Evaluation of Alveolar Bone Dimensions and Root Positioning of Anterior Teeth in the Maxilla

Buccal bone walls present significant resorption after tooth extraction, possibly related to the smaller bone thickness, length, and the sagittal position of the root, as well as the bone morphology. The goal of the present study was to measure the thickness of the cortical bone of the vestibular and palatal walls in the anterior maxilla by means of CBCT images. Measurements were taken from CBCT scans of 300 maxillary anterior teeth from 50 patients (25 women, 25 men) aged 18 to 30 years. The parameters evaluated included the thickness of the buccal and palatal cortical bone in the cervical, apical, and middle thirds of the root, as well as six specific angular measurements from each tooth. The lateral incisors showed a significant difference in thickness between each of the buccal and palatal thirds, and measurements were also significantly smaller than the central and canine incisors. Bone anatomy is tooth- and location-specific, and thus the sagittal root position within the alveolus influences the regional bone morphology and may explain the gingival zenith position in the anterior maxilla. These specific buccal and palatal anatomic parameters should be carefully taken into consideration for surgical planning and intervention in the esthetic area.

Historically, it has been postulated that gingival anatomy is dictated by the underlying bone anatomy and that there are associations between tissue form and function; thus, the fundamental concept of periodontal biotype in contemporary clinical periodontics was established by assessing the periodontal anatomy and its intimate relation with tooth dimensions and bony architecture. The recognition of positive associations between gingival thickness, keratinized tissue, and bone morphotype may be helpful for successful dental treatment and has become a fundamental diagnostic and prognostic factor in periodontal, restorative, orthodontic, and implant therapies due to its potential influence on hard and soft tissue anatomy and behavior after periodontal and implant therapies.4

Despite the fact that buccal and palatal bone dimensions appear to be directly related to the root anatomy of the teeth (such as their diameter, length, and inclination), limited attention has been given to the influence of tooth position in the alveolar process at the apicocoronal and buccolingual directions and in relation to labial plate thickness.

In order to facilitate the accurate diagnosis and treatment choice after exodontia, CBCT scanning has been recommended.

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Given the need to study bone dimensions and the related dental root positioning and bone anatomy in anterior maxillary teeth, the goal of the present study was to evaluate, via CBCT, the dental root positioning in the anterior maxilla in relation to the underlying buccal and palatal bone anatomy.

Materials and Methods

Participant Enrollment

This cross-sectional study was conducted in accordance with the guidelines of the World Medical Association Declaration of Helsinki (version VI, 2002) after approval of the study design and consent by the Ethics Committee of the Faculty of Medical Sciences and Health of Juiz de Fora (Juiz de Fora, Minas Gerais, Brazil; CAAE no: 48225315.2.0000.5103). The study sample included systemically healthy patients aged between 18 and 30 years, without distinction between race and socioeconomic level, with clinically healthy anterior superior teeth (canine to canine) present. These patients also demonstrated the absence of (1) any inflammatory processes, (2) angular alveolar bone loss, (3) horizontal alveolar bone loss > 2 mm, and (4) history of periodontal, surgical, restorative, and endodontic treatments (Fig 1). Patients were excluded from the study if they: (1) were undergoing treatment with medicines that influence periodontal soft tissue (phenytoin, cyclosporine, and nifedipine); (2) were pregnant; (3) had a current smoking habit; and/or (4) had untreated metabolic disorders.

Cone Beam Computed Tomography

CBCT scans were acquired with the same scanning device (i-Cat, Imaging Sciences International) with the patient at the maximum usual intercuspatation and positioned according to the luminous indications of the tomograph, taken according to the following acquisition protocol: 37.07 mAs, 120 kVp, field of view variable according to the purpose of the examination, 0.25-mm voxel, and a 26-second scanning time with 360-degree rotation. The evaluation was performed quantitatively on parasagittal cuts of the most central region of each of the teeth of interest. Before measurements were taken, all scans were aligned with a standardized protocol with three-dimensional guidelines. The sagittal plane was placed in the middle of the selected tooth along the buccolingual axis; the frontal plane was placed in the center of the selected tooth, along the mesiodistal axis; and the axial plane was placed perpendicular to the long axis of the selected tooth at the cementoenamel junction (CEJ) level along the apico-coronal axis. These cuts were selected and archived, and all analyses of each element were made by a single examiner (I.C.C.F.) and repeated in duplicate to determine the Pearson correlation coefficient among initial and repeated measurements as well as percentage of absolute differences in the same cut.

