Evaluation of Horizontal and Vertical Buccal Ridge Dimensional Changes After Immediate Implant Placement and Immediate Temporization With and Without Bone Augmentation Procedures: Short-Term, 1-Year Results. A Randomized Controlled Clinical Trial

This prospective randomized controlled clinical trial aimed to compare changes in the horizontal and vertical soft tissue and the alveolar ridge dimension over the course of 12 months following immediate implant placement and temporization with or without simultaneous augmentation with a deproteinized bovine bone mineral with 10% collagen (DBBM-C). Thirty-two patients with a hopeless maxillary anterior tooth and fully intact sockets received an immediate implant and provisional or custom healing abutment after a flapless extraction. Patients were randomized to a control group (n = 16), which received no graft, or to a test group (n = 16), which received DBBM-C grafts. Horizontal and vertical soft tissue changes as well as soft tissue thickness were compared digitally between groups on casts obtained from impressions made at baseline and 3, 6, and 12 months. The test group showed less horizontal dimensional change than the control group; however, the change between the two groups was not statistically significant. Vertical dimensional soft tissue changes from baseline to 12 months showed a statistically significant difference at the distal papilla, favoring the test group. No statistically significant difference was observed for vertical changes between both groups at mesial papillae and midbuccal soft tissue; however, the test group showed lower values overall. No statistically significant differences in soft tissue thickness between groups were detected. Immediate implant placement and temporization with and without adding DBBM-C demonstrate favorable clinical outcomes regarding horizontal and vertical soft tissue changes. Both groups showed loss of tissue volume. Adding DBBM-C in the gap of immediately placed implants slightly lowered the change in tissue parameters, which was not statistically significant, for the first 12 months after implant placement.


The alveolar ridge undergoes remodeling of the socket’s buccal and lingual walls subsequent to tooth extraction, with more pronounced bone loss on the buccal aspect, limited to the marginal one-third of the postextraction site. The hypothesized cause of this greater buccal bone loss is the thinner nature of the buccal bone, especially in the anterior maxilla, resulting in a decreased blood supply to the buccal plate once the periodontal ligament is severed. Studies have shown that the average buccal plate thickness in the anterior region ranges from 0.5 to 1.6 mm.

In order to minimize horizontal dimensional alterations, several surgical protocols have been described. Among them is a flapless surgical technique with lingualized implant placement, immediate provisionalization, and incorporation of various bone grafts, with a reported average loss of horizontal tissue dimension of –0.1 to –1.2 mm.

Studies that have incorporated a connective tissue graft at the time of immediate implant placement were the only studies that demonstrated a post-baseline gain in horizontal tissue dimension. Further, it has been suggested that placement of biomaterials into fresh extraction sockets may result in less vertical and horizontal...
contraction of the bone crest. To date, it is still uncertain which biomaterial is most predictable for use as a graft during tooth extraction with or without immediate implant placement.

A deproteinized bovine bone mineral graft (Bio-Oss Collagen, Geistlich) that contains 90% natural nonantigenic porous deproteinized bovine bone mineral with an additional 10% porcine has been studied for various clinical applications including periodontal grafting, ridge augmentations, preservation procedures, and peri-implant grafting. However, the benefits of DBBM-C as a bone graft material at the time of immediate implant placement and immediate provisional use have not been evaluated in a randomized controlled clinical trial in humans.

Therefore, the aim of the current study was to digitally and clinically evaluate the horizontal and vertical soft tissue dimensional changes associated with grafting of the buccal gap with a deproteinized bovine bone mineral graft (Bio-Oss Collagen) after flapless extraction of teeth in the esthetic zone and immediate placement and provisionalization of the dental implant.

