Review

Influence of Laser-Microtextured Surface Collar on Marginal Bone Loss and Peri-Implant Soft Tissue Response: A Systematic Review and Meta-Analysis

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Background: A laser-microtextured surface (LMS) dental implant collar appears to promote a more tooth-like gingival collagen fiber attachment, which may help to stabilize peri-implant tissues. The purpose of this systematic review is to assess the clinical effect of an LMS versus non-LMS collar on crestal bone level and peri-implant soft tissue response.

Methods: Electronic and manual literature searches were performed by two independent reviewers for articles written in English up to December 2016. Studies were included if they were human clinical trials with the purpose of evaluating the impact of an LMS collar on peri-implant hard and soft tissues. Cumulative marginal bone loss (MBL), probing depth (PD), and survival rate (SR) with 95% confidence intervals (CIs) were calculated to show the performance of LMS implant collars. MBL, PD, and SR data were analyzed with a random effects model to compare the influence of LMS collars with non-LMS collars (e.g., roughened surface and machined surface).

Results: Fifteen human clinical studies (three randomized controlled trials, six cohort studies, and six case series) with 772 implants met the inclusion criteria. For the overall data, the weighted mean MBL was 0.72 mm (95% CI: 0.59 to 0.85 mm), PD was 1.81 mm (95% CI: 1.13 to 2.49 mm), and SR was 0.97 (95% CI: 0.95 to 0.98). MBL around an LMS collar was significantly less than around machined-surface collars (weighted mean difference [WMD]: –0.77; 95% CI: –1.01 to –0.52; I^2 = 95.2%; P <0.001). PD in the LMS group was significantly shallower than in the machined-surface group (WMD: –1.34; 95% CI: –1.62 to –1.05; I^2 = 81.4%; P <0.001). However, no statistically significant difference was detected for MBL between the LMS and roughened-surface groups (WMD: –0.04; 95% CI: –0.16 to 0.08; I^2 = 0.0%; P = 0.75). No statistically significant difference was found for SR between the LMS and non-LMS groups (risk ratio: 1.01; 95% CI: 0.97 to 1.04; I^2 = 0.0%; P = 0.91).

Conclusions: Meta-analysis showed that an LMS collar can reduce the amount of MBL and PD compared with a machined-surface collar. Due to high heterogeneity between the included studies, results should be interpreted cautiously. *J Periodontol 2017;88:651-662.*

KEY WORDS

Alveolar bone loss; dental implants; evidence-based dentistry; meta-analysis as topic; review literature as topic.

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Marginal bone loss (MBL) after loading of implants is regarded as a determining factor of esthetic outcome and survival.[1-4] Generally, the acceptable MBL is ≤1.5 mm during the first year and not exceeding 0.2 mm per year afterward.[5,6] Since the attachment between the conventional implant collar and soft tissue is weak, many factors, such as peri-implant inflammation and mechanical injuries, may break down this fragile attachment and cause continuous MBL.[7] In turn, excessive MBL may also induce pocket formation, which could be unfavorable for the health of peri-implant tissues.[8,9]

Novel collar configurations and topographic characterizations have been proposed[10-13] to promote soft and hard tissue integration around the implant, and to preserve crestal bone level and soft tissue health. One promising design modification is a laser-microtextured surface (LMS) collar,[14] in which a computer-controlled laser ablation technique is used to texture neck segments of implants with 8- and 12-μm microgrooves. Compared with human gingival fibroblasts on titanium or zirconia surfaces, those on LMSs had a more mature morphology and greater proliferation and differentiation, creating a better soft tissue seal around implants.[15] Histologic studies[16-19] demonstrated that, unlike fibers aligned in a direction parallel and circumferential to the traditional implant neck as a fibrous capsule, fibers around an LMS present with a perpendicular, functional physical attachment. This kind of attachment is similar to that of a natural tooth, which is indispensable as a barrier against bacterial infection,[16] helping to stabilize peri-implant soft tissue and diminish MBL.[20] Several clinical studies have found that LMS collars could improve marginal bone preservation[21-36] and reduce probing depth (PD).[22-25,28-36] However, some scholars[27,30] have different opinions, stating that there is no significant difference in MBL around an LMS compared with a roughened-surface. To date, there is no consensus in the literature with regard to the effectiveness of LMS compared with non-LMS configurations and the influence of an LMS collar on peri-implant tissues.

Therefore, it is necessary to make a systematic review and conduct a meta-analysis of available publications with regard to the impact of an LMS collar on MBL, PD, and survival rate (SR) around implants compared with a non-LMS collar, in order to identify whether the LMS collar has clinical superiority and to develop recommendations for future research.

MATERIALS AND METHODS

This systematic review and meta-analysis was written and conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement,[37] and the protocol was registered in PROSPERO (CRD 42016050661).

Focus Question

The focus question was developed considering the Population, Intervention, Comparison, and Outcome (PICO) elements:[38] in patients who receive dental implant treatment, does the use of an LMS collar, compared with a non-LMS collar, result in less MBL, shallower PD, and lower implant failure rate?

Selection Criteria

Eligible studies were included in this systematic review if they met the following inclusion criteria: human clinical trials (prospective or retrospective, randomized or not, cohort or case series trials) aimed at appraising the impact of laser-microtextured collars on MBL, PD, and SR. The additional inclusion criteria for study selection were studies with 1) ≥10 patients and 2) a mean follow-up period after loading of implants ≥12 months.

Screening Process and Study Selection

Electronic literature searches were performed in four databases, including MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Oral Health Group Trials Register, for articles written in English up to December 2016.

