*European Journal of Orthodontics* 29 (2007) 583–588
*doi:10.1093/ejo/cjm060*
*Advance Access publication 18 September 2007*



# Apical root resorption of upper incisors during the torquing stage of the tip-edge technique

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SUMMARY The purpose of this study was to investigate whether treatment with the Tip-Edge® appliance resulted in more apical root resorption (ARR) of the central and lateral incisors during the torquing (third stage) than the non-torquing phases (first two stages) of orthodontic treatment. The three stages of this orthodontic technique make it possible to examine the amount of root shortening during torque separately from other types of tooth movement. The ARR ratio was calculated in 31 Caucasian patients (20 females, 11 males), after the non-torquing stage of treatment and after the torquing phase, by analysing periapical radiographs taken at the beginning of treatment (T1), before the start of the torquing stage (T2), and at the end of treatment (T3). At T1, the mean age was 13 years 6 months (± 3 years 3 months). The mean, standard deviation and range of the ARR ratios were calculated and compared ($P < 0.001$). *T*-tests were performed to determine levels of significance, at different stages of treatment, between teeth with and without ARR (ARR ratio = 1).

Root shortening at T3 was observed for 70 per cent of the central and 76 per cent of the lateral incisors. At T2, ARR was 48 and 53 per cent, respectively. Compared with T2, 38 per cent of the central incisors and 55 per cent of the lateral incisors showed ARR during the application of torque. At T3, the finding for both was 22 per cent. The mean ARR ratio for the central and lateral incisors was the same after the non-torquing stage of treatment but was significantly different from a tooth with no root resorption. After the torquing stage, the ARR ratio for the central incisors was 0.96 and for lateral incisors 0.92. At the end of treatment, the ratio was 0.89 and 0.85, respectively.

This study revealed that both the central and the lateral incisors showed comparable amounts of ARR during the torquing and non-torquing stage of Tip-Edge® treatment.

## Introduction

Apical root resorption (ARR) is a common idiopathic problem associated with orthodontic treatment. According to Reitan and Rygh (1994), no orthodontic tooth movement is possible without root resorption. Fortunately, in most cases root resorption will be minor and therefore of no clinical importance. However, moderate to severe root resorption has been reported to occur with a frequency of 10–20 per cent (Hollender *et al.*, 1980; Levander and Malmgren, 1988; Brin *et al.*, 2003). Extreme root resorption (more than one-third of the original root length) is very rare (Levander *et al.*, 1994). Several causes have been mentioned to determine resorption, such as biological and mechanical (Brezniak and Wasserstein, 2002a,b).

It has been stated that light wire techniques, such as Tip-Edge or Begg, cause less root resorption than edgewise techniques (Malmgren *et al.*, 1982). However, in the final stage of these light wire techniques, in which torque is applied, some resorption will occur (Goldson and Henrikson, 1975; Ten Hoeve and Mulie, 1976; Hall, 1978; Remmelink, 1984). Beck and Harris (1994) and Levander and Malmgren (1988) found that the light wire and edgewise techniques carried the same risk and degree of ARR. It therefore appears that it is not the type of appliance responsible for resorption but more the type of orthodontic tooth movement. Linge and Linge (1991) found that initial overjet, among other variables, contributed significantly to ARR. According to Sameshima and Sinclair (2001b), horizontal displacement of the incisor apices is responsible for root resorption. Between the different types of tooth displacements, intrusion seems to cause the most damage to the roots (Dermaut and De Munck, 1986; McFadden *et al.*, 1989; Beck and Harris, 1994), followed by torque and bodily movement (Goldson and Henrikson, 1975; Reitan and Rygh, 1994).

In most studies, the incisors are the teeth that have been found to be mostly affected by root resorption (Brezniak and Wasserstein, 1993; Harris, 2000; Sameshima and Sinclair, 2001a,b). Janson *et al.* (2000) reported that the upper central incisors showed more root resorption than the upper lateral incisors, while others found the opposite (Blake *et al.*, 1995; Harris, 2000; Sameshima and Sinclair, 2001b). Also, teeth with abnormal root shape (pipette, pointed, or dilacerated) are more prone to ARR (Kjær, 1995; Mirabella and Årtun, 1995; Taithongchai *et al.*, 1996; Sameshima and Sinclair, 2001a).

