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Assessment of external apical root resorption and root shape: Periapical VS panoramic films of maxillary incisors during orthodontic treatment: A prospective study

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Abstract

Background of the study: External apical root resorption (EARR) is the permanent loss of root structure involving the apical region which can be attributed to the forces acting on to the teeth by fixed appliance & more commonly seen in the upper incisors. The aim of this study was to analyse the amount of EARR (external apical root resorption) of maxillary incisors and to evaluate the root shape by comparing with periapical and panoramic films and also to evaluate the contribution of the gender and duration (pre & post space closure).

Methodology: 30 subjects undergoing orthodontic treatment were selected for this study and were divided into 15 male and 15 female patients within the age range of 12-26 yrs. Totally 120 teeth were scanned (central & lateral). At the pre-treatment stage, standardized intraoral periapical films and digitalized panoramic films were taken. Crown and root lengths of the four maxillary incisors on the scanned periapical and panoramic films were measured. At post space closure follow up films were obtained and EARR were measured. All measurements were performed for each tooth separately. Any image distortion between the crown lengths for pre-treatment and post space closure films was corrected by using correction factor (CF). A root shape assessment was performed for each tooth by a 5 parameter ordinal scale which was categorized into the following, D----dilacerated, O----bottle shaped, B----blunted, P----pointed, N----normal. All the data underwent statistical analysis for comparison between groups.

Results: Out of 120 teeth scanned through periapical and panoramic films, both central and lateral incisor showed EARR and the amount was greater for the maxillary lateral incisors compared to -bcxthe central incisors which was more evident in panoramic films. Based on gender, females showed more EARR compared with males and tendency being more for maxillary lateral incisors and the frequency of abnormal shapes in panoramic films were more compared with periapical films.

Conclusions: The study concluded that all maxillary incisors showed significant root resorption post space closure, the amount of EARR being more for lateral than central incisors in both the films. Females showed more EARR than males and it was more clinically significant for lateral incisors. Root shape are more difficult to assess on panoramic films as the amount of root resorption will be exaggerated.

Keywords: EARR, active orthodontic treatment, gender, duration, root shape earr (External apical root resorption)

Introduction

External apical root resorption (EARR) is the permanent loss of root structure involving the apical region. It is an undesirable sequale to orthodontic treatment which can be attributed to the forces acting on teeth by fixed appliance. Root resorption associated with orthodontic treatment is more prevalent where the applied forces are strong and of extended duration. EARR is considered to be a multifactorial problem and has been related to factors associated with biological variation as well as treatment modalities. EARR, which is more commonly seen in the upper incisors has been of concern to clinicians since the first description of root resorption by BATES in 1856^[1], and latter correlated to orthodontics by Ottolengui in 1914^[2] and Ketchman in 1929.^[3] Still the fundamental cause of external apical root resorption remains unknown and the clinical studies are almost unpredictable to gauge the magnitude of

resorption. There are controversies that exists in the reports of clinical and laboratory investigations of root resorption, regarding the amount and the incidence of external apical root resorption (EARR). The mean degree of resorption varies from 0.2 [4] to 2.93 mm [5] whereas the prevalence of root resorption detected radio graphically varies from 0 to 100 % [6]. There is a general agreement, that the presence of preexisting root resorption increases the risk factor [7, 8, 9] and the involvement of genetic predisposition accounts for 50% of the variation in EARR [12, 13]. In addition, appliance type and mechanics seem to influence the degree of root resorption [3, 14, 15].

There have been considerable differences in the type of teeth examined, sample sizes [15, 16], duration of follow up [4, 17], type of tooth movement, methods of measurements and patient characteristics. Qualitative assessment from periapical radiographs have been evaluated by many investigators, where others have defined EARR quantitatively from cephalometric images [5, 16] or from standard periapical radiographs with the long cone paralleling technique [15, 23]. Therefore comparison of the studies cited in literature is difficult. Resorption process usually stops once the active fixed appliance is removed [27]. The ability to identify the risk of EARR before or early in treatment may, therefore, be of clinical significance.

