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Efficiency of Rotary Instruments with Greater Taper in Preparing Oval Root Canals

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To My Family

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Introduction

Although root canal preparation instruments have been progressively developed and optimized, a complete mechanical debridement of the root canal system is rarely achievable (Uzun *et al*. 2007, Rödig *et al*. 2007, Aydin *et al*. 2007). One of the main reasons is the geometrical dissymmetry of the root canal and preparation instruments. Rotary instruments regardless of their type and form produce a preparation with a round outline, which in most 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 a 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.

Oval canals are the simplest deviation from a round outline can be found in all types of teeth. The oval outline is more pronounced in mid root 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 (Ruttermann *et al*. 2007, Zmener *et al*. 2005, Wu *et al*. 2003, Weiger *et al*. 2002, Rödig *et al*. 2002, Wu & Wesselink 2001, Lumley *et al*.1993). 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 (Ruttermann *et al*. 2007, Weiger *et al*. 2002, Rödig *et al.* 2002, Barbizam *et al*. 2002, Wu & Wesselink 2001).

The ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) system offers progressively tapered instruments with up to 19% taper. The Mtwo system (VDW, Munich, Germany) includes small instruments (size 10 and 15) with a

taper of up to 7%. The combination of the small size instruments and the increased taper might result in a better preparation of oval root canals.

The 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 teeth with oval root canals were selected from a total of 179 mandibular incisor and molar teeth. Initial identification of the oval root canals was performed radiographically by comparing the mesial and buccal radiographs of each root; an oval canals 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 degree. The teeth were then embedded in a polyethylene binding material (Delo, Landsberg, Germany) and sectioned at two levels “a” and “c”. Section “a” was near 0.5 mm coronal to the junction between the middle and apical third (3.5 to 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 to 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 X 30 magnification using a M400 stereo microscope (Wild, Heebrugg, Switzerland). In order 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 mm − 0.8 mm). C_{max} (Range: 0.9 mm − 4 mm) and the minimum dentine wall thickness (Range: 1.05 mm − 2.05 mm) then randomized to three similar groups (n= 30 per group) (Table1). 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 visible at the apex. The working length in each root canal was defined to be 1mm short of the apical foramen.

In order to simulate clinical conditions during preparation of the root canals, 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 canals were initially prepared using NiTi hand files to size 15 and the coronal third was flared using Gates Glidden drills number 1 to 3.

Three systems were used to accomplish the root canal preparation:

NH group - NiTi hand files (Dentsply Maillefer, Ballaigues, Switzerland)
PT group - ProTaper (Dentsply Maillefer, Ballaigues, Switzerland)
MT group - Mtwo (VDW GmbH, Munich, Germany)

In the NH group the Balanced Force technique (14) 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, .04 Taper to size 40, .04 Taper) was used to the full working length. The apical preparation size was 40 (PT group 40/.06) (F4) and MT group 40/.04). Additionally, the oval middle third of the root canal was prepared with each instrument used as follows; in the NH group the circumferential filing was performed, in PT and MT groups, the instruments were used in a circumferential filing manner, i.e. the instruments (freely rotating in the root canal) were brushed against the root canal walls and then withdrawn in a coronal direction. Irrigation was performed after each instrument using 2mL of 1% sodium hypochlorite through a needle with 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 with 5 mL sodium hypochlorite was

passively activated for 1 minute using an ultrasonic device Piezon Master 600 (EMS, GmbH, Munich, Germany).

Root canal sections were then disassembled and re-photographed under X30 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 µm of dentine wall was removed

$D_{<500}$ = Identifies sections with a remaining dentine wall thickness of less than 500 µm (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 were calculated 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 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 to $L_{average}$, the corresponding 95% confidence intervals indicated that there was no statistically significant difference between Mtwo and ProTaper. Both groups, however, performed significantly better than group NH (Table1). 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 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%) root canals of the MT 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) (Table1). The discrepancy between the outline form of the root and canal in each section is visualized in Fig. 3. The more distinct the discrepancy was, the more oval the root was.

Discussion

No instrumentation technique was able to prepare the dentine walls entirely, which is in agreement with other studies. (Ruthermann *et al*. 2007, Weiger *et al* 2002, Rödig *et al*. 2002, Barbizam *et al*. 2002, Wu & Wesselink 2001). 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 chosen because it represents removal of more than 50% and 75% of dentine wall in narrow and wide roots 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 only 16-20% of the root canal outline, the thickness of dentine removed was more than 200 µm (Table 1), which shows that contemporary instruments are not satisfactory for sufficient preparation of oval canals.