For the PubMed library, the search terms were as follows: ((((“dental implants”[MeSH Terms] OR “dental implantation”[MeSH Terms]) OR “dental implantation, endosseous”[MeSH Terms]) OR oral implant[Title/Abstract]) OR implant[Title/Abstract]) AND ((((laser-microtextured[Title/Abstract] OR laser-lok[Title/Abstract]) OR laser-etched[Title/Abstract]) OR laser-modified[Title/Abstract]) OR laser microgrooved[Title/Abstract]). For EMBASE, the search strategy was: “tooth implant”/explosion OR “tooth implantation”/exp OR implant:ab,ti AND (“laser microtexured”:ab,ti OR “laser lok”:abstract, title OR “laser etched”:abstract, title OR “laser modified”:abstract, title OR microthread:abstract, title OR microgrooved:abstract, title). For the Cochrane Library, laser-microtextured OR laser-lok OR laser microgrooved was applied in Title, Abstract, and Keywords in Trials.

Additionally, to complete the survey, a hand search was performed in implant-related journals: *Journal of Clinical Periodontology*, *Journal of Periodontology*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Implant Dentistry*, *European Journal of Oral Implantology*, *Journal of Oral Implantology*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Oral and Maxillofacial Surgery*, and *International Journal of Periodontics and Restorative Dentistry*.

References of selected studies and related reviews were further scanned for potentially relevant articles.

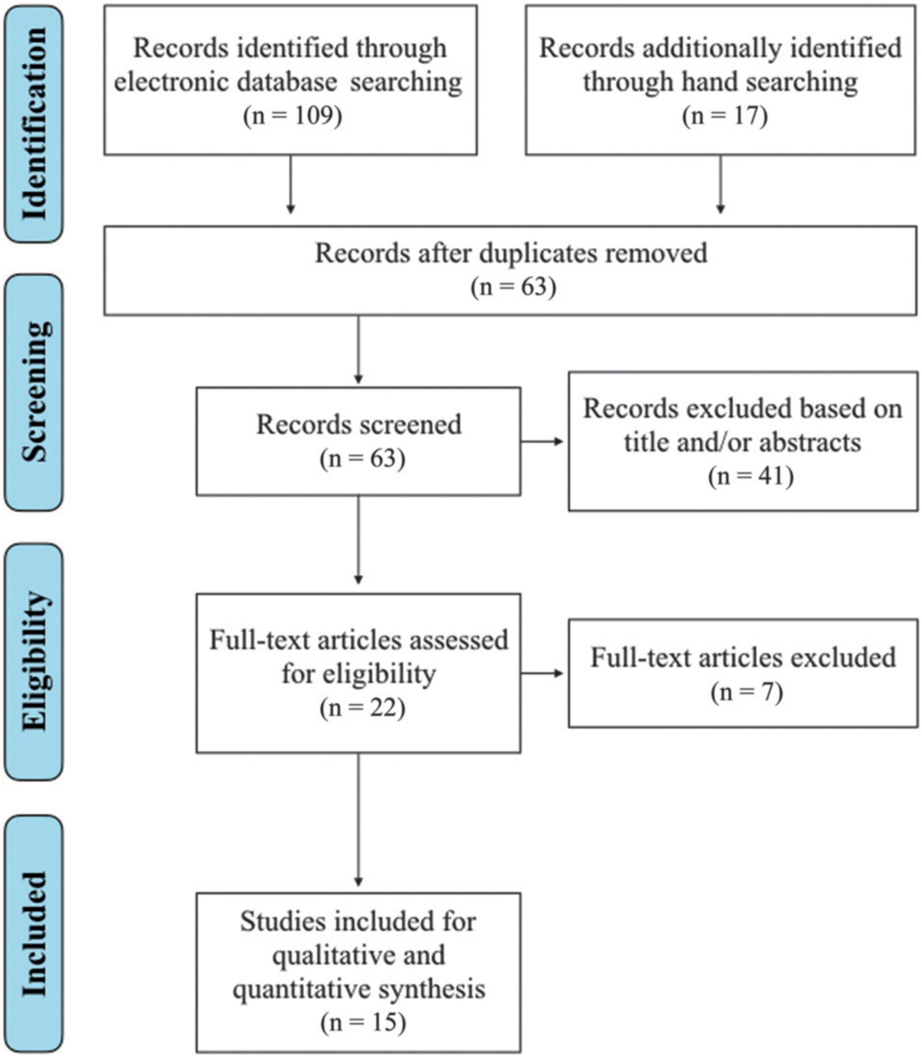

Figure 1.
PRISMA flowchart illustrates the publication selection process.

The screen process was carried out by two reviewers (ZC and YZ), who independently ran the search and performed the study selection. According to selection criteria, titles and abstracts of search results were screened, and screening of the full-text articles was conducted. In the presence of duplicate publications, only the study with the most inclusive data was selected. A consent final decision was reached by discussion.

Quality Assessment

Two independent reviewers (ZC and JL) evaluated all the included studies. Any disagreement was resolved by discussion. Randomized controlled trials (RCTs) were assessed with the RCT checklist of the Cochrane collaboration,[39] including: 1) selection bias: random sequence generation/allocation concealment; 2) performance bias: masking of participants and personnel; 3) detection bias: masking of outcome assessment; 4) attrition bias: incomplete outcome data; 5) reporting bias: selective outcome reporting; and 6) other possible sources of bias. For each domain, an estimated risk of bias ("low," "high," or "unclear") was assigned. The Newcastle-Ottawa Scale[40] was applied for quality assessment of the included cohort studies. Each study was judged on eight items categorized into three groups: 1) selection of cohorts (four items); 2) comparability of the cohorts (one item); and 3) ascertainment of the outcome (three items). One star is awarded for each item in "selection" and "outcome" if the criteria are fulfilled, whereas "comparability" can be awarded a maximum of two stars. Final scores ranged from 0 to 9, with 0 to 3 considered low, 4 to 6 moderate, and 7 to 9 high quality.

