The Effect of Keratinized Mucosa Width on Peri-implant Health: A Systematic Review

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Purpose: *The aim of this systematic review was to investigate the effect of keratinized mucosa width (KMW) on clinical parameters of peri-implant health and stability.* ***Materials and Methods:*** *Two independent reviewers conducted a comprehensive search to identify studies on human subjects reporting KMW as a bivariate factor (≥ 2 mm and < 2 mm), along with mean pocket depth (PD), bleeding on probing (BOP), modified Bleeding Index (mBI), Gingival Index (GI), Plaque Index (PI), modified PI (mPI), and implant survival with a minimum follow-up of 6 months after implant loading. Eight studies were included in the systematic review and seven in the meta-analyses to ascertain summary effects for differences in the aforementioned parameters among groups of KMW.* ***Results:*** *Pooled analyses showed that GI, PI, and mPI were significantly higher in the group with KMW of < 2 mm, while mBI was also higher but only marginally significant. In contrast, PD was not significantly different between the two groups. Differences in BOP and implant survival rate could not be analyzed because of limited data availability. Heterogeneity was highly significant among the pooled studies for all investigated variables.* ***Conclusion:*** *Reduced KMW around implants appears to be associated with clinical parameters indicative of inflammation and poor oral hygiene. However, based on the selected evidence, the predictive value of KMW is limited.* Int J Oral Maxillofac Implants 2013;28:1536–1545. doi: 10.11607/jomi.3244

Key words: *dental implants, meta-analysis, mucosal tissue, oral mucosa, peri-implantitis*

In the early years of implant dentistry, long-term survival of osseointegrated implants in the absence of symptoms and minimal progression of peri-implant bone loss were considered the primary endpoints to determine the success of dental implant therapy.[1] However, some of those original assumptions have now changed.[2,3] Maintenance of functionally loaded, osseointegrated implants in an adequate state of health and esthetics has emerged as the new therapeutic goal. The importance of outcomes such as patient satisfaction, absence of peri-implant inflammation, stability of marginal bone levels, and optimal restoration and peri-implant soft tissue esthetics has been widely recognized.[4–7] However, satisfying these current success criteria is often challenging.

The absence of periodontal ligament, root cementum, and connective tissue attachment around dental implants, as well as the submucosal location of the margin of the majority of cement-retained restorations, may make peri-implant tissues more susceptible to the development of a robust inflammatory response when dental plaque accumulation and microbial invasion take place.[8–11] The role of dental plaque in the etiology of peri-implant diseases involving soft and hard tissues is well documented in the literature.[12–15] Peri-implant mucositis has been defined as a reversible inflammatory lesion of the peri-implant mucosa without bone loss.[16] Pontoriero and coworkers[17] conducted a study to determine and compare the clinical and microbiologic features of experimental gingivitis and experimental peri-implant mucositis. No significant differences were found in clinical and microbiologic outcomes between experimentally induced peri-implant mucositis and

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gingivitis around natural teeth.[17] The study suggested that biofilm is one component of the biologic and mechanical systems leading to peri-implant mucositis, in a similar cause-and-effect relationship between the accumulation of bacterial plaque and the development of inflammation, as was reported for gingivitis several decades ago.[18]

For these reasons, it may be logical to think that the presence of a cufflike mucosal barrier, provided by a band of peri-implant keratinized mucosa (KM), is a requisite to ensure successful long-term maintenance of peri-implant tissues from both a biologic and esthetic standpoint. However, although it has been demonstrated that the presence of 2 mm of keratinized gingiva, with at least 1 mm of attached gingiva, plays an important role in the maintenance of periodontal health around the natural dentition,[19,20] the significance of KM width (KMW) around dental implants remains a controversial issue.[21,22] Therefore, the aim of this systematic review was to determine the effect of KMW on clinical parameters of peri-implant health and stability.

METHODS

This systematic review and subsequent meta-analysis were performed following a protocol that complied with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement guidelines.[23] The focused question was: Is a width of keratinized mucosa < 2 mm around functionally loaded implants detrimental for peri-implant health?

Population and Intervention

The population included in this study consisted of healthy adult (older than 18 years) human subjects with at least one implant-supported restoration that had been under functional loading for more than 6 months.

