Review

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

Guo-Hao Lin,* † Hsun-Liang Chan, † and Hom-Lay Wang †

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 $\chi^2$ 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.

* Department of Stomatology, Taipei Veterans General Hospital, Taipei, Taiwan.
† Private practice, Hsin-chu, Taiwan.
‡ Graduate Periodontics, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, MI.

doi: 10.1902/jop.2013.120688
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])).


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

<table>
<thead>
<tr>
<th>Variables</th>
<th>Positive Relationship</th>
<th>No Relationship</th>
<th>Negative Relationship</th>
</tr>
</thead>
</table>
| **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 \(^{34}\)  
                                  | Boyne\u0161ri 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**            | 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 \(^{32}\)  
                                  | Boyne\u0161ri 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) \(^{48}\)  
                                  | Boyne\u0161ri et al., 2012 (BOP) \(^{30}\)  
                                  | Esper et al., 2012 (GI) \(^{35}\) | |
| **PD**                             | Brägger et al., 1997 \(^{31}\) | Lekholm et al., 1986 (lingual) \(^{44}\)  
                                  | Apse et al., 1989 (lingual) \(^{24}\)  
                                  | Mericske-Stern, 1990 (on buccal) \(^{44}\)  
                                  | Mericske-Stern et al., 1994 (lingual) \(^{45}\)  
                                  | 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 \(^{34}\)  
                                  | Boyne\u0161ri 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 \(^{35}\) |
modified GI (mGI); \(^5\),\(^8\) 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 \(k\) 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.,\(^6\) 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.

### 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, 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.

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.

### Table 1. (continued)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Positive Relationship</th>
<th>No Relationship</th>
<th>Negative Relationship</th>
</tr>
</thead>
</table>
| MR        | Braegger et al., 1997\(^3\)\(^1\)  
Artzi et al., 2006\(^2\)\(^5\)  
Zigdon and Machtei, 2008\(^5\)\(^0\)  
Kim et al., 2009\(^4\)\(^1\)  
Schrott et al., 2009\(^4\)\(^8\)  
Adibrad et al., 2009\(^2\)\(^3\)  
Crespi et al., 2010\(^2\)\(^4\) | Bengazi et al., 1996\(^5\)\(^1\) |                      |
| AL        | Mericske-Stern et al., 1994 (on lingual)\(^4\)\(^5\)  
Braegger et al., 1997\(^3\)\(^1\)  
Zigdon and Machtei, 2008\(^5\)\(^0\)  
Adibrad et al., 2009\(^2\)\(^3\) | Mericske-Stern et al., 1994 (on buccal)\(^4\)\(^5\) |                      |
| BL        | Block and Kent, 1996\(^2\)\(^8\)  
Hanisch et al., 1997\(^3\)\(^6\)  
Roos-Jansaker et al., 2006\(^4\)\(^7\)  
Bouri et al., 2008\(^2\)\(^9\)  
Kim et al., 2009\(^4\)\(^1\)  
Kehl et al., 2011\(^2\)\(^0\) | Lekholm et al., 1986\(^4\)\(^2\)  
Chung et al., 2006\(^3\)\(^3\) |                      |

\(\text{PI} = \text{plaque index; BI} = \text{bleeding index; GI} = \text{gingival index; BOP} = \text{bleeding on probing; PD} = \text{probing depth; MR} = \text{mucosal recession; AL} = \text{attachment loss; BL} = \text{bone loss.}\)

\(\)\(^\text{§}\) 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 \( \chi^2 \) 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 \( \kappa \) 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 \( \geq 2 \) 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

