Review

The Significance of Keratinized Mucosa on Implant Health: A Systematic Review

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Background: Whether a minimal width of keratinized mucosa (KM) is required to maintain peri-implant tissue health has been a topic of interest. This systematic review and meta-analysis aims to investigate the effect of KM on various peri-implant health-related parameters.

Methods: An electronic search of five databases (from 1965 to October 2012) and a hand search of peer-reviewed journals for relevant articles were performed. Human cross-sectional or longitudinal studies with data on the relationship between the amount of KM around dental implants and various peri-implant parameters, with a follow-up period of at least 6 months, were included.

Results: Eleven studies, seven cross-sectional and four longitudinal, were included. Weighted mean difference (WMD) and confidence interval (CI) were calculated with meta-analyses for each clinical parameter. The results showed statistically significant differences in plaque index (PI) and modified PI (WMD = –0.27, 95% CI = –0.43 to –0.11), modified gingival index (mGI) (WMD = –0.48, 95% CI = –0.70 to –0.27), mucosal recession (MR) (WMD = –0.60 mm, 95% CI = –0.85 to –0.36 mm), and attachment loss (AL) (WMD = –0.35 mm, 95% CI = –0.65 mm to –0.06 mm), all favoring implants with wide KM. However, comparisons of other parameters (bleeding on probing, modified bleeding index, GI, probing depth, and radiographic bone loss) did not reach statistically significant differences. The result of heterogeneity test showed only one parameter (AL, *P* value for the χ^2 test = 0.30 and I^2 test = 18%) had a low degree of heterogeneity among analyzed studies; meta-analyses of other parameters presented moderate-to-high degree of heterogeneity. Limitations of the present review include limited number of selected studies (n = 11), existence of heterogeneity and publication bias, and only English-written articles searched.

Conclusion: Based on current available evidence, a lack of adequate KM around endosseous dental implants is associated with more plaque accumulation, tissue inflammation, MR, and AL. *J Periodontol 2013;84:1755-1767.*

KEY WORDS

Dental implantation; dental implants; gingiva; gingival recession; peri-implantitis; review.

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The width of keratinized mucosa (KM) around natural teeth is defined as the distance between the mucogingival junction and the free gingival margin. Whether it is required to maintain periodontal health has been a topic of interest. Clinically, a narrow band of KM is often observed together with gingival recession and inflamed periodontium, giving an impression that a certain amount of KM might be necessary for periodontal stability. Lang and Löe[1] reported that, even with supervised oral hygiene, all sites with <2 mm of KM showed clinical signs of inflammation and 80% of sites with ≥2 mm of KM remained healthy; therefore, they concluded that ≥2 mm of KM is needed to maintain the health of periodontal tissues. However, a cross-sectional study[2] showed a similar degree of plaque accumulation and gingival inflammation, regardless of the width of KM. Subsequent studies[3-8] demonstrated that it is possible to maintain the periodontal attachment level through the control of gingival inflammation despite the absence of KM. Therefore, the current consensus[9] is that, provided with adequate oral hygiene, periodontal stability could be maintained even without adequate KM.

With the popularity of implant therapy, the same question arises: whether the amount of KM is important for peri-implant health. The same consensus from natural dentition might not be applicable to implants because of fundamental anatomic and structural differences between teeth and implants.[10-17] The gingival fibers of natural teeth run perpendicularly to the root surfaces and invest in the root cementum, but around dental implants, the connective tissue fibers run in a parallel/oblique direction to the titanium surfaces and do not attach to the implant.[16-18] Tissue breakdown was more pronounced at implant sites than at teeth, when induced by ligatures.[19] Evidences regarding the effect of KM on peri-implant health in animals are divergent. Warrer et al.[20] concluded that the existence of KM significantly decreased mucosal recession (MR) and attachment loss (AL). In contrast, Strub et al.[21] reported that no significant differences in recession or bone loss of peri-implant tissues could be found between implants with and without adequate KM.

Numerous human studies (Table 1)[11,22-51] investigated different variables to provide scientific evidences for this important issue. In an early review, Schou et al.[52] concluded that maintenance of peri-implant health through providing adequate oral hygiene is possible despite the absence of KM. Other reviews[43,53-55] also failed to support the concept that the lack of KM could jeopardize the maintenance of soft tissue health around dental implants. In view of a lack of agreement toward this topic of high clinical significance, it is the aim of this systematic review to investigate the effect of KM on various peri-implant health-related parameters.

MATERIALS AND METHODS

Focused Question

Does a minimal width of KM around dental implants have a beneficial effect on the health of peri-implant soft and hard tissues?

Search Strategy

A search of five electronic databases for relevant studies published in the English language from 1965 to October 2012 was performed: 1) PubMed; 2) Ovid (MEDLINE); 3) EMBASE; 4) Web of Science; and 5) Cochrane Central. The search terms used, in which "mh" represented the MeSH terms and "tiab" represented title and/or abstract, include the following: ("dental implants"[mh] OR "dental implantation"[mh] OR (("implant"[tiab] OR "implants"[tiab]) AND (dental[tiab] OR oral[tiab] OR tooth [tiab]))) AND ("mouth mucosa"[mh] OR "gingival recession"[mh] OR (("peri-implant"[tiab] OR "masticatory"[tiab] OR "attached"[tiab] OR "keratinized"[tiab]) AND ("mucosa"[tiab] OR "gingiva" [tiab]))).

A hand search was also performed in dental and implant-related journals from January 2000 to October 2012, including the following: 1) *Journal of Periodontology*; 2) *Clinical Implant Dentistry and Related Research*; 3) *International Journal of Oral and Maxillofacial Implants*; 4) *Clinical Oral Implants Research*; 5) *Implant Dentistry*; 6) *International Journal of Oral and Maxillofacial Surgery*; 7) *Journal of Oral and Maxillofacial Surgery*; 8) *Journal of Dental Research*; 9) *Journal of Prosthetic Dentistry*; 10) *International Journal of Prosthodontics*; 11) *Journal of Oral Implantology*; 12) *Journal of Clinical Periodontology*; and 13) *International Journal of Periodontics & Restorative Dentistry*. *European Journal of Oral Implantology* was searched from Spring 2008 to Autumn 2012. Furthermore, a search in the references of included papers was conducted for publications that were not electronically identified. The search strategy was performed by one examiner (G-HL).

All cross-sectional, longitudinal (prospective or retrospective) human studies with data on examination of the relationship between the KM width around dental implants and the outcomes of various peri-implant tissue health-related parameters, with a follow-up period of at least 6 months after implant placement, were considered for inclusion. The recorded peri-implant parameters included: 1) bleeding on probing (BOP); 2) bleeding index (BI);[56,57] 3) modified BI (mBI);[58] 4) plaque index (PI);[56,57,59] 5) modified PI (mPI);[58] 6) gingival index (GI);[56,57,59] 7)

Table 1.

