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Microtomography-based Comparison of Reciprocating Single-file F2 ProTaper Technique versus Rotary Full Sequence

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Key words: single-file F2 ProTaper technique, μCT, root canal preparation, instrumentation.

Running title: Rotation versus reciprocation

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Abstract

Introduction A preparation technique using only one single instrument was proposed based on the reciprocating movement of the F2 ProTaper instrument. The present study was designed to quantitatively assess canal preparation outcomes achieved by this technique.

Methods Twenty-five extracted human mandibular first molars with two separate mesial root canals were selected. Canals were randomly assigned to one of the two experimental groups: Group 1: Rotary conventional preparation using ProTaper and Group 2: Reciprocate instrumentation with one single ProTaper F2 instrument. Specimens were scanned initially and after root canal preparation with an isotropic resolution of 20 μm using a micro-computed tomography system. The following parameters were assessed: changes in dentin volume, percentage of shaped canal walls and degree of canal transportation. In addition, the time required to reach working length with the F2 instrument was recorded.

Results Preoperatively, there were no differences regarding root canal curvature and volume between experimental groups. Overall, instrumentation led to enlarged canal shapes with no evidence of preparation errors. There were no statistical differences between the two preparation techniques in the anatomical parameters assessed ($P > 0.01$), except for a significantly higher canal transportation caused by the reciprocating file in the coronal canal third. On the other hand, preparation was faster using the single-file technique ($P < 0.01$).

Conclusions Shaping outcomes with the single-file F2 ProTaper technique and conventional ProTaper full-sequence rotary approach were similar. However, the single-file F2 ProTaper technique was markedly faster in reaching working length.

Introduction

Since the introduction of nickel-titanium rotary instruments in the 1990s, new rotary files and NiTi systems have been introduced to the dental market with increasing frequency. While many companies and manufacturers have jumped on the NiTi bandwagon, few have actually addressed the inherent problems that have become apparent over the years with this type of instruments (1). NiTi instruments are expensive, which limits their usage in poorer regions of the world and/or forces practitioners to use instruments repeatedly. This, however, poses problems from a standpoint of disease transmission (2). In addition, NiTi rotaries are bound to fracture after extended usage (3).

In 2008, a new preparation technique using only one single instrument – F2 ProTaper – was introduced (4) and coined the single-file F2 ProTaper technique. The single-file F2 ProTaper technique is based on the reciprocating movement of this instrument. For obvious reasons, this technique is more cost-effective than the conventional multi-file approach, and problems related to the multiple uses of endodontic instruments are reduced. The first clinical impressions of the single-file F2 ProTaper technique were promising (4). Furthermore, two recent in vitro studies yielded favorable input for the single-file F2 ProTaper technique: first, the reciprocating movement extended the cyclic fatigue life of F2 ProTaper instruments when compared to the conventional rotary movement (5), and second, the reciprocating and rotary movements produced similar amounts of apically extruded debris (6). On the other hand, the single-file F2 ProTaper technique left more vital tissue in oval-shaped canals compared to the conventional ProTaper full sequence (7). However, before further conclusions can be drawn, the efficacy and preparation quality of the single-file F2 ProTaper technique needs to be evaluated using a reliable and well-established three-dimensional assessment method.

Thus, the present study was designed to quantitatively assess canal preparation outcomes achieved by the single-file F2 ProTaper technique, engine-driven under reciprocating movement. The conventional ProTaper full sequence was used as reference technique for comparison. High-definition micro-computed tomography (μCT) was employed to compare the following parameters in extracted human mandibular molars with two separate mesial canals: changes in dentin volume, percentage of shaped canal walls, and degree of canal transportation. In addition, the time required to reach working length with the F2 instrument was recorded. The null hypothesis was that there was no difference between the techniques regarding any of the investigated outcomes.