Eligibility Criteria

This systematic review was primarily aimed at identifying the value of KMW as a predictor of implant-related outcomes. Therefore, only cross-sectional and prospective observational studies were included.[24] Editorials, letters to the editor, case reports, case series, retrospective studies, clinical interventional studies, and any kind of review article were not included. Only studies including human subjects that reported peri-implant KMW around oral implants with a minimum follow-up of 6 months after functional loading were included. Additionally, to be included in the meta-analysis, reported KMW had to be stratified into two groups (≥ 2 mm and < 2 mm), and its influence on other clinical parameters of peri-implant health had to be analyzed in the original publication. For inclusion, an individual subject did not have to present sites with both reduced and adequate KM.

Search Strategy

The articles included in this systematic review were identified through searches of two electronic databases: Web of Knowledge (Thomson Reuters) and MEDLINE/PubMed, U.S. National Library of Medicine (National Institutes of Health). The Medical Subject Heading (MeSH) term "dental implant" was used in combination with the terms "keratinized," "masticatory," and "mucosa" applying the following strategy: (dental implant* [MeSH Heading (mh)] OR implant-supported dental prosthesis [mh] AND keratinized [Title and Abstract (tiab)] OR masticatory [tiab] AND mucosa [tiab]). Both databases were searched for the period January 1990 to February 2012. The searches were restricted to studies involving human subjects only. No restrictions regarding original language of the article or publication status were set. The references of the selected articles and related reviews were cross-searched for additional publications of interest. Finally, the following journals were hand-searched (from January 2000 to January 2012): *Journal of Periodontology, Journal of Clinical Periodontology, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, International Journal of Oral & Maxillofacial Implants, Implant Dentistry, International Journal of Periodontics & Restorative Dentistry*, and *International Journal of Oral and Maxillofacial Surgery*.

Outcome Measures

The primary outcome measures in this systematic review were different clinical parameters and peri-implant KMW. These parameters included the following:

- Probing depth (PD), distance from the gingival margin to the base of the sulcus in millimeters
- Bleeding on probing (BOP), a dichotomic variable that indicated the presence of bleeding at the level of the mucosal sulcus after probing
- Modified Bleeding Index (mBI)[25]
- Gingival Index (GI)[26]
- Plaque Index (PI)[27]
- Modified PI (mPI)[25]
- Implant survival rate, ie, the percentage of functionally loaded implants present in the oral cavity after a given period of time)

Mucosal recession (REC) was not included given the wide heterogeneity of published protocols used to measure this parameter that exists in the literature.

Article Selection

Two independent reviewers (LG and GA) screened the titles and abstracts of the articles obtained after the

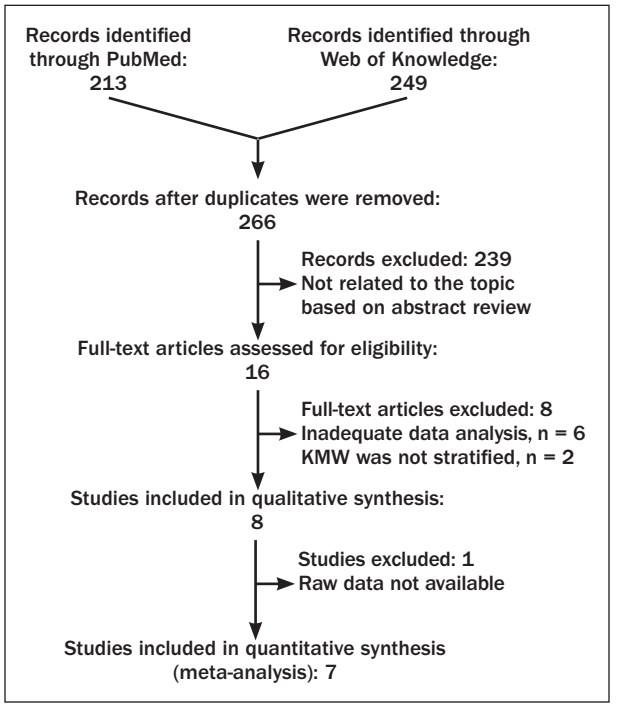

Fig 1 Flow chart depicting the process of article selection.