Literature That Investigated the Relationship Among KM and Clinical Parameters

Variables	Positive Relationship	No Relationship	Negative Relationship
Implant survival	Block et al., 1996[27] Baqain et al., 2012[26]	Adell et al., 1981[22] Albrektsson et al., 1986[11] Mericske-Stern and Zarb, 1993[46] Iacono et al., 2000[38] Martin et al., 2009[43]	
Plaque accumulation/PI	Chung et al., 2006[33] Bouri et al., 2008[29] Schrott et al., 2009 (on lingual)[48] Adibrad et al., 2009[23] Crespi et al., 2010[34] Boynueğri et al., 2012[30]	Lekholm et al., 1986[42] Mericske-Stern, 1990[44] Mericske-Stern et al., 1994[45] Wennström et al., 1994[49] Brägger et al., 1997[31] Kim et al., 2009[41] Schrott et al., 2009 (on buccal)[48] Esper et al., 2012[35]	
Tissue inflammation (BI/GI/BOP/mucosal problem/gingivitis)	Artzi et al., 2006 (GI)[25] Chung et al., 2006 (GI)[33] Roos-Jansaker et al., 2006 (BOP)[47] Bouri et al., 2008 (GI)[29] Zigdon and Machtei, 2008 (BOP)[50] Schrott et al., 2009 (BI, on lingual)[48] Adibrad et al., 2009 (BOP and GI)[23] Crespi et al., 2010 (BI and GI)[34] Camargos et al., 2012[32] Boynueğri et al., 2012 (GI)[30]	Lekholm et al., 1986 (gingivitis)[42] Apse et al., 1989 (GI and BI)[24] Mericske-Stern, 1990 (BI)[44] Mericske-Stern et al., 1994 (BI)[45] Wennström et al., 1994 (GI and BOP)[49] Brägger et al., 1997 (BOP and BI)[31] Kaptein et al., 1999 (BOP)[39] Chung et al., 2006 (BI)[33] Heckmann et al., 2004 (BI)[37] Kim et al., 2009 (GI)[41] Schrott et al., 2009 (BI, on buccal)[48] Boynueğri et al., 2012 (BOP)[30] Esper et al., 2012 (GI)[35]	
PD	Brägger et al., 1997[31]	Lekholm et al., 1986[42] Apse et al., 1989[24] Mericske-Stern, 1990 (on buccal)[44] Mericske-Stern et al., 1994[45] Wennström et al., 1994[49] Kaptein et al., 1999[39] Chung et al., 2006[33] Bouri et al., 2008[29] Kim et al., 2009[41] Adibrad et al., 2009[23] Crespi et al., 2010[34] Boynueğri et al., 2012[30]	Mericske-Stern, 1990 (on lingual)[44] Roos-Jansaker et al., 2006[47] Zigdon and Machtei, 2008[50] Esper et al., 2012[35]

Table 1. (continued)

Literature That Investigated the Relationship Among KM and Clinical Parameters

Variables	Positive Relationship	No Relationship	Negative Relationship
MR	Brägger et al., 1997[31] Artzi et al., 2006[25] Zigdon and Machtei, 2008[50] Kim et al., 2009[41] Schrott et al., 2009[48] Adibrad et al., 2009[23] Crespi et al., 2010[34]	Bengazi et al., 1996[51]	
AL	Mericske-Stern et al., 1994 (on lingual)[45] Brägger et al., 1997[31] Zigdon and Machtei, 2008[50] Adibrad et al., 2009[23]	Mericske-Stern et al., 1994 (on buccal)[45]	
BL	Block and Kent, 1990[28] Hanisch et al., 1997[36] Roos-Jansaker et al., 2006[47] Bouri et al., 2008[29] Kim et al., 2009[41] Kehl et al., 2011[40]	Lekholm et al., 1986[42] Chung et al., 2006[33]	

PI = plaque index; BI = bleeding index; GI = gingival index; BOP = bleeding on probing; PD = probing depth; MR = mucosal recession; AL = attachment loss; BL = bone loss.

modified GI (mGI);[54,58] 8) probing depth (PD); 9) MR; 10) radiographic bone loss (BL); and 11) AL. Reviews and case reports were excluded, but the bibliographies of these studies were screened for potential articles to be included. Potential articles were examined in full text by two reviewers (G-HL and H-LC), and their eligibility for this review was confirmed after discussion. The level of agreement between the reviewers regarding study inclusion was calculated using κ statistics.

Risk of Bias Assessment

The criteria used to assess the quality of the selected studies were modified from the study of Kahn et al.,[60] which provided guidelines for the following parameters: 1) representative of general population; 2) defined inclusions/exclusions; 3) allocation concealment method; 4) masking of the examiner; 5) intraexaminer and interexaminer calibration; 6) correction for confounding factors; 7) appropriate statistics methods; 8) participant dropout; and 9) analysis accounts for patient losses. The degree of bias were categorized as follows: 1) low risk if all the criteria were met; 2) moderate risk when only one criterion was missing; and 3) high risk if two or more criteria were missing. Two reviewers (G-HL and H-LC) assessed all the included articles independently.

Data Extraction

Data were extracted by two observers (G-HL and H-LC) independently from the included papers that met the criteria and processed for analysis. If any disagreement was found, an agreement was accomplished with a discussion. The parameters recorded for each study included the following: 1) authors' names; 2) year of publication; 3) study design; 4) sample size; 5) demographic information of the participants; 6) number of fixture placement; 7) surface characteristics of implants; 8) masking of examiners; and 9) follow-up period.

Additional variables recorded for each study, if there were any, were clinical outcomes of BOP, BI, mBI, PI, mPI, GI, mGI, PD, MR, BL, and AL of the patients obtained from peri-implant tissues with wide or narrow width of KM. If indicated, authors of the potentially qualified papers were contacted for more detailed data.

Data Analyses

The primary outcomes were PI and mPI (PI/mPI, the data from the two indexes were pooled), and the secondary outcomes included BOP, mBI, GI, mGI, PD, MR, BL, and AL. The pooled weighted mean difference (WMD) and the 95% confidence interval (CI) were estimated using a computer program.§ The contributions of each article to the primary outcome and the secondary outcome were weighed based on the sample size. Random-effects meta-analyses of the selected studies were applied to account for

§ Review Manager (RevMan) v.5.0, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark.

potential bias being caused by methodologic differences among studies. Forest plots were produced to graphically represent the difference in outcomes of the wide and narrow KM groups for all included studies using "implant" as the analysis unit. $P = 0.05$ was used as the level of significance. Heterogeneity was assessed with χ^2 test and I^2 test, which ranges from 0% to 100%, and lower values represent less heterogeneity. In addition, the funnel plot was also used to assess the presence of the publication bias. The reporting of these meta-analyses adhered to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement.[61]

RESULTS

The screening process (see supplementary Fig. 1 in the online *Journal of Periodontology*) Electronic and hand searches yielded 914 articles, of which 29 articles were selected for full-text evaluation after screening their titles and abstracts. Eighteen articles were further excluded; the reasons for exclusion were listed in supplementary Table 1 (see the online *Journal of Periodontology*). Eleven articles[23,29,30,33-35,41,44,45,48,50] are included in this systematic review. The main features and conclusions of the included studies are summarized in Table 2. The outcomes of various parameters for each included study are presented in Table 3.