Materials and Methods

Patient Selection, Study Population, and Design

This single-center, randomized, controlled clinical trial study was approved by the Institutional Review Board of Columbia University Medical Center. Subjects 18 years of age and older were recruited through the Columbia University College of Dental Medicine’s Periodontics and Implant Dentistry clinics. Patients with a single maxillary anterior hopeless tooth (first premolar to first premolar) in need of extraction due to caries, fracture, or poor endodontic prognosis were screened. All patients included in the study were periodontally healthy with minimal (< 10%) or no bone loss at the study site and adjacent teeth. Only patients with the buccal bone plate present without any defects after extraction provided informed consent and were included in the study. Exclusion criteria included any systemic condition preventing implant placement or any other surgical procedure; female subjects who were pregnant, lactating, or who intended to become pregnant during the study period; presence of acute infectious lesions in the surgical area; history of smoking within the last 6 months; unfavorable occlusal schemes for immediate loading; presence of the following adjacent to the study site: implants, infrabony defects with attachment loss, periodontal disease, endodontic lesions, and/or caries.

Enrolled subjects were randomized to one of two groups: a control group without any grafting or a test group that received a deproteinized bovine bone mineral with 10% collagen (DBBM-C; Bio-Oss Collagen) at the time of implant placement to graft the gap between the implant and the buccal bone plate. Additionally, graft material was placed into the soft tissue zone following the dual-zone grafting concept. Randomization was done sequentially (randomization based on 1:1 allocation) by treatment groups, and each group comprised 16 patients. Randomization envelopes were prepared by the investigators, and the envelopes were sealed and mixed to avoid randomization bias. The envelopes were opened on the day of surgery.

Since no comparable randomized controlled trials were available at the start of the study, the power analysis was based on a study by Covani et al. In order to detect a difference of 10% with a power of 80% at a significance level of .05 between groups accounting for potential drop-outs, 16 patients were required per treatment method. With a follow-up of up to 12 months after completion of the restorative treatment, the primary outcome was the horizontal change (buccolingual change) and the secondary outcomes were changes in vertical dimensional and soft tissue thickness. The null hypothesis is that there will be no difference between the study groups.

All surgical procedures were completed by one surgeon (U.S.S.), and one prosthodontist (N.B.) supervised all prosthetic steps to ensure standardization.

Surgical Procedure

All patients were premedicated with either amoxicillin (2 g) or clindamycin (600 mg) 1 hour prior to surgery. Flapless extraction of hopeless teeth and evaluation of the socket...
walls were performed to confirm that the buccal plate was intact. Several patients had a periapical pathology that did not compromise the integrity of the buccal plate. For these patients, the granulomatous tissue was removed in its entirety until hard, bleeding bone was felt entirely throughout the socket.

Implants (Certain, Zimmer Biomet) were immediately placed following the manufacturer’s instructions. The implant platform was placed 3 to 4 mm from the cementoenamel junction (CEJ) of the adjacent teeth to allow for adequate space to develop the subgingival contours. The implant platform was located at the level of the buccal plate or 1 mm below. Implants were placed, titrating the insertion torque in increments of 5 Ncm, to determine the final insertion torque. All implants were placed in a lingualized position to allow for the final restoration to be designed as screw-retained.

Before insertion of the provisional restoration, the test group received DBBM-C (Fig 1). The deproteinized bone mineral was hydrated in sterile saline for 5 minutes as per the manufacturer’s recommendations and was packed into the gap between the implant and the buccal plate of bone, up to the coronal-most level of the soft tissue. A healing abutment was kept in place during graft placement to prevent the DBBM-C particles from affecting the complete seating of the provisional restoration.

Subjects were given postsurgical instructions and medications including antibiotics (amoxicillin, 875 mg; or clindamycin, 300 mg), analgesics (ibuprofen, 600 to 800 mg), and an antimicrobial mouth rinse (0.12% chlorhexidine gluconate).

Prosthetic Procedure

At the baseline visit for each patient, an alginate impression (Jeltrate Fast Set, Dentsply) was made of the maxillary and mandibular arches. The impressions were poured in type III gypsum (Microstone, Whip Mix). Additional casts were taken at the 3-, 6-, and 12-month follow-ups.