search. Articles with abstracts that did not provide sufficient information to make a decision were included in the full text evaluation to prevent the exclusion of potentially relevant information. To enhance the reliability of the assessment and to reduce the risk of bias, the reviewers did not communicate with each other during the selection process. The same reviewers performed full manuscript evaluation of the articles that were initially selected or those that could not be properly assessed by reading the title and abstract. Any disagreement with respect to article selection was resolved by open discussion between both reviewers. If no agreement could be achieved, a third reviewer (NK) was designated as a referee.

Data Extraction

Two independent reviewers (LG and CW) extracted the data of interest from the selected articles by populating custom-designed data abstraction forms. The extracted data included the following: number of subjects enrolled, number of implants, number of withdrawals or exclusions, mean age, gender and race distribution, socioeconomic status, smoking habit, diagnostic criteria, study duration, number of adverse events, baseline and follow-up KMW, PD, BOP, mBI, GI, PI, mPI, and implant survival rate. Articles were excluded from the qualitative analysis if clinical outcome variables were not correlated with KMW or if KMW was not stratified. Articles were excluded from the quantitative analysis (meta-analysis) if the required data were not available in the manuscript or if authors could not be contacted or did not reply within 2 weeks after raw data were requested.

Data Analysis, Risk of Bias, and Heterogeneity Assessment

The association between KMW and mean PD, BOP, mBI, GI, PI, and mPI was assessed. Meta-analyses were conducted for each outcome with a random-effects model.[28] KMW was categorized into two groups: KMW ≥ 2 mm (group A) and KMW < 2 mm (group B). Each of the outcome variables was compared between the two KMW groups. Weighted mean differences were calculated, as the measurements used to assess study outcomes were highly homogeneous across studies.[29] Heterogeneity across studies was assessed with the I^2 statistic.[30] Sources of heterogeneity were explored by reviewing data from the papers. Because of the limited number of studies, no subgroup analyses were performed. Publication bias was evaluated with Begg and Egger's tests, as well as with examination of Egger's and funnel plots. Sensitivity analyses were conducted; ie, the pooled effect estimates were evaluated after omitting each study individually, to determine the effect of individual studies on the overall mean difference.[29] All analyses were conducted with Stata version 11.

RESULTS

Search Outcomes

The comprehensive search yielded 213 articles from PubMed and 249 articles from Web of Knowledge. Hand searches and cross referencing did not result in any additional articles. After initial screening and application of the eligibility criteria, a total of 16 potentially relevant articles were identified (Table 1).[31–46] Eight were prospective observational studies and eight were cross-sectional studies (Table 1). After full reading of the remaining manuscripts, six studies were excluded because of inadequate data analysis, since the effect of KMW on other peri-implant clinical variables was not performed,[31–36] and two because KMW was not stratified.[37,38] Therefore, eight studies were included in the final systematic review selection (Fig 1). One study was excluded from the meta-analysis because raw data were not available, although attempts were made to contact the corresponding author. [39]

Description of Qualitative Analysis

As reported in Table 2, six articles documented cross-sectional studies[39–44] and two papers described prospective observational studies.[45,46]

In these studies, 430 subjects received 1,586 implants, representing the total sample population.

Table 1 Description of Studies Identified After Initial Screening and Reason for Exclusion from Qualitative Analysis

