Three Dimensional Evaluation of External Root Resorption of Maxillary Teeth During Orthodontic Treatment

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Abstract: One of an important problem during orthodontic treatment is root resorption. Mainly, the root resorption is evaluated by using two-dimensional images. However, the incorrect way for taking the x-ray and magnification is main problem that affect the way for diagnosis of root resorption. The purpose of this study will three-dimensional evaluation of external root resorption during orthodontic treatment. The cone bean computed tomography (Cbct) was used to evaluate the rate of root resorption in maxillary teeth before and after orthodontic treatment. The standardization criteria were used for both treatment, material and Cbct. The results showed significant change in root dimension in three dimensions, length, apical, middle and cervical diameter. The 2nd premolars showed less significantly than other teeth. The anterior teeth were more resorption than posterior one. The overall the results showed all the type of resorption were happened within the normal resorption rate

Keywords: Orthodontic Retraction, Cbct, Root Resorption, Cervical Root Resorption, Apical Root Resorption, Orthodontic Fixed Appliance.

1. Introduction

Tooth movement is fundamentally a biological response to a physical stimulus and accelerating this response helps in preventing frequent iatrogenic complications such as root resorption dental caries, white spot lesions and periodontal disease (Feller et al., 2016). Root resorption is a difficult condition to diagnose and treat in most cases. Orthodontists have therefore invested in a variety of technology to accelerate the movement of teeth in order to minimize the adverse effects of prolonged treatment and to satisfy the needs of their patients (Benson et al., 2015). It is possible to have root resorption because of orthodontic movement, periodontal treatment, dental trauma, internal whitening and other unknown causes (Deng et al., 2018). Since conventional radiography are unable to distinguish between resorption on the inside or outside of the tooth, advances in endodontics have made it possible to diagnose the nature and location of bone loss. Through the year's endodontic therapy planning has been aided by the development of new diagnostic techniques. Dental structures may now be seen in three dimensions thanks to cone beam computed tomography (CBCT), which produces pictures in all three planes (axial, coronal, and sagittal) (Miles, 2017).

By using CBCT imaging, endodontics can examine the internal anatomy of the root canal, diagnose dental trauma, plan endodontic surgery, as well as evaluate endodontic problems such root resorption and root fractures (Drage, 2018; Drage, 2018).

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There has been extensive research into the effects of orthodontic therapy on root length and alveolar bone using two-dimensional approaches, which has known drawbacks such as distortion and under or overestimate (Miles, 2017). Cone-beam computed tomography CBCT provides more precise quantitative and qualitative evaluations of root resorption and bone level resorption.

2. Experimental Details

In this study 20 adult female patients (average age, 18-25 years) were selected. The sample will consist of 40 cone-beam computed tomographic (CBCT) scans for a two different periods (before start orthodontic treatment, after 6 months (finished cases). CBCTs were taken for the purpose of research. The CBCT scans of this study were taken in one of the private dental radiology centers (Smart Dental Clinic) in Erbil city.

The inclusion criteria were used for patients selected include, No periodontal disease, No metallic restoration in the first or second permanent maxillary and mandibular premolars and molars, No missing teeth except for third molars, No genetic syndromes or craniofacial pathology, No history of facial trauma, No previous orthodontic treatment and no previous orthognathic surgery, Medically fit patient.

The CBCT images were acquired using NEWTOM GIANO 3D CBCT scanner (Verona, Italy). The technical parameters used were: 90 kV, 10 mA with emission time (3.6 s ÷ 9.0 s) and scan time (14 s). A field of view (FOV) "11*8" was used for the maxilla and mandible respectively, and voxel size was (0.25 × 0.25 mm).

The images were created in DICOM format and evaluated by axial, coronal, sagittal, multiplanar (MPR) reconstructions, with a cutting interval of 1.5 mm (Figure 3.1). Images were captured using a flat panal detector. Primary reconstruction of the data using 1.5 mm axial slices was performed automatically and the total time consumed was 60 s.