After implant placement, one of two prosthetic protocols was followed depending on the insertion torque of the implant (Fig 2). Implants with torque values greater than 20 Ncm were restored with an immediate full-contour screw-retained provisional made of auto-polymerized polymethyl methacrylate (Super-T, American Consolidated) and maintained out of occlusion (n = 22). Implants with primary stability ≤ 20 Ncm were restored with a customized healing abutment. The customized healing abutment was made with a temporary abutment and auto-polymerized polymethyl methacrylate (Super-T) to create the subgingival contours used to maintain the soft tissue contours while keeping the restoration out of occlusion. An Essix appliance or provisional bonded (Maryland type) fixed dental prosthesis was made as a provisional restoration and kept out of occlusion to restore the missing tooth (n = 10). By customizing the subgingival contour of the abutments, the soft tissue component was the same for both treatment methods, ensuring a standardized soft tissue aspect without compromising implants with lower stability.

Since 12 patients presented with loose temporary healing abutments,
an effort was made to standardize the abutment connection/disconnection by removing the temporary restorations of patients whose abutments were not loose after 6 months of healing and 3 weeks prior to the final impression. Additionally, patients with a customized healing abutment had a full-contour provisional fabricated prior to the final restoration following the protocol previously described.

All final impressions were made 6 months after implant placement using an open-tray impression coping (Zimmer Biomet), disposable stock plastic trays (Disposable Trays, GC America), and polyether impression material (Impregum, 3M). To accurately record the dimension of the soft tissues, the contour of the provisional restorations was copied with polyvinyl siloxane material (Blu-Mousse, Parkell), and the replicated contour was transferred to the impression copings using auto-polymerized polymethyl methacrylate (Super-T, American Consolidated).

The final restoration was designed as a screw-retained, porcelain-fused-to-metal restoration that was torqued to 20 Ncm as per the manufacturer’s protocol.

Clinical Measurements

Several measurements were taken during the study:

Tissue Biotype
The biotype was determined to be thin if the probe was visible through the soft tissue when probing the midbuccal aspect of the tooth to be extracted with a colored probe (15 UNC color-coded probe, Hu-Friedy), and thick if the probe was not.32

Buccal Bone Level
A periodontal probe (12 UNC color-coded probe, Hu-Friedy) was used to measure the distance from the free gingival margin (FGM) to the buccal bone level.

Tissue Thickness
Measured at 3, 4, and 8 mm from the FGM using a 15-endodontic file and a rubber stopper (Hedstrom, Kerr). The file was advanced through the soft tissue until the first point of bony contact.

Buccal Plate Thickness
Measured at 4 and 8 mm from the FGM. Measurements were made using an Iwanson caliper (1 Iwanson Spring Caliper for Metal, Hu-Friedy). Measurements were calculated by subtracting the soft tissue thickness measurements, recorded using an endodontic file, from the caliper measurement. A measurement of 0.0 mm was recorded if the buccal plate was present but had a thickness thinner than a legible measurement on the caliper.

Buccal Gap Distance
The distance from the buccal aspect of the implant to the internal buccal aspect of the socket wall was measured horizontally using a color-coded probe (15 UNC, Hu-Friedy).

Vertical Distance of the Implant
The vertical distance of the implant from the buccal bone level was derived by subtracting the distance of the implant to the FGM from the distance of the buccal bone level to the FGM. All measurements were performed using a color-coded probe (15 UNC, Hu-Friedy).

Vertical Position of the Soft Tissue
A tooth-supported Essix stent was used to record the distance from three reference marks (mesial papilla, midbuccal margin, and distal papilla) to the FGM using a color-coded probe (15 UNC, Hu-Friedy) (Fig 3). The same stent was used for measurements at the 3-, 6-, and 12-month follow-ups.

One-Year Evaluation

Implant survival, patient esthetic perception, presence of soft tissue inflammation, and prosthesis complications were noted at the 12-month follow-up visit.

Radiographic Measurements

Prior to enrollment, every patient received a cone beam computed tomography (CBCT) scan of the maxillary arch (image resolution: 0.3 mm) to evaluate the presence of a fully intact buccal plate of the study tooth. The buccal plate thickness of the tooth to be extracted was measured and recorded on a sagittal section through the tooth, 3 mm apical from the CEJ. In addition, buccal plate thickness was recorded at 4 and 8 mm apical from the CEJ.
Cast Analysis

A digital scanner (Romexis, Planmeca) was used to digitally scan all casts made at baseline and at the 3-, 6-, and 12-month follow-up visits. Prior to digitally scanning the models, a pencil was used to draw a straight line on the baseline casts at the midbuccal margin, from the FGM to the vestibule. A horizontal line bisecting the vertical line was drawn to mark the FGM, and three parallel lines were drawn above that at 3, 4, and 8 mm (Fig 4).

