months after abutment connection)[3] and late (>12 months after abutment connection). The question was as follows: "In patients who receive implant treatment, does the long abutment height (>2 mm) compared with short one (≤2 mm) results in earlier or later marginal bone loss?" Randomized controlled trials (RCTs) or clinical controlled trials (CCTs) reporting the impact of abutment height on marginal bone loss (≥6 months follow-up) were included. Reviews, case reports, animal studies, in vitro studies, finite element analyses, and correlation studies not comparing short and high abutment height were excluded.

Electronic literature screening was conducted in 3 databases (PubMed, EMBASE, and Cochrane) by 2 independent reviewers (Z.C., C.-Y.L.) through May 2018. The search strategy is showed in Table 2. Furthermore, according to Assessing the Methodological Quality of Systematic Reviews (AMSTAR) guidelines,[26] an additional search was performed in the Gray Literature Report (New York Academy of Medicine). A hand search was then performed in journals from January 2000 to May 2018 (*Clinical Oral Implants Research, Journal of Periodontology, Clinical Implant Dentistry and Related Research, European Journal of Oral Implantology, Journal of Prosthetic Dentistry, International Journal of Oral and Maxillofacial Implants, Implant Dentistry,* and *International Journal of Periodontics and Restorative Dentistry*).

The risk-of-bias assessment of the selected articles was performed by the 2 reviewers independently. RCTs were evaluated using the Cochrane collaboration RCT checklist,[27] and the Newcastle-Ottawa Scale[28] was used to assess the quality of the selected CCTs.

Three reviewers (Z.C., C.-Y.L., J.L.) were involved in data extraction. A software program (Stata v14.0; StataCorp LP) was used in statistical analyses. The weighted mean difference (WMD) of marginal bone loss (early or late) between the 2 groups at the same implant level (bone or tissue level) was calculated using a random-effects model. The heterogeneity among studies was assessed by Q statistic (significant if $P<.1$) and the I^2 test

Table 1. PICO elements

Element	Contents
Population	Systemically healthy subjects with osseointegrated dental implants.
Intervention	Based on the abutment height, implants were divided into short-abutment group (≤2 mm, test group) and long-abutment group (>2 mm, control group).
Comparison	The differences in outcomes regarding marginal bone loss between the two groups were analyzed.
Outcome	The primary outcome was the radiographic marginal bone loss. Besides, secondary outcomes considered the effectiveness of other confounding factors (healing type [submerged vs nonsubmerged], implant/abutment connection [platform switching vs nonplatform switching], and type of restoration [screw- vs cement-retained]) on marginal bone loss.

PICO, Population, Intervention, Comparison, and Outcome.

Table 2. Search strategy

Database	Search Strategy
Pubmed	((dental implant[MeSH Terms] OR dental implantation[MeSH Terms] OR dental implantation, osseointegrated[MeSH Terms] OR oral implant[Title/Abstract]) OR implant[Title/Abstract])) AND ((abutment height[Title/Abstract] OR collar height[Title/Abstract] OR running space[Title/Abstract] OR abutment length[Title/Abstract] OR collar length[Title/Abstract] OR neck length[Title/Abstract] OR smooth neck portion[Title/Abstract] OR transmucosal height[Title/Abstract] OR gingival height[Title/Abstract]) OR tissue thickness[Title/Abstract] OR tissue biotype[Title/Abstract] OR tissue phenotype [Title/Abstract] OR mucosa thickness[Title/Abstract])).
EMBASE	('dental implantation'/exp OR 'dental implantation' OR 'dental implantation, endosseous'/exp OR 'dental implantation, endosseous' OR 'dental implantation, endosseous, endodontic'/exp OR 'dental implantation, endosseous, endodontic' OR 'tooth implantation'/exp OR 'tooth implantation' OR 'dental implant'/exp OR 'dental implant' OR 'implant'/exp OR 'implant' OR 'implants'/exp OR 'implants') AND ('abutment height' OR 'abutment length' OR 'collar height' OR 'collar length' OR 'gingival height' OR 'neck height' OR 'neck length' OR 'smooth neck' OR 'transmucosal height' OR 'soft tissue thickness':ab,ti OR 'mucosa thickness':ab,ti OR 'biotype':ab,ti OR 'phenotype':ab,ti) AND ('bone loss'/exp OR 'bone loss').
Cochrane	'abutment height in Title Abstract Keyword AND marginal bone loss in Title Abstract Keyword AND dental implant in Title Abstract Keyword - (Word variations have been searched)'

