Peri-implant Bone Loss Around Single and Multiple Prostheses: Systematic Review and Meta-Analysis

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Purpose: *The objective of this systematic review and meta-analysis was to assess and compare the marginal bone loss around implants supporting single fixed prostheses and multiple-unit screw-retained prostheses.* ***Materials and Methods:*** *The literature was searched manually and electronically to identify studies in which the marginal peri-implant bone loss around single-implant prostheses and screw-retained multiple-implant prostheses was evaluated radiographically. Two reviewers independently selected the literature and extracted the data. The random-effects method was used to obtain estimates of marginal peri-implant bone loss (means and 95% confidence intervals [CIs]).* ***Results:*** *Of the 2,107 studies identified by a preliminary search, 17 fulfilled the inclusion criteria; 7 were related to single-implant prostheses and 10 to multiple-implant screw-retained fixed prostheses. The mean marginal peri-implant bone loss was 0.9 mm (95% CI, 0.49 to 1.32 mm) for multiple-implant screw-retained prostheses and 0.58 mm (95% CI, 0.37 to 0.80 mm) for single-implant prostheses.* ***Conclusion:*** *This indirect comparison provided no evidence to support the assertion that there are differences in marginal peri-implant bone loss between single implant prostheses and multiple screw-retained prostheses.* Int J Oral Maxillofac Implants 2014;29:79–87. doi: 10.11607/jomi.3316

Key words: *meta-analysis, multiple implant–supported prosthesis, peri-implant bone loss, single implant–supported prosthesis, systematic review*

Peri-implant marginal bone loss is influenced by many factors, including surgical technique,[1] implant positioning,[2] tissue thickness,[3] the presence of a microgap[4] at the implant-abutment interface,[5] and implant design,[6] all of which can also influence the marginal bone crest. One of the possible theories of the pathogenesis of marginal peri-implant bone loss, a common phenomenon ranging from minor marginal bone loss to implant failure, is that the stresses in the prosthesis/implant/bone system contribute to the process.[7] Any stress generated by the transmission of forces to the bone can cause problems in the prosthesis (screw loosening or fracture), the implant (implant fracture), or the bone (marginal peri-implant bone loss or osseointegration failure).[8,9] Stress in this system can be exerted by occlusal forces or by a lack of passive fit of the prosthetic framework in multiple-unit screw-retained prostheses.

Adequate clinical adaptation of the prosthesis with passivity is important in maintaining osseointegration, although a specific level of such passivity has not yet been established.[10] The absence of the periodontal ligament may prevent the implant from proper seating in a nonpassively fitting situation, which occurs independent of the moment of loads applied to the implants.[11] In fact, a certain biologic bone tolerance for stress caused by the misfit may be present.[12] Inaccurate adaptation of the prosthesis to the implants causes stress that can lead to biologic or mechanical failure of the implant itself, if the misfit is too extreme.[13,14] One way to avoid such failures during dental prosthesis fabrication is to achieve passive fit.[15] An absolute passive fit seems to be difficult to achieve through conventional casting procedures,[16] as the fit is affected by each step of the prosthesis manufacturing process.[17] In fact, computer-aided procedures are able to produce frameworks with greater precision compared with traditional casting methods.[18,19]

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Absolute passive fit between implants and prostheses has been widely discussed as a way of reducing biomechanical complications in the treatment of total or partial edentulism.[20,21] When the adaptation between the implants and the prosthesis is inaccurate, some units support the major part of the load, whereas others bear virtually no load.[22] Therefore, single fixed prostheses tend to show better passive fit than multiple screw-retained prostheses and thus induce little or none of the tension caused by a lack of passivity, leading to the hypothesis that a single fixed prosthesis will show less bone loss.[23–26]

The vast number of available publications has created a need for syntheses to facilitate access to the full data set and allow conclusions to be drawn from the comparison or combination of results from multiple sources. One way to accomplish this is through systematic reviews with or without meta-analysis.[27] Recently, systematic reviews in the field of implant dentistry have been performed with the objective of establishing evidence-based practices.[28–31]

The literature concerning the effect of stress on marginal peri-implant bone loss has not yet been evaluated systematically. Therefore, the present study aimed to use meta-analysis to evaluate and compare marginal peri-implant bone loss between single fixed prostheses and multiple-implant screw-retained prostheses in an attempt to determine whether the extent of marginal peri-implant bone loss differs between these two types of implant-supported prostheses.