Radiography is an useful tool in various disciplines of medicine and dentistry for diagnosis and treatment planning. Changes in quality of radiographs may lead to misinterpretation, resulting in incorrect diagnosis and treatment planning. [28] In orthodontics radiographic assessment is an essential diagnostic process to detect external apical root resorption and to evaluate root shape during orthodontic treatment. In the daily practice of dentistry, panoramic radiography takes second place in importance to intra oral radiography. However panoramic radiography may be more beneficial to patients because it offers both excellent anatomical assessments and excellent evaluations. It has the additional benefits of reduced radiation exposure compared to full mouth intra oral radiographs but with a disadvantage of magnification of image in the anterior region. Though periapical films also have a magnification factor, it is usually less than 5%. [29] Periapical films have been found to be superior to Panoramic images for fine detail and less distortion. Panoramic films tended to underestimate the amount of osseous destruction that was visible on periapical films. The difficulty in identifying the cemento enamel junction was given as the main reason for the inability to measure on panoramic films. Keeping in view the above literature the aim of this study was to measure the amount of external apical root resorption and assess the root shape by comparing periapical of maxillary incisors with panoramic radiographs and its contribution to gender and duration (pre & post space closure).

2. Materials and methods

This study consisted of 30 subjects 15 male and 15 female (120 maxillary teeth) who were undergoing orthodontic treatment with different malocclusion, within the age range of 12-26yrs were included in this study with the following inclusion criteria. Not having a history of, systemic disorders, periodontal disease, genetic or developmental abnormalities, hormonal imbalance, trauma, impacted maxillary canine, previous orthodontic treatment, crown fracture or abrasion of upper incisors and endodontic treatment of the maxillary incisors and the exclusion criteria included, Poor quality radiographs, previous root resorption before initiation of

treatment and individuals with major illness or medical conditions. A consent form was taken from the patients before the starting of the orthodontic treatment. The treatment protocol consisted of measuring the EARR (external apical root resorption) and evaluating the root shape by comparing with intra oral periapical and panoramic films, pretreatment and post space closure and also to evaluate the contribution of gender, duration (pre-treatment and post space closure). Initially at the pre-treatment stage, standardized intra oral periapical films and digitalized panoramic films of the patients were taken. The intra oral periapical films (Fig 1) were taken with a long cone paralleling technique by a single operator using Kodak Ekta speed films and the digitalized panoramic films were taken by Planmeca machine.

The crown and root length of the maxillary incisors were obtained using the method described below on both periapical and panoramic films. The radiographs obtained were scanned at a resolution of 1000 dpi and viewed on a large monitor. The incisal edge, apex and cemento enamel junction (CEJ) of each maxillary incisor were demarcated. The distinct landmark for CEJ either mesial or distal was used. Once selected any one side was used for follow up radiographs. The long axis of each tooth were constructed from incisal edge to the root apex considering root canal as a point. The marked CEJ were perpendicularly projected to this axis (using Adobe photoshop CS4 Ver 11.0). Crown length were measured from the incisal edge to the projected CEJ & root length from projected CEJ to the apex. All measurements were performed for each tooth separately, within an accuracy of 0.01 mm (Fig 4). The same procedure was done after post space closure. Any image distortion between the clinical crown for the radiographs was corrected by using a correction factor. $CF = C1/C2$ In which $C1 = CL$ (crown length) on pre-treatment & $C2 = CL$ (crown length) on post space closure.

EARR was then calculated using the formula. $EARR = R1 - (R2 \times CF)$ where as $R1 = RL$ (root length) on pre-treatment & $R2 = RL$ (root length) on post space closure. EARR of 1 mm or more during orthodontic treatment is considered clinically significant. Assessment of root shape was done based on a 5 parameter ordinal scale which was categorized into, D - dilacerated, O-bottle shaped, B-blunted, P-pointed and N-normal on the pretreatment and post space closure radiographs respectively.

2.1 Statistical analysis

Changes in root length that occurred between pre-treatment and post space closure for the central and lateral incisors were determined with paired sample t-test. EARR of more or less than 1mm, post space closure were assessed using Mc Nemar test. Regression analysis was done to evaluate the effect of gender. Root shape assessment was done using Mc Nemars test.