A digital comparison software (Compare, Planmeca) was used to superimpose the casts (Fig 4). Each baseline cast was digitally trimmed at the lingual aspect to create a reference line. The casts were sliced at the midbuccal margin, and three-dimensional sagittal sections were viewed (Fig 5). A protractor was aligned with the vertical reference line on the baseline cast, and the horizontal portion of the protractor was used to draw a line from the baseline cast to the 3-month cast at the 3- and 4-mm markings to measure the buccal contour difference. This technique was also used to measure differences between baseline and 6- and 12-month casts. There was no blinding on the cast analysis, as the same researcher in charge of randomization performed the cast analysis.

Statistical Analyses

Summary statistics (mean, standard deviation, and range) were calculated for all variables. Results between groups were compared using Student t test for normal distribution. Categorical values were compared using chi-square test. To assess the correlation between values, Pearson correlation test was

Fig 2 (a) Full-contour temporary restoration. (b) Facial view of the temporary restoration after insertion. (c) Custom healing abutment. (d) Facial view of custom healing abutment after insertion.

Fig 3 Stent used to measure the vertical distance from the FGM to the bottom of the perforation at the mesial papilla, midfacially, and distal papilla.
Results

Patient Demographics and Clinical Parameters of Treatment

Thirty-two patients, 9 males and 23 females, ages ranging from 26 to 86 years old (mean: 52.3 ± 4 years) met the inclusion criteria for enrollment in the study, and 16 patients were included per group. No patients were withdrawn from the study after enrollment. All patients presented for the 3- and 6-month follow-up appointments. One patient from the control group failed to attend the 12-month follow-up appointment. There were no significant differences between the baseline demographics between the two groups. The distribution of maxillary sites included 17 incisors (7 test, 10 control), 1 canine (control), and 14 premolars (9 test, 5 control).

Periodontal and tissue parameters at baseline were evaluated, and no differences in periodontal parameters were detected.
among groups, including the initial probing depths. Only two patients in the test group and three in the control group had a thin biotype. No significant differences were found between the test and control groups for the socket parameters (all Appendix Tables can be found in the online version of this article at www.quintpub.com). All patients presented with a Type I socket with no detectable dehiscence or fenestration. Patients had an average distance of 3.4 ± 0.8 mm and 3.3 ± 0.6 mm from the FGM to the buccal plate midfacially in the test and control groups, respectively. Further, tissue thickness did not vary between groups at 3, 4, and 8 mm from the FGM (Appendix Table 1).

The buccal plate thickness at 4 mm from the FGM was 0.8 ± 0.6 mm in the test group, while in the control group it was 0.8 ± 0.8 mm. At 8 mm from the FGM, the buccal plate thickness in the control group was 0.8 ± 0.9 mm compared to the test group’s thickness of 1.0 ± 0.7 mm. CBCT buccal plate thickness at 4 mm from the FGM was 1.1 ± 0.7 mm (range: 0.3 to 2.4 mm) for the test group and 1.0 ± 0.9 mm (range: 0.3 to 4.0 mm) in the control group. At 8 mm from the approximate FGM, the CBCT buccal plate thickness was 0.8 ± 0.5 mm (range: 0.3 to 1.9 mm) for the test group and 0.9 ± 0.7 mm (range: 0.3 to 3.4 mm) for the control group. A correlation was observed between both probing and CBCT measurements of the buccal plate thickness at both measurement points, 4 and 8 mm from the FGM: \( r = 0.73 \) and \( r = 0.76 \), respectively.

