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The effect of maintaining apical patency on canal transportation

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Abstract

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Aim To evaluate, *ex vivo*, the effect of maintaining apical patency on the original canal shape during preparation of curved roots by two different techniques.

Methodology Forty extracted human maxillary and mandibular molars were evaluated. Occlusal surfaces were ground and roots sectioned to the level of the cemento-enamel junction to allow only one root to remain for evaluation in each tooth. Specimens were divided into four experimental groups (10 canals each): Group 1 – root canals prepared using the balanced force technique with stainless steel K-files, and patency established with size 10 K-files between each instrument; Group 2 – same as Group 1 but without the use of a patency file; Group 3 – canals instrumented with LightSpeed® instruments and patency established with size 10 K-files between each instrument; and Group 4 – same as Group 3 but without the use of a patency file. Specimens were mounted and a series of radiographs taken. Initial and post-preparation digital images were superimposed and the distance between two central axes at 1, 2 and 4 mm from the working length (WL) was measured to obtain an indication of the degree of apical transportation. Results were subjected to statistical analysis using two-way analysis of variance (ANOVA).

Results No significant differences were found in degree of apical transportation at different levels of the root canal ($P > 0.05$) nor in loss of WL between groups ($P > 0.05$).

Conclusion In this laboratory study, maintaining apical patency did not influence canal transportation in the apical 4 mm.

Keywords: apical patency, root canal preparation.

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Introduction

The aim of mechanical root canal preparation is to remove organic tissue and debris from the root canal and to shape the canal to allow effective cleaning and filling. The apical part of curved canals is most challenging to prepare (Schäfer *et al.* 1995). Stainless steel files tend to straighten the canal which results in alterations of the apical anatomy, such as zipping or perforations. These alterations are generally seen as shortening of working length (WL) (Guelzow *et al.* 2005).

As the curvature of the canal space increases, it is progressively more difficult to maintain the original shape of the canal, especially near the apical foramen (Cailleteau & Mullaney 1997). Apical patency is a technique in which the apical portion of the canal is maintained free of debris by recapitulation with a small file through the apical foramen (Glossary of Endodontic Terms 2003). Apical patency may help to prevent root canal blockage by frequent use of patency files (Buchanan 1991). A patency file is defined as a small, flexible file which will move passively through the terminus of a root canal without binding or enlarging the apical constricture (Buchanan 1991). A patency file is set at a length 1 mm longer than the final WL.

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Patency maintenance is believed to control debris accumulation in the apical portion of the canal, thus preventing ledge formation, transportation, and apical perforation (Buchanan 1989, Cailleteau & Mullaney 1997). In teeth with necrotic and infected pulps, patency may help remove the periapical bacterial plaque that is present mostly around the main apical foramen (Lomcali *et al.* 1996). In vital cases, apical patency is intended exclusively to prevent dentine chips compacting into the apical region forming a plug that can interfere with the WL (Souza 2006).

Approximately 50% of dental schools in the United States teach the concept of patency (Cailleteau & Mullaney 1997), but the use of this technique is a matter of controversy due to biological consequences such as over-enlargement of the apical foramen (Goldberg & Massone 2002), damage to the periapical tissues (Ricucci 1998, Ricucci & Langeland 1998), inadvertent extrusion of the contaminated dentine chips and debris (Martin & Cunningham 1982, Fairbourn *et al.* 1987, Lambrianidis *et al.* 2001), and postoperative pain (Siqueira 2003).

The aim of the present study was to evaluate, *ex vivo*, the effect of maintaining apical patency on the original canal shape, apical transportation and loss of WL during preparation of curved root canals by two different techniques.

Materials and methods

Forty extracted human maxillary and mandibular molars were selected. The occlusal surfaces were removed and access preparation performed with high-speed diamond burs. Roots were removed to the level of the cemento-enamel junction and only one root remained in each tooth. All evaluated roots were approximately the same length as measured by a ruler. Only roots were selected in which a size 10 file (Mani Inc., Takanezawa, Japan) could be just be inserted to the full length until it emerged through the apical foramen. Roots in which a size 10 file passed freely through the apex were excluded.

The coronal parts of the roots were prepared with Gates Glidden drills Nos. 1, 2, and 3 (Dentsply Maillefer, Ballaigues, Switzerland). WL was determined by subtracting 1 mm from the length at which the size 10 K-file appeared visible through the apical foramen viewed under ×2.6 magnification (Orascoptic, Middleton, WI, USA). Canals were prepared to the WL using size 15 stainless steel K-files. Each tooth was inserted into a Plexiglass jig and secured with the help of self polymerized acrylic (Iqbal *et al.* 2003). Specimens were mounted on the angle metre and a series of radiographs taken using a size 1 digital intraoral CCD sensor (Sopix, Sopro Imaging, Acteon Group, La Ciotat, France). The sensor of the digital radiographic unit was secured to the Plexiglas wall located behind the turntable. To obtain the initial radiographs, the specimens were rotated in small increments until the file appeared straight on the radiographs and then rotated 90 to reveal the maximum curvature of the canal. The degree of rotation of the turntable was measured with the help of a protractor that was glued to the platform immediately below the turntable. After canal preparation, final radiographs were taken at the same angle as the initial ones to allow direct comparison between images.