MATERIALS AND METHODS

Search and Selection Protocols

This systematic review was performed using the methodology developed by the Cochrane Collaboration Group.[32] A broad and detailed electronic search was conducted to identify appropriate studies among articles published in English up to and including January 2013. The following electronic databases were searched: Medline (via PubMed), Science Direct, the Cochrane Central Register of Controlled Trials (CENTRAL), and Scopus. These electronic searches were complemented by a manual search of articles published in the *International Journal of Oral & Maxillofacial Implants*, *International Journal of Prosthodontics*, *International Journal of Periodontics & Restorative Dentistry*, and *Clinical Oral Implants Research*.

The online searches were performed using different key words and terms that were combined using the logical combination system (Boolean operators) with the "AND" operator; these terms included "marginal bone loss," "dental implants," "single prostheses," and "multiple prostheses." The groups of key words were combined with the "OR" operator when searching for terms that appear as descriptors of medical vocabulary (Medical Subject Headings [MeSH terms]) or words in the text.

Only clinical trials and prospective and retrospective longitudinal studies involving human beings were included. Another criterion for inclusion was that the study included periapical radiographic evaluations of marginal peri-implant bone loss, with results (means and standard deviations [SDs]) reported in millimeters. Only studies published in English were included. The following types of studies were excluded: case reports; studies in animals; studies in cadavers; in vitro studies; studies involving immediate implants, immediate loading, bone grafts, cement-retained multiple prostheses, platform switching, removable prostheses, or the presence of cantilevers; studies in patients with systemic disease; studies in which subjects were followed up for less than 1 year; and studies with incomplete data.

At this stage, the abstracts of all the identified studies were evaluated for potential inclusion by two reviewers (CF and MM), who worked independently using the preestablished inclusion and exclusion criteria. Abstracts on which the reviewers disagreed were discussed with a third researcher (GMV) until a consensus was reached.

Data Extraction

The full texts of the selected studies were obtained for data extraction by the same researchers. The data extracted included the: authors and year of publication, number of patients, number of implants, implant system (commercial brand), length of follow-up period, retention system, region (maxilla or mandible), type of prosthesis (single or multiple), extent of prosthesis (total or partial in the case of multiple-unit prostheses), implant design, prosthetic connection, implant success/survival rate, and means and SDs of marginal peri-implant bone loss. The corresponding authors of the studies were contacted when necessary to obtain missing or unpublished information.

Meta-Analysis

The data were subjected to meta-analysis to estimate the pooled mean values for mean marginal peri-implant bone loss (95% confidence interval [CI]) for each type of prosthesis (single and multiple) using the random-effects method. These estimates were calculated by the inverse variance weighting method. The Cochran Q method was used to evaluate the homogeneity of the studies. The potential bias of the publications was tested using Begg's rank correlation test[33] and Egger's test.[34] All statistical analyses were performed using commercial software (STATA version 6, Stata Corp). The significance level was set at 5% ($P \leq .05$) for all analyses.

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RESULTS

The systematic review identified 2,107 studies during the first stage of selection. Initial application of the inclusion/exclusion criteria excluded 1,731 studies based on a review of the titles of the studies and their abstracts. The remaining 376 studies were analyzed in full, and 359 studies were excluded; 127 did not fulfill the inclusion criteria (Table 1) and 232 met at least 1 of the exclusion criteria (Table 2). Among the seven studies that were excluded because of incomplete data (Table 2), four did not include separate results for single and multiple-unit prostheses,[35–38] one lacked separate values for screw-retained and cement-retained prostheses,[39] and two did not report the type of prosthesis retention (cement or screws).[40,41] Finally, 17 papers were selected for meta-analysis, of which 7 concerned single-unit fixed prostheses and 10 multiple-unit screw-retained prostheses.