The majority of implants that were placed were 4.1 mm in diameter and 11.5 or 13 mm in length (Appendix Table 2). Implant diameter ranged from 3.25 mm in narrow sites (4 in the control group and 4 in the test group) to one canine site in the test group that received a 5.0-mm–diameter implant. There was no statistically significant difference between the average insertion torque of 31.6 ± 15.1 Ncm (range: 5 to 50 Ncm) and 27.8 ± 11.1 Ncm (range: 10 to 50 Ncm) in the test and control groups, respectively (\( P = .43 \)). Clinical measurements recorded are shown in Appendix Table 2. No significant differences between groups were found regarding the horizontal and vertical implant position. Implants in the control group were placed with an average buccal gap distance of 2.9 ± 1.3 mm and implants in the test group were placed with a distance of 3.1 ± 0.9 mm (\( P = .63 \)). The vertical distance of the implants from the implant to the FGM was 4.3 ± 0.6 mm in the test group while in the control group it was 4.1 ± 0.6 mm (\( P = .61 \)). There was no difference between the two groups regarding the method of temporization (full contoured provisional restoration that was out of occlusion or a custom healing abutment that captured the soft tissue profile of the socket) (Appendix Table 2).

All subjects in the test group tolerated the DBBM-C well, and implants in both groups showed a 100% survival rate at the last follow-up appointment 12 months after implant placement. Patients were satisfied with the appearance of the implant-supported crowns, and all patients presented an intact crown with no signs of screw loosening at the 1-year follow-up appointment. No signs of clinical inflammation were observed.

Fig 6 Bar graphs illustrating soft tissue thickness changes between test (n = 13) and control (n = 14) groups at 3, 4, and 8 mm from the FGM from baseline to 12 months. Here, the number of patients per group varies from the number at 12 months because some measurements could not be taken.
**Horizontal Dimensional Changes from Baseline to 12 Months**

Although the test group (n = 13) had greater mean soft tissue thickness at 3, 4, and 8 mm than the control group (n = 14), no statistical significance was reached (P = .39, \( P = .31 \), \( P = .13 \), respectively) after 12 months (Fig 6). Even though the test group had less dimensional change on average than the control group at all three time points (baseline to 3, 6, and 12 months), there were no statistically significant differences between groups (Appendix Table 3). In general, patients presented with a loss in the buccolingual dimension at all subsequent time points after implant placement. However, one patient in the test group showed a 0.15-mm gain from baseline to 12 months at 4 mm from the FGM. At 3 mm from the FGM, patients in the test group had a mean loss of 0.84 ± 0.64 mm while patients in the control group had a mean loss of 1.01 ± 0.45 mm from baseline to 12 months. At 4 mm from the FGM, patients in the test group had a mean loss of 0.64 ± 0.62 mm while patients in the control group had a mean loss of 0.80 ± 0.33 mm from baseline to 12 months (Appendix Table 3).

**Vertical Dimensional Changes from Baseline to 12 Months**

Vertical changes recorded using a tooth-supported Essix stent showed a significant difference in buccal soft tissue vertical height change from baseline to 12 months, only at the distal papilla site, favoring the test group (Appendix Table 4). There was no statistically significant difference between groups for the change in vertical dimension at mesial papillae and midbuccal sites.

Further, no statistically significant difference was observed for decreasing midbuccal height in either the control (P = .07) or test (P = .338) group. In contrast, there was a statistically significant linear trend for decreasing vertical height in both control (P = .034) and test (P = .0094) groups at the mesial papilla sites as well as for distal papilla sites in both control (P = .0008) and test (P = .019) groups.

To determine whether there is a relationship between soft tissue thickness and horizontal dimensional changes in test and control groups from baseline to 12 months, a correlation analysis was conducted and revealed only a poor correlation between these two parameters. Therefore, patients who had significant vertical dimensional changes were not necessarily those with significant horizontal changes, showing that these variables are independent of each other. In addition, a poor correlation was found between buccal gap distance and horizontal dimensional change at 3 and 4 mm from the FGM, irrespective of grafting, from baseline to 12 months.

**Discussion**

The present results show that although the group that received DBBM-C (Bio-Oss Collagen) at the time of implant placement to graft the gap between the implant and buccal bone plate (test group) had less dimensional change on average than those who received no grafting (control group), this difference was insufficient to show a statistically significant result between both groups. Analysis of the vertical dimension revealed a significantly higher preserved vertical height of the distal papillae from baseline to 12 months in the test group, whereas there was no statistically significant difference between test and control groups at mesial papillae and midbuccal sites.