The radius of curvature was calculated as described by Pruett *et al.* (1997). Specimens were divided into four experimental groups (10 canals each) so that the average radius of canal curvature in each group was similar to the other groups. Root canals were prepared as follows:

Group 1 – Canals prepared by a balanced force technique with stainless steel K-files (Mani Inc.) up to size 40 and step-back to size 70. Files were introduced into the canal until bound and rotated 90 to 180 clockwise with light apical pressure. Files were then rotated in a counterclockwise direction 120 to 360 applying an inward apical pressure. Patency was established with size 10 K-files between each instrument.

Group 2 – Same as Group 1 but without the use of a patency file.

Group 3 – After assuring that size 15 K-file was loose fit at the WL, canals were instrumented with LightSpeed® instruments (LightSpeed Technology Inc., San Antonio, TX, USA) to size 40 and step-back to size 70. Patency was established with size 10 K-files between each NiTi instrument.

Group 4 – Same as Group 3 but without the use of a patency file.

RC-Prep (Premier Dental Products, Norristown, PA, USA) was used and all canals were irrigated with 1 mL of 5.25% NaOCl after each instrument. Following mechanical preparation, canals were irrigated with 5 mL of 5.25% NaOCl and 5 mL of 17% EDTA.

Digital images were exported to Adobe Photoshop (Adobe Systems Inc., San Jose, CA, USA) and artistic filters were applied to posterize the edges to improve contrast. AutoCad 2005 computer program (Autodesk Inc., San Rafael, CA, USA) was used to draw the central axis of the K-file. Initial and post-preparation images were superimposed and the distance between two

central axes at 0, 1, 2 and 4 mm from the WL was measured to achieve an indication of the degree of apical transportation. Any loss of the WL between the initial and final files was also calculated. In order to ensure blind assessment, the evaluator was not aware of the particular group while measuring the degree of apical transportation and loss of WL.

Results were subjected to statistical analysis using two-way analysis of variance (ANOVA) ($P < 0.05$).

Results

Blockage of the canal in the middle portion was found in two teeth from Groups 1 and 2 and separated instruments in three teeth from Groups 3 and 4. These five teeth were excluded.

Mean radius of curvature is shown in Table 1. No significant difference was found between groups ($P > 0.05$).

Table 2 shows the mean values of apical transportation at different levels. In some samples it was impossible to calculate apical transportation at the D0 and D1 levels owing to a loss of WL. Due to the small number of specimens available for calculation at D0, the statistical analysis was performed only at the levels D1, D2 and D4. No significant difference was found between groups ($P > 0.05$) in the degree of apical transportation at different levels of the root canal.

Table 3 shows no significant differences in loss of WL between groups ($P > 0.05$). However, there was a tendency for WL to be maintained better when patency was maintained (Groups 1 and 3).

Table 1 Average values and standard deviation of radius of curvature between groups

Group (n = 10)	Mean radius of curvature
Balanced force (SS) + patency	5.47 ± 2.18
Balanced force (SS) w/o patency	5.43 ± 1.96
LightSpeed® (NiTi) + patency	5.48 ± 1.54
LightSpeed® (NiTi) w/o patency	5.44 ± 1.66

Table 3 Loss of working length in the four groups (mm)

Group	Sample size	Mean loss of WL
Balanced force (SS) + patency	3	0.77 ± 0.50
Balanced force (SS) w/o patency	4	0.92 ± 0.71
LightSpeed® (NiTi) + patency	5	0.32 ± 0.31
LightSpeed® (NiTi) w/o patency	7	0.44 ± 0.59
Total	19	0.61 ± 0.53

Discussion

An attempt was made to correlate the influence of maintaining apical patency in curved root canals on apical transportation and loss of WL. A rotating turntable with the angle metre is attributed to Maggiore (1994) and has been used to study apical transportation (Iqbal *et al.* 2003, 2004). This technique allows identification of the place of maximum curvature and setting it perpendicular to the X-ray beam. In the present study, the abruptness of curvature was calculated as proposed by Pruett *et al.* (1997) by measuring the radius of curvature. There was similar distribution of the specimens according to the radius of curvature between groups (Table 1).

