

# Horizontal and Vertical Dimensional Changes of Peri-implant Facial Bone Following Immediate Placement and Provisionalization of Maxillary Anterior Single Implants: A 1-Year Cone Beam Computed Tomography Study

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**Purpose:** This cone beam computed tomography study (CBCT) evaluated horizontal and vertical dimensional changes to the facial bone following maxillary anterior single immediate implant placement and provisionalization.

**Materials and Methods:** CBCT scans taken immediately after (T1) and 1 year after surgery (T2) were evaluated. The midsagittal cut of each implant was identified, and measurements were made at predetermined levels. Horizontal facial bone thickness (HFBT) was measured at 0, 1, 2, 4, 6, 9, and 12 mm apical to the implant platform. Vertical facial bone level (VFBL) was the perpendicular distance from the implant platform (0) to the most coronal point of the facial bone. Measurements were recorded and changes between T1 and T2 were calculated. The data were analyzed statistically at a significance level of  $\alpha = 0.05$ . **Results:** CBCT scans of 21 patients were analyzed. At T2, the mean HFBT changes ranged from  $-1.23$  to  $-0.08$  mm at the seven different levels evaluated. The mean VFBL change was  $-0.82$  mm. The HFBT changes at the 1- to 9-mm levels were not significantly different from one another, but they were significantly smaller than the change at the 0-mm level and significantly greater than the change at the 12-mm level. Significant positive correlations were observed only between horizontal and vertical changes and between horizontal change and initial VFBL at the implant platform. While the VFBL of eight implants (38%) was apical to the implant platform at T2, none was noted at T1. **Conclusions:** Dimensional changes to the peri-implant facial bone following maxillary anterior single immediate implant placement and provisionalization should be expected. The greatest HFBT change was noted at the implant platform level, in part because HFBT change is correlated to the initial VFBL and the change in VFBL at that level. *Int J Oral Maxillofac Implants* 2012;27:393–400

**Key words:** cone beam computed tomography, facial bone, immediate implant placement and provisionalization, immediate tooth replacement, maxillary anterior implants, measurement

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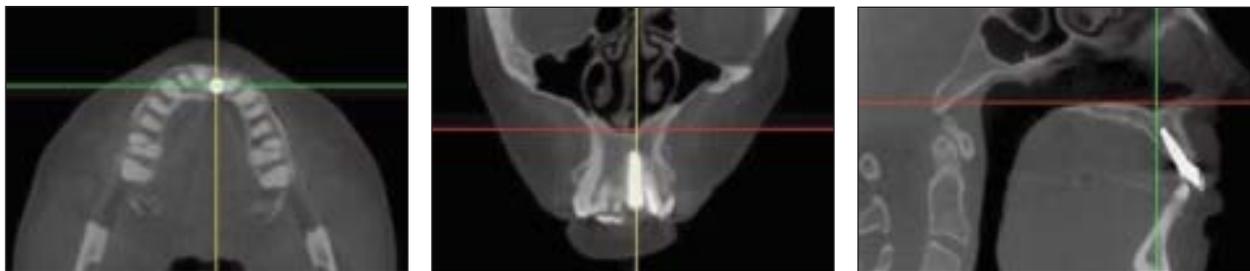
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The long-term results and relative merits of maxillary anterior single immediate implant placement and provisionalization in the esthetic zone have been well documented, and the procedure is considered a viable treatment option for the replacement of failing teeth when established clinical guidelines are followed.<sup>1–9</sup> The advantages of immediate implant placement and provisionalization in the anterior maxilla include reduced treatment time, immediate tooth replacement, and preservation of the existing osseous and gingival architecture.<sup>1,3,7,8</sup>

In recent years, facial dimensional changes to the alveolar process following tooth extraction and immediate implant placement have been under investigation in both humans<sup>10–16</sup> and animals.<sup>17–21</sup> Additional studies have demonstrated that the placement of graft



**Fig 1** Secondary reconstruction on the two-dimensional orthogonal multiplanar reformatting screen of an immediate implant placement and provisionalization procedure in (left to right) axial view, where a vertical reference line (in yellow) bisected the implant in the faciopalatal direction; coronal view, where the implant long axis is parallel to the vertical reference line (in yellow); and sagittal view, where the palatal plane is parallel to the horizontal vertical line (in red). Note that the three images shown are not from the same screen but from the different respective rotations performed.

materials into the implant-socket gap could minimize the resorptive process<sup>22</sup> and/or promote better healing.<sup>23,24</sup> While many methods<sup>10-21</sup> have been used to assess the facial bone, they either lack the required precision, are invasive, or are not sequentially reproducible for longitudinal studies.

