Dimensions of Peri-Implant Mucosa: An Evaluation of Maxillary Anterior Single Implants in Humans

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Background: Attempts have been made to evaluate the biologic dimension of osseointegrated implants; however, most are histologic studies in animals, and the effect of soft tissue support from adjacent teeth on the interproximal dimension of the peri-implant mucosa for anterior single implants has not been addressed. This study clinically evaluated the dimensions of the peri-implant mucosa around 2-stage maxillary anterior single implants in humans after 1 year of function. The influence of the peri-implant biotype was also examined.

Methods: Forty-five patients (20 males and 25 females) with a mean age of 47.3 years were included in this study. A total of 45 maxillary anterior single implant crowns with a mean functional time of 32.5 months (range, 12 to 78) were evaluated. The dimensions of peri-implant mucosa were measured by bone sounding using a periodontal probe at the mesial (MI), mid-facial (F), and distal (DI) aspects of the implant restoration and the proximal aspects (MT, DT) of adjacent natural teeth. In addition, the peri-implant biotype was evaluated and categorized as thick or thin. Statistical analysis was performed using an independent t test (P < 0.05).

Results: The means and standard deviations of the dimensions of peri-implant mucosa at MT, MI, F, DI, and DT were 4.20 ± 0.77 mm, 6.17 ± 1.27 mm, 3.63 ± 0.91 mm, 5.93 ± 1.21 mm, and 4.20 ± 0.64 mm, respectively. The dimensions of peri-implant mucosa in the thick biotype were significantly greater than the thin biotype at MT, MI, and DT (P < 0.05).

Conclusions: The mean facial dimension of peri-implant mucosa of 2-stage implants is slightly greater than the average dimension of the dentogingival complex. The level of the interproximal papilla of the implant is independent of the proximal bone level next to the implant, but is related to the interproximal bone level next to the adjacent teeth. Greater peri-implant mucosal dimensions were noted in the presence of a thick peri-implant biotype as compared to a thin biotype. J Periodontol 2003;74:557-562.

KEY WORDS
Alveolar bone; biologic width; dental esthetics; dental implants; dental papilla; dentogingival complex; peri-implant.

Gargiulo et al. histologically evaluated the dimensions of the gingival sulcus, epithelial attachment, and connective tissue attachment of natural teeth, now collectively known as the dentogingival complex. The dimension and stability of the dentogingival complex, as well as the changes due to surgical and/or restorative procedures, have been extensively investigated. The average dimension of the dentogingival complex at the facial aspect has been shown to be 3 mm, while a dimension of 4.5 mm was observed at the interproximal aspect of natural teeth. This dimensional difference may be attributed to the presence of adjacent teeth and the size of the gingival embrasure. If the adjacent tooth support is removed, the interproximal dentogingival complex dimension (4.5 mm) can be expected to collapse to a dimension similar to that of the unsupported facial dentogingival complex (3 mm). An understanding of the dentogingival complex and its variation allows clinicians to predictably balance the physiologic requirement and esthetic demand of restorations in natural teeth in the esthetic zone.

Achieving optimal gingival esthetics around anterior single implants is a challenging procedure, and maintaining it over time can be an equally demanding task. Despite the high success rates achieved with osseointegrated implants, the peri-implant mucosal response is not clearly understood. For anterior single implants, up to 16% of gingival recession has been reported. On the other hand, spontaneous rebound of the receded gingiva has also been observed following a few years of function. The peri-implant mucosa changes had been postulated as an attempt to establish a stable biological dimension. Peri-implant mucosa, like its natural teeth counterpart (the dentogingival complex), comprises similar histologic components (gingival sulcus and epithelial and connective tissue attachments)
and dimension (~3 mm).\textsuperscript{21-27} While the dimension of each component may change over time, these changes do not significantly affect the overall dimension.\textsuperscript{24,26} However, the effect of the adjacent tooth support on the interproximal dimension of the peri-implant mucosa has not been investigated.

It has been suggested that the periodontal biotype (thick or thin gingiva)\textsuperscript{28,29} affects the dimension of the periodontal tissue.\textsuperscript{10,30,31} A thick biotype is resilient and therefore prone to pocket formation, while a thin biotype is friable and thus often subject to gingival recession following mechanical and/or surgical manipulation.\textsuperscript{10,30,31} The question remains as to whether or not the biotype of the peri-implant mucosa would behave in a similar manner.

The purpose of this study was to clinically evaluate the dimensions of the peri-implant mucosa of 2-stage (submerged) maxillary anterior single implants in humans with at least 1 year of function by bone sounding using a periodontal probe. The influence of the peri-implant biotype also was examined.

\textbf{MATERIALS AND METHODS}

This study was approved by the Institutional Review Board of Loma Linda University. The patients were informed of the study procedures and provided consent. The procedures were conducted at the Center for Prosthodontics and Implant Dentistry, Loma Linda University School of Dentistry, Loma Linda, California.