2.1 Patient Position

Patient position is in seated position, the patient's head was then centered and fixed in the CBCT system. The Frankfurt plane (line) was a reference, so laser light was set on along that reference. If the position of the head was incorrect, scout images were obtained and position were modified, if the position was incorrect yet, all the measurements were standardized by three dimensional changing and volume correction shown in (figure 3.2). The machine unit NewTom Giano 3D is shown in (figure 3.3). The raw data were reconstructed using the CBCT software NNT Version 15.3 (Verona, Italy). This system has Smart Beam intelligent program that milli Ampere (mA) and time are changing depending on body size in the Gantry while Kilo Voltage (KVP) remain constant. A special ruler of the software program was selected and the areas determined were measured in all the data's and registered in special checklists. The images were viewed in a dimly lit room using a 24-inch LG Flatron monitor (LG, Seoul, Korea), with a screen resolution of 1440× 900 pixels and a 32-bit color depth.

2.2 Images Analysis

All the images were evaluated by an oral and maxillofacial radiologist, a specialized orthodontist and a post-graduate student of orthodontic department. Observer were free to choose the settings of the software, including brightness and contrast, with no time limitation. Before evaluation the images, the observer was given sufficient explanation about the methodology and study design and observers were quite aware of how to work with NNT viewer and on demand 3D dental software's. By the electronic caliber, bone height and other parameters were measured in marked areas, then data were recorded in the check list by two observers separately. Figure (1).

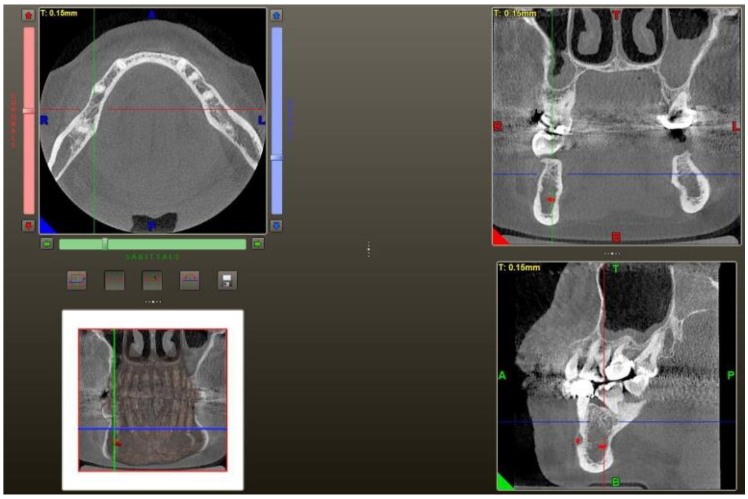

Figure 1: Alignment of 3D CBCT data set visualization in terms of an alignment of the four views (A.axial, B.coronal , C sagittal, D 3Dimensional view) planes.

The NewTOM CBCT software(NNT) allows the user to measure linear distances in 3D by using different sagittal slices. Vertical and horizontal distance were measured by digital electronic caliper on the most prominent sagittal slice in which the intended tooth site appeared. The operator then measures the height and width distances by millimeter, after selecting these landmarks, the linear distance between points was automatically calculated. The measurements were included one vertical measurement include the length of the root from cemento-enamel junction and the apex, and three horizontal measurements include the apex, middle and cervical of the roots. All these measurements were calculated before and after treatments. Figure 2.

