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RESEARCH ARTICLE

COMPARISON OF BUCCAL AND PALATAL CORTICAL BONE THICKNESS CHANGES DURING EN-MASSE RETRACTION USING SKELETAL ANCHORAGE- A CBCT STUDY

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ABSTRACT

Introduction: To evaluate and compare the labial and lingual cortical bone thickness in maxillary anterior segments during en masse retraction using skeletal anchorage aided by micro implants. **Methods**: The study was done in-vivo on 10 subjects**,** with angle's class i bi-maxillary protrusion and/or angle's class ii div 1 protrusion patients between the age group of 18-30 years in the permanent dentition.pre-treatment and post treatment CBCT's were taken for all the patients. titanium small head micro implants, were used as anchor units for en-masse retraction. changes in cortical bone thickness were measured at cervical(s1),middle(s2)and apical(s3)regions.
Results:One-way Anova test and Paired t test were performed on the given data which stated that statistically significant increase in cortical bone thickness was seen in at s2&s3 on the buccal aspect with a p value of <0.001,whereas on the palatal aspect there was significant decrease in s1 s2 and s3 after retraction.
Conclusion-This current study concluded that orthodontic retraction force causes significant change in the thickness of cortical plates ie: reduction in thickness along the direction of force and differential remodelling at s1,s2 &s3.Increase in labial cortical plate thickness was seen after correction of inclination and retraction of maxillary anterior segment.

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INTRODUCTION

Over the years, a lot of research has been conducted on cortical bone thickness before and after orthodontic treatment (Sarikaya *et al*., 2002; Ferreira *et al*., 2013; Vincent DeAngelis, 1970). Some of the patients demonstrated bone dehiscence that was not visible radiographically, some patients also exhibited fenestration and dehiscence in the direction of movement, although these problems did not exist before treatment (Ferreira *et al*., 2013). A basic axiom in orthodontics is "bone traces tooth movement," which suggests that whenever orthodontic tooth movement occurs, bone around the alveolar socket will remodel to the same extent (Vincent, 1970; Murray, 1980; Reitan, 1963; Reitan, 1964), ie, a ratio of bone remodeling to tooth movement (b/t) of 1:1 develops (Reitan, 1963; Reitan, 1964). In the transverse dimension, dehiscence and fenestration of the buccal cortical plate have been reported in rapid maxillary expansion, suggesting that root movement of the buccal dental segment surpasses lateral bone remodeling (Vardimon *et al*., 1991). Even a single tooth movement in a buccolingual direction can produce the same effect (Wainwright, 1973).

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In the vertical dimension, during orthodontic tooth extrusion, bone increase is usually less than the dental displacement, leading to an increase in the clinical crown (Kajiyama *et al*., 1993). In the same vertical dimension, tooth intrusion showed more coherence in maintaining a 1:1 b/t ratio (Murakami *et al*., 1989), though tooth intrusion has been shown to exceed bone reduction (Melsen *et al*., 1988; Melsen *et al*., 1989). In the sagittal dimension, a different reaction is demonstrated between the posterior and anterior segments. In the posterior dental segment, a 1:1 b/t ratio is well maintained as long as tooth movement is restrained between the two cortical plates, ie, affecting the intermittent cancellous bone in the anterior segment, both the palatal (or lingual) and the labial cortical plates are involved in all antero-posterior tooth movements of the maxillary (or mandibular) anterior dental segments. The bulk of evidence supports the doubt that a 1:1 b/t ratio does not hold true in the anterior segment (Engelking, 1982). In an orthodontist's office, the most common cases one gets to see is class 2 malocclusions and bimaxillary protrusions. Both of which require anterior teeth retraction to attain a stable occlusion and better profile (Kaur *et al*., 2013; Park). Treatment mechanics for both types of malocclusions would require a maximum anchorage in most cases as the anterior segments need to be retracted more than the protraction of posterior teeth, therefore anchorage preparation has to be meticulously planned so as to prevent anchorage loss (Bae *et al*., 2002; Al-Sibaie *et al*., 2013). Anchorage loss is the reciprocal reaction of the anchor unit that can obstruct the success of orthodontic treatment by complicating antero-posterior correction. Anchorage loss is a reciprocal reaction that could obstruct the success of orthodontic treatment by complicating the antero-posterior correction of the malocclusion and possibly detracting from facial esthetics. A major concern when correcting severe crowding, excessive overjet, and bimaxillary protrusion is control of anchorage loss. Anchorage loss is an unfavorable sequele that has plagued clinicians since the dawn of orthodontics. The introduction of skeletal anchorage has largely helped counteract this problem and has improved treatment outcomes.