<table>
<thead>
<tr>
<th>Authors (Year)</th>
<th>Design</th>
<th>n</th>
<th>Mean age (SD) and Sex</th>
<th>KM Width (mm): T1/T2</th>
<th>Body Surface</th>
<th>Platform Surface</th>
<th>Restoration Types</th>
<th>Implants (n) T1/T2</th>
<th>Location</th>
<th>Loading Period (months)</th>
<th>Main Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mericske-Stern (1990)</td>
<td>CS</td>
<td>67</td>
<td>64 (0.9); 28 males, 39 females</td>
<td>≥2/≤ 1</td>
<td>Rough</td>
<td>Smooth</td>
<td>OD</td>
<td>B: 66/71, L: 76/61</td>
<td>Mandible</td>
<td>66</td>
<td>Only PD of lingual side had SSD; no SSD was found in mBI and mPI.</td>
</tr>
<tr>
<td>Mericske-Stern et al. (1994)</td>
<td>LG</td>
<td>32</td>
<td>69 (7); 15 males, 17 females</td>
<td>≥2/&lt;2</td>
<td>Rough</td>
<td>Smooth</td>
<td>OD</td>
<td>B: 40/24, L: 39/25</td>
<td>Mandible</td>
<td>135.6</td>
<td>Only AL of lingual side had SSD; mBI, mPI and PD did not.</td>
</tr>
<tr>
<td>Chung et al. (2006)</td>
<td>CS</td>
<td>69</td>
<td>55.7 (12.88); 28 males, 41 females</td>
<td>≥2/&lt;2</td>
<td>Smooth/rough</td>
<td>Smooth/rough</td>
<td>FIX/OD</td>
<td>B: 255/84</td>
<td>198 maxilla, 141 mandible</td>
<td>97.2 (2.76)</td>
<td>Both GI and mPI had SSD; mBI, mPI and PD did not.</td>
</tr>
<tr>
<td>Bouri et al. (2008)</td>
<td>CS</td>
<td>76</td>
<td>NR</td>
<td>≥2/&lt;2</td>
<td>NR</td>
<td>NR</td>
<td>FIX</td>
<td>B: 110/90</td>
<td>NR</td>
<td>53.52 (31.56)</td>
<td>BL, mPI and mGI had SSD; PD had no SSD.</td>
</tr>
<tr>
<td>Zigdon and Machtei (2008)</td>
<td>CS</td>
<td>32</td>
<td>58.6 (10.9); 18 males, 14 females</td>
<td>&gt;1/≤1</td>
<td>Rough</td>
<td>NR</td>
<td>FIX</td>
<td>B: 22/41</td>
<td>NR</td>
<td>35.24 (16.65)</td>
<td>BOP, PD, MR, and BL all showed SSD.</td>
</tr>
<tr>
<td>Adibrad et al. (2009)</td>
<td>CS</td>
<td>27</td>
<td>63.1 (6.9); 12 males, 15 females</td>
<td>≥2/&lt;2</td>
<td>NR</td>
<td>NR</td>
<td>OD</td>
<td>B: 36/30</td>
<td>24 maxilla, 42 mandible</td>
<td>25.40 (10.28)</td>
<td>BOP, mPI, mGI, PD, MR, BL, and AL all showed SSD; PD did not.</td>
</tr>
<tr>
<td>Kim et al. (2009)</td>
<td>CS</td>
<td>100</td>
<td>52: 52 males, 48 females</td>
<td>≥2/&lt;2</td>
<td>Rough</td>
<td>NR</td>
<td>FIX</td>
<td>B: 186/90</td>
<td>132 maxilla, 144 mandible</td>
<td>12.71 (4.87)</td>
<td>MR and BL had SSD; PI, GI, and PD had no SSD.</td>
</tr>
<tr>
<td>Schrott et al. (2009)</td>
<td>LG</td>
<td>73</td>
<td>58 (9.6); 35 males, 38 females</td>
<td>≥2/&lt;2</td>
<td>Rough</td>
<td>Smooth</td>
<td>FIX</td>
<td>B: 346/40, L: 249/137</td>
<td>Mandible</td>
<td>60</td>
<td>Both mBI and mPI of lingual sides and MR of buccal side had SSD.</td>
</tr>
<tr>
<td>Crespi et al. (2010)</td>
<td>LG</td>
<td>29</td>
<td>25 to 67; 18 males, 11 females</td>
<td>≥2/&lt;2</td>
<td>Rough</td>
<td>Smooth</td>
<td>FIX</td>
<td>B: 125/39</td>
<td>132 maxilla, 32 mandible</td>
<td>48</td>
<td>mBI, mPI, mGI, and MR showed SSD; PD did not.</td>
</tr>
</tbody>
</table>
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 studies29,33-35,41,48 were synthesized and analyzed, WMD = −0.28, 95% CI = −0.48 to −0.09, P = 0.004), mGI (two studies29,34 were synthesized and analyzed, WMD = −0.44, 95% CI = −0.68 to −0.20, P = 0.0003), MR (four studies34,41,48,50 were synthesized and analyzed, WMD = −0.67 mm, 95% CI = −0.94 to −0.40 mm, P < 0.00001), and AL (only one study50) were significantly lower in the wide KM group. For implants restored with removable prosthesis, wide KM was beneficial in reducing PI/mPI (five studies23,30,33,44,45 were synthesized and analyzed, WMD = −0.24, 95% CI = −0.48 to −0.01, P = 0.04), GI (two studies30,33 were synthesized and analyzed, WMD = −0.35, 95% CI = −0.61 to −0.10, P = 0.006), and mGI (only one study23). 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 study50) 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 studies23,30,33,44,45 were synthesized and analyzed, WMD = −0.24, 95% CI = −0.48 to −0.01, P = 0.04), AL (only one study45), and PD (two studies44,45 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
Three 29, 33, 34 studies were considered to have a moderate risk of bias; however, the other eight studies23, 30, 35, 41, 44, 45, 48, 50 were considered to have a high risk of bias.