The purpose of this cone beam computed tomography (CBCT) study was to evaluate the changes in horizontal facial bone thickness (HFBT) and vertical facial bone level (VFBL) following immediate placement and provisionalization of single implants in the anterior maxilla.

## MATERIALS AND METHODS

### Patient Selection

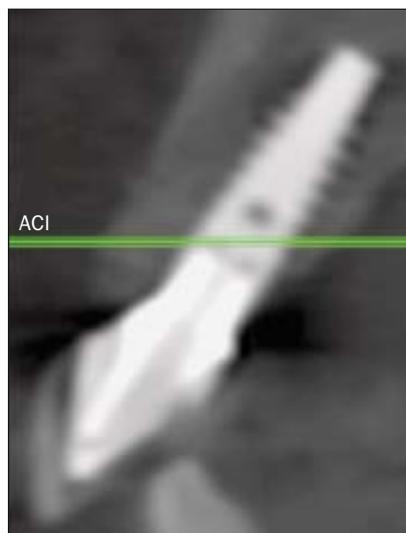
This retrospective study was approved by the Institutional Review Board of Loma Linda University and was conducted in the Center for Prosthodontics and Implant Dentistry, Loma Linda University School of Dentistry, California. Treatment records and CBCT images of patients who received treatment between May 2007 and September 2010 were reviewed. The clinical technique used for each study subject has been previously described.<sup>25</sup> To be included in this study, patients had to meet the following criteria: (1) they needed to be at least 18 years old at the time of treatment; (2) received treatment for a single failing anterior maxillary tooth (incisor) with a flapless immediate implant placement and provisionalization procedure; (3) an intact labial bony plate had to be present before and after tooth removal, along with a normal bone-to-gingiva relationship on the facial aspect (~3 mm) of the failing tooth as well as on the interproximal aspects (~4.5 mm) of the adjacent teeth; (4) implants were at least 13 mm long; (5) the implant-socket gap was filled with deproteinized anorganic bovine bone graft material (Bio-Oss,

Osteohealth); (6) pretreatment, immediate posttreatment, and 1-year posttreatment CBCT data were available; and (7) no radiographic evidence of infection was present at the 1-year follow-up.

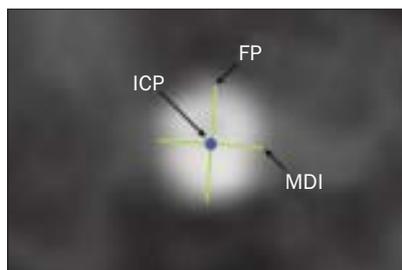
### Data Reconstruction and Image Acquisition

Following the primary reconstruction, the CBCT volumetric data were accessed using a two-dimensional orthogonal multiplanar reformatting viewer (Fig 1) for the secondary reconstruction. In the axial view, the image was rotated so that the vertical reference line bisected the implant in the faciopalatal direction according to the implant position on the arch form. In the coronal view, the image was rotated until the implant's long axis was parallel to the vertical reference line. In the sagittal view, the image was rotated so that the palatal plane (the line joining anterior and posterior nasal spines) was parallel to the horizontal reference line. The data were exported as a DICOM (Digital Images and Communications in Medicine) file and opened using a volumetric DICOM viewer (OsiriX Imaging Software, version 3.7, Pixmeo) for facial bone evaluation. In the axial view, the location of the implant-abutment gap was identified, and the axial cut (AC1) immediately apical to the abutment was used to create two-dimensional curved multiplanar reformatted images, on which the measurements were performed (Fig 2).