Horizontal dimensional changes between the two groups at 3 and 4 mm from the FGM revealed no statistically significant difference between test and control groups at any time point. It is important to note that at 3 and 4 mm from the FGM, the crestal bone is the thinnest and most vulnerable to remodeling. From baseline to 12 months at 3 and 4 mm, patients in the test group had a mean loss of 0.84 ± 0.64 mm and 0.64 ± 0.62 mm, respectively, while patients in the control group had a slightly higher mean loss of 1.01 ± 0.45 mm and 0.80 ± 0.33 mm, respectively. There was no statistically significant difference between groups on the buccolingual reduction. This is not in agreement with the studies completed by Sanz et al, where immediate implants without immediate provisionalization that received DBBM-C showed statistically significantly less reduction than the group that did not receive a bone graft. Other studies have shown that placing a bone graft at the time of immediate placement with
mediate implant placement; this over long-term follow-up after implant placement has shown that the papillae improve in vertical dimension, on average. Studies have demonstrated that patients with a customized healing abutment received a provisional crown before a final impression was taken. Also, since the contour of the papilla depends on the contact of the restoration, there could be some inaccuracies in the values obtained based on the different restorations’ contours.

To determine if there is any association between the horizontal and vertical dimensional changes in each patient, a correlation from baseline values was performed at 3, 6, and 12 months. A poor correlation was found between the horizontal dimension changes at 3 and 4 mm from the FGM and midbuccal dimensional changes at all time points. This may indicate that the factors influencing the horizontal dimensional changes may not necessarily be those that affect vertical changes.

No significant differences between groups were found regarding horizontal and vertical implant positions between groups. However, the horizontal gap distance showed a wide range (2.9 ± 1.3 mm for the control group and 3.1 ± 0.9 mm in the test group). Further studies evaluating the relationship of the gap distance with the use of bone graft material to the buccolingual collapse are recommended.

This study had several methodologic limitations. The sample size for this study is limited. Additional studies, with potentially larger sample sizes, are necessary to test each factor to determine which specific techniques or materials could result in minimal dimensional changes on a predictable basis. Also, the overall patient follow-up time was limited, and soft tissue could potentially present further changes after 12 months of loading. Further studies with longer follow-up times may be recommended to evaluate long-term behavior of the tissues with immediately placed implants. Stratifying the groups based on implant diameter could be beneficial in future studies as well, in order to compare the relationship of the implant diameter to the bone collapse seen.

Conclusions

No detrimental effects were demonstrated with the use of immediate implants and immediate provisionalization and all implants survived up to the 12-month mark. Both groups showed loss of tissue volume. Given the limitations of the study, several conclusions can be drawn. Patients who received a DBBM-C bone graft at the time of implant placement showed slightly less horizontal dimension decrease; however, there is no significant difference between the group that received deproteinized bovine bone mineral with 10% collagen (Geistlich Bio-Oss Collagen) and the group that did not after 12 months. There was, however,
significantly more favorable vertical dimensional stability in the test group at the distal papillae at 12 months. There was also no statistically significant difference between soft tissue thickness in test and control groups at 3 and 4 mm from the FGM.

A larger sample size and longer follow-up time may be necessary to see if additional dimensional changes can be detected in either group. Overall, this research shows that adding a deproteinized bovine bone mineral with 10% collagen into the gap on immediately placed implants showed no statistically significant difference from the group that did not receive a graft; however, adding the graft showed slightly less dimensional changes in the soft tissue on average.

**Acknowledgments**

We want to thank Jaffer Shariff, BDS, MPH, MS, for his statistical support. The study was supported by Geistlich Pharma USA. None of the authors has a conflict of interest to declare.

