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# Root resorption during orthodontic tooth movements

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SUMMARY The aim of the study was to compare the extent of maxillary incisor root resorption during different orthodontic tooth movements using three different techniques, namely the basal intrusion arch, the three component arch, and levelling of the upper dental arch with the straightwire appliance. The radiographs of 49 subjects (20 males and 29 females) with a mean age of 14.5 years were taken at two time points: in groups 1 and 2 after the levelling phase and in group 3 immediately after placement of the archwire (T1) and in all groups after a period of 6 months (T2). The amount of root resorption of the central incisors was determined at T2. The average incisor resorption was different in the three groups, with group 2 (three component arch) showing greater resorption (0.46 mm) than groups 1 (basal arch) and 3 (straightwire) of 0.26 and 0.25 mm, respectively. Analysis of variance (ANOVA) demonstrated that differences in root resorption in the three groups were not significant. Wilcoxon paired test showed that the root resorption occurring between T1 and T2 in the three groups was not significant. There was also no significant difference among the rates of resorption in the three groups. Grouping the subjects on the basis of the extent of root resorption and the biomechanics used showed differences in the percentage of subjects with the least (<0.5 mm) and greatest (0.5–0.9 mm) amounts of root resorption between the three groups. This again showed that the technique of three component intrusion arch resulted in the greatest increase in root resorption.

## Introduction

External root resorption during orthodontic treatment, referred to as 'surface root resorption' by Andreasen (1988), is considered an unwanted consequence of orthodontic treatment that could result in loss of tooth structure. The upper incisors most commonly show root resorption after orthodontic treatment (DeShields, 1969; Dermaut and De Munck, 1986; McFadden *et al.*, 1989; Kaley and Philips, 1991; Mirabella and Årtun, 1995; Phillips, 1955; Levander and Malmgren, 2000; Sameshima and Sinclair, 2001) and are used to determine root resorption during experimental studies. It has been shown that when there is no root resorption of the upper or lower incisors, resorption of other teeth is improbable (Copeland and Green, 1986).

Parker and Harris (1998) stated that the main reasons for using the upper incisors to determine external root resorption is that it most commonly occurs in these teeth, which are easily visualized on a lateral cephalogram, and that maxillary incisors undergo more displacement than other teeth following extraction therapy. They further stated that among the mechanical factors, the orthodontic techniques used may be related to root resorption and, in movements such as tipping, torque, and incisor intrusion, the root surface is directly compressed against the alveolar bone resulting in root resorption.

The main aim of the present study was to compare the extent of root resorption of the maxillary central incisors during different orthodontic tooth movements when using three different techniques, namely the basal intrusion arch, the three component intrusion arch, and levelling of the upper dental arch with the straightwire technique.

## Subjects and methods

The original sample comprised 54 patients treated at the Department of Orthodontics, Faculty Hospital Hradec Králové, Prague, Czech Republic, with fixed appliances. The subjects were selected on the basis of the technique to be used for treatment, which was determined after diagnosis. In 52 patients, the upper right central incisor was used to determine any root resorption and in two the upper left incisor was used as the upper right central incisor did not meet the required criteria for inclusion. Age and gender were not considered in patient selection. Patients with skeletal or dental anomalies or those requiring more complex treatment were excluded. The mean age of the patients was 14.5 years (range 9–30.1 years, standard deviation 3.2 years). Root development of the incisors was complete in all subjects at the beginning of treatment.

Inclusion criteria included informed consent of the patient/parent/guardian, fixed orthodontic appliance therapy for 6 months to carry out the orthodontic tooth movement, vital maxillary incisors with developed roots as seen on the radiographs and without any extensive fillings or prosthetic treatment or the presence of a wide palatal vault thus allowing correct positioning of the film in a holder according to the transfer key. It was ensured that the selected patients also did not have systematic diseases or metabolic anomalies, trauma, or periapical inflammation of the upper central incisors, endodontic treatment of the incisors, root resorption prior to orthodontic treatment, tumours, and cysts in the examined area and nail biting or other habits.