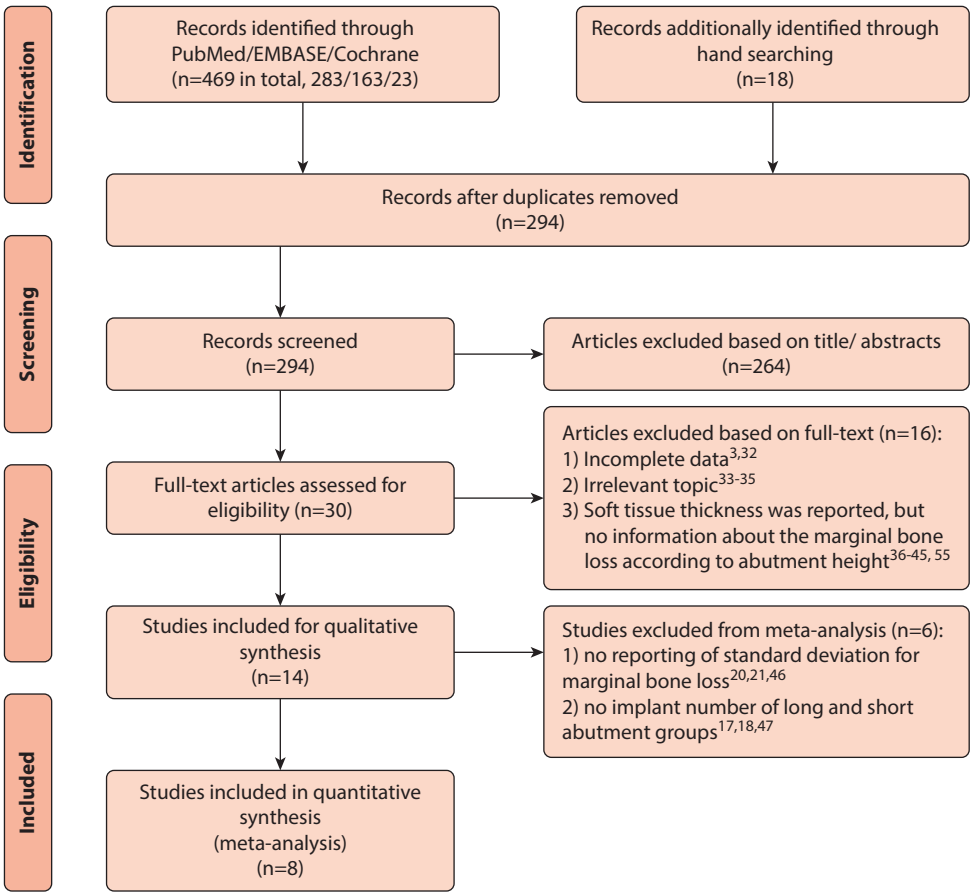

Figure 1. PRISMA flowchart illustrates publication selection process.

Table 3. Overview of studies included in systematic review

No.	Author and Year	Study Type	Pts (n)	Follow-Up (mo)	Implant Type	AH (mm) S	AH (mm) L	Measurement	Restoration Type/Loading
1	Blanco et al 2018[13]	RCT	22	6	Bone level	1	3	PA (STD)	Multiunit/screw-retained/regular
2	Spinato et al 2018[12]	CCT (retro)	51	12	Bone level	<2	≥2	PA (non-STD)	Single crown/cement retained/regular
3	Nóvoa et al 2017[16]	CCT (retro)	60	12/24/36	Bone level	1	2.5	PA (non-STD)	Splint unit/screw-retained/regular
4	Spinato et al 2017[14]	CCT (pros)	94	12	Bone level	<1.6	>2.4	PA (non-STD)	Single or multiunit crown/cement-retained/regular
5	Spinato et al 2017[15]	CCT (retro)	75	12	Bone level	<2	≥2	PA (non-STD)	Single crown/cement-retained/regular
6	Vervaeke et al 2014[17]	CCT (pros)	50	3/12/24/36/108	Bone level	≤1.5	3, ≥4.5	PA (non-STD)	Full-arch prosthesis/screw-retained/regular
7	Galindo-Moreno et al 2016[47]	CCT (retro)	108	6/18	Bone level	<2	≥2	Pano	Fixed prosthesis/screw-retained/regular
8	Galindo-Moreno et al 2014[19]	CCT (retro)	128	6/18	Bone level	<2	≥2	Pano	Mixed
9	Vervaeke et al 2016[18]	CCT (retro)	79	12/24	Bone level	<2, 2	3, ≥4	PA (non-STD)	Removable complete denture/regular
10	Collaert and De Bruyn 2002[46]	CCT (pros)	25	7-24	Bone level	0, 1.5	>3	PA (non-STD)	Fixed cross-arch/screw-retained/early loading
11	Joly et al 2003[20]	RCT	4	4/12	Tissue level	1.8	2.8	PA (STD)	NA/cement-retained/regular
12	Hanggi et al 2015[21]	CCT (retro)	68	4-6/6-11/12/24/36	Tissue level	1.8	2.8	PA or Pano	Mixed
13	Tan et al 2010[22]	RCT	18	6/12	Tissue level	1.8	2.8	PA (STD)	NA
14	Herrero-Climent et al 2014[23]	RCT	25	3/6/12	Tissue level	0.7	1.5	PA (STD)	Mixed/screw-retained/regular

