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Comparative evaluation of changes in the alveolar bone level and thickness pre and post Alignment of crowded mandibular incisors in non-extraction cases – A prospective CBCT study

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Abstract

Aim: To compare and evaluate alveolar bone level and cortical bone thickness Pre and Post alignment of crowded mandibular incisors in non-extraction cases using CBCT.

Methods: We used 27 prealignment and postalignment cone-beam computed tomography images (13 female and 14 male subjects; average age, 16-30 years; average treatment time, 6±2 months) to measure cortical bone thickness, ridge thickness, distance from the apex to the labial cortical bone, and the distance from the cementoenamel junction to the marginal bone crest. Changes in the cementoenamel junction to the marginal bone crest distance were correlated with pretreatment measurements and treatment changes.

Results: Although there were great variations, the average facial vertical bone loss was 0.16±0.11 mm, average decrease in the mid-root level cortical bone thickness by 0.21±0.04 mm on lingual side of the alveolar bone, decrease in the mid-root level ridge thickness of the mandibular central incisors by 0.21±0.17 mm, decrease in apex-level ridge thickness of the mandibular central incisors by 0.32±0.15 mm, increase in the cortical bone thickness from apex to internal border of labial cortical bone mandibular lateral incisors by 0.8±0.07 mm.

Conclusion: Thinning of the cortical bone at the mid-root level and apex level occurs on the surface undergoing vertical bone loss in mandibular incisors. With increase in facial marginal alveolar bone level there is an increase in the cortical bone thickness from apex to internal border of labial cortical bone in lateral incisors. With increase in facial marginal alveolar bone level there is a decrease in the ridge thickness at mid-root level and apex level in the central incisors. There was no difference seen in the alveolar bone changes in the right side as compared to the left side after alignment of crowded mandibular incisors in non-extraction cases.

Keywords: CBCT, Cementoenamel junction, cortical bone

Introduction

Orthodontic tooth movement is a process where the application of force induces bone resorption on the pressure side and bone apposition on the tension side. Orthodontic movement can be either quick or slow, depending on the physical characteristics of the applied force, the size, and the biological response of the periodontal ligament. According to Vardimon, Oren, and Ben-Bassat, there is an axiom in orthodontics that says: “tooth movement leaves marks on the bone”, however, this fact is not always favorable, the bone around the alveolar socket will remodel to the same extent.[1]

In the vertical direction, during tooth extrusion, the changes in the underlying bone tissue may not follow tooth displacement, leading to an increase in the clinical length of the tooth crown, oftentimes undesirable. In transverse and anteroposterior directions, bone dehiscence and fenestration have been reported when the incisors are either protruded or retracted. According to Handelman, labial and lingual/ palatal bone cortical plates at incisors’ apexes may represent anatomical limits to orthodontic tooth movement.[1] However, sometimes there may not be coherence with this rule, and an unfavorable bone response may occur after incisor retraction. [2, 3]

Increased distances from the cementoenamel junction to the bone crest may be indicative of alveolar bone dehiscence.[4] Dehiscence results when the marginal bone is lost, and when there is still some bone in the cervical region, the defect is termed fenestration. The direction of tooth movement, frequency and magnitude of the force applied and the anatomic integrity of the periodontal tissues, determine the occurrence of dehiscence and fenestration.[5] Alveolar bone dehiscence resulting from orthodontic movement may be either not clinically evident or identified as extensive gingival recession compromising esthetics.

The alveolar bone's thickness defines the boundaries of the orthodontic tooth movement, and challenging these limits may cause undesirable collateral effects for the periodontal tissues. The most critical orthodontic movement includes dental arch expansion and incisor buccal-lingual movements. Such mechanics can decentralize teeth from the alveolar bone envelope, causing bone dehiscence, fenestrations, and gingival recession, depending on the initial morphology of alveolar bone and the amount of tooth movement.[6]

In orthodontic diagnosis, the lower incisors are of great importance and frequently form a limiting factor in treatment planning. The small labio-lingual dimension of the alveolar process in this area implies a thin layer of bony support of the lower incisors.[7] This is due to the relatively small dimensions of teeth and the small distances between them, and frequent dental crowding may intensify these difficulties further.[8] So, when moving the lower incisors orthodontically, the advantages must be weighed carefully against possible iatrogenic damage.[7]

Alleviation of crowding without extractions and reduction of tooth material can be achieved by distal movement of posterior teeth, expansion of the dental arch, and incisor proclination.[9] There is no evidence of a relationship between treatment time and alveolar bone resorption or the influence of extraction or non-extraction treatment on alveolar bone resorption.[10]

