Evaluation of Orthodontic Mini-Implant Placement in the Maxillary Anterior Alveolar Region in 15 Patients by Cone Beam Computed Tomography at a Single Center in South India

Background: In this study, we aimed to evaluate orthodontic mini-implant placement in the maxillary anterior alveolar region by cone beam computed tomography (CBCT) in 15 patients at a single center in South India.

Material/Methods: A total of 15 CBCT scans of orthodontic patients after completion of leveling and aligning stage were included. The thickness of labial alveolar bone, labio-palatal bone, and inter-radicular distance between the maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3) at vertical levels 4 mm, 6 mm, and 8 mm above the interdental cementoenamel junction were measured. Descriptive statistics, ANOVA, and Tukey post hoc tests were done to assess the differences among the groups. An independent t-test was done to analyze differences by sex.

Results: The thickness of cortical bone in the labial region was higher in the U2-U3 site than in the U1-U1 site, at a height of 4 mm. Also, there was a significant difference between 4 mm and 8 mm heights in the U2-U3 region. No significant difference was noted in bone dimensions among men and women and in the labio-palatal bone thickness among the different sites. The inter-radicular distance was the highest between the U2-U3 site, while it was the lowest in the U1-U2 site.

Conclusions: The findings from this center showed that when CBCT was used to evaluate orthodontic mini-implant placement in the maxillary anterior alveolar region, the U2-U3 and U1-U1 locations at heights between 6 mm to 8 mm apical to the interdental cementoenamel junction were optimal for placement of the mini-implants.

Keywords: Bone Development • Maxilla • Orthodontics, Corrective

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Background

The most important factor for successful orthodontic treatment is anchorage control. The introduction of mini-implants/mini-screws as a skeletal anchorage device can provide absolute anchorage during various movements of the tooth, such as anterior retraction, anterior intrusion, molar intrusion, molar distalization, and molar protraction [1-5]. The advantages of mini-implants over other skeletal anchorage devices, such as miniplates, plates, and dental implants, are their small size, ease of placement and removal, decreased discomfort, increased number of placement sites, lack of surgical defects, and immediate loading [6-11].

Mini-implants are commonly inserted in the inter-radicular alveolar bone. Successful placement of the mini-implant requires a thorough knowledge of the root morphology of the adjacent teeth, distance between the radicular bone, thickness of the alveolar bone, and technique of mini-implant placement [3]. Various clinical guidelines have also been proposed regarding the placement of inter-radicular implants, including that the inter-root distance must be greater than 3 mm [12] and that, to avoid any root damage, the path of a mini-implant placement should be angulated [7]. Some authors also suggest that mini-implants can even be inserted in cases in which the inter-radicular distances are less than 3 mm, if the bone thickness along the path of insertion is greater than the length of the threaded portion [13].

Even though inter-radicular implants are most commonly positioned in the posterior alveolus for retraction, they can also be placed in the anterior alveolus for anterior intrusion and molar protraction [14-21]. The prevalence of vertical maxillary excess in the Brazilian population, as well as the Asian population, was reported to be nearly 22% [22], whereas it was nearly 30% in the South Indian population [23]. Vertical maxillary excess and gummy smile of mild to moderate severity are very well camouflaged by the mini-implant-aided anterior intrusion [14-21].

The placement of a mini-implant in the anterior regions could also be used for purposes of molar protraction in cases of congenitally missing teeth. According to the Misch classification of bone density, the anterior part of the maxilla falls into the category of D2 and D3 bone, which is thin and porous [24]. Hence, it is essential to evaluate the thickness of the cortical bone for predicting the long-term stability of mini-implants placed in the anterior region if used for protraction of posterior teeth, which have a greater root surface area than anterior teeth.

Cone beam computed tomography (CBCT) is an accurate radiographic method widely used for evaluating bone morphology [25]. There are many studies using CBCT for assessing bone thickness in the molar, premolar, and mid-palatal areas for mini-implant placement [12,13,26-29]. There is a considerably high prevalence of vertical maxillary excess in the South Indian population, while there are few studies assessing the anterior alveolar bone thickness for orthodontic mini-implant placement. Therefore, the present study was conducted to assess the labial bone thickness, labio-palatal bone thickness, and inter-radicular distance using CBCT and to determine the ideal site for positioning of mini-screws in the upper anterior region in the South Indian population. The variation in bone thickness by sex was also evaluated. Therefore, this study aimed to evaluate orthodontic mini-implant placement in the maxillary anterior alveolar region by CBCT in 15 patients at a single center in South India.