The κ value for inter-reviewer agreement for potentially relevant articles was 1 (titles and abstracts) and 0.85 (full-text articles), indicating an "almost perfect" agreement between the two reviewers according to the criteria of Landis and Koch.[62]

Features of the Included Studies

Study design and participant features. Seven cross-sectional studies[23,29,33,35,41,44,50] and four longitudinal studies[30,34,45,48] were included. Of these articles, three studies[44,45,48] recorded the primary and secondary outcomes on both buccal and lingual sides; the other studies only evaluated the outcomes on the buccal aspect. As such, average values were calculated and used in this review. The age of the participants ranged from 16[35] to 86[33] years old. In addition, the average loading period varied among studies, with a mean loading period of 50.7 months, ranging from 12[30,35] to 135.6[45] months. Smokers were included in 6 studies.[23,29,33,34,48,50]

Installation site and restoration characteristics. Four studies[23,30,44,45] placed dental implants for supporting overdentures. Of these four studies, three studies[30,44,45] only included implants placed in mandibular arches, whereas another study[23] had implants in both maxillary and mandibular arches. Patients in six studies[29,34,35,41,48,50] were reconstructed with fixed restorations, including single crown and partial or complete fixed restorations. Of these six studies, Crespi et al.[34] included implants in anterior and posterior regions from both jaws, Kim et al.[41] had implants in posterior areas from both jaws, Schrott et al.[48] only included implants placed in completely mandibular edentulous patients, and Esper et al.[35] included fixtures placed in the maxillary cleft area. Another two studies[29,50] did not specify installation site. One study[33] included implants restored with fixed or removable prostheses, and the implants were placed in anterior or posterior regions from both jaws.

Implant surfaces. Implants exclusively with rough body and smooth platform were examined in five studies,[30,34,44,45,48] whereas one study[33] had both rough and smooth surfaced implants. Three studies[23,29,35] did not report the implant system used; therefore, the surface characteristics could not be obtained.

Other features. Of the selected studies, one study[34] evaluated the peri-implant mucosal health of immediately loaded implants placed in fresh extraction sockets, whereas the other studies were designed to examine only delayed loading of dental implants. Esper et al.[35] evaluated the role of KM around dental implants in patients with cleft lip and/or cleft palate, and all patients underwent alveolar bone grafting to restore the thickness of the alveolar ridge before implant placement. Although most studies defined tissues with KM ≥2 mm as the wide group, two studies[44,50] used 1 mm as the cutoff point. Only one study[29] did adjustment for variables when performing statistical analysis.

Results of the Meta-Analyses

The statistical results from each of the selected studies were converted into effect sizes and combined in the meta-analyses. Four of the nine periodontal parameters (PI/mPI, mGI, MR, and AL) showed significant differences between wide and narrow width of KM, all favoring the wide KM group. However, most comparisons presented considerable heterogeneity between studies; only AL showed low heterogeneity. The results and forest plots of meta-analyses for each clinical parameter were demonstrated in Table 4 and Figure 1. Only outcomes with significant differences are discussed because of space limitation. For the other outcomes and funnel plots, please refer to supplementary Figures 2 and 3 in the online *Journal of Periodontology*.

Ten articles were included for evaluation of PI/mPI: WMD = –0.27 mm, with a 95% CI = –0.43 to –0.11 ($P = 0.001$) (Fig. 1A). For mGI, three articles were included: WMD = –0.48, with a 95%

Table 2.

Features of the Included Articles

Authors (Year)	Design	Participants		KM Width (mm): T1/T2	Fixtures						Main Conclusions
		n	Mean age (SD) and Sex		Body Surface	Platform Surface	Restoration Types	Implants (n) T1/T2	Location	Loading Period (months)	
Mericske-Stern (1990)[44]	CS	67	64 (0.9); 28 males, 39 females	≥2/≤ 1	Rough	Smooth	OD	B: 66/71, L: 76/61	Mandible	66	Only PD of lingual side had SSD; no SSD was found in mBI and mPI.
Mericske-Stern et al., (1994)[45]	LG	32	69 (7); 15 males, 17 females	≥2/<2	Rough	Smooth	OD	B: 40/24, L: 39/25	Mandible	135.6	Only AL of lingual side had SSD; mBI, mPI and PD did not.
Chung et al. (2006)[33]	CS	69	55.7 (12.88); 28 males, 41 females	≥2/<2	Smooth/ rough	Smooth/ rough	FIX/OD	B: 255/84	198 maxilla, 141 mandible	97.2 (2.76)	Both GI and mPI had SSD; mBI, PD. and BL did not.
Bouri et al. (2008)[29]	CS	76	NR	≥2/<2	NR	NR	FIX	B: 110/90	NR	53.52 (31.56)	BL, mPI, and mGI had SSD; PD had no SSD.
Zigdon and Machtei (2008)[50]	CS	32	58.6 (10.9); 18 males, 14 females	>1/≤1	Rough	NR	FIX	B: 22/41	NR	35.24 (16.65)	BOP, PD, MR, and BL all showed SSD.
Adibrad et al. (2009)[23]	CS	27	63.1 (6.9); 12 males, 15 females	≥2/<2	NR	NR	OD	B: 36/30	24 maxilla, 42 mandible	25.40 (10.28)	BOP, mPI, mGI, PD, MR, BL, and AL all showed SSD; PD did not.
Kim et al. (2009)[41]	CS	100	52; 52 males, 48 females	≥2/<2	Rough	NR	FIX	B: 186/90	132 maxilla, 144 mandible	12.71 (4.87)	MR and BL had SSD; PI, GI, and PD had no SSD.
Schrott et al. (2009)[48]	LG	73	58 (9.6); 35 males, 38 females	≥2/<2	Rough	Smooth	FIX	B: 346/40, L: 249/137	Mandible	60	Both mBI and mPI of lingual sides and MR of buccal side had SSD.
Crespi et al. (2010)[34]	LG	29	25 to 67; 18 males, 11 females	≥2/<2	Rough	Smooth	FIX	B: 125/39	132 maxilla, 32 mandible	48	mBI, mPI, mGI, and MR showed SSD; PD did not.