Orthodontic objectives consist of obtaining the best aspect in facial aesthetics, an efficient masticatory apparatus, stable treatment results, and healthy dental and periodontal tissues.[10] Classical Orthodontics considered the amount of dental crowding, the lower incisor position, and the growth facial pattern as the tripod which defines diagnosis and treatment planning. Contemporary Orthodontics included the smile and facial aesthetics to the list of importance. Future Orthodontics will add the patient initial periodontal morphology to the other four features.[6] Orthodontic treatment planning, assessment of the progress of the treatment and the outcome of the treatment are largely dependent on the morphology of the tooth-alveolar bone complex.[5]

Before orthodontic treatment, alveolar morphology must be determined through imaging to avoid these problems.[11] Previous studies have been done with the help of 2-D imaging, which fail to represent the complex curving structures of the tooth-alveolar complex.[5] The information provided by radiographic cephalometry is limited by its two-dimensional (2D) nature and has certain limitations and shortcomings such as the overlap of structures (or) superimposition, projection errors, magnification errors, and geometric distortion which may restrict the reliability of the results.[5,12] Cone beam computed tomography (CBCT) provides images in which anatomical structures do not overlap, which ensures greater accuracy than two-dimensional radiographic images.[4]

CBCT also provides high-resolution buccal and lingual teeth views using less radiation and at a lower cost than conventional and multi-slice conventional computed tomography (CT).[4,11] CBCT can be used as a tool to qualitatively evaluate hard-tissue changes in the alveolar bone plates in three dimensions, as the technique has a one-to-one image-to-reality ratio and the measurements are not affected by changes in the orientation of the skull. The resulting images allow clinicians and researchers to quantitatively evaluate hard-tissue changes in three dimensions.[3]

This article aims to determine alveolar bone level cortical bone thickness, ridge thickness, and distance from apex to the labial cortical bone Pre (T_0) and Post (T_1) alignment of crowded mandibular incisors and to compare the labial and lingual alveolar bone changes in the right and left mandibular incisors.

Materials and Method

The present study is an in *vivo*, experimental study, with a study sample selected using a purposive sampling method. The study's sample consisted of 27 patients whose CBCT were taken as part of their orthodontic treatment [Pre-alignment of mandibular incisors (T_0) and Post-alignment of mandibular incisors (T_1)] from the Department of Orthodontics and Dentofacial Orthopaedics at Pacific Dental College and Hospital in Udaipur. No CBCT scans were taken solely for research purposes. The sample size was determined using GPower software (Neu-Isenburg, Germany).

The study included untreated orthodontic patients aged 16-30 years, with a full complement of teeth with completely erupted mandibular 2nd molar, who had mild to moderate mandibular incisors crowding (2-5mm), and patients who require orthodontic treatment with a non-extraction treatment plan using Preadjusted Edgewise Appliances with 0.022" × 0.028" bracket slot.

The study excluded patients with mixed or deciduous dentition, missing teeth, habit of bruxism, periodontitis, craniofacial deformities, TMJ dysfunction, and patients who had undergone previous orthodontic treatment or had a history of traumatic dental injury to the lower anterior teeth.

A 5×5 cm field of view (FOV) CBCT scans were taken Pre-alignment(T_0) of the mandibular incisors for all selected patients using Carestream 9000 3D Extraoral Imaging System (Carestream Health, Rochester, New York). The patients were instructed to stand in an upright position in reference with the Frankfort Horizontal Plane parallel to the floor for accurate CBCT scans. They were also informed to breathe normally through the nose and to avoid swallowing and any movements during the scanning process.[13]

All bonding procedures were done by a single experienced orthodontist under a standardized method. The surface of the enamel for each tooth was cleaned with fine pumice and rubber cup for 10 seconds. A 37% Orthophosphoric acid etch was applied on the enamel surfaces for 15 seconds, and then the tooth was washed with water and dried. A thin layer of bonding agent (ORMCO, Orange, California, US) was coated on the etched surface with a disposable brush, then gently air-dried and light cured for 15 seconds. The metal brackets (3M Unitek™ Gemini Metal brackets, Maplewood, Minnesota, US) were positioned on the buccal surface at their proper position mesio-distally and occluso-gingivally, with a parallel angulation to the long axis of the tooth using light cure composite (ORMCO, Orange, California, US). Pressure was applied to the brackets until fully seated on the enamel surfaces. Excess adhesive around the bracket removed using a probe. Then, light curing was done for 20 seconds.[14] Bonding was first done in the maxillary arch followed by the bonding of the mandibular arch.

After 6±2 months of alignment with 0.012", 0.014", 0.016", 0.018" and 0.017" × 0.025" Nickel Titanium (NiTi) wires, Post-alignment (T_1) CBCT were taken in the similar way as that of the Pre-alignment (T_0) CBCT as explained previously.