AH, abutment height; CCT, clinical controlled trial; L, long; NA, not announced; No., number; PA, periapical radiograph; Pano, panoramic radiograph; Pts, patients; RCT, randomized clinical trial; S, short; STD, standardized.

Table 4. Results of marginal bone loss

No.	Implant System S	Implant System L	Implant Type/ Stages/Flap	Implant Position S	Implant Position L	AH (mm) S	AH (mm) L	Implants (n) S	Implants (n) L	Marginal Bone Loss (mm) S	Marginal Bone Loss (mm) L
1	LASAK	LASAK	PS/1/F	NA	NA	1	3	22	20	6 mo: 0.91 ±0.19	6 mo: 0.11 ±0.09
2	I-RES	I-RES	PS/2/F	Crest	Crest	<2	≥2	13	12	12 mo: 0.56 ±0.37	12 mo: 0.10 ±0.09
	Zimmer	Zimmer	Non-PS/2/F			<2	≥2	16	9	12 mo: 1.19 ±0.59	12 mo: 0.23 ±0.24
3	Straumann	Straumann	PS/NA/NA	Crest	Crest	1	2.5	30	30	12 mo: 0.82 ±0.99; 24 mo: 0.22 ±0.37; 36 mo: 1.23 ±1.61	12 mo: 0.2 ±0.28; 24 mo: 1.27 ±1.02; 36 mo: 0.35 ±0.62
4	I-RES	I-RES	PS/2/F	Crest	Crest	<1.6	>2.4	10	19	12 mo: 0.51 ±0.30	12 mo: 0.25 ±0.21
5	I-RES SDE	I-RES SDE	PS/2/F	Crest	Crest	<2	≥2	20	17	12 mo: 0.59 ±0.34	12 mo: 0.14 ±0.11
6	Astra Tech	Astra Tech	PS/1/F	NA	NA	≤1.5	3	NA	NA	3 mo: 0.69 ±0.81; 12 mo: 0.76 ±0.87; 24 mo: 0.82 ±0.96; 36 mo: 1.00 ±1.16; 108 mo: 1.81 ±2.16	3 mo: 0.20 ±0.50; 12 mo: 0.19 ±0.41; 24 mo: 0.11 ±0.34; 36 mo: 0.39 ±0.67; 108 mo: 0.78 ±0.94
			PS/1/F				≥4.5		NA		3 mo: 0.08 ±0.38; 12 mo: −0.08 ±0.43; 24 mo: 0.11 ±0.34; 36 mo: 0.11 ±0.56; 108 mo: 0.56 ±0.63
7	Astra Tech 4.5	Astra Tech 4.5	PS/2/F	NA	NA	<2	≥2	NA	NA	6 mo: 0.562 (0.433-0.692) mesial/0.696 (0.560-0.833) distal; 18 mo: 1.08 (0.917-1.255) mesial/1.323 (1.159-1.487) distal	6 mo: 0.195 (0.107-0.238) mesial/0.230 (0.145-0.315) distal; 18 mo: 0.408 (0.297-0.518) mesial/0.456 (0.338-0.574) distal
	Astra Tech 5.0	Astra Tech 5.0	PS/2/F	NA	NA	<2	≥2	NA	NA	6 mo: 0.557 (0.212-0.902) mesial/0.765 (0.368-1.163) distal; 18 mo: 1.272 (0.754-1.790) mesial/1.269 (0.819-1.718) distal	6 mo: 0.549 (0.294-0.804) mesial/0.498 (0.245-0.752) distal; 18 mo: 0.912 (0.520-1.304) mesial/1.182 (0.595-1.768) distal
8	Astra Tech	Astra Tech	PS/NA/NA	Crest	Crest	<2	≥2	171	137	6 mo: 0.20 ±0.03 mean/0.18 ±0.03 mesial/0.22 ±0.03 distal; 18 mo: 0.64 ±0.09 mean/0.57 ±0.04 mesial/0.70 ±0.05 distal	6 mo: 0.05 ±0.005 mean/0.06 ±0.004 mesial/0.04 ±0.005 distal; 18 mo: 0.3 ±0.04 mean/0.30 ±0.04 mesial/0.31 ±0.04 distal
9	Astra Tech	Astra Tech	PS/1/F	Crest	Crest	<2	3	NA	NA	12 mo: 1.17; 24 mo: 1.23	12 mo: 0.38; 24 mo: 0.41
			PS/1/F	Crest	Crest	2	≥4	NA	NA	12 mo: 0.86; 24 mo: 1.03	12 mo: 0; 24 mo: 0
10	Astra Tech	Astra Tech	PS/1/F	NA	NA	0	>3	26	41	7-24 mo: 1.2	7-24 mo: 0.4
			PS/1/F			1.5		41		7-24 mo: 0.6	
11	Straumann	Straumann	One-piece/1/F	Crest	Crest	1.8	2.8	6	6	4 mo: 0.56; 12 mo: 0.99	4 mo: 0.32; 12 mo: 0.86
12	Straumann	Straumann	One-piece/1/F	Crest	Crest	1.8	2.8	101	100	12 mo: 0.7; 24 mo: 0.8	12 mo: 0.5; 24 mo: 0.7
13	Straumann	Straumann	One-piece/1/F	crest	1 mm subcrest	1.8	2.8	18	18	12 mo: 0.87 ±0.8	12 mo: 1.31 ±0.65
14	Klockner	Klockner	One-piece/1/F	NA	0.8 mm subcrest	0.7	1.5	37	44	3 mo: −0.35 ±0.50; 6 mo: 0.17 ±0.56; 12 mo: 0.83 ±0.68	3 mo: −0.25 ±0.59; 6 mo: 0.28 ±0.70; 12 mo: 1.05 ±0.73