Table 2. (continued)

Features of the Included Articles

Authors (Year)	Design	Participants		KM Width (mm): T1/T2	Fixtures						Main Conclusions
		n	Mean age (SD) and Sex		Body Surface	Platform Surface	Restoration Types	Implants (n) T1/T2	Location	Loading Period (months)	
Boynueğri et al. (2012)[30]	LG	15	54 (10); 7 males, 8 females	≥2/<2	Rough	Smooth	OD	B: 15/15	Mandible	12	Both PI and GI had SSD; PD and BOP did not.
Esper et al. (2012)[35]	CS	109	16 to 50; NR	≥2/<2	NR	NR	FIX	B: 133/69	Mandible	12	SSD was found only in PD; PI and GI did not.

Standard deviations are indicated in parentheses.
* = unpublished data; NR = unclear/not reported; CS = cross-sectional; LG = longitudinal; T1 = wide KM group; T2 = narrow KM group; OD = implant-supported overdenture; FIX = implant-retained fixed restoration; B = implants studied on the buccal site; L = implants studied on the lingual site; SSD = statistically significant difference.

CI = –0.70 to –0.27 (P <0.0001) (Fig. 1B). Five articles were included for evaluation of MR: WMD = –0.60 mm, with a 95% CI = –0.85 to –0.36 mm (P <0.00001) (Fig. 1C). For AL, three articles were included: WMD = –0.35 mm, with a 95% CI = –0.65 to –0.06 mm (P = 0.02) (Fig. 1D).

Meta-Analyses Results Stratified by Types of Prostheses

Implants supporting fixed and removable dentures were further analyzed separately. For implants restored with fixed prostheses, the mean values of PI/mPI (six studies[29,33-35,41,48] were synthesized and analyzed, WMD = –0.28, 95% CI = –0.48 to –0.09, P = 0.004), mGI (two studies[29,34] were synthesized and analyzed, WMD = –0.44, 95% CI = –0.68 to –0.20, P = 0.0,003), MR (four studies[34,41,48,50] were synthesized and analyzed, WMD = –0.67 mm, 95% CI = –0.94 to –0.40 mm, P<0.00001), and AL (only one study[50]) were significantly lower in the wide KM group. For implants restored with removable prosthesis, wide KM was beneficial in reducing PI/mPI (five studies[23,30,33,44,45] were synthesized and analyzed, WMD = –0.24, 95% CI = –0.48 to –0.01, P = 0.04), GI (two studies[30,33] were synthesized and analyzed, WMD = –0.35, 95% CI = –0.61 to –0.10, P = 0.006), and mGI (only one study[23]). No statistical significance was found for the other clinical parameters.

Meta-Analyses Results Stratified by Measurement Site

To evaluate the influence of KM width on the buccal and lingual areas, respectively, meta-analyses were performed separately for both sides. Of the included studies, data of the lingual region were only available for four parameters (mBI, PI/mPI, PD, and AL); therefore, the results of these parameters were compared. For buccal side, the mean values of PI/mPI (all studies were synthesized and analyzed except for one study,[50] WMD = –0.24, 95% CI = –0.43 to –0.06, P = 0.01) and AL (only one study[50]) were significantly lower in the wide KM group. No statistically significant difference was found in mBI and PD. For the lingual side, three parameters, PI/mPI (five studies[23,30,33,44,45] were synthesized and analyzed, WMD = –0.24, 95% CI = –0.48 to –0.01, P = 0.04), AL (only one study[45]), and PD (two studies[44,45] were synthesized and analyzed, WMD = 0.32 mm, 95% CI = 0.06 to 0.58 mm, P = 0.02), showed statistical difference. Interestingly, although a wide width of KM proved more beneficial in reducing PI/mPI and AL, it was associated with deeper PD in lingual side.

Results of Risk of Bias Assessment

The results of risk of bias assessment were summarized in supplementary Table 2 (see the online

Table 3.

Summary of Various Outcomes That Are Investigated in This Systematic Review

Authors (year)	Implants (n) T1/T2	BOP T1	BOP T2	BOP *P* value	mBI T1	mBI T2	mBI *P* value	PI/mPI T1	PI/mPI T2	PI/mPI *P* value	GI T1	GI T2	GI *P* value	mGI T1	mGI T2	mGI *P* value
Mericske-Stern (1990)[44]	B: 66/71 L: 76/61				B: 0.6 (0.7) L: 0.7 (0.7) 0.65 (0.7)	B: 0.9 (0.9) L: 0.8 (0.9) 0.85 (0.9)	>0.05 >0.05	B: 0.6 (0.6) L: 0.8 (0.8) 0.71 (0.72)	B: 0.6 (0.6) L: 1.1 (0.9) 0.83 (0.79)	>0.05 >0.05						
Mericske-Stern et al., (1994)[45]	B: 40/24 L: 39/25				B: 0.10 (0.3) L: 0.35 (0.1) 0.22 (0.26)	B: 0.16 (0.1) L: 0.24 (0.6) 0.2 (0.43)	>0.05 >0.05	B: 0.40 (0.6) L: 0.69 (0.7) 0.54 (0.66)	B: 0.50 (0.5) L: 0.48 (0.7) 0.49 (0.6)	>0.05 >0.05						
Chung et al. (2006)[33]	B: 255/84				0.54 (1.44)	0.40 (0.55)	>0.05	1.26 (0.80)	1.51 (0.82)	**<0.05**	0.76 (0.64)	0.94 (0.64)	**<0.05**			
Bouri et al. (2008)[29]	B: 110/90							1.25 (0.53)	1.78 (0.78)	**<0.001**				0.91 (0.72)	1.50 (0.77)	**<0.001**
Zigdon and Machtei (2008)[50]	B: 22/41	0.363 (0.295)	0.226 (0.347)	**0.031**												
Adibrad et al. (2009)[23]	B:36/30	0.38 (0.34)	0.49 (0.30)	**0.04**				1.20 (0.71)	1.87 (0.59)	**0.02**				1.01 (0.67)	1.65 (0.78)	**0.01**
Kim et al. (2009)[41]	B: 186/90							0.74 (0.83)	0.74 (0.91)	0.943	0.38 (0.66)	0.44 (0.72)	0.472			
Schrott et al. (2009)[48]	B: 346/40 L: 249/137				B: 0.07 (0.32) L: 0.13 (0.41) 0.1 (0.36)	B: 0.05 (0.24) L: 0.22 (0.53) 0.18 (0.48)	0.13 **<0.05**	B: 0.25 (0.56) L: 0.40 (0.68) 0.31 (0.62)	B: 0.24 (0.54) L: 0.67 (0.85) 0.57 (0.81)	0.38 **0.001**						
Crespi et al. (2010)[34]	B: 125/39				0.35 (0.05)	0.78 (0.05)	**0.008**	1.18 (0.09)	1.71 (0.12)	**0.005**				0.67 (0.09)	1.01 (0.11)	**0.004**
Boynueğri et al. (2012)[30]	B: 15/15	0.241 (0.304)	0.392 (0.356)	>0.05				0.250 (0.486)	0.583 (0.532)	**<0.05**	0.067 (0.258)	0.583 (0.595)	**<0.05**			
Esper et al. (2012)[35]	B: 133/69							0.60 (0.62)	0.67 (0.71)	>0.05	1.25 (0.61)	1.11 (0.58)	>0.05			

Journal of Periodontology). Three[29,33,34] studies were considered to have a moderate risk of bias; however, the other eight studies[23,30,35,41,44,45,48,50] were considered to have a high risk of bias.