A single CBCT machine rotation of 270-degree and 20-second-high resolution scan were obtained with isotropic voxel size set at 0.2 mm and 536×536 mm field of view. CBCT data obtained by software (Carestream Health, Rochester, New York) were reconstructed using a slice thickness of 0.2 mm. The raw images were exported into

Digital Imaging and Communication in Medicine (DICOM).[13]
All landmark identifications and measurements were done using CS 3D Imaging Software (Carestream Health, Rochester, New York). To examine the morphologic features of the alveolar bone, each CBCT image was oriented along the long axis of the mandibular right and left incisors (bisecting the pulp and the canal) in the sagittal and coronal planes, and bisecting the canal in a labiolingual direction in the axial plane at the same time.[13] [Figure 1].

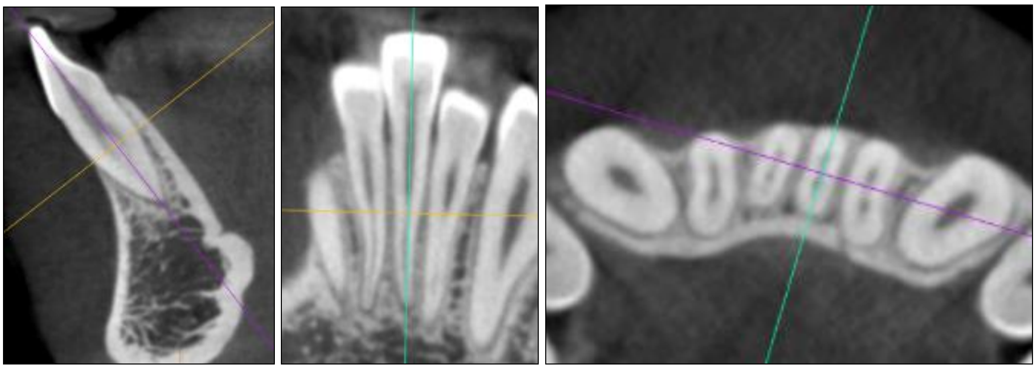

Fig 1: Orientation of tooth

Distance from the labial (F-CEJ-MBC) and lingual (L-CEJ-MBC) aspects were made from the most apical portion of the cementoenamel junction (CEJ) to the most coronal aspect of the marginal bone crest.[13] [Figure 2]

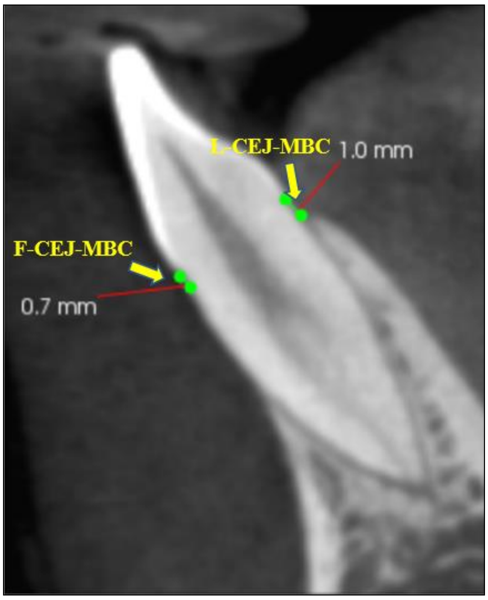

Fig 2: F-CEJ-MBC and L-CEJ-MBC

From the height of the labial CEJ point, a horizontal line was made. From this line, a vertical distance from the labiolingual midpoint of the pulp canal to the apex of the root was measured. This distance was halved, and a horizontal was drawn demarking the height at which the mid-root level ridge thickness (MRR) and mid-root level cortical bone thickness (MLCB and MFCB) was measured.[13] [Figure 3]

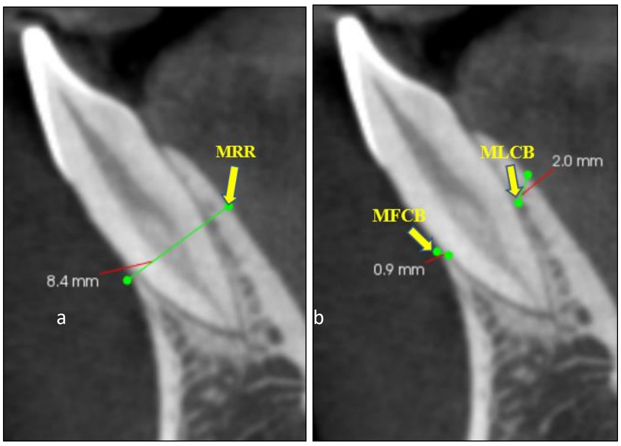

Fig 3: (a) MRR, (b) MFCB and MLCB

Another horizontal line was drawn at the height of the apex. This height was used to measure apex-level ridge thickness (AR) [Figure 14], cortical bone thickness (ALCB and AFCB), and distance (ACB) from the apex to the internal border of the labial cortical bone.[13] [Figure 4]