Tomographic Anatomic Landmarks

The landmarks employed for linear and angular measurements are
depicted in Fig 2. The long axis (LA) of the tooth was determined as the line connecting the root apex (a) to the incisal edge (b). Then, a line (GH) tangential to point (a) and perpendicular to LA was drawn at the root apex, connecting the palatal (g) and the facial (h) bones. Another line (G2H2) parallel to GH was drawn 2 mm coronally to GH, determining the facial (h2) and palatal (g2) bones once again. Additional points were determined at the facial bone crest (c) and the palatal bone crest (f) and at the CEJ at the facial (d) and palatal (e) aspects. Then, an additional line (D2E2) parallel to GH was drawn 2 mm apical to the CEJ; this line intersects the facial bone facially (d2) and at the facial periodontal ligament (PL) space (c2) as well as the palatal bone palatally (e2) and at the palatal PL (f2). Finally, a line (JI) parallel to GH was drawn, bisecting the facial plate between (h2) and (d2) and the palatal plate between (e2) and (g2), intersecting the facial bone facially (j) or at the facial PL (cj). Similar points were established at the palatal (i) and PL (fi) aspects of the palatal bone. The thickness of the facial and palatal bone plates were measured perpendicularly to LA at three levels (corresponding to lines G2H2, D2E2, and JI) from the inner aspect of the bone plate, facing the PL, to the external surface of the bone plate at points on the buccal (h2-ch2, d2-c2, and j-cj) and palatal (g2-fg2, e2-f2 and i-fi) plates.

Linear Measurements

The thickness of the facial and palatal bone plates were measured perpendicularly to LA at three levels (corresponding to lines G2H2, D2E2, and JI) from the inner aspect of the bone plate, facing the PL, to the external surface of the bone plate at points on the buccal (h2-ch2, d2-c2, and j-cj) and palatal (g2-fg2, e2-f2, and i-fi) plates (Fig 2). Moreover, measurements of the palatal bone thickness were obtained from the angular measurement of the internal and external aspects of the palatal bone (A6), described below in Angular Measurements, at the root apex (A6.1 = g to h), CEJ (A6.3 = d to e), and at the midpoint between them (A6.2).

Angular Measurements

In order to gain further insight at the anatomical relationships between root and bone, six angular measurements were performed (Fig 3), including: (A1) buccal bone crest and LA; (A2) buccal bone crest and the buccal root surface; (A3) buccal bone crest and the palatal root surface; (A4) internal aspect of the palatal alveolar bone and LA; (A5) external aspect of the palatal alveolar bone and the tooth axis; and (A6) the external and internal aspects of the palatal alveolar bone.
Statistical Analysis

Summary statistics (mean, SD, median, minimum, and maximum values) were calculated for all endpoints in each experimental group. For the secondary analysis, one-way analysis of variance was used to detect group differences. Post hoc multiple comparisons were made using the Holm-Bonferroni method. Statistical significance was set at the 95% probability level (P < .05).

Results

Measurements of CBCT images from 300 maxillary teeth comprising 100 canines (C), 100 lateral incisors (LI), and 100 central incisors (CI) were performed in 50 patients (25 women, 25 men).

Horizontal Buccal Linear Measurements

Results from the horizontal buccal linear measurements (Table 1) showed that buccal bone thickness at the middle and apical thirds of LI were significantly different than those at C. Measurements from C showed significantly increased thickness at middle and apical thirds in comparison with the cervical third. However, on LI, the middle measurements were smaller than both the cervical and apical measurements. No significant differences were found for other measurements.

Horizontal Palatal Linear Measurements

Results from the horizontal palatal linear measurements (Table 2) showed that palatal bone thickness at the middle and apical thirds of LI, CI, and C were significantly different than those at the cervical region. Palatal bone thickness at the apical thirds of LI, CI, and C were significantly different than those at the middle region. Measurements from C and CI showed significantly increased thickness at cervical, middle, and apical thirds compared to LI. No significant differences were found for the other measurements. Measurements of the palatal bone thickness (A6.1, A6.2, and A6.3) obtained from the angular measurement of the internal and external aspects of the palatal alveolar bone (A6) showed that palatal bone at IC and C is significantly thicker than at LI (Table 3).