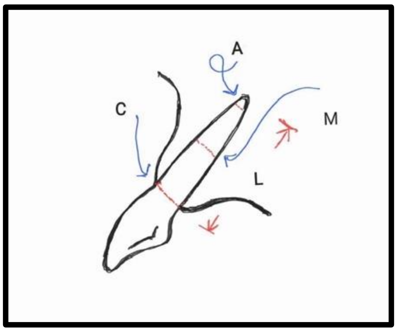

Figure 2. Scheme of tooth structure with 4th measurements. A =Apex, M=middle, C= cervical, and L=length

2.3 Standardization Criteria

The following standardization criteria were taken it during the measurement. Type of orthodontic malocclusion was Class II div I (over jet 8-10 mm), Roth orthodontic brackets 0.022" (Dentaurum, Germany), 16x22 stainless steel wire (Dentaurum, Germany), Continuous force (Niti closing spring, Dentaurum, Germany), Cbct view: Include both maxilla and mandible in one shoot, all Cbcts were taken in same center with same device.

The differences of all measurement were taken before and after treatment because the variability of human teeth and differences were very little. The formula was used as follow :(D=Difference, M1=before treatment, M2=After treatment)

$$D=M1-M2$$

This formula was used in all measurements.

2.4 Statistical Analysis

Microsoft Excel (2020) and the Statistical Package for Social Sciences (SPSS, IBM, version 22) will use for data entry and analysis. The analysis will be including the descriptive statistics were calculated including; means, standard deviations, minimum and maximum values for summarizing the numerical. ANOVA test with t tests werte used to evaluate the difference between distances.

3. Results

In all the twenty patients, the roots resorption during orthodontic movement were significant difference between the teeth through the fourth measuring areas, the differences between the root length and also the three horizontal measurement of the root (cervically, middle and apically) before and after treatment was investigated. The meaning of the differences was used because variability of human teeth has different length and width. The difference between after and before for each tooth separately and then comparing the differences between each other's. The mean, standard deviation, standard error, minimum and maximum of the fourth measured areas can be showed in the following tables (1,2,3,4,5,6,7,8).

Table 1: Comparison of LENGTH among the eight different teeth

Length	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
UR1	20	0.30000	0.017770	.003974	.29168	.30832	.270	.330
UR2	20	0.50000	0.072548	.016222	.46605	.53395	.400	.600
UR3	20	0.30000	0.017472	.003907	.29182	.30818	.270	.330
UR5	20	0.09000	0.064072	.014327	.06001	.11999	.000	.200
UL1	20	0.30000	0.014510	.003244	.29321	.30679	.270	.330
UL2	20	0.50000	0.072548	.016222	.46605	.53395	.400	.600
UL3	20	0.20000	0.064889	.014510	.16963	.23037	.100	.300
UL5	20	0.10500	0.051042	.011413	.08111	.12889	.000	.200
Total	160	0.28688	0.155370	.012283	.26262	.31113	.000	.600

UR1= upper right central incisor, UR2= upper right lateral incisor, UR3=upper right canine, UR5=upper right second premolar, UL1= upper left central incisor, UL2= upper left lateral incisor, UL3=upper right canine, UL5=upper left second premolar

Table 2: Comparison of Apex among the eight different teeth

Apex	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
UR1	20	.565	.2346	.0525	.455	.675	.1	.8
UR2	20	.200	.0649	.0145	.170	.230	.1	.3
UR3	20	.460	.0821	.0184	.422	.498	.4	.6
UR5	20	.085	.0587	.0131	.058	.112	.0	.2
UL1	20	.600	.0649	.0145	.570	.630	.5	.7
UL2	20	.095	.0605	.0135	.067	.123	.0	.2
UL3	20	.300	.0175	.0039	.292	.308	.3	.3
UL5	20	.200	.0562	.0126	.174	.226	.1	.3
Total	160	.313	.2156	.0170	.279	.347	.0	.8

UR1= upper right central incisor, UR2= upper right lateral incisor, UR3=upper right canine, UR5=upper right second premolar, UL1= upper left central incisor, UL2= upper left lateral incisor, UL3=upper right canine, UL5=upper left second premolar