\textbf{Study Population}

From the computer database, a list of patients who had received 2-stage single implants in the anterior maxilla (#6 – 11) at the Center for Prosthodontics and Implant Dentistry, Loma Linda University School of Dentistry between January 1995 and June 2001 was compiled. The patients were selected according to the following inclusion criteria: 1) presence of natural teeth adjacent to the implant, with definite proximal contacts; 2) the implant was placed as a 2-stage procedure in an edentulous site; 3) the implant must have been in function for at least 1 year; 4) in the patient with more than one implant single crown, only the lowest numbered implant was included in the study (e.g., implant #6 would be selected over implant #11); 5) at the time of clinical evaluation, the implant had to be considered successful;\textsuperscript{32} and 6) there was no evidence of complications that had or would have required any exploratory and/or corrective surgical procedures throughout the implant’s functional period.

\textbf{Clinical Evaluation and Data Collection}

\textbf{Peri-implant mucosa dimension.} After local anesthetic administration (2% polocaine with 1:20,000 levonordrehin)\textsuperscript{§} to the examination site, the dimensions of peri-implant mucosa were measured by bone sounding using a periodontal probe\textsuperscript{¶} at 5 sites: the mesial (MI), mid-facial (F), and distal (DI) aspects of the implant restoration, and the proximal aspects (MT and DT) of the adjacent teeth (Fig. 1). The distance from the crest of the bone to the free gingival margin (facial aspect) or tip of the interproximal papilla (proximal aspects) was recorded to the closest 0.5 mm (Fig. 1). All measurements were made by one examiner.

\textbf{Peri-implant biotype.} The peri-implant biotype of each studied implant was evaluated and categorized into a thick or thin group.\textsuperscript{28,29} To evaluate the biotype, a periodontal probe was placed into the facial aspect of the peri-implant mucosa. The peri-implant biotype was categorized as thin if the outline of the underlying periodontal probe could be seen through the gingiva, and thick if the probe could not be seen.

\textbf{Statistical Analysis}

The bone-sounding measurements at each site were recorded and the means, standard deviations, and frequency were calculated. The bone-sounding depths for thick and thin peri-implant biotypes were compared using the independent \textit{t} test.\textsuperscript{¶} Statistical significance was denoted when \( P < 0.05 \).

\textbf{RESULTS}

A total of 45 single implant crowns in 45 patients (20 males and 25 females) with a mean age of 47.3 years

\textsuperscript{§} AstraZeneca LP, Wilmington, DE.

\textsuperscript{¶} University of North Carolina color probe, Hu-Friedy, Chicago, IL.

\textsuperscript{¶} SPSS Version 10 software, SPSS Inc., Chicago, IL.
(range, 20 to 82) were included in this study. The mean implant functional time was 32.5 months (range, 12 to 78). Twenty-five central incisors, 13 lateral incisors, and 7 canine single-implant crowns were evaluated. The peri-implant biotype of 28 implants was categorized as thick, and that of 17 implants as thin.

The means and standard deviations of the bone-sounding measurements at MT, MI, F, DI, and DT were $4.20 \pm 0.77$ mm, $6.17 \pm 1.27$ mm, $3.63 \pm 0.91$ mm, $5.93 \pm 1.21$ mm, and $4.20 \pm 0.64$ mm, respectively (Fig. 2).

Figures 3 through 7 depict the frequencies of various bone-sounding measurements at the evaluated sites. A range of the most frequently recorded bone-sounding measurements at these sites was also calculated. Seventy-one percent (32/45) and 69% (31/45) of the bone-sounding measurements were between 4.0 to 4.5 mm at MT and DT, respectively (Figs. 3 and 7). At F, 71% (32/45) of the bone-sounding measurements were between 3.0 to 4.0 mm (Fig. 5). Bone-sounding measurements between 5.0 to 7.0 mm constituted 71% (32/45) and 75% (34/45) of the measurements at MI and DI, respectively (Figs. 4 and 6).

The bone-sounding measurements of the thick biotype group were significantly greater than those of the thin biotype group at MT, MI, and DT ($P < 0.05$). No significant differences were found at F or DI (Table 1 and Fig. 8).

**DISCUSSION**

In this bone-sounding study, the mean facial dimension (3.63 mm) of the peri-implant mucosa for 2-stage implants is slightly greater than the corre-
sponding histologic dimensions of the dentogingival complex reported by Gargiulo et al.\textsuperscript{1} (2.73 mm) and Vacek et al.\textsuperscript{3} (3.25 mm), but is comparable to the histometric dimensions reported by others for 2-stage (3.11 to 3.80 mm) and 1-stage implants (2.84 to 3.57 mm).\textsuperscript{21-26} Variations in facial dentogingival complex dimensions have been observed and classified as normal (3 mm), high (<3 mm), or low (>3 mm) crest.\textsuperscript{2,33} Likewise, dimensional variations (2 to 6 mm) in the facial aspect of peri-implant mucosa have been noted in this study (Fig. 5). Nevertheless, unlike natural teeth, the most frequently observed facial dimension of peri-implant mucosa was between 3 to 4 mm (normal crest, 71%) (Fig 5). Less than 3 mm of peri-implant mucosa dimension (high crest, 9%) was uncommon, and can be related to either thin biotype, implants that were placed too labially, and/or an over-contoured facial prosthetic emergence. On the other hand, a total dimension of >4 mm (low crest, 20%) was usually associated with thick biotype.