DISCUSSION

Although previous reviews[43,53-55] have failed to support the concept that the lack of KM could jeopardize the maintenance of soft tissue health around dental implants, the results of the current review and meta-analyses, derived mainly from cross-sectional studies, suggested that the presence of at least 1- to 2-mm-wide KM might be beneficial in decreasing plaque accumulation, tissue inflammation, MR, and AL.

According to the results of meta-analyses, although only one parameter (mGI) related to tissue inflammation showed statistically significant difference, mBI and GI also presented a tendency of favoring wide KM. This revealed that the presence of a minimal amount of KM may help decrease peri-implant inflammation. Moreover, PI/mPI was statistically significantly lower in the wide KM group, suggesting a positive effect of KM on decreasing plaque accumulation. Similar results were reported previously.[29,48,49]

Additionally, the presence of KM is also associated with less MR and AL. This is in concurrence with several studies.[20,23,25,50] However, Bengazi et al.[51] reported that the lack of KM was a poor predictor of soft tissue recession occurring during the first 2-year follow-up period, and the recession of peri-implant soft tissue could be merely a result of tissue remodeling to establish biologic width of the peri-implant mucosa. The discrepancy might result from potential confounding factors, for example, differences in follow-up period, implant position, soft- and hard-tissue quality, and oral hygiene standards among studies.

Interestingly, the mean PD, although without statistical difference, was shallower in the narrow KM group. This relationship was also reported and in accordance with previous studies.[35,44,47,50] Zigdon and Machtei[50] described that the phenomenon might be related to the fact that greater MR, and thereby less pocket formation, was more common in regions with narrow width of KM.

Table 3. (continued)

Summary of Various Outcomes That Are Investigated in This Systematic Review

Authors (year)	Implants (n) T1/T2	PD			MR			BL			AL		
		T1	T2	*P* value	T1	T2	*P* value	T1	T2	*P* value	T1	T2	*P* value
Mericske-Stern (1990)[44]	B: 66/71 L: 76/61	B: 2.8 (0.9) L: 3.2 (1.1) 3.01 (1.03)	B: 2. 6 (0.9) L: 2.8 (0.81) 2.69 (0.82)	>0.05 **<0.05**									
Mericske-Stern et al., (1994)[45]	B: 40/24 L: 39/25	B: 2.82 (0.9) L: 3.05 (1.0) 2.93 (0.95)	B: 2.45 (1.1) L: 2.88 (0.8) 2.67 (0.93)	>0.05 >0.05							B: 3.30 (1.2) L: 3.23 (1.2) 3.27 (1.2)	B: 3.16 (1.3) L: 3.72 (1.1) 3.45 (1.22)	>0.05 **<0.05**
Chung et al. (2006)[33]	B: 255/84	2.90 (0.80)	2.85 (0.55)	>0.05				0.11 (0.32)	0.11 (0.18)	>0.05			
Bouri et al. (2008)[29]	B: 110/90	3.72 (0.75)	3.87 (0.66)	0.132				1.24 (0.69)	1.72 (1.18)	**<0.001**			
Zigdon and Machtei (2008)[50]	B: 22/41	3.13 (0.868)	2.664 (0.776)	**0.04**	0.274 (0.515)	0.9 (0.778)	**0.001**				2.65 (0.862)	3.34 (1.19)	**0.019**
Adibrad et al. (2009)[23]	B:36/30	2.98 (0.51)	3.11 (0.56)	0.115	0.55 (0.49)	0.85 (0.79)	**0.03**	1.12 (0.75)	1.24 (0.91)	**0.07**	2.95 (0.89)	3.21 (1.01)	**0.04**
Kim et al. (2009)[41]	B: 186/90	2.84 (1.80)	2.62 (1.55)	0.328	0.32 (0.69)	0.72 (0.99)	**<0.001**	0.41 (0.75)	0.65 (0.81)	**0.019**			
Schrott et al. (2009)[48]	B: 346/40 L: 249/137				0.08 (0.86)	0.69 (1.11)	**<0.001**						
Crespi et al. (2010)[34]	B: 125/39	2.73 (0.34)	2.81 (0.41)	0.531	0.24 (0.16)	1.30 (0.80)	**0.008**						
Boynueğri et al. (2012)[30]	B: 15/15	1.714 (0.160)	1.970 (0.158)	>0.05									
Esper et al. (2012)[35]	B: 133/69	3.02 (1.05)	2.43 (1.02)	**<0.05**									

P values with statistically significant differences are marked in bold. Empty fields indicate that no data was reported in the selected article.
* = calculated by the authors; T1 = wide KM group; T2 = narrow KM group; B = buccal; L = lingual; O = overall.

According to the findings of the present study, there is a trend, but not statistically significant, to have more BL in the narrow KM group. This result confirmed previous findings by Chung et al.[33] that the absence of a wide width of KM has little to no impact on alveolar bone level. Conversely, the results of other studies[28,29,36,40,41,47] stated a positive correlation between alveolar BL and narrow KM. More controlled studies are needed to confirm the influence of KM on peri-implant BL.

Although in the present review both implant-restored removable and fixed prostheses were included for meta-analyses, peri-implant tissues might perform differently between these two types of restorations. Kaptein et al.[39] reported that implants under overdentures presented worse peri-implant tissue health and had more risk for BL. However, when the width of KM was considered, there was no significant correlation with any clinical parameters of implants restored with either fixed or removable prostheses.[33,39]

The present review also evaluated the effect of KM on the peri-implant tissue health at buccal or lingual area. Although the separate results were similar to the pooled outcomes, PD was significantly lower in the narrow KM group than in the wide KM group at the lingual side. The reason for this finding is unknown; however, it is notable that the two studies[44,45] included in the meta-analyses are from the same group, and the publication bias might exist.

The effect of different implant surfaces and designs on marginal bone level was widely investigated. Kehl et al.[40] reported that BL at straight, threaded implants with a machined surface was greater than at implants with a partially machined surface. In contrast, a recent review by Abrahamsson and Berglundh[63] concluded that there was a lack of evidence to claim that modified surfaces might be superior to smooth implant surfaces with respect to preserving marginal bone. Nevertheless, whether implant surface characteristics might influence the effect of KM on peri-implant tissues is less discussed. Rough surface is associated with a higher rate of peri-implantitis, and therefore, KM width might be more critical for rough-surface implants than smooth-surface implants for maintaining peri-implant

Table 4.