Retraction of the anterior segment can be done with the canine being distalised first, followed by the other four incisors, this reduces the anchorage burn of the posterior teeth. Though this method is popular, it still takes extra time because of the lengthy retraction process (Al-Sibaie *et al*., 2013; Hyo-Sang, 2004). Keeping time as a determining factor in mind, most patients opt for en-masse retraction of all 6 anterior teeth ,which does cause anchorage loss. In such cases anchorage can be augmented by the use of intraoral devises such as transpalatal bars and nance palatal buttons or by extraoral appliances such as headgears (Mclaughlin, 1991; Creekmore, 1983). However these intraoral devices provide minimal anchorage preservation and extraoral devices require good patient compliance[19].Extraoral appliances are bulky and the patient does not prefer wearing it in public.

Creekmore in his studies with mini screws gave us an insight on the possibility of absolute skeletal anchorage (Sung-Seo, 2010). Mini screws,dental implants and mini plates can be used for absolute anchorage and they have numerous benefits such as ease of placement and removal, cost effectiveness and it requires minimal/no patient compliance. Being small in size they can be placed in various parts of the bone intraorally,even in between the roots of teeth without causing discernable damage (Sung-Seo, 2010; Deguchi, 2003). What is most advantageous to orthodontists is the fact that microimplants can be almost immediately loaded with orthodontic forces after placement (Melsen, 2003; Mah, 2005). These type of implants can be called as temporary anchorage devices because of the ease of removal. They do not get osseointegrated with the bone therefore they can be removed when the term of their use is completed (Mah, 2005). Studies have reported successful treatment of bimaxillary protusion with enmasse retraction method done with the use of micro implant aided anchorage system (Upadhyay, 2008; Upadhyay *et al*., 2008). The best method to analyze alveolar bone thickness in all dimensions is a 3-dimensional approach. One such method could be computed tomography. CBCT is an evolution of the original computed tomography proposed by Hounsfield and Comark. CBCT scans allow the orthodontist to assess the patient's hard and soft tissue in three dimensions (3d) (Grauer, 2009; Hatcher, 2003). The accuracy and reliability of such images have been tested and were found to be adequate for implant planning, periodontal disease quantification, and assessment of tumor/lesion volumes (Misch, 2006). The need for this investigation is to evaluate the precise changes of maxillary labial and lingual cortical bone thickness during en-masse retraction by micro implant anchorage system.

MATERIALS AND METHODS

The study was done in-vivo on 10 subjects, among the patients with angle's classI bi-maxillary protrusion and/or angle's classII div 1 protrusion patients between the age group of 18-30 years in the permanent dentition. Patients underwent en-masse using TAD aided skeletal anchorage.Consent was taken regarding placement and removal of TADs under local anesthesia, the extraction of 2 upper and 2 lower premolars and of 2 CBCT scans to be done.

Inclusion

Criteria

- class I bi-maxillary protrusion cases, class II div 1 malocclusion cases
- no impacted teeth except third molars
- no missing teeth except third molars medically fit individuals with no systemic diseases and not under any medications.
- healthy periodontium
- age group 18-30

Exclusion criteria

- previous history of orthodontic treatment
- syndromic patients
- cleft lip and palate cases
- pregnant women

In all subjects pre-treatment CBCT scans of the anterior maxillary dentoalveolar complex region were taken.All patients were treated with the preadjusted edgewise appliance system, MBT prescription, slot size 0.022 x 0.028".The teeth were levelled and aligned with the following wire sequence- 0.016 HANT, 0.017x0.025 HANT, 0.019x0.025 HANT. The initial round wire was kept as long as the crowding was relieved, the average time being about 3 months. Only the first molars were banded, the second molars and the teeth mesial to the first molars were bonded. After levelling and aligning, 0.19 x 0.025 stainless steel archwires were placed for a period of 4 weeks before the start of retraction phase. This was done to ensure that the wires would remain passive. These wires had crimpable hooks placed distal to the lateral incisor brackets, which would aid in retraction. Periapical radiographs, taken with the paralleling technique, aided in the placement of the TADs. Titanium small head micro implants, were used as anchor units,the diameter being 1.3mm and 0.6mm in the maxilla.

