Introduction

Bimaxillary protrusion (BP) is a facial trait characterized by underlying skeletal prognathism, protrusive teeth and lips, and a decreased interincisal angle. These skeletal and dental traits often result in mentalis strain, lip incompetence, increased gingival display, and facial convexity. While BP can be seen in individuals of any race, it is more common in the African American (AA) population. These facial and dental characteristics are often deemed esthetically unacceptable by patients, prompting them to seek treatment from orthodontists and oral surgeons.1-3

The orthodontic treatment goals for BP are decreasing lip protrusion, facial convexity, retraction, and uprighting. These goals can be accomplished by premolar extraction with orthodontics or by a combined orthodontic-surgical approach. When considering premolar extraction, first premolars are often extracted to increase the retraction of anterior teeth utilizing maximum anchorage in the posterior area.3 The maximum anchorage can be accomplished with skeletal anchorage devices, such as mini-implants and miniplates, or intraoral appliances such as Nance appliances.4 Previous studies have found that the extraction of four bicuspids resulted in improved dental characteristics associated with BP. Additionally, a study observed an improvement in lip protrusion following extraction with maximum anchorage space closure.5

When closing a large extraction space, the amount of re-
traction is limited by the thickness of the cortical and cancellous bone surrounding the tooth. Tooth movement occurs by widening the periodontal ligament with resorption of bone on the pressure side and apposition on the tension side. Thus, if tooth movement exceeds the biological limit of the surrounding alveolar bone, specific adverse effects such as root resorption, alveolar bone loss, gingival recession, root dehiscence, and fenestration can occur.

When considering incisor retraction in cases of maximum anchorage extraction, the biological limit is the alveolar bone surrounding the apical one-third of the incisors. Thus, 3-dimensional imaging is essential to fully visualize the available bone to determine the amount of tooth movement possible. A previous study conducted by Lee et al. investigated the alveolar bone of lower incisors skeletal class III adults of different vertical patterns using cone-beam computed tomography (CBCT) images. They found that skeletal class III subjects with high mandibular plane angles showed thinner mandibular alveolar bone than low-angle patients.

Most previous studies utilized CBCT and focused on the thickness of the facial bone wall surrounding the anterior dentition of the maxilla to place immediate implants. Such studies have concluded that most tooth sites in the anterior maxilla have a thin facial bone wall, averaging less than 1 mm. This study used a similar method and techniques, but focused on both the buccal and lingual aspects of the alveolus in order to obtain a more comprehensive view of housing size for tooth retraction.

A recent study from Goshtasbi et al. discovered that the heritability of alveolar bone thickness ranged from 50.3% to 58.0%. That study suggested that genetic factors play a significant role in alveolar thickness, with a moderate to high effect. If genetic predispositions are relevant for alveolar thickness, then race and ethnicity could perhaps be a determining factor for alveolar width and height.

The primary objective of this study was to quantitatively analyze the thickness and height of alveolar bone around the maxillary and mandibular incisors. Additionally, this study aimed to compare and contrast bone parameters (bone thickness and bone height) in Caucasian (CC) and AA female patients. The null hypothesis was that the bone parameters (bone thickness and bone height) of the maxillary and mandibular incisor locations would not be different between these racial groups.

**Materials and Methods**

An institutional review board exemption was obtained for evaluating CBCT volumes, acquired from the database of Georgia School of Orthodontics, Atlanta. Following the screening of 161 CBCT scans, this retrospective study reviewed 50 CBCT scans of female patients who were referred to the Division of Orthodontics for treatment. All CBCT scanned images were de-identified for protected health information by authorized personnel before using them as a part of the study. CBCT scans were acquired using an i-CAT CBCT unit (Imaging Sciences International, Hatfield, PA, USA), with the standard protocol of the i-CAT for an extended field of view (FOV), ranging from 21 × 13 inches to 30 × 22 inches, with 0.3-mm voxel size and 17.5-s acquisition time.

Subjects were selected based on the following inclusion criteria: female; AA or CC; between the ages of 18 and 50 at the time of the CBCT; normo-divergent; and Angle’s class I, end-on class II, or mild class III malocclusion. The exclusion criteria were anterior open bite; anterior crossbite; congenitally missing, extracted, malformed, or impacted anterior teeth; generalized root resorption; periapical pathology; the presence of cleft lip or palate; history of past orthodontic treatment; periodontal disease or evidence of anterior bone loss; syndromic patients; history of skeletal or bone disorders; or poor CBCT quality. For each subject, the name, date of birth, date of CBCT, sex, race, CBCT FOV, voxel size, dental malocclusion (class I, II, or III), vertical skeletal relationship (hypo-, hyper-, or normo-divergent), and approximate dental crowding or spacing were recorded. Patients’ vertical relationships were assessed qualitatively by referencing Bjork’s 7 structural signs for growth rotation.

All CBCT scans were evaluated using a third-party CBCT reconstruction software (Dolphin Imaging version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, CA, USA).