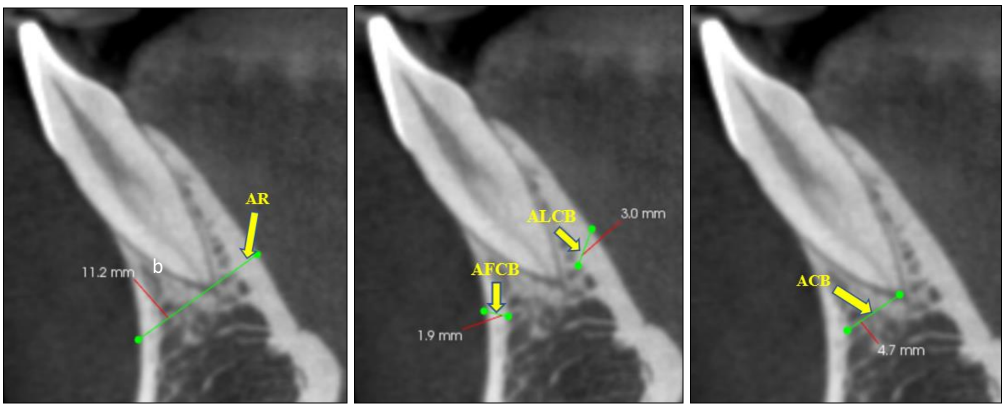

Fig 4: (a) AR, (b) AFCB, ALCB and (c) ACB

Cortical bone thickness was measured as the line from the point where the horizontal line intersected the internal border of the cortical plate, perpendicular to the external border of the cortical plate.[13] For each patient these distances will be measured using the millimetric ruler provided by software – Carestream 3D imaging. [Figure 5]

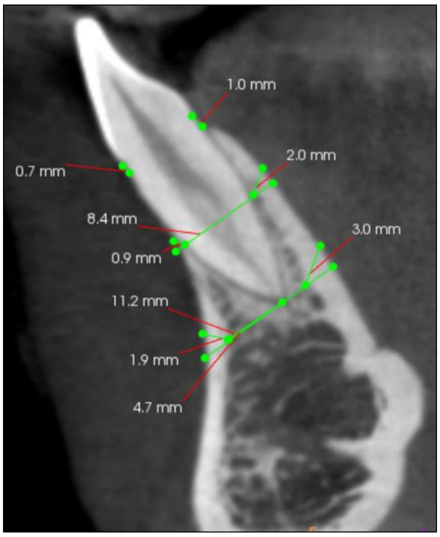

Fig 5: Millimetric measurement in CS 3D Imaging Software

Table 1: Comparison of alveolar bone level and thickness Pre (T_0) and Post (T_1) alignment of right central incisor

Variable	Interval	Mean	SD	t value	p value
F-CEJ-MBC	Pre	1.21	0.31	2.231	0.035*
	Post	1.09	0.29		
L-CEJ-MBC	Pre	1.33	0.36	-1.385	0.178
	Post	1.45	0.34		
MRR	Pre	7.41	0.96	3.396	0.002*
	Post	7.19	0.85		
MFCB	Pre	1.11	0.29	3.834	0.001*
	Post	0.89	0.37		
MLCB	Pre	1.63	0.82	1.800	0.084
	Post	1.54	0.68		
AR	Pre	9.23	2.33	3.443	0.002*
	Post	8.86	2.22		
ACB	Pre	3.55	1.46	-0.497	0.623
	Post	3.61	1.33		
AFCB	Pre	1.54	0.26	2.982	0.006*
	Post	1.40	0.38		
ALCB	Pre	2.46	0.42	3.498	0.002*
	Post	2.20	0.52		

All the data collected were entered in Microsoft Excel Spreadsheet 2019 (Microsoft Corporation, New Mexico, United States). The data was then statistically analysed by using Statistical package for Social Science (SPSS) software Version 20 (IBM Corporation, New York, United States).