**DISCUSSION**

Although previous reviews43, 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.

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 Machtei50 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. Summary of Various Outcomes That Are Investigated in This Systematic Review

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Implants (n)</th>
<th>T1/T2</th>
<th>BOP</th>
<th>mBI</th>
<th>PI/mPI</th>
<th>GI</th>
<th>mGI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mericske-Stern (1990)</td>
<td>B: 66/71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L: 76/61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mericske-Stern et al.</td>
<td>B: 40/24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L: 39/25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chung et al. (2006)</td>
<td>B: 255/84</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boir (2008)</td>
<td>B: 110/90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zigdon and Machtei (2008)</td>
<td>B: 22/41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adelrad et al. (2009)</td>
<td>B: 33/30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kim et al. (2009)</td>
<td>B: 18/69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schrott et al. (2009)</td>
<td>B: 34/40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L: 24/137</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crespi et al. (2010)</td>
<td>B: 125/39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boyraj et al. (2012)</td>
<td>B: 15/15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esper et al. (2012)</td>
<td>B: 133/69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significance of Keratinized Mucosa on Implant Health**

Volume 84 Number 12

Although previous reviews 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.
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 studies28,29,36,40,41,47 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 studies44,45 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. Neither et al.33 reported a positive correlation between alveolar BL and narrow KM. More controlled studies are needed to confirm the influence of KM on peri-implant BL.

The effect of different implant surfaces and designs on marginal bone level was widely investigated. Neither et al.33 reported a positive correlation between alveolar BL and narrow KM. More controlled studies are needed to confirm the influence of KM on peri-implant BL.

Table 3. (continued)

Summary of Various Outcomes That Are Investigated in This Systematic Review

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Implants (n)</th>
<th>PD</th>
<th>MR</th>
<th>BL</th>
<th>AL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mericske-Stern (1990)</td>
<td>B: 66/71 L: 76/61</td>
<td>B: 2.8 (0.9) L: 3.01 (1.0)</td>
<td>B: 2.6 (0.9) L: 2.69 (0.82)</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mericske-Stern et al. (1994)</td>
<td>B: 40/24 L: 39/32</td>
<td>B: 2.82 (0.9) L: 2.93 (0.95)</td>
<td>B: 2.45 (1.1) L: 2.67 (0.93)</td>
<td>&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Chung et al. (2006)</td>
<td>B: 255/84</td>
<td>B: 2.90 (0.80) L: 2.85 (0.55)</td>
<td>&gt;0.05</td>
<td>0.11 (0.32) L: 0.11 (0.18)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Bouri et al. (2008)</td>
<td>B: 110/90</td>
<td>B: 3.72 (0.75) L: 3.87 (0.66)</td>
<td>0.132</td>
<td>1.24 (0.69) L: 1.72 (1.18)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Zipolon and Macht (2008)</td>
<td>B: 22/41</td>
<td>B: 3.13 (0.868) L: 2.664 (0.776)</td>
<td>0.04</td>
<td>0.274 (0.515) L: 0.078</td>
<td>0.001</td>
</tr>
<tr>
<td>Adorlad et al. (2009)</td>
<td>B: 36/30</td>
<td>B: 2.98 (0.51) L: 3.11 (0.56)</td>
<td>0.115</td>
<td>0.55 (0.49) L: 0.85 (0.79)</td>
<td>0.03</td>
</tr>
<tr>
<td>Kim et al. (2009)</td>
<td>B: 186/90</td>
<td>B: 2.84 (1.80) L: 2.62 (1.55)</td>
<td>0.328</td>
<td>0.32 (0.69) L: 0.72 (0.99)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Schrot et al. (2009)</td>
<td>B: 346/40 L: 249/17</td>
<td>B: 2.73 (0.34) L: 2.81 (0.41)</td>
<td>0.032</td>
<td>0.24 (0.16) L: 1.30 (0.80)</td>
<td>0.008</td>
</tr>
<tr>
<td>Crespi et al. (2010)</td>
<td>B: 125/39</td>
<td>B: 1.714 (0.160) L: 1.970 (0.158)</td>
<td>&gt;0.05</td>
<td>0.14 (0.75) L: 0.65 (0.81)</td>
<td>0.019</td>
</tr>
<tr>
<td>Boynueglu et al. (2012)</td>
<td>B: 15/15</td>
<td>B: 3.02 (1.03) L: 2.43 (1.02)</td>
<td>&gt;0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = calculated by the authors; T1 = wide KM group; T2 = narrow KM group; B = buccal; L = lingual; O = overall.