3. Results & Discussion

3.1 Results

3.1.1 For periapical films

For the 60 central incisors examined, EARR at post space closure was found to be on an average 1.31 ± 0.38 mm whereas for the 60 lateral incisors examined on an average, EARR was 1.47 ± 0.36 mm at post space closure respectively (Table 1 & 2)

3.1.2 For panoramic films

For the 60 central / 60 lateral incisors examined, teeth showed EARR at active orthodontic treatment. On average. EARR

was 1.60 ± 0.34 mm for central incisors and 1.74 ± 0.35 mm for lateral incisors. The amount of EARR was greater for the maxillary lateral incisors compared to the central incisors, with the differences being statistically significant ($p < 0.001^{**}$). (Table 1&2)

3.1.3 Gender based

While evaluating for gender the amount of EARR was found to be greater in females post space closure follow up for both tooth groups and both films. In periapical films the EARR for central incisors in females was on an average 1.34 ± 0.41 and in males it was 1.27 ± 0.36 ($p=0.473$) (Table 3). For lateral incisor, EARR in females was 1.57 ± 0.38 and in males it was 1.38 ± 0.33 ($p=0.044^{*}$) (Table5), However in panoramic films EARR for central incisors in females was on an average 1.71 ± 0.38 mm and in males it was 1.50 ± 0.24 mm ($p=0.013^{*}$) (Table 4) and for lateral incisor in females EARR was 1.83 ± 0.42 mm and in males it was 1.65 ± 0.24 mm respectively (Table6) ($p=0.039^{*}$) which showed clinically significant features for lateral incisors in females. The gender risk factor was associated with root resorption more with females and tendency being more for maxillary lateral incisors.

3.1.4 Root shape

On evaluating root shape on all maxillary incisors it was found that the frequent abnormal shape on periapical films on pre-treatment radiographs was dilacerations (70%) followed by pointed (11.65%) and blunted (2%). Where as in panoramic films the most abnormal shape found was dilacerations (38.3%), blunted (4%) and pointed (18.35%). On post space closure the abnormal shape found on periapical films was dilacerations (60%) followed by blunted (15%) and pointed (10.8%). On an panoramic films abnormal shape found was dilacerations (60%) followed by blunted (23.35%), pointed (10%) and bottle shaped (1.7%) (Graph 1 & 2) showing the pre and post treatment assessment of root shape in percentage.

4. Discussion

The most common iatrogenic consequence of orthodontic treatment is external apical root resorption and in the literature there is an common agreement among authors that the maxillary incisors are the teeth more susceptible to EARR [36, 38, 39]. Also any changes in quality of radiographs may lead to misinterpretation, resulting in incorrect diagnosis and treatment planning [28]. Thus the aim was focussed on measuring EARR (external apical root resorption) and evaluating the root shape pre-treatment and post space closure and comparing with intra oral periapical and panoramic films. Considering the age limit in this study, range of 12-26 yrs. The selection of 12 yrs, as the lower age limit of the sample was to exclude undesirable effect of residual root growth [15, 21]. The higher age limit of 26 yrs was chosen as in adults unfavourable effect of age may lead to increased EARR due to longer hyalinization duration, more hyalinised areas and lower healing activity [33, 36, 37]. The methodology used in this study to measure the EARR were obtained using a similar method to the one used by Linge and Linge. [15] A correction factor (CF) was used to rectify the accuracy of the measurements of crown lengths between pre-treatment and post space closure radiographs by eliminating any dimension or angulation difference between the two radiographic exposures. [24, 38, 26].

EARR is considered to be a multifactorial problem as indicated by previous investigations. Apart from relation with active orthodontic treatment it is associated with treatment

factors as well as patient characteristics [3, 9, 32, 34, 35]. The clinical consequences of EARR associated with active orthodontic treatment are not well reported in the literature. A statistically significant EARR may not be of clinical significance [38]. In some cases, the treatment plan needs to be reviewed due to root structure loss in order to avoid excessive tooth mobility and eventually tooth loss [6]. Thus in the present study, EARR of 1mm at post space closure of active orthodontic treatment was used to determine the clinical significance.