Table 1 No. of Studies Excluded After Review of Inclusion Criteria

Inclusion criterion	No. of papers excluded
1. Lack of radiographic evaluation	64
2. Panoramic radiography	17
3. Lack of standard deviation	46
Total	127

Table 2 No. of Studies Excluded After Review of Exclusion Criteria

Exclusion criterion	No. of papers excluded
1. Case reports	20
2. Studies in animals	8
3. Studies in cadavers	2
4. Studies in vitro	59
5. Immediate implants	8
6. Immediate load	54
7. Bone grafts	15
8. Cement-retained multiple prostheses	15
9. Platform switching	11
10. Systemic diseases	4
11. Removable prostheses	26
12. With cantilevers	1
13. Less than 1 year of follow-up	2
14. Incomplete data	7
Total	232

Selected Studies

Implant systems used. The great majority of the selected studies used the Brånemark implant system (Nobel Biocare), with a total of 1,591 implants placed.[42–50] The follow-up period ranged from 1 to 20 years, and all implants had a cylindric threaded design and an external-hexagon prosthetic connection. The marginal peri-implant bone loss ranged from 0.3 to 1.62 mm with an SD of 0.3 to 0.9 mm.

The second most-used implant system (four studies) was the Osseotite system (Biomet 3i), with a total of 247 implants placed, all of which had a cylindric threaded design and external-hexagon prosthetic connection.[51–54] The follow-up period ranged from 1 to 5 years. The marginal peri-implant bone loss ranged from 0.4 to 0.8 mm with an SD of 0.16 to 1.4 mm.

Prosthetic connection. The majority of the studies used implants with an external-hexagon prosthetic connection, with a total of 1,852 implants placed and a follow-up period of 1 to 20 years. The marginal peri-implant bone loss ranged from 0.3 to 1.62 mm with an SD of 0.16 to 1.4 mm for the studies of implants with external-hexagon prosthetic connections.[42–55]

Four studies used implants with internal connections; three of these used Astra Tech implants (Astra Tech)[56–57] and the other the Straumann implant system (Straumann Institute).[58] A total of 660 implants were placed, and the follow-up period ranged from 1 to 11 years. For this type of connection, the marginal peri-implant bone loss ranged from 0.26 to 0.88 mm with an SD of 0.53 to 1.0 mm.

Studies involving single fixed prostheses. The data extracted from the studies on single fixed prostheses are represented in Table 3. Of the selected studies, seven concerned single fixed prostheses, and all were prospective in nature. One study concerned screw-retained prostheses only,[55] one evaluated screw-retained and cement-retained prostheses,[48] and five cemented prostheses only.[49–53] The ages of the patients ranged from 17 to 75 years. In all, 213 patients received a total of 310 implants and prostheses in function. The follow-up period ranged from 1 to 15 years. An external-hexagon prosthetic connection was used in all seven studies.[48–53,55] The implants in six of the seven studies had a cylindric design, while only one study examined implants with a conical design.[55] The implant success/survival rate was 100% for the five studies that provided this information[48,50–53]; two studies did not provide this information.[49,55]

Studies involving multiple-unit screw-retained prostheses. The data extracted from the studies involving multiple screw-retained prostheses are represented in Table 4. All 10 selected studies on screw-retained prostheses were prospective, and 1 also included retrospective data.[43] Of these studies, three concerned fixed partial prostheses[42,46,54] and seven evaluated fixed complete prostheses.[43–45,47,56–58]

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Table 3 Characteristics of the Studies of Single-Implant Prostheses