The TADs were placed between the roots of the 2nd premolar and 1st molar at a height of about 3-5mm at the muco-gingival junction.to avoid trauma, these were placed 2-3 mm higher if there was any root interference predicted. Retraction was done with the help of e-chains/closed coil springs from the TAD head to the crimpable hook. The force measured in each quadrant was averaged to about 150 grams. The surgical procedure for TAD placement involved manual insertion of the screws into the buccal cortical bone under local anesthesia with a TAD driver (Figure1:a,b,c,d,e).TheTADs were checked for primary stability and strict instructions were given to the patient regarding oral hygiene. The TADs were then immediately loaded extending from the TAD head to the crimpable hooks for en-masse retraction of anterior teeth.After retraction was completed, another CBCT scan was done to evaluate changes in cortical bone thickness in both cases.

Fig1.c

Fig 1.d

Fig 1.e

Fig1.Intraoral photographs after TAD placement and loading. a) right lateral view b) left lateral view c) frontal view d) maxillary occlusal view e) mandibular occlusal view

Figure 2.a Radiant software panel showing saggital view

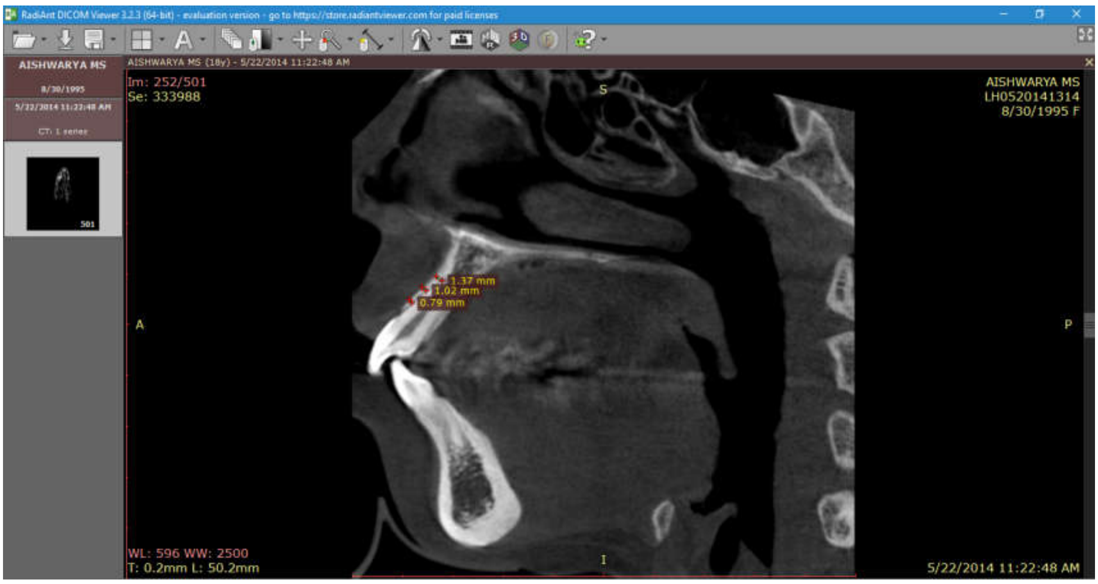

Figure 2.b Linear measurements of buccal cortical bone thickness