Materials and Methods

Experimental teeth

From teeth that had been extracted for reasons unrelated to the current study, human mandibular first molars were collected and stored in 0.1% thymol solution at 4°C until further use. X-rays were taken (Digora, Soredex, Tuusula, Finland) in mesio-distal direction to identify molars with two separate mesial root canals. Coronal filling materials, if present, were removed using a high-speed handpiece and diamond-coated burs. Subsequently, teeth were pre-scanned using a high-resolution micro-computed tomography system (μCT 40, Scanco Medical, Brüttisellen, Switzerland) with an isotropic resolution of 72 μm at 70 kV and 114 μA. After three-dimensional reconstruction, teeth with two mesial root canals and separate apical foramina were selected for further investigations. Subsequently, root canals of all teeth were accessed using a diamond-coated bur (Dentsply Maillefer, Ballaigues, Switzerland). If dentin blocked the access to the root canal orifices it was removed using long-neck metal Burs (LN burs, Dentsply Maillefer). Root canals were negotiated using size 08 K-files (Dentsply Maillefer) until the tip was just visible beyond the apex and x-rays with K-files in place were taken (Digora) in bucco-oral direction to determine the root canal curvature using the method of Schneider (8). Only teeth with mesial root canal curvatures between 20 and 40° were included. Thus, 25 teeth fulfilling the above mentioned criteria were selected for the current study.

Preparation of teeth

Root canals were randomly assigned to one of the two experimental groups. Randomization was stratified to ensure that mesiobuccal and mesiolingual canals were distributed equally to each group. Canals assigned to the reciprocating instrumentation group did not receive any further preparation prior to working length determination. Canals assigned to the group using sequential ProTaper (Dentsply Maillefer) instrumentation were preflared using the SX file in coronal part of the root canal and S1 to two thirds of the estimated working length. Working length (WL) was determined by subtracting 1 mm from the length of a size 08 K-file that became visible at the apex.

Group 1: Rotary preparation using ProTaper instruments

A glide path was established using size 10 and 15 to full WL. Subsequently, rotary instrumentation was accomplished using S1, S2, F1 and F2 to full WL in a torque-controlled system (ATR Tecnika, Pistoia, Italy) at 250 rpm. After each instrument canals were irrigated with 1 mL of 3% NaOCl and apical patency was verified using a size 08 K-file.

Group 2: Reciprocate instrumentation with one single ProTaper F2 instrument

The root canal preparation was performed with one ProTaper F2 in clockwise (CW) and counterclockwise (CCW) motion. The settings of the ATR Tecnika motor were four-tenth of a circle CW and two-tenth of a circle CCW with 400rpm rotational speed (4). During preparation the instrument was used with slow pecking motions and light apical pressure. If some resistance was felt that would have required more apical pressure the instrument was removed and the flutes were cleaned in a NaOCl-soaked sponge. This was repeated until working length was reached.

Both groups

After instrumentation all canals were irrigated with 5 mL of 17% EDTA followed by 5mL of 3% NaOCl using a 30-gauge side-vented irrigating tip (Max-i-Probe, Hawe-Neos, Dentsply, Bioggio, Switzerland) to WL. Finally, canals were irrigated with sterile physiological saline solution to wash out any NaOCl remnants.

μCT scanning procedures and evaluation

Specimens were scanned initially and after root canal preparation at 70 kV and 114 μA with an isotropic resolution of 20 μm using a commercially available micro-computed tomography system (μCT 40, Scanco Medical). Virtual root canal models were reconstructed based on μCT scans and superimposed with a precision of better than 1 voxel. Precise repositioning of pre- and various post-preparation images was ensured by a combination of a custom-made mounting device and a software-controlled iterative superimposition algorithm (9); the resulting color-coded root canal models (green indicates preoperative, red postoperative canal surfaces) enabled quantitative comparison of the matched root canals before and after shaping. From individual canal models, canal volumes up to the level of the cemento-enamel junction (CEJ) as well as in the apical 4 mm were determined using custom-made software (IPL, Scanco Medical) as described previously (10).

