Efficacy of rotary instruments with greater taper in preparing oval root canals

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Abstract

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Aim To compare the preparation quality of two rotary systems and NiTi-hand files in oval root canals, and to evaluate the effect of canal dimensions on the preparation.

Methodology Ninety roots with oval root canals were selected. The middle third was cross sectioned at two levels and photographed. The maximum and minimum diameters of the root and canal were recorded. Teeth were distributed in three groups ($n = 30$) using stratified randomization, and prepared under simulated clinical conditions with Mtwo, ProTaper, or NiTi-hand files. The pre- and post-preparation photographs were traced and superimposed, the thickness of dentine removed was measured and the ratio of prepared canal outline was calculated. The impact of preparation system and canal dimensions on the quality of the preparation was evaluated using regression analysis.

Results With regards to the ratio of prepared canal outline, no statistical significant difference was found between Mtwo (0.75 [95%CI: 0.69; 0.81]) and ProTaper (0.75 [95%CI: 0.69; 0.80]), but both systems performed significantly better than NiTi-hand files (0.65 [95%CI: 0.60; 0.71]). In six root canals in Mtwo-group (20%), and eight root canals in ProTaper-group (27%), the minimal thickness of dentine-wall after preparation was less than 0.5 mm. In contrast to the maximum diameter of the root canal, the minimum diameter influenced the quality of the preparation ($P = 0.0006$).

Conclusions No instrumentation technique was able to circumferentially prepare the oval outline of root canals. Nevertheless, instruments with greater taper (ProTaper and Mtwo) were more efficient than NiTi- hand files, but this was, in some cases, at the expense of remaining dentine-wall thickness.

Keywords: dentine wall thickness, nickel titanium rotary systems, oval root canal preparation, root canal dimensions.

Introduction

Although instruments for root canal preparation have been progressively developed and optimized, a complete mechanical debridement of the root canal system is rarely achievable (Aydin *et al.* 2007, Rödig *et al.* 2007, Uzun *et al.* 2007). One of the main reasons is the geometrical dissymmetry between the root canal and preparation instruments. Rotary instruments regardless of their type and form produce a preparation with a round outline if they are used in a simple linear filing motion, which in most of the cases do not coincide with the outline of the root canal. Similarly, popular manual instrumentation techniques, such as the Balanced Force technique (Roane *et al.* 1985), usually implement rotation movement of files, which tends to create a round root canal preparation. Consequently, incomplete shaping is usually observed when the canal outline deviates from a round form.

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Oval root canals are the simplest deviation from a round outline and can be found in all types of teeth. The oval outline is more pronounced in mid root regions and decreases towards the apex, where the outline is almost round (Wu *et al.* 2000). Therefore, oval canals are, in most of the cases, highly tapered along the length of the root.

Many preparation techniques and instruments have been advocated to facilitate the preparation of oval root canals (Lumley *et al.* 1993, Wu & Wesselink 2001, Rödig *et al.* 2002, Weiger *et al.* 2002, Wu *et al.* 2003, Zmener *et al.* 2005, Ruttermann *et al.* 2007). The most common technique is circumferential filing with hand files or also with rotary instruments by pressing the instruments against the root canal wall (Weiger *et al.* 2002). Nevertheless, incomplete preparations were observed in most of the studies (Wu & Wesselink 2001, Barbizam *et al.* 2002, Rödig *et al.* 2002, Weiger *et al.* 2002, Ruttermann *et al.* 2007).

The ProTaper system (Dentsply Maillefer, Ballaigues, Switzerland) offers progressively tapered instruments with up to 19% taper. The Mtwo system (VDW, Munich, Germany) includes small instruments (sizes 10 and 15) with a taper of up to 7%. The combination of the small sized instruments and the increased taper might result in a better preparation of oval root canals.

This study compared the ratio of prepared dentine walls in oval canals shaped with either Mtwo, ProTaper, or NiTi hand files; the influence of root canal dimensions on the preparation was also evaluated.