In the present study, at post space closure, for periapical films, all the central incisors and lateral incisors examined showed EARR at active orthodontic treatment. On an average, EARR was 1.31 ± 0.38 mm ($p < 0.001^{**}$) & 1.47 ± 0.36 mm ($p < 0.001^{**}$) which was clinically significant. For panoramic films, all the central incisors /Lateral incisors examined, showed EARR on active orthodontic treatment with a mean average of 1.60 ± 0.34 ($p < 0.001^{**}$) and 1.74 ± 0.35 mm ($p < 0.001^{**}$) which was clinically significant. The observed amount of root resorption, as computed from panoramic films, was found to be greater overall when compared with periapical films. This differences can be attributed due to the magnification in the two types of films [29]. Controversy exists regarding which incisors show more resorption: centrals or laterals. Some studies have reported that lateral incisors were more susceptible to the process [41], while others have favoured central incisors [7, 30]. In the present study the amount of EARR was greater for the maxillary lateral incisors than central incisors, with difference being statistically significant ($p = 0.001^{**}$).

A majority of the studies conducted support a lack of correlation between gender and root resorption. In this study, the maxillary lateral incisors especially of female patients showed more EARR than those of male patients, the difference being statistically significant. Previous studies conducted by Levander and Malmgren [18], kjaer [39], Horiuchi *et al.* [21] have shown no correlation between EARR and gender, While Remington DN *et al.* [35] and Sameshima and Sinclair [41] cite evidence for greater male prediction. There is speculation about the difference in level of hormonal titres as being the causative factor of gender predilection of EARR. [9] The co-relation between EARR and duration of treatment is controversial as some studies have supported the significance of treatment time on EARR [25, 18, 24, 40, 41]. Where as few others have not [19, 37]. This can be attributed to the fact that longer duration causes stress on the periodontal ligament which could cause hyalinization and less repair at the compressed area, causing more damage to root surface [24, 36]. Beck and Harris [19] and Mirabella and Artun [37] have argued that amount of tooth movement is not directly related with duration as most tooth movements occurs during the initial aligning and levelling period. Later phases need minor tipping and paralleling of roots. There is therefore no substantive reason why the rate of resorption should be associated with duration of treatment [19, 37]. De Shields [30] and Linge and Linge [15] report statistically significant but low correlation between EARR and the length of time a patient was banded. Thus in this study we evaluated the clinical significance of EARR over post space closure of active orthodontic treatment and found that there was a correlation between degree of EARR and duration.

Kalwarf *et al.* showed that a linear relationship exists between the root length and percentage of periodontal attachment and so any minor loss in root length is important. Apical root resorption decreases the root surface area and change in the

root shape. Recent literature supports the findings that abnormal root shape is significantly associated with apical root resorption. In this study it was found that the frequent abnormal shape on periapical films on pre-treatment radiographs was dilacerations (70%) followed by pointed (11.65%) and blunted (2%) shapes. Where as in panoramic films the most abnormal shape found was dilacerations (38.3%), blunted (4%) and pointed (18.35%). On post space closure the abnormal shape found on periapical films was dilacerations (60%) followed by blunted (15%) and pointed (10.8%). On an panoramic films abnormal shape found was dilacerations (60%) followed by blunted (23.35%), pointed (10%) and bottle shaped (1.7%).

The results of the present study shows that the two films are significantly different in assessment of root shape. Roots found to have abnormal shape on periapical films varied with panoramic films. The difference in this study can be explained due to the magnification between the films and also the variation of the results concerned with root shape, which can be attributed to the small sample size. Therefore it is recommend that a study with a larger sample size with longer follow up periods could be of a greater value to overcome the limitations associated with this study.



Fig 1: I.O.P.A paralleling technique/Digitalized panoramic machine

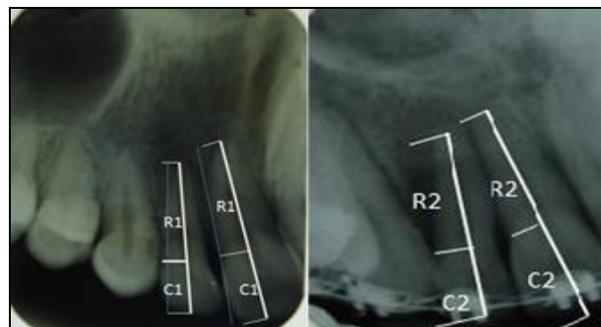


Fig 2: Pre treatment /post space closure crown and root length measurements on IOPA radiograph.