Study	No. of patients	No. of implants	System/mfr	Retention	Follow-up	Jaw and region
Henriksson and Jemt[48]	11	11	MK III, Nobel Biocare	Screwed	1 y	Ant max
Drago[51]	69	104	Osseotite, Biomet 3i	Cemented	1 y	Post max, post mand
Henriksson and Jemt[48]	9	13	MK III	Cemented	1 y	Ant max
Glauser et al[49]	19	36	MK II	Cemented	4 y	Max, mand, incisors, canines, premolars
Vigolo et al[52]	20	40	Osseotite	Cemented	4 y	Post max (32), post mand (8)
Hall et al[55]	14	14	Southern Implants	Screwed	1 y	Ant max
Jemt[50]	27	32	Brånemark, Nobel Biocare	Cemented	15 y	Ant max
Vigolo and Zaccaria[53]	44	60	Osseotite	Cemented	5 y	Post max

Ant = anterior; post = posterior; max = maxilla; mand = mandible; mfr = manufacturer.

Table 4 Characteristics of the Studies of Multiple-Implant Screw-Retained Prostheses

Study	No. of patients	No. of implants	System/mfr	Total/partial	Follow-up period	Jaw, region
Steenberghe et al[42]	147	427	Brånemark	Partial	5 y	Ant/post max/mand
Jemt and Book[43]	7	44	Brånemark	Total	1 y	Ant max
Lindquist et al[44]	45	270	Brånemark	Total	15 y	Ant mand
Arvidson et al[56]	91	517	Astra Tech	Total	5 y	Ant mand
Carlsson et al[45]	44	273	Brånemark	Total	15 y	Mand, incisors, canines, premolars
Bryant and Zarb[46]	66	306	Brånemark	Partial	11 y	Ant/post max/mand
Ekelund et al[47]	30	179	Brånemark	Total	20 y	Ant mand
Fischer et al[58]	7	39	SLA, Straumann	Total	5 y	Ant max
Chang and Wennström[55]	16	43	Osseotite, Biomet 3i	Partial	3 y	Post max (29), post mand (14)
Mertens et al[57]	15	94	TiOblast, Astra Tech	Total	11 y	Ant/post max

All prostheses were screw-retained.
Ant = anterior; post = posterior; max = maxilla; mand = mandible; mfr = manufacturer.

The ages of the patients ranged from 18 to 81 years. The studies comprised a total of 475 patients, with a total of 2,230 implants placed and 474 prostheses in function. The follow-up period ranged from 1 to 20 years. Seven studies used implants with an external-hexagon prosthetic connection[42–54] and three examined internal-connection implants.[56–58] Nine studies used implants with a cylindric design,[42–47,54,56,57] and only one study presented an implant with a conical design.[58] The implant success/survival rates ranged from 89.1% to 98.9% for the seven studies that provided this information.[44–47,56,57,58]

Meta-Analysis

The studies in which the mean values of marginal peri-implant bone loss associated with single or multiple-unit prostheses over implants were subjected to meta-analysis. None of the studies directly compared marginal peri-implant bone loss between single fixed prostheses and multiple-unit screw-retained prostheses over implants. Therefore, the grouped means of marginal peri-implant bone loss were estimated separately for single prostheses and multiple-unit prostheses and compared indirectly.

The mean marginal peri-implant bone loss was 0.583 mm (95% CI, 0.369 to 0.798 mm) for single prostheses and 0.920 mm (95% CI, 0.448 to 1.317 mm) for multiple-unit prostheses (Figs 1a and 1b). Heterogeneity between studies was not observed in either analysis (single prostheses $Q = 4.466$, $P = .725$; multiple-unit prostheses $Q = 6.033$, $P = .737$).

