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http://dx.doi.org/10.1590/1678-775720130464

Apical transportation associated with ProTaper® Universal F1, F2 and F3 instruments in curved canals prepared by undergraduate students

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Submitted: July 29, 2013 - Modification: October 14, 2013 - Accepted: November 26, 2013

ABSTRACT

Objective: This study evaluated apical transportation associated with ProTaper® Universal F1, F2 and F3 rotary files in curved canals prepared by undergraduate students. Material and Methods: Twenty mesial roots of mandibular molars with curvatures ranging between 25° and 35° were selected. Mesiobuccal canals were instrumented by twenty students with the ProTaper® system (Dentsply-Maillefer, Ballaigues, Switzerland) according to the manufacturer's instructions. Pre-flaring was performed with S1 and SX files. A #15 K-file was inserted into the root canal up to the working length (WL), and an initial digital radiograph was taken in a buccolingual direction (baseline). Afterwards, the S1, S2, F1, F2, and F3 files were employed up to the WL. Other radiographies were taken in the same orientation of the baseline after the use of the F1, F2, and F3 files, with each file inserted into the root canal. The radiographic images were overlapped, and the Image J software was used to measure the distance between the rotary files' ends and the #15 K-file's end, characterizing the apical transportation. Data were analyzed by Repeated Measure ANOVA and by the SNK post hoc test (P<0.05). Results: It was verified that file size affected apical transportation significantly (P<0.001). The F3 file showed higher apical transportation than F1 and F2, while between these last files there was no difference. Conclusion: The undergraduate students produced lower apical transportation in curved canals when they did not use the F3 rotary file.

Keywords: Undergraduate medical education. Root canal preparation. Root canal therapy.

INTRODUCTION

Apical transportation is an undesirable occurrence sometimes observed in the mechanical preparation of root canals that present pronounced curvature[11,22]. This procedural error is defined as "the removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation''[2]. Apical transportation impairs the proper cleaning of the entire extension of root canal space[27], resulting in failure of the infection control, and therefore can compromise the outcome of endodontic therapy.

The development of nickel-titanium (NiTi) rotary instruments with improved flexibility has resulted in safer mechanical preparation of curved root canals. The use of these more flexible instruments reduces iatrogenic errors such as canal transportation[27-29]. Several NiTi rotary instruments have been made available in the last years, including the ProTaper® Universal system (Dentsply-Maillefer, Ballaigues, Switzerland), which presents instruments to shape (SX, S1, and S2) and to finish (F1, F2, and F3)

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the root canal preparation. These instruments are used in a crown-down manner in combination with electric torque control motors or air-driven handpieces at low rotational speed[28,30].

The use of only three instruments (S1, S2, and F1) has been advocated to simplify the ProTaper® technique in the mechanical preparation of curved and narrow canals[21]. Some authors have demonstrated that this simplified technique results in proper shape even when the operator is inexperienced[17,26]. Furthermore, this operative sequence avoids the use of finishing instruments with higher diameter (F2 and F3) in the apical region. Thus, since F2 and F3 files are more prone to causing apical transportation[13,15,22,24], the simplified operative sequence can prevent apical preparation damage. However, the instrumentation using only the F1 file (tip equal to a #20) can leave untouched some areas of the root canal walls in the apical region and thus impair the reduction of contaminants[1,3]. Thus, a more pronounced apical enlargement in curved canals seems desirable for improving debridement and reducing bacterial toxic products[6,16].

In the last decade, several studies evaluated the root canal preparations that undergraduate students had performed using different NiTi rotary techniques. These techniques have met with high acceptance among students, and mechanical preparation does yield better results than the use of hand instruments[17,20,25,26]. Few studies, however, evaluated the apical transportation related to apical enlargement during the rotary instrumentation of curved canals performed by undergraduate students. Evaluating these operators' technical performance during root canal preparation can promote the choice of better safety clinical procedures in dental schools.

Hence, the present study aimed to evaluate the apical transportation of curved canals after mechanical preparation performed by undergraduate students using F1, F2, or F3 instruments for apical enlargement. The hypothesis tested was that the use of instruments with higher diameter increases the chances of apical transportation.