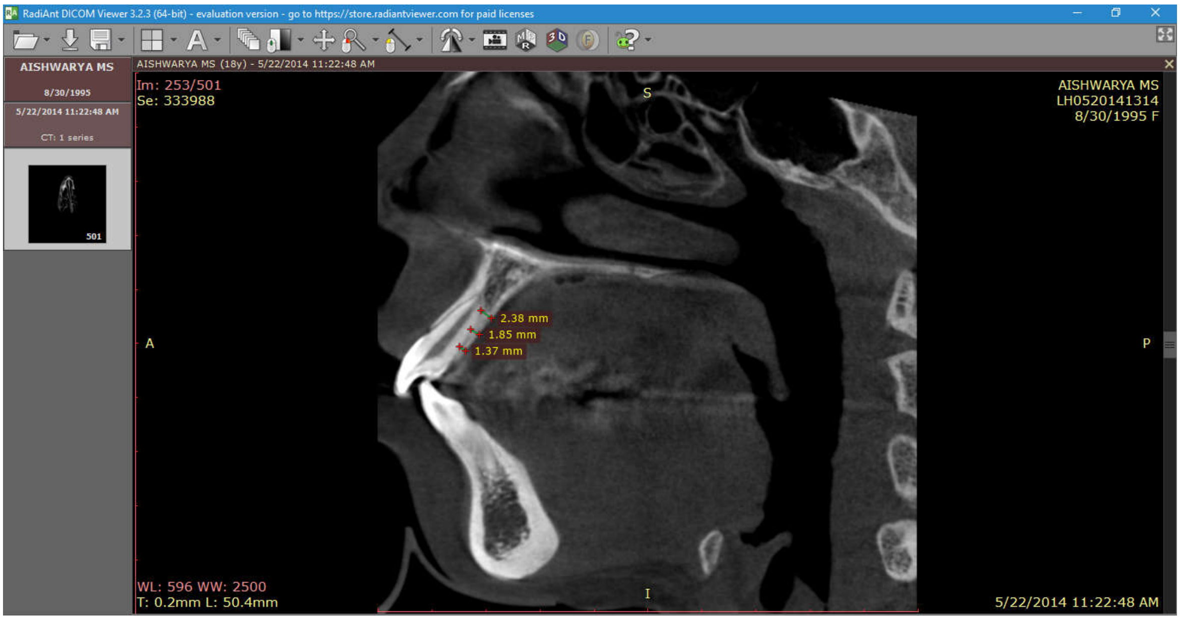

Figure 2.c Linear measurements of lingual cortical bone thickness

Table 1. Comparison of mean values of maxillary palatal cortical bone width measured from CBCT scans before and after retraction of maxillary anterior teeth

		T1		T2		Difference		P
		X	Sd	X	Sd	X	Sd	
Maxillary palatal right lateral	S1	1.33	0.06	1.12	0.10	0.03	0.09	0.001
	S2	2.17	0.13	1.95	0.14	0.27	0.04	0.001
	S3	2.72	0.10	2.40	0.21	0.36	0.20	0.001
Maxillary palatal right central	S1	1.50	0.06	1.23	0.07	0.26	0.10	0.001
	S2	2.54	0.33	2.16	0.37	0.37	0.23	0.001
	S3	3.33	0.19	3.07	0.19	0.25	0.11	0.001
Maxillary palatal left central	S1	1.51	0.07	0.87	0.11	0.26	0.059	0.001
	S2	2.53	0.27	2.21	0.37	0.32	0.24	0.001
	S3	3.32	0.19	1.81	0.77	0.25	0.23	0.001
Maxillary palatal left lateral	S1	1.31	0.07	1.24	0.04	0.18	0.11	0.001
	S2	2.22	0.11	1.95	0.14	0.27	0.04	0.001
	S3	2.77	0.09	2.40	0.21	0.36	0.20	0.001

The Dicom files were then transferred to the radiant dicom viewer (64-bit) software for cortical bone thickness estimation. The length tool was used for linear measurements of bone thickness. (Figure: 2a,b,c). This method was used to measure the pre treatment and post treatment cortical bone thickness of all the maxillary anterior teeth and the mean value was taken. .