The results of Begg's test with continuity correction and Egger's test showed no evidence of publication bias. The results of Begg's test were $P = .686$ for single

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Implant design	Prosthetic connection	Survival/ success rates	Marginal bone loss ± SD (mm)
Cylindric	External	100%/–	0.4 ± 0.3
Cylindric	External	100%/–	0.45 ± 0.16
Cylindric	External	100%/–	0.3 ± 0.6
Cylindric	External	–/–	1.2 ± 0.5
Cylindric	External	–/100%	0.4 ± 0.3
Conical	External	–/–	0.78 ± 1.01
Cylindric	External	100%/–	0.66 ± 0.78
Cylindric	External	100%/–	0.8 ± 0.2

Implant design	Prosthetic connection	Survival/ success rates	Marginal bone loss ± SD (mm)
Cylindric	External	–/–	0.4 ± 0.65
Cylindric	External	–/–	0.5 ± 0.56
Cylindric	External	–/98.9%	1.2 ± 0.74
Cylindric	Internal	98.7%/–	0.26 ± 0.53
Cylindric	External	98.9%/–	1.4 ± 0.40
Cylindric	External	89.1%/–	1.62 ± 0.84
Cylindric	External	98.9%/–	1.6 ± 0.9
Conical	Internal	95.7%/–	0.3 ± 1.0
Cylindric	External	–/–	0.6 ± 1.4
Cylindric	Internal	96.8%/92.6%	0.88 ± 0.99

prostheses and P = .858 for multiple-unit prostheses. For Egger's test, a publication bias graph, in which the values of the mean difference are grouped versus the variance difference, was used to illustrate the absence of publication bias (Figs 2a and 2b).

DISCUSSION

Summary of Key Results

This meta-analysis showed a mean marginal peri-implant bone loss of 0.9 mm for multiple-unit screw-retained prostheses and 0.58 mm for single fixed prostheses. Indirect comparison showed no statistically significant difference in the marginal peri-implant bone loss between multiple-unit and single-unit prostheses.

Overall Completeness and Applicability of Evidence

Unlike conventional prostheses, under which an abutment tooth can move up to 100 µm inside its periodontal ligament and thus compensate for a certain degree of imprecision in a fixed prosthesis, implants can move only within a 10-µm range.[59,60] An in vitro study showed that the implant-prosthesis interface had a mean misfit value of 31.63 µm, which is greater than the bone compensation limit of 10 µm. This lack of flexibility at the bone-implant interface means that any traction, compression, or flexion forces imposed by superstructure misfit can lead to lack of passive fit, which can result in problems such as marginal peri-implant bone loss.[61–64] Another factor that can compensate for the limited flexibility in the bone-implant interface of multiple-unit prostheses is the cementation line. Bottino et al[65] showed that the smallest values of maladaptation for cemented prostheses were greater than 36.6 µm, regardless of the type of cement used. Because these values were greater than the mean misfit in the implant-prosthesis interface, it was assumed that cement-retained multiple prostheses would easily achieve passive fit without causing tension at the bone-implant interface. Nissan et al[66] compared the marginal bone loss around screw-retained and cemented multiple-unit prostheses. The mean marginal bone loss was 1.4 mm for the former compared to 0.69 mm for the latter.[66] Therefore, cement-retained multiple (splinted) prostheses were considered to be an exclusion criterion, while cement-retained single fixed prostheses were allowed during the selection of studies for the present review, as lack of passive fit is a problem exclusive to screw-retained multiple prostheses. Therefore, the single cemented prostheses of the Henrikson and Jemt[48] study were included in the meta-analysis. Because the authors provided separate values of marginal bone loss for cemented and screw-retained single prostheses, the results for the two types of prostheses were considered separately.

None of the studies included in the present review directly compared marginal peri-implant bone loss around single-unit and multiple-unit screw-retained prostheses. The marginal peri-implant bone loss was evaluated for single prostheses in seven studies and for multiple-unit screw-retained prostheses in 10 studies. Therefore, two separate meta-analyses were conducted to evaluate marginal peri-implant bone loss around single and multiple-unit prostheses, which allowed indirect comparison of marginal peri-implant bone loss.