Data Extraction and Statistical Analyses

Two reviewers (ZC and YZ) extracted the data from the eligible studies independently. Any interreviewer disagreement was resolved by discussion. Corresponding authors were contacted in cases of missing or unclear data.

All statistical analyses were conducted using one statistical software program.§ For the overall studies, the cumulative MBL, PD, and SR of LMS implants with 95% confidence intervals (CIs) were calculated using a random effects model to avoid potential bias caused by methodologic differences between studies. Data of MBL, PD, and SR were analyzed with a random effects model to compare the influence of an LMS collar and non-LMS collar (e.g., roughened-surface and machined-surface). Heterogeneity was estimated by the Q statistic (significant at $P<0.10$) and quantified with the I^2 test. The value of $I^2 \geq 75\%$ suggests high heterogeneity.[41] Galbraith plots analyses were conducted to investigate the potential source of heterogeneity.[42]

The possibility of publication bias (see supplementary Fig. 1 in online *Journal of Periodontology*)

§ Stata software, v14.0, StataCorp, College Station, TX.

Table 1.

Overview of Studies Included in Systematic Review

Study (year)	Study Type	Patients, n (males/ females)	Mean Age, years (range)	Arch	Follow-Up Period, months	Collar Surface Type	Implants System	Implants, n	Failed/ Placed Implants, n	MBL, mean ± SD mm	PD, mean ± SD mm	Placement Protocol	Loading / Restoration Protocol	Type of Restoration
Botos et al. (2011)[28]	Cohort	15 (8/7)	57 (40 to 74)	Anterior mandible	12	M	*	15	1/16	1.13 ± 0.61	1.64 ± 0.93	Delayed	Imm. loading	OD
						LMS	†	15	1/16	0.42 ± 0.34	0.43 ± 0.51			
						M	*	14	0/14	0.55 ± 0.32	NA		Unloaded	None
						LMS	†	14	0/14	0.29 ± 0.2	NA			
Farronato et al. (2014)[33]	RCT	77 (36/42)	49.3 (45 to 65)	Maxilla & mandible	36	M	‡	38	1/39	1.24 ± 0.28 (mean) 1.24 ± 0.35 (mesial) 1.38 ± 0.26 (distal)	1.81 ± 0.47 (mean) 1.80 ± 0.30 (mesial) 1.98 ± 0.41 (distal) 1.73 ± 0.54 (midfacial)	Delayed	Imm. restor.	SC
						LMS	§	38	1/39	0.65 ± 0.22 (mean) 0.61 ± 0.34 (mesial) 0.70 ± 0.11 (distal)	0.54 ± 0.32 (mean) 0.56 ± 0.33 (mesial) 0.61 ± 0.29 (distal) 0.48 ± 0.32 (midfacial)			
Gopalakrishnan et al. (2014)[24]	CS	13 (8/5)	NA	Maxilla & mandible	18	LMS	§	20	0/20	1.06 ± 0.30 (mean) 1.13 ± 0.32 (mesial) 1.00 ± 0.28 (distal)	2.56 ± 0.59	Delayed	6 months	SC
Grande et al. (2013)[25]	CS	35	NA	Maxilla & mandible	24	LMS	§	75	5/107	0.66 ± 1.3	NA	Delayed	Imm. loading	FP (2 units/3 units/4 units)
Guarnieri et al. (2014)[23]	CS	46 (24/22)	45.5 (26 to 60)	Anterior maxilla	24	LMS	§	44	2/46	0.58 ± 0.62 (mean) 0.58 ± 0.53 (mesial) 0.57 ± 0.70 (distal)	1.52	Immediate	Imm. restor.	SC
Guarnieri et al. (2014)[36]	Cohort	300 (155/145)	49.3 (45 to 75)	Maxilla & mandible	24	M	‡	135	5/140	1.09 ± 0.37	NA	Immediate / Delayed	Imm. restor. /4 months	SC
						LMS	§	156	4/160	0.58 ± 0.17	NA	Immediate / Delayed	Imm. restor./4 months	
Guarnieri et al. (2016)[31]	RCT	17	57.1	Maxilla & mandible	12	M	‡	17	0/17	0.353 ± 0.17 (mean) 0.333 ± 0.14 (healthy subgroup) 0.388 ± 0.21 (compromised subgroup)	2.75 ± 0.87 (mean) 2.66 ± 0.83 (healthy subgroup) 2.84 ± 1.0 (compromised subgroup)	Delayed	3 to 4 months	SC
						LMS	§	17	0/17	0.188 ± 0.06 (mean) 0.171 ± 0.04 (healthy subgroup) 0.204 ± 0.09 (compromised subgroup)	1.46 ± 0.52 (mean) 1.31 ± 0.51 (healthy subgroup) 1.61 ± 0.58 (compromised subgroup)			
Guarnieri et al. (2016)[22]	CS	12 (7/5)	42	Anterior maxilla	36	LMS	§	12	0/12	0.35 ± 0.18	NA	Immediate	Imm. restor.	SC
		13 (8/5)	40			LMS	§	13	0/13	0.42 ± 0.21	NA	Delayed	Imm. restor.	
Gultekin et al. (2016)[34]	Cohort	62 (28/34)	52.24 ± 13.38 (23 to 76)	Maxilla & mandible	36	M	‡	56	0/56	1.34 ± 0.25	3.37 ± 0.29	Delayed	3 months	SC/FP
						LMS	§	47	0/47	0.53 ± 0.28	2.31 ± 0.42			

Table 1. (continued)