The alveolar bone surrounding the maxillary and mandibular incisors was evaluated. The measurement protocol was similar to that described by Garlock et al. For each incisor examined, the volume was oriented in all 3 planes of space (sagittal, coronal, axial), as shown in Figure 1. Orientation was accomplished in order to generate a CBCT slice through the middle of the pulp canal, along the long axis of the tooth. The sagittal section was then used to generate measurements relevant to the study. Prior to measuring bone thickness, a plan was drawn at the cementoenamel junction (CEJ). Each root was measured from the apex to the CEJ and halved to determine the mid-root point. The rater then reviewed the images on a laptop screen (MacBook Air, Apple Computers Inc., Cupertino, CA, USA) under standardized conditions of ambient light and sound. The investigator had the full capability to evaluate the volumes in all.
3 orthogonal planes and manipulate contrast and histograms. To test the intra-examiner reliability, the same person measured bone parameters on 5 randomly selected scans two weeks later.

The following measurements were recorded: 1) from the CEJ to the lingual/palatal alveolar crest; 2) from the CEJ to the buccal alveolar crest; 3) the alveolar ridge thickness at the mid-root level; 4) alveolar ridge thickness at the apex; 5) the buccal bone thickness at 3, 6, and 9 mm from the CEJ plane; 6) the lingual/palatal bone thickness at 3, 6, and 9 mm from the CEJ plane (Fig. 2). The bone thickness refers to the distance between the root surface to the outer surface of the cortical bone at a specific vertical location. The alveolar ridge thickness refers to the horizontal distance between the buccal and lingual surfaces at a specific vertical location (Fig. 2). Overall, 10 measurements were made for each incisor (80 measurements [40 maxillary and 40 mandibular] per patient), leading to a total of 4,000 measurements.

Simple descriptive statistics were used to summarize the data. Mean, standard deviation, standard error of the mean, maximum, minimum, range, and 95% confidence intervals were computed for the bone parameters of the maxillary and mandibular incisors (alveolar height: labial and lingual, alveolar thickness: mid-root and apex, and bone thickness: labial and lingual at 3 different vertical locations - 3 mm, 6 mm and 9 mm from the alveolar crest). For all outcomes, intra-examiner reliability was computed by Cronbach alpha values (intra-class correlation coefficients). The 1-sample Kolmogorov-Smirnov test was used to examine the normality of distribution for bone measurements at different locations. All the measurements were normally distributed. For the variability of the bone parameters for each incisor, between 2 racial groups (CC and AA), between the maxilla and mandible, and between labial and lingual, the independent-sample t-test was performed. All statistical tests were 2-sided, and to minimize the probability of type I errors, a P-value of <0.05 was deemed to indicate statistical significance. Statistical analyses were conducted using Graph Pad.
Comparison of anterior maxillary and mandibular alveolar parameters in African American and Caucasian women: A retrospective pilot...

**Fig. 2.** Bone measurements used in the study. Alveolar height: (A) labial, (B) lingual/palatal; bone thickness at 3 mm (C and D), 6 mm (E and F), and 9 mm (G and H) from the alveolar crest; alveolar thickness: (J) mid-root, and (I) apex.

**Table 1.** Descriptive statistics and comparison of bone measurements of the maxillary central incisors between Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category                        | Race  | Mean ± SD  | 95% CI     |
|-------------------------|--------------------------------|-------|------------|------------|
| Buccal                  | Bone thickness                 | CC    | 0.80 ± 0.44 | 0.68-0.93  |
|                         |                                | AA    | 0.82 ± 0.35 | 0.70-0.93  |
|                         | Bone thickness                 | CC    | 0.71 ± 0.35 | 0.61-0.81  |
|                         |                                | AA    | 0.60 ± 0.33 | 0.49-0.70  |
|                         | Bone thickness                 | CC    | 0.71 ± 0.44 | 0.59-0.84  |
|                         |                                | AA    | 0.59 ± 0.81 | 0.33-0.85  |
|                         | Bone thickness                 | CC    | 1.50 ± 0.59 | 1.30-1.60  |
|                         |                                | AA    | 1.40 ± 0.60 | 1.20-1.60  |
|                         | Bone thickness                 | CC    | 2.50 ± 1.00 | 2.20-2.80  |
|                         |                                | AA    | 2.10 ± 0.95 | 1.70-2.40  |
|                         | Bone thickness                 | CC    | 3.80 ± 1.50 | 3.40-4.20  |
|                         |                                | AA    | 2.90 ± 1.10*| 2.60-3.30  |
| Lingual                 | Bone thickness                 | CC    | 1.50 ± 0.59 | 1.30-1.60  |
|                         |                                | AA    | 1.40 ± 0.60 | 1.20-1.60  |
|                         | Bone thickness                 | CC    | 2.50 ± 1.00 | 2.20-2.80  |
|                         |                                | AA    | 2.10 ± 0.95 | 1.70-2.40  |
|                         | Bone thickness                 | CC    | 3.80 ± 1.50 | 3.40-4.20  |
|                         |                                | AA    | 2.90 ± 1.10*| 2.60-3.30  |
| Mid-root                | Alveolar ridge thickness       | CC    | 8.30 ± 1.60 | 7.80-8.70  |
|                         |                                | AA    | 7.90 ± 1.20 | 7.50-8.20  |
| Apex                    | Alveolar ridge thickness       | CC    | 9.40 ± 1.80 | 8.80-9.90  |
|                         |                                | AA    | 8.40 ± 1.70*| 7.80-8.90  |
| Labial height           | Bone height                    | CC    | 1.70 ± 0.65 | 1.50-1.90  |
|                         |                                | AA    | 1.70 ± 0.71 | 1.50-1.90  |
| Lingual height          | Bone height                    | CC    | 1.50 ± 0.89 | 1.20-1.70  |
|                         |                                | AA    | 1.30 ± 1.10 | 0.97-1.70  |

