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A CBCT assessment of bone density changes after accelerated orthodontic retraction of canine by microosteoperforations

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Abstract

AIM: The study was conducted to assess the changes in bone density before and after performing accelerated orthodontic maxillary canine retraction by microosteoperforations (MOPs).

MATERIALS AND METHODS: Forty patients (120 cone-beam computed tomography [CBCT] images) within the age group of 15 to 25 years undergoing fixed orthodontic treatment with bilateral maxillary first premolar extraction were enrolled in this study. The right and left sides of the maxillary jaw in the same patients were selected as experimental and control sites. To accelerate the tooth movement, MOPs were performed distal to the canine root in the extraction space under local anesthesia with a miniscrew. Thereafter, the maxillary canine retraction was initiated using a NiTi closed coil spring. The CBCT images were taken and evaluated at the following time intervals: 1 week before MOPs(T0);1 week after MOPs(T1);3 weeks after MOPs(T2).

RESULTS: A statistically significant reduction in bone density was observed at the center of resistance of canine on the experimental site (after MOPs) at 1 week and 3 weeks (T0-T1 = 0.000,0.115; T1-T2 = 0.0025,0.0117), whereas a statistically non-significant difference was found 1 week before and 3 weeks later in the control group.

CONCLUSION: Accelerated orthodontics by MOPscan result in a substantial reduction in bone density during canine retraction, leading to an increase in the tooth movement rate, hence lowering the overall orthodontic treatment time.

Keywords:

Canine retraction, CBCT, microosteoperforations, mini screw

Introduction

In fixed orthodontics, a major drawback, especially for adult patients is the prolonged treatment time. Over the last few years, accelerated orthodontics has been introduced to overcome this issue. Accelerated orthodontics was popularized by the Wilcko brothers, who coined the term "Wilckodontics." Subsequently, many device-assisted and surgical approaches have been introduced to accelerate the tooth movement, thus decreasing the treatment time.[1]

Some examples of effective approaches in accelerating orthodontic tooth movement are as follows: distraction osteogenesis, corticotomy, osteotomy, Piezocision technique, periodontally accelerated osteogenic orthodontics (PAOO), and microosteoperforations (MOPs). However, all these surgical approaches have major disadvantages, such as their

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aggressiveness, the cost factor, and the possible risk of complications.[2] These approaches are dependent on the regional acceleratory phenomenon (RAP), which occurs after any surgical trauma. It is a naturally localized reaction of soft and hard tissues in response to trauma and is related to increased perfusion, bone turnover, and reduced bone density. It is comparable to the procedure related to normal fracture healing, which consists of a reactive phase, a reparative phase, and a remodeling phase.

Alikhani *et al*. reported that MOP, a minimally invasive method, resulted in a 60% increase in the tooth movement rate[3,4];however, very few studies have analyzed bone density changes using this method.[3-8]

Alikhani *et al.*[3] conducted a study on both animal models on rats and a human clinical trial on MOPs treatment and concluded that MOP significantly increased molar protraction with a concomitant rise in osteoclastogenesis, inflammatory cytokine expression, and remodelingofalveolar bone. In rats and humans, an increase in the rate of canine retraction concomitant with increased Levels of Tumor Necrosis Factor-α (TNF-α) and interleukin 1-beta (IL-1β) levels in the gingival crevicular fluid was observed. Decreased bone density observed following surgical trauma stems from an increase in bone porosity and calcium depletion.[3] Verna *et al.*and Bridges *et al.* observed that after orthodontic treatment, there was decreased alveolar bone fraction and tissue mineral density in rat models.[9,10] Cattaneo *et al.*[11] studied the reaction of the alveolar bone to orthodontic forces with three-dimensional (3D) finite element models of the teeth and jaw bone. Factors related to bone remodeling are produced by periodontal ligament cells in adequate amount to disperse into Gingival crevicular fluid (GCF). The GCF level of prostaglandin E2 (PGE2) replicates the biologic action in the periodontium at the time of orthodontic tooth movement, and it is significantly greater in both compression and tension surfaces.[12]