Overview of Studies Included in Systematic Review

Study (year)	Study Type	Patients, n (males/ females)	Mean Age, years (range)	Arch	Follow-Up Period, months	Collar Surface Type	Implants System	Implants, n	Failed/ Placed Implants, n	MBL, mean ± SD mm	PD, mean ± SD mm	Placement Protocol	Loading / Restoration Protocol	Type of Restoration
Hegazy et al. (2016)[30]	RCT	36 (24/12)	61.9 ± 6.69 63.3 ± 5.01	Anterior mandible	12	R LMS	‖ §	30 30	0/30 0/30	1.51 ± 0.34 1.45 ± 0.31	2.4 ± 0.15 2.3 ± 0.5	Delayed	Early loading (2 weeks)	OD
Iorio-Siciliano et al. (2015)[35]	Cohort	45	47.2 ± 10.7	NA	60	M	‡	28	3/31	2.02 ± 0.32 (mean) 2.03 ± 0.3 (mesial) 2.01 ± 0.34 (distal)	4.2 ± 0.78 (mean) 4.1 ± 0.6 (mesial) 4.3 ± 0.9 (buccal) 4.3 ± 0.7 (distal) 4.1 ± 0.9 (lingual)	Delayed	4 to 6 months	SC/FP
			47.7 ± 12			LMS	§	32	2/34	0.81 ± 0.24 (mean) 0.87 ± 0.21 (mesial) 0.75 ± 0.25 (distal)	2.3 ± 0.46 (mean) 2.3 ± 0.5 (mesial) 2.1 ± 0.3 (buccal) 2.4 ± 0.5 (distal) 2.4 ± 0.5 (lingual)			
Iorio-Siciliano et al. (2016)[21]	CS	20 (7/13)	46.5 ± 11.4	NA	24	LMS	§	20	0/20	0.70 ± 0.16 (mean) 0.72 ± 0.16 (mesial) 0.67 ± 0.15 (distal)	2.57 ± 0.70 (mean) 2.6 ± 0.50 (mesial) 2.5 ± 0.69 (lingual) 2.6 ± 0.69 (distal) 2.55 ± 0.94 (buccal)	Delayed	3 to 6 months	SC
Linkevicius et al. (2015)[27]	Cohort	30 (12/18)	42.3 ± 2.4 (20 to 55)	Posterior mandible	12	R LMS	¶ §	30 30	0/30 0/30	1.43 ± 0.23 1.41 ± 0.42	NA NA	Delayed	2 months	FP (splinted/ 3-unit FP)
Pecora et al. (2009)[29]	Cohort	15 (6/9)	55.8 (42 to 69)	Maxilla & mandible	37	M LMS	NA †	20 19	0/20 1/20	1.94 0.59	NA NA	Delayed	4 months	FP
Shapoff et al. (2010)[26]	CS	41	62	Maxilla & mandible	36	LMS	§	30	1/50	0.46 ± 0.12	NA	Immediate/ Delayed	4.8 months	FP

M = machined-surfaced collar; NA = not available; Imm. = immediate; OD = overdenture; Imm. restor. = immediate restoration; SC = single crown; CS = case series; FP = fixed partial denture; R = roughened-surface collar.
* NobelReplace, Nobel Biocare, Gothenburg, Sweden.
† Silhouette Laser-Lok, Bio-Lok International, Deerfield Beach, FL.
‡ RBT tapered internal implant, BioHorizons, Birmingham, AL.
§ Laser-Lok tapered internal implant, BioHorizons.
‖ NanoTite, Biomet 3i, Palm Beach Gardens, FL.
¶ Certain Prevail, Biomet 3i.

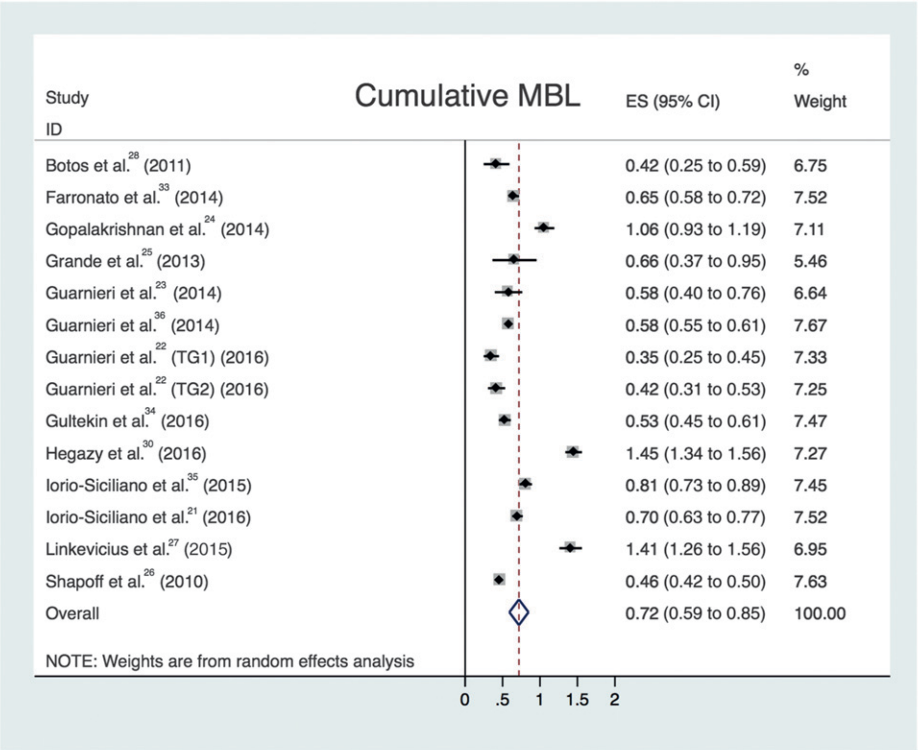

Figure 2.
Cumulative MBL in selected studies with a duration of at least 12 months. ES = effect sizes.

was assessed with Egger funnel plots for continuous data elements and with the Harbord test for dichotomous data. A significant publication bias was considered if $P < 0.05$.[43] However, results of these tests were not separately reported since this method is considered unreliable when studies included in the meta-analysis are <10.