Study	Year	Title	Study type	Included in systematic review?	Reason for exclusion from meta-analysis
Adibrad et al[40]	2009	Significance of the width of keratinized mucosa on the health status of the supporting tissue around implants supporting overdentures	Cross-sectional	Yes	Included
Bengazi et al[31]	1996	Recession of the soft tissue margin at oral implants. A 2-year longitudinal prospective study	Prospective observational	No	Inadequate data analysis
Benic et al[32]	2009	Clinical and radiographic comparison of implants in regenerated or native bone: 5-year results	Cross-sectional	No	Inadequate data analysis
Botticelli et al[37]	2008	Implants in fresh extraction sockets: A prospective 5-year follow-up clinical study	Prospective observational	No	KMW was not stratified
Bouri et al[41]	2008	Width of keratinized gingiva and the health status of the supporting tissues around dental implants	Cross-sectional	Yes	Included
Bragger et al[36]	1997	Associations between clinical parameters assessed around implants and teeth	Cross-sectional	No	Inadequate data analysis
Chang and Wennstrom[33]	2010	Peri-implant soft tissue and bone crest alterations at fixed dental prostheses: A 3-year prospective study	Prospective observational	No	Inadequate data analysis
Chung et al[42]	2006	Significance of keratinized mucosa in maintenance of dental implants with different surfaces	Cross-sectional	Yes	Included
Crespi et al[45]	2010	A 4-year evaluation of the peri-implant parameters of immediately loaded implants placed in fresh extraction sockets	Prospective observational	Yes	Included
Gallucci et al[34]	2009	Five-year results of fixed implant-supported rehabilitations with distal cantilevers for the edentulous mandible	Prospective observational	No	Inadequate data analysis
Kim et al[43]	2009	Evaluation of peri-implant tissue response according to the presence of keratinized mucosa	Cross-sectional	Yes	Included
Roos-Jansaker et al[38]	2006	Nine- to fourteen-year follow-up of implant treatment. Part III: Factors associated with peri-implant lesions	Prospective observational	Yes	KMW was not stratified
Schrott et al[46]	2009	Five-year evaluation of the influence of keratinized mucosa on peri-implant soft tissue health and stability around implants supporting full-arch mandibular fixed prostheses	Prospective observational	Yes	Included
Weber et al[35]	2006	Peri-implant soft tissue health surrounding cement- and screw-retained implant restorations: A multi-center, 3-year prospective study	Prospective observational	No	Inadequate data analysis
Wennstrom et al[39]	1994	The influence of the masticatory mucosa on the peri-implant soft tissue condition	Cross-sectional	Yes	Included
Zigdon and Machtei[44]	2008	The dimensions of keratinized mucosa around implants affect clinical and immunological parameters	Cross-sectional	Yes	Included

Average age ranged from 49.5 to 63.1 years. Smoking habits were reported in four studies,[40–42,44] while smoking status information was not available in the remaining articles.[39,41,43,45] The length of the included prospective observational studies ranged from 4 to 5 years. In all but two of the included studies, implants were placed in partially edentulous patients; the other two studies assessed implant-supported overdentures[40] and full-arch fixed prostheses.[46]

Most of the studies reported the values of different parameters of interest related to KMW. Only one article reported the implant survival rate,[45] which was

Table 2 Description of Studies Included in the Final Selection for the Systematic Review, in Chronological Order

Study	Year	Country	Objectives	No. of subjects	No. of implants	Mean age (y)	% male
Wennstrom et al[39]	1994	Sweden and Italy	To evaluate the soft tissue conditions at osseointegrated oral implants in relation to the width of masticatory mucosa	39	171	56	43.6
Chung et al[42]	2006	United States	To investigate the significance of KM in the maintenance of root-form dental implants with different surfaces	69	339	61.3	40.6
Bouri et al[41]	2008	United States	To determine whether an association exists between the width of keratinized mucosa and the health of implant-supporting tissues	76	200	NR	NR
Zigdon and Machtei[44]	2008	Israel	To investigate the association between KMW and mucosal thickness with clinical and immunologic parameters around dental implants	32	63	58.6	56.2
Adibrad et al[40]	2009	Iran	To evaluate whether KMW around implants supporting overdentures has a positive effect on the health of the peri-implant tissues	27	66	63.1	44
Kim et al[43]	2009	South Korea	To evaluate the effect of the presence of KM on peri-implant tissues	100	276	52.2	52
Schrott et al[46]	2009	United States	To investigate the influence of KMW on long-term peri-implant soft tissue health and stability over a period of 5 years	58	307	58	48
Crespi et al[45]	2010	Italy	To study the correlation between KMW and long-term maintenance of dental implants placed in fresh sockets and immediately loaded	29	164	49.5	62

ISR = implant-supported restorations; NR = not reported.