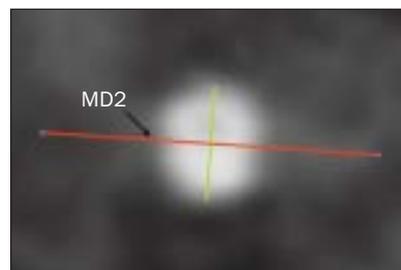
On the AC1, the implant center point was identified by drawing perpendicular lines (faciopalatal [FP] and mesiodistal [MD1] lines) bisecting the implant (Fig 3). From the implant center point along the MD1 line, a line (MD2) was extended 6.4 mm mesially and distally for a total length of 12.8 mm (Fig 4). The open-polygon tool was then used to form a line (MD3) superimposing the MD2 line, and two-dimensional curved multiplanar reformatted images at 0.8-mm intervals were created (Fig 5). The sagittal cut used for the facial bone measurements coincided with the FP line (Fig 6). The



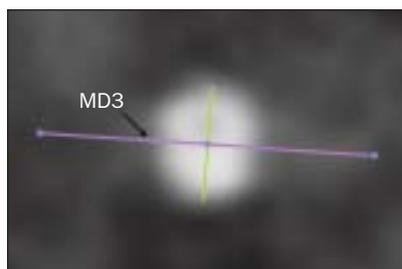
**Fig 2** The axial cut (AC1) immediately apical to the abutment (*center green line*) is identified on the sagittal view.



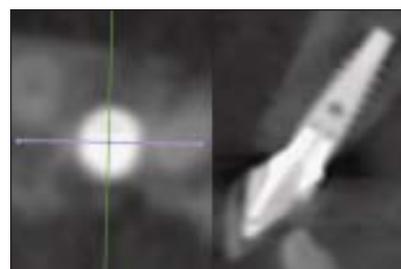
**Fig 3** Implant center point (ICP) was identified by drawing perpendicular lines (facio-palatal [FP] and mesiodistal [MD1]; *green*) bisecting the implant.



**Fig 4** The MD2 line (*red*) extends 6.4 mm mesially and distally from implant center point (ICP) and overlaps the MD1 line.



**Fig 5** The open-polygon tool was used to form the MD3 line (*purple*), which is superimposed upon the MD2 line.



**Fig 6** (Left) The master sagittal cut (*long green line*), coincident with the FP line, produces (right) a sagittal image that is then used for facial bone evaluation.

image contrast was adjusted to facilitate the discrimination of tissues with different densities. Using the measurement tool, a 10-mm horizontal line was drawn onto the sagittal image.

### Horizontal and Vertical Facial Bone Measurements

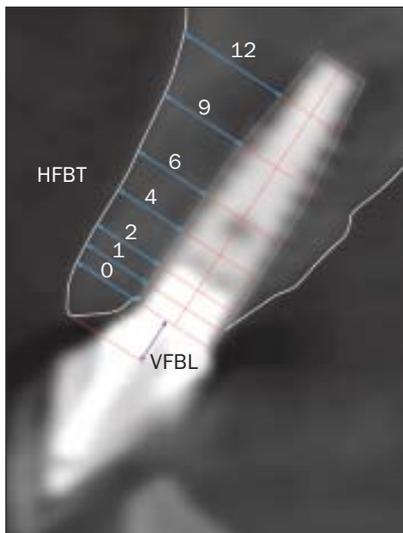
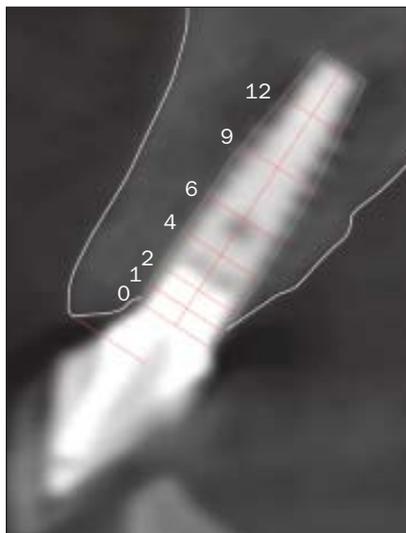
Next, the image was screen-captured and imported into a presentation program (Keynote 2009, Apple) at a resolution of  $1,920 \times 1,080$  pixels. The horizontal line was duplicated using the line drawing tool (Shapes), and the number of pixels per millimeter was calculated. The known implant length and diameter were calculated in pixel values using the following formula:

$$\text{Line value in pixels} = (\text{line value in mm}) \times (\text{no. of pixels/mm})$$