RESULTS

Screening Process

The study selection process is illustrated in a flowchart (Fig. 1). One hundred and nine records were retrieved from the electronic search and 17 records by hand searching. After duplicates were discarded, 63 records remained. Review of the titles and abstracts resulted in 22 articles identified as full-text articles, and seven were excluded for the following reasons: follow-up <12 months;[44,45] redundant studies;[32] LMS design not only in implant neck;[21,46] performed with additional surgeries such as hard[47] or soft tissue[48] augmentation. Finally, 15 eligible articles[21-31,33-36] were included in this study. The characteristics of the included studies are presented in Table 1.

Description of the Studies

Study design. Three articles are RCTs[30,31,33] and six are cohort studies.[27-29,34-36] Six case series[21-26] observing implants with LMS collars without controls were also included to evaluate the overall performances of the LMS design. All articles were published from 2009 to 2016. Ten studies[21,23-25,27-31,33] were identified as prospective studies, and five studies[22,26,34-36] were retrospectively designed.

Sample size and duration of follow-up. A total of 772 dental implants were placed, and of these, 393 implants were LMS, 319 machined-surface, and 60 roughened-surface. There are four studies[27,28,30,31] with controlled groups providing data with follow-up periods of 12 months, one study[36] with a follow-up period of 24 months, three studies[29,33,34] with follow-up periods of 36 months, and one study[35] with 5-year follow-up. Most of the case series were short-term, with an observation period of 18 months in one study,[24] 24 months in three studies,[21,23,25] and 36 months in two studies.[22,26]

Prosthesis type, placement, and loading protocol. Two articles[28,30] were designed to support overdentures, and the remaining 13 articles to support fixed prostheses. For fixed reconstruction, seven articles[21-24,31,33,36] studied implant-supported single crowns only, another three[25,27,29] reported on implant-supported fixed partial dental prostheses only, and the remaining two studies[34,35] had both types of prostheses. Regarding the placement and loading protocol, seven studies[21,24,27,29,31,34,35] used the delayed placement and delayed loading protocol; two studies[22,28] adopted the delayed placement and immediate restoration protocol; two studies[25,28] reported the delayed placement and immediate loading protocol; and one study[30] used the delayed placement with early loading protocol.

Quality Assessment

The risk of bias in three included RCTs was assessed and summarized (see supplementary Table 1 in online *Journal of Periodontology*). Two studies[30,33] (66.7%) had unclear risk of bias for allocation concealment, one study[30] (33.3%) had high risk and two studies[31,33] (66.7%) had unclear risk of bias for participants and personnel, and two studies[30,33] (66.7%) had unclear risk of bias for blinding of outcome assessment. Of the six included cohort studies, a mean score of 6.67 ± 0.52 (66.7% seven