Material and Methods

The study was approved by the Institutional Review Board. The IEC approval number was SRB/SDC/ORTHO-1801/20/041. Informed consent was obtained from all participants involved in the study. This was a prospective cross-sectional study conducted in the Department of Orthodontics and was conducted for a period of 11 months, from April 2020 to March 2021.

The sample size was calculated for a power of 95%, a 0.05 effect size using G power analysis, based on the results from the study by Choi et al [25]. Based on the sample size calculation, CBCT scans of 15 orthodontic patients (8 women, 7 men) who were residents of South India for the past 3 generations and in the age group of 20 to 30 years were included. The inclusion criteria were patients with a Class I skeletal base, average vertical growth pattern, deep dental bite requiring intrusion of maxillary anterior, crowding of less than 2 mm to 3 mm, and healthy periodontium. Patients with systemic bone disorders and craniofacial anomalies were excluded. Informed consent was signed by all patients. The anteroposterior and vertical relationship of the jaw bases was evaluated using the pre-treatment lateral cephalogram. ANB values of 2 to 4 degrees with a Frankfort mandibular plane angle of 25±5 degrees were considered to have a Class I skeletal base with an average growth pattern. All patients were bonded with 0.022” slot MBT metal brackets. Leveling and aligning were done using the following wire sequence: 0.016″ NITI, 0.016×0.022″ NITI, 0.017×0.025″ SS, and 0.019×0.025″ SS. CBCT scans were taken after the completion of the leveling and aligning at 6 weeks after the placement of the 0.019×0.025″ SS wire. All CBCT scans were taken by the same radiologist, with the patient’s head positioned such that the occlusal plane of the maxilla was kept parallel to the floor.

Measurements

CBCT evaluations were performed using Galileos Viewer Software (Model v 22.8, Denstply Sirona). For making
measurements, the maxillary occlusal plane was used as the horizontal reference plane. The thickness of the cortical bone on the labial side (Figure 1), labio-palatal bone thickness (Figure 1), and inter-radiclar thickness (Figure 2) were measured between the 3 interdental root areas, specifically, between U1-U1, U1-U2, and U2-U3. Each of the measurements was performed at 3 vertical levels, namely, 4 mm, 6 mm, and 8 mm apical to the interdental CEJ (Figure 3). Labio-palatal bone thickness was measured from the labial side of the labial cortical plate to the palatal side of the palatal cortical plate or the labial wall of the incisive canal in the order of occurrence [25]. Similarly, the inter-radiclar distance was also measured in the narrowest interdental region. Measurements were made on both sides and the mean value of the right and left sides for each sample was used for statistical analyses.

**Statistical Analysis**

All measurements were examined by a single investigator. Intra-examiner reliability was performed by repeating the measurements in 8 randomly selected samples after 2 weeks, and an intraclass correlation coefficient test revealed 0.96, which indicated excellent intra-examiner reliability. The Shapiro-Wilk test showed normally distributed data. An independent t test was used to determine the differences in bone dimensions between sexes. One-way analysis of variance and the Tukey post hoc test were used to compare the mean differences between maxillary alveolar bone thickness, labio-palatal thickness, and the inter-radiclar distance at 3 inter-dental regions, as well as at 3 different vertical levels. The significance level was set at 0.05. All the statistical analyses were performed utilizing IBM SPSS Statistics Software Version 20.0 for Windows.

**Results**

The average age of the patients was 23.6±2.8 years. The independent sample t test reported a significance value greater than 0.05, indicating that statistically evident differences were not evident in labial alveolar bone thickness, labio-palatal bone thickness, and inter-radiclar distance between the sexes at all the measured sites (Table 1).