Increases in canal volume (i.e. amount of removed dentin) were calculated by subtracting the scores for the treated canals from those recorded for the untreated counterparts. Matched images of the surface areas of the canals, before and after preparation, were examined to evaluate the amount of non-instrumented canal wall surface. This parameter was expressed as a percentage of the number of static voxel surface to the total number of surface voxels. The software counts a surface voxel as belonging to any given structure when the full voxel belongs to it. Therefore, to be counted as instrumented, at least one full voxel (i.e. 20µm) had to be registered as removed from the preoperative canal model after superimposition. Canal transportation was assessed from centers of gravity, which were calculated for each slice and then connected along the z-axis with a fitted line. Mean transportation scores were then calculated by comparing the centers of gravity before and after treatment for the apical, middle and coronal thirds of the canals.

In addition to the µCT-evaluation, the duration of root canal preparation was compared between the two techniques. This was done by recording the time needed to mechanically shape the root canals. Instrument changes, irrigation and intermediate cleaning of the instruments were not counted.

Data presentation and statistical analysis

Preoperative canal volumes, dentin removal and untreated surface were evaluated both over the total canal length and in the apical 4 mm.

Data of preoperative root canal volumes, preoperative canal angles, and time required for preparation of the root canals were normally distributed (Shapiro-Wilk test), and are thus presented as means ± standard deviations. Comparisons regarding the above outcomes between the two groups were done using paired t-test.

Data pertaining to removed dentin, untreated surface and canal transportation were skewed and therefore compared between tooth types using Mann-Whitney U test. For all statistical analyses a commercially available computer program (JMP, SAS Institute Inc., Cary, NC, USA) was used with the alpha-type error set at 1% ($P < 0.01$).

Results

Preoperatively, there were no differences regarding root canal curvature and volume among experimental groups (Table 1). Canal preparation in both groups led to enlarged canal shapes with no evidence of preparation errors. No instrument fractured during the course of this study. Removal of circumferential pulpal dentin ranged between 0.91 to 4.61 mm^3; in the apical 4 mm between 0.05 to 0.82 mm^3. No statistical differences between experimental groups could be revealed (Table 2). Mechanically untreated (non-instrumented) canal wall areas ranged between 9.6 to 47.6% for the whole canal length and 9.6 to 72.9% for the apical 4 mm of the root canals (Figure 1). There were no statistical differences between the two preparation techniques (Table 2).

Moreover, median canal transportation in the middle and apical thirds of the root canals did not differ significantly between the two techniques ($P > 0.01$). However, there was significantly ($P < 0.01$) more transportation with the reciprocating file in the coronal root third (Table 2). The coronal transportation was in the direction of the canal furcation in all cases.

Preparation was faster using the single-file technique ($P < 0.01$). Working length was reached with the ProTaper F2 instrument in 37.7 ± 13.8 sec using the single-file versus 55.5 ± 12.4 sec using the conventional technique.

Discussion

The current study revealed similarity between shaping a canal to ProTaper F2 using the single-file reciprocating technique and the conventional ProTaper full-sequence rotary approach regarding the anatomical outcomes that were investigated. The only difference was a minor, yet statistically significant difference between groups regarding canal transportation in the coronal root third. This may be attributed to the brushing motion during rotary instrumentation with the S1 and S2 instruments towards the mesial aspects. Consequently, this outcome may be related to preparation habits of the practitioner who performed the procedures rather then the technique per se. On the other hand, the single-file technique was markedly faster. This speed preparation results are also in line with a recently published report on the efficacy of the single-file reciprocating technique (11). In their study, You and co-workers reached working length in curved canals of extracted human molars in 21 ± 7 sec and 46 ± 18 sec using the single-file and the conventional approach, respectively. This is comparable to the results reported here.