The patients were divided into three groups according to the biomechanics used (Table 1). The upper central incisors were intruded in group 1 ($n=17$) using a basal intrusion arch, in group 2 ($n=18$), a three component intrusion arch was used, and in group 3 ($n=19$), levelling of the upper dental arch was undertaken with the straightwire appliance.

Periapical radiographs were used to assess the extent of root resorption during the different types of tooth movement. The radiographs at T1 in groups 1 and 2 were obtained after the levelling phase but before intrusion or any other complex tooth movement, while in group 3 they were taken immediately after placement of the fixed appliance. Follow-up radiographs were obtained for all groups after 6 months (T2). This period was selected as it is believed that a period of 5–6 months is required for reliable radiological representation of root resorption (Levander *et al.*, 1998a). Since it was not possible to take the second radiograph after exactly 6 months, a period of 10 days before or 10 days after 6 months was used. The patients were selected on the basis that the desired movement of the incisors would occur during the uninterrupted 6 month period. However, five patients were eliminated from the sample as they failed to attend regular follow-ups (Table 1). Thus, 49 pairs of radiographs (20 males and 29 females) were statistically analysed.

Pre-requisites for the study of root resorption between T1 and T2:

1. No changes in the biomechanics used.
2. No disturbance in the position of the incisor brackets.
3. Good quality radiographs of the upper central incisors including the root apices.

*Biomechanics*

Roth brackets with a 0.018 × 0.030 inch slot (Dentaurum, Ultra-Minitrim, Ispringen, Germany) were used in all three groups.

In group 1, intrusion of the upper central incisor was undertaken using an intrusion arch: [titanium molybdenum alloy (TMA)] 0.017 × 0.025 inch wire or a (connecticut intrusion arch:CIA) 0.016 × 0.022 inch wire, employing a force of 10 cN per maxillary incisor. Stainless steel wires, 0.017 × 0.025 or 0.018 × 0.025 inch, were used in the anterior and posterior segments, and a transpalatal arch in the posterior segments.

Intrusion and retraction of the upper central incisor were carried out in group 2 using the three component intrusion arch: intrusion levers made of 0.016 × 0.022 inch TMA wire were used to achieve controlled activation of 20 cN on each side, in addition to elastic chains delivering a force of 25 cN to each side. Stainless steel wires, 0.017 × 0.025 or 0.018 × 0.025 inch, were used in the anterior and posterior segments and a transpalatal arch in the posterior segments.

In group 3, levelling of the upper dental arch was achieved with a 0.012 or 0.014 inch nickel titanium archwire.

For the radiographic method employed, the periapical parallel projection, it was necessary that the periapical region was visible without overlapping of the roots of the central incisors. Further, the periapical parallel projection had to be adapted to meet the objectives of the study.

A Hawe Super-Bite X-ray holder (Hawe Neos Dental SA, Zona Strecce, Bioggio, Switzerland), an extension of the cone parallelling device (Figure 1), was modified so that the distance between the tooth and the film, and the tooth and the X-ray tube could be kept constant and accurately measured. In order to achieve this, a composite plate with the bite plane along an indentation and a stop to allow for accurate positioning of the sliding ring was used. The distance between the film and the sliding ring was fixed at 70 mm. This distance was assumed to be constant for all examined teeth at T1 and T2.

To determine the radiographic angle for the central incisors, a universal transfer key made of 0.018 × 0.025 inch stainless steel wire was used (Figure 2a,b). The diameter of the wire was determined by the orthodontic

**Table 1** Number of subjects and division into different groups depending on the biomechanics used. Periapical radiographs taken prior to (T1) and after 6 months (T2) of orthodontic treatment.

| Groups | T1 | T2 | Eliminated |
|---|---|---|---|
| 1 (intrusion – basal intrusion arch) | 17 | 15 | 2 |
| 2 (intrusion and retraction –three component intrusion arch) | 18 | 17 | 1 |
| 3 (levelling – straightwire) | 19 | 17 | 2 |
| Total | 54 | 49 | 5 |