Summary of Meta-Analyses for Each Clinical Parameter

Variables	Studies (n)	Mean Difference	*P* Value for the Mean Difference	τ^2	*P* Value for the χ^2 Test	I^2
BOP	3	–0.03	0.73	0.02	**0.05**	67%
mBI	5	–0.12	0.34	0.07	**<0.00001**	97%
PI/mPI	10	–0.27	**0.001**	0.06	**<0.00001**	90%
GI	4	–0.12	0.26	0.04	**0.002**	80%
mGI	3	–0.48	**<0.0001**	0.03	**0.02**	75%
PD	10	0.09	0.27	0.05	**<0.00001**	83%
MR	5	–0.60	**<0.00001**	0.06	**0.0008**	79%
BL	4	–0.20	0.10	0.04	**0.001**	81%
AL	3	–0.35	**0.02**	0.01	0.30	18%

P values with statistically significant differences are marked in bold.

tissue health. Chung et al.[33] reported that the presence of KM was not a critical factor for maintaining dental implants regardless of their surface configurations. In the current review, most included studies used implants with a rough-surface implant body and smooth-surface platform; therefore, it is difficult to make a comparison. Clinical trials are necessary to investigate this interesting topic.

Various surgical procedures aimed to preserve and/or reconstruct KM around dental implants have been advocated to facilitate restorative procedures and to enhance esthetics and plaque control.[64-66] In a recent review,[53] it was suggested that surgical augmentation of keratinized tissue could be indicated to make hygiene easier, to minimize ongoing MR or AL, to decrease soreness when brushing, or to improve esthetics. Based on the results of the current review, there might be therapeutic advantages to augmenting KM. However, the beneficial role of surgical augmentation of keratinized tissue has to be confirmed by interventional studies.

To examine the heterogeneity among studies, χ^2 and I^2 tests were introduced in meta-analyses. Only one parameter (AL) presented a low degree of heterogeneity (*P* value for the χ^2 test = 0.30 and I^2 test = 18%). The limited number of included studies for AL (n = 3) and the combination of studies with different designs in meta-analyses might be responsible for the considerable heterogeneity. To avoid the bias from combining studies with different designs,[67] meta-analysis of each parameter with the same study design (longitudinal and cross-sectional) was also performed separately. However, none of the parameters showed any change of statistical significance when examining pooled results of cross-sectional studies and longitudinal studies. It is worth noting that two parameters (mGI and MR) presented extremely low value of I^2 test, which represented less heterogeneity, when only cross-sectional studies were analyzed. For mGI, the pooled results of two cross-sectional studies[23,29] had an I^2 test value of 0%; for MR, three cross-sectional studies[23,41,50] were analyzed and had an I^2 test value of 5%, both favoring the wide KM group. These two parameters presented very low heterogeneity, and highly statistically significant difference when only cross-sectional studies were examined.

Several limitations of the present review are worth noting. First, most related studies are cross-sectional studies; Changes of peri-implant tissues over time in relation to the amount of KM will be more meaningful to assess the true effect of KM on peri-implant health. Second, although meta-analyses are performed in this review, heterogeneity and publication bias exist. Heterogeneity is related to the presence of confounding factors within and among the selected studies, for example, smoking habits and underlying diseases. However, only one included study[48] adjusted for related confounding factors. Heterogeneity is also related to the low number of the included papers (n = 11). Third, the current review only included studies written in English, and this could introduce publication bias. Fourth, the use of average values of secondary outcomes on both buccal and lingual sides might also be noted when interpreting the findings of meta-analysis. Fifth, the results of clinical parameters

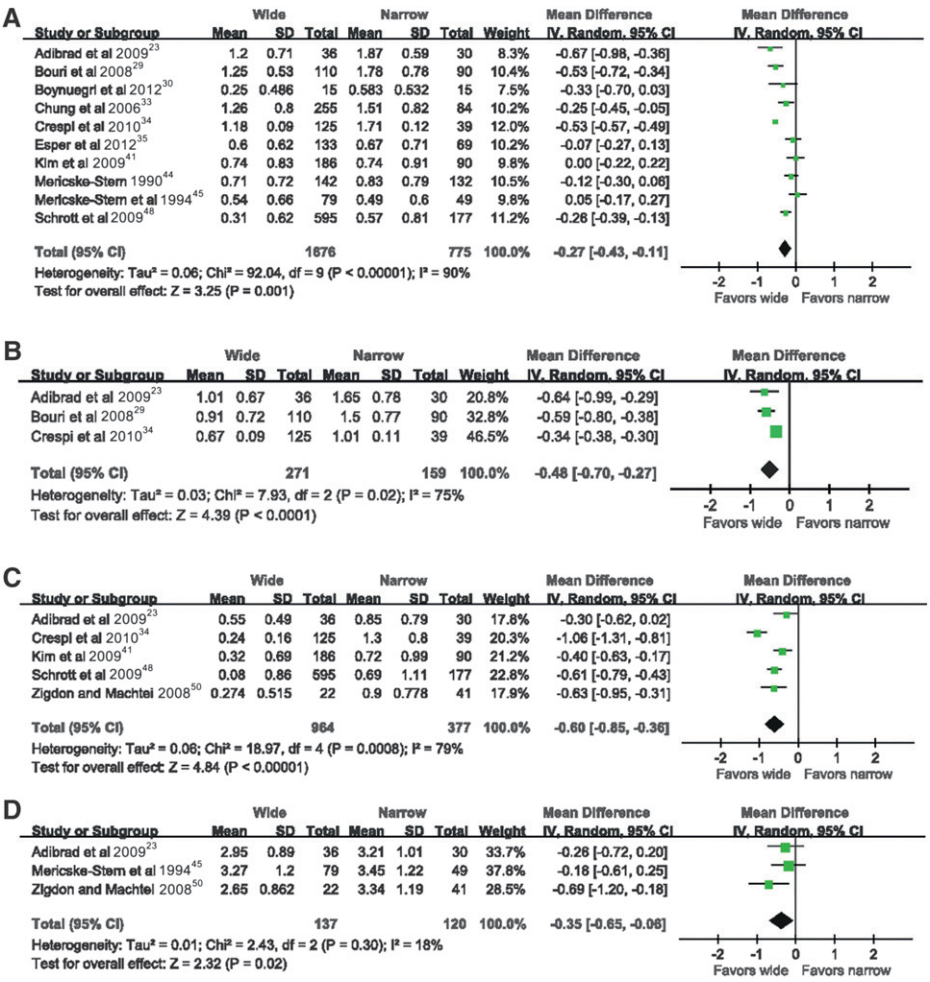

Figure 1.
A) *Meta-analysis for the comparison of PI/mPI. The WMD in PI and mPI between implants with wide and narrow KM was –0.27 (95% CI = –0.43 to –0.11), favoring the wide group with statistical significance (P = 0.001).* ***B)*** *Meta-analysis for the comparison of mGI. The WMD in mGI between implants with wide and narrow KM was –0.48 (95% CI = –0.70 to –0.27), favoring the wide group with statistical significance (P <0.0001).* ***C)*** *Meta-analysis for the comparison of MR. The WMD in MR between implants with wide and narrow KM was –0.60 mm (95% CI = –0.85 to –0.36 mm), favoring the wide group with statistical significance (P <0.00001).* ***D)*** *Meta-analysis for the comparison of AL. The WMD in AL between implants with wide and narrow KM was –0.35 mm (95% CI = –0.65 to –0.06 mm), favoring the wide group with statistical significance (P = 0.02).*

were strongly related to the degree of patients' oral hygiene and supportive cares, but this information was not provided in most studies.