Materials and methods

Ninety oval root canals were selected from mandibular incisor (43 canals) and molar teeth (47 canals). Initial identification of the oval root canals was performed radiographically by comparing the mesial and buccal radiographs of each root; an oval canal was identified when the width of the root canal in one aspect was twice or more than that in the other aspect. The selected root canals had a maximum curvature of 10 °. The teeth were embedded in a polyethylene binding material (Delo, Landsberg, Germany), and sectioned at two levels 'a' and 'c'. Section 'a' was 0.5 mm coronal to the junction between the middle and apical third (3.5–5 mm from the apex), section 'c' was 0.5 mm apical to the junction between the coronal and middle third of the root canal (6.5–8 mm from the apex). A detailed description of the procedure to determine the sectioning levels was published in a previous article (Weiger *et al.* 2002). Sections were photographed at 30× magnification using a M400 stereo microscope (Wild, Heebrugg, Switzerland). To evaluate the effect of root canal dimensions on the preparation, the maximum and minimum diameter of the root (R_{max} and R_{min}) and the root canal (C_{max} and C_{min}) in each section were recorded using AxioVision LE software (Carl Zeiss, Jena, Germany). The minimum dimension of the root and canal was measured mesio-distally and the maximum dimension was measured bucco-lingually. A total of 179 teeth were inspected to select the 90 root canals used for this study. Root canals with irregular oval outline (for example dumbbell shape) were excluded. The ratio of C_{max}/C_{min} in all root canals were more than 2 (an oval outline with the length two times larger than the width). The root canals were stratified according to C_{min} (Range: 0.2–0.8 mm), C_{max} (Range: 0.9–4 mm) and the minmum dentine wall thickness (Range: 1.05–2.05 mm) then randomized to three similar groups ($n = 30$ per group) (Table 1). The root sections were then reassembled using internal fixation screws placed through the embedding material. The pulp chamber was conventionally accessed and the distance to the apical foramen was determined by inserting a size 06 file into the root canal until the tip was just visible at the apex. The working length in each root canal was defined to be 1 mm short of the apical foramen.

To simulate the clinical conditions of root canal preparation, the assembled teeth were mounted in a dental mannequin (KaVo, Biberach, Germany) at their anatomical position. Root canal preparation procedures were performed by three endodontists who are experienced with the preparation system used. The root

Table 1 Mean values and the corresponding 95% confidence intervals of various parameters, C_{max}/C_{min}: ratio of the maximum and minimum diameter of the canal, R_{max}/R_{min}: ratio of the maximum and minimum diameter of the root, $L_{average}$: average of the ratio of prepared outline in both sections 'a' and 'c', L_{200}/L_{orig}: ratio of canal outline with >200 μm of dentine removed, $D_{<500}$: percentage of teeth with <500 μm of remaining dentine wall thickness

Group	C_{max}/C_{min}	R_{max}/R_{min}	$L_{average}$	L_{200}/L_{orig}	$D_{<500}$
Mtwo	5.2 (4.5; 5.9)	2.3 (2.2; 2.4)	0.75 (0.69; 0.81)	0.20 (0.17; 0.24)	20% ($n = 6$) (10%; 37%)
NiTi hand files	5.4 (4.6; 6.3)	2.2 (2.2; 2.4)	0.65 (0.60; 0.71)	0.16 (0.12; 0.20)	0% ($n = 0$)
ProTaper	5.7 (4.6; 6.9)	2.3 (2.2; 2.4)	0.75 (0.69; 0.80)	0.20 (0.17; 0.24)	27% ($n = 8$) (14%; 44%)

canals were initially prepared using NiTi hand files to size 15 and the coronal third was flared using Gates Glidden drills numbers 1–3.

Three systems were used to accomplish the root canal preparation as follows:

- NH group – NiTi hand files (Dentsply Maillefer)
- PT group – ProTaper (Dentsply Maillefer)
- MT group – Mtwo (VDW GmbH).

In the NH group the Balanced Force technique (Roane *et al.* 1985) was used to prepare the root canals to an apical size 40. In the PT and MT groups the instruments were used in the sequence recommended by the manufacturer. The instrument sequence in PT was S1 and SX until the apical third then S1, S2, F1, F2, F3 and F4. In MT each instrument (size 10, 0.04 taper to size 40, 0.04 taper) was used to the full working length. The apical preparation size was 40 (PT group 40/0.06 (F4) and MT group 40/0.04). Additionally, the middle third of the root canal was shaped with each file/instrument used as follows: in the NH group the circumferential filing was performed, in the PT and MT groups, the instruments were used in a circumferential filing manner, i.e. the instruments (freely rotating in the root canal) were pressed (brushed) against the root canal walls and then withdrawn in a coronal direction. Irrigation was performed after each instrument using 2 mL of 1% sodium hypochlorite through a needle having a diameter of 0.3 mm. The irrigation needle was placed as deeply as possible in the root canal without dentine wall contact. The final irrigation of 5 mL sodium hypochlorite was passively activated for 1 min using an ultrasonic device Piezon Master 600 (EMS GmbH, Munich, Germany).