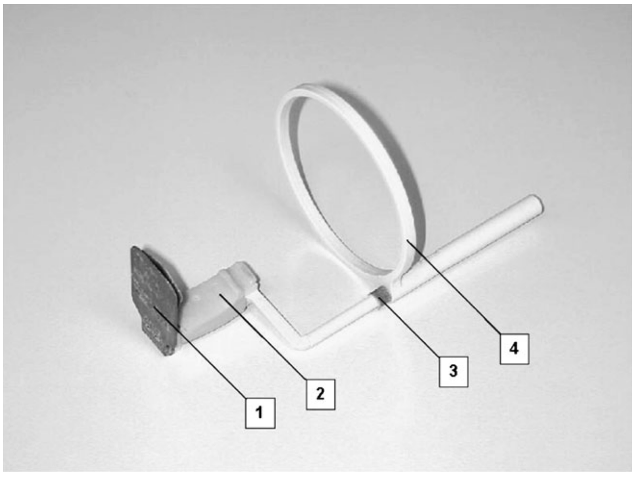



**Figure 1** Modified film holder. 1. Grove for fixing the film; 2. Composite plate with the bite plane along an indentation; 3. Stop defining the distance between the X-ray tube and film; 4. Sliding ring for attaching the holder to the X-ray tube.

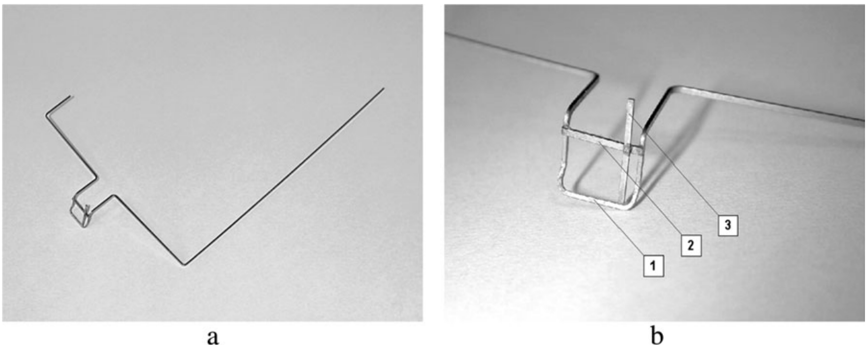



**Figure 2** (a and b) Transfer key. 1. Horizontal part inserted into the slot of the orthodontic bracket; 2. Horizontal wire to strengthen the rigidity of the system; 3. Vertical wire to determine the reference distance (10 mm).

bracket used for treatment which had a 0.018 × 0.030 inch slot. To increase rigidity, the transfer key was strengthened with a horizontal steel connector between the vertical arms. In addition, a 0.018 × 0.025 inch stainless steel wire with a length of 10 mm was welded vertically. This wire determined the reference distance during radiographic evaluation. The transfer key was placed perpendicular to the long axis of the examined tooth. It was important to maintain the same angle between the long axis of the incisor and the transfer key at T1 and T2 in each patient regardless of the quality and quantity of the tooth movement.

Periapical radiographs were taken with a Planmeca Prostyle intra machine (Planmeca Oy, Helsinki, Finland) using 60 kV and 0.1 second exposure and Kodak Ultra-Speed 25 × 35 mm films. The holder attached to the X-ray tube was positioned parallel to the transfer key. Thus, accurate distances and angles for obtaining identical radiographs of the examined teeth over the period of time were achieved (Figure 3).

With the universal transfer key and the modified holder, it was possible to obtain pairs of periapical radiographs at T1 and T2. The periapical radiographs were taken by the same radiographer, thus minimizing errors. The radiographs (Figure 4a,b) were evaluated using a computer software program (PC Dent, Dialogmis spol. s.r.o, Slavickova, Prague, Czech Republic). The reference distance was fixed at 10 mm, since it was the fixed component of the transfer key. As the computer software program used 50 mm as the reference distance, it was necessary to reduce the values to one-fifth and this distance was defined as the shortest distance between the shadow of the horizontal connector of the transfer key and the shadow of the root apex.

*Statistical analysis*

The values measured were statistically analysed on Excel using the Number Cruncher Statistical System (NCSS Statistical Software, Kaysville, Utah, USA). Analysis of variance (ANOVA) and Wilcoxon paired tests were also performed at a level of significance of 0.05.