CONCLUSIONS

Eleven articles were available to investigate the effect of KM on maintenance of peri-implant health. The results of meta-analyses suggested that inadequate KM was associated with higher PI/mPI, mGI, MR, and AL. However, no significant difference was found with regard to BOP, mBI, GI, PD, and BL. Future interventional studies are needed to confirm the above results.

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REFERENCES

1. Lang NP, Löe H. The relationship between the width of keratinized gingiva and gingival health. *J Periodontol* 1972;43:623-627.
2. Miyasato M, Crigger M, Egelberg J. Gingival condition in areas of minimal and appreciable width of keratinized gingiva. *J Clin Periodontol* 1977;4:200-209.
3. Dorfman HS, Kennedy JE, Bird WC. Longitudinal evaluation of free autogenous gingival grafts. *J Clin Periodontol* 1980;7:316-324.
4. Dorfman HS, Kennedy JE, Bird WC. Longitudinal evaluation of free autogenous gingival grafts. A four year report. *J Periodontol* 1982;53:349-352.
5. Kennedy JE, Bird WC, Palcanis KG, Dorfman HS. A longitudinal evaluation of varying widths of attached gingiva. *J Clin Periodontol* 1985;12:667-675.
6. Lindhe J, Nyman S. Alterations of the position of the marginal soft tissue following periodontal surgery. *J Clin Periodontol* 1980;7:525-530.
7. Wennström J, Lindhe J. Role of attached gingiva for maintenance of periodontal health. Healing following excisional and grafting procedures in dogs. *J Clin Periodontol* 1983;10:206-221.
8. Wennström JL. Lack of association between width of attached gingiva and development of soft tissue recession. A 5-year longitudinal study. *J Clin Periodontol* 1987;14:181-184.
9. Lindhe J, Echeverria J. Consensus report of session II. In: Lang NP, Karring T, eds. *Proceedings of the 1st European Workshop on Periodontology*. Berlin, Germany: Quintessence; 1994:210-214.

10. Abrahamsson I, Berglundh T, Moon IS, Lindhe J. Peri-implant tissues at submerged and non-submerged titanium implants. *J Clin Periodontol* 1999;26:600-607.
11. Albrektsson T, Jansson T, Lekholm U. Osseointegrated dental implants. *Dent Clin North Am* 1986;30:151-174.
12. Berglundh T, Lindhe J, Ericsson I, Marinello CP, Liljenberg B, Thomsen P. The soft tissue barrier at implants and teeth. *Clin Oral Implants Res* 1991;2:81-90.
13. Buser D, Weber HP, Donath K, Fiorellini JP, Paquette DW, Williams RC. Soft tissue reactions to non-submerged unloaded titanium implants in beagle dogs. *J Periodontol* 1992;63:225-235.
14. Ericsson I, Berglundh T, Marinello C, Liljenberg B, Lindhe J. Long-standing plaque and gingivitis at implants and teeth in the dog. *Clin Oral Implants Res* 1992;3:99-103.
15. Ericsson I, Lindhe J. Probing depth at implants and teeth. An experimental study in the dog. *J Clin Periodontol* 1993;20:623-627.
16. Gould TR, Westbury L, Brunette DM. Ultrastructural study of the attachment of human gingiva to titanium in vivo. *J Prosthet Dent* 1984;52:418-420.
17. Jansen JA, de Wijn JR, Wolters-Lutgerhorst JM, van Mullem PJ. Ultrastructural study of epithelial cell attachment to implant materials. *J Dent Res* 1985;64:891-896.
18. Gould TR, Brunette DM, Westbury L. The attachment mechanism of epithelial cells to titanium in vitro. *J Periodontal Res* 1981;16:611-616.
19. Lindhe J, Berglundh T, Ericsson I, Liljenberg B, Marinello C. Experimental breakdown of peri-implant and periodontal tissues. A study in the beagle dog. *Clin Oral Implants Res* 1992;3:9-16.
20. Warrer K, Buser D, Lang NP, Karring T. Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. An experimental study in monkeys. *Clin Oral Implants Res* 1995;6:131-138.
21. Strub JR, Gaberthüel TW, Grunder U. The role of attached gingiva in the health of peri-implant tissue in dogs. 1. Clinical findings. *Int J Periodontics Restorative Dent* 1991;11:317-333.
22. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg* 1981;10:387-416.
23. Adibrad M, Shahabuei M, Sahabi M. Significance of the width of keratinized mucosa on the health status of the supporting tissue around implants supporting overdentures. *J Oral Implantol* 2009;35:232-237.
24. Apse P, Ellen RP, Overall CM, Zarb GA. Microbiota and crevicular fluid collagenase activity in the osseointegrated dental implant sulcus: A comparison of sites in edentulous and partially edentulous patients. *J Periodontal Res* 1989;24:96-105.
25. Artzi Z, Carmeli G, Kozlovsky A. A distinguishable observation between survival and success rate outcome of hydroxyapatite-coated implants in 5-10 years in function. *Clin Oral Implants Res* 2006;17:85-93.
26. Baqain ZH, Moqbel WY, Sawair FA. Early dental implant failure: Risk factors. *Br J Oral Maxillofac Surg* 2012;50:239-243.
27. Block MS, Gardiner D, Kent JN, Misiek DJ, Finger IM, Guerra L. Hydroxyapatite-coated cylindrical implants in the posterior mandible: 10-year observations. *Int J Oral Maxillofac Implants* 1996;11:626-633.
28. Block MS, Kent JN. Factors associated with soft- and hard-tissue compromise of endosseous implants. *J Oral Maxillofac Surg* 1990;48:1153-1160.
29. Bouri A Jr., Bissada N, Al-Zahrani MS, Faddoul F, Nouneh I. Width of keratinized gingiva and the health status of the supporting tissues around dental implants. *Int J Oral Maxillofac Implants* 2008;23:323-326.
30. Boynueğri D, Nemli SK, Kasko YA. Significance of keratinized mucosa around dental implants: A prospective comparative study. *Clin Oral Implants Res* 2013;24:928-933.
31. Brägger U, Bürgin WB, Hämmerle CH, Lang NP. Associations between clinical parameters assessed around implants and teeth. *Clin Oral Implants Res* 1997;8:412-421.
32. Camargos GdeV, do Prado CJ, das Neves FD, Sartori IA. Clinical outcomes of single dental implants with external connections: Results after 2 to 13 years. *Int J Oral Maxillofac Implants* 2012;27:935-944.
33. Chung DM, Oh TJ, Shotwell JL, Misch CE, Wang HL. Significance of keratinized mucosa in maintenance of dental implants with different surfaces. *J Periodontol* 2006;77:1410-1420.
34. Crespi R, Capparè P, Gherlone E. A 4-year evaluation of the peri-implant parameters of immediately loaded implants placed in fresh extraction sockets. *J Periodontol* 2010;81:1629-1634.
35. Esper LA, Ferreira SB Jr., de Oliveira Fortes Kaizer R, de Almeida AL. The role of keratinized mucosa in peri-implant health. *Cleft Palate Craniofac J* 2012;49:167-170.
36. Hanisch O, Cortella CA, Boskovic MM, James RA, Slots J, Wikesjö UM. Experimental peri-implant tissue breakdown around hydroxyapatite-coated implants. *J Periodontol* 1997;68:59-66.
37. Heckmann SM, Schrott A, Graef F, Wichmann MG, Weber HP. Mandibular two-implant telescopic overdentures. *Clin Oral Implants Res* 2004;15:560-569.
38. Iacono VJ; Committee on Research, Science and Therapy, the American Academy of Periodontology. Dental implants in periodontal therapy. *J Periodontol* 2000;71:1934-1942.
39. Kaptein ML, De Lange GL, Blijdorp PA. Peri-implant tissue health in reconstructed atrophic maxillae—Report of 88 patients and 470 implants. *J Oral Rehabil* 1999;26:464-474.
40. Kehl M, Swierkot K, Mengel R. Three-dimensional measurement of bone loss at implants in patients with periodontal disease. *J Periodontol* 2011;82:689-699.
41. Kim BS, Kim YK, Yun PY, et al. Evaluation of peri-implant tissue response according to the presence of keratinized mucosa. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107:e24-e28.
42. Lekholm U, Adell R, Lindhe J, et al. Marginal tissue reactions at osseointegrated titanium fixtures. (II) A cross-sectional retrospective study. *Int J Oral Maxillofac Surg* 1986;15:53-61.
43. Martin W, Lewis E, Nicol A. Local risk factors for implant therapy. *Int J Oral Maxillofac Implants* 2009;24(Suppl.):28-38.
44. Mericske-Stern R. Clinical evaluation of overdenture restorations supported by osseointegrated titanium implants: A retrospective study. *Int J Oral Maxillofac Implants* 1990;5:375-383.