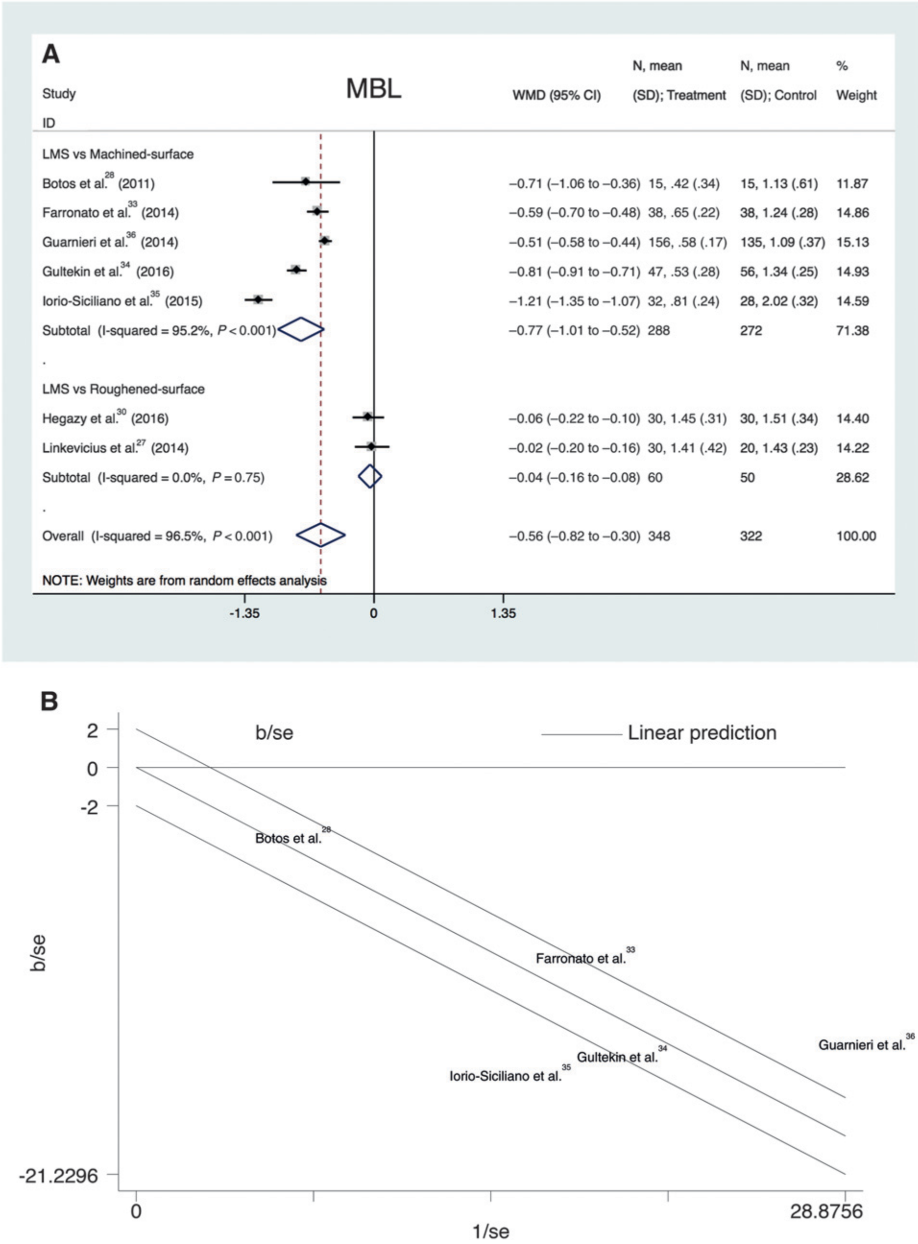

Figure 3.
A) *Meta-analysis for the comparison of MBL between LMS and non-LMS neck implants (overall), between LMS and machined-surfaced neck implants, and between LMS and roughened-surfaced neck implants.* ***B)*** *Galbraith plot assessing heterogeneity of the studies included in the comparison of MBL between LMS and machined-surfaced neck implants. b/se = standardized estimates; 1/se = precision.*

stars,[27,28,35,36] 33.3% six stars[29,34]) was obtained, showing the "medium-high" level of evidence of the included studies (see supplementary Table 2 in online *Journal of Periodontology*). For the six case series, the majority[21,23-25] were prospective in design with consecutively enrolled patients.

Results of Meta-Analyses for MBL

There were two RCTs,[30,33] five cohort studies,[27,28,34-36] and six case series[21-26] providing valid data of MBL. Radiographic evaluation of MBL was performed by means of periapical radiographs in all included studies. MBL at the longest follow-up interval was included in the analysis when it was measured at more than one follow-up interval in the study. One study[22] had two LMS-collar arms with different placement protocols, and each of them were included in the meta-analysis as a single study unit. Thus, the remaining 13 studies were treated as 14 study units in the analysis. The weighted mean MBL in implants with LMS collars after a follow-up of at least 12 months was estimated to be 0.72 mm (95% CI: 0.59 to 0.85 mm) (Fig. 2). The results of MBL around implants with and without an LMS collar were further analyzed. Among the selected studies, five,[33-36] examined LMS and machined-surface collars, whereas two studies[27,30] compared LMS collars with roughened-surface collars. The result demonstrated that the MBL in LMS was less than in the machined-surface group (weighted mean difference [WMD]: –0.77, 95% CI: –1.01 to –0.52) (Fig. 3A), with significant heterogeneity between these studies (I^2 = 95.2%; P <0.001). The Galbraith plot (Fig. 3B) showed that the considerable heterogeneity was generated by two studies. With these studies removed, the heterogeneity decreased effectively (I^2 = 15.6%; P = 0.31), and the result remained significant (WMD: –0.54, 95% CI: –0.61 to –0.47). No significant difference was detected between the LMS and roughened-surface groups (WMD: –0.04, 95% CI: –0.16 to 0.08, I^2 = 0.0%; P = 0.75).

Results of Meta-Analyses for PD

Valid PD data were provided in eight of the 15 studies, including three RCTs,[30,31,33] three cohorts,[28,34,35] and two case series.[21,24] The weighted mean PD around LMS collars was estimated to be 1.81 mm (95% CI: 1.13 to 2.49 mm) (Fig. 4A). LMS collars and