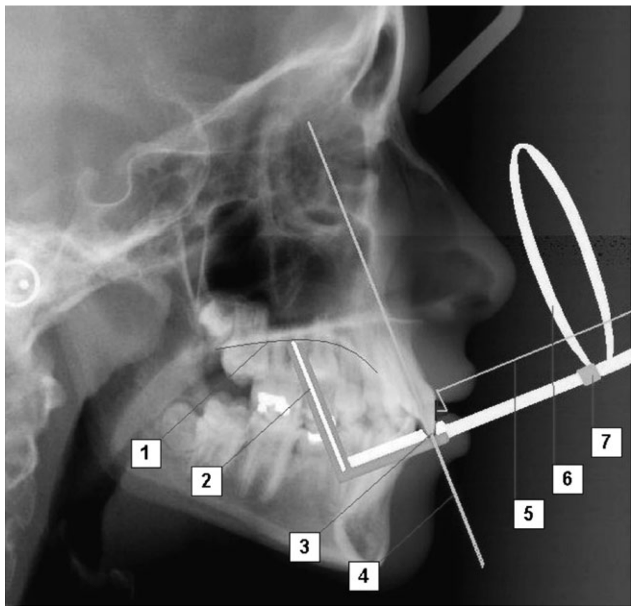


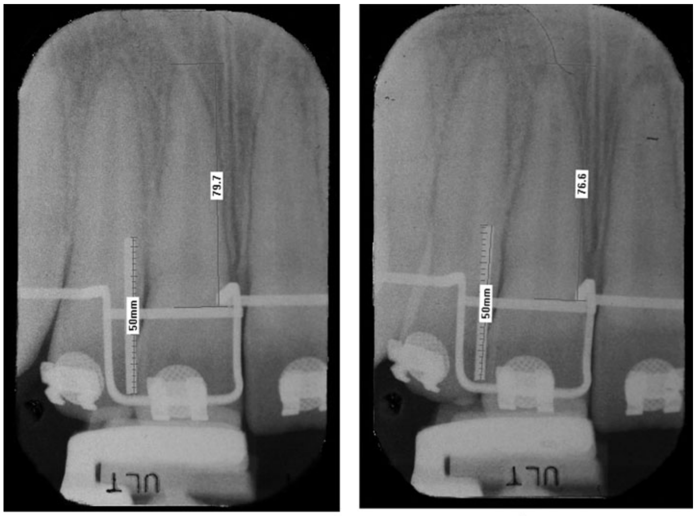

**Figure 3** Cephalogram showing the transfer key and film holder. 1. Palatal vault; 2. Film fixed in the modified holder; 3. Indentation in the composite plate with the bite plane; 4. Long axis of the upper central incisor; 5. Transfer key fixed in the slot of the incisor bracket; 6. Sliding ring to fix the holder to the X-ray tube; 7. Stop defining the distance between the X-ray tube and film.

## Results

The average incisor resorption at T2 was 0.26 mm in group 1, 0.46 mm in group 2, and 0.25 mm in group 3 (Table 2).

ANOVA was used to assess the differences in root resorption of the upper central incisor in the three groups (Figure 5). Although the root resorption in group 2 was almost double that of groups 1 and 3, the differences were not significant ($P = 0.103$).

Wilcoxon paired test showed that root resorption that occurred between T1 and T2 in all three groups was not




a b

**Figure 4** Periapical radiographs at the start (a) and after 6 months (b) of orthodontic treatment.

**Table 2** Average mean root resorption in groups 1 (intrusion – basal intrusion arch), 2 (intrusion and retraction – three component intrusion arch), and 3 (levelling – straightwire) at the start of treatment (Tl) and after a period of 6 months.

