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Comparative Evaluation of the Shaping Ability of Nickel Titanium Rotary Instruments in curved canals, Protaper Next vs Twisted File an In-Vitro Study

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ABