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Effect of Maxillary Central Incisor Inclination on Palatal Bone Width

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Objectives This study aimed to evaluate the effect of labiopalatal inclination of maxillary right central incisor on palatal bone width using cone-beam computed tomography (CBCT).
Methods The angle formed between the longitudinal axis of the right central incisor and the palatal plane was measured on 75 CBCT images, and classified into three groups of labially-inclined, lingually-inclined, and normal groups. The total palatal bone thickness in the apical region of the upper right central incisor was linearly measured perpendicular to the tooth axis on sagittal slices. The intraclass correlation coefficient, Kolmogorov-Smirnov test, one-way ANOVA, and Pearson's and Spearman's correlation coefficients were used for data analysis (alpha=0.05).
Results A significant difference was noted among the groups in the total apical palatal bone thickness ($P<0.05$). The labially-inclined group had significantly lower bone thickness than the other two groups ($P=0.002$, 95% CI: 5.5-7.38); however, this correlation was inverse (Pearson's $R=-0.58$), which means that as the angle between the upper central incisor axis and the palatal plane increased, the bone thickness significantly decreased. No correlation was found between the palatal bone thickness (cancellous or cortical) and tooth inclination ($P>0.05$). Arch length was not correlated with any group either ($P>0.05$).
Conclusion Labial inclination of upper central incisor causes the root apex to be closer to the palatal alveolar bone, resulting in less apical bone support in the palatal area.
Keywords Incisor; Palate; Cone-Beam Computed Tomography

Introduction

Anatomical structures in the craniofacial area and their relationship with each other are the primary influential factors in designing the best possible orthodontic treatment plan. Insufficient attention to correct diagnosis can lead to severe complications; therefore, regardless of the orthodontic technique adopted to achieve the treatment goals, the patient's biological limits are of critical importance.[1] Since orthodontic tooth movement occurs within the alveolar bone[2], alveolar bone morphology, especially at the apical region of the maxillary incisors, is a significant factor defining the limits of orthodontic tooth movement.[3] Moreover, to achieve safe anteroposterior orthodontic movement of maxillary incisors in patients with different abnormalities, careful assessment of the three-dimensional (3D) position of tooth apices is also essential.[4-6]

Before the advent of computed tomography technology, studies based on conventional radiography were not highly reliable because of distortion and superimposition of anatomical structures.[7] Also, assessment of tooth position and bone width was not accurately possible. The use of cone-beam computed tomography (CBCT) in dentistry allows morphological evaluation of the dentoalveolar complex on high-definition actual-size 3D images.[7, 8]

Previous studies have confirmed the accuracy of angular and linear measurements on CBCT images for evaluation of dental and maxillofacial structures.[9-11] Therefore, one of the various indications of CBCT is assessment of the alveolar bone thickness surrounding the roots and determining their 3D orientation.[1, 12, 13]

Evaluation of the amount of bone tissue around the roots and the inclination of maxillary incisors is pivotal to find the most appropriate treatment procedures. It helps orthodontists to find the limits of tooth movement and design the safest treatment plan to minimize the risk of iatrogenic complications such as bone loss, root resorption, and periodontal problems, and prevent the aggravation of already existing conditions before orthodontic treatment.[14, 15]

Many studies quantitatively assessed the palatal bone thickness and sagittal root angulation. However, to the best of our knowledge, only a few studies evaluated the relationship between the inclination of maxillary central incisor and the palatal alveolar bone width; therefore, the relationship between these two parameters remains unclear.

Do et al.[16] reported a moderate inverse correlation between the angulation of upper lateral incisor and apical palatal bone thickness in both genders. However, there was no such a correlation for central incisors. Sendyk et al.[1] evaluated these two parameters in maxillary incisors (lateral and central) of 35 patients. They found an inverse correlation between apical tooth angulation and palatal alveolar bone thickness. The apical alveolar bone thickness of maxillary incisors was significantly lower in patients with class III skeletal relationship who showed greater mean inclination of maxillary incisors compared with normal-occlusion subjects.

Considering the significance of apical palatal bone thickness, especially in the maxillary central incisor area, the importance of knowledge about the limitations of orthodontic tooth movement, and the gap of information on this topic, this study aimed to evaluate the relationship of apical cortical and cancellous bone width and the labiopalatal inclination of maxillary central incisors. The second objective was to investigate the relationship between the maxillary arch length, width, and palatal bone width in the palatal aspect of central incisors using a high-resolution CBCT scanner.

