Facial Fenestration and Dehiscence Defects Associated With Immediate Implant Placement Without Flap Elevation in Anterior Maxillary Ridge: A Preliminary Cone Beam Computed Tomography Study

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Purpose: To examine cone beam computed tomography (CBCT) anatomical findings, such as the concavity of the ridge and angulation of the tooth and alveolar ridge, either facial or palatal, in order to assess the potential clinical risks of performing flapless implant surgery. Materials and Methods: CBCT images that met the inclusion criteria were examined. All images in maxillary anterior areas (canine to canine), facial bone thickness at 3 and 5 mm from the cementoenamel junction (CEJ), angulation of the tooth and alveolar ridge (Angle T: the angulation between the long axis of the tooth and the palatal plane; Angle D: the angulation between the long axis of the tooth and the midline of the ridge), the deepest point of facial concavity, the distance from the deepest point of facial concavity to the apex of the tooth and alveolar bone crest, nasopalatine canal, dehiscence, and fenestrations were measured and statistically analyzed.

Results: In total, 21 patients (12 women and 9 men) with a mean age of 55.9 years who met the inclusion criteria were included in the analysis. Data from 21 patients, 6 image sections per patient (total of 126 CBCT images) were analyzed. The mean value of facial bone thickness was 0.99 mm and 0.60 mm at 3 and 5 mm from CEJ, respectively. The distance from the deepest point of facial concavity to the apex of the tooth and alveolar bone crest was 2.79 and 11.29 mm, respectively. In canine areas, the mean values of facial bone thickness were larger at 3 mm but thinner at 5 mm. Also, canines were found to have a larger Angle D and a higher incidence of fenestration and dehiscence.

Conclusion: Based on the findings, fenestration and a larger Angle D were associated with thinner facial bone thickness at 5 mm, and the tooth types also had an impact. Hence, for immediate implant surgery without flap elevation, besides anatomical structures, both angulation of the tooth and the alveolar ridge also need to be assessed. Int J Oral Maxillofac Implants 2018;33:1112–1118. doi: 10.11607/jomi.6575

Keywords: angulation of tooth and ridge, concavity, cone beam computed tomography, flapless implant surgery, immediate implant placement, nasopalatine canal, occlusion
facial bone wall (> 1 mm) and sufficient bone volume at both the apical and palatal regions. Unfortunately, only less than 3% of sites evaluated with cone beam computed tomography (CBCT) measurements had an initial facial bone thickness > 1 mm in healthy central incisors, and the results can be associated with further risks of fenestration, dehiscence, and soft tissue recession after implant placement. Furthermore, significant reduction of the ridge was found in sockets 8 weeks after tooth extraction, especially in the midfacial side of anterior teeth with initial dehiscence or fenestration defects. Additionally, the existence of nasalopalatine canal (NPC) can partially occupy the available bone volume at the palatal side of the ridge, and the occurrence of NPC in CBCT images, was statistically associated with facial bone wall measurement. With the observation of superimposed bone models in CBCT, bone resorption is not inevitable after tooth extraction; however, a flapless approach may offer some benefit in reducing early bone loss. When immediate implant placement without flap elevation at esthetic priority sites is being considered, careful assessment is essential for favorable outcomes. Apart from known contributing factors (eg, bone thickness, initial defect size, extent and morphology, anatomical limitations, surgical methods), there are few studies discussing the angulations of the tooth and alveolar ridge. Tooth and alveolar ridge angulation can be used to describe not only the facial concavity of the ridge, but also the inclination of the tooth. Furthermore, the relationship between the ridge and the tooth can be assessed in the angle of intersection as well. During immediate implant placement without flap elevation, the angulation deviation between the natural tooth and the alveolar ridge often makes this treatment more challenging. Hence, the CBCT anatomical assessment would be very helpful in this clinical situation. However, the relationships between the angulation and incidence of facial bony defects as well as the influence of tooth types have not yet been extensively studied. Therefore, the purpose of the present study was to determine the relationship between anatomical morphology assessed by CBCT and the incidence of facial fenestration and dehiscence during immediate implant placement without flap elevation in maxillary anterior teeth.