| | Mean | SD | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| Group 1 | | | | | |
| T1 | 15.67 | 1.8 | 15.6 | 13.5 | 19.7 |
| T2 | 15.41 | 1.75 | 15.6 | 13.5 | 19.2 |
| Difference | 0.26 | 0.24 | −0.2 | −0.8 | 0.06 |
| Group 2 | | | | | |
| T1 | 15.67 | 1.66 | 15.6 | 12.5 | 18.3 |
| T2 | 15.21 | 1.77 | 15 | 12.2 | 18.2 |
| Difference | 0.46 | 0.32 | −0.5 | −0.9 | 0.06 |
| Group 3 | | | | | |
| T1 | 1.09 | 0.99 | 16 | 14.3 | 18.3 |
| T2 | 1.84 | 0.94 | 15.8 | 14.1 | 17.6 |
| Difference | 0.25 | 0.37 | −0.1 | −1.1 | 0.12 |

significant ($P<0.05$). In order to interpret the results in another way, the patients studied were divided into three groups, according to the extent of apical root resorption and the biomechanics used (Table 3).

In group 1, apical root resorption was less than 0.5 mm for 87 per cent of the examined upper central incisors and 0.5–0.9 mm in 13 per cent. A similar situation was found in group 3 where resorption was less than 0.5 mm for 76 per cent of the upper central incisors, 0.5–0.9 mm in 18 per cent and greater than 1 mm for one incisor. Group 2 showed different results with root resorption less than 0.5 mm for 47 per cent of upper central incisors and 0.5–0.9 mm for 53 per cent. While the greatest root resorption, 1.08 mm, was found in group 3, this group showed the least mean value for root resorption.

Correlation of apical root resorption of the upper central incisors with the age of the patients was tested using simple linear regression analysis and the zero regression co-efficient. The results showed that root resorption was not dependent on age ($P=0.564$).

The Mann–Whitney *U*-test was used to determine the dependence of the apical root resorption on the gender of the patient and the test proved the null hypothesis ($P=0.729$) that the difference in gender was not significant.

A comparison was also made between the three groups using an unpaired *t*-test. The *P* values were 0.081 (groups 1 and 2), −0.056 (groups 2 and 3), and 0.0925 (groups 3 and 1), which showed that there was no significant difference in the rates of root resorption.

## Discussion

It is well known that root resorption is a serious iatrogenic problem during orthodontic treatment. External root resorption is known to occur as a result of the application of orthodontic force (Levander *et al.*, 1998b). Resorption craters have been observed with low force application, and sometimes even with no orthodontic treatment, which has led to the observation that resorption is of a physiological nature (Reitan, 1974; Reitan and Rygh, 1994; Kurol *et al.*, 1996; Kurol and Owman-Moll, 1998). Many studies on root resorption have been confined to biological and mechanical factors on the development of resorption during treatment (Copeland and Green, 1986; Brezniak and Wasserstein, 1993; Blake *et al.*, 1995; Levander *et al.*, 1998a; Owman-Moll and Kurol, 2000). The presence of risk factors along with orthodontic treatment has been found to increase the extent of root resorption (Linge and Linge, 1983; Levander and Malmgren, 1988; Remington

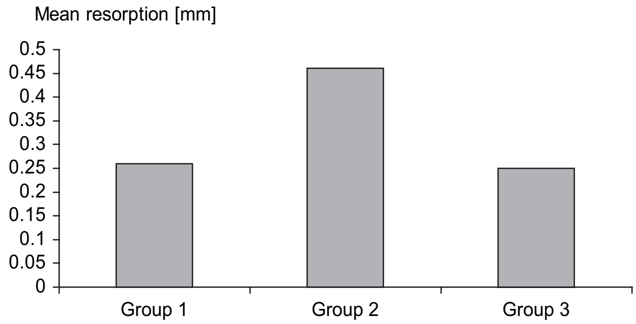



**Figure 5** Graphical representation of mean resorption of groups 1 (intrusion–basal retrusion arch), 2 (intrusion and retraction–three component intrusion arch) and 3 (levelling–straight wire).