SD: standard deviation, CI: confidence interval, \(*: P < 0.05\) compared with CC
Results

In this study, 161 CBCT scans were screened and after applying the selection criteria, a review of 50 CBCT scans of patients (25 CC and 25 AA) with a mean age of 32.5 years was conducted. The maxillary arch measurements of 6 patients were excluded from the statistical analysis due to the presence of cysts, an impacted canine, or the periodontal condition in those maxillary arches. The average intra-rater reliability was determined to be 0.84. The reliability was highest ($\geq 0.96$) for lingual bone measurements at 6 and 9 mm from the CEJ and the alveolar width at the mid-root and apex levels. The reliability was lowest for labial thickness at 6 mm and for the labial bone height.

Maxillary incisors

Bone thickness: No significant differences ($P>0.05$) in cortical bone thickness at 3 mm, 6 mm, or 9 mm from the alveolar crest were found between the CC and AA populations for most of the measurements (Tables 1 and 2). Significant differences were observed for the bone thickness at 9 mm on the lingual surface for maxillary central incisors (CC: 3.8 ± 1.6 mm, AA: 2.9 ± 1.1 mm, $P<0.05$), and at 6 mm on the buccal surface for maxillary lateral incisors (CC: 0.62 ± 0.59 mm, AA: 0.33 ± 0.32 mm, $P<0.05$).

Alveolar ridge thickness: A significant difference in alveolar ridge thickness was found between the CC and AA population at the apex for both the central (CC: 9.4 ± 1.8 mm, AA: 8.4 ± 1.7 mm, $P<0.05$) and lateral incisors (CC: 8.2 ± 1.6 mm, AA: 7.0 ± 1.4 mm, $P<0.05$) (Tables 1 and 2). No significant difference in alveolar ridge thickness was found at the mid-root level ($P>0.05$) (Tables 1 and 2).

Alveolar height: Except for the labial bone height of lateral incisors (CC: 2.0 ± 1.1 mm, AA: 1.4 ± 0.88 mm, $P<0.05$), all the measurements showed non-significant findings for the labial or lingual alveolar height when the 2 racial groups were compared (Tables 1 and 2).

Mandibular incisors

Bone thickness: Except at 3 mm (CC: 0.9 ± 0.63 mm, AA: 0.8 ± 0.46 mm, $P<0.05$) and 6 mm (CC: 0.62 ± 0.59 mm, AA: 0.33 ± 0.32 mm, $P<0.05$), all the measurements showed non-significant findings for the labial bone thickness at 9 mm on the lingual surface for maxillary central incisors (CC: 3.8 ± 1.6 mm, AA: 2.9 ± 1.1 mm, $P<0.05$), and at 6 mm on the buccal surface for maxillary lateral incisors (CC: 0.62 ± 0.59 mm, AA: 0.33 ± 0.32 mm, $P<0.05$).

Table 2. Descriptive statistics and comparison of bone measurements of the maxillary lateral incisors between Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category                  | Race   | Mean ± SD    | 95% CI       |
|------------------------|---------------------------|--------|--------------|--------------|
| Buccal                 | Bone thickness            | CC     | 0.80 ± 0.56  | 0.64-0.97    |
|                        |                           | AA     | 0.64 ± 0.43  | 0.50-0.77    |
|                        |                           | CC     | 0.62 ± 0.59  | 0.45-0.79    |
|                        |                           | AA     | 0.33 ± 0.32* | 0.22-0.43    |
|                        |                           | CC     | 0.40 ± 0.54  | 0.25-0.56    |
|                        |                           | AA     | 0.25 ± 0.38  | 0.13-0.37    |
|                        |                           |        |              |              |
| Lingual                | Bone thickness            | CC     | 0.84 ± 0.57  | 0.68-1.00    |
|                        |                           | AA     | 1.10 ± 0.63  | 0.88-1.30    |
|                        |                           | CC     | 1.70 ± 0.60  | 1.60-1.90    |
|                        |                           | AA     | 1.80 ± 0.84  | 1.60-2.10    |
|                        |                           | CC     | 2.70 ± 0.87  | 2.50-3.00    |
|                        |                           | AA     | 2.50 ± 0.90  | 2.20-2.80    |
| Mid-root               | Alveolar ridge thickness  | CC     | 7.40 ± 0.81  | 7.10-7.60    |
|                        |                           | AA     | 7.20 ± 0.95  | 6.90-7.50    |
| Apex                   | Alveolar ridge thickness  | CC     | 8.20 ± 1.60  | 7.70-8.60    |
|                        |                           | AA     | 7.00 ± 1.40* | 6.50-7.50    |
| Labial height          | Bone height               | CC     | 2.00 ± 1.10  | 1.60-2.30    |
|                        |                           | AA     | 1.40 ± 0.88* | 1.20-1.70    |
| Lingual height         | Bone height               | CC     | 2.10 ± 1.20  | 1.80-2.50    |
|                        |                           | AA     | 1.60 ± 1.50  | 1.10-2.10    |