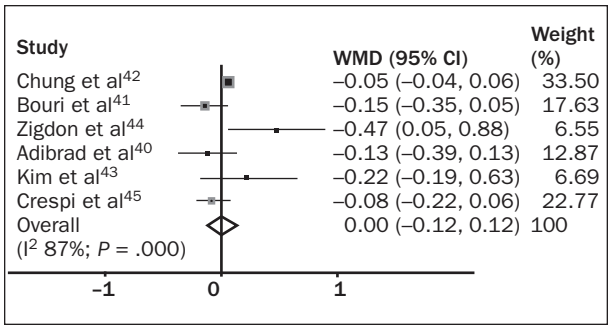

Fig 2 Forest plot comparing mean PD difference between test and controls. Squares represent the weighted mean difference in PD; size of the squares is proportional to the study weight of the trials. Error bars represent 95% CIs. The diamond shape represents the pooled estimates within each analysis.

100% after 4 years of loading. For this reason, survival rates were excluded from further comparative analyses. Six articles reported on PDs,[40–45] three reported on mBI,[42,45,46] four reported on GI,[40–43] three reported on PI,[40,41,43] and three reported on mPI.[42,45,46] Only two of the selected studies reported BOP relative to KMW[40,44]; hence, it was not possible to conduct a proper meta-analysis for this clinical parameter.

Meta-Analysis and Assessment of Bias and Effect Modification

Probing depths. Pooled analyses showed that PD was not significantly different between groups. The mean (95% confidence interval [CI]) difference between groups in PD was 0.00 mm (–0.118, 0.119; $P = .994$) (Fig 2). Heterogeneity I^2 value was 62.9%, with $P = .019$, indicating significant heterogeneity among the pooled studies. Funnel plots revealed the possible existence of publication bias; however, further testing with Begg and Egger tests and graphs ruled out this possibility (Egger $P = .615$, Begg $P = .707$). Sensitivity analysis did not result in a significant modification of the results by any of the studies.

Smoking habits	Study duration	Interventions or exposures	Clinical outcomes correlated to KMW	Outcome
NR	Cross-sectional	Full-arch ISRs (n = 21); partial-arch ISRs (n = 18); minimum loading of 5 y	PI, GI, BOP, PD, marginal tissue mobility	The study failed to demonstrate that a lack of KM may jeopardize the maintenance of health around dental implants.
Current smokers (2)	Cross-sectional	Partial-arch ISRs (minimum loading of 3 y)	mPI, mBI, GI, PD	The absence of KM or AM was associated with higher PI and GI, but not with more annual bone loss
NR	Cross-sectional	ISRs, type unspecified (minimum loading of 1 y)	PI, GI, KM thickness, PD	Increased width of KM around implants was associated with lower mean alveolar bone loss and improved indices of soft tissue health.
Stratified: Never (24), former smoker (5), current smoker (3)	Cross-sectional	Fixed ISRs (minimum loading of 1 y)	PI, GI, BOP, PD, REC, peri-implant attachment level, KM thickness	KM width and thickness around dental implants affected both clinical and immunologic parameters. A narrow band of KM may lead to increased recession.
Stratified: Never (22), former smoker (2), current smoker (3)	Cross-sectional	ISRs (removable overdentures) (average loading, 25.4 ± 10.2 mo)	PI, GI, BOP, PD, REC, peri-implant attachment level	The absence of adequate KM around implants was associated with higher plaque accumulation, gingival inflammation, BOP and mucosal recession.
NR	Cross-sectional	Fixed ISRs (minimum loading of 6 mo)	GI, PI, PD, REC	Decreased KMW was associated with REC and marginal bone resorption; no significant differences were observed in terms of PI, GI, or PD.
Current smokers (< 10 cigarettes/d): 18; heavy smokers (> 10 cigarettes/d) excluded	5 y	Full-arch fixed ISRs	mPI, mBI, REC	The existence of at least 2 mm of KM was beneficial for reduced lingual plaque accumulation and bleeding, as well as buccal REC.
NR	4 y	Full- and partial-arch fixed ISRs	mPI, mBI, GI, PD, REC	KMW was not a critical factor in the maintenance of interproximal bone, but less KMW was associated with more gingival inflammation, plaque accumulation, and recession.