The line bisecting the implant along its long axis represented the implant length. The implant diameter was the line drawn on the implant platform perpendicular to the implant length line. The alveolar housing and body of the implant were then outlined. Only the peaks of the implant threads were reflected on the implant outline. Lines parallel to the implant platform

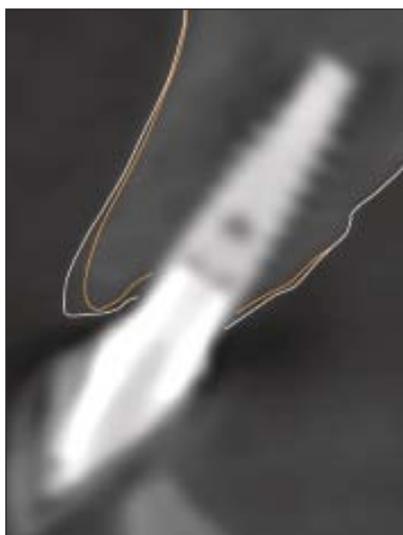
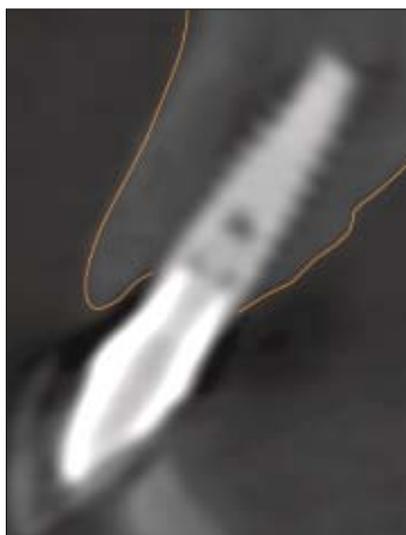
(horizontal implant lines) were placed at 1, 2, 4, 6, 9, and 12 mm apical to the implant platform and at the most coronal point of the facial bone (Fig 7). The HFBT at each level, including the implant platform (0 mm) level, was measured on the line extending from the corresponding horizontal implant line to the outline of the facial bone. The VFBL is the perpendicular distance from the implant platform (0) to the most coronal point of the facial bone. Positive or negative values were designated when the most coronal point of the facial bone was located coronal or apical to the implant platform, respectively. These measurement line pixels were enumerated and calculated in millimeters (Fig 8).

For each study subject, HFBT and VFBL were evaluated immediately following surgery (T1) and at 1 year following implant surgery (T2) (Figs 9 and 10). To assess the reliability of the measurement method, two calibrated examiners (PR and JYK) independently measured the HFBT at 0, 2, 4, and 6 mm apical to the implant platform, as well as VFBL, on 10 CBCT scans. The interexaminer reliability of the measurements was expressed as the intraclass correlation coefficient (ICC) (0.88 to 0.98; Table 1). Subsequently, one examiner (PR) performed all the measurements and data collection.



**Fig 7 (Left)** The alveolar housing and the body of the implant were outlined. Lines parallel to the implant platform (0) were placed 1, 2, 4, 6, 9, and 12 mm apical to the implant platform and at the most coronal point of the facial bone.

**Fig 8 (Right)** Horizontal facial bone thickness (HFBT) at each level was measured on the line extended from the corresponding horizontal implant lines to the outline of the facial bone. Vertical facial bone level (VFBL) was the perpendicular distance from the most coronal point of facial bone to the implant platform.



**Fig 9 (Left)** Image at 1 year after implant placement with the implant and the alveolar process outlined.

**Fig 10 (Right)** Superimposition of images at different times (white = immediately after implant placement; orange = 1 year after implant placement) shows changes in peri-implant bone morphology.

**Table 1 ICCs of the Facial Bone Dimension Measurements (n = 10) Between Two Examiners**

Measurement	ICC
HFBT <sup>0</sup>	0.98
HFBT <sup>2</sup>	0.88
HFBT <sup>4</sup>	0.92
HFBT <sup>6</sup>	0.94
VFBL	0.91

HFBT<sup>n</sup> = horizontal facial bone thickness at the n-mm measurement level; VFBL = vertical facial bone level.