AH, abutment height; F, flap; L, long; NA, not announced; No., number; PS, platform switching; Pts, patients; S, short.

(high heterogeneity if $I^2 \geq 75\%$).[29] A Galbraith plots analysis was conducted to identify studies that might cause heterogeneity.[30] The sensitivity analysis was performed by removing 1 study each time to assess the stability of the result. The potential influence of the confounding factors such as platform- or nonplatform-switching connection; submerged or nonsubmerged healing; and cement- or screw-retained restoration was analyzed by meta-regression analysis (significant if $P<.05$). The possibility of publication bias was evaluated using the Egger linear plots (significant if $P<.05$; Supplementary Fig. 1).[31]

RESULTS

The study-selection process is illustrated in a PRISMA flowchart (Fig. 1). Initial screening yielded a total of 469 records, and 294 records remained after duplicates were discarded. The review of the titles/abstracts resulted in 30 articles, 16 of which were excluded in the full-text screening. Finally, 14 studies were included in the systematic review, with 8 further included in the meta-analysis. The details of the 14 articles are reported in Table 3, and the reasons for exclusion of 16 studies[3,32-45] are presented in Table 4. Four articles are RCTs,[13,20,22,23] and the rest are CCTs. Six studies[12,13,18,20,22,23] were identified as prospective and 8 were retrospective.

Marginal bone loss was reported in all 14 studies, and meta-analysis could be conducted, with 8 studies[12-16,19,22,23] having valid data (n, mean ±standard deviation). Of those eight, 6[12-16,19] used bone-level implants and 2[22,23] used tissue-level implants. For early bone loss around bone-level implants, 1 study[12] had 2 arms using different