Table 3: Comparison of middle among the eight different teeth

Middle	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
UR1	20	.05000	.007255	.001622	.04660	.05340	.040	.060
UR2	20	.02750	.007864	.001758	.02382	.03118	.020	.040
UR3	20	.12400	.162914	.036429	.04775	.20025	.060	.600
UR5	20	.01200	.004104	.000918	.01008	.01392	.010	.020
UL1	20	.02750	.007864	.001758	.02382	.03118	.020	.040
UL2	20	.12400	.162914	.036429	.04775	.20025	.060	.600
UL3	20	. 5000	. 07255	. 01622	. 4660	. 5340	. 40	. 600
UL5	20	.00250	.004443	.000993	.00042	.00458	.000	.010
Total	160	.05219	.091326	.007220	.03793	.06645	.000	.600

UR1= upper right central incisor, UR2= upper right lateral incisor, UR3=upper right canine, UR5=upper right second premolar, UL1= upper left central incisor, UL2= upper left lateral incisor, UL3=upper right canine, UL5=upper left second premolar

Table 4: Comparison of cervical among the eight different teeth

Cervical	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
UR1	20	.02000	.007255	.001622	.01660	.02340	.010	.030
UR2	20	.00200	.004104	.000918	.00008	.00392	.000	.010
UR3	20	.00850	.006708	.001500	.00536	.01164	.000	.020
UR5	20	.01200	.004104	.000918	.01008	.01392	.010	.020
UL1	20	.08000	.007947	.001777	.07628	.08372	.070	.090
UL2	20	.05000	.007255	.001622	.04660	.05340	.040	.060
UL3	20	.00200	.004104	.000918	.00008	.00392	.000	.010
UL5	20	.02700	.008013	.001792	.02325	.03075	.020	.040
Total	160	.02519	.026278	.002077	.02108	.02929	.000	.090

UR1= upper right central incisor, UR2= upper right lateral incisor, UR3=upper right canine, UR5=upper right second premolar, UL1= upper left central incisor, UL2= upper left lateral incisor, UL3=upper right canine, UL5=upper left second premolar

According to the length, the results showed the both upper lateral incisors right and left had a high rate of resorption comparing with other teeth. The upper second premolars showed lower rate of resorption, the other teeth showed in between showed in table 1. According to the horizontal measurement, the upper central incisors showed a high rate of resorption at the apex comparing with upper second premolars gave a lowerest rate of resorption. table () According to the middle of root measurement, the upper canines gave a high rate of resorption the lowest rate of resorption comparing with upper second premolars showed in tables 2,3,4.

From another hand, the comparisons between the right and left of all the measurements were showed in tables 5,6,7,8 respectively. the significant difference among the test's teeth were shown in through different measurements at P =0.001

Table 5: Comparison between upper right central incisor and upper left central incisor

Tooth	Mean	N	Std. Deviation	*p-value	t-test
UR1L	0.300	20	0.0177	0.999	Non-significant
UL1L	0.300	20	0.0145		
UR1A	0.565	20	0.2346	0.531	Non-significant
UL1A	0.600	20	0.0649		
UR1M	0.050	20	0.0072	0.001	Significant
UL1M	0.027	20	0.0078		
UR1C	0.020	20	0.0072	0.001	Significant
UL1C	0.080	20	0.0079		

A= Apical, M= middle, C= cervical. Significant at P=0.001

Table 6: Comparison between upper right lateral incisor and upper left lateral incisors

Tooth	Mean	N	Std. Deviation	*p-value	t-test
UR2L	0.500	20	0.072	0.999	Non-significant
UL2L	0.500	20	0.072		
UR2A	0.200	20	0.064	0.001	Significant
UL2A	0.095	20	0.060		
UR2M	0.027	20	0.0078	0.015	Significant
UL2M	0.124	20	0.1629		
UR2C	0.002	20	0.0041	0.001	Significant
UL2C	0.050	20	0.0072		