Root canal sections were then dissembled and re-photographed at 30× magnification. In each section, the pre- and post-preparation photographs were traced and superimposed. The following parameters were recorded for each section:

L_{orig} = original length of root canal outline

L_{prep} = the part of L_{orig} that was prepared

L_{200} = the part of L_{orig} where more than $200 \mu m$ of dentine wall were removed

$D_{<500}$ = identifies teeth with a remaining dentine wall thickness of less than $500 \mu m$ (0.5 mm)

All parameters were recorded by one operator who was unaware of the preparation technique used.

The ratio L_{prep}/L_{orig} was calculated. A value of $L_{prep}/L_{orig} = 1$ indicates that the root canal outline was completely prepared (= 100%), a value of 0 indicates that none of the root canal walls was touched with the preparation instruments (= 0%). For each root canal the ratio L_{prep}/L_{orig} of both section 'a' and 'c' were averaged ($L_{average}$). The mean of $L_{average}$ was calculated and the 95% confidence interval was used to compare the groups. The impact of preparation technique, and canal dimensions (C_{max} and C_{min}) on $L_{average}$ was evaluated by performing regression analysis with the level of significance α set to 0.05.

Removal of more than 200 μm from dentine wall was evaluated by calculating the ratio L_{200}/L_{orig} and the corresponding 95% confidence interval. The difference between the outline-form of the canal and root was determined by performing paired analysis of C_{max}/C_{min} and R_{max}/R_{min}, in each section. The difference between C_{max}/C_{min} and R_{max}/R_{min} was plotted against their mean.

Results

In respect of $L_{average}$, the corresponding 95% confidence intervals indicated that there was no statistical significant difference between Mtwo and ProTaper. Both groups, however, performed significantly better than group NH (Table 1). The cumulative frequency distribution of L_{prep}/L_{orig} demonstrated that the variation in group NH was most distinct (Fig. 1). Regression of $L_{average}$ on root canal dimensions highlights the influence of C_{min} ($P < 0.001$) on the quality of root canal preparation in contrast to C_{max} ($P = 0.22$).

The mean values of the ratio L_{200}/L_{orig} (= removal of more than 200 μm from dentine-wall) were presented in Table 1. Statistically there was no significant difference between the three groups. The individual values
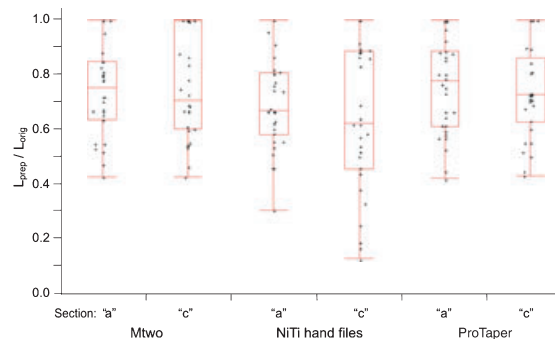

Figure 1 Box and whiskers plot of the ratio of prepared root canal walls (L_{prep}/L_{orig}) for each group and for each sectioning level ('a' and 'c').

varied between 0.0 and a maximum of 0.42 (group MT), 0.59 (group NH) and 0.45 (group PT).

In six specimens (20%) of the MT group and eight specimens (27%) of the PT group) the minimal thickness of dentine wall after preparation was less than 0.5 mm (Table 1). No excessive dentine loss was observed in group NH.

The outline form of the root was not similar to that of the canal. The mean difference between root and canal dimensions (R_{max}/R_{min} and C_{max}/C_{min}) was 3.2 (95% CI: 2.7; 3.7) (Table 1). The discrepancy between the outline form of the root and canal in each section is visualized in Fig. 2. This discrepancy was more distinct, the more oval the root was.

Discussion

No instrumentation technique was able to prepare the dentine walls entirely, which is in agreement with other

Figure 2 Plot of paired analysis of root (R_{max}/R_{min}) and canal (C_{max}/C_{min}) dimension-ratios, distances to the zero-axis represent the difference between the outline of the root and canal. The differences are more distinct in teeth with large mean dimensions.

studies (Wu & Wesselink 2001, Barbizam *et al.* 2002, Rödig *et al.* 2002, Weiger *et al.* 2002, Ruttermann *et al.* 2007). Nevertheless, the MT and PT groups had higher $L_{average}$ ratios with a mean of 0.75 compared with 0.65 of the NH group. This may be explained by the fact that instruments with greater taper (4% and more) are more rigid and thus contributed to more lateral cutting in dentine walls. The measure of 0.5 mm of remaining dentine wall was choosen because it represents removal of more than 50% and 75% of dentine wall in narrow and wide roots of the specimens respectively. The preparation with MT and PT instruments resulted in excessive dentine removal; a thin dentine wall (<0.5 mm) was present in 17% of the cases in the MT group and 27% in the PT group. This was mainly observed in the root canals of mandibular molars (13/ 14 root canals); these frequently had a high ratio of C_{max}/C_{min}. Regardless of the preparation system used, dentine cutting was either uneven (Fig. 3, upper row) or minimal (Fig. 3, lower row). Removal of 200 μm from dentine on opposite canal walls has been suggested to provide sufficient preparation in molars (Weiger *et al.* 2006), in infected root canals this may be insufficient because bacterial invasion of dentinal tubules may exceed 500 μm (Peters *et al.* 1995). In only 16–20% of the root canal outline, the thickness of dentine removed was more than 200 μm (Table 1).