The mean and standard deviation of the labial alveolar bone thickness, labio-palatal bone thickness, and inter-radiclar distance are given in Tables 2 and 3, respectively. Tables 4 and 5 show the level of significant difference between 4 mm, 6 mm, and 8 mm and between the sites U1-U1, U1-U2, and U2-U3, respectively.
The labial cortical bone thickness was highest between U2-U3, at a height of 8 mm (1.16±0.22 mm). The lowest thickness of 0.71±0.12 mm was observed between U1-U1 at 4 mm (Table 1). A statistically significant difference was noted in the thickness of labial cortical (compact) bone between 4 mm and 8 mm in all 3 sites (Table 4). The cortical bone thickness increased as the distance from the CEJ increased apically. A critical distinction was additionally noted in the range of 6 mm and 8 mm in the U2-U3 site. The thickness was more in the U2-U3 site when compared with the U1-U1 site at a height of 4 mm from the CEJ. (Table 5)

**Labio-Palatal Bone Thickness**

A minimum of 8 mm of labio-palatal bone thickness was observed in all the sites assessed (Table 2). There was no critical distinction in the labio-palatal bone thickness between the various sites at different vertical levels (Tables 4, 5).

**Inter-Radicular Distance**

The inter-radicular distance increased as it moved apically away from the CEJ. A maximum distance of 4.21±0.98 mm was seen between the U2-U3 site at a level of 8 mm and the lowest distance of 2.78±0.88 mm was seen between the U1-U2 site at a level of 4 mm (Table 3). A statistically significant difference in the inter-radicular distance was observed between sites U1-U1 and U1-U2 and between sites U2-U3 and U1-U2 at all 3 vertical levels (Table 5). A significant difference was also noted between 4 mm and 8 mm at sites U1-U1 and U2-U3 (Table 4).

### Table 1. Descriptive statistics for labial cortical bone thickness.

| Site         | Level | 4 mm | Mean (mm) | SD (mm) | 6 mm | Mean (mm) | SD (mm) | 8 mm | Mean (mm) | SD (mm) |
|--------------|-------|------|-----------|---------|------|-----------|---------|------|-----------|---------|
| U1-U1        | 4 mm  | 0.71 | 0.12      | 0.84    | 0.18 | 0.98      | 0.20    |
|              | 6 mm  | 0.84 | 0.18      | 0.91    | 0.12 | 1.07      | 0.22    |
|              | 8 mm  | 0.98 | 0.20      | 1.16    | 0.15 | 1.16      | 0.22    |

Maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3).

### Table 2. Descriptive statistics for labio-palatal bone thickness.

| Site         | Level | 4 mm | Mean (mm) | SD (mm) | 6 mm | Mean (mm) | SD (mm) | 8 mm | Mean (mm) | SD (mm) |
|--------------|-------|------|-----------|---------|------|-----------|---------|------|-----------|---------|
| U1-U1        | 4 mm  | 8.20 | 1.73      | 7.95    | 1.99 | 8.13      | 2.63    |
|              | 6 mm  | 9.18 | 1.96      | 9.33    | 2.24 | 9.81      | 2.34    |
|              | 8 mm  | 9.07 | 1.86      | 8.65    | 2.15 | 9.04      | 2.29    |

Maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3).

### Table 3. Descriptive statistics for inter-radicular distance.

| Site         | Level | 4 mm | Mean (mm) | SD (mm) | 6 mm | Mean (mm) | SD (mm) | 8 mm | Mean (mm) | SD (mm) |
|--------------|-------|------|-----------|---------|------|-----------|---------|------|-----------|---------|
| U1-U1        | 4 mm  | 2.76 | 0.88      | 3.13    | 1.15 | 3.82      | 1.08    |
|              | 6 mm  | 2.00 | 0.50      | 2.19    | 0.60 | 2.50      | 0.75    |
|              | 8 mm  | 2.94 | 0.82      | 3.60    | 0.96 | 4.21      | 0.98    |

Maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3).
that the teeth tip and torque were expressed almost equally. Implants are placed for intrusion. This was done to ensure that the mini-implants depend upon the thickness of the bone and the proximity of the implant to the vital anatomical structures. Bone thickness is known to vary among different races and ethnicities. Therefore, the present study evaluated the thickness of compact bone at a height of 8 mm was more than that observed at 4 mm but less than that seen at 6 mm, which only partly agreed with the results of the present study [13]. In another study conducted in a Korean population by Choi et al [25], the alveolar bone measured 0.02±0.09 to 0.52±0.54 mm, and 0.1±0.29 to 1.46±0.47 mm were seen in the U1-U1, U1-U2, and U2-U3 sites at levels of 4 mm and 6 mm apical to the interdental distance available. Also, there was no considerable difference in bone dimensions between men and women.