Methods and Materials

The minimum sample size for this study was calculated to be 25 patients in each of the three groups based on a previous study. (5) Therefore, a population of 75 patients aged 18 to 35 years (mean age = 27.09±4.70 years) with no history of previous orthodontic treatment who presented to the Department of Oral Radiology, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran, for a maxillary CBCT for orthodontic diagnosis or other oral treatments was selected. In addition, the DICOM data and demographic information of patients, including age and gender, were retrospectively obtained. The study was approved by the ethics committee of the School of Dentistry, Shahid Beheshti University of Medical Sciences (IR.SBMU.RIDS.REC.1395.309).

The inclusion criteria for the clinical data were (a) no history of receiving prior orthodontic treatment, (b) presence of all maxillary incisors, premolars, and first molars, (c) absence of severe scattering and distortion of images, (d) crowding and spacing less than 3 and 1 mm, respectively in the anterior segment of the maxilla, (e) no radiographic evidence of apical lesion, dental trauma, surgical treatment or root resorption in the maxillary incisor area, (e) absence of bone pathologies in the palatal bone, and (f) absence of cleft lip and palate.

All CBCT images were acquired using NewTom CBCT scanner (Quantitative Radiology, Verona, Italy) with the exposure settings of 110 Kvp, 10.65 mA, 7.5x10 cm field of view, and 200 µm voxel size. All measurements were performed by importing the DICOM files into the NNT Viewer software (NNT 8; Image Works, Verona, Italy). The slice thickness was 0.25 mm for all CBCT images.

Since the right and left palatal bone thickness in the central incisor area did not significantly differ in this study[17], the right central incisor was evaluated in all patients. The angle between the right maxillary central incisor longitudinal axis (a straight line passing from the root canal center by connecting the incisal edge to the root apex) and the palatal plane was measured on the sagittal slice reconstructed from the original DICOM file.

Three groups were designed based on the CBCT images of 25 patients according to the angle formed between the longitudinal axis of the tooth and the palatal plane (U1-PP angle) as shown in Figure 1. Three measurements were made in each group:

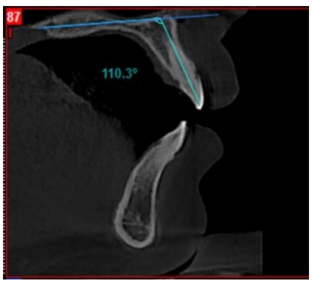

Figure 1: Measuring the buccolingual inclination based on the angle between the axis of the maxillary central incisor and the palatal plane (U1-PP) on the median sagittal view

1. Palatal thickness of alveolar bone perpendicular to the tooth axis was measured linearly at the level of the tooth apex (Figure 2); the cancellous bone thickness was calculated by subtracting the cortical bone thickness from the whole apical bone thickness.

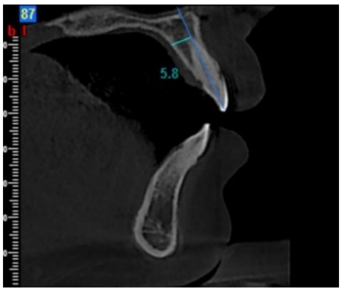

Figure 2: Measuring the thickness of total alveolar bone thickness in the palatal region of maxillary central incisor

2. Maxillary arch width: The distance between the contact area of the permanent first molar and permanent second premolar in the right and left sides.
3. Maxillary arch length: Perpendicular distance from the contact point of right central incisor to the line indicating the arch width. The width and length measurements of the maxillary arch were made on transverse reconstructions.

Before the study onset, a sample of 26 CBCT images was chosen randomly and measured by an oral and maxillofacial radiologist. To assess the intra-examiner reliability, the same images were re-measured after a 2-week interval. The intraclass correlation coefficient was found to be 0.77, indicating good agreement.[5]

The correlation between tooth inclination and cortical, cancellous, and total bone thickness, and arch length in maxillary incisors' palatal region was analyzed. Moreover, the correlation between arch length and width with total bone thickness in this area was evaluated in each group.

The Kolmogorov-Smirnov test showed that most of the measurements had a normal distribution of probability values. Therefore, a parametric correlation test (Pearson's correlation) was used to detect the relationship between the parameters with linear and normal distribution. For the variables that did not show normal distribution, a non-parametric correlation test (Spearman's correlation) was utilized. Furthermore, the descriptive data of each group were analyzed by one-way ANOVA, and pairwise comparisons of the groups were conducted using the Tamhane's post-hoc test. All statistical analyses were accomplished with SPSS version 21.0 (SPSS Inc., Chicago, IL, USA) at 0.05 level of significance.