Although the mean marginal peri-implant bone loss was 0.58 mm for single fixed prostheses and 0.9 mm for multiple-unit prostheses, this difference was not statistically significant because of superimposition of the confidence intervals of their mean values (95% CI for

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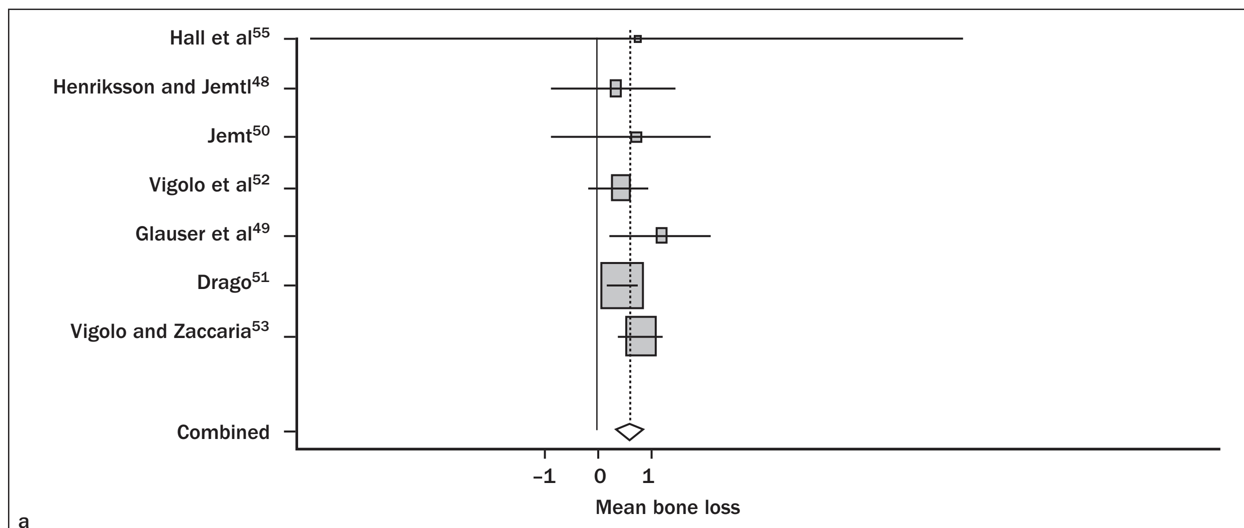