Results:

There was a significant increase in the marginal alveolar bone level Post alignment (T_1) of mandibular right central incisor at F-CEJ-MBC by 0.12 mm, and a significant decrease in the alveolar bone thickness at MRR by 0.22 mm, at MFCB by 0.22 mm, at AR by 0.37 mm, at AFCB by 0.14 mm and at ALCB by 0.26 mm. (Table I)

There was a significant decrease in the marginal alveolar bone thickness Post alignment (T_1) of mandibular right lateral incisor at MRR by 0.27 mm, at MLCB by 0.26 mm and at ALCB by 0.27 mm and an increase in the marginal alveolar bone thickness Post alignment (T_1) of mandibular right lateral incisor at ACB by 0.79 mm. (Table II)

There was a significant increase in the marginal alveolar bone level Post alignment (T_1) of mandibular left central incisor at F-CEJ-MBC

Table 2: Comparison of alveolar bone level and thickness Pre (T_0) and Post (T_1) alignment of right lateral incisor

Variable	Interval	Mean	SD	t value	p value
F-CEJ-MBC	Pre	1.30	0.31	1.644	0.112
	Post	1.20	0.41		
L-CEJ-MBC	Pre	1.47	0.42	-0.716	0.480
	Post	1.54	0.43		
MRR	Pre	7.69	0.74	2.248	0.033*
	Post	7.43	0.77		
MFCB	Pre	1.05	0.36	0.561	0.580
	Post	1.01	0.39		
MLCB	Pre	1.98	0.71	2.244	0.034*
	Post	1.72	0.67		
AR	Pre	9.27	2.05	0.994	0.329
	Post	9.09	2.11		
ACB	Pre	3.49	1.46	-4.777	<0.001*
	Post	4.28	1.45		
AFCB	Pre	1.62	0.35	1.913	0.067
	Post	1.48	0.23		
ALCB	Pre	2.83	0.57	2.290	0.030*
	Post	2.56	0.62		

Table 3: Comparison of alveolar bone level and thickness Pre (T_0) and Post (T_1) alignment of left central incisor

Variable	Interval	Mean	SD	t value	p value
F-CEJ-MBC	Pre	1.28	0.38	2.704	0.012*
	Post	1.13	0.32		
L-CEJ-MBC	Pre	1.53	0.29	-0.081	0.936
	Post	1.54	0.44		
MRR	Pre	7.31	0.82	2.935	0.007*
	Post	7.11	0.75		
MFCB	Pre	1.12	0.34	1.007	0.323
	Post	1.06	0.30		
MLCB	Pre	1.69	0.55	2.866	0.008*
	Post	1.56	0.55		
AR	Pre	9.01	1.93	3.334	0.003*
	Post	8.74	1.89		
ACB	Pre	3.41	1.36	-1.947	0.062
	Post	3.89	1.43		
AFCB	Pre	1.40	0.18	0.674	0.506
	Post	1.37	0.32		
ALCB	Pre	2.40	0.31	1.727	0.096
	Post	2.27	0.45		

Table 4: Comparison of alveolar bone level and thickness Pre (T_0) and Post (T_1) alignment of left lateral incisor

Variable	Interval	Mean	SD	t value	p value
F-CEJ-MBC	Pre	1.39	0.44	3.506	0.002*
	Post	1.19	0.41		
L-CEJ-MBC	Pre	1.53	0.37	-0.753	0.458
	Post	1.60	0.31		
MRR	Pre	7.75	1.03	1.983	0.058

	Post	7.64	1.03		
MFCB	Pre	1.05	0.38	-0.677	0.505
	Post	1.09	0.39		
MLCB	Pre	2.08	0.69	2.938	0.007*
	Post	1.82	0.69		
AR	Pre	9.50	2.03	1.442	0.161
	Post	9.35	2.08		
ACB	Pre	3.52	1.38	-6.660	<0.001*
	Post	4.41	1.46		
AFCB	Pre	1.55	0.29	0.453	0.654
	Post	1.53	0.22		
ALCB	Pre	2.77	0.36	1.100	0.282
	Post	2.66	0.69		

by 0.15 mm, and a significant decrease in the alveolar bone thickness at MRR by 0.20 mm, at MLCB by 0.13 mm and at AR by 0.27 mm. (Table III)

There was a significant increase in the marginal alveolar bone level and thickness Post alignment (T_1) of mandibular left lateral incisor at F-CEJ-MBC by 0.20 mm and at ACB by 0.89 mm and a significant decrease in the alveolar bone thickness at MLCB by 0.26 mm. (Table IV)

The comparison between right and left incisors did not show any significant changes in the alveolar bone level and thickness Pre (T_0) and Post (T_1) alignment of crowded mandibular incisors in non-extraction cases.

Discussion

Tissue reaction to orthodontic tooth movement is known to occur either through bone or with bone. Tooth movement through bone is characterised by indirect resorption at a distance from the periodontal ligament, a so-called undermining resorption starting from the adjacent bone marrow.[2]

Increased distances from the cementoenamel junction to the bone crest may be indicative of alveolar bone dehiscence, and Persson *et al* (1998) [15] and Baysal *et al* (2013) [16] adopted this classification when this distance is greater than 2 mm.