Modified Bleeding Index. Pooled analyses showed that the difference between mean mBI was marginally significant between groups. The mean (95% CI) difference between groups was –0.09 (–0.52, 0.34; $P = .681$) (Fig 3). Heterogeneity I^2 value was 99.9%, with $P < .001$, indicating significant heterogeneity among the pooled studies. Funnel plots did not indicate the existence of publication bias, and further testing with Begg and Egger tests and graphs confirmed this finding (Egger $P = .969$, Begg $P = .602$). Sensitivity analysis did not result in a significant modification of the results by any of the studies.

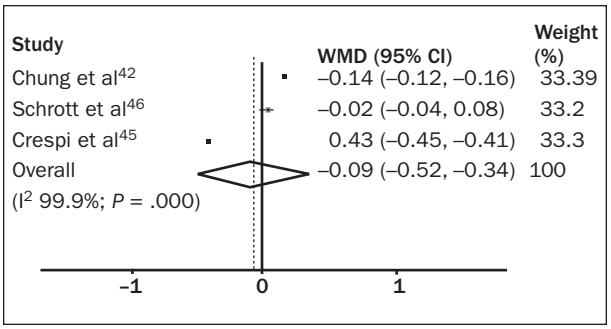

Fig 3 Forest plot comparing mean mBI difference between test and controls. Squares represent the weighted mean difference in mBI; size of the squares is proportional to the study weight of the trials. Error bars represent 95% CIs. The diamond shape represents the pooled estimates within each analysis.

Gingival Index. Pooled analyses showed that GI was significantly higher in group B compared to group A. The mean (95% CI) difference between groups in GI was 0.310 (–0.438, –0.182; $P = .001$) (Fig 4). Heterogeneity I^2 value was 95.6%, with $P = .001$, indicating significant heterogeneity among the pooled studies. The limited number of studies made the interpretation of the funnel plots somewhat difficult. Further testing with Begg and Egger tests and graphs ruled out the possibility of publication bias (Egger $P = .374$, Begg $P = .624$). Sensitivity analysis did not result in a significant modification of the results by any of the studies.

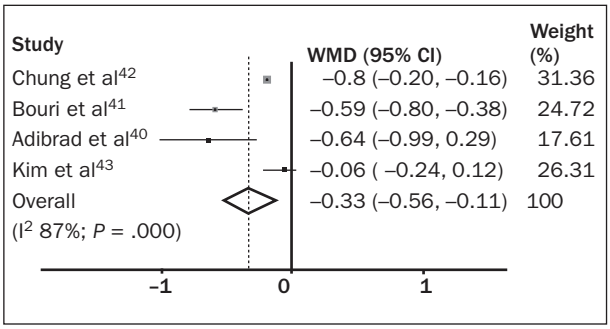

Fig 4 Forest plot comparing mean GI difference between test and controls. Squares represent the weighted mean difference in GI; size of the squares is proportional to the study weight of the trials. Error bars represent 95% CIs. The diamond shape represents the pooled estimates within each analysis.

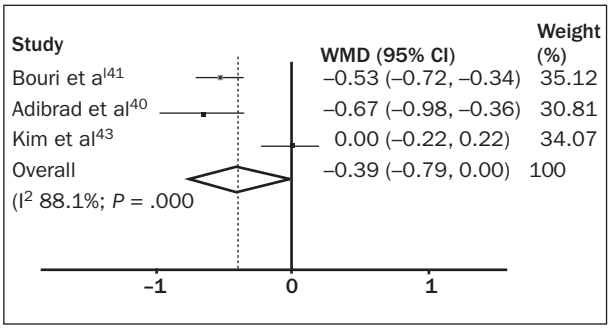

Fig 5 Forest plot comparing mean PI difference between test and controls. Squares represent the weighted mean difference in PI; size of the squares is proportional to the study weight of the trials. Error bars represent 95% CIs. The diamond shape represents the pooled estimates within each analysis.