SD: standard deviation, CI: confidence interval, *: $P<0.05$ compared with CC.
Comparison of anterior maxillary and mandibular alveolar parameters in African American and Caucasian women: A retrospective pilot...

Table 3. Descriptive statistics and comparison of bone measurements of the mandibular central incisors between Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category                  | Race  | Mean ± SD   | SD  | 95% CI       |
|-------------------------|---------------------------|-------|-------------|-----|--------------|
| Buccal                  | Bone thickness            | CC    | 0.77 ± 0.50 | 0.50| 0.62-0.91    |
|                         |                           | AA    | 0.71 ± 0.55 | 0.55| 0.56-0.87    |
|                         | Bone thickness            | 6 mm  | 0.47 ± 0.59 | 0.59| 0.30-0.64    |
|                         |                           | AA    | 0.49 ± 0.36 | 0.59| 0.39-0.59    |
|                         | Bone thickness            | 9 mm  | 1.30 ± 0.95 | 0.95| 0.98-1.50    |
|                         |                           | AA    | 1.50 ± 0.56 | 0.56| 1.30-1.60    |
| Lingual                 | Bone thickness            | CC    | 0.90 ± 0.63 | 0.63| 0.72-1.10    |
|                         |                           | AA    | 0.57 ± 0.46*| 0.46| 0.44-0.71    |
|                         | Bone thickness            | 6 mm  | 1.20 ± 0.57 | 0.57| 1.00-1.30    |
|                         |                           | AA    | 0.79 ± 0.61*| 0.61| 0.61-0.96    |
|                         | Bone thickness            | 9 mm  | 1.80 ± 0.74 | 0.74| 1.60-2.00    |
|                         |                           | AA    | 1.70 ± 0.72 | 0.72| 1.40-1.90    |
| Mid-root                | Alveolar ridge thickness  | CC    | 6.60 ± 0.93 | 0.93| 6.30-6.90    |
|                         |                           | AA    | 6.30 ± 0.65 | 0.65| 6.20-6.50    |
| Apex                    | Alveolar ridge thickness  | CC    | 7.00 ± 1.80 | 1.80| 6.50-7.50    |
|                         |                           | AA    | 7.70 ± 1.60*| 1.60| 7.30-8.20    |
| Labial height           | Bone height               | CC    | 2.20 ± 1.30 | 1.30| 1.80-2.50    |
|                         |                           | AA    | 2.40 ± 1.50 | 1.50| 2.00-2.90    |
| Lingual height          | Bone height               | CC    | 2.60 ± 1.40 | 1.40| 2.20-3.00    |
|                         |                           | AA    | 2.80 ± 1.30 | 1.30| 2.40-3.10    |

SD: standard deviation, CI: confidence interval, *: $P < 0.05$ compared with CC

0.57±0.46 mm, $P < 0.05$ and 6 mm (CC: 1.2±0.57 mm, AA: 0.79±0.61 mm, $P < 0.05$) from the lingual surface of the maxillary central incisors, there were no significant differences ($P>0.05$) in the labial or lingual cortical bone thickness at 3 mm, 6 mm, or 9 mm from the alveolar crest between the CC and AA populations (Tables 3 and 4).

Alveolar ridge thickness: Except at the apex of the central incisors (CC: 7.0±1.8 mm, AA: 7.7±1.6 mm, $P<0.05$), all other measurements for alveolar thickness showed a non-significant difference ($P>0.05$) between the 2 groups (Tables 3 and 4).

Alveolar height: All the labial or lingual alveolar bone height measurements showed non-significant findings when the 2 racial groups were compared (Tables 3 and 4).

Maxillary versus mandibular incisors

A significant difference in bone thickness was found ($P < 0.05$) for the lingual surface of the central incisor at 3 mm, 6 mm, and 9 mm for both racial groups, with maxillary bone thickness found to be higher than mandibular thickness. For the central incisors, significantly higher maxillary alveolar ridge thickness was found in CCs at the mid-root and apex, but only at the mid-root for AAs ($P<0.05$). Significantly higher mandibular alveolar ridge thickness was found in the AA group for the mandibular lateral incisors at the apex ($P<0.05$). For the majority of bone height parameters for both CCs and AAs, a comparison of the maxillary versus mandibular arch showed a significant difference, with bone height measurements being higher for the mandibular arch ($P<0.05$). A descriptive comparison of the maxillary versus mandibular arch can be found in Table 5.