It has been shown that root resorption of the upper incisors, observed during the initial 6–9 months of treatment with fixed appliances, results in a higher risk for continuing root resorption during subsequent treatment (Levander and Malmgren, 1988). It has therefore been recommended that periapical radiographs should be obtained after 6 months of orthodontic treatment (Levander *et al.*, 1994; Levander and Malmgren, 1998, 2000).

To radiographically assess the amount of ARR, the parallel technique is the view of choice. Using a film holder, with a fixed film packet and X-ray tubehead positions, the technique is reproducible and thus sequential films can be used for comparative purposes to assess the progression of resorption (Leach *et al.*, 2001). To measure the amount of ARR on radiographs, most studies refer to an arbitrary score that represents a specific amount of resorption (Dermaut and De Munck, 1986; Kaley and Phillips, 1991; Beck and Harris, 1994; Levander *et al.* 1994; Blake *et al.*, 1995; Mirabella and Årtun, 1995; Baumrind *et al.*, 1996; Kurol *et al.*, 1996; Taithongchai *et al.*, 1996; Lee *et al.*, 1999; Janson *et al.*, 2000; Harris, 2000).

The purpose of this study was to determine if ARR occurs during orthodontic treatment using the Tip-Edge® appliance and to define if the amount of ARR is more pronounced during the final than the non-torquing stage.

## Subjects and methods

Ethical approval for this study was given by the Ethics Committee of the University Hospital Ghent, project EC UZG 2006/141.

The experimental group consisted of 31 Caucasian patients (20 females, 11 males) treated at the Orthodontic Department of the University of Ghent by postgraduate students, using the Tip-Edge® appliance (TP Orthodontics, La Porte, Indiana, USA). This technique is divided into three stages: during the first and second stage of the technique, the teeth are well aligned, antero-posterior and occlusal relationships corrected, and possible extraction spaces closed. These two stages will be referred to as the 'non-torquing stage', and the final (third) stage of the technique that aims to upright and to torque teeth as the 'torquing stage'. During the non-torquing stage of treatment, no active torque was applied to the teeth. Rectangular archwires were used at the start of the torquing phase, while uprighting and torquing was produced by side winder springs (auxiliary spring fabricated in 0.014-inch stainless steel used to upright and torque the teeth as required). When individual tooth positions were not optimal after complete uprighting, extra torque was bent in the rectangular archwire or could be achieved with other torquing auxiliaries. No evaluation of the required torque was made at the end of stage 2 because the amount of torque required was dependent upon two main factors: upper incisor inclination and tipping at the end of stage 2 and individual aesthetic judgement concerning the amount of torque required. These variables could not be controlled in this clinical study. Moreover, a quantitative evaluation of the amount of torque can only be made on cephalograms. For ethical reasons, it was decided not to expose the patients to more radiation since periapical radiographs had been obtained at the beginning of treatment (T1), at the start of the torquing stage (T2), and at the end of treatment (T3).

At T1, the mean age of the patients was 13 years 6 months (± 3 years 3 months). The mean treatment time was 2 years 3 months (± 6 months). The non-torquing stage lasted 11 months (± 4 months) and the torquing phase 1 year 4 months (± 6 months).

To measure the amount of ARR, the long-cone radiographic technique was used (Van de Poel and Duinkerke, 1975). Because the film is parallel to the tooth and the X-ray beam perpendicular to the film, minimal distortion or enlargement can be expected which enables more accurate measurement of changes in root length than panoramic radiographs. Three periapical radiographs were taken, at T1, T2, and T3. The central and lateral incisors in the same quadrant were registered on a single intra-oral radiographic film to limit the patient's exposure to radiation. The radiographs were developed, magnified (×3), and digitized using Agfa ScanWise 1.2.0.5® (Mortsel, Belgium). The images were then imported to Jasc® Paint Shop Pro 7™ (Eden Prairie, USA). The edge of the bracket, cementoenamel junction, and root apices were marked and used to define crown and root length (Dermaut and De Munck, 1986). While most studies use the incisal edge instead of the edge of the bracket, in this investigation the bracket edge was used because some teeth were abraded or reshaped during treatment and when the bracket was not replaced, the tooth could still be included. A second reason was the fact that the image of the incisal edge was not always optimally observable on the radiographs while the edge of the bracket was always well defined.