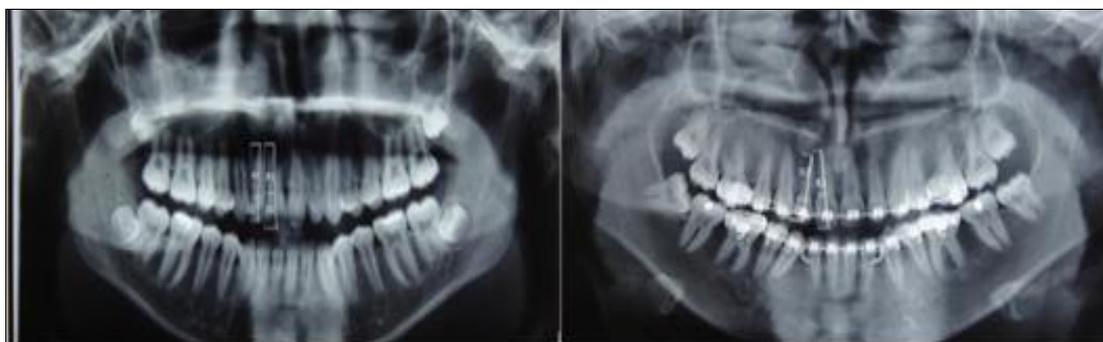


Fig 3: Pretreatment /post space closure crown and root length measurements on panoramic radiograph

Table 1: Comparison of variables in Central incisor between periapical and panoramic films

Central incisor (Right+Left)	Periapical (n=60)	Panoramic (n=60)	Significance
Crown length pre-treatment	9.94±1.58	10.12±1.67	t=1.455;p=0.151
Root length pre treatment	15.59±2.56	15.44±2.06	t=0.548;p=0.586
Crown length post space closure	9.96±1.59	10.15±1.59	t=1.837;p=0.071+
Root length post space closure	14.29±2.47	13.97±1.91	t=1.226;p=0.225
External apical root resorption	1.31±0.38	1.60±0.34	t=6.087;p<0.001**

Table 2: Comparison of variables in Lateral incisor between periapical and panoramic films

Lateral incisor (Right +Left)	Periapical (n=60)	Panoramic (n=60)	Significance
Crown length pre-treatment	8.65±1.53	8.91±1.52	t=1.908;p=0.061+
Root length pre treatment	14.28±2.67	14.32±1.99	t=0.127;p=0.900
Crown length post space closure	8.62±1.42	8.88±1.59	t=1.658;p=0.103
Root length post space closure	12.74±2.36	12.56±1.96	t=0.574;p=0.568
External apical root resorption	1.47±0.36	1.74±0.35	t=7.628;p<0.001**

Table 3: Comparison of variables based on periapical films in Central incisor between Male and Female

Central incisor (right +Left)	Female	Male	Significance
Crown length pre treatment	10.18±1.75	9.7±1.37	t=1.175;p=0.244
Root length pre treatment	16.4±2.65	14.79±2.23	t=2.544;p=0.013*
Crown length post space closure	10.23±1.77	9.69±1.37	t=1.304;p=0.197
Root length post space closure	15.08±2.54	13.5±2.15	t=2.604;p=0.012*
External apical root resorption	1.34±0.41	1.27±0.36	t=0.728;p=0.473

Table 4: Comparison of variables based on panoramic films in Central incisor between Male and Female