Labial versus lingual bone parameters

Table 6 shows a comparison of the bone thickness of labial and lingual surfaces. A significant difference was found for maxillary central incisors, maxillary lateral incisors, and mandibular lateral incisors at 6 mm and 9 mm, with the lingual bone thickness being higher than the labial bone thickness ($P<0.05$). No significant difference was found in bone height upon comparison of the labial and lingual surfaces ($P>0.05$).
Discussion

In the present study, the height and width of the alveolar bone surrounding the maxillary and mandibular incisors were measured and the mean values were compared between AA and CC normo-divergent female populations. Significant differences were found in bone thickness, alveolar thickness, and bone height on the labial and lingual sides of the maxillary and mandibular incisors for a few of the measurements (Tables 1-4).

A clinically relevant finding of this study was that the mean labial bone thickness of all maxillary measurements was less than 1 mm (range, 0.25-0.82 mm) (Tables 1 and 2). These results are in agreement with Nowzari et al., who reported a high prevalence of thin facial bone overlying maxillary central incisors. They showed that the percentage of maxillary central incisors with a cortical thickness $\geq 2$ mm measured at levels of 1, 2, 3, 4, and 5 mm was 0%, 1.5%, 2.0%, 3.0%, and 2.5%, respectively. The overall mean thickness of the bone was 1.05 mm for all 4 maxillary incisors. Their findings are higher than those of the current study, as the mean thickness of buccal bone was 0.68 mm in CCs and 0.57 mm in AAs (Tables 1 and 2). One reason for this disparity could be differences in study methodology and the location of measurements.

Furthermore, except for the central incisor at 9 mm ($P < 0.05$), no significant findings were found for maxillary lingual thickness. In general, the measurements of lingual bone thickness were larger than those of labial bone thickness for both races, and a significant difference was found for bone thickness at 6 mm and 9 mm for the maxillary incisors and mandibular lateral incisors ($P < 0.05$, Table 5). This suggests that following the extraction of premolars, during the retraction, incisors may remain within the alveolar housing more successfully than in non-extraction treatment with subsequent flaring of incisors, provided there is initial crowding. This hypothesis is supported by Thilander, who found that bony defects could be filled by moving teeth that remain in the alveolar walls. However, during orthodontic tooth movement, if a tooth is moved through the bony plate and alveolar dehiscence is created, no bone remineralization is observed.

Table 4. Descriptive statistics and comparison of bone measurements of the mandibular lateral incisors between Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category       | Race  | Mean ± SD | 95% CI    |
|-------------------------|----------------|-------|-----------|-----------|
| Buccal                  | Bone thickness| CC    | 0.77 ± 0.50 | 0.63-0.91 |
|                         |               | AA    | 0.88 ± 0.51 | 0.73-1.00 |
| 3 mm                    | Bone thickness| CC    | 0.40 ± 0.37 | 0.29-0.50 |
|                         |               | AA    | 0.41 ± 0.29 | 0.33-0.50 |
| 6 mm                    | Bone thickness| CC    | 0.87 ± 0.64 | 0.69-1.10 |
|                         |               | AA    | 0.97 ± 0.55 | 0.81-1.10 |
| 9 mm                    | Bone thickness| CC    | 0.77 ± 0.50 | 0.63-0.91 |
|                         |               | AA    | 0.88 ± 0.51 | 0.73-1.00 |
| Lingual                 | Bone thickness| CC    | 0.89 ± 0.62 | 0.71-1.10 |
|                         |               | AA    | 0.83 ± 0.50 | 0.69-0.97 |
| 3 mm                    | Bone thickness| CC    | 1.50 ± 0.76 | 1.20-1.70 |
|                         |               | AA    | 1.40 ± 0.95 | 1.10-1.70 |
| 6 mm                    | Bone thickness| CC    | 2.00 ± 1.00 | 1.70-2.30 |
|                         |               | AA    | 1.90 ± 0.96 | 1.70-2.20 |
| 9 mm                    | Bone thickness| CC    | 2.50 ± 1.40 | 2.10-2.90 |
|                         |               | AA    | 2.40 ± 0.67 | 2.20-2.60 |
| Mid-root                | Alveolar ridge thickness| CC    | 7.40 ± 0.97 | 7.20-7.70 |
|                         |               | AA    | 7.10 ± 0.78 | 6.90-7.30 |
| Apex                    | Alveolar ridge thickness| CC    | 7.70 ± 1.70 | 7.20-8.20 |
|                         |               | AA    | 8.20 ± 1.50 | 7.70-8.60 |
| Labial height           | Bone height    | CC    | 2.20 ± 1.60 | 1.80-2.70 |
|                         |               | AA    | 2.20 ± 1.60 | 1.80-2.60 |
| Lingual height          | Bone height    | CC    | 2.50 ± 1.40 | 2.10-2.90 |
|                         |               | AA    | 2.40 ± 0.67 | 2.20-2.60 |

SD: standard deviation, CI: confidence interval
Comparison of anterior maxillary and mandibular alveolar parameters in African American and Caucasian women: A retrospective pilot...  