Patients who showed root resorption before treatment, endodontically treated teeth or teeth with earlier trauma were excluded from the study. Poor radiographs were also excluded resulting in a final total of 50 central and 49 lateral incisors. No distinction was made between age, gender, race, root shape, treatment time, or treatment plan. The only aim of this study was to determine if ARR occurs using the Tip-Edge® appliance and to define if this is more pronounced during the torquing than the non-torquing stage. At the end of stage 2 in the tip-edge technique, spaces are closed, teeth are well aligned, and the overjet and overbite are corrected. In other words, the clinical situation for every patient, before the torquing stage, was to some extent comparable. Therefore, some standardization of the patients was present at T2.

To eliminate enlargement differences of the three radiographs, a mathematical formula was used (Dermaut and De Munck, 1986; Linge and Linge, 1991; Blake *et al.*, 1995; Mirabella and Årtun, 1995; Lee *et al.*, 1999).

The ARR ratio was calculated as follows (Figure 1): $C1/C2 \cdot R2/R1$, where $C$ is the crown length and $R$ the root length at different time points. When a tooth showed no root resorption during the different treatment periods, the ARR ratio was classified as 1.

The mean, standard deviation (SD), and range of these measurements were calculated. *T*-tests were performed to determine the levels of significance, at the different stages of treatment, between teeth with and without ARR (ARR ratio = 1).

*Error of the method*

All periapical radiographs were taken by the same researcher and measured by the same person. The reliability of the intra-oral radiographic measuring method has been tested previously (Dermaut and De Munck, 1986). Because the control group (15 dental students) underwent no therapy and the observation period between the measurements was short (28 weeks), no measurable ARR was expected and the root lengths should be the same at the two observation times. Nevertheless, the relationship was calculated for each of the control teeth and showed a mean ratio of 0.99 (SD = 0.08), due to a small measuring error. The *t*-test showed no significant difference.

## Results

Figures 2 and 3 show that at T2, 24 out of 50 central incisors and 26 out of 49 lateral incisors showed ARR. At T3, these figures were 35 and 37, respectively. Compared with root length at the end of T2, 19 central incisors showed some ARR, whereas in 27 lateral incisors ARR was noticed after torque application. Of the 19 central incisors with ARR during the torquing stage, eight teeth already showed resorption during the non-torquing phase. Eleven of the central incisors that showed ARR after the torquing stage did not show root resorption in the first stage of treatment. Arrested ARR was seen during the torquing stage for 16 of the 24 central incisors that did show ARR after the first stage of treatment. For the 27 lateral incisors with ARR, 16 had ARR during the non-torquing phase of treatment while 11 were affected only during the torquing stage. Arrested ARR was seen during the torquing stage for 10 of the 26 lateral incisors that showed ARR after the first stage of treatment.

At T2, the mean ratio was 0.93 (SD 0.08) for the central and lateral incisors (Table 1). The ratios varied between 0.70 and 1.03 for the central incisors and between 0.80 and 1.03 for the lateral incisors. These mean ratios were significantly different from a tooth without resorption (ARR ratio 1). This ratio increased for the central incisors to 0.96 (SD 0.07) during the final stage of treatment, but the difference was not statistically significant. The opposite tendency was observed for the lateral incisors: i.e. the ratio decreased from 0.93 to 0.92 (SD 0.09). This difference was also not statistically significant. The overall ratio for ARR at the end of treatment was 0.89 (SD 0.08) for the central incisors, ranging between 0.66 and 1.03, and 0.85 (SD 0.10) for the lateral incisors, ranging between 0.66 and 1.01. These ratios were statistically different from the theoretical where there was no ARR (ratio = 1).