**Data Analysis**

The HFBT values at T1 and T2 at each measurement level were compared using the paired *t* test. Repeated-measures one-way analysis of variance (ANOVA) with Bonferroni adjustment for pairwise comparisons was

used to compare the HFBT change (T2 – T1) at different measurement levels (0 to 12 mm). Correlations among the HFBT change, VFBL change, initial (T1) HFBT, and initial (T1) VFBL were analyzed at the measurement levels 0, 1, and 2 mm. The level of significance was set at  $\alpha = 0.05$ .

**RESULTS**

The T1 and T2 CBCT scans of 21 patients (7 men and 14 women) with a mean age of 48.8 years (range, 27 to 85 years) were included in this study. Four implant systems (NobelActive, Nobel Biocare; NobelReplace, Nobel Biocare; Straumann Bone Level, Straumann; OsseoSpeed, AstraTech) replacing 16 central and 5 lateral incisors were evaluated. The high ICC (0.88 to 0.98; Table 1) achieved indicated that the measurement method was reliable and reproducible.

**Table 2 Comparison of Facial Bone Dimensions Between Time Intervals and Comparison of Horizontal Facial Bone Dimensional Change at Different Levels (0 to 12 mm) (n = 21)**

Measurement	Facial bone dimension (mm)		P (T1 vs T2)*	Dimensional change (mm)	
	T1	T2		T2 – T1	P (T2 – T1, HFBT <sup>0-12</sup> )**
HFBT <sup>0</sup>	2.51 ± 0.93	1.28 ± 1.39	< .01	-1.23 ± 0.75 <sup>a</sup>	< .01
HFBT <sup>1</sup>	2.66 ± 0.92	2.02 ± 1.17	< .01	-0.64 ± 0.55 <sup>b</sup>	
HFBT <sup>2</sup>	2.57 ± 0.92	2.11 ± 0.99	< .01	-0.46 ± 0.27 <sup>b</sup>	
HFBT <sup>4</sup>	2.35 ± 0.88	1.87 ± 0.91	< .01	-0.48 ± 0.29 <sup>b</sup>	
HFBT <sup>6</sup>	2.21 ± 0.82	1.70 ± 0.92	< .01	-0.50 ± 0.31 <sup>b</sup>	
HFBT <sup>9</sup>	2.19 ± 1.08	1.88 ± 1.18	< .01	-0.32 ± 0.29 <sup>b</sup>	
HFBT <sup>12</sup>	2.58 ± 1.56	2.50 ± 1.58	.14	-0.08 ± 0.24 <sup>c</sup>	
VFBL	0.95 ± 0.73	0.13 ± 0.86	< .01	-0.82 ± 0.64	

T1 = immediately following surgery; T2 = 1 year after implant surgery; HFBT<sup>n</sup> = horizontal facial bone thickness at the n-mm measurement level; VFBL = vertical facial bone level.

\*Paired t test; \*\*repeated one-way ANOVA with Bonferroni adjustment; a significance level of  $\alpha = 0.05$  was used.

<sup>a,b,c</sup>Different superscript letters denote statistically significant differences ( $P < .05$ ).

The means and standard deviations of facial bone dimensions at different time intervals and measurement levels are presented in Table 2. Except for HFBT at the 12-mm level ( $P = .14$ ; Table 2), significant negative changes were observed in VFBL ( $P < .01$ ; Table 2) and HFBT at all other levels (0 to 9 mm) ( $P < .01$ ; Table 2) when comparing the facial bone dimensions between T1 and T2.

The mean HFBT changes at 0, 1, 2, 4, 6, 9, and 12 mm were  $-1.23 \pm 0.75$  mm,  $-0.64 \pm 0.55$  mm,  $-0.46 \pm 0.27$  mm,  $-0.48 \pm 0.29$  mm,  $-0.50 \pm 0.31$  mm,  $-0.32 \pm 0.29$  mm, and  $-0.08 \pm 0.24$  mm, respectively (Table 2). Repeated-measures one-way ANOVA revealed statistically significant differences between the HFBT changes at different measurement levels ( $P < .01$ ; Table 2). Bonferroni adjustments showed that the HFBT changes at 1, 2, 4, 6, and 9 mm were not significantly different from one another ( $P > .05$ ), but they were significantly lower than the change at 0 mm ( $P < .05$ ; Table 2) and significantly greater than the change at 12 mm ( $P < .05$ ; Table 2). The mean VFBL change was  $-0.82 \pm 0.64$  mm. The VFBL of seven implants (33%) and one implant (5%) was apical to the implant platform and the 1-mm level, respectively, at T2; however, no VFBL values apical to the platform had been noted at T1.