Angular Measurements

Angular evaluations showed that measurements for A4, A5, and A6 were significantly bigger at CI and C than at LI (Table 4). Moreover, A1 and A2 measurements from LI were significantly bigger than those at CI and C. No significant differences were found for the other measurements.
Surgical and esthetic treatments in the anterior maxilla are a significant clinical challenge due to important anatomical limitations, such as buccal and palatal bone dimensions and root anatomy, diameter, length, and/or inclination.\(^5,6\) Sagittal root position within the alveolus and regional bone morphology should be evaluated, particularly if exodontia and/or implant placement are contemplated.\(^11,13\)

In the present study, measurements were performed at selective levels from the CEJ to the root apex in order to gain better knowledge of the entire extent of the buccal and palatal bone. Data showed that buccal bone thickness at the middle and the apical thirds of LI were significantly different than those at C, while the buccal bone thickness in C were significantly increased at the middle and apical thirds compared to the cervical third. On LI, the

### Table 1  Buccal Bone Thickness

<table>
<thead>
<tr>
<th></th>
<th>Central incisors</th>
<th>Lateral incisors</th>
<th>Canines</th>
<th>All teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>0.78 ± 0.50</td>
<td>0.93 ± 0.50</td>
<td>0.78 ± 0.50</td>
<td>0.86 ± 0.56</td>
</tr>
<tr>
<td>Medium</td>
<td>0.81 ± 0.54</td>
<td>0.83 ± 0.58(^a)</td>
<td>0.79 ± 0.30(^a)</td>
<td>0.81 ± 0.55</td>
</tr>
<tr>
<td>Apical</td>
<td>0.93 ± 0.50</td>
<td>1.18 ± 0.74(^a)</td>
<td>1.11 ± 0.70(^a)</td>
<td>1.15 ± 0.70</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>0.87 ± 0.32</td>
<td>0.98 ± 0.63</td>
<td>0.90 ± 0.61</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented in millimeters as mean ± SD. \(^{a}P < .05\) vs the cervical third.

### Table 2  Palatal Bone Thickness

<table>
<thead>
<tr>
<th></th>
<th>Central incisors</th>
<th>Lateral incisors</th>
<th>Canines</th>
<th>All teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>1.66 ± 0.68(^c)</td>
<td>1.29 ± 0.59</td>
<td>1.68 ± 0.50(^c)</td>
<td>1.54 ± 1.03</td>
</tr>
<tr>
<td>Middle</td>
<td>3.58 ± 1.37(^a,c)</td>
<td>2.64 ± 1.15(^a)</td>
<td>3.50 ± 1.24(^a,c)</td>
<td>3.23 ± 1.32</td>
</tr>
<tr>
<td>Apical</td>
<td>6.70 ± 2.60(^a,b,c)</td>
<td>4.22 ± 1.78(^a,b)</td>
<td>6.55 ± 2.33(^a,b,c)</td>
<td>5.82 ± 2.53</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>3.98 ± 2.71</td>
<td>2.71 ± 1.74</td>
<td>3.90 ± 2.67</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented in millimeters as mean ± SD. \(^{a}P < .05\) vs the cervical third. \(^{b}P < .05\) vs the middle third. \(^{c}P < .05\) vs lateral incisors.

### Table 3  Palatal Bone Thickness Derived from Angular Measurement A6

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Central incisors</th>
<th>Lateral incisors</th>
<th>Canines</th>
<th>All teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>A6.1</td>
<td>9.24 ± 2.35(^a)</td>
<td>6.55 ± 1.92</td>
<td>9.22 ± 2.62(^a)</td>
<td>8.33 ± 2.63</td>
</tr>
<tr>
<td>A6.2</td>
<td>5.94 ± 1.48(^a)</td>
<td>4.30 ± 1.21</td>
<td>5.94 ± 1.72(^a)</td>
<td>5.39 ± 1.67</td>
</tr>
<tr>
<td>A6.3</td>
<td>2.81 ± 1.04(^a)</td>
<td>2.06 ± 0.76</td>
<td>2.72 ± 0.88(^a)</td>
<td>2.52 ± 0.96</td>
</tr>
</tbody>
</table>

A6 = the external and internal aspects of the palatal alveolar bone; A6.1 = A6 measured at the root apex (from points g to h); A6.2 = the midpoint between A6.1 and A6.3; A6.3 = A6 measured at the CEJ (from points d to e). Data are presented in millimeters as mean ± SD. \(^{a}P < .05\) vs lateral incisors.
middle measurements were smaller than both the cervical and apical measurements, thus the LI thickness formed a “C” shape that should be carefully evaluated in order to minimize the risk of dehiscence and fenestration bone defects in the area. These results are similar to previously reported data⁶,⁹,¹⁴,¹⁸,¹⁹ that also showed that buccal bone thickness did not vary significantly apicocoronally,⁹ was not influenced by participant age,⁹ and may indeed be influenced by gingival thickness or vice-versa.⁷,²⁰ Unfortunately, none of the previous literature has aimed to evaluate the buccal bone thickness in the context of sagittal root inclination, as done in the present study.