In this study there was a statistically significant ($p<0.05$) increase in the facial alveolar bone level (bone deposition) by 0.16 mm as the distance from the facial/labial cementoenamel junction to marginal alveolar bone crest distance (F-CEJ-MBC) decreased from a mean of 1.29 mm Pre alignment (T_0) to a mean of 1.13 mm Post alignment (T_1). There was decrease in the lingual alveolar bone level (bone resorption) by 0.07 mm as the distance from the lingual cementoenamel junction to marginal alveolar bone crest distance (L-CEJ-MBC) increased from a mean of 1.46 mm Pre alignment (T_0) to a mean of 1.53 mm Post alignment (T_1) which was not statistically significant.

There was a statistically significant ($p<0.05$) decrease in the mid-root level cortical bone thickness by 0.21 mm on lingual side of the alveolar bone (MLCB) from a mean of 1.91 mm Pre alignment (T_0) to a mean of 1.70 mm Post alignment (T_1). There was a statistically significant ($p<0.05$) decrease in the mid-root level ridge thickness (MRR) of the mandibular central incisors by 0.21 mm from a mean of 7.36 mm Pre alignment (T_0) to a mean of 7.15 mm Post alignment (T_1) and the apex-level ridge thickness (AR) of the mandibular central incisors by 0.32 mm from a mean of 9.12 mm Pre alignment (T_0) to a mean of 8.80 mm Post alignment (T_1). Also, there was a statistically significant ($p<0.05$) increase in the cortical bone thickness from apex to internal border of labial cortical bone (ACB) mandibular lateral incisors by 0.8 mm from a mean of 3.50 mm Pre alignment (T_0) to a mean of 4.30 mm Post alignment (T_1). There was no statistical significance found in L-CEJ-MBC, MFCB, AFCB and ALCB.

A study conducted by Yodthong *et al* (2013) [3], demonstrated that there was a significant increase in labial/buccal bone thickness at the crestal level by 1.0 ± 0.3 mm and there was a non–statistically significant decrease in palatal bone thickness by 0.4 ± 0.3 mm after upper incisor retraction which was similar to the present study. Bimstein *et al* (1990) [17] also found that there was an increase in the labial crestal bone in 58.8% of the case which was also similar to our study. On the contrary, studies done by Sarikaya *et al* (2002) [18], Vardimon *et al* (1998) [19], Wehrbein *et al* (1995,1996) [20, 21], Wainwright *et al* (1973) [22], and Ten Hoeve *et al* (1976) [23] found that the labial cortical thickness decreased after incisor retraction. This may be from either shorter retraction time or small samples or it may be due to the fact that the increases in the labial crestal bone (F-CEJ-MBC) by 0.16 mm is due to lingual positioning of the procumbent mandibular permanent central incisors.

Chaudhary *et al* (2017) [5] conducted a study and found that the maximum prevalence of fenestration in the maxillary arch was found around the maxillary first premolar and the maximum prevalence of dehiscence in the mandibular arch was found around the central incisors. Enhos *et al* (2012) [11] also, observed similar findings with prevalence of dehiscence in the mandibular central incisors (30.55%). Ferreira *et al* (2010) [24], found that there was lesser dehiscence prevalence observed at the cervical level in hyperdivergent samples. Orthodontic mechanics may result in dehiscence (crestal alveolar bone loss) or fenestration (loss of alveolar bone overlying the root surface), based on the initial morphology of the alveolar bone as well as on the amount of tooth movement. Orthodontists must be aware of these predisposing factors, and movements in the labio-lingual direction should be limited.[5] The possible reason for fenestrations at the first premolars in maxillary arch could be the anatomical location of these teeth, which are in area that gets narrow upwards and in the mandible it may be because the bone becomes thinner from the posterior to the anterior region.[5] In the present study the maximum amount of dehiscence (marginal alveolar bone loss) due to the orthodontic forces applied during the treatment was also observed in the lateral incisor region by 0.07 mm at L-CEJ-MBC from Pre alignment (T_0) to Post alignment (T_1) of crowded mandibular anteriors. Although the bone dehiscence observed at L-CEJ-MBC in the present study was not statistically significant. This may be due to the small sample size of this study and due to the fact that the measurements were done after the alignment stage and not after the complete orthodontic treatment.