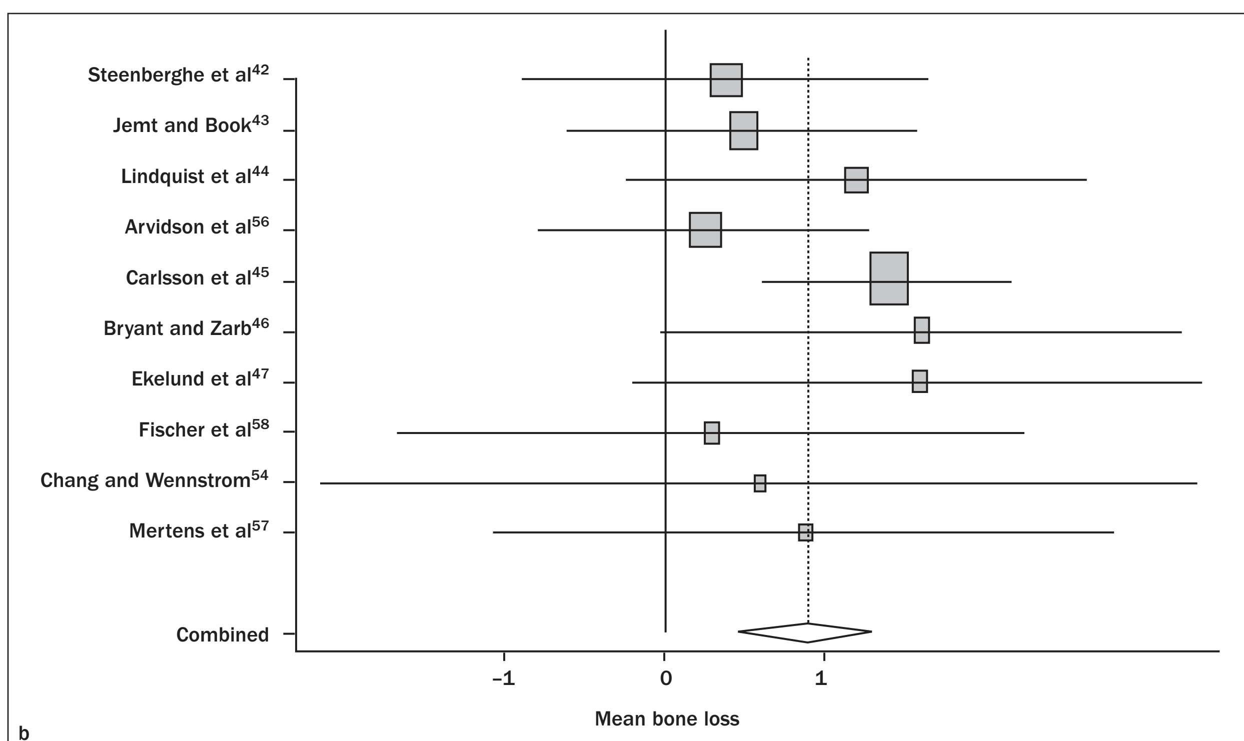

Figs 1a and 1b Mean marginal peri-implant bone loss for (*a*) single prostheses and (*b*) multiple-unit screw-retained prostheses.

single prostheses, 0.37 to 0.80 mm; 95% CI for multiple-unit prostheses, 0.49 to 1.32 mm). However, it may be noteworthy that multiple screw-retained prostheses tend to produce greater bone loss than single fixed prostheses, which could be a result of the difficulty of obtaining passive fit for multiple-unit screw-retained prostheses.[9] This lack of statistically significant difference could be related to other factors that should also be considered. None of the selected studies in this meta-analysis presented biomechanical data related to the occlusal loads, such as loading magnitude, force direction, and frequency and number of cycles; and only Carlsson et al evaluated the bite force and the masticatory efficiency of the patients.[45] Other factors associated with marginal peri-implant bone loss must also be investigated, including the prosthesis retention system (screw-retained or cemented) and the prosthetic connection (internal or external).

Quality of Evidence

The methodologic quality of the studies selected for this meta-analysis was assessed by the method proposed by Esposito et al.[67] Of the 17 studies selected for the meta-analysis, none reported the calculation

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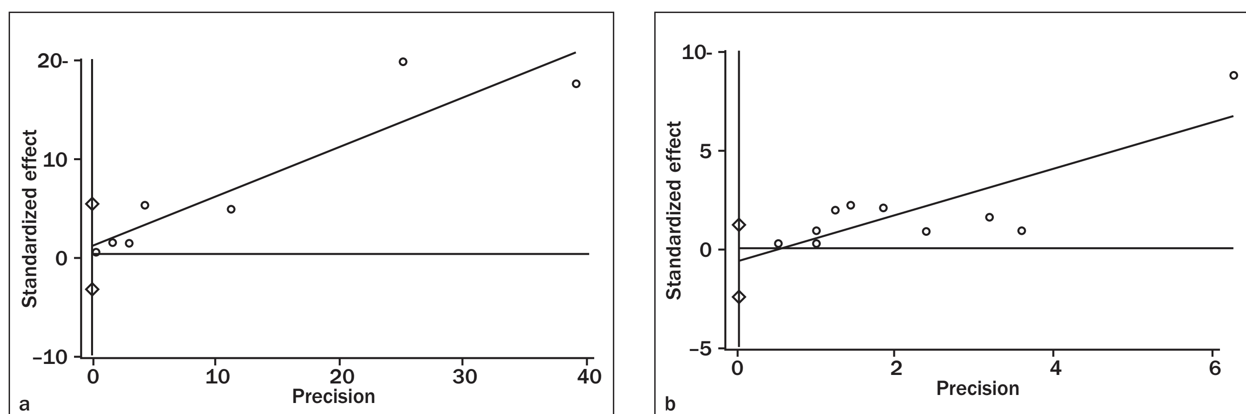