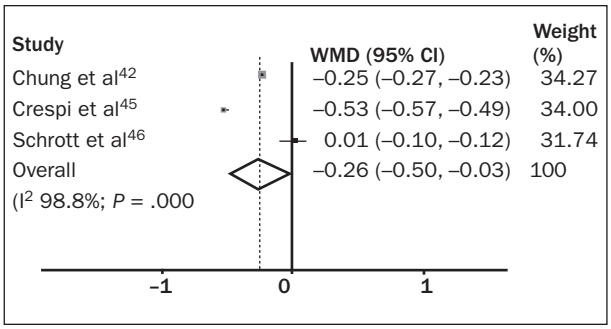

Fig 6 Forest plot comparing mean mPI difference between test and controls. Squares represent the weighted mean difference in mPI; size of the squares is proportional to the study weight of the trials. Error bars represent 95% CIs. The diamond shape represents the pooled estimates within each analysis.

Plaque Index. Pooled analyses showed that PI was higher in group B compared to group A. The mean (95% CI) difference between control and tests in PD was 0.39 (–0.79, –0.004; P = .052) (Fig 5). Heterogeneity I^2 value was 88.1%, with P < .001, indicating significant heterogeneity among the pooled studies. Funnel plots showed a somewhat symmetric distribution of studies. Further testing with Begg and Egger tests and graphs ruled out the possibility of publication bias (Egger P = .885, Begg P = .602). Sensitivity analysis did not result in a significant modification of the results by any of the studies.

Modified Plaque Index. Pooled analyses showed that mPI was significantly higher in group B compared to group A. The mean (95% CI) difference between groups in PI was –0.26 (–0.49, –0.03; P = .027) (Fig 6). Heterogeneity I^2 value was 98.8%, with P < .001, indicating significant heterogeneity among the pooled studies. Funnel plots as well as testing with Begg and Egger graphs ruled out the possibility of publication bias (Egger P = .93, Begg P = .602). Sensitivity analysis did not result in a significant modification of the results by any of the studies.

DISCUSSION

Although it is widely accepted that an adequate zone of KM is essential for optimal esthetic outcomes and may also facilitate oral hygiene performance, it remains unclear whether a dearth of KM should be considered a risk factor for peri-implant bone loss.[21] Several studies have stressed the importance of KM around dental implants for the maintenance of peri-implant health and patient comfort,[36,38,40,41,43,44,47] while others have reported comparable implant survival rates and peri-implant parameters irrespective of KMW.[31,39,48–52] This illustrates the controversy associated with this topic. In fact, several reviews on the significance of KM around implants have been published.[21,22,53] However, given the descriptive nature of these studies, there is an inherently high risk of bias. Hence, this systematic review was conducted to determine the effect of KMW on such peri-implant parameters as PD, BOP, mBI, GI, PI, mPI, and implant survival rate.

Within the limits of the authors' knowledge, this is the second systematic review on this topic that adheres to PRISMA guidelines.[54] The recent publication by Lin et al[54] was aimed at "investigating the effect of KM on various peri-implant health–related parameters," which is similar to the present study. However, there are important methodologic differences that make these studies complementary in some aspects. The present study focused on consistent clinical parameters that can provide valuable information to clinicians, while Lin et al included outcomes such as REC and attachment loss, which are not validated given the difficulty in standardizing REC measurements around implants from different systems or around those that support noncomparable prosthetic elements. Additionally, Lin et al pooled PI and mPI for the data analysis, which the current authors respectfully consider a methodologic error, since these indices are substantially different.[25,26] On the other hand, the implications

of variables that may influence the significance of KMW around implants, such as radiographic marginal bone loss, anatomical location, prosthesis type, and implant surface (rough or smooth), were analyzed by Lin et al but were considered out of the scope of the present review.