The results of the study showed that the sites U2-U3 and U1-U1 at a height of 6 mm to 8 mm were the best for placement of mini-implants, according to the amount of labial cortical thickness, labio-palatal bone thickness, and inter-radicular distance available. Also, there was no considerable difference in bone dimensions between men and women. Cortical bone thicknesses of 0.02±0.09 to 0.52±0.54 mm, 0.04±0.19 to 0.48±0.59 mm, and 0.1±0.29 to 1.46±0.47 mm were seen in the U1-U1, U1-U2, and U2-U3 sites at levels of 4 mm and 6 mm apical to the CEJ, respectively, in a study by Lee et al in 2009. The thickness of compact bone at a height of 8 mm was more than that observed at 4 mm but less than that seen at 6 mm, which only partly agreed with the results of the present study [13]. In another study conducted in a Korean population by Choi et al [25], the alveolar bone measured 0.70±0.27 mm to 0.90±0.34 mm, 1.2±0.30 mm to 1.10±0.21 mm, and 1.15±0.27 mm to 1.20±0.13 mm in the U1-U1, U1-U2, and U2-U3 sites at levels of 4 mm to 8 mm apical to the interdental

Table 4. Significance value obtained from ANOVA and Tukey post hoc tests comparing the mean difference of cortical thickness, labio-palatal bone thickness, and inter-radicular distance between 4 mm, 6 mm, and 8 mm.

| Site       | 4-6 mm | 6-8 mm | 4-8 mm |
|------------|--------|--------|--------|
|            | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance |
| U1-U1      | 0.114  | 0.948  | 0.607  | 0.960  | 0.970  | 0.177  | <0.001* | 0.997  | 0.022* |
| U1-U2      | 0.364  | 0.979  | 0.692  | 0.117  | 0.825  | 0.366  | <0.001* | 0.712  | 0.085  |
| U2-U3      | 0.379  | 0.847  | 0.161  | 0.003* | 0.868  | 0.150  | <0.001* | 0.999  | 0.001* |

* P value <0.05 indicates statistically significantly difference. Maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3).

Table 5. Significance value obtained from ANOVA and Tukey post hoc tests comparing the mean difference of cortical thickness, labio-palatal bone thickness, and inter-radicular distance between the sites.

| Site       | U1-U1 & U1-U2 | U1-U2 & U2-U3 | U1-U1 & U2-U3 |
|------------|---------------|---------------|---------------|
|            | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance | Cortical bone thickness | Labio-palatal bone thickness | Inter-radicular distance |
| 4 mm       | 0.074  | 0.326  | 0.022* | 0.851  | 0.987  | 0.004* | 0.021* | 0.408  | 0.788  |
| 6 mm       | 0.442  | 0.190  | 0.023* | 0.884  | 0.654  | 0.001* | 0.216  | 0.648  | 0.401  |
| 8 mm       | 0.448  | 0.155  | 0.001* | 0.523  | 0.663  | <0.001* | 0.065  | 0.569  | 0.497  |

* P value <0.05 indicates statistically significantly difference. Maxillary central incisors (U1-U1), maxillary central and lateral incisor (U1-U2), and maxillary lateral incisor and canine (U2-U3).

Discussion

The use of mini-implants in the maxillary region is expanding very rapidly [14-21]. Mini-implants are advantageous over the conventional intrusion arches in obtaining true maxillary anterior intrusion with minimal sagittal and vertical anchorage loss of the posteriors [18,19]. The safety and strength of the mini-implants depend upon the thickness of the bone and the proximity of the implant to the vital anatomical structures [30-32].
CEJ, respectively. Sadek et al [33] compared the thickness of the buccal compact bone at all inter-radicular sites in the maxilla for different vertical growth patterns and reported an average thickness of 0.8 to 0.9 mm of compact bone in the anterior maxilla in all 3 growth patterns, with no significant differences among the groups; their results were not consistent with the values obtained in the present study. Cassetta et al and Ono et al revealed that the thickness and density of the compact bone were lower in the maxillary anterior segment than in the posterior segment. They also stated that a difference in cortical bone thickness by sex was noted in the previous studies, in which they observed men had thicker cortical bone than women [34,35]. However, this variation was significant in the posterior region, which can be attributed to the higher biting force of the men, whereas there was no difference in thickness of bone in the anterior region between men and women. The results of these studies were similar to those we observed in this study.