Statistically significant positive correlations were observed only between HFBT change and VFBL change ( $r = .55$ ,  $P = .01$ ) and between HFBT change and initial VFBL at the implant platform level ( $r = .44$ ;  $P = .046$ ). No significant correlations were noted among the parameters at other levels.

## DISCUSSION

The relationship between the bone and gingiva around natural teeth and implants has been well documented.<sup>26-28</sup> Various methods and instruments have been used to measure the alveolar process, such as the periodontal probe,<sup>11,29</sup> manual caliper,<sup>14</sup> digital caliper,<sup>16</sup> and histomorphometric analysis.<sup>17-21</sup> The periodontal probe provides a simple means for direct bone measurement, but it lacks the precision of other methods. The caliper is limited to measuring bone thickness in the extraction socket only and is not useful after implant placement. Histomorphometric analysis allows observation of remodeling patterns adjacent to the implant and quantification of bone dimensions, but it requires en bloc resection and thus cannot be used for longitudinal evaluation. The advantage of CBCT is that it allows the clinician to measure peri-implant bone dimensions using standardized measurements at multiple levels over time.

Although CBCT produces a much lower effective radiation dose (13 to 82  $\mu\text{Sv}$ )<sup>30</sup> than multislice CT (474 to 1,160  $\mu\text{Sv}$ ),<sup>30</sup> it can nevertheless produce clear images of highly contrasting structures.<sup>31-33</sup> All CBCT units provide voxel resolutions that are isotropic (equal in all three dimensions) and produce a submillimetric resolution from 0.4 to 0.125 mm.<sup>31</sup> In addition, CBCT images have a substantially lower level of metal artifacts than conventional CT images.<sup>31,34</sup> Furthermore, studies have shown that measurements made on CBCT images were accurate and not significantly different from

those made on multislice CT images or direct measurements of anatomic structures in the dentomaxillofacial area.<sup>35,36</sup> In this study, the high ICC (0.88 to 0.98; Table 1) achieved between the two examiners is similar to those observed in other CBCT studies,<sup>37–39</sup> which indicates that this method is reliable and reproducible.

Few studies have provided data regarding the horizontal and/or vertical facial bone response to immediate implant placement and provisionalization procedures.<sup>10,11,22,29,40</sup> In this study, significant HFBT changes were observed at all ( $P < .01$ ; Table 2) but the 12-mm level ( $P = .14$ ; Table 2). This indicates that, even with bone grafting, a decrease in facial bone thickness should be expected following immediate implant placement and provisionalization. Except for a significantly greater HFBT loss observed at the implant platform level ( $-1.23$  mm;  $P < .01$ ; Table 2), the HFBT underwent a relative consistent change of approximately  $-0.5$  mm at the 1- to 9-mm levels and minimal change at the 12-mm level during the first year (Table 2). The significantly greater change in HFBT at the implant platform level could be partially explained by its positive correlations with the change in VFBL ( $r = .55$ ,  $P = .01$ ; HFBT loss becomes greater as VFBL loss increases) and the initial VFBL ( $r = .44$ ;  $P = .046$ ; HFBT loss becomes greater as initial VFBL decreases), which were not observed at any other levels.

In this study, the VFBL of eight implants (38%) was located apical to the implant platform at T2, while no VFBL values were apical to the platform at T1. The mean initial VFBL of these implants was 0.47 mm, compared to 0.95 mm of the mean overall initial VFBL (Table 2). At T2, the HFBT at the platform level of these implants was considered zero and thus contributed to the dramatic loss of HFBT at this level. It is also worthwhile to note that after 1 year of function, the VFBL of the implants undergoing immediate implant placement and provisionalization rarely remodeled beyond 1 mm apical to the implant platform (1/21 implants = 5%).