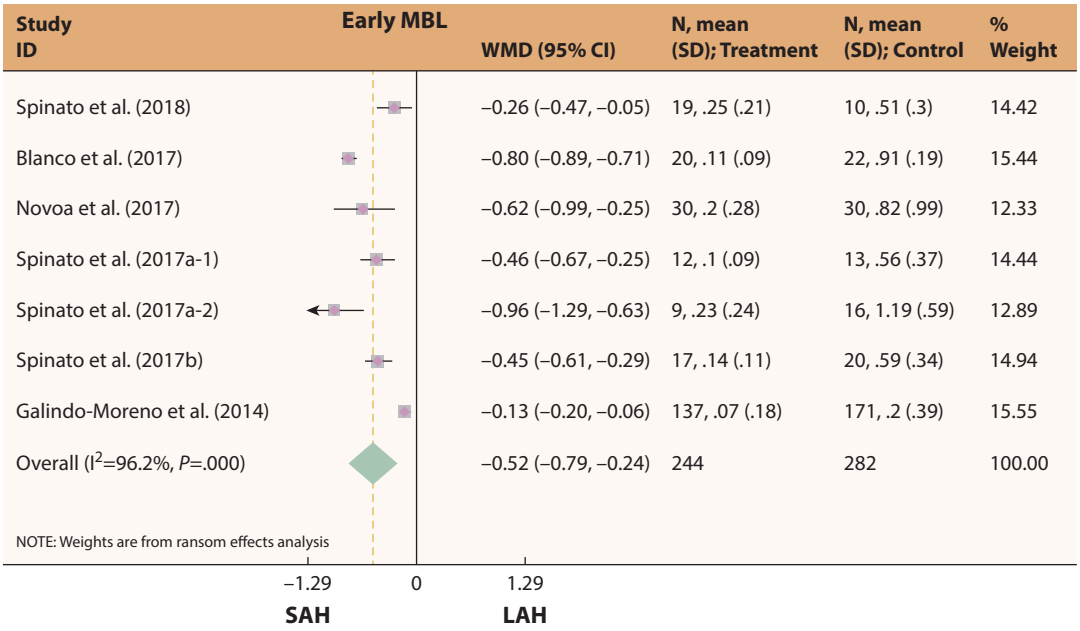

Figure 2. Meta-analysis for comparison of marginal bone loss (MBL) between bone-level implants with long abutment height (LAH) and short abutment height (SAH). CI, confidence interval; SD, standard deviation; WMD, weighted mean difference.

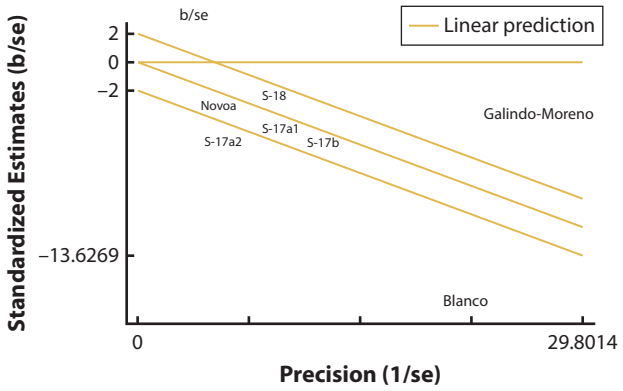

Figure 3. Galbraith plot assessing heterogeneity of studies included in comparison of marginal bone loss between bone-level implants with long and short abutment heights.

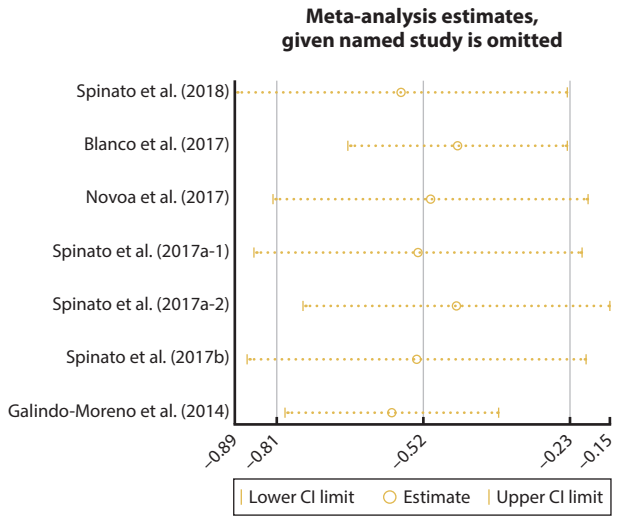

Figure 4. Sensitivity analysis of comparison of early marginal bone loss between bone-level implants with long and short abutment heights. CI, Confidence interval.

platform designs, and each of them was included in the meta-analysis as a single-study unit. Thus, 6 studies were treated as 7 units in the analysis, and WMD was −0.52 mm (95% confidence interval [CI]: −0.81 to −0.22, *P*=.001; Fig. 2), revealing less bone loss in the long-abutment group. The heterogeneity among these studies was high (I^2=97.7%, *P*<.001), and the Galbraith plots (Fig. 3) showed that 3 units were located outside of the 2 lines. After removing outliers, the heterogeneity decreased effectively (I^2=18.4%, *P*=.299), and the result remained significant (WMD: −0.42 mm, 95% CI: −0.54 to −0.30, *P*<.001). The sensitivity analysis (Fig. 4) demonstrated the robustness of the result. For the early bone loss around tissue-level implants, more resorption was found in the long-abutment group (WMD: 0.28 mm; 95% CI: 0.03 to 0.54; *P*=.031; Fig. 5), and the comparison showed a low heterogeneity (I^2=0.0%, *P*=.447). For the late bone loss, only 2 studies[16,19] using bone-level implants provided valid data. The WMD was −0.52 mm (95% CI: −1.02 to −0.02, *P*=.041; I^2=62.6%, *P*=.102; Fig. 6), favoring long-abutment height.

