The Influence of Mucosa Thickness and Quality on Single Implant Tissue Stability: A Prospective Controlled Clinical Trial

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This prospective controlled clinical trial investigated the possible correlation among mucosa thickness, mucosa height, and width of keratinized mucosa on the contour changes of the peri-implant soft tissue collar over a period of 12 months. Forty patients were selected to undergo implant placement. Impressions were taken with polyether impression material at delivery of the final restorations (baseline) and at 1, 3, 6, and 12 months. Master casts were fabricated and scanned using an indirect digitalization. Baseline and corresponding follow-up scans were then virtually superimposed and matched. At 1 year, 20 patients who received the buccal pedicle flap showed an average thickness increase of 1.49 mm ($\mu$s = 0.95; range: 0.01 to 2.56 mm), whereas the 5 patients who received a connective tissue graft at second-stage surgery reported an average thickness increase of 0.33 mm ($\mu$s = 0.70; range: –0.62 to 1.23 mm). Finally, the remaining 15 patients who did not receive any soft tissue grafting nor any type of plastic surgery showed an average mucosa thickness increase of 0.51 mm ($\mu$s = 0.28; range: –2.33 to 2.52 mm).


Despite the high success rate of endosseous dental implants, failures or complications may occur in 5% to 10% of cases.1 It is believed that the mucosa integrity may be crucial for the maintenance of peri-implant tissue health.2 In particular, a significant function seems to be played by the keratinized peri-implant mucosa that constitutes a barrier between the oral environment and endosseous dental implants.3 The term keratinized mucosa describes the masticatory mucosa that extends from the mucogingival junction to the movable oral mucosa.4 Among other factors implicated in disease progression, mucosa thickness seems to have a key role5 in both ailing and failing dental implants.6 The peri-implant mucosa thickness is defined as the horizontal component of the peri-implant soft tissue. Some authors7 have postulated that an increased amount of tissue thickness may be desirable to decrease the risk of recessions8 and excessive peri-implant bone remodeling.7,9 In addition, the low predictability of peri-implantitis treatment10 and the challenging treatment of mucosal deformities around implants in the esthetic regions11,12 have emphasized the importance of peri-implant mucosa stability during follow-up visits. Finally, the esthetic outcome of an implant-supported restoration seems to be strictly related to soft

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tissue volume and thickness, which may significantly influence pink esthetics around endosseous dental implants.\textsuperscript{13–15} The peri-implant supracrestal tissue height is the vertical dimension of the soft tissue that surrounds a dental implant from the mucosal margin to the crestal bone,\textsuperscript{16} and results suggest that the potential for significant changes in soft tissue levels after completion of restorative therapy need to be considered for implant therapy in esthetic areas.\textsuperscript{17}

The aim of this prospective controlled clinical study was to investigate whether the peri-implant supracrestal tissue height and thickness, as well as the width of keratinized mucosa, may play a critical role in the contour changes of the peri-implant soft tissue collar over time.

**Material and Methods**

This single-center (G.T.), prospective clinical trial on the variations of implant mucosa thickness was conducted in accordance with the Declaration of Helsinki on human studies, following approval from the Ethical Committee Lazio 1 San Camillo-Forlanini Hospital (Rome, Italy; ref. no. 1079/CE Lazio 1). The subjects were recruited according to the following inclusion criteria: (1) need for an implant-supported single-crown restoration; (2) $\geq 21$ years of age; (3) needing any type of definitive abutment; (4) needing single-cement- or screw-retained definitive restorations; and (5) monoedentulism. Smokers, former periodontal patients, and patients who received no tissue augmentation or bone augmentation and/or soft tissue augmentation (either or both) were still included in order to have a more realistic sample size. The exclusion criteria were as follows: (1) any systemic disorder or medication known to alter bone metabolism; (2) infection of the implant site; (3) probing depth $> 4$ mm at natural teeth; (4) inadequate oral hygiene; (5) pregnancy; (6) lactation; and (7) uncontrolled medical conditions, such as diabetes mellitus. Written informed consent was obtained from all patients for this study. Forty suitable patients to undergo single implant placement were then selected.

Two months after second-stage surgery, an impression was taken with polyether impression material (Impregum Penta Super Quick Medium Body, 3M ESPE) to produce a provisional single crown. Eight weeks after provisional loading, a new impression was taken, and a final cement- or screw-retained restoration was delivered. Before connecting the final crown to the implant platform, the buccal and lingual thicknesses of the peri-implant mucosa were measured with a caliper (Straight Castroviejo Caliper, long 0–40 mm, Hu-Friedy) on the mesial, medial, and distal aspects, considering the conical connection as an absolute point of reference (Fig 1), as the internal hexagon of each implant was positioned with the flat surfaces toward the buccal/facial aspect. The peri-implant mucosa thickness was measured at the level of the implant platform and defined as the horizontal component of the peri-implant soft tissue. The mucosal thickness was calculated, at the same aspects as previously described, from the implant shoulder to the external mucosa point.