This study also evaluated mandibular bone thickness, and found significantly higher bone thickness in CCs at 3 mm and 6 mm from the alveolar crest on the lingual side of mandibular central incisors (Tables 3 and 4). However, given that width measurements were made at 8 different locations and for 4 separate teeth (a total of 32 width measurements), no direct correlation was observed regarding the relationship between alveolar bone width and race (Tables 3 and 4). Morad et al.\textsuperscript{15} found the labial bone thickness for mandibular anterior teeth to be between 0.5 and 0.8 mm within the first 5 mm from the CEJ. Han and Jung\textsuperscript{16} examined the alveolar crest width and height in Korean cadavers and found similarly thin bone around the mandibular central and lateral incisors, averaging 0.86±0.59 mm and 0.88±0.70 mm, respectively. Although the methods in these studies were not identical to those of the present study, the results are similar to the findings of the present study in an adult female population. In the current study, the mean labial bone width ranged from 0.47 mm to 1.5 mm (Tables 3 and 4).

When assessing the height of alveolar bone, the only significant finding was found for the labial height on the maxillary lateral incisor (Tables 1-4). A study conducted by Ghassemian et al.\textsuperscript{17} found that patients 50 years or older had a 1 mm larger CEJ-bone crest distance than those 30 or younger. While the present study did not include individuals over 50 years of age, the average age of the 2 groups was very similar, with CCs averaging 33.60 years and AAs averaging 33.64 years. When evaluating the alveolar ridge thickness, significantly greater alveolar ridge thickness was found in CCs for maxillary central and lateral incisors and mandibular central incisors at the apex ($P<0.05$, Tables 1-4). This observation has specific implications for orthodontic treatment, as clinicians can utilize this evidence to predict the range of predictable root movement and torque expression without undesirable side effects.

Finally, when comparing maxillary and mandibular bone

### Table 5. Comparison of maxillary and mandibular bone measurements of the central and lateral incisors in Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category                  | Race   | Maxillary versus mandibular central incisor | Maxillary versus mandibular lateral incisor |
|-------------------------|---------------------------|--------|---------------------------------------------|---------------------------------------------|
|                         | Mean difference           | 95% CI | Mean difference                             | 95% CI                                      |
| Buccal 3 mm Bone thickness | CC                        | 0.04  | $-0.6022$ to $0.6745$                        | 0.03                         | $-0.6102$ to $0.6664$                          |
|                         | AA                        | 0.10  | $-0.5691$ to $0.7711$                        | $-0.24$                        | $-0.9111$ to $0.4291$                          |
| Buccal 6 mm Bone thickness | CC                        | 0.24  | $-0.3979$ to $0.8787$                        | 0.22                         | $-0.4155$ to $0.8612$                          |
|                         | AA                        | 0.11  | $-0.5631$ to $0.7771$                        | $-0.09$                        | $-0.7571$ to $0.5831$                          |
| Buccal 9 mm Bone thickness | CC                        | $-0.54$| $-1.174$ to $0.1029$                        | $-0.46$                        | $-1.102$ to $0.1745$                           |
|                         | AA                        | $-0.86^*$| $-1.534$ to $-0.1939$                    | $-0.72^*$                       | $-1.393$ to $-0.05240$                         |
| Lingual 3 mm Bone thickness | CC                        | 0.58  | $-0.05915$ to $1.217$                      | $-0.04$                        | $-0.6827$ to $0.5940$                          |
|                         | AA                        | 0.85^*| $0.1759$ to $1.516$                        | 0.25                         | $-0.4201$ to $0.9201$                          |
| Lingual 6 mm Bone thickness | CC                        | 1.29^*| $0.6481$ to $1.925$                        | 0.26                         | $-0.3752$ to $0.9014$                          |
|                         | AA                        | 1.27^*| $0.5964$ to $1.937$                        | 0.45                         | $-0.2201$ to $1.120$                           |
| Lingual 9 mm Bone thickness | CC                        | 1.98^*| $1.344$ to $2.621$                         | 0.71^*                       | $0.07501$ to $1.352$                           |
|                         | AA                        | 1.26^*| $0.5884$ to $1.929$                        | 0.58                         | $-0.09110$ to $1.249$                          |
| Mid-root Alveolar ridge thickness | CC                        | 1.70^*| $1.061$ to $2.338$                         | $-0.06$                       | $-0.6995$ to $0.5772$                          |
|                         | AA                        | 1.52^*| $0.8464$ to $2.187$                        | 0.06                         | $-0.6111$ to $0.7291$                          |
| Apex Alveolar ridge thickness | CC                        | 2.33^*| $1.688$ to $2.965$                         | 0.50                         | $-0.1334$ to $1.143$                           |
|                         | AA                        | 0.63  | $-0.03560$ to $1.305$                      | $-1.15^*$                     | $-1.824$ to $-0.4834$                          |
| Labial height Bone height | CC                        | $-0.43$| $-1.073$ to $0.2036$                      | $-0.27$                       | $-0.9077$ to $0.3690$                          |
|                         | AA                        | $-0.73^*$| $-1.402$ to $-0.06140$                  | $-0.76^*$                     | $-1.433$ to $-0.09240$                         |
| Lingual height Bone height | CC                        | $-1.12^*$| $-1.762$ to $-0.4856$                  | $-0.38$                       | $-1.019$ to $0.2573$                           |
|                         | AA                        | $-1.45^*$| $-2.116$ to $-0.7754$                  | $-0.77^*$                     | $-1.440$ to $-0.09940$                         |