In the present study, there were no variations noted in the labio-palatal bone thickness between the various sites, with measured values of 7.95±1.99 mm to 9.81±2.34 mm. In the U1-U1 site, the thickness was limited by the presence of the incisive canal. A similar range was observed in the study done by Choi et al [25]; however, they observed that the thickness was significantly high in the U1-U2 site, while it was low in the U1-U1 site.

In the present study, the inter-radicular distance was high in the U2-U3 site, whereas it was low in the U1-U2 site. This was expected because the measurements were taken after the completion of leveling and aligning using the MBT bracket prescription. The inter-radicular distance increased as it moved apically from the CEJ in all 3 sites. Choi et al [25] observed a similar trend in the inter-radicular distance when measured on pre-treatment CBCT scans. Analyzing the results obtained for all 3 parameters in the present study, we observed that the sites U1-U1 and U2-U3, at a vertical level of 6 mm and 8 mm with the maximum buccal cortical bone thickness and an average inter-radicular distance of 3 mm, are the ideal sites for anterior mini-implant positioning. Assuming the thickness of the mini-implant to be 1.5 mm and a clearance of 1 mm of bone on either side of the implant, a minimum of 3 mm of inter-radicular distance is essential for the safe placement of implants, as stated by Schnelle et al and Park et al [12,36]. With a labio-palatal bone thickness of 7.95±1.99 mm to 9.81±2.34 mm, mini-implants of lengths 8 mm to 9 mm can be placed safely with or without angulation in the maxillary anterior region. Atalla et al and Sosny et al concluded in their systematic reviews that anterior mini-implants can be efficiently used for maxillary anterior teeth intrusion [37,38]. Alsamak et al [39] concluded in their systematic review that the optimal site of placement of mini-implants in the anterior maxilla is between the canine and first premolar, whereas Fayed et al [40] concluded the optimal site is between the central and lateral incisors. Also, maxillary anterior intrusion with good control over buccal angulation is seen when using 2 mini-implants that are placed between the canine and lateral incisor on right as well as the left side, rather than a single midline implant, as reported by Vela-Hernández [41].

The ideal bone thickness of mini-implants has been discussed by numerous authors, as stated above. Bone thickness is positively correlated to the success rates of mini-implant placement, which in turn affects the outcome of the orthodontic treatment [13]. Hence, it is essential to know the optimal bone thickness at the most common mini-implant placement sites [33].

All the studies that measured bone thickness in the maxillary and mandibular jaw have used only the CBCT technique. CBCT offers the highest possible accuracy in linear measurements of cortical thickness. Tsutsumi et al stated that conventional methods cannot accurately assess bone thickness [42].

The limitations of the present study include a smaller sample size, with only patients with Class I skeletal and average growth patterns being included. At the same time, attempts were made to limit the confounding variables by including only patients with similar growth patterns and an almost equal number of men and women. A shortcoming of using this method for assessing bone thickness would be the variations in the height of the CEJ of adjacent teeth, as that was used as a reference landmark. Along with this, the patients were not classified based on their bone density, which might vary among individuals.

This study provides help in choosing locations for mini-implants in the anterior part of the maxilla. Future studies assessing the same topic in different skeletal growth patterns and larger sample sizes are recommended for validation of the present results. These should discuss the results and how they can be interpreted from the perspective of previous studies and the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

Conclusions

The findings from this center showed that when CBCT was used to evaluate orthodontic mini-implant placement in the maxillary anterior alveolar region, the U2-U3 and U1-U1 locations at a height of between 6 mm to 8 mm apical to the interdental CEJ were optimal for anterior placement of the mini-implants.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.
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