Results

The lingually-inclined group (U1-PP ≤ 110.10 o) included 11 males and 14 females with a mean age of 28.32±6.15 years; the normal group (110.10 < U1-PP ≤121.50 o) included 12 males and 13 females with a mean age of 27.72±4.57 years, and the labially-inclined group (U1-PP > 121.50 o) included 13 males and 12 females with a mean age of 27.68±3.00 years.

The mean and standard deviation of tooth inclination, palatal total bone thickness of the right maxillary central incisor, arch length, and arch width are listed in Table 1.

Table1- Descriptive statistics of tooth angulation, total, cortical, and cancellous palatal bone thickness, arch width, and arch length

Groups	Inclination	Total bone thickness	Cortical bone thickness	Cancellous bone thickness	Arch width	Arch length
Labially-inclined group	123.47±1.34	6.44±0.94	1.35±0.37	5.09±0.90	43.95±3.26	25.04±2.43
Normal group	114.83±2.16	8.35±1.46	1.07±0.33	7.24±1.66	44.49±3.18	24.93±2.93
Lingually-inclined group	99.51±9.84	8.02±0.96	1.55±0.39	6.38±1.20	43.54±2.34	25.53±1.66

Table 2 shows pairwise comparisons of the groups in each measured parameter. Accordingly, the mean inclination differed significantly between all three groups (P< 0.05). The Pearson and Spearman's correlation coefficients between different parameters with normal and non-normal probability distribution are shown in Table 3. The total bone thickness values in the labially-inclined group were significantly lower than those in the other two groups (P<0.05). In addition, a statistically significant inverse correlation was observed between the inclination and palatal bone thickness of maxillary central incisors in patients of this group (P<0.05). On the other hand, no significant association was found linking the palatal bone width to tooth inclination in other groups (P=0.750 in normal group, P=0.276 in lingually-inclined group); moreover, the correlation between the cortical (P=0.207, P=0.396, and P=0.276), or cancellous (P=0.011, P=0.945, and P=0.569) bone thickness in palatally inclined, normal and lingually-inclined groups respectively and the inclination of maxillary central incisors was not statistically significant in any group.

According to Pearson/Spearman's correlation coefficient test, there was a weak association between the apical total bone thickness and palatal width as well as palatal arch length. Our results also showed that maxillary arch length and tooth inclination of central incisors were not significantly correlated (P=0.407, P=0.277, and P=0.804, respectively).

		Comparison analysis between groups		
		Group1		Group2
		Group2	Group3	Group3
Inclination	Mean difference	8.64*	23.95*	15.31*
	Standard error	0.51	1.98	2.01
	significance	0.000	0.000	0.000
	95% CI	(7.36,9.91)	(18.86,29.04)	(10.17,20.45)
TBT	Mean difference	-1.90*	-1.57*	0.32
	Standard error	0.34	0.26	0.35
	significance	0.000	0.000	0.731
	95% CI	(-2.77,-1.03)	(-2.24,-0.90)	(-0.54,1.20)
Cortical bone thickness	Mean difference	0.27*	-0.20	-0.47*
	Standard error	0.10	0.10	0.10
	significance	0.028	0.193	0.000
	95% CI	(0.02,0.52)	(-0.47,0.06)	(-0.73,-0.22)
Cancellous bone thickness	Mean difference	-2.15*	-1.29*	0.85
	Standard error	0.37	0.30	0.41
	significance	0.000	0.000	0.125
	95% CI	(-3.10,-1.20)	(-2.04,-0.54)	(-0.16,1.88)
Arch width	Mean difference	-0.54	0.40	0.95
	Standard error	0.91	0.80	0.79
	significance	0.91	0.94	0.55
	95% CI	(-2.79,1.71)	(-1.58,2.40)	(-1.01,2.91)
Arch length	Mean difference	0.10	-0.49	-0.60
	Standard error	0.76	0.59	0.67
	significance	0.99	0.79	0.75
	95% CI	(-1.78,1.99)	(-1.96,0.97)	(-2.29,1.08)

*The mean difference is significant at 0.05 level.