![Diagram showing the exact points of measurement based on the conical connection of the endosseous implants. DL = distolingual; L = lingual; ML = mesiolingual; DB = distobuccal; B = buccal; MB = mesiobuccal.](image)
perpendicular to the implant major axis. The keratinized mucosa width was registered with a periodontal probe (15 UNC Color-Coded Probe, Hu-Friedy) buccally and lingually, as well as mesially, medially, and distally from the mucogingival junction to the free mucosal margin. The mucosal height was calculated at the same aspects from the implant platform to the upper gingival margin of the supra-implant tissue.

After delivery of the final restoration, master casts made of dental stone (Fujirock, Type IV, GC) were fabricated. Impressions were taken with polyether impression material (Impregum Penta Super Quick Medium Body) at delivery of the final restorations (baseline) and at 1, 3, 6, and 12 months. Using 3D digital measuring methods, each cast was scanned using an intraoral scanner (TRIOS 3, 3Shape), and an indirect digitalization of models was applied. Data were acquired by ultra-fast sectioning technique based on a structured illumination, thus creating multiple digital models from the casts. Baseline and corresponding follow-up scans (taken at 1, 3, 6, and 12 months) of each clinical case were then virtually superimposed and matched. By overlapping the models and using the conical connection implant platform as an absolute reference point for the superpositioning of the different time points, this technique allowed an evaluation of dynamic minimal morphologic changes. The 3D digital models were only used to obtain perfect overlapping, but a secondary 2D analysis was executed. Of each patient, five different models at 0, 1, 3, 6, and 12 months were superimposed. A predefined area of interest (buccally, lingually, mesially, medially, and distally from the mucogingival junction to the free mucosal margin) was measured at each time interval.

### Statistical Analyses

The timing related to the follow-up was identified with a set of \( X_i \) \( i \in \{0, 5\} \) and with \( \Delta \) \( \mu \) \( \in \{ \text{distobuccal (DB), buccal (B), mesiobuccal (MB), distolingual (DL), lingual (L), mesiolingual (ML)} \} \) the difference of the measured mucosa thicknesses at the sites \( \mu \) between the \( X \)-th and \( X \)-th months. The hypothetical mucosal thickness value \( Y_i \) at point \( \mu \) after \( X \) months for each implant was reported as the differences \( Y_i - Y_0 \). The target information is the differences \( \Delta \), so that the final result depends on a shift of the initial thickness. However, since it was considered of clinical interest the mucosa growth, the differences \( \Delta Y_{ij} = Y_i - Y_0 \) was calculated as follows:

\[
\Delta Y_{ij} = Y_{ij} - Y_0 = \frac{1}{n} \sum_{j=1}^{n} \Delta Y_{ij} - \frac{1}{n} \sum_{j=0}^{n} \Delta Y_{ij}
\]

The Spearman index analyzed how mucosa thickness changed compared to different treatment modalities during the first year of implant function.

### Results

Forty patients (16 women, 24 men) with a mean age of 53 years (range: 30 to 79 years) were recruited to receive a single-crown implant-supported restoration. Only 7 patients were smokers and none of the patients missed an examination, at which point the dynamic changes of the mucosa were analyzed. Out of 40 implants, 24 were placed in the mandible and 16 in the maxilla. At second-stage surgery, 20 patients received the buccal pedicle flap, 5 patients received a connective tissue (CT) graft, and the remaining 15 patients were subjected to a standard crestal incision with no grafting or plastic procedure. None of the cases was treated with collagen matrices or any type of biomaterial for soft tissue thickening. Among the inserted implants, 28 were restored with screw-retained final restorations and 12 with cemented restorations. At delivery of the final restoration, the average achieved band of keratinized mucosa was 5.325 ± 0.858 mm, the initial mucosa thickness was 3.122 ± 1.098 mm, and the initial mucosa height was 3.124 ± 1.011 mm. The average increase of keratinized mucosa at 12 months was 0.98 ± 1.149 mm, thus showing a natural thickening and maturation of the peri-implant soft tissues. Patients who received the buccal pedicle flap showed an average 5.13-mm keratinized mucosa width (range: 2.50 to 7.83 mm), 3.02-mm mucosa thickness (range: 0.5 to 5.16 mm), and 3.08-mm mucosa height (ranging from 0.66 to 5.83 mm). Patients who received the CT graft reported an average keratinized mucosa width of 4.73 mm (range: 3 to 7.83 mm), 2.90-mm mucosa thickness (range: 2 to 4.83 mm), and 2.40-mm mucosa height (range:
1.16 to 3.50 mm). The remaining 15 patients who received a standard crestal incision had an average keratinized mucosa width of 5.77 mm (range: 2.83 to 8.83 mm), 3.33-mm mucosa thickness (range: 1.33 to 5.50 mm), and 3.42-mm mucosa height (range: 1.66 to 5 mm).