Various non-invasive methods can be used to evaluate the alveolar bone density, such as dual-energy X-ray absorptiometry, digital image analysis of microradiographs, and ultrasound. However, cone-beam computed tomography (CBCT) gives both density and structure of body tissue.[13] CBCT provides 3D images, and it is low cost with low ionizing radiation exposure in comparison to computed tomography (CT).[14] Currently, very fewstudies have reported the changes in bone density after performing MOP using CBCT.[5,13,15,16] The use of CBCT and micro CT in orthodontic research has provided great insights into alveolar bone density changes incident to tooth moving forces.[17] CBCT can be used in orthodontic research to measure alveolar bone density, width, and treatment outcome.[14,18] Hsu *et al.*[13] assessed the changes in bone density around the teeth after 7 months of orthodontic treatment using the CBCT method.They concluded that CBCT is practical for assessing changes in bone density around teeth during orthodontic treatment. Ibrahim *et al.*[16] using CBCT assessed the root surface changes and bone density with two different methods of accelerated orthodontic tooth movement. They observed a decrease in bone density in both groups after canine retraction.However, the image quality of CBCT is influenced by many factors, such as voxel resolution, Field of View (FOV), and object morphology.[13]

The present study was conducted with a null hypothesis stating that there is no difference in bone density with control and MOP method after accelerated orthodontic retraction of maxillary canine. The present study was conducted to assess the changes in bone density before and after accelerated orthodontic retraction by the MOP method using CBCT images.

Materials and Methods

This prospective controlled clinical trial was conducted in the Department of Orthodontics and Dentofacial Orthopedics, from Feb 2017 to April 2018, after obtaining ethical approval from the institutional ethics committee IEC, RIB Ref no. 2017/022. The sample consisted of 40 patients within the age group of 15 to 25 years. Written informed consent was taken from all patients before starting the treatment.

The sample size was chosen based on the earlier studies.[5,19] The sample size was calculated with the help of PS: Software Version 3.1.2for Power and Sample Size Calculation (Vanderbilt University, Nashville, Tennessee, USA). Based on an overall clinical performance score of 56%, 36 cases were required in each group to test the null hypothesis with a power of 0.8. Hence, 40 patients were selected to increase the power of the study and recompense for possible dropouts. During the study period, it was planned to incorporate more patients. A statistical significance of $P < 0.05$ can be accomplished.

The inclusion criteria for the study were as follows: patients with Angle's Class I malocclusion or Angle's Class I bi-maxillary protrusion malocclusion requiring first premolar extraction, patients with no radiographic bone loss, no systemic disease, no history of periodontal disease, and no history of medication or smoking. Patients not willing to participate were excluded from the study.

MOP procedure

The subjects enrolled were treated using a Roth prescription pre-adjusted straight wire appliance of a 0.022 slot. The right side of the patients' maxilla was the experimental site where MOPs were performed, where as the left side was the control site where MOPs were not performed. Self-drilling temporary anchorage devices (TADs) (Unitek™ TAD, 1.8 × 8 mm) were placed buccally between the upper second premolar and first molar bilaterally. Indirect anchorage was done by placing L-shaped 0.019″ × 0.025″ stainless steel wire in the auxiliary tube of the upper first molar bands and attached to the mini-screws with a flowable composite ball. Later, premolar extraction was done to remove any bias. The canine retraction phase was initiated after initial alignment and complete healing of the extraction socket.[5]

A preretraction (T0) alginate impression and CBCT image were taken for the upper arch, and a rigid stainless steel retraction arch wire 0.017″ × 0.025″ was inserted. An L-shaped wire guide with its vertical segment equal to two-thirds of canine root length was ligated to the canine bracket. Three random perforations in the vertical plane were performed distal to the canine (experimental site) midway in the extraction space under local anesthesia. For MOP, at midway in the extraction space, mini-screw was screwed using TAD on the experimental site into the alveolar bone mesiodistally and perpendicular to the bone surface in the extraction area until slight blanching of the surrounding soft tissue was attained to ensure full-length penetration; then, the TAD was unscrewed and removed. The canine retraction was then started bilaterally using a NiTi closed coil spring engaged from molar tube hook to canine hook by applying 150 g of force.[5]