Considering the limited number of studies included in early bone loss (tissue-level implants) and late bone loss (bone-level and tissue-level implants), the meta-regression analysis was applied only to the early bone loss (bone-level implants) model. The results showed that different implant/

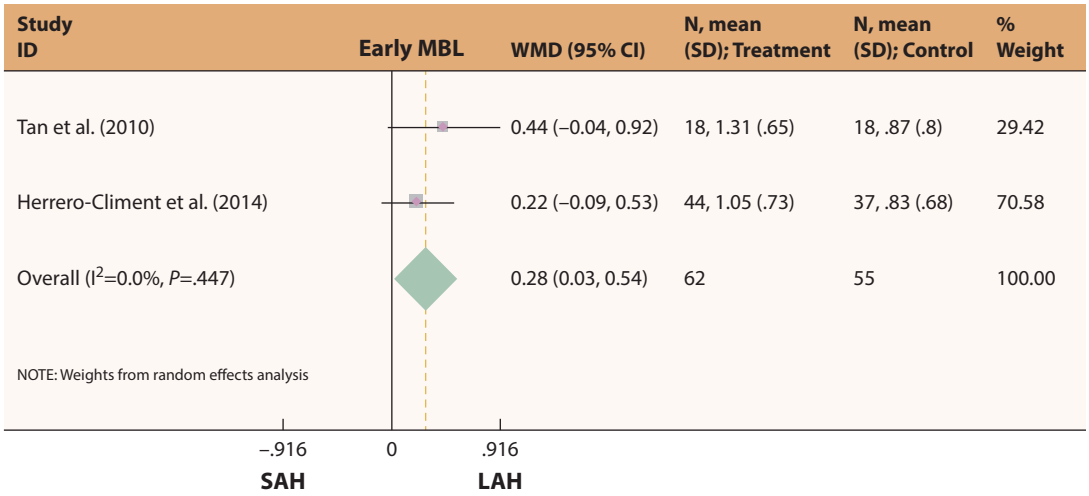

Figure 5. Meta-analysis for comparison of early marginal bone loss (MBL) between tissue-level implants with long abutment height (LAH) and short abutment height (SAH). CI, confidence interval; SD, standard deviation; WMD, weighted mean difference.

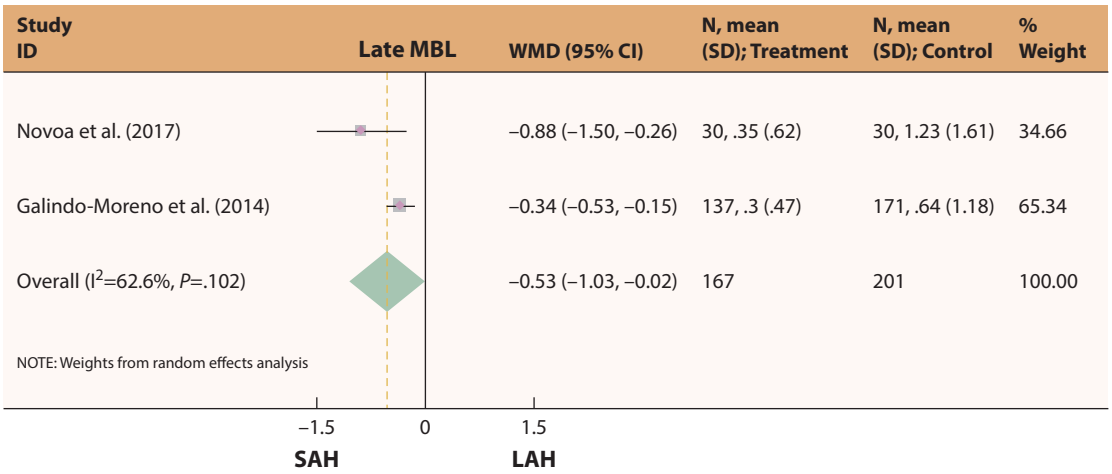

Figure 6. Meta-analysis for comparison of late marginal bone loss (MBL) between bone-level implants with long abutment height (LAH) and short abutment height (SAH). CI, confidence interval; SD, standard deviation; WMD, weighted mean difference.

abutment connection (*P*=.119), healing type (*P*=.246), and cement- or screw-retained implant restoration (*P*=.342) did not significantly impact the outcome of analyses.