MATERIALS AND METHODS

This study was conducted in the Department of Periodontics at Chang Gung Memorial Hospital, Taipei, Taiwan. The patients included in the study had to meet the following inclusion criteria: had CBCT with clear images; had complete dentition from canine to canine; nonsmoker; and no history of ridge augmentation, regeneration, extraction, and dental implants. The exclusion criteria for the study were patients with a history of orthodontic therapy, dental trauma, flap surgery, endodontic treatment with apical surgeries, restoration involving cementoenamel junction (CEJ), chemotherapy, and radiotherapy. In addition, patients with pathologic findings related to maxillary anterior teeth were also excluded from the study.

CBCT Imaging

All CBCT scans were taken at 120 kVp, 12 mA, 40 seconds, and a 0.25 mm³ voxel size standard set up by the hospital. The images were reconstructed, and all measurements were done by i-CAT Vision (Imaging Sciences International) and Dolphin imaging software (Dolphin Software). Among all parameters, linear measurement was performed with i-CAT Vision, while the angulation relationship was assessed with Dolphin imaging software. At the beginning, the scans were set with the occlusal plane parallel to the floor, and the cross-sectional images could be taken perpendicularly to the middle of the ridge in all tooth sites. One calibrated examiner (C.Y.L.) completed all measurements.

CBCT Image Measurements

Facial Bone Thickness. With the landmark of CEJ, the thickness of facial bone was measured at the coronal (3 mm from CEJ) and middle (5 mm from CEJ) parts of the ridge, and the distance from CEJ to the most coronal point of the facial ridge was also documented at each tooth site (Fig 1).

Distance Associated with Ridge Concavity

The distance of facial ridge concavity was measured from the deepest point of facial concavity to the tangent line of the facial ridge. In addition, the distance from the deepest point of facial concavity to the apex of the tooth was also measured. When this value was negative, it indicated that the location of the deepest point of facial concavity was located coronally to the apex (Fig 1).

Bony Defects (Dehiscence, Fenestration)

Dehiscence was recorded when the CEJ below the alveolar crest was more than 3 mm. Fenestration, in other words, represents isolated bone loss in the facial alveolar ridge (Fig 2). Generally speaking, the bone existed above and below the fenestration defect.

Location of NPC

The distance from the most coronal point of the entrance of NPC to the alveolar crest was documented in the central incisors (Fig 3).
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**Angulation (Angle T and Angle D)**

Angle T was the angulation between the long axis of the tooth and the palatal plane, whereas Angle D represented the angulation between the long axis of the tooth and the midline of the ridge (Figs 4 and 5).

**Statistical Analysis**

The statistical significance level ($P$ value) was at $P < .05$. Descriptive statistics and frequent analyses were performed by Excel and were analyzed by SPSS software SPSS Statistics 20.0 (IBM). Independent $t$ test was used for comparison of BT and angulations between sexes. To figure out the relationship between all of the parameters involved, one-way analysis of variance (ANOVA) was used to compare all of them. Using a linear regression model could statistically define any possible correlation among all data.
RESULTS

In total, 21 patients (12 women and 9 men, aged from 33 to 80 years with a mean age of 55.9 years), representing 126 tooth sites, who fulfilled inclusion criteria were recruited for the study. The intraexaminer reliability was calculated by intraclass correlation coefficient (ICC). The value of ICC was 0.96, which represented a high value in intraobserver and test-retest reliability.

Of the 126 CBCT images in maxillary anterior areas, descriptive outcomes of all parameters (age, facial bone thickness, bony defect, NPC, angulations) were obtained (Table 1).

Facial Bone Thickness
There was a positive correlation between the location of fenestration and facial bone thickness at both the coronal and middle part of the ridge. It implies that thicker facial bone thickness had a more apically positioned fenestration. On the other hand, negative correlation was found between the distance from the deepest point of facial concavity (Point C) to the apex of tooth; CEJ–crest = the distance from CEJ to crest of ridge; NPC–crest = the distance from nasopalatine canal to crest of ridge; SD = standard deviation.

Sexes
The participants were 12 women and 9 men. The mean values of facial bone thickness at 3 mm for women and men were 0.91 ± 0.64 mm and 1.09 ± 0.70 mm,
respectively; the mean values of facial bone thickness at 5 mm for women and men were 0.51 ± 0.60 mm and 0.71 ± 0.61 mm, respectively. For angulation, the mean values of Angle T for women and men were 106.0 ± 9.27 degrees and 102.62 ± 9.74 degrees; the mean values of Angle D for women and men were 21.57 ± 10.12 degrees and 22.15 ± 10.16 degrees. In t test analysis, a significantly larger Angle T was measured in women but no significant difference for Angle D and facial bone thickness at both 3 mm and 5 mm.