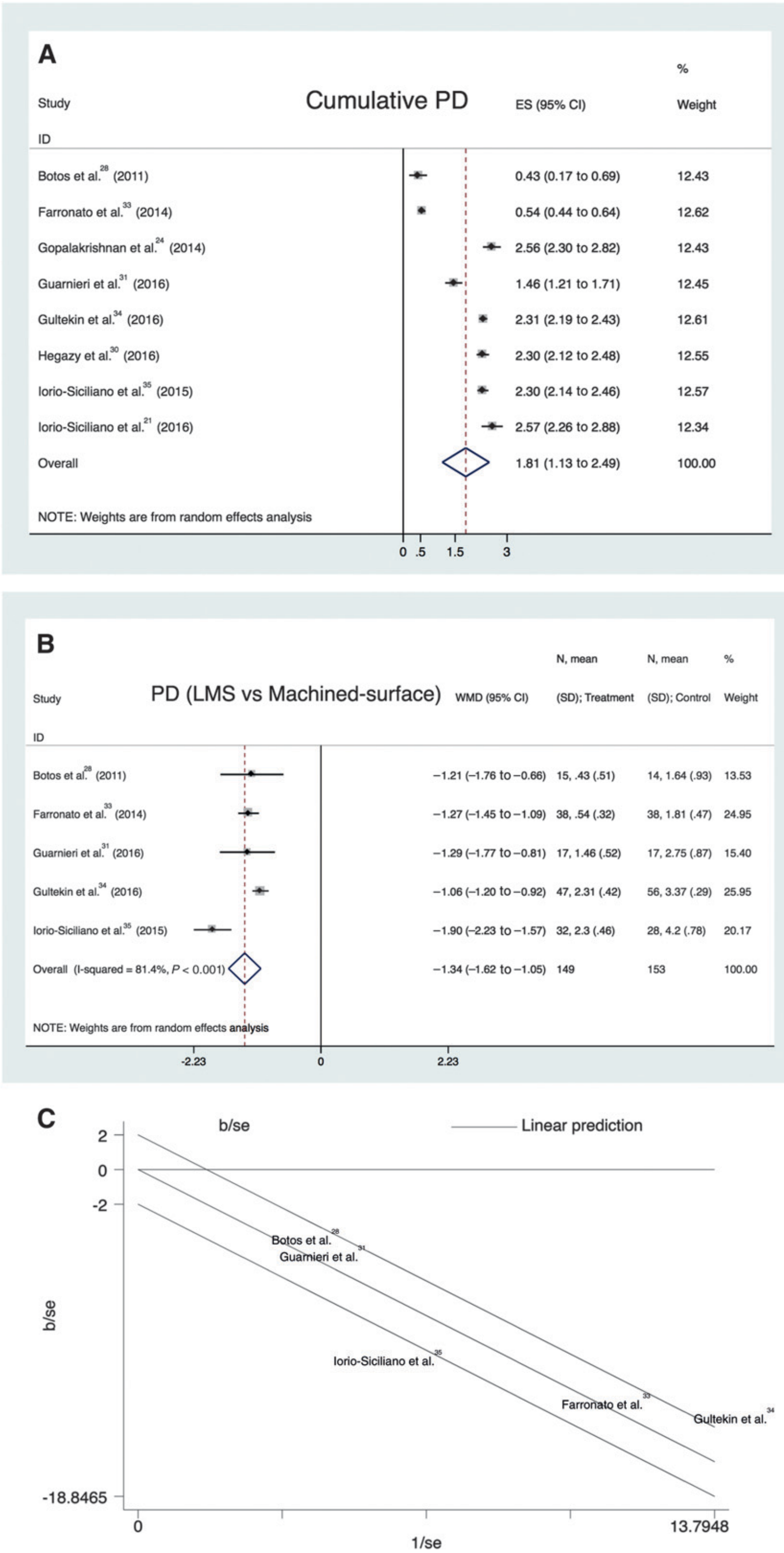

Figure 4.
A) *Cumulative PD in selected studies with a duration of at least 12 months.* ***B)*** *Forest plot for PD in the comparison between LMS and machined-surface neck implants.* ***C)*** *Galbraith plot assessing heterogeneity of studies included in the comparison of PD between LMS and machined-surface neck implants. ES = effect sizes; b/se = standardized estimates; 1/se = precision.*

machined-surface collars were examined in five studies,[28,31,33-35] and only one study compared LMS collars with roughened-surface collars.[30] Implants with LMS collars had shallower PDs compared with implants with machined-surface collars (WMD: –1.34, 95% CI: –1.62 to –1.05) (Fig. 4B). However, a high degree of heterogeneity was noted (I^2 = 81.4%; P <0.001). The Galbraith plot (Fig. 4C) demonstrated that the heterogeneity mainly came from one study.[35] After excluding data from this study, the homogeneity test showed acceptable heterogeneity among the remaining four studies (I^2 = 16.8%; P = 0.31), and results showed that the WMD was –1.16 mm (95% CI: –1.29 to –1.03 mm).

Results of Meta-Analyses for SR

SR was assessed in 15 studies.[21-31,33-36] Meta-analysis of these data showed failure rate of implants with LMS collars of 3% (95% CI: 2% to 5%) (Fig. 5A). No statistically significant difference was shown between SR of implants with LMS and non-LMS collars (risk ratio [RR]: 1.01, 95% CI: 0.97 to 1.04, I^2 = 0.0%; P = 0.91) (Fig. 5B).

DISCUSSION

In this review, the WMD showed implants with an LMS collar to have significantly less MBL and PD than the machined-surface group. The result suggests that LMS design is effective for prevention of peri-implant bone loss. Reasons may be as follows. First, there is increased resistance to probing as perpendicular fibers establish a functional physical attachment in the neck of LMS implants. Second, a firm connective tissue (CT) attachment to LMS implants can diminish apical migration of epithelial tissue and prevent invasion of bacterial toxins, conferring resistance to the alveolar bone against resorption.[49] Third, the in vitro study demonstrated that high stress concentration was found in the area of crestal bone around the machine-turned neck,[50] which may lead to crestal bone dieback to the level of the first implant thread.[51]

No significant difference in MBL was detected between LMS and roughened-surface groups. However, the present review did not have sufficient evidence to confirm this statement, as only two