The mean dentogingival complex dimensions at MT and DT were both 4.20 mm, with the most frequently observed measurements between 4 to 4.5 mm (normal crest, 71% and 69%, respectively) (Figs. 3 and 7). These results are similar to the data reported by van der Velden, in which a mean distance of 4.33 mm between the location of the gingival margin and the bone level was observed 3 years after denudation of the interdental alveolar bone.\textsuperscript{34}

On the other hand, the mean MT and DT dimensions (4.20 mm) are only slightly less than the reported interproximal bone-sounding measurements of non-

### Table 1.

**Bone-Sounding Measurements of Anterior Implant Single Crowns Comparing Thick and Thin Biotypes**

<table>
<thead>
<tr>
<th>Bone-Sounding Depth (mean ± SD, mm)</th>
<th>Site</th>
<th>Thick Biotype (n = 28)</th>
<th>Thin Biotype (n = 17)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT</td>
<td>4.46 ± 0.78</td>
<td>3.76 ± 0.53</td>
<td>0.002*</td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>6.54 ± 1.05</td>
<td>5.56 ± 1.40</td>
<td>0.011*</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3.79 ± 0.89</td>
<td>3.38 ± 0.91</td>
<td>0.150</td>
<td></td>
</tr>
<tr>
<td>DI</td>
<td>6.14 ± 1.11</td>
<td>5.59 ± 1.31</td>
<td>0.137</td>
<td></td>
</tr>
<tr>
<td>DT</td>
<td>4.45 ± 0.57</td>
<td>3.79 ± 0.56</td>
<td>0.001*</td>
<td></td>
</tr>
</tbody>
</table>

* Statistically significant (P <0.05).
surgically involved human teeth (4.5 to 5 mm). These findings concur with clinical observations where the interproximal papilla of 2-stage anterior single implants is often slightly more apically located than the papilla at corresponding sites on the contralateral tooth. While minor recession of the interproximal papilla can be expected following a 2-stage implant surgery, the presence of considerably stable dimensions at MT and DT indicates that, for an anterior single implant, the implant papilla level is dependent on the bone level of the adjacent natural tooth.

The overall mean peri-implant mucosa dimensions at MI and DI were 6.17 mm and 5.93 mm, with the most frequently recorded measurements between 5 to 7 mm (71% and 75%, respectively) (Figs. 4 and 6). These measurements are similar to the data reported by Garber et al., in which a mean vertical soft tissue depth of 6.5 mm was measured interproximally immediately adjacent to the implant. These measurements (~6 mm), although substantially greater than the facial measurements (3.63 mm), are not unexpected. In maxillary anterior teeth, the osseous architecture follows the cemento-enamel junction, resulting in an osseous scallop that is more apical at the facial and lingual aspects and more coronal at the interproximal aspect of the tooth. On the other hand, in an anterior single implant with adjacent teeth, the osseous architecture can only mimic the topography of the implant platform, which is flat. The loss of osseous scallop at the interproximal aspect of the implant in conjunction with the existence of the gingival scallop maintained by the bone support of the adjacent teeth, results in pseudo-pockets at MI and DI. This explains the wide range of MI and DI dimensions (3 to 9 mm) when compared to other sites (Figs. 3 through 7). Evidently, for anterior single implants with adjacent natural teeth, the implant papilla is independent of the bone levels at the interproximal sites (Figs. 3 through 7).

Studies have demonstrated that a thick mucosa has a significantly greater periodontal probing depth than its thin counterpart. Likewise, the dimensions of peri-implant mucosa can also be influenced by the gingival thickness. The greater peri-implant mucosa dimensions of the thick biotype observed at all sites in this study (Table 1 and Fig. 8) seem to substantiate this assumption. Furthermore, while the bone-sounding measurements at MT and DT (~4.5 mm) in subjects with the thick biotype is comparable to the normal interproximal dentogingival dimension (4.5 mm), it is significantly greater than in subjects with the thin biotype (~3.8 mm; P <0.05). Following tooth removal, the interproximal papilla usually collapses due to the loss of tooth support and the degree of collapse depends on the thickness of the mucosa. Under such circumstances, the papilla may be restored with an implant-tooth replacement to varying degrees depending on the peri-implant biotype. While the implant papilla may be maintained at or reestablished to the normal level (4.5 mm from the underlying bone) with the thick biotype, it can seldom be recreated beyond 4 mm with the thin biotype (Table 1 and Fig. 8).

CONCLUSIONS

Within the confines of this study, the following conclusions can be drawn:

1. The mean facial dimension of peri-implant mucosa of a 2-stage implant is slightly greater than the average dentogingival complex dimension.

2. The level of the interproximal papilla of the implant is independent of the proximal bone level next to the implant, but is related to the interproximal bone level next to the adjacent teeth.

3. At all evaluated sites, greater peri-implant mucosal dimensions were noted in the presence of the thick peri-implant biotype as compared to the thin biotype.

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