**References**


Errata

doi: 10.11607/prd.4270
In the article by Cagidiaco et al (RCT on Single Zirconia Crowns with Feather-Edge vs Chamfer Finish Lines: Four-Year Results), in Volume 29, Number 6 (November/December), 2019, the decision on a study hypothesis was incorrectly reported. Results of the study support the acceptance of the first null hypothesis, and this has been corrected in the online version of the article.

doi: 10.11607/prd.3195
In the article by Moreno Rodriguez and Caffese (Nonincised Papillae Surgical Approach [NIPSA] in Periodontal Regeneration: Preliminary Results of a Case Series), in Volume 28, supplemental issue, 2018, Figure 2c was incorrectly printed. The correct image is a periapical radiograph prior to treatment, and this has been corrected in the online version of the article.
### Appendix

#### Appendix Table 1 Baseline Clinical and Radiographic Parameters of the Extraction Socket (Mean ± SD) Between Test and Control Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test (n = 16)</th>
<th>Control (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGM to midfacial bone level, mm (range)</td>
<td>3.4 ± 0.8 (2.5 to 5.0)</td>
<td>3.3 ± 0.6 (2.0 to 4.0)</td>
</tr>
<tr>
<td><strong>Tissue thickness</strong>&lt;sup&gt;a&lt;/sup&gt; (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 mm</td>
<td>1.7 ± 0.6 (0.8 to 3.0)</td>
<td>1.7 ± 0.7 (0.5 to 3.5)</td>
</tr>
<tr>
<td>4 mm</td>
<td>1.4 ± 0.4 (0.5 to 2.5)</td>
<td>1.6 ± 0.8 (0.25 to 4.0)</td>
</tr>
<tr>
<td>8 mm</td>
<td>1.5 ± 0.5 (0.75 to 2.5)</td>
<td>1.8 ± 0.8 (0.5 to 4.0)</td>
</tr>
<tr>
<td><strong>Clinical buccal plate thickness</strong>&lt;sup&gt;a&lt;/sup&gt; (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 mm</td>
<td>0.8 ± 0.6 (0.0 to 2.3)</td>
<td>0.8 ± 0.8 (0.0 to 3.5)</td>
</tr>
<tr>
<td>8 mm</td>
<td>1.0 ± 0.7 (0.0 to 2.5)</td>
<td>0.8 ± 0.9 (0.0 to 0.25)</td>
</tr>
<tr>
<td><strong>CBCT buccal plate thickness</strong>&lt;sup&gt;b&lt;/sup&gt; (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 mm</td>
<td>1.1 ± 0.7 (0.3 to 2.4)</td>
<td>1.0 ± 0.9 (0.3 to 4.0)</td>
</tr>
<tr>
<td>8 mm</td>
<td>0.8 ± 0.5 (0.3 to 1.9)</td>
<td>0.9 ± 0.7 (0.3 to 3.4)</td>
</tr>
</tbody>
</table>

FGM = free gingival margin; CBCT = cone beam computed tomography.

<sup>a</sup>Measured from the free gingival margin.

<sup>b</sup>Measured from the cementoenamel junction + recession.

#### Appendix Table 2 Implant Parameters (Mean ± SD) at the Time of Insertion Between Test and Control Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test (n = 16)</th>
<th>Control (n = 16)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant diameter, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.25 mm</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4.1 mm</td>
<td>11</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>5.0 mm</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Implant length, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.5 mm</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10 mm</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>11.5 mm</td>
<td>7</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>13 mm</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>15 mm</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Insertion torque, Ncm (range)</td>
<td>31.6 ± 15.1 (5 to 50)</td>
<td>27.8 ± 11.1 (10 to 50)</td>
<td>.43</td>
</tr>
<tr>
<td>Buccal gap distance, mm (range)</td>
<td>2.9 ± 1.3 (1.0 to 5.0)</td>
<td>3.1 ± 0.9 (1.0 to 5.0)</td>
<td>.63</td>
</tr>
<tr>
<td>Implant to FGM, mm (range)</td>
<td>4.3 ± 0.8 (3.5 to 5.5)</td>
<td>4.1 ± 0.6 (3.0 to 5.0)</td>
<td>.61</td>
</tr>
<tr>
<td>Implant to bone level, mm (range)</td>
<td>−0.8 ± 0.5 (−2.0 to 0.0)</td>
<td>−0.8 ± 0.5 (−2.0 to 0.0)</td>
<td>.73</td>
</tr>
<tr>
<td>Temporization method, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Custom healing abutment</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Full-contour temporary</td>
<td>10</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