A= Apical, M= middle, C= cervical. Significant at P=0.001

Table 7: Comparison between upper right canine and upper left canine

Tooth	Mean	N	Std. Deviation	p-value	t-test
UR3L	0.300	20	0.0174	0.001	Significant
UL3L	0.200	20	0.0649		
UR3A	0.460	20	0.0821	0.001	Significant
UL3A	0.300	20	0.0174		
UR3M	0.124	20	0.1629	0.052	Non-significant
UL3M	0.050	20	0.0072		
UR3C	0.008	20	0.0067	0.001	Significant
UL3C	0.002	20	0.0041		

A= Apical, M= middle, C= cervical. Significant at P=0.001

Table 8: Comparison between upper right second premolars and upper left second premolars

Tooth	Mean	N	Std. Deviation	p-value	t-test
UR5L	0.090	20	0.0641	0.481	Non-significant
UL5L	0.105	20	0.0510		
UR5A	0.085	20	0.0587	0.001	Significant
UL5A	0.200	20	0.0562		
UR5M	0.012	20	0.0041	0.001	Significant
UL5M	0.002	20	0.0044		
UR5C	0.012	20	0.0041	0.001	Significant
UL5C	0.027	20	0.0080		

A= Apical, M= middle, C= cervical. Significant at P=0.001

4. Discussion

This work was a pioneer with the use of a CBCT technique, which was used to investigate the link between degree of tooth movement during orthodontic treatment and root resorption. Histologic examination makes it possible to identify changes in the surface tissues of a root with a high degree of sensitivity and to make precise observations on the extent of root resorption. Histologic examination was used by certain researchers in the past to analyses root resorption in animal tests (Fujimura et al, 2009) as well as in human participants (Kurol et al., 1996); however, this could only be done in extracted teeth, most often the premolars. According to Estrela et (Estrela et al., 2008) and Liedke et al (Liedke et al., 2009) found that when it comes to the detection of apical periodontitis, and CBCT pictures provided a higher level of sensitivity as well as reliability than panoramic and periapical films. Patients in this research belonged to the age group from 20 to 25, making individuals much older than the minimum age requirement of 11.5 years for root development in external root resorption driven by orthodontic therapy (Horiuchi et al., 1998). Furthermore, a number of studies have shown that there is no significant association between root resorption and gender; hence, the data all pertained to female subjects, which effectively nullified the influence of gender (Kurol et al., 1996; Sameshima et al., 2001a).

The findings of this research agree with the findings of a study conducted by Sameshima and Sinclair (Sameshima et al., 2001a). That study found that root resorption happened more often in the front teeth of the maxilla instead of being in the posterior teeth with 868 orthodontic patients. In addition, this research found that the intensity of root resorption increased with the length of orthodontic therapy, which is consistent with the findings of previous studies (Sameshima et al., 2001b; Baumrind et al., 1996) that have indicated that the intensity of root resorption rises with the time of orthodontic treatment. In order to reduce the amount of variation in the results, each of the eight participants in the current research received treatment for the same with amount of time (six months). According to Artun et al (Årtun et al., 2005), found that the resorption rate was higher in the lateral maxillary incisors than those in the central ones.

Some distinctions between the research findings (Liaw et al., 2007) were shown possible explanation for these differences is that the different studies used different types of materials for their arch wires. For example, one study used a better super elastic NiTi-alloy arch wire that is able to deliver a much gentler force as well as reduce the stress hysteresis, which in turn decrease the number of root resorption. The future study should take additional human examples in order to justify the findings from the previous research, which was suggested in a number of different ways by previous research. In addition, the impact of age and gender on the relationship between roots that should be taken into consideration in further research.

5. Conclusion

1. The root resorption can be seen in all teeth after orthodontic treatment but the rate of it was different from one tooth to another.
2. The narrow and thin apexes like in lateral incisors were more affected in resorption than another apex.
3. The less affected teeth were the second premolars because we used mini screw for retraction and no any affected forces on the premolars.
4. Anterior teeth more affected than posterior one.
5. The cervical region was less affected than the middle and apex region.

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