RESULTS

Changes in palatal cortical bone

Comparison of mean values of maxillary palatal cortical bone width measured from CBCT scans before and after retraction of maxillary anterior teeth (Table 1&5).On comparison of the mean values of pre treatment and post treatment palatal cortical bone thickness, the mean values of post treatment is higher and are statistically significant at s1,s2 and s3 level (Table:2,3,4). At s1 level all four incisors showed a p value of <0.001. At s2 level right and left lateral incisor and right central incisor showed a p value of <0.001 while left central incisor cortical bone thickness changes showed p value of 0.002. At s3 level right and left lateral incisor and right central incisor showed a p value of <0.001 while left central incisor cortical bone thickness changes showed p value of 0.007.

Changes in buccal cortical bone

On comparison of the mean values of PRETREATMENT and POSTTREATMENT buccal cortical bone thickness of maxillary incisors the mean values of POSTTREATMENTl is higher and is statistically not significant(Table 6).At s2 level right and left lateral incisor and right central incisor showed a p value of <0.001 while left central incisor cortical bone thickness changes showed p value of 0.012 (Table 7). At s3 level right and left lateral incisor and right central incisor showed a p value of <0.001 while left central incisor cortical bone thickness changes showed p value of 0.001(Table 8)

DISCUSSION

The samples selected in the study was mainly bimaxillary dentoalveolar proclination and needed maximum anchorage control for retraction of the anterior teeth. anchorage was reinforced using temporary anchorage devices or micro-implants in the alveolar bone between 2^{nd} premolar and first molar in the right and left maxillary segments. In patients with severely proclined or flared incisors, it is observed that the thickness of buccal cortical bone is comparitivly less due to anterior positioning of the incisors against the cortical plate. In extreme cases periodontal bone defects such as fenestration and dehiscence can be observed which cannot be visualised on routine diagnostic procedures such as clinical examination and conventional radiographs. It is of utmost importance for the orthodontist to evaluate the quality and quantity of supporting bone prior to retraction of anterior teeth in to the space available, to avoid any iatrogenic damage such as loss of periodontal support, delayed closure of spaces and bone defects i.e fenestration and dehiscence.

Table 2. Comparison of the pre and post values at s1

			Mean	N	Std. Deviation	Paired differences		T	Df	P value
S1	Pair 1	Pretreatment right lateral	1.333	10	0.06961	0.212	0.085088	7.879	9	≤0.001
		Post treatment right lateral	1.121	10	0.109793					
	Pair 2	Pretreatment right central	1.5	10	0.066667	0.266	0.104158	8.076	9	≤0.001
		Posttreatment right central	1.234	10	0.075454					
	Pair 3	Pretreatment left central	1.516	10	0.075307	0.268	0.059777	14.177	9	≤0.001
		Posttreatment left central	1.248	10	0.042374					
	Pair 4	Pretreatment left lateral	1.316	10	0.071678	0.18		4.758	9	0.001
		Posttreatment left lateral	1.136	10	0.104478					

Table 3. Comparison of the pre and post values at s2

			Mean	N	Std Deviation	Paired differences		T	Df	P value
S2	Pair 1	Pretreatment right lateral	2.172	10	0.1334	0.267	0.097758	8.637	9	≤0.001
		Posttreatment right lateral	1.905	10	0.197611					
	Pair 2	Pretreatment right central	2.54	10	0.336914	0.374	0.236653	4.998	9	0.001
		Posttreatment right central	2.166	10	0.39733					
	Pair 3	Pretreatment left central	2.537	10	0.27244	0.321	0.244334	4.155	9	0.002
		Posttreatment left central	2.216	10	0.378981					
	Pair 4	Pretreatment left lateral	2.228	10	0.119703	0.272	0.04341	19.814	9	≤0.001
		Posttreatment left lateral	1.956	10	0.141044					

Table 4. Comparison of the pre and post values at s3

			Mean	N	Std deviation	Paired differences		T	Df	P value
S3	Pair 1	Pretreatment right lateral	2.726	10	0.10997	0.283	0.142521	6.279	9	<0.001
		Posttreatment right lateral	2.443	10	0.219902					
	Pair 2	Pretreatment right central	3.332	10	0.197135	0.258	0.117265	6.957	9	<0.001
		Posttreatment right central	3.074	10	0.192827					
	Pair 3	Pretreatment left central	3.326	10	0.199566	0.253	0.231903	3.45	9	0.007
		Posttreatment left central	3.073	10	0.166002					
	Pair 4	Pretreatment left lateral	2.772	10	0.098522	0.369	0.204094	5.717	9	<0.001
		Posttreatment left lateral	2.403	10	0.218177					