**Table 3** Grouping of patients according to the biomechanics used and the amount of root resorption.

| Biomechanics (mm) | Group 1 ($n$=15) | Group 2 ($n$=17) | Group 3 ($n$=17) |
|---|---|---|---|
| | Basal intrusion arch | Three component intrusion arch | Straightwire |
| Resorption <0.5 | 13 | 8 | 13 |
| Resorption 0.5–0.9 | 2 | 9 | 3 |
| Resorption 1.0–1.4 | 0 | 0 | 1 |
| Maximum resorption | 0.82 | 0.96 | 1.08 |

*et al.*, 1989; Spurrier *et al.*, 1990; Lee *et al.*, 1999). The aim of the present study was to explore improved techniques of radiographic quantification of apical root resorption. A similar study was carried out by Costopoulos and Nanda (1996) in a sample of 17 patients. They used an individually made steel wire fixed in a resin block that was parallel with the long axis of the incisor prior to taking the cephalogram and periapical radiograph. This served as a reference distance and allowed calculation of the change in the length of the tooth. In the present study, a universal key was fixed in the slot of the orthodontic bracket, instead of a steel wire. Thus, the error of measurement was significantly reduced (variation coefficient <1%). However, this simplified procedure can only be used for maxillary incisors.

In group 1, the average maxillary incisor root resorption from T1 to T2 was 0.26 mm, with an applied intrusive force of 10 cN per maxillary incisor. Costopoulos and Nanda (1996) applied a force of 15 cN per incisor for 4 months and found average incisor root resorption of 0.6 mm. The results in the present study as well as those of Costopoulos and Nanda (1996) were slightly different with respect to the extent of resorption of the maxillary central incisors when a continuous arch was used (resorption of 0.25 mm after 6 months and 0.2 mm after 4 months of orthodontic treatment). The difference in the extent of resorption after the use of the intrusion arch is attributed to the extent of the force applied. Despite the fact that intrusion took 2 months longer in the present study, root resorption was 50 per cent less. It seems that intrusion with a lower force may reduce the extent of external apical root resorption. This needs to be substantiated by further studies, which would, apart from evaluation of external apical root resorption, assess the extent of intrusive movement of maxillary incisors when a force of 10 cN per incisor is applied. Furthermore, this study assessed intrusion only according to the adjustment of the depth of bite during individual check-ups.

Marek *et al.* (2001), in a study of maxillary incisor resorption using basal and three component intrusion arches, found average apical root resorption of 1.75 and 0.94 mm, respectively. In the present study, maxillary central incisor resorption at T2 following intrusion with a basal intrusion arch and combined movement with a three component intrusion arch was 0.26 mm and 0.46 mm, respectively. Thus, apical root resorption in both groups was much less than that reported by Marek *et al.* (2001).

As mentioned previously, the highest prevalence of apical root resorption was found in group 2, where intrusion as well as retraction of the upper anterior segment was undertaken simultaneously. This probably increased the torque of maxillary incisor roots against the palatal cortical plate. Kaley and Philips (1991), however, suggested a more secure procedure, i.e. first to carry out intrusion during which the maxillary incisor roots move into spongious bone and then to apply retraction only as the second step. However, this procedure may lead to a longer treatment time with fixed appliances, which may again result in higher resorption. The findings of the present study also showed greater resorption (0.46 mm), which seems to suggest that intrusion and retraction whether carried out simultaneously or consecutively, does not greatly affect the extent of root resorption.

The average root resorption was 0.46 mm in group 2, which was higher when compared with groups 1 and 3, where the average apical root resorption was 0.26 and 0.25 mm, respectively. When the patients were divided into three groups on the basis of the extent of root resorption and the biomechanics used, again group 2 showed the greatest root resorption with 53 per cent having resorption of 0.5–0.9 mm whereas in groups 1 and 3, only 13 and 18 per cent, respectively, showed resorption between 0.5 and 0.9 mm. Further studies using all the three techniques would be necessary before any definite conclusions can be made as to whether one or another technique results in greater or lesser root resorption.

## Conclusion

The three different techniques used in this study, namely the basal intrusion arch, the three component arch, and levelling with the straightwire appliance resulted in varying degrees of upper central incisor root resorption during the 6 month treatment period. However, the differences were not statistically significant. There was also no significant difference among the rates of resorption in the three groups or any relationship between upper central incisor apical root resorption with the age or gender of the patients.

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