P values with statistically significant differences are marked in bold. Empty fields indicate that no data was reported in the selected article.
Significance of Keratinized Mucosa on Implant Health

Volume 84 • Number 12

1764

tissue health. Chung et al.\(^3\) 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.\(^6\) In a recent review, 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, \(\chi^2\) and \(I^2\) tests were introduced in meta-analyses. Only one parameter (AL) presented a low degree of heterogeneity (\(P\) value for the \(\chi^2\) 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,\(^6\) 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

---

Table 4.

Summary of Meta-Analyses for Each Clinical Parameter

<table>
<thead>
<tr>
<th>Variables</th>
<th>Studies (n)</th>
<th>Mean Difference</th>
<th>(P) Value for the Mean Difference</th>
<th>(\tau^2)</th>
<th>(P) Value for the (\chi^2) Test</th>
<th>(I^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOP</td>
<td>3</td>
<td>-0.03</td>
<td>0.73</td>
<td>0.02</td>
<td>0.05</td>
<td>67%</td>
</tr>
<tr>
<td>mBI</td>
<td>5</td>
<td>-0.12</td>
<td>0.34</td>
<td>0.07</td>
<td>&lt;0.00001</td>
<td>97%</td>
</tr>
<tr>
<td>PI/mPI</td>
<td>10</td>
<td>-0.27</td>
<td>0.01</td>
<td>0.06</td>
<td>&lt;0.00001</td>
<td>90%</td>
</tr>
<tr>
<td>GI</td>
<td>4</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.04</td>
<td>0.002</td>
<td>80%</td>
</tr>
<tr>
<td>mGI</td>
<td>3</td>
<td>-0.48</td>
<td>&lt;0.00001</td>
<td>0.03</td>
<td>0.02</td>
<td>75%</td>
</tr>
<tr>
<td>PD</td>
<td>10</td>
<td>0.09</td>
<td>0.27</td>
<td>0.05</td>
<td>&lt;0.00001</td>
<td>83%</td>
</tr>
<tr>
<td>MR</td>
<td>5</td>
<td>-0.60</td>
<td>&lt;0.000001</td>
<td>0.06</td>
<td>0.0008</td>
<td>79%</td>
</tr>
<tr>
<td>BL</td>
<td>4</td>
<td>-0.20</td>
<td>0.10</td>
<td>0.04</td>
<td>0.001</td>
<td>81%</td>
</tr>
<tr>
<td>AL</td>
<td>3</td>
<td>-0.35</td>
<td>0.02</td>
<td>0.01</td>
<td>0.30</td>
<td>18%</td>
</tr>
</tbody>
</table>

\(P\) values with statistically significant differences are marked in bold.
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.

ACKNOWLEDGMENTS

This review was partially supported by the University of Michigan Periodontal Graduate Student Research Fund. The authors acknowledge Prof. Kerby A. Shedden, Department of Statistics, University of Michigan, Ann Arbor, Michigan, for providing statistical consultation, and Mr. Mark MacEachern, Liaison Services Librarian, University of Michigan, Ann Arbor, Michigan, for gathering the articles for this review. The authors report no conflicts of interest related to this review.

REFERENCES


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.


Correspondence: Dr. Hom-Lay Wang, 1011 N. University Ave., Ann Arbor, MI 48109-1078. Fax: 734/936-0374; e-mail: homlay@umich.edu.

Submitted November 25, 2012; accepted for publication January 15, 2013.