Table 5. Comparison of mean values of maxillary buccal cortical bone width measured from CBCT scans before and after retraction of maxillary anterior teeth

		T1		T2		Difference		P
		X	Sd	X	Sd	X	Sd	
Maxillary labial right lateral	S1	0.81	0.06	0.84	0.12	-0.03	0.13	0.001
	S2	0.92	0.03	1.01	0.04	-0.08	-0.10	0.001
	S3	1.02	0.04	1.13	0.05	-0.10	0.04	0.001
Maxillary labial right central	S1	0.84	0.04	0.87	0.08	-0.03	0.11	0.001
	S2	0.89	0.04	1.00	0.06	-0.10	0.05	0.001
	S3	1.04	0.05	1.15	0.05	-0.11	0.05	0.001
Maxillary labial left central	S1	0.83	0.08	0.87	0.11	-0.03	0.09	0.001
	S2	0.90	0.03	0.97	0.08	-0.06	0.06	0.001
	S3	1.00	0.05	1.11	0.06	-0.10	0.06	0.001
Maxillary labial left lateral	S1	0.82	0.06	0.87	0.10	-0.04	0.10	0.001
	S2	0.84	0.05	1.00	0.07	0.27	0.04	0.001
	S3	1.00	0.04	1.16	0.05	-0.15	0.05	0.001

Table 6. Comparison of the pre and post maxillary buccal cortical bone thickness values at s1

			Mean	N	Std deviation	Paired differences		T	Df	P value
S1	Pair 1	Pretreatment right lateral	0.813	10	0.062725	-0.03	0.136545	-0.695	9	0.505
		Posttreatment right lateral	0.843	10	0.123832					
	Pair 2	Pretreatment right central	0.843	10	0.046679	-0.03	0.112744	-0.841	9	0.422
		Posttreatment right central	0.873	10	0.088826					
	Pair 3	Pretreatment left central	0.839	10	0.053635	-0.038	0.114581	-1.049	9	0.322
		Posttreatment left central	0.877	10	0.110559					
‘	Pair 4	Pretreatment left lateral	0.825	10	0.066039	-0.048	0.105494	-1.439	9	0.184
		Posttreatment left lateral	0.873	10	0.102746					

Table 7. Comparison of the pre and post maxillary buccal cortical bone thickness values at s2

			Mean	N	Std deviation	Paired differences		T	Df	P value
S2	Pair 1	Pretreatment right lateral	0.922	10	0.036758	-0.089	0.039285	-7.164	9	≤0.001
		Posttreatment right lateral	1.011	10	0.041218					
	Pair 2	Pretreatment right central	0.895	10	0.041164	-0.108	0.053707	-6.359	9	≤0.001
		Posttreatment right central	1.003	10	0.066173					
	Pair 3	Pretreatment left central	0.907	10	0.032335	-0.068	0.068767	-3.127	9	0.012
		Posttreatment left central	0.975	10	0.082496					
	Pair 4	Pretreatment left lateral	0.849	10	0.059339	-0.157	0.082064	-6.05	9	≤0.001
		Posttreatment left lateral	1.006	10	0.070585					

Table 8. Comparison of the pre and post maxillary buccal cortical bone thickness values at s3

			Mean	N	Std deviation	Paired differences		T	Df	P value
S3	Pair 1	Pretreatment right lateral	1.028	10	0.044422	-0.109	0.041486	-8.308	9	≤0.001
		Posttreatment right lateral	1.137	10	0.054782					
	Pair 2	Pretreatment right central	1.045	10	0.050166	-0.113	0.053759	-6.647	9	≤0.001
		Posttreatment right central	1.158	10	0.050509					
	Pair 3	Pretreatment left central	1.007	10	0.056578	-0.103	0.066005	-4.935	9	0.001
		Posttreatment left central	1.11	10	0.065828					
	Pair 4	Pretreatment left lateral	1.008	10	0.048944	-0.158	0.056726	-8.808	9	≤0.001