45. Mericske-Stern R, Steinlin Schaffner T, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study. *Clin Oral Implants Res* 1994;5:9-18.
46. Mericske-Stern R, Zarb GA. Overdentures: An alternative implant methodology for edentulous patients. *Int J Prosthodont* 1993;6:203-208.
47. Roos-Jansåker AM, Renvert H, Lindahl C, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part III: Factors associated with peri-implant lesions. *J Clin Periodontol* 2006;33:296-301.
48. Schrott AR, Jimenez M, Hwang JW, Fiorellini J, Weber HP. 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. *Clin Oral Implants Res* 2009;20: 1170-1177.
49. Wennström JL, Bengazi F, Lekholm U. The influence of the masticatory mucosa on the peri-implant soft tissue condition. *Clin Oral Implants Res* 1994;5: 1-8.
50. Zigdon H, Machtei EE. The dimensions of keratinized mucosa around implants affect clinical and immunological parameters. *Clin Oral Implants Res* 2008;19: 387-392.
51. Bengazi F, Wennström JL, Lekholm U. Recession of the soft tissue margin at oral implants. A 2-year longitudinal prospective study. *Clin Oral Implants Res* 1996;7:303-310.
52. Schou S, Holmstrup P, Hjørting-Hansen E, Lang NP. Plaque-induced marginal tissue reactions of osseointegrated oral implants: A review of the literature. *Clin Oral Implants Res* 1992;3:149-161.
53. Greenstein G, Cavallaro J. The clinical significance of keratinized gingiva around dental implants. *Compend Contin Educ Dent* 2011;32:24-31; quiz 32, 34.
54. Salvi GE, Lang NP. Diagnostic parameters for monitoring peri-implant conditions. *Int J Oral Maxillofac Implants* 2004;19(Suppl.):116-127.
55. Wennström JL, Derks J. Is there a need for keratinized mucosa around implants to maintain health and tissue stability? *Clin Oral Implants Res* 2012;23(Suppl. 6): 136-146.
56. Löe H, Silness J. Periodontal disease in pregnancy. I. Prevalence and severity. *Acta Odontol Scand* 1963;21: 533-551.
57. Silness J, Löe H. Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand* 1964;22:121-135.
58. Mombelli A, van Oosten MA, Schurch E Jr., Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiol Immunol* 1987;2:145-151.
59. Löe H. The gingival index, the plaque index and the retention index systems. *J Periodontol* 1967;38(Suppl. 6):610-616.
60. Kahn K, ter Riet G, Popay J, Nixon J, Kleijen J. *Stage II: Conducting the Review. Phase 5: Study Quality Assessment*. York, UK: Centre for Reviews and Dissemination, University of York; 2001:1-20.
61. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Ann Intern Med* 2009;151:W65-W94.
62. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33: 159-174.
63. Abrahamsson I, Berglundh T. Effects of different implant surfaces and designs on marginal bone-level alterations: A review. *Clin Oral Implants Res* 2009;20 (Suppl. 4):207-215.
64. Barone R, Clauser C, Grassi R, Merli M, Prato GP. A protocol for maintaining or increasing the width of masticatory mucosa around submerged implants: A 1-year prospective study on 53 patients. *Int J Periodontics Restorative Dent* 1998;18:377-387.
65. Cairo F, Pagliaro U, Nieri M. Soft tissue management at implant sites. *J Clin Periodontol* 2008;35(Suppl. 8): 163-167.
66. Landi L, Sabatucci D. Plastic surgery at the time of membrane removal around mandibular endosseous implants: A modified technique for implant uncovering. *Int J Periodontics Restorative Dent* 2001;21:280-287.
67. Higgins JP, Green S, eds. *Cochrane Handbook for Systematic Reviews of Interventions*, Version 5.1.0 (updated March 2011). The Cochrane Collaboration; 2011. Available at: www.cochrane-handbook.org.

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