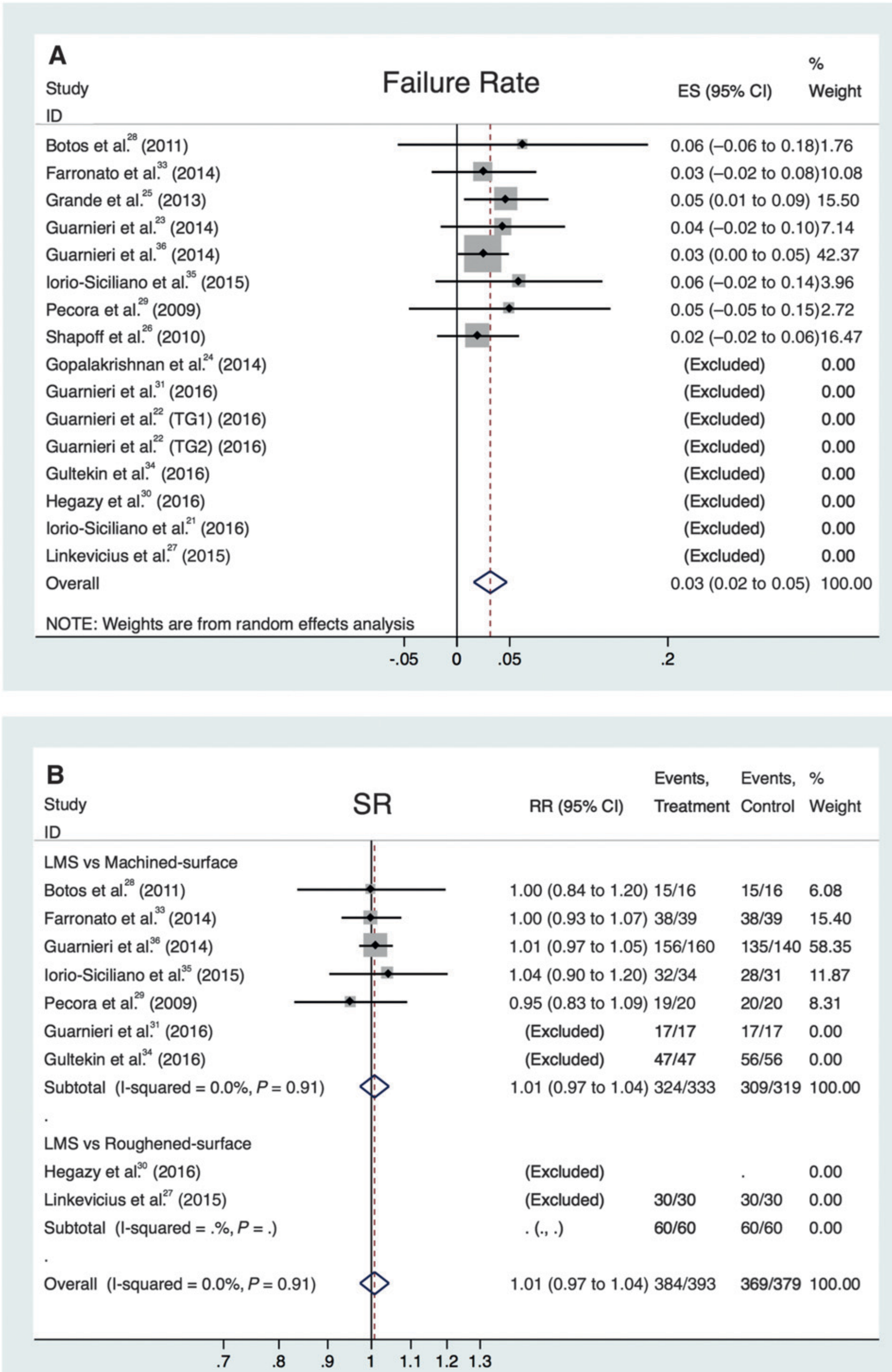

Figure 5.
A) *Forest plot analysis of implant survival for the 15 studies reviewed.* ***B)*** *Forest plot for SR in the comparison between LMS and non-LMS neck implants (overall), LMS and machined-surfaced neck implants, and LMS and roughened-surfaced neck implants. ES = effect sizes.*

articles[27,30] compared MBL in those two groups. The roughened-surface group in one study[30] was nanosurface-treated. It has been reported that a nanoscale-textured surface can augment surface energy and improve osseointegration compared with the normal acid-etched roughened implant surface.[52] This may indicate that both the LMS and nanoscale-textured surface have an effect on MBL. Meanwhile, the other study[27] only included implant sites with soft tissue thickness <2 mm, which may reduce the benefit of the ability of the LMS to diminish MBL. As a minimum, 2 mm of soft tissue thickness is required for the establishment of the biologic width; the latest meta-analysis[53] confirmed that in the presence of thin tissue (<2 mm), higher values of MBL will occur.

The results of the meta-analysis – even the significant mean differences of MBL and PD favoring the LMS design compared with a polished collar – should be interpreted with caution, since the comparisons presented considerable heterogeneity. Several confounding factors, such as different study designs; follow-up periods; and clinician-, implant-, and patient-related elements, may contribute to MBL and PD. For example, insertion depth in some of the studies differed or was not clearly addressed when characterizing the surgical procedure. When the implant is placed crestally or subcrestally, the laser-microtextured surface is in contact mostly with the bone and not with the CT, which may reduce the benefit of the physical CT attachment compared with when the implant is placed supracrestally.[34] Regarding the type of prostheses design, most included studies rehabilitated the patients with fixed prostheses. However, details of the retention type were frequently not present, which cannot eliminate the influence of cement[54] on MBL and PD as possible etiology. In addition, implant-abutment connection type is also an important factor in MBL.[55,56] Nevertheless, these data were not sufficiently clear in some of the included studies. The study population has several confounding factors for peri-implant MBL and PD. Among patient-related factors, periodontal health condition[57] and smoking[57-59] are considered to be associated with increased MBL. However, only one study[31] investigated the periodontal health condition and found that in both of the subgroups of patients (periodontally healthy and periodontally compromised), LMS collars have a better clinical outcome compared with machined-surface collars. None of the studies investigated the influence of LMS collar design on MBL and PD while comparing smokers with non-smokers.

The limitations of this meta-analysis should be acknowledged. 1) Most of the included studies had small sample sizes and short follow-up periods. 2) There were inconsistencies in methodologies, various treatment modalities, and different implant systems. 3) It is important to state that eight[21-23,25,31,33,35,36] of the 15 included studies were conducted by the same research group. Heavier contributions from the same research group may cause some risk of bias attributable to data overlapping. 4) Radiographic evaluation of MBL was performed by means of periapical radiographs in all included studies, which only showed the mesial and distal aspects of an implant but missed the information of buccal and lingual bone. 5) The present review includes only English-language publications, which may have introduced selection bias. Therefore, there is a substantial need for RCTs with longer follow-up periods, powerful sample size, and without mixed design, comparing the hard and soft tissue responses around implants with and without LMS collars, to provide stronger evidence of the possible benefits of LMS implants for marginal bone preservation and peri-implant health.

CONCLUSIONS

Within the limitations of this systematic review and meta-analysis, the following conclusions were drawn: 1) compared with the machined collar, an LMS design in the implant collar can significantly reduce the amount of MBL; 2) PD around implants with an LMS collar is shallower than with a machined-surface collar; 3) further long-term, well-conducted, RCTs are needed before establishing the long-term predictability of LMS design in preserving marginal bone levels and peri-implant soft tissue health.

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