It has been suggested that the initial HFBT has a direct influence on the VFBL change.<sup>17,22,29</sup> In a study examining healed sites, Spray et al<sup>29</sup> reported the effect of bone thickness on facial marginal bone response to implant placement. Sites that displayed a negative VFBL change presented with a mean HFBT between 1.3 to 1.8 mm following preparation of the osteotomy. Those sites that exhibited no negative VFBL change presented with a mean HFBT of  $\geq 1.8$  mm. A comparison of the facial bone thickness with the facial bone height response suggested that vertical bone loss decreases as the thickness increases. However, no significant correlation was observed in this study between the initial HFBT and VFBL change between 0 to 2 mm from the implant platform ( $P > .05$ ). This may be a result of the fact that the majority (79%) of initial HFBT

values recorded at the 0- to 2-mm levels were greater than 1.8 mm (mean = 2.51 to 2.66 mm), and thus the effect of low HFBT (1.3 to 1.8 mm) could not be expressed. Another contributing factor may be the difference in the facial bone response between implants placed in extraction sockets and those placed in healed sites. Nevertheless, the mean VFBL change of  $-0.82$  mm observed in this study indicates that peri-implant VFBL should be expected 1 year after immediate implant placement and provisionalization with bone grafting.

Studies have reported HFBT changes of  $-0.32$  mm for immediate implant placement with bone grafting,<sup>22</sup>  $-1.10$  to  $-1.90$  mm for immediate implant placement without bone grafting,<sup>10,11</sup> and  $-0.40$  mm for implants placed in healed sites.<sup>40</sup> Similarly, studies involving the vertical facial bone response to immediate implant placement have reported VFBL changes of  $-0.10$  mm for grafted sites,<sup>22</sup>  $-0.30$  to  $-1.00$  mm for nongrafted sites,<sup>10,11</sup> and  $-0.70$  mm for implants placed in healed sites.<sup>29,40</sup> While the results of this study (HFBT changes =  $-0.123$  to  $-0.08$  mm; VFBL change =  $-0.82$  mm) were within the range of the aforementioned studies, comparisons should be made with caution because of differences in study design and measurement methods.

The need for bone grafting material in the implant-socket gap has been questioned, as studies have reported resolution of the implant-socket gap following immediate implant placement with or without the use of bone graft material and barrier membranes.<sup>10,22,41–43</sup> However, maxillary anterior teeth typically present with thin facial bone and are consequently at higher risk for resorption following extraction and immediate implant placement.<sup>44</sup> For that reason, the addition of a graft material with slow resorption rates, such as deproteinized anorganic bovine bone, may be prudent, as it can alter the rate of facial/buccal remodeling.<sup>22,42</sup> Recent studies have reported that placement of implants in fresh extraction sites without bone graft material in the implant-socket gap resulted in approximately 50% reduction in the original horizontal bone thickness following facial/buccal bone remodeling.<sup>10,22,45,46</sup> In contrast, sites that received deproteinized anorganic bovine bone exhibited a horizontal dimensional loss of approximately 25%.<sup>22</sup> In the present study, deproteinized anorganic bovine bone material was placed into the implant-socket gap of each patient. At T2, the HFBT changes were 49%, 24%, 18%, 20%, 23%, 15%, and 3% at the 0-, 1-, 2-, 4-, 6-, 9-, and 12-mm levels, respectively. This suggests that adjunct bone grafting procedures in the implant-socket gap may be instrumental in minimizing facial horizontal bone changes following maxillary anterior single immediate implant placement and provisionalization.

It should be noted that this 1-year retrospective study involved multiple implant systems, and because

of the limited sample size (21 implants total), the differences in the bone responses among different implant systems were not explored. Future studies involving a larger sample size with a long-term follow-up will undoubtedly provide more information regarding the peri-implant facial bone response following immediate implant placement and provisionalization. In addition, as it has been shown that the peri-implant soft tissue dimension can also be evaluated from CBCT images,<sup>47</sup> a comprehensive esthetic assessment of the peri-implant tissues following immediate tooth replacement procedures could be simultaneously performed clinically and radiographically. It should be noted that although a single CBCT scan incurs an acceptable level of effective radiation,<sup>30</sup> radiation risks are cumulative. Therefore, it is critical that strategies for dose reduction are considered in the examination and treatment of patients.<sup>48</sup>

## CONCLUSIONS

Although bone graft procedures in the implant-socket gap are beneficial for horizontal bone stability following maxillary anterior single immediate implant placement and provisionalization, horizontal and vertical bone losses should still be expected, especially at the implant platform level. This is partially due to the fact that, at the implant platform, changes in horizontal facial bone thickness are correlated to the initial vertical facial bone level and changes in the vertical facial bone level.

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