Alteration in canal shape following preparation has been evaluated using various methods. Bramante *et al.* (1987) proposed the re-assembly of cross-sectioned teeth. Other techniques used drawings of projected radiographic images of the files to compare the position of the largest file used in the apical preparation with the position of a small file placed in the canal before instrumentation (Backman *et al.* 1992), and a double exposure radiographic technique with superimposition of pre- and post-instrumentation radiographs (Wu *et al.* 2000). However, these techniques use buccal and proximal views to evaluate apical transportation, which does not always reveal neither the maximum canal curvature, nor the position of the curve. In the present study, digital images and use of computer software allowed precise evaluation of even minor changes in the canal geometry.

Table 2 Average values and standard deviation of canal transportation at different apical levels (mm)

Group	Apical level		
	D1	D2	D4
Balanced force (SS) + patency	0.13 ± 0.10 (n = 8)	0.07 ± 0.06(n = 9)	0.11 ± 0.09(n = 9)
Balanced force (SS) w/o patency	0.11 ± 0.11 (n = 8)	0.07 ± 0.07(n = 9)	0.12 ± ±0.08(n = 9)
LightSpeed® (NiTi) + patency	0.09 ± 0.07 (n = 9)	0.08 ± 0.04 (n = 9)	0.09 ± 0.05 (n = 9)
LightSpeed® (NiTi) w/o patency	0.06 ± 0.04 (n = 7)	0.07 ± 0.05 (n = 8)	0.07 ± 0.05(n = 8)
Total	0.10 ± 0.08 (n = 32)	0.07 ± 0.06 (n = 35)	0.09 ± 0.07 (n = 35)

The concept of using a patency file is controversial. Souza (2006) advocates that endodontic treatment should extend to the full canal length and should not be limited to a point located 1 mm short of the apical foramen.

Apical patency is established during root canal preparation with the purpose of maintaining access to the foramen (mechanical goal), but it is important that after instrumentation the foramen is not only patent but also clean (biological goal) (Souza 2006). During instrumentation dentin chips may be inadvertently compacted into the apical portion of the canal and form a dentine plug resulting in blocking of the apical foramen (al-Omari & Dummer 1995, Beeson *et al.* 1998). Thus, the first purpose of the establishing of apical patency is to maintain access to the foramen (mechanical goal). In addition, it is important that after instrumentation the foramen is not only patent but also clean (biological goal).

The patency file should passively move through the apical constriction without widening it (Buchanan 1989). But, as the apical foramen usually deviates from the apical centre (Kuttler 1955), the patency file may change the apical anatomy by acting on one wall of the apical foramen. Transportation produced by the use of stainless steel and nickel-titanium K-files as patency files has been evaluated. In 33.3% of the specimens, apical transportation started with the use of size 10 K-file (Goldberg & Massone 2002). Thus, using a patency file without modifying the shape an/or calibre of the apical foramen in curved canals is likely to be impossible (Goldberg & Massone 2002).

From biological point of view, periapical tissues should not be traumatized and instrumentation should remain within the confines of the root canal (Ricucci 1998, Ricucci & Langeland 1998, Holland *et al.* 2005). An *in vivo* histologic study showed the most favourable conditions when instrumentation and obturation remained at or short of the apical constriction, even when bacteria had penetrated the foramen and were present in the periapical tissues (Ricucci & Langeland 1998).

The periapical healing process of teeth in dogs with or without apical patency and after root filling with two types of sealers was assessed (Holland *et al.* 2005). Significantly better healing was found in the groups in which patency was not maintained. Patency files push debris ahead and extrude it through the apical foramen when patency is maintained (Fairbourn *et al.* 1987, Lambrianidis *et al.* 2001).

In the present study, no significant difference was found in the degree of apical transportation and in loss of WL between groups. Similar to the previous studies (Iqbal *et al.* 2003, 2004), the data for transportation for most of the samples at D0 was not available because of loss of WL (Table 2), indicating the degree of precision with which measurements can be obtained when using AutoCAD.

In previous studies, little or no apical canal transportation was found when curved canals were instrumented using the LightSpeed® instruments. In 20 extracted human molar teeth, using a double exposure radiographic technique to assess the presence or absence of apical transportation, only one tooth instrumented using the LightSpeed® exhibited apical transportation (Knowles *et al.* 1996). Less apical transportation was also found with the LightSpeed® technique than with the step-back technique (Portenier *et al.* 1998).

Flex-R-Files have been recommended to use with the balanced force technique (Roane & Powell 1986), but K-files and other hand instruments may also be utilized (Peters & Peters 2006). When other instrumentation techniques were compared to hand instruments, the balanced force technique produces less deviation from the centre of the original canal (Leseberg & Montgomery 1991, Backman *et al.* 1992).

In 38 root canals in extracted human molars, significantly less apical canal centre movement was found with LightSpeed® compared with the balanced force technique (Shadid *et al.* 1998). In the present study, there was no significant difference in apical transportation and loss of WL between techniques.

Conclusion

Maintaining apical patency did not reduce apical transportation or influence loss of WL in curved root canals using either the balanced force technique or LightSpeed® files.

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