Measurement of bone density using CBCT

The beam hardening effect was prevented by eliminating patients with metal crowns, dental bridges. The CBCT images were taken for each patient before start of the procedure (T0), 1 week after (T1), and 3 weeks (T2) after orthodontic treatment (MOPs) using the Galileos Comfort Sirona CBCT machine. Three CBCT images per patient, that is, 120 CBCT images, were taken for evaluation [Figure 1]. Before CBCT scanning, the patient was positioned with the head upright so that the intersection lines were straight horizontal and vertical through the center of the region of interest.[13] In all patients, the CBCT imaging was done using the following parameters: 3.8 mA, 120 kVp, the scan time of 40 s, focal spot of 3.3 mm, 16-cm field of view (FOV), and voxel size of 0.093 mm.[18] To measure bone density, a3D model was resliced to attain a new CBCT slice of the teeth that was perpendicular to the longitudinal axis of the teeth (i.e., passing from the tips of the crowns to the tips of the roots) using the "reslice" function in the software program. To check the intra-examiner reliability and accuracy in the location of landmarks and the linear measurements, 20 CBCT images were randomly chosen and the obtained measurements were compared with the first measurements to determine the difference. The bone density around the tooth was evaluated at the center of the resistance of canine and root apex. The combined area of the tooth with periodontal ligament (PDL) was deducted from the entire area (tooth plus PDL plus surrounding bone) using a Boolean operation to obtain the bone density (as the grayscale value) of the bone around the tooth.[13]

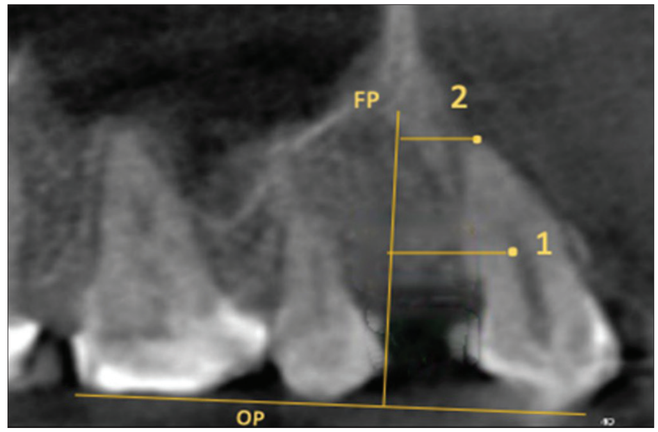

Figure 1: CBCT image showing canine retraction measurements: constructed frontal plane (FP) and constructed occlusal plane (OP).(1) Upper right canine center distance moved (center of canine to FP);(2) upper right canine root apex distance moved (root apex to FP)

Measurement of tooth movement

Evary upper stone model (T0–T4) was scanned using the 3Shape R900 scanner (3Shape A/S, Copenhagen, Denmark) to achieve the .stl format of the digital upper model. With 3-point superimposition, the digital model (T0) was superimposed on the pre-retraction CBCT image using T1-T3 and the frontal plane (FP) was constructed, which was used as a reference plane to detect the rate of canine retraction and anchorage loss.[5]

Statistical analysis

The obtained data were analyzed using SPSS (Statistical Package for Social Sciences), version 22.0. A paired *t*-test was employed to compare the level of significance in the bone density between the experimental and control groups at different time points with a 0.05 significance level.