These results point out that a fast and reliable mechanical enlargement of the root canal space can be predictably produced by an automatized single-file approach. In other words, a tapered preparation can be achieved quickly. It is noteworthy that this contrasts with the traditional concept of "cleaning & shaping", proposed by Schilder (12) as a joined, synchronized and simultaneous trans-operative procedure. Cleaning is a function of irrigation, and the irrigants require considerable time to do their task. As has been mentioned (13), time is a factor that is often overlooked in clinical and pseudo-clinical trials. In the context of root canal debridement and disinfection, faster is not necessarily better. To state the matter differently, after only few minutes of mechanical instrumentation, the root canal space can now be enlarged properly with an approach such as the single-file F2 ProTaper technique, but a minimum standard of debridement is unlikely to be reached. A recent study comparing the two techniques regarding their necrotic tissue debridement in oval canals found the reciprocating approach to be inferior to the standard rotary sequence (7). Logic would dictate that this had to do with the shorter time the sodium hypochlorite was agitated by the instruments inside the canal in the single-file approach and the time the irrigant remained in the canal during instrument changes. However, this was not specifically addressed.

The focus of the present laboratory investigation was clearly on the quality of the final canal shape. Mesial roots of mandibular molars were chosen as the study object because these contain canals that are often curved in two planes. Furthermore, if there are two separate canals in this root, their original shape tends to be similar (Table 1), which is the ideal model to compare mechanical alterations promoted by two different instrumentation schemes. However, the limitations of the current study are clear:

extracted human teeth were instrumented in a set-up that differs from the clinical situation. Patient comfort (which can be an issue with the reciprocating technique) and other strictly clinical outcomes could thus not be investigated. Furthermore, merely one experienced operator performed the operative procedures rendering the experiment better standardized. However, conclusions cannot straightly be extrapolated to the average potential user of the techniques under investigation.

More single-file systems are about to appear on the dental market or will already have appeared when this paper is published. Studying these in comparison to conventional systems will be complicated by the differing shapes of the instruments in test and control groups, a factor that could be controlled nicely in the current study. Future studies should start to address some clinical issues related to reciprocating instrumentation techniques, such as patient and operator comfort, and the learning curve demanded for each preparation approach. Furthermore, it would be interesting to assess if a glide path is necessary for the use the reciprocate preparation approach or not.

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Figure Caption

FIG. 1: Representative example of micro-computed tomography data of mesial canals in mandibular molars, initially (left column) and prepared (middle column) with either reciprocating single-file (mesiobuccal canal) or rotary full sequence technique (mesiolingual canal). A: Three-dimensional views from the mesial, distal and mesio-distal in the top, middle and bottom row, respectively. Green area is unprepared, red area is prepared. B: cross-sections in the apical, middle and coronal root canal third. Green and red areas are pre- and postoperative cross-sections.