Differences in ARR ratios between the central and lateral incisors during the torquing phase and at the end of treatment were not statistically significant.

## Discussion

It has been reported that particularly the upper incisors are prone to ARR (Brezniak and Wasserstein, 1993; Harris,

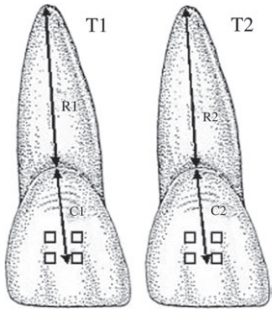


**Figure 1** Calculation of apical root resorption ratio between the beginning of treatment (T1) and at the start of the torquing stage (T2). ARR ratio = $C1/C2 \cdot R2/R1$, where $C$ = crown length at T1 or T2 and $R$ = root length at T1 or T2

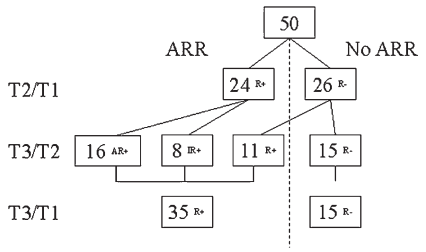


**Figure 2** Number of central incisors ($n$ = 50) with apical root resorption (ARR). T1, start of treatment; T2, end of non-torquing stage; T3, end of treatment; R+, ARR present; R−, no ARR present; AR+, arrested ARR (present ARR of non-torquing stage); IR+, increased AR.

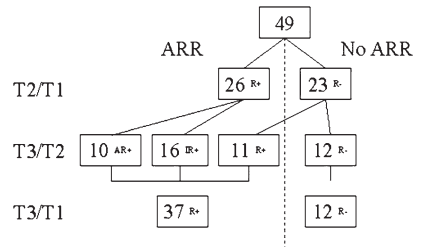


**Figure 3** Number of lateral incisors ($n$ = 49) with apical root resorption (ARR). T1, start of treatment; T2, end of non-torquing stage; T3, end of treatment; R+, ARR present; R−, no ARR present; AR+, arrested ARR (present ARR of non-torquing stage); IR+, increased ARR.

2000; Sameshima and Sinclair, 2001a). According to some studies, 90 per cent of patients show root resorption at the end of orthodontic treatment (Andreasen, 1988; Proffit, 1993; Reitan and Rygh, 1994). The findings of the present investigation are somewhat different: 70 per cent of the central incisors and 76 per cent of the lateral incisors showed ARR at the end of treatment. However, the difference was not statistically significant.

Although 48 per cent of the central incisors in the present study showed ARR at T2, only 33 per cent of these affected teeth had a tendency for increased root resorption at T3. For the lateral incisors, the percentages were slightly different: 62 per cent showed root resorption at T2, the root length reduced slightly more during torquing. But still, 38 per cent of these lateral incisors showed arrested ARR during the torquing stage.

These findings are somewhat different from the results reported by Levander and Malmgren (1988), who concluded that initial ARR, diagnosed after 6–9 months of treatment, is an indication for further ARR during the following stages of treatment. In the present study, radiographs were taken, on average, after 11 months of treatment. For teeth without ARR after this period, 11 out of 26 (42 per cent) centrals and 11 out of 23 (42 per cent) lateral incisors, that initially had no ARR, showed ARR during the torquing stage. These findings suggest that torquing, although not the only causative variable for ARR, is an aggravating factor.

According to Wheeler (1974), the average mean root length for an incisor is 13 mm (Figure 4). These average values were used as a starting point to calculate the amount of ARR. The following conclusions could be drawn: with a root resorption ratio of 0.93 at T2 and a root resorption ratio of 0.96 at T3, the root length of the central incisors diminished by 0.9 mm during the first stage of treatment and a further 0.5 mm during the torquing stage. The total amount of ARR for a central incisor after treatment was 1.4 mm. For the lateral incisors, the amount of ARR after the first stage of treatment was also 0.9 mm and during the torquing stage an additional 1.0 mm, which makes the total amount of ARR 1.9 mm. Thus, the central and lateral incisors had an average root length of 12.1 mm at the beginning of the torquing stage. At the end of treatment, the central incisor had an average root length of 11.6 mm and the lateral incisor a root length of 11.1 mm.