Among the 4 included RCTs (Supplementary Table 1), 1 (25%) showed unclear risk of bias for random-sequence generation, 3 (66.7%) had unclear risk of bias for allocation concealment, 4 (100%) showed unclear risk of bias for blinding participants and personnel, and 3 (75%) showed unclear risk of bias for blinding of outcome assessment. Of the 10 included CCTs (Supplementary Table 2), a mean score of 5.9 (20% [seven stars], 50% [six stars], and 30% [five stars]) was obtained, showing the medium-high level of evidence.

DISCUSSION

This systemic review and meta-analysis was designed to assess radiographic marginal bone loss around implants with long or short abutments. Peri-implant marginal bone loss, in general, can be divided into initial bone remodeling for the first year and further bone loss during functional loading.[48] Therefore, the 2 reports of marginal bone loss were analyzed.

Regarding the early marginal bone loss around bone-level implants, the meta-analyses revealed that using a long abutment favored bone-level stability. Possible reasons are when the implant/abutment connection is placed at the level of the alveolar crest and the crown margin is put around the gingival margin, the abutment height reflects the soft tissue thickness. As a result, a short abutment height (≤2 mm) may indicate a thin soft tissue. Based on a previous systematic review,[49] thin tissue (≤2 mm) may cause more marginal bone loss for biologic width reformation. Second, even when the tissue is thick, a short abutment would make the gap between the crown/abutment and the bone smaller.[13,50]

Boynueğri et al[51] found that placing this gap, a microbial reservoir, apically to the bone would be associated with more inflammatory biomarkers.

For early bone loss around tissue-level implants, an opposite outcome was found in that implants with a long collar showed more bone resorption than with a short one. However, the evidence is insufficient to confirm this statement as only 2 studies[22,23] were included in the meta-analysis. In addition, implants from both the groups in these 2 studies were inserted to a depth of the same distance as the gap between the crown/abutment and bone crest. To be more specific, in 1 study,[22] implants with 1.8-mm machined collar were placed with a smooth/rough interface located at the level of bone, whereas implants with 2.8-mm collar were inserted approximately 1-mm apical to the crest. In this situation, additional bone loss in the long group may come from bone remodeling to the level of the smooth/rough interface of the implant. In addition to the studies included in the meta-analysis, Hanggi et al[21] reported that a smaller mean value of bone loss (12 months of follow-up) was found in the 2.8-mm collar group than that in the 1.8-mm collar group when all the smooth/rough interfaces were placed at the crestal level. A similar result was also noticed by Joly et al.[20] However, neither study showed a statistical difference. Possible explanations might be small sample size, smaller biologic width dimension for tissue-level implants than with bone-level implants,[52] and the 1.8-mm abutment height being close to the 2.0-mm threshold.

Regarding late bone resorption, only 2 studies using bone-level implants were eligible for meta-analysis, and the result showed additional bone loss around implants with a short abutment. In addition to these 2 articles, Vervaeke et al[17] reported bone loss around bone-level implants with overdentures after 2 years of loading and also with complete-arch fixed restorations after a mean follow-up of 9 years.[18] Both the studies were in an agreement with the current meta-analysis. In addition, Derks et al[53] reported a higher odds ratio (2.3) for peri-implantitis in implants with the crown margin positioned less than 1.5 mm from the bone. Short abutments may hamper the soft tissue seal and thereby promote bone loss beyond its initial remodeling and the onset of the disease. In addition, a deep margin could lead to excess undetected cement and plaque accumulation, which might be a long-term irritant to soft and hard tissues.[54]

The limitations of the study included that the marginal bone loss in all included studies was measured by periapical or panoramic radiographs that only provided mesiodistal aspects of the implants. Heavy contributions from the same group (3[12,14,15] of the 7 included units in meta-analysis) may cause some risk of bias. Factors such as smoking and a history of periodontal disease might increase bone loss, but some studies did not exclude participants with these conditions. Tissue thickness and gingival biotype were absent in most of the selected articles. Future studies are needed to investigate which of the factors—tissue thickness, abutment height, or platform position—are the most important or how they work together to influence bone loss.

CONCLUSION

Within the limitation of this systematic review and meta-analysis, the following conclusions were drawn:

1. Abutment height can influence early marginal bone loss around bone-level implants.
2. The evidence is insufficient to determine its impact on late marginal bone loss around bone-level implants and early and late marginal bone losses around tissue-level implants.