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 ($L_{average}$=0.58). This may be due to the smaller taper and lower cutting efficiency of Hero instruments (Uzan *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 two folds higher than that of R_{max}/R_{min} (Table1). 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 the oval root canal walls. Mtwo and ProTaper were more efficient than NiTi hand files, but this was, at the expense of the remaining dentin-wall thickness.
The minimum diameter of the oval outline of the root canal has a determinate role on the quality of the preparation.

Pictures and Tables

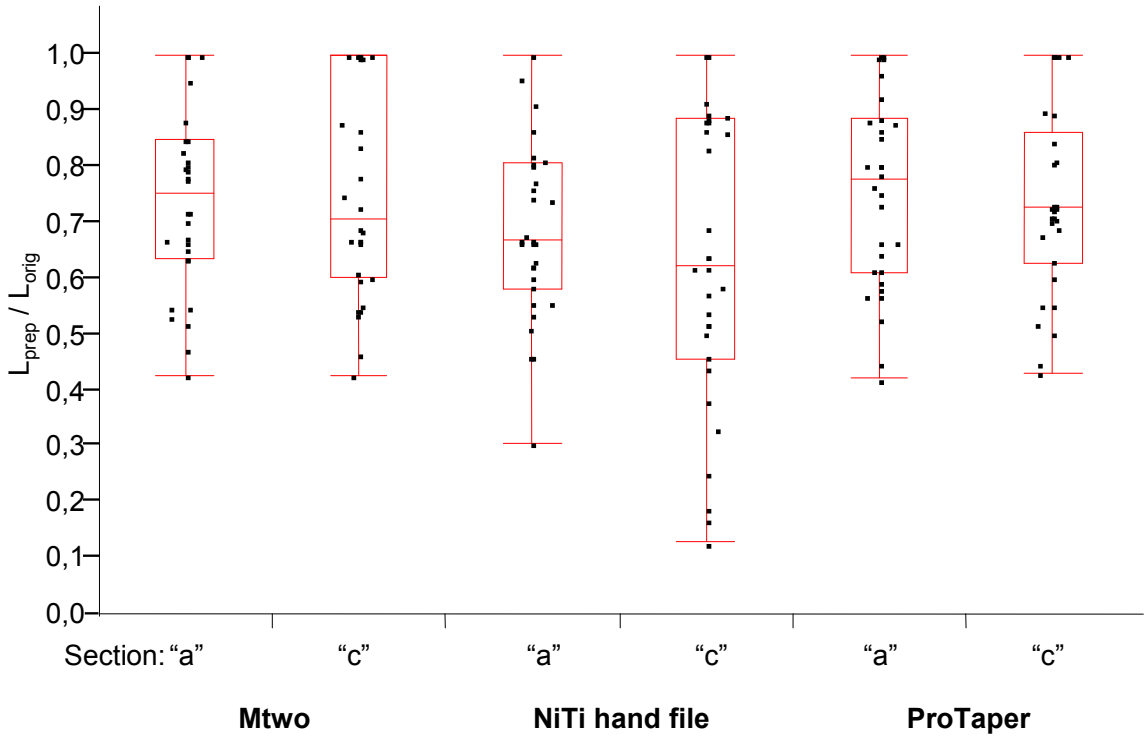

Figure 1 Box and whisker plot of the ratio of prepared root canal walls (L_{prep} / L_{orig}) for each group and for each sectioning level ("a" and "c")