Results

Table 1 demonstrates the comparison of bone density at the center of the canine and the root apex between the experimental and control sites at three different time intervals, that is, T0, T1, and T2. A statistically significant decrease in bone density was observed at the center of canine on the experimental site at 1 week (T0-T1) and

Table 1: Comparison of bone density between experimental and control sites at three time intervals

S. No.	Time intervals	Probable scores of paired *t*-test B/W successive time intervals in the experimental site group for CEJ			
		Experimental site	Significance	Control site	Significance
Center of canine	T0 & T1	0.0000*	$P<0.05$ (SIG.)	0.1230	$P>0.05$ (NS)
	T1 & T2	0.0115*	$P<0.05$ (SIG.)	0.1825	$P>0.05$ (NS)
	T0 &T2	0.0829	$P>0.05$ (NS)	0.1233	$P>0.05$ (NS)
Root apex	T0 & T1	0.0025*	$P<0.05$ (SIG.)	0.1338	$P>0.05$ (NS)
	T1 & T2	0.0117 *	$P<0.05$ (SIG.)	0.2367	$P>0.05$ (NS)
	T0 &T2	0.0989	$P>0.05$ (NS)	0.1320	$P>0.05$ (NS)

*Significant difference at 0.05 level of significance, $P<0.05$

3 weeks (T1-T2), that is, 0.000 and 0.0115, respectively. However, a statistically non-significant difference was noticed at 1 week and 3 weeks after MOPs (T0-T2 0.0829). However, a statistically non-significant difference on the control site was observed between T0-T1, T1-T2, and T0-T2, that is, 0.1230, 0.1825, and 0.1233, respectively.

In contrast, at root apex, a statistically significant decrease was found in bone density in the experimental site at 1 week (T0-T1) and 3 weeks (T1-T2), 0.0025 and 0.0117, respectively, whereas a statistically non-significant difference, was detected at 1 week and 1month after MOPs (T0-T2 0.0989).However, there were statistically non-significant differences in the control site between T0-T1, T1-T2, and T0-T2 at root apex, 0.1338, 0.2367, and 0.1320, respectively.

Table 2 demonstrates the overall reduction in the bone density percentage between the experimental and control sites at three time intervals, T0-T1, T1-T2, and T0-T2.

Table 2: The overall decrease in bone density in percentage (%) at three time intervals on the experimental site and control site

	Time intervals	At the center of canine	At root apex
Experimental site	T0-T1	15.10%	18.71%
	T1-T2	12.47%	13.54%
	T0-T2	10.50%	10.78%
Control site	T0-T1	10.46%	12.68%
	T1-T2	09.18%	10.25%
	T0-T2	09.10%	10.02%

Discussion

Orthodontic tooth movement involves both tooth movement and tissue response inside the alveolar bone with bone remodeling.[13] Two years is the average orthodontic treatment period needed.[5] Hence, numerous techniques are used to decrease the time needed for orthodontic treatment time.[16]

The present study was done to evaluate the changes in bone density after MOPs. CBCT images of the maxilla were taken at three time intervals: 1 week before the MOP procedure (T0), 1 week after MOPs(T1), and then 3 weeks after MOPs (T2).On average, the MOP procedure generally lasts for 2to 3months.[5] This clinical pilot study was done initially for 3 weeks to evaluate the changes in bone density after MOPs. A further follow-up is required at the end of the treatment time around 3 to 4 months (T4) to verify the duration and amount of retraction of the canine tooth during orthodontic traction.

Alikhani *et al*.[4] concluded that MOP was a safe and minimally invasive treatment in reducing the orthodontic treatment time because controlled trauma by MOPs triggers inflammatory pathways and enhanced osteoclastic activity. This minimally invasive approach is based on RAP occurring following any surgical trauma. The MOPs were done using the mini screw of 1.4 mm in diameter and 7 mm in length. According to Aboalnaga *et al*.,[5] the use of the mini screw allowed the standardization of the width and depth of the perforations. Our findings are in agreement with Babanouri *et al*.'s study[6] who observed that MOPs were effective in accelerating the orthodontic tooth movement, and they also noticed that the quantity of acceleration was not clinically considerable in the case of canine retraction. Similarly, Gulduren *et al*.[7] observed an increased rate of tooth movement in the MOP. In contrast to our findings, Aboalnaga *et al*.[5] concluded that MOP cannot accelerate the rate of canine retraction. Cheung *et al*.[15] stated that MOP increases inflammation and causes osteoporosis of bones during the healing process. After trauma, osteoclast-osteoblast coupling occurs regulated by the interaction of cytokines and growth factors that activate osteoblasts to form new bone sufficiently replacing lost bone from the osteoclast activity. They found a significant decrease in bone density after MOP using a micro CT scan.