Concavity
As for the concavity at the facial side of the ridge, the mean distance from the alveolar crest to the deepest point was 11.29 mm, and the mean value of the distance from the deepest point of facial concavity to the apex of the tooth was 2.79 mm. In statistical analysis, positive correlation was noted between the depth of the deepest point and the distance from the deepest point of facial concavity to the apex of the tooth. No intergroup significant difference was found in the Pearson correlation (Table 3) when evaluating the relationship between the location of concavity (deepest point of facial concavity to the apex of the tooth > 10 mm or ≤ 10 mm) and tooth site.

Bony Defect (Dehiscence, Fenestration) and NPC
The incidence in different tooth types with the mean values was shown in narrative analysis. In this study, fenestration (28 out of 66 teeth) most likely existed at the facial bone in canine areas, and dehiscence (16 out of 38 teeth) also appeared mostly in canines; the mean values of the size were 4.67 and 3.72 mm for fenestration and dehiscence, respectively.

According to the narrative analysis, the mean value of distance from NPC to the alveolar crest was 6.93 mm. Apart from that, only one patient got dehiscence, fenestration, and NPC in central incisors with bilateral existence of NPC.

Angulation
In regression correlations, there were negative correlations between facial bone thickness at 5 mm, Angle T, and Angle D. Intergroup significant difference could be observed between larger Angle D and tooth sites by one-way ANOVA, especially in canine areas (Table 4). On the other hand, there was a significant intergroup difference with the condition of smaller Angle T in canines (Table 5).

DISCUSSION
Obviously, there were several biologic considerations around the implant that should be followed during implant placement to achieve better esthetic outcomes. As to the facial side of the ridge, the thickness of the bone should be at least 2 mm to prevent mucosal recession in long-term follow-up. In one clinical study with more than 3,000 implants, facial bone thickness after osteotomies was 1.7 ± 1.13 mm during implant surgery; this might decrease the amount of bone loss, and in some cases, even bone gain was noted. The results from the present study showed that mean values of facial bone thickness at 3 and 5 mm from CEJ were less than 1 mm (0.59 to 0.98 mm). This is in agreement with several previous studies. In other words, the residual bone thickness at the facial aspect, even under minimal invasive procedures (flapless, atraumatic

Table 3
<table>
<thead>
<tr>
<th>Tooth No.</th>
<th>Distance from deepest point of facial concavity to apex of tooth</th>
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<tbody>
<tr>
<td></td>
<td>≤ 10 mm</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
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<tr>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>39</td>
</tr>
</tbody>
</table>

Pearson chi² (5) = 8.8011, Pr = 0.117.
Fisher’s exact = 0.144.
FDI tooth-numbering system.
N = numbers of teeth.

Table 4
<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3,139.04</td>
<td>5</td>
<td>627.81</td>
<td>7.45</td>
<td>0</td>
</tr>
<tr>
<td>Within groups</td>
<td>10,116.19</td>
<td>120</td>
<td>84.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13,255.22</td>
<td>125</td>
<td>106.04</td>
<td></td>
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</table>

| Tooth No. |  |  |  |  |  |  |
|-----------|---|---|---|---|---|
| 7         | 4.16 | | | | |
| 6         | 11.06*, + | 6.90 | | |
| 9         | 0.02 | -4.14 | -11.04*, + | | |
| 10        | 5.49 | 1.32 | -5.57 | 5.47 | |
| 11        | 13.02*, + | 8.86* | 1.97 | 13.01*, + | 7.54 |

*Statistically significant at P < .05.
+Statistically significant at P < .01.
FDI tooth-numbering system.
tooth extraction), might not be adequate for immediate implant placement. Hence, the need for a more palatal position of the implant with angulation adjustment is critical in preoperative CBCT assessment.