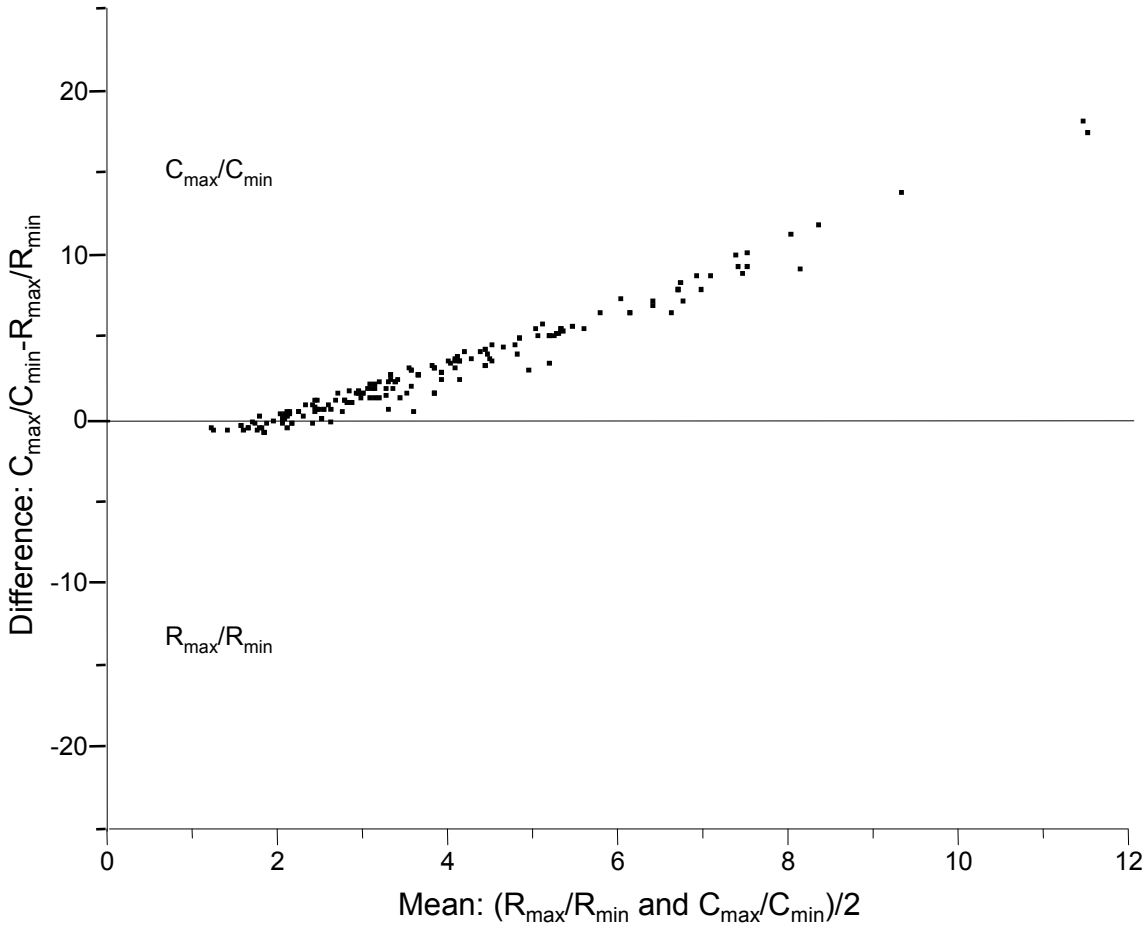

Figure 2 Plot of paired analysis of the ratio of root (R_{max}/R_{min}) and canal (C_{max}/C_{min}) dimension-ratios, distances to the zero-axis represent the difference between the outline of the root and canal. The differences are more distinct in teeth with large mean dimensions.

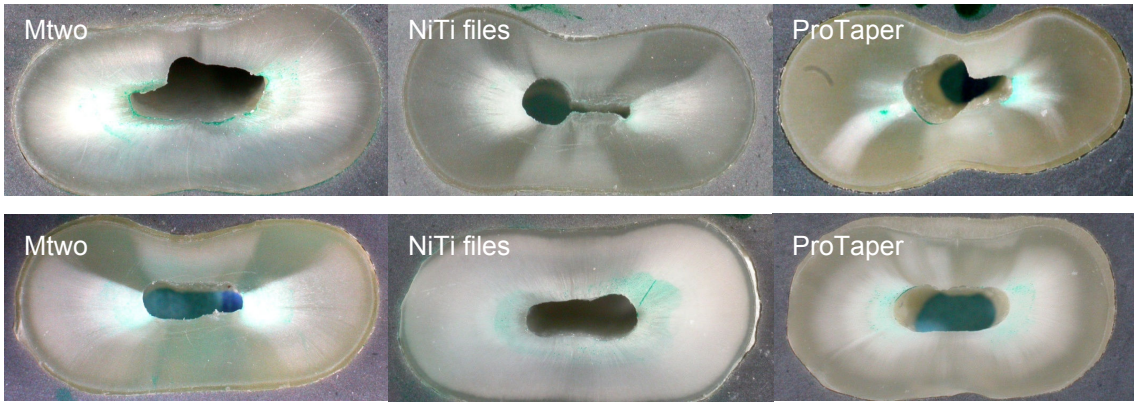

Figure 3 Photographs of post-preparation sections in narrow (upper row) and wide (lower row) oval root canals.

Table 1. Mean values and the corresponding 95% confidence intervals of various parameters

Group	C_{max}/C_{min}	R_{max}/R_{min}	$L_{average}$	I_{200}/I_{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=6/30) (10%; 37%)
NiTi Hand File	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= 0/30)
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= 8/30) (14%; 44%)

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