MATERIAL AND METHODS

This study was approved by the Research Ethics Committee, State University of Montes Claros, Brazil (protocol CAAE n. 15426313.0.0000.5146). Twenty mesial roots of mandibular molars with curvatures ranging between 25° and 35° (by the Schneider's method[23]) were selected. The mechanical preparation was performed only in mesiobuccal canals. The coronal access was performed with a carbide bur #1577 (SS White Dental Products, Rio de Janeiro, RJ, Brazil), followed by compensatory wear of the mesial wall with an Endo-Z bur (Dentsply-Maillefer, Ballaigues, Switzerland). The crown was sectioned with a diamond disc to yield a level surface that could serve as a stable reference for adjusting the silicone stop during root canal exploration and length determination. A #10 K-file (Dentsply-Maillefer) was inserted into the root canal up to its visualization at apical foramen, thus establishing the patency length. The working length was determined to be 0.5 mm shorter than this measurement. The canals were irrigated with 2.5% sodium hypochlorite (NaOCl), and the roots were included in acrylic resin cylinders to facilitate the handling.

The resin cylinders containing the roots were positioned in an acrylic box filled with condensation silicon impression material, creating a standardized position after the cure of the impression material. This experimental model permitted the standardized positioning of samples as radiographs were obtained. Another similar acrylic box was used to insert a digital radiographic sensor (WYS, Softys Dental, France). An impression of the sensor was made with acrylic resin to permit a sensor to be inserted in the same position for all radiographs. The two acrylic boxes were placed over a radiographic platform, always in the same position to yield standardized radiographs —70 Kvp, 8 Ma, 25 mm of distance between the tube and the sensor, and exposition time of 0.04 s.

Twenty undergraduate students received instructions about NiTi instruments and rotary techniques for 2 h. Tooth preparation with ProTaper® rotary instruments (Dentsply-Maillefer) was demonstrated by an experienced endodontist, and each student performed a preliminary training in one simulated curved canal in resin block. Afterwards, each undergraduate student instrumented one mesiobuccal canal with ProTaper® rotary technique, according to the manufacturer's instructions. The S1 and SX files were used to prepare 2/3 more cervical region of each root canal. A #15 K-file (Dentsply-Maillefer) was inserted into the root canal up to the working length, and an initial radiograph was taken in a buccolingual direction (baseline). Afterwards, the S1, S2, F1, F2, and F3 files were employed up to the working length. The rotary files were attached to an electric motor (X Smart, Dentsply-Maillefer) at a speed of 300 rpm and torque of 3 N/cm, and the automatic auto-reverse function was used. Between each rotary file, the root canal was irrigated by a 27-gauge needle with 2.5% NaOCl after each instrument, and a #10 K-file was used to assure the patency length. The NiTi files were replaced every five instrumentations[21]. After the use of the F1, F2, and F3 files, other radiographies were taken in the same orientation of the baseline with the file inserted into the root canal. Thus, four buccolingual radiographic images were obtained for each root canal: a baseline (#15 K-file), and F1, F2, and F3 files (Figure 1).

The evaluation of the apical transportation was based on previous studies[8,13]. Adobe Photoshop® software (Adobe Systems, Inc., San Jose, CA, USA) was used to overlap the radiographic images, obtained with F1, F2, and F3 files, with the respective baseline radiograph, obtained with the #15 K-file. The colors of the F1, F2, and F3 files introduced into the canal and observed in radiographic images were altered respectively to yellow, red, and blue. The color alteration was performed to make easier the evaluation of apical transportation for each file (Figure 2). Afterwards, the images were exported to Image J software (Wayne Rasband; National Institutes of Health, Bethesda, MD, USA). The distances between the F1, F2, and F3 files' ends and the #15 K-file's end were measured. The measured distance (in millimeters) determined the apical transportation. Data were analyzed by Repeated Measure ANOVA and the SNK *post hoc* test ($P<0.05$).

RESULTS

The means (and standard deviations) for F1, F2, and F3 files were 0.000 (0.000), 0.032 (0.067), and 0.124 (0.115), respectively. Data presented normality and equal variance. ANOVA showed significant effect of file size on apical transportation ($P<0.001$). The power of test was 1.0. The results of the SNK test are displayed in the Figure 3. The F3 file showed higher apical transportation than F1 and F2, while between these last files there was no difference.