Figs 2a and 2b Egger's publication bias plots: mean peri-implant marginal bone loss according to the type of prosthesis (*a*: single-unit fixed prostheses; *b*: multiple-unit screw-retained prostheses).

of sample size; furthermore, none of them related the marginal bone loss in the different groups to other important prognostic factors, such as plaque and gingival indices at the beginning of the studies. Six studies randomized the form of treatment.[43,50,52,53,55,58] Only one study reported that the examiner was blinded when evaluating the periapical radiographs.[46] Four studies were based on well-defined criteria for assessing the survival rate of the implants.[50–52,57] Complete follow-up of the patients was performed in all studies. All studies performed statistical analysis, although descriptive statistical analysis only was performed in one study.[47]

Presence and Impact of Potential Biases

This systematic review included only papers published in English. This could be a source of bias. Another important aspect was the inclusion of manual searches of dental periodicals. To avoid or minimize the risk of bias, the authors selected scientific periodicals related to implant dentistry. It is important to emphasize that bias might possibly have been minimized if more periodicals had been included in the manual search.

It seems that marginal bone loss around implants has a multifactorial etiology. Some of the etiologic factors are the establishment of biologic width around implants,[68] three-dimensional implant position,[69] platform position,[70] platform switching,[71] implant design,[72] prosthesis design,[72] abutment composition[73] and design,[74] and the presence of residual cement in deep submucosal margins.[75] These factors were not controlled in the selected studies, and they should be considered in future randomized controlled clinical trials comparing marginal bone loss in single and multiple-unit prostheses. Another important confounding factor related to marginal bone loss is the mucosal marginal inflammation, evaluated through the Gingival Index or its variants. In the present systematic review, only five studies included this information, and they used different methodologies.[42,49,52,56,58]

Well-elaborated inclusion and exclusion criteria must be established to minimize the risk of introducing bias during the selection of studies and, consequently, into the results of a review.[76] In the present study, the inclusion and exclusion criteria were rigorously elaborated, which was confirmed by the homogeneity observed among the studies. The use of the periapical radiographic technique for evaluating bone loss was used as an inclusion criterion in this study. Several studies have demonstrated the accuracy of this technique for evaluating changes in the bone crest as well as its superiority to panoramic radiographs for this purpose.[29,77,78] This led the authors to consider the panoramic technique less than ideal for the present study, as its use could introduce bias. Another important aspect in the choice of inclusion/exclusion criteria is the fact that only studies with a follow-up period of at least 1 year were selected. The classic study of Adell et al[63] showed that marginal peri-implant bone loss occurs during the first year and then tends to stabilize for the majority of implants.[63]

Although heterogeneity was not observed in either meta-analysis, the different characteristics of the selected studies in factors such as surgical protocol and type of prosthetic connection may have influenced the indirect comparison of multiple-unit screw-retained prostheses and single fixed prostheses, which is a limitation of this review. The power of the tests for heterogeneity and publication bias used in the present meta-analysis may be considered limited, as only 17 studies were included. This suggests the need for future randomized controlled trials to improve the quality of information on which to make clinical evidence-based decisions.

Agreement with Previous Reviews

To the best of our knowledge, this is the first systematic review on this topic, and therefore, a comparison with previous reviews is not feasible.

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CONCLUSION

The available literature does not allow direct comparison of marginal peri-implant bone loss between single fixed and multiple-unit screw-retained prostheses because of an insufficient number of randomized controlled clinical trials employing both types of prostheses. There is no evidence to support differences in marginal peri-implant bone loss through indirect comparison of single and multiple-unit fixed prostheses.

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