© 2019 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.
Appendix Table 3  Horizontal Dimensional Changes (Mean ± SD) From a Digital Superimposition Using Compare Software at 3 and 4 mm Apical to the Baseline FGM Position

<table>
<thead>
<tr>
<th>Distance from FGM, mm</th>
<th>Test (n = 16)</th>
<th>Control (n = 15)</th>
<th>( P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>0–3 mo, mm</td>
<td>-0.58 ± 0.56</td>
<td>-0.49 ± 0.51</td>
<td>-0.76 ± 0.58</td>
</tr>
<tr>
<td>Range</td>
<td>(-1.74 to 0.06)</td>
<td>(-1.8 to 0.05)</td>
<td>(-0.76 to 0.58)</td>
</tr>
<tr>
<td>0–6 mo, mm</td>
<td>-0.76 ± 0.57</td>
<td>-0.66 ± 0.58</td>
<td>-0.85 ± 0.46</td>
</tr>
<tr>
<td>Range</td>
<td>(-1.88 to 0.05)</td>
<td>(-1.62 to 0.10)</td>
<td>(-1.58 to 0.063)</td>
</tr>
<tr>
<td>0–12 mo, mm</td>
<td>-0.84 ± 0.64</td>
<td>-0.64 ± 0.62</td>
<td>-1.01 ± 0.45</td>
</tr>
<tr>
<td>Range</td>
<td>(-2.02 to 0.09)</td>
<td>(-1.87 to 0.15)</td>
<td>(-1.55 to 0.17)</td>
</tr>
</tbody>
</table>

FGM = free gingival margin.
Intent-to-treat analysis was performed to account for the patient who did not return for 12-month follow-up.

\( a \) Between-group comparison.

Appendix Table 4  Buccal Soft Tissue Changes in Vertical Dimension (Mean ± SD) From a Tooth-Supported Stent to the Free Gingival Margin

<table>
<thead>
<tr>
<th>Site</th>
<th>Test (n = 16)</th>
<th>Control (n = 15)</th>
<th>( P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>0–3 mo, mm</td>
<td>-0.7 ± 1.1</td>
<td>-0.5 ± 1.4</td>
<td>-0.7 ± 1.0</td>
</tr>
<tr>
<td>Range</td>
<td>(-3 to 1)</td>
<td>(-3 to 2)</td>
<td>(-3 to 0.5)</td>
</tr>
<tr>
<td>3–6 mo, mm</td>
<td>-0.3 ± 0.7</td>
<td>-0.3 ± 0.8</td>
<td>-0.1 ± 1.0</td>
</tr>
<tr>
<td>Range</td>
<td>(-1.5 to 1)</td>
<td>(-2 to 1)</td>
<td>(-1.5 to 1.5)</td>
</tr>
<tr>
<td>0–6 mo, mm</td>
<td>-1.0 ± 1.0</td>
<td>-0.8 ± 1.4</td>
<td>-0.8 ± 1.2</td>
</tr>
<tr>
<td>Range</td>
<td>(-2 to 2)</td>
<td>(-3 to 1.5)</td>
<td>(-2 to 0.5)</td>
</tr>
<tr>
<td>6–12 mo, mm</td>
<td>0.4 ± 1.1</td>
<td>-0.1 ± 1.1</td>
<td>0.4 ± 1.3</td>
</tr>
<tr>
<td>Range</td>
<td>(-1.5 to 3)</td>
<td>(-2.5 to 1.5)</td>
<td>(-1.5 to 3)</td>
</tr>
<tr>
<td>0–12 mo, mm</td>
<td>-0.6 ± 1.2</td>
<td>-0.9 ± 1.2</td>
<td>-0.4 ± 1.2</td>
</tr>
<tr>
<td>Range</td>
<td>(-3 to 1)</td>
<td>(-3 to 2)</td>
<td>(-2 to 1.5)</td>
</tr>
</tbody>
</table>

M = mesial papilla; B = midbuccal papilla; D = distal papilla.

\( ^a \) Between-group comparison.

*Statistically significant.