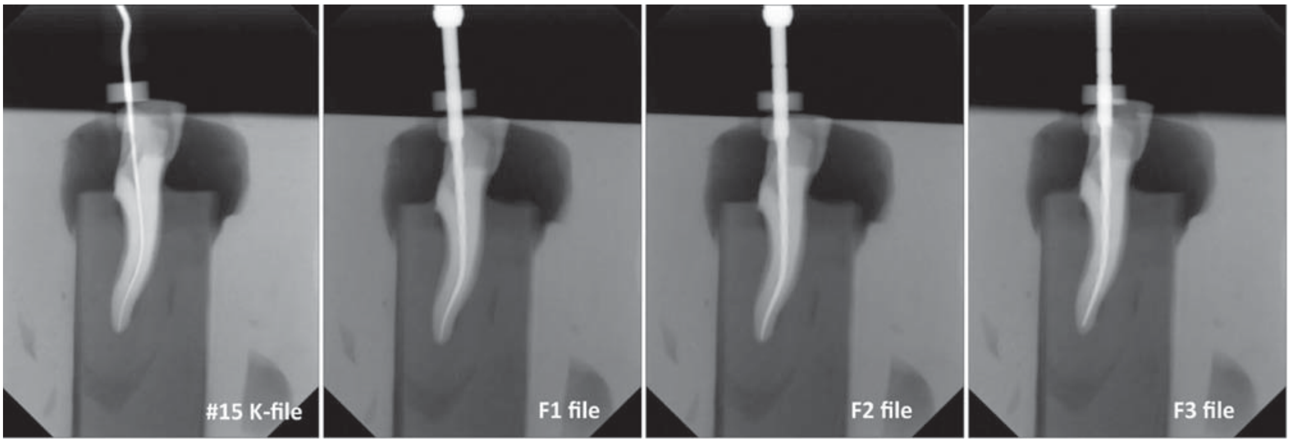

Figure 1- Left to right, standardized radiographic images obtained with #15 K-file (baseline), and F1, F2 and F3 files

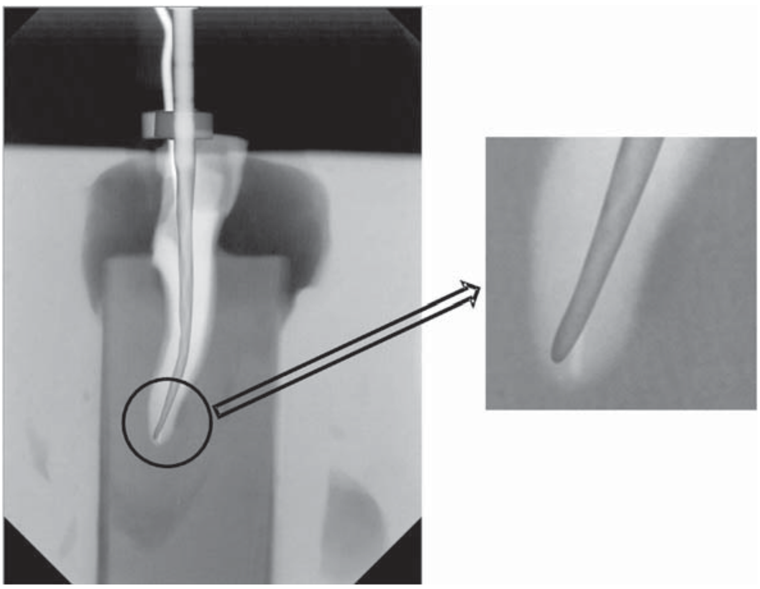

Figure 2- Representative image illustrating the image obtained with a F3 file introduced into root canal overlapping the image acquired in baseline (#15 K-file). The color of the image with the F3 file was altered to blue to permit higher contrast with the image obtained at baseline

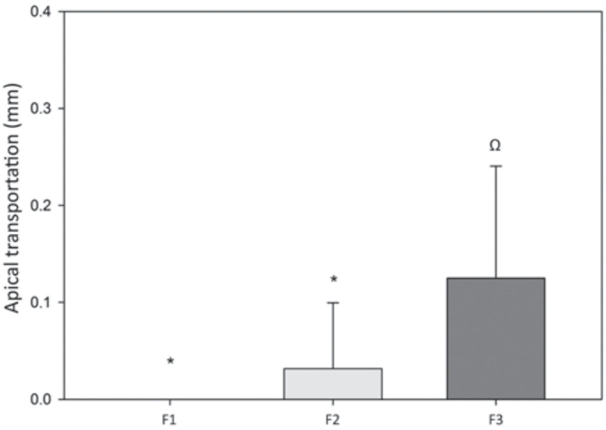

Figure 3- Mean values (in mm) of apical transportation observed for F1, F2 and F3 files. Distinct symbols indicate statistical difference (P<0.05)