A similar study (Weiger *et al.* 2002) evaluated the preparation of Hedström files and Hero instruments in oval canals. When considering those results as control, Nickel-titanium hand files ($L_{average}$ = 0.65) were significantly better than Hedström files ($L_{average}$ = 0.56). This was not expected because stainless-steel files have a greater cutting efficiency. In the present study the circumferential filing was not only performed by large files; small files with sizes of 15–35 were also used, which may have allowed a better access to narrow root canal recesses and fins. Similarly, Mtwo and ProTaper ($L_{average}$ = 0.75) performed better than Hero instrument
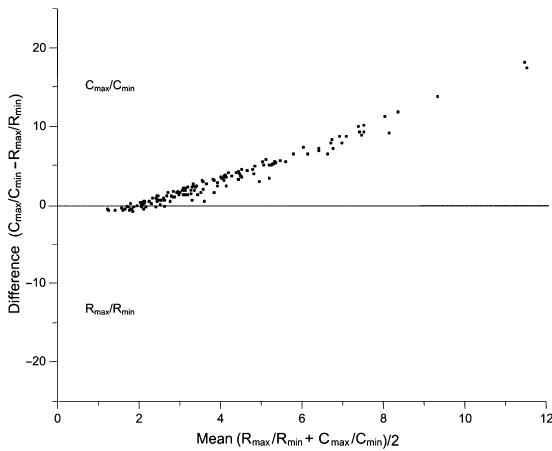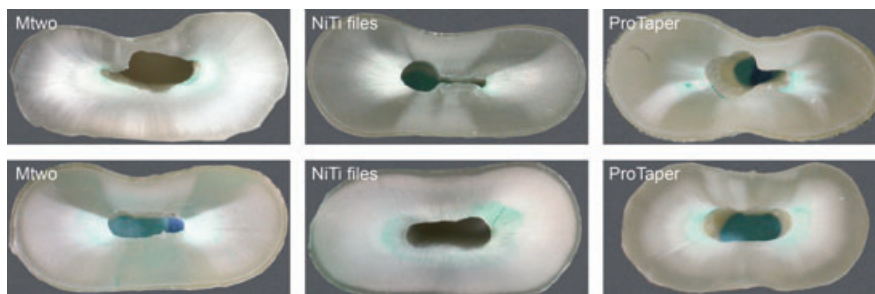

Figure 3 Photographs of post-preparation sections in narrow (upper row) and wide (lower row) oval root canals.

(L_{average} = 0.58). This may be because of the smaller taper and lower cutting efficiency of Hero instruments (Uzun *et al.* 2007).

The minimum diameter of the root canal measured mesio-distally ($C_{\min}$) influenced the quality of the preparation. In cross sections it was frequently observed that narrow oval root canals (small $C_{\min}$) were inadequately prepared (Fig. 3, upper row) most probably because in narrow canals the accessibility of the instruments to the whole outline is limited. In contrast, in wide root canals (large $C_{\min}$), although dentine removal was minimal, most of the canal outline was prepared (Fig. 3, lower row) regardless of the maximum dimension of the root canal ($C_{\max}$).

The outline of the root did not correspond to the root canal outline as it is generally believed; the mean of the ratio $C_{\max}/C_{\min}$ was more than twofolds higher than that of $R_{\max}/R_{\min}$ (Table 1). Therefore, in some cases, reliable prediction of the form of the root canal from that of the root is not possible. The oval form of the root canal was in nearly all of the cases narrower than that of the root, and the difference tended to be higher in roots with large dimensions (Fig. 2). This may be a sequel of secondary dentine deposition as a result of aging process or following irritation of the pulp (Stanley *et al.* 1983, Pashley 1996).

Conclusions

Instruments with greater taper were unable to completely prepare oval root canal walls. Mtwo and ProTaper were more efficient than NiTi hand files, but this was, in some cases, at the expense of the remaining dentine wall thickness. The minimum diameter of the oval outline of the root canal has a determinate role on the quality of the preparation.

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