In this systematic review, given the nature of the study question, which considered KMW as a clinical predictive factor, only cross-sectional and prospective observational studies were included. Five cross-sectional studies, with a total of 304 subjects, and two prospective observational studies, with a total of 87 subjects, were included in the meta-analysis according to the eligibility criteria.[40–46] Quantitative analyses revealed that GI, PI, and mPI were significantly higher in group B compared to group A, while differences in mBI were marginally significant. Differences in PD between both KMW groups were not statistically significant (the mean value was 0.00 mm). Differences in implant survival rate and BOP could not be analyzed because of limited data availability. Mucosal REC and, therefore, peri-implant attachment level, were intentionally not considered as outcome variables. The rationale for this decision was based on the fact that values from different studies were not comparable, since the point of reference used to record REC varied among them. Nevertheless, it was interesting to observe that, of the seven articles included in the quantitative analysis, five assessed the correlation between KMW and REC. As reported in Table 2, all five studies found a positive correlation between increased REC and reduced KMW.[40,43–46] Although this information is valuable, it is important to note that this observation is based on a nonanalytic assessment of the literature.

The results of this meta-analysis essentially indicated that, despite the association between plaque accumulation and signs of peri-implant mucosal inflammation with KMW < 2 mm, PD did not vary between the KMW subgroups. Interestingly, while increasing PD and REC have been associated with peri-implant attachment loss and implant failure in preclinical and clinical studies,[13,55,56] the reliability of other parameters such as BOP, plaque accumulation, or cross-sectional PD measurements to predict implant-related biologic complications is questionable.[57] For example, the GI[26] is a visual assessment of the gingival or mucosal tissue that surrounds teeth or implants, respectively. Lining mucosa tends to present a more intense red color than keratinized gingiva. Therefore, the mucosal condition around implants with a narrow band of keratinized tissue or total absence of it might have been perceived as signs of inflammation, as compared to the coral pink appearance of KM, leading to a false-positive result. On the other hand, while mBI[25] can be considered a more accurate parameter to assess peri-implant inflammation, this diagnostic test also has shortcomings. Although mBI is more reliable around implants than around natural teeth,[58] the detection of BOP is not necessarily associated with future progression of disease.[59,60] Other approaches to assess and monitor peri-implant inflammation, such as the analysis of pro-inflammatory molecules in crevicular fluid samples,[61] may progressively overcome the limitations of traditional clinical methods involving visual assessment or stimulated bleeding responses.[62]

The association between plaque accumulation, as measured by PI and mPI, and a narrow zone of KM (< 2 mm) was very significant. This finding may be explained by the difficulty that patients may have in performing adequate oral hygiene in those locations because of increased sensitivity or insufficient access into the mucosal sulcus.[39] It is important to note that, despite the demonstrated association between plaque accumulation and peri-implant bone loss,[63–65] particularly in smokers and patients with a history of periodontal disease,[66] the current evidence does not support an association between peri-implant bone loss and reduced KMW. However, it has to be noted that peri-implant marginal bone loss is typically assessed on interproximal sites of two-dimensional radiographic images. Therefore, the implications of plaque accumulation on the facial or lingual aspect of implants as it relates to bone loss in these locations might have been consistently underestimated in the literature.

On the basis of this critical assessment of the results, it might be inferred that the predictive value of KMW as an indicator of future peri-implant breakdown is limited. However, the results obtained in this quantitative analysis should be interpreted with caution, since for all of the parameters analyzed, with the exception of PD, data from no more than four studies could be pooled. In this regard, it is noteworthy that, despite the amount of information in the literature regarding KMW and parameters of peri-implant health and implant survival, only seven studies could be included in the quantitative analysis and several interesting outcome variables could not be quantitatively analyzed (BOP, REC, and implant survival). This could be explained by the methodologic heterogeneity characterizing the studies available in this area of knowledge, which is a poor indicator of quality. As previously highlighted by other authors,[57,67,68] there is still a need for well-designed prospective longitudinal clinical trials to elucidate the importance of KMW in the maintenance of peri-implant health and patient perception of outcomes. This information may be valuable for clinicians during treatment planning and periodic assessment of patients enrolled in a maintenance program. Additionally, the role of other factors such as KM thickness (ie, mucosal biotype) and smoking habits in situations of

limited KMW should be determined to develop clinical protocols associated with high success rates for a variety of clinical scenarios.

CONCLUSION

It was observed that limited KMW around implants (< 2 mm) is associated with clinical parameters of inflammation. However, on the basis of the selected evidence, the predictive value of KMW is limited. There is a need for adequately powered prospective longitudinal clinical trials to elucidate the importance of KMW in the maintenance of peri-implant health.

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