The findings of the current study indicate that 1 week after MOPs, there was a definite reduction in bone density by 12.47% and 13.54% at the center of canine resistance and root apex, respectively. This is in agreement with Aboalnaga *et al*. study's (2019)[5] where more root movement after MOP was observed compared to the canine cusp tip and the center of the canine. Accelerated orthodontics may lead to a considerable decrease in bone density during canine retraction, improving tooth movement, and decreasing orthodontic treatment time.

In the present study, measurement of bone changes was made from the center of resistance of canine. Yang *et al*. have revealed that the maximum stress encountered during canine retraction was at its cervix at the distolabial side. Based on their supposition, the MOPs were only executed distal to the canine and vertically disseminated along the cervical two-thirds of the canine root length.[19] In the present study, the center of canine resistance and root apex is the reference point for taking measurements, identifying 3D images. Hsu *et al*.[13] for evaluation of bone density during tooth movement, divided tooth into three sections (cervical, intermediate, and apical) to conclude whether the bone density change varied with tooth level.

The patients included in this study were 15 to 25 years old; this was in accordance with the Bridges and Kyomen *et al.* studies that emphasized that age plays a major role in tooth movement and this is related to bone density and osteoclast recruitment or activation.[10,20] Nimeri *et al*.[2] have also documented that the younger the age, the higher the Receptor activator of NF-κB (RANK) OPG ratio, hence better will be the osteoclastic activity, leading to an increased rate of bone remodeling.

CBCT is an imaging system with many advantages, such as the lowest radiation dose (0.62 mGy) because a small field of view is used, shorter acquisition times, and sub millimeter resolution.[13,21] In CBCT, X-ray attenuation degree is indicated by grayscale (voxel value), even though CBCT manufacturers and software providers indicate grayscales as the Hounsfield unit (HU).[10]

The efficacy of CBCT for bone density evaluation was validated by Mah *et al*.,[22] who found that there is a strong linear relationship between HU in CT scan and grayscale in CBCT, suggesting that the voxel value in CBCT can be used for bone density assessment. This is in contrast with Oliveira *et al*.'s[23] study, which has demonstrated that CT is a very useful approach for evaluating the alveolar bone density. However, CT is not a good option for the present study because of its high radiation dosage, as we exposed three CBCT scans with small FOV imaging to reduce the radiation dose for each patient. In the literature, very few studies have been conducted on the quantification of bone density after MOP in human subjects.[5] In another study by Wilcko *et al*.,[24] an increased localized demineralization and remineralization phenomenon was seen using a CT scan after corticotomy. Ferguson[25] termed this phenomenon an osteopenic process consistent with the wound healing pattern of RAP, which is responsible for the increased rate of orthodontic tooth movement.

In the present study, the null hypothesis was canceled because there was increased orthodontic tooth movement with the MOP method compared to the control group.

Limitations of the study

The limitations of the present study were: duration and amount of retraction were not evaluated, short duration of study for 3 weeks, no randomization procedure followed and we chose left and right sides of the jaw as test and control groups, respectively. Further studies are warranted to observe the changes in bone density on a larger sample size for a longer duration of treatment (3–6 months).

Conclusion

On the evaluation of bone density before and after MOPs during canine retraction, the following conclusions were drawn: The application of three MOPs caused a significant reduction in bone density after 1 week; the reduction in bone density after MOPs was 10.56% and 10.97% at the center of canine and root apex level, respectively; the reduction in bone density was found to be more at the root apex compared to the center of canine resistance; and the bone density was normalized after 1month.

Ethical approval

Obtained from the institute.

Patient declaration in not part of article text

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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