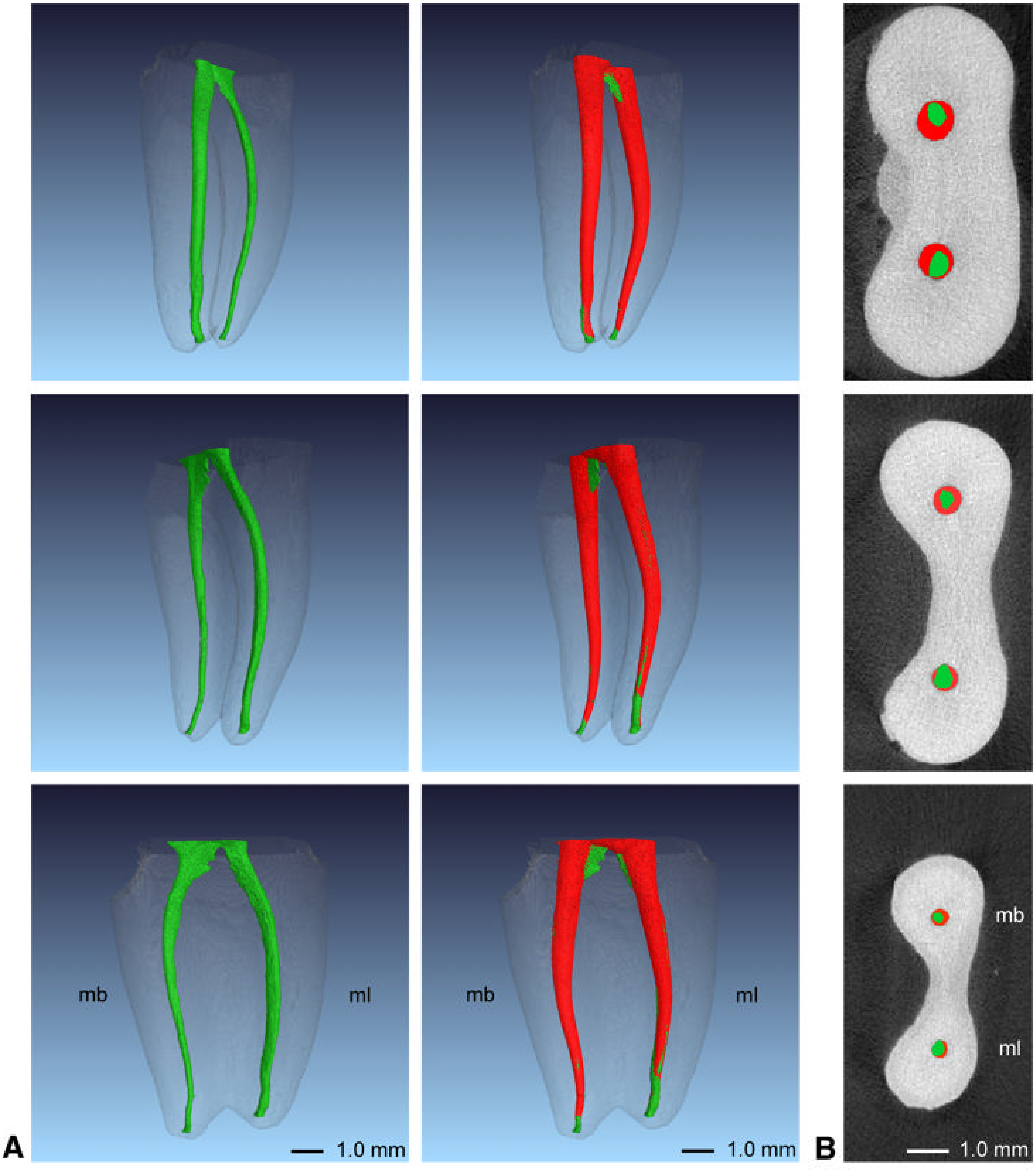

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TABLE 1. Preoperative Data (*n* = 25) for Mesial Root Canals in Mandibular Molars Before Preparation (Means ± Standard Deviations)

	Reciprocating technique	**Rotary technique**
Total volume [mm^3]	1.43 ± 0.49	1.47 ± 0.62
Apical volume [mm^3]	0.32 ± 0.15	0.34 ± 0.18
Root canal angle [°]	24.6 ± 3.8	25.6 ± 3.2
Curvature radius [mm]	9.2 ± 1.3	9.3 ± 1.5

Data sets between groups were statistically similar (paired t-test, $P > 0.5$).

TABLE 2. Median Values and Inter-quartile Ranges of Outcome Variables Related to Canal Anatomy

	Reciprocating technique	Rotary technique	Mann-Whitney U test*
Dentin removal total [mm^3]	2.26 (1.31)	1.70 (1.25)	*P* = 0.07
Dentin removal apical [mm^3]	0.33 (0.23)	0.27 (0.20)	*P* = 0.39
Non-instrumented surface total [%]	16.2 (13.1)	18.7 (15.9)	*P* = 0.46
Non-instrumented surface apical [%]	25.1 (19.2)	29.9 (25.8)	*P* = 0.35
Canal transportation coronal third [µm]	162.3 (79.6)	106.9 (79.9)	*P* < 0.01
Canal transportation middle third [µm]	83.0 (73.5)	72.4 (56.1)	*P* = 0.18
Canal transportation apical third [µm]	46.9 (49.1)	51.6 (33.4)	*P* = 0.71

*Pair-wise comparison between reciprocating and rotary technique.