DISCUSSION

Currently, the use of NiTi rotary instruments by undergraduate students for root canal preparation is a reality in dental schools worldwide. It is estimated that approximately 30% of Brazilian dental schools recommend NiTi rotary techniques in their undergraduate curricula[14]. The ProTaper® Universal system, introduced in the early years of the last decade, is one of the most popular rotary techniques used in endodontic therapy, even by undergraduate students[17,20,26]. Thus, the present study addressed the question: "How safe is it for root canals to be prepared by undergraduate students in curved canals using different ProTaper® rotary finishing files?". Knowledge and standardization of rotary instrumentation protocols in dental schools is important for reducing the number of procedural errors and for making root canal preparation more predictable. This study also enabled the first contact of the evaluated students with the rotary technique in extracted teeth. This provided a preclinical training to improve the students' technical performance for future clinical procedures[17].

Apical root canal transportation was evaluated through various image methods, such as radiographs[5,8,15,26,27], cone-beam computed tomography (CBCT)[12,18] and micro-computed tomography (micro-CT)[7,9,28,29]. Although CBCT and micro-CT images allow a 3-dimensional evaluation of the root canal before and after preparation, standardized radiographs are a more accessible method, by which curvature changes are verified by comparison of the pre- and postoperative images[5,8,26,27]. In the present study, apical transportation was characterized by deviation of the finishing rotary files in relation to the baseline file[13]. A creative procedure altering the color of the rotary files provided a clear endpoint reference to measure the distance of the overlapped files in the radiographic images. Another valuable aspect of this study's methodology was that it compared the apical transportation for F1, F2, and F3 files in the same specimen, thus reducing anatomical bias.

Some studies conducted with ProTaper® Universal system have suggested that the use of the F1 file in apical region of root canals permits proper instrumentation of curved and narrow canals[21,26]. The apical region of infected canals, however, contains numerous microorganisms that mechanical instrumentation with a F1 file cannot fully eliminate[1,3]. The apical enlargement to sizes larger than #25 permits more efficient irrigation[4], which is essential to reducing microbial contamination during endodontic therapy. In addition, a file size higher than #40 has been advocated for removing a higher amount of infected dentin and for promoting the proper cleaning of the apical region in curved root canals[3,16,19].

The present results indicate, however, that only the use of the F1 file assured the preservation of the original apical canal shape in all samples. A reduced apical transportation was observed until the use of the F2 file, which has a diameter #25 at its tip. Thus, the tested hypothesis was accepted: once the tip size of finishing instruments had increased, the apical transportation measurements also progressively increased. These results are consonant with those of a previous study[26], which showed that inexperienced operators using F1 ProTaper® as the master apical file were able to maintain the root canal curvature in extracted mandibular molar teeth. Another study using radiographic and micro-CT images demonstrated that an F2 file also produces lower apical transportation in mesial canals of mandibular molars prepared by dental students[9].

An evident tendency of the F3 file (tip equal to a #30) to deviate from the canal path in the apical region was observed in the present study. It is important to emphasize here that the root canals were prepared by inexperienced undergraduate students. Nevertheless, the same tendency was observed even with experienced operators in canals presenting a pronounced curvature[11,13,22,24]. The F3 file's tendency to produce higher deviation in the apical region is due to this instrument's larger taper, in combination with the sharp cutting edges of these instruments[22]. Since the taper increases by 9%, the diameter of an F3 file varies from 0.30 to 0.57 mm at the tip to 3 mm at the end, reducing the instrument's flexibility[10,13]. In addition, the asymmetrical cross sectional design of the F3 file tends to concentrate all the pressure of the cutting edges on the canal wall, which can result in more straightening of the canal curvature during preparation[11,13,15,22]. It is reasonable to suppose, then, that it is preferable for inexperienced operators to use finishing ProTaper®

rotary files with reduced diameters (e.g. F1) when they prepare curved root canals, in order to avoid apical transportation. An alternative aiding apical preparation could be the use of 0.2-taper NiTi rotary files. Sizes higher than #30 can be used safely in the apical region of curved canals because of the greater flexibility of these files[13,19].

CONCLUSION

Considering the limitations of the present study, it was concluded that undergraduate students produced lower apical transportation in curved root canals when they did not use an F3 ProTaper® rotary file.

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