The association between orthodontic treatment and changes in the distance between the cementoenamel junction and the bone crest has been widely studied.[11,25,26,27] Castro *et al* (2016) [4] conducted a study and found that before orthodontic treatment, the highest alveolar bone dehiscence frequency was found in the buccal surfaces of maxillary and mandibular canines and the lingual surfaces of mandibular central incisors and after orthodontic treatment, in the buccal surfaces of maxillary canines (60%) and the lingual surfaces of mandibular central incisors (55%). A similar study was done by Yagci *et al* (2012) [28], who found a high frequency of alveolar bone dehiscence in the region of the mandibular central incisors (27.92%), regardless of type of malocclusion. Another similar study done by Evangelista *et al* (2010) [27] found that the frequency of alveolar bone dehiscence was lower in mandibular second molars (5.38%), however a study done by Lund *et al* (2012) [29] found that maxillary canines (4.2%) had the lowest frequency of bone dehiscence. These findings are contrary to our study as there was statistically significant bone deposition of 0.16 mm observed at facial marginal alveolar bone (F-CEJ-MBC) and a non-statistically significant decrease by 0.07 mm in the lingual marginal alveolar bone (L-CEJ-MBC). Although the bone dehiscence observed in the present study was not statistically significant. The previous studies found dehiscence (decreased marginal bone level) in the buccal surfaces of mandibular anterior teeth, particularly because these surfaces have a thinner cortical bone and less bone marrow. [30, 31, 32]

In this study, orthodontic treatment did not include tooth extractions, which is different from the study conducted by Lund *et al* (2012) [29]. Those authors found that during the course of extractive orthodontic treatment for a relatively common type of malocclusion, there were large decreases of marginal bone height in the buccal and lingual surfaces of anterior teeth, but these decreases were smaller in most proximal surfaces. Although some differences may be explained by reasons other than the orthodontic treatment per se, it seems likely that loss of marginal bone height, at least in the short term, is a side effect of extractive orthodontic treatment for a specific type of malocclusion, during which the retraction of teeth in anterior regions results in remodeling of the alveolar bone.

It has been previously reported that more dehiscence occurred in patients with thin symphysis than those with a thick symphysis.[33] It has been shown that a thin symphysis is associated with thinner cortical bone, and when cortical bone thickness decreases, so too does bone density. Therefore, in patients with thinner ridges, and thus thinner and less dense cortical bone, the alveolus could be more prone to microfractures associated with tooth movement, resulting in increased vertical bone loss.[34] Based on 11 subjects, Fuhrmann R (1996) [35] reported that small symphysis with reduced labiolingual bone widths, frontal crowding, and thin facial or lingual cortical bone were risk factors for bone dehiscence (marginal alveolar bone loss). Batenhorst *et al* (1974) [36] found that 6 mm of incisor proclination yielded an average of 5 mm greater bone loss compared with teeth that were not proclined. Steiner *et al* (1981) [37], using an experimental model, showed that 3.05 mm of labial incisor movement caused an average of 5.48 mm of vertical bone loss. Garlock *et al* (2016) [13] observed that on the surface where vertical bone recession happened, thinning of the cortical bone on the same side also occurred, whereas the opposite side showed less cortical bone thinning. In the present study the alveolar bone level and thickness was evaluated in mild to moderate crowding of mandibular anteriors Pre (T_0) and Post (T_1) alignment in non-extraction cases and it was found that there was a decrease in the F-CEJ-MBC distance from Pre alignment (T_0) to Post alignment (T_0), this indicated bone deposition at the facial surface of alveolar crest by 0.16 mm and there was an increase in the L-CEJ-MBC distance from Pre alignment (T_0) to Post alignment (T_1), suggesting bone resorption by 0.07 mm at the lingual surface of the alveolar crest (L-CEJ-MBC). Although the resorption at L-CEJ-MBC was not clinically significant. This may be due a smaller number of sample size. The present study showed similar results as the side where vertical bone loss occurred (L-CEJ-MBC) there was thinning of the cortical bone at the mid-root level (MLCB) by 0.21 mm.

According to a study conducted by Atik *et al* (2018) [38] where they investigated the changes in alveolar bone after maxillary incisor intrusion in deep-bite patients. They found that the amount of intrusion during upper incisor intrusion might increase the risk of alveolar bone loss. Lee *et al* (2012) [39] reported that there was no statistically significant correlation between the degree of incisor inclination change and the extent of alveolar bone change. These findings do not coincide with the findings of the present study as with increase in incisor proclination the was bone deposition at F-CEJ-MBC by 0.16 mm and bone resorption at L-CEJ-MBC by 0.07 mm, at MLCB by 0.21 mm and at ALCB. Although resorption seen at L-CEJ-MBC and ALCB were not statistically significant. This may be due to the fact that previous studies were treated with extraction of premolars.