The Spearman index was able to effectively discriminate the different types of observed growth (Fig 2). An index close to 1 indicated a significant and continuous global mucosa thickness growth from delivery of final restoration to 12 months, whereas a Spearman index of 0.8 and 0.9 showed an initial minor soft tissue collapse during the first month followed by a gradual increase in tissue thickness. In these cases, the average width of keratinized mucosa was 5.37 mm (range: 2.5 to 8 mm), the initial mucosa thickness was 3.087 mm (range: 0.5 to 5.166 mm), and mucosa height was 3.212 mm (range: 0.666 to 5.833 mm). Finally, based on the type of soft tissue management executed at the second-stage surgery (buccal pedicle flap, CT graft, or traditional uncovering with crestal incision), the Spearman indices of all patients correlated the initial band width of keratinized mucosa, its height, and its thickness with mucosal thickness changes at 1 year (Figs 3 to 5). At 1 year, the 20 patients who received the buccal pedicle flap showed an average thickness increase of 0.33 mm ($\rho_s = 0.70$; range: −0.62 to 1.23 mm). The remaining 15 patients who did not receive any soft tissue grafting nor any type of plastic surgery showed an average mucosal thickness increase of 0.51 mm.
Fig 3 Spearman rank correlation coefficient for keratinized tissue and uncovering technique. Some overlapping points have been moved slightly horizontally for better visualization.

Fig 4 Spearman rank correlation coefficient for mucosa height and uncovering technique. Some overlapping points have been moved slightly horizontally for better visualization.
after 12 months (ρs = 0.28; range: –2.33 to 2.52 mm).

Furthermore, seven patients reported decreased mucosa thickness. Among these, five were treated with crestal incision and two with a CT graft. All patients who reported no soft tissue thickening were smokers. A Spearman index of 1 was achieved only when a buccal pedicle flap was executed; the average achieved band of keratinized mucosa measured 5.10 mm (range: 2.5 to 7.66 mm), the average initial thickness was 3.03 mm (range: 1.66 to 4.50 mm), and the mucosa height was 3.45 mm (range: 2.5 to 5.83 mm). A Spearman index of 1 achieved an average mucosal thickness increase of 1.56 mm (range: 0.01 to 2.56 mm).

**Discussion**

Quantity and quality of peri-implant mucosal tissues can influence esthetics as well as the maintenance of peri-implant health. Keratinized mucosa, which provides dense connective tissue, may establish a more efficient soft tissue seal, and its height may be beneficial for esthetic purposes. The present study analyzed progressive mucosa changes, which seem to be more important when referred to disease assessment. In fact, while advanced peri-implant bone loss is easily recognized by radiographs, early alterations of the mucosa are often site-specific and discrete, and they might indicate a forthcoming breakdown of the peri-implant health status. The buccal pedicle flap was significantly (ρs = 0.95) associated with a better outcome compared to CT graft and traditional crestal incision (Figs 6 and 7). These results are significant, especially because CT graft and buccal pedicle flap were performed when soft tissue deficiencies were registered, at the second-stage surgery. However, the uncovering technique was not randomized, and the use of a caliper rather than tomographic acquisitions may have influenced the volumetric findings of the scanner, which we attributed mainly to modifications of the peri-coronal

![Spearman rank correlation coefficient for initial mucosa thickness and uncovering technique. Some overlapping points have been moved slightly horizontally for better visualization.](image)
soft tissues. Major changes in soft tissue volumes were registered not at the deepest part of the sulcus and close to the implant platform, but about 3 mm apically (Fig 8). This may be related to the band of keratinized mucosa, which could act as a protecting collar of the underlying bone, thus preventing remodeling.\textsuperscript{23} On the contrary, major changes (up to 1.5 mm) were shown apical to the mucogingival junction, especially on those patients who received bone augmentation procedures. From an esthetic point of view, a number of in vitro and clinical studies demonstrated 2 mm of mucosal thickness to be a critical threshold.\textsuperscript{12,24} However, no specific soft tissue thickness could be defined from a biologic point of view, according to a recent systematic review.\textsuperscript{25,26} The present study reported the best outcomes with a 5-mm keratinized mucosa width and 3-mm mucosa thickness and height. In fact, when these measurements were registered, the peri-implant mucosa had an average increased thickness of 1.47 mm at 12 months.

A possible limitation of this study is that measurements were obtained using a periodontal probe, which allows for values to be made to the nearest millimeter. In fact, this method may be affected by possible bias consisting of nonstandardized periodontal probe inclination. Furthermore, there could be intrinsic errors, such as inaccuracy of the software, cast fabrication, and impression procedures, which could have been eliminated by direct intraoral scanning. However, these errors were compensated by the statistical analysis and by taking into consideration the dynamic changes of the mucosa over a 12-month period.
not static measurements. Finally, an overall mean peri-implant mucosal height of 3.12 mm was reported in the present study, which was lower than the 3.6 mm seen in Fuchigami et al. However, these differences could be related to the depth and area of insertion of the implants, which can significantly influence mucosa height. Another possible explanation of these differences could be the mucosa thickness, as described by Bengazi et al., who suggested that the mucosa height is related to the bone level but also to soft tissue thickness.

**Conclusions**

The understanding of a stable soft tissue collar might have relevant influence on how to properly manage the peri-implant mucosa at first- or second-stage surgery and prevent biologic and esthetic complications. The buccal pedicle flap showed promising results for better stability and thickening of the peri-implant mucosa.

**Acknowledgments**

The authors declare no conflicts of interest.

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