CI: Confidence interval, ^*: $P<0.05$ for the comparison of maxillary vs. mandibular parameters
A significant difference was found specifically for the lingual bone width of central incisors, with the maxillary bone thickness being higher than the mandibular bone thickness ($P < 0.05$, Table 5). Mid-root alveolar ridge thickness showed a similar trend for the central incisors. This information could be useful in orthodontic treatment planning and applying differential biomechanical principles for maxillary and mandibular arches.

Additionally, the quality of the CBCT images has a huge impact on the reliability and accuracy of the measurements. Molen\textsuperscript{18} found 0.3- and 0.4-mm voxel size to be inadequate to properly visualize thin bone for various reasons. Most notably, he found that thin bone was especially susceptible to partial volume averaging, meaning that the angle at which the image plane intersects the bone wall could cause a thin bone to appear thicker or thinner than it actually was. Patcas et al.\textsuperscript{19} suggested that a smaller voxel size (0.125 mm) was more accurate for visualizing thin bone, but with the trade-off of an increase in radiation exposure to patients. Additionally, with the decrease in voxel size, the image became more sensitive to noise, resulting in poorer spatial resolution. Güngör and Doğan\textsuperscript{20} conducted a CBCT study evaluating the effects of 0.25-, 0.3-, and 0.4-mm voxel sizes on the accuracy of linear distance and concluded that the linear measurements were similar and reliable. Baumgaertel et al.\textsuperscript{21} published a CBCT study evaluating the reliability and accuracy of CBCT dental measurements. They utilized a 0.28-mm voxel size and concluded that the dental measurements proved to be reliable and accurate. Based on this evidence, linear measurements made on CBCT scans with a 0.3-mm voxel size in the present study should be considered reliable and accurate.

Even though differences between the 2 racial groups were sparse and lacking in clinical applicability, it is still important to accurately assess alveolar housing dimensions when planning orthodontic tooth movement. If non-extraction treatment is anticipated, and crowding exists, the labial bone dimensions are relevant for determining how much proclination.

### Table 6. Comparison of labial and lingual bone measurements of the central and lateral incisors in Caucasian (CC) and African American (AA) female patients

| Location of measurement | Category | Race | Maxillary (central incisor) | Mandibular (central incisor) |
|-------------------------|----------|------|-----------------------------|-----------------------------|
|                         |          |      | Labial versus lingual       | Labial versus lingual       |
|                         |          |      | Mean difference 95% CI      | Mean difference 95% CI      |
| 3 mm Bone thickness    | CC       | -0.68* | -1.290 to -0.06013          | -0.13                       |
|                        | AA       | -0.61 | -1.279 to 0.06855           | 0.14                        |
| 6 mm Bone thickness    | CC       | -1.75* | -2.365 to -1.135            | -0.70*                      |
|                        | AA       | -1.46*| -2.131 to -0.7839           | -0.30                       |
| 9 mm Bone thickness    | CC       | -3.10*| -3.711 to -2.481            | -0.58                       |
|                        | AA       | -2.32*| -2.996 to -1.649            | -0.20                       |
| Height Bone height     | CC       | 0.28  | -0.3357 to 0.8940           | -0.41                       |
|                        | AA       | 0.38  | -0.2936 to 1.054            | -0.33                       |

**Note:** CI: Confidence interval, $*: P < 0.05$ on the comparison of labial vs. lingual parameters
Comparison of anterior maxillary and mandibular alveolar parameters in African American and Caucasian women: A retrospective pilot... nation is acceptable. If a patient is proscriptive to begin with, and premolar extraction/incisor retraction is planned, the abundance of lingual bone is important. Srebrzyńska-Witek et al. found that mandibular anterior bone tended to be thicker on the lingual than the labial aspect (with measurements at 3 mm, 6 mm, and 9 mm). Another similar finding was that the bone increased in width from the cervical to the apical region, except at the 6-mm labial measurement point where the mean bone width was thinnest (Tables 1-4). Overall, this finding suggests that there may be more tolerance for incisor retraction than proclination. Thilander found that areas of bony dehiscence did not remineralize unless the tooth was moved back within the alveolar housing. It was, therefore, deemed important to respect this boundary. Alveolar bone width might be genetically controlled, and thus does not increase when teeth are moved outside of the alveolar process.

Although the present study comprehensively evaluated the alveolar housing surrounding the maxillary and mandibular anterior teeth, the outcomes were limited by the small number of samples. Moreover, additional raters should be used for each set of data to evaluate interrater reliability to ensure a more accurate data set. Lastly, it was difficult to compare the results of the present study to those of other studies due to the lack of previous research comparing alveolar bone morphology between AAs and CCs. The majority of previous research was concerned with the labial aspect of the bone in CCs. Future studies should also include larger sample sizes for greater statistical power based on the current study data.