CBCT is used in our study for precise qualitative and quantitave evaluation of the supporting alveolar bone. The amount of retraction that can be carried out for the anteriors is limited to the cortical plates on the labial and palatal sides also known as the orthodontic walls. As all the samples taken, underwent first premolar extraction, maximum amount of space available was used for retaction of anteriors using micro-implants which prevents taxing of anchorage from the posterior segment. Orthodontic force is known to remodel the supporting alveolar bone resulting in movement of the teeth along the socket. Previous studies have shown that the displacement of teeth and supporting alveolar bone is not at the same rate[13]. Remodelling along the alveolar bone itself is also differential i.e the amount of remodelling at different levels of alveolar bone and anatomic locations, is also varied. The results of the present study stated that there was a resultant increase in labial cortical bone thickness whereas the cortical bone thickness of the palatal region decreased to a significant level.this finding is supported by the similar pattern of bone remodelling in study conducted by Wehrbein *et al*,who concluded that there was significant reduction in the cortical bone thickness toward the direction of tooth movement.

The increase in the labial cortical plate thickness was also observed to be differential at levels, s1, s2 and s3. Although there was minimal increase in the post treatment thickness of labial cortical plate at level s1, the difference was not statistically significant. This differential remodelling can be explained by the bone bending theory proposed by Farrar which explains the displacement by bending of the bone rather than absolute remodelling. The retraction force was applied from the micro-implant as close to centre of resistance as possible to facilitate bodily tooth movement of the anterior segment. during the levelling and aligning phase. Complete torque expression was achieved by rectangular arch wire, to position the root in the cancellous bone, which was positioned close to the labial cortical plate. The post treatment CBCT was taken immediately after completion of treatment to evaluate the immediate effects of retraction force on the cortical plate thickness, and eliminate any change due to osteoblastic activity during the retentive phase. New alveolar bone formation at the defect sites are expected to form by 4 to 6 months of retention period. Ten Hoeve and Mulier, on the basis of their laminagraphic evidence, suggested that the cortical plate would be reestablished within 6 months, irrespective of the amount the tooth movement.

This effect can be attributed to two reasons, first being the osteoblastic activity during the retention phase and second being the relapse of tooth movement and torque. The cortical plate was evaluated around the four anterior teeth i.e centrals and lateral incisors of left and right side. The change in thickness was not uniform along the entire segment. Along the labial cortical plate of left central incisor ,the mean increase at level s1,s2,s3 was 0.068mm and 0.015mm respectively. Where as for left lateral, it was 0.0157mm and 0.0158mm at s1,s2 and s3 respectively. The values varied between the right and left segments , at right central the increase in thickness was at s1,0.108mm at s2 and 0.113mm at s3 .and for right lateral the amount of increase was at s1,0.089 at s2 and 0.109mm at s3. The changes at s1 are minimal and statistically insignificant. Lingual cortical plate being along the direction of force applied ,undergoes osteoclastic activity resulting in apparent reduction in cortical plate thickness after retraction. The decrease in cortical plate thickness of left cental incisor at level s1,s2,s3 was 0.268,0.321 and 0.253 respectively. Where as for left lateral,it was 0.18,0.272 and 0.369 at s1,s2 and s3 respectively. At right central the decrease in thickness was 0.266 at s1, 0.374 at s2 and0.258 at s3 .and for right lateral the amount of increase was 0.212 at s1 0.267 at s2 and 0.283 at s3.Melsen stated that there is more osteoblastic activity in tension sites and osteoclastic activity on the compression, which explains the increased thickness at labial cortical plate and reduced thickness at palatal cortical plate.

Conclusion

The results indicates that when maxillary anteriors are retracted using TADs there is differential deposition and resorption in the anterior cortical bone thickness. These changes can be precisely measured using CBCT and will help to reduce the risk of dehiscence and fenestration. Long term follow up is needed to evaluate the amount of cortical bone repair that takes place during the retentive period.

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