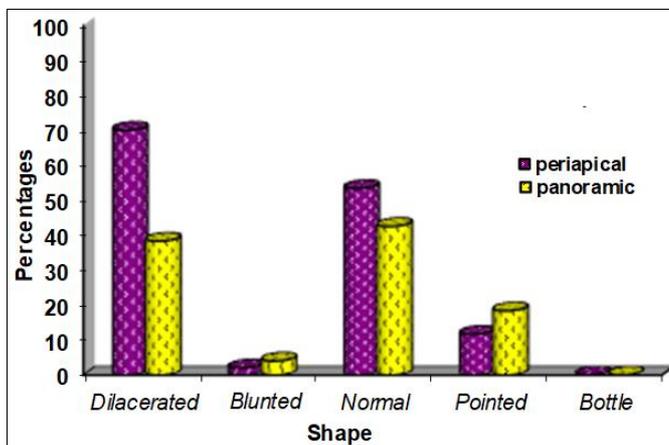
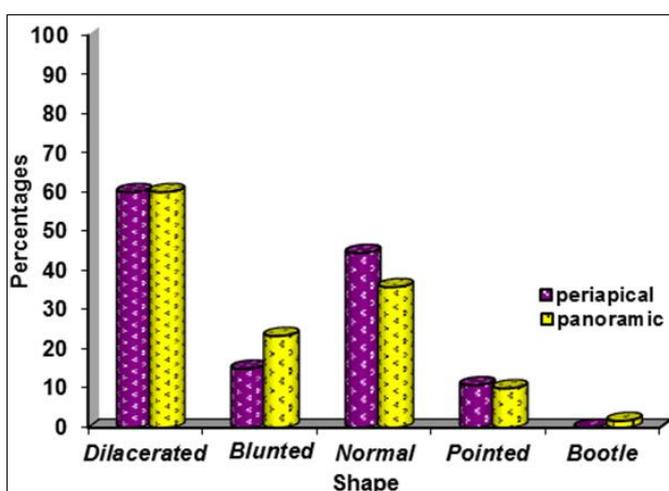
Central incisor (right +Left)	Female	Male	Significance
Crown length pre-treatment	10.42±1.88	9.84±1.42	t=1.344;p=0.183
Root length pre treatment	15.91±2.01	14.97±2.03	t=1.808;p=0.075+
Crown length post space closure	10.30±1.83	10.00±1.34	t=0.736;p=0.464
Root length post space closure	14.26±1.79	13.70±2.00	t=1.147;p=0.225
External apical root resorption	1.71±0.38	1.50±0.24	t=2.566;p=0.013*

Table 5: Comparison of variables based on periapical films in Lateral incisor between Male and Female

Lateral incisor (right +Left)	Female	Male	Significance
Crown length pre-treatment	8.78±1.73	8.51±1.31	t=0.684;p=0.496
Root length pre treatment	14.84±2.94	13.72±2.3	t=1.684;p=0.104
Crown length post space closure	8.78±1.6	8.47±1.23	t=0.848;p=0.399
Root length post space closure	13.26±2.59	12.22±2.04	t=1.732;p=0.089+
External apical root resorption	1.57±0.38	1.38±0.33	t=2.056;p=0.044*

Table 6: Comparison of variables based on panoramic films in Lateral incisor between Male and Female

Lateral incisor (right +Left)	Female	Male	Significance
Crown length pre-treatment	9.15±1.68	8.68±1.32	t=1.227;p=0.224
Root length pre treatment	14.93±2.00	13.7±1.82	t=2.480;p=0.016*
Crown length post space closure	9.06±1.82	8.71±1.32	t=0.845;p=0.399
Root length post space closure	13.04±2.08	12.09±1.75	t=1.911;p=0.061+
External apical root resorption	1.83±0.42	1.65±0.24	t=2.111;p=0.039*

**Graph 1:** Pre-treatment assessment of root shape in percentage.**Graph 2:** Post treatment assessment of root shape in percentage.

4. Conclusions

Conclusions: From this study the following conclusions can be drawn.

- During active orthodontic treatment all the maxillary incisors showed significant root resorption post space closure, the amount of EARR being statistically

significant more for maxillary lateral incisors than central incisors in both the films.

- Since the degree of EARR was correlated with treatment duration, patients who are at risk of root resorption can be identified early during treatment. Also during treatment it is recommended to monitor EARR. Caution to be exercised with patients during treatment for longer periods especially with extraction cases.
- Gender wise females showed more EARR than males and it was more clinically significant for lateral incisors. Though genetic predispositions is blamed often, the operator associated risk factors have to be overcome.
- Root shape are more difficult to assess on panoramic films as the amount of root resorption will be exaggerated, so clinicians should check the films carefully and order periapical radiographs if the roots cannot be visualized accurately.

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