According to a study conducted by De Angelis (1970) [40], he found that mechanotherapy induces alveolar distortion, which alters the electric environment via a process attributed to the piezoelectricity of bone. As a result, theory suggests that highly synchronized, coordinated changes are triggered, and the alveolar bone retains its structural characteristics and size as it moves due to coordinated apposition and resorption. This was contradictory to the present study as the alveolar bone did not retain its structural characteristics and size. In our study there was a statistically significant deposition of 0.16mm seen at F-CEJ-MBC and a non-statistically significant decrease by 0.07 mm seen at L-CEJMBC and a reduction in the cortical ridge thickness at the mid-root level (MRR) by 0.21 mm and at the apex root level (AR) by 0.32 mm in the mandibular central incisors. This could be attributed to the fact that due to various environmental and mechanical factors playing a role during the fixed orthodontic treatment, the amount of bone resorption is not always equal to the amount of bone deposition in the bone remodeling process.

Sarikaya *et al* (2002) [18] found that the lingual alveolar bone of the mandible decreased significantly over the central incisors (at the crest, mid-root, and apex levels) in patients who had 4 first premolars extracted, even though the labial bone maintained its thickness. This suggests that the bone thins as a tooth or root approaches cortical bone. However, as a tooth or root distances itself from the cortical bone, bone thickness does not change. It appears that the closer the root apex is moved toward the facial cortical bone during treatment, the more facial bone recession occurs. Yu *et al* (2009) [41] concluded that when teeth are facially proclined, the root apex approximates the lingual cortical plate, indicating that proclination alone will not move the apex forward. Therefore, the apex can move closer to the facial cortical bone only through uncontrolled lingual crown tipping, translation in the labial direction, a combination of these, or proclination accompanied with labial bodily movement. The decrease in the cortical bone thickness at the mid-root level (MRR) and at the apex level (AR) is the previous studies is similar to the decrease in the cortical bone thickness at the mid-root level (MRR) by 0.21 mm and at the apex level (AR) by 0.32 mm of central incisors in the present study. In our study there was a significant increase in the distance between the apex and the internal border of the labial cortical bone (ACB) by 0.8 mm but in the previous studies[13,18,41] they did not find the distance between the apex and the internal border of the labial cortical bone (ACB) to be statistically significant, this may be due to the fact that some of the previous studies were done on maxillary anteriors which have thicker cortical bone as compared to the mandibular anteriors and some studies done involved extraction of all 4 first premolars followed by retraction of incisors which provides a translatory/bodily movement as compared to the non-extraction cases where tipping may occur, owing to the increase in the distance at ACB.

Another study done by Yodthong *et al* (2013) [3] where they used loop and sliding mechanics to retract the upper incisors during orthodontic treatment found out that mechanics had no significant association with changes in alveolar bone thickness. Moreover, no significant correlation was observed between changes in alveolar bone thickness and the type of wire, retraction time, tooth movement distance, or the sex of the patient. Whereas in the present study sliding mechanics were used instead of frictionless mechanics. Further studies need to be done to compare the effect of loop and sliding mechanics to retract mandibular incisors to evaluate its effect on the alveolar bone level and thickness.

Based on the various studies conducted it can be said that in general, fenestrations (loss of alveolar bone overlying the root surface) are commonly observed in the maxilla, whereas dehiscence (marginal alveolar bone loss) are more predominant in the mandibular arch.[11] Thus the rate of tooth movement must be carefully monitored to avoid undesirable thickening of alveolar bone. Moreover, the risk of alveolar bone loss should be considered during incisor retraction, and the anatomical limitations of the labial and lingual bone on tooth movement should be greatly emphasized.[3] It was found that thinning of cortical bone occurs on the surface opposite of the one undergoing vertical bone loss and the movements of the mandibular incisor apex moving away from the facial cortical bone produce greater amounts of vertical bone loss on the facial/labial side.[13] This was contradictory to our study it was found that thinning of cortical bone occurs on the same surface (MLCB, ACB) as the one undergoing vertical bone loss (L-CEJ-MBC) and the movements of the mandibular incisor apex moving away from the facial cortical bone produce greater amounts of vertical bone loss on the lingual side (L-CEJ-MBC). This may be due to the fact that our study was done only till the alignment stage, whereas the previous studies were done till completion of orthodontic treatment.

Conclusion

Thinning of the cortical bone at the mid-root level (MLCB) and apex level (ALCB) occurs on the surface undergoing vertical bone loss (L-CEJ-MBC) in mandibular incisors.

With increase in facial marginal alveolar bone level (F-CEJ-MBC) there is an increase in the cortical bone thickness from apex to internal border of labial cortical bone (ACB) in lateral incisors.

With increase in facial marginal alveolar bone level (F-CEJ-MBC) there is a decrease in the ridge thickness at mid-root level (MRR) and apex level (AR) in the central incisors.

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