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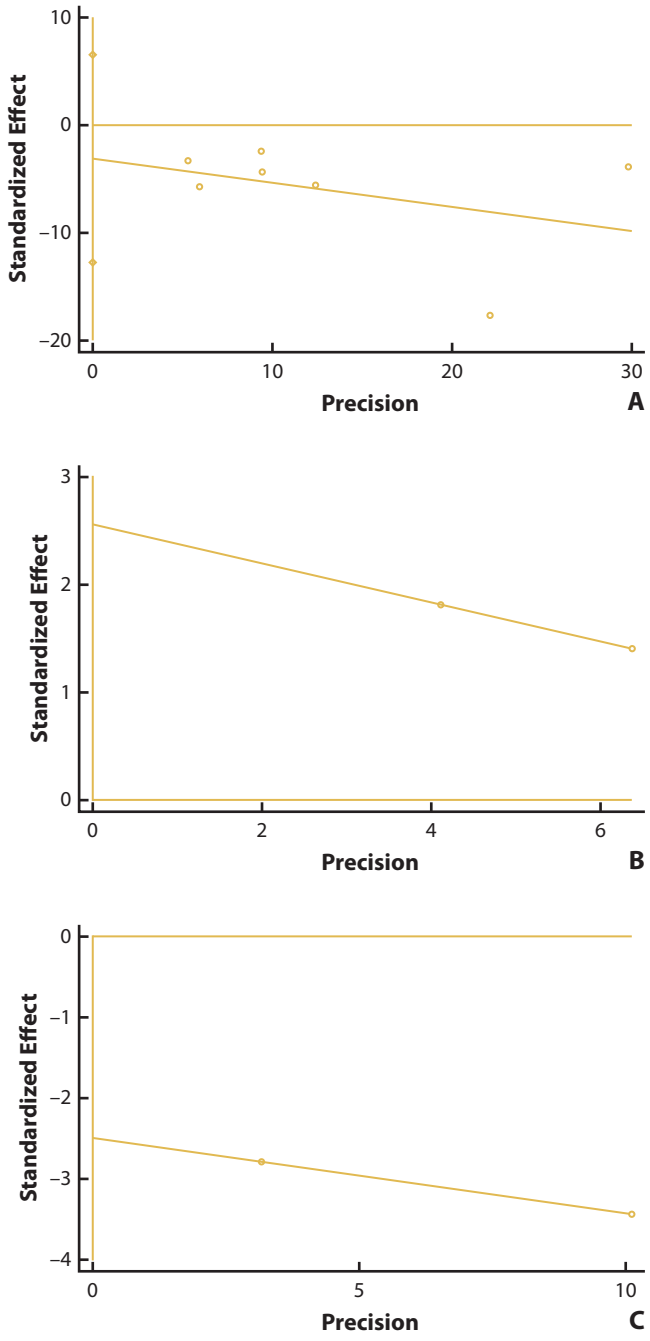

Supplementary Figure 1. Publication bias: Egger linear plots for continuous-data elements. A, Early marginal bone loss (bone-level implant) (*P*=.446). B, Early marginal bone loss (tissue-level implant). C, Late marginal bone loss (bone-level implant).

Supplementary Table 1. Quality assessment and risk of bias of included randomized controlled trials

Study	Year	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Bias
Joly et al[20]	2003	Unclear	Unclear	Unclear	Unclear	Low	Low	Low
Tan et al[22]	2010	Low	Unclear	Unclear	Unclear	Low	Low	Low
Herrero-Climent et al[23]	2014	Low	Unclear	Unclear	Low	Low	Low	Low
Blanco et al[13]	2018	Low	High	Unclear	Unclear	Low	Low	Low

Supplementary Table 2. Quality assessment and risk of bias of included nonrandomized studies

Study	Year	Representative of exposed cohort	Selection of nonexposed cohort	Ascertainment of exposure	Outcome of interest not present at start of study	Comparability of cohorts on basis of design or analysis	Assessment of outcome	Sufficient follow-up for outcome to occur	Adequacy of follow-up	Total
Collaert and De Bruyn[46]	2002	★	★	★	☆	☆☆	☆	★	★	5
Hanggi et al[21]	2005	★	★	★	☆	☆☆	☆	★	★	5
Galindo-Moreno et al[19]	2014	★	★	★	☆	☆☆	★	★	★	6
Galindo-Moreno et al[47]	2016	★	★	★	☆	☆☆	☆	★	★	5
Spinato et al[12]	2018	★	★	★	☆	★☆	☆	★	★	6
Spinato et al[14]	2017	★	★	★	☆	★☆	★	★	★	7
Spinato et al[15]	2017	★	★	★	★	☆☆	★	★	★	7
Nóvoa et al[16]	2018	★	★	★	☆	☆☆	★	★	★	6
Vervaeke et al[18]	2016	★	★	★	☆	★☆	☆	★	★	6
Vervaeke et al[17]	2014	★	★	★	☆	★☆	☆	★	★	6

White- and black-colored stars represent non-conformity and conformity, respectively.