Table 3- Pearson and Spearman's correlation tests between variables in groups with different inclinations

Variable	Labially-inclined group		Normal group		Lingually-inclined group	
	(P) / (S)	**p-value**	**(P) / (S)**	**p-value**	**(P) / (S)**	**p-value**
Inclination of maxillary central incisor						
Total bone thickness	-0.581* (p)	0.002*	0.067 (p)	0.750	-0.227 (p)	0.276
Cortical bone thickness	-0.262 (p)	0.207	0.178 (p)	0.396	0.293 (S)	0.276
Cancellous bone thickness	-0.146 (p)	0.011	0.014 (p)	0.945	-0.120 (p)	0.569
Arch length	-0.174 (S)	0.407	0.226 (S)	0.277	-0.52 (S)	0.804
Total bone thickness						
Arch width	-0.169 (S)	0.419	-0.56 (S)	0.790	0.344 (p)	0.092
Arch length	0.034 (p)	0.873	-0.059 (p)	0.780	0.197 (S)	0.345

*shows statistically significant correlations.
Correlation is significant at 0.05 level
(P) indicates Pearson's correlation and (S) indicates Spearman's correlation test

Discussion

Careful evaluation of maxillary incisors' apical bone thickness helps the orthodontists to improve the treatment outcomes and prevent probable future iatrogenic sequelae. Due to the important role of alveolar bone thickness in limiting the sagittal orthodontic tooth movements and the existing concerns about the health of teeth and the surrounding periodontal structures, evaluation of alveolar bone thickness and the related factors by using CBCT is a priority. However, studies evaluating the relationship of apical palatal bone width of maxillary central incisors as a significant determining factor in buccolingual tooth movement are limited. Thus, this study aimed to assess the correlation of labio-palatal angulation of maxillary central incisors with palatal cortical and cancellous apical bone thickness and evaluated the probable effect of arch length and width on total bone thickness. We found that as the tooth angulation increased above 121.5o, the mean total bone thickness decreased significantly.

Although the cortical and cancellous bone thickness did not show any significant change, the values demonstrated in Table 1 showed a slight increase in the mean cortical bone thickness of labially-inclined group; this might indicate the possibility of bone deposition at the palatal side as a compensatory mechanism. Same wise, the mean cancellous bone thickness in the same group showed a non-significant decrease. Moreover, the arch width and length did not affect the total bone thickness, irrespective of tooth angulation.

The abovementioned findings should encourage the orthodontists to take extra caution in palatal movement of incisors in cases with incisor inclination more than 121.5o. The anticipated tooth movement according to the treatment requirements can be controlled through careful planning of movement mechanics. The torque control of the central incisors is of paramount importance in such cases; whereas, failure to control the mechanics of central incisors' movement can cause unfavorable external root resorption, bone fenestration, and dehiscence.

According to the literature, when root apex touches the dense cortical bone, additional forces are transferred from the root to the bone that can cause root resorption and fenestration.[18] On the other hand, dehiscence and fenestration are reported to occur with translation movements.[19-21] This iatrogenic effect cannot be repaired unless the root apex is moved away from the site.[22-24] Therefore, a careful investigation of palatal total bone thickness must be done in patients with labially-inclined incisors and an anticipated palatal tooth movement. The periodontium, supporting bone, and root integrity should be evaluated before the treatment onset. The available information should be discussed with the patients, and the side effects should be entirely explained as part of the informed consent step of treatment.

The present measurements showed that in patients with labially-inclined teeth, the possible movement of root apex palatally in a linear manner is approximately up to 3 mm into the cancellous bone, leaving 1 mm before impinging the cortical plate. Similarly, in normal and lingually-inclined groups, the possible palatal apex movement is at least 4.5 mm and 4.1, respectively. However, these numbers should be interpreted cautiously since the facial type and skeletal class can affect the cortical bone thickness.[25, 26]

The use of CBCT facilitates the evaluation of bone thickness with good resolution.[27] Although orthodontists use lateral cephalograms, panoramic view, and periapical radiographs for diagnosis on a regular basis, it is of no use in bone thickness assessment due to low accuracy.[2] Using conventional radiographs to assess the labiolingual bone width causes overestimation of measurements.[28] However, CBCT has its own limitations due to voxel size; if the cortical bone is not seen in cases with bone defect, we should remember that it does not mean that it is not there.

Since CBCT has technical limitations with minimal dimensions, it is impossible to detect a change in total bone thickness less than 0.2 mm. In order to reduce systematic errors, we repeated the measurements two times, and the interclass correlation coefficient was found to be good. Further studies with larger sample size are required to enhance the statistical power and detect the differences more accurately.

The results of this study can help the orthodontists in more accurate diagnoses and treatment planning.

Conclusion

Maxillary central incisors with labial inclination have less palatal bone support in the apical region, with a moderate correlation strength (Pearson's R=-0.581); on the other hand, there was a significant inverse correlation between total bone thickness in the palatal side of tooth apex and inclination of maxillary central incisors. The maxillary arch width and length were not correlated with total bone thickness. Similarly, the maxillary incisors' cortical and cancellous apical bone thickness did not depend on their inclination.

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Conflict of Interest

No Conflict of Interest Declared ■

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