In conclusion, there was no significant difference in maxillomandibular anterior alveolar bone measurements between normo-divergent adult AA and CC women except for a few parameters at varying locations. However, future studies can be planned based on the current pilot study data, which may provide valuable information.

Conflicts of Interest: None

References
1. Solem RC, Marasco R, Gutierrez-Pulido L, Nielsen I, Kim SH, Nelson G. Three-dimensional soft-tissue and hard-tissue changes in the treatment of bimaxillary protrusion. Am J Orthod Dentofacial Orthop 2014; 144: 218-28.
2. Ogundipe OK, Otuyemi OD. Surgical and orthodontic treatment methods in patients with bimaxillary protrusion - a systematic review. J West Afr Coll Surg 2017; 7: 31-46.
3. Bills DA, Handelman CS, BeGole EA. Bimaxillary dentoalveolar protrusion: traits and orthodontic correction. Angle Orthod 2005; 75: 333-9.
4. Araújo TM, Caldas LD. Tooth extractions in orthodontics: first or second premolars? Dental Press J Orthod 2019; 24: 88-98.
5. Leonardi R, Annuziata A, Liciardello V, Barbato E. Soft tissue changes following the extraction of premolars in non-growing patients with bimaxillary protrusion. A systematic review. Angle Orthod 2010; 80: 211-6.
6. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. Am J Orthod 1973; 64: 278-302.
7. Lee S, Hwang S, Jang W, Choi YJ, Chung CJ, Kim KH. Assessment of lower incisor alveolar bone width using cone-beam computed tomography images in skeletal Class III adults of different vertical patterns. Korean J Orthod 2018; 48: 349-56.
8. Gracco A, Luca L, Bongiorno MC, Siciliani G. Computed tomography evaluation of mandibular incisor bony support in untreated patients. Am J Orthod Dentofacial Orthop 2010; 138: 179-87.
9. Januário AL, Duarte WR, Barriquiera M, Mesti JC, Araújo MG, Lindhe J. Dimension of the facial bone wall in the anterior maxilla: a cone-beam computed tomography study. Clin Oral Implants Res 2011; 22: 1168-71.
10. Nowzari H, Molayem S, Chiù CH, Rich SK. Cone beam computed tomographic measurement of maxillary central incisors to determine prevalence of facial alveolar bone width ≥ 2 mm. Clin Implant Dent Relat Res 2012; 14: 595-602.
11. Goshatsbi N, Hazzard J, Mehrkholdavandi N, Al-Qawasmi R. The heritability of alveolar bone thickness in siblings seeking orthodontic treatment. Am J Orthod Dentofacial Orthop 2020; 157: 803-8.
12. Skieller V, Björk A, Linde-Hansen T. Prediction of mandibular growth rotation evaluated from a longitudinal implant sample. Am J Orthod 1984; 86: 359-70.
13. Garlock DT, Buschang PH, Araujo EA, Behrens RG, Kim KB. Evaluation of marginal alveolar bone in the anterior mandible with pretreatment and posttreatment computed tomography in nonextraction patients. Am J Orthod Dentofacial Orthop 2016; 149: 192-201.
14. Thilander B. Infrabony pockets and reduced alveolar bone height in relation to orthodontic therapy. Semin Orthod 1996; 2: 55-61.
15. Morad G, Behnia H, Motamedian SR, Shahab S, Gholapin P, Khorosrvani K, et al. Thickness of labial alveolar bone overlying healthy maxillary and mandibular anterior teeth. J Craniofac Surg 2014; 25: 1985-91.
16. Han JY, Jung GU. Labial and lingual/palatal bone thickness of maxillary and mandibular anterior teeth in human cadavers in Koreans. J Periodontal Implant Sci 2011; 41: 60-6.
17. Ghassasian M, Nowzari H, Lajolo C, Verdugo F, Pirronti T, D’Addona A. The thickness of facial alveolar bone overlying healthy maxillary anterior teeth. J Periodontol 2011; 83: 187-97.
18. Molen AD. Considerations in the use of cone-beam computed tomography for buccal bone measurements. Am J Orthod Dentofacial Orthop 2010; 137 (4 Suppl): S130-5.
19. Patcas R, Müller L, Ullrich O, Peltomäki T. Accuracy of cone-beam computed tomography at different resolutions assessed on the bony covering of the mandibular anterior teeth. Am J Orthod Dentofacial Orthop 2012; 141: 41-50.
20. Güngör E, Doğan MS. Reliability and accuracy of cone-beam...
computed tomography voxel density and linear distance measurement at different voxel sizes: a study on sheep head cadaver. J Dent Sci 2017; 12: 145-50.

21. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. Am J Orthod Dentofacial Orthop 2009; 136: 19-28.

22. Srebrzyńska-Witek A, Koszowski R, Różyło-Kalinowska I. Relationship between anterior mandibular bone thickness and the angulation of incisors and canines - a CBCT study. Clin Oral Investig 2018; 22: 1567-78.