The SD of the calculated ratios (Table 1) varied between 0.06 and 0.10 indicating that differences in ARR were observed between patients. This is in agreement with some other studies indicating that ARR is not dependent on force magnitude (Owman-Moll *et al.*, 1996; Maltha *et al.*, 2004) or type of movement, but as suggested by some authors (Linge and Linge, 1991; Al-Qawasmi *et al.*, 2003; Ngan *et al.*, 2004; Årtun *et al.*, 2005), on a genetic component. According to Wheeler's (1974) mean root length value, the measured SD in the present study was approximately 1 mm.

The registered values for ARR for the present sample of central incisors are in agreement with Baumrind *et al.* (1996), Parker and Harris (1998), and Sameshima and

**Table 1** Apical root resorption ratio for central and lateral incisors at T1, start of treatment; T2, end of non-torquing stage, and T3, end of treatment.

| | Central incisors ($n$ = 50) | | | Lateral incisors ($n$ = 49) | | |
|---|---|---|---|---|---|---|
| | Ratio T2/T1 | Ratio T3/T2 | Ratio T3/T1 | Ratio T2/T1 | Ratio T3/T2 | Ratio T3/T1 |
| Mean | 0.93*** | 0.96*** | 0.89*** | 0.93*** | 0.92*** | 0.85*** |
| SD | 0.08 | 0.07 | 0.08 | 0.06 | 0.09 | 0.10 |
| Range | 0.70–1.03 | 0.82–1.04 | 0.66–1.03 | 0.80–1.03 | 0.70–1.01 | 0.66–1.01 |

Levels of significance between teeth without ARR (ARR ratio = 1) and the experimental teeth: ***$P < 0.001$.

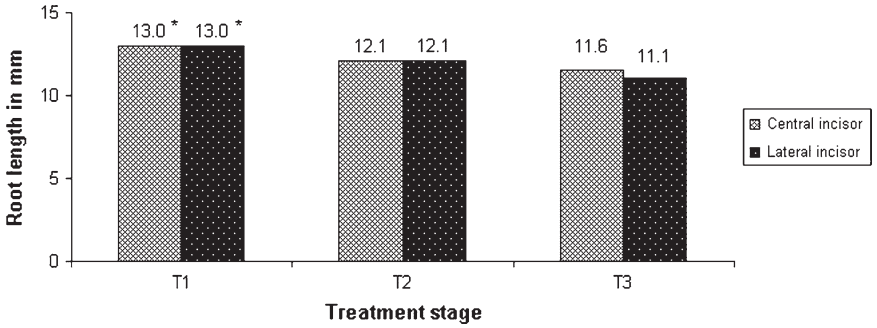


**Figure 4** Root length for the central and lateral incisors, based on mean root lengths according to Wheeler* (1974), at T1, start of treatment; T2, end of non-torquing stage; T3, end of treatment.

Sinclair (2001a,b). The observed amount of ARR for lateral incisors is also in agreement with other studies (Dermaut and De Munck, 1986; McFadden *et al.*, 1989; Taithongchai *et al.*, 1996). Although the present findings seem to have comparable results with other researchers (Blake *et al.*, 1995; Harris, 2000; Sameshima and Sinclair, 2001a; Brin *et al.*, 2003; Smale *et al.*, 2005) in as much as more ARR was found for the laterals than for central incisors, the results of this study showed there was no statistically significant difference, even though the number of lateral incisors with root resorption during the torquing stage was higher in proportion to central incisors.

In this limited sample, torquing biomechanics seem to have the same influence on ARR since no statistically significant difference was found between the central and lateral incisors. All upper incisors showed a comparable amount of ARR in the first and final stages of treatment.

## Conclusion

Torque seems to be accompanied by the same amount of ARR in upper incisors as other types of tooth movements during treatment with the tip-edge technique.

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