Data from the present study concurred with previous studies that facial bone thickness increased from the central incisor to the canine at 3 mm from CEJ; however, this was not the same when it came to the middle part of the facial bone thickness (5 mm from CEJ); to be more specific, the thinnest facial bone thickness was found in the lateral incisor area. Interestingly, the canine had relatively thinner facial bone thickness at 5 mm compared with the coronal part of the ridge. The incidence of facial bone thickness < 1 mm in canine areas was varied at different distances from CEJ but high in the present study. Several studies that included premolars actually found that the facial bone thickness at first premolars was the thinnest in the maxillary anterior region, especially the middle part of the ridge. The difference between previous studies and the present study was that the present study did not include the premolars. As a result, when looking at canine areas, the middle part of the ridge should be focused on more than the coronal part due to a thinner facial bone thickness. This finding suggests that when planning the immediate implant without flap elevation in canine areas, CBCT is often needed to recognize the need to perform bone regeneration or place the implant slightly toward palatal. Still, this study examined the correlation between facial bone thickness and all parameters. First of all, there was a positive relationship between facial bone thickness and the position of fenestration; that is, thicker facial bone thickness (both 3 and 5 mm from CEJ) would result in a more apically positioned fenestration. In addition, the mean value of the distance from the fenestration to the ridge crest was 4.27 mm, which implied that the existence of fenestration might be confronted during implant placement, particularly with the standard length of implant and flapless approach.

Furthermore, there was a negative relationship between facial bone thickness and the distance from the deepest point of facial concavity to the apex of the tooth, which indicated that thinner facial bone thickness would go with more apically positioned facial concavity. Unlike fenestration, facial concavity was located more apically to the apex, which implies that the concavity of the ridge was not a strong risk factor for an immediate implant. Most importantly, middle facial bone thickness correlated with Angle D in negative correlation. That is to say, the results suggest that a larger Angle D could be one of the potential risk factors for an immediate implant without flap elevation because of the difficulties in operation and existence of thin facial bone thickness. In other words, preoperative CBCT can be necessary at this point, and surgical guide fabrication can also diminish the risk of implant axis deviation. In summary, facial bone thickness determines the risk and difficulty in immediate implant placement, and other parameters, including fenestration and Angle D, might also contribute to the complexity of this situation.

Also, the results from the present study illustrated that canines might be more vulnerable for fenestration when compared with central and lateral incisors. This is in agreement with studies that showed higher incidence of fenestration in canines and first premolars and less in the central incisors. Similarly, the data from the present study also indicated that canine areas had the highest dehiscence percentage, which is in accordance with a previous publication, because of the larger distance from CEJ to the bone crest in canine areas. The aforementioned findings are further supported by the CBCT data that indicate negative correlation between Angle T and Angle D. This means the canine area has a larger Angle D but smaller Angle T, which might attribute to higher risk of having fenestration and dehiscence than other tooth sites.

![Table 5](image)
One of the main limitations of this study is the accuracy of CBCT in detecting dehiscence and fenestration. CBCT has been shown to have relatively lower positive predictive values, especially in thin bone.\textsuperscript{11,12,13} If the defects are larger than 2.2 mm, the accuracy of CBCT improves.\textsuperscript{12} Although CBCT has been regarded as a standard tool nowadays to detect three-dimensional images, some of the CBCT inherited problems are inevitable. Therefore, the results extracted from the present study should be interpreted with caution. Other limitations of this study include limited sample size and lack of actual clinical documentation to support current findings. Hence, there is a need for a clinical study with a large sample size to verify the current results.

Immediate implant surgery without flap elevation is one of the most appealing treatment options in esthetic priority areas; however, it also creates many challenges ahead due to existing soft and hard tissue structures. With preoperative CBCT evaluation, clinicians now will be able to better select cases to avoid potential facial bone dehiscence and fenestration.

CONCLUSIONS

Within the limitations of this study, the following conclusions could be drawn. When immediate implant surgery is performed without flap elevation in the maxillary anterior areas, clinicians should carefully assess CBCT, especially angulation of the tooth and alveolar ridge. Fenestration and a larger Angle D were associated with thinner facial bone thickness; dehiscence was related to a lower bone level in lateral incisors. The tooth sites did have an impact on the prevalence of bony defects, and canine areas surprisingly had the largest deviation of facial bone thickness among the six maxillary anterior teeth. Therefore, prior to immediate implant surgery without flap elevation, anatomical structures, angulation of the tooth, and alveolar ridge all need to be assessed either with CBCT or other advanced imaging tools.

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