Interestingly, buccal bone thickness and periodontal biotypes appeared to be correlated,²⁰ with a positive associative trend between thin soft tissues and a thinner buccal plate.⁹,¹⁸ The present study also documented that on the palatal aspect, bone thickness significantly increased apically and is significantly thinner in LI than in both CI and C, providing quantitative data for the bone anatomy of the palatal region of maxillary anterior teeth, which may be of great relevance for the stabilization of implants placed immediately after tooth extraction.²¹

Dental angulation in relation to alveolar bone walls is another important consideration in determining a tissue biotype and in immediate implant placement in the anterior maxilla.³⁻⁷,⁹ The methodology employed in the present study may be particularly useful for evaluating root positioning in relation to anatomic landmarks more commonly employed for periodontal diagnosis and dental implant placement. CBCT images make these landmarks readily available for evaluation, and therefore may provide a more user-friendly approach than other historically used methods for the evaluation of sagittal root positioning, particularly in orthodontics.²⁰,²²,²³

In the present study, angles A1 and A2 were significantly increased in LI, while angles A4, A5, and A6 were significantly decreased in LI, showing that the LA of LI are more inclined toward the palatal aspect. This also clearly documents that the sagittal root position within the alveolus influenced the regional bone morphology in the anterior maxilla. An increased A1 angle indicates buccal inclination of the tooth’s LA, while an increased A2 indicates buccal inclination of the root in relation to the bone crest in CI and C. Greater buccal prominences of tooth surfaces may result in apically positioned gingival margins,¹⁰ and this data may explain why the gingival margins of CI and C are located more apically than in LI.²⁴ In addition, the combined effects of reduced A4, A5, and A6 angles in LI indicate a more limited area for correct implant position and adequate stabilization. It also demonstrates that correct implant axial inclination may be more challenging, which may result in an additional need for tissue grafting.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Central incisors</th>
<th>Lateral incisors</th>
<th>Canines</th>
<th>All teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>13.35 ± 2.38</td>
<td>15.15 ± 3.02b,c</td>
<td>13.14 ± 2.71</td>
<td>13.88 ± 2.86</td>
</tr>
<tr>
<td>A2</td>
<td>3.92 ± 1.64</td>
<td>5.09 ± 1.87b,c</td>
<td>4.04 ± 1.63</td>
<td>4.35 ± 1.79</td>
</tr>
<tr>
<td>A3</td>
<td>29.48 ± 5.90</td>
<td>30.00 ± 6.51</td>
<td>29.67 ± 6.48</td>
<td>29.71 ± 6.29</td>
</tr>
<tr>
<td>A4</td>
<td>16.25 ± 2.42a</td>
<td>14.22 ± 3.20</td>
<td>16.50 ± 2.96a</td>
<td>15.66 ± 3.05</td>
</tr>
<tr>
<td>A5</td>
<td>20.47 ± 3.65a</td>
<td>16.30 ± 2.65</td>
<td>20.50 ± 3.64a</td>
<td>19.09 ± 3.88</td>
</tr>
<tr>
<td>A6</td>
<td>39.42 ± 9.53a</td>
<td>33.39 ± 8.46</td>
<td>39.47 ± 8.64a</td>
<td>37.43 ± 9.31</td>
</tr>
</tbody>
</table>

A1 = buccal bone crest and LA; A2 = buccal bone crest and the buccal root surface; A3 = buccal bone crest and the palatal root surface; A4 = internal aspect of the palatal alveolar bone and LA; A5 = external aspect of the palatal alveolar bone and the tooth axis; A6 = the external and internal aspects of the palatal alveolar bone (see Fig 3 for angle midpoints).

Data are presented in degrees (graus) as mean ± SD.

*P < .05 vs lateral incisors.

**P < .05 vs central incisors.

***P < .05 vs canines.
and/or customized restorative approaches.

Conclusions

Bone anatomy is specific to the tooth and location, and thus the sagittal root position within the alveolus influences the regional bone morphology and may explain the gingival zenith position in the anterior maxilla. Buccal bone anatomy in the anterior maxilla may increase the risk for dehiscence and fenestration bone defects, particularly in lateral incisors. Therefore, specific buccal and palatal anatomic parameters should be carefully taken into consideration for interventions in the esthetic area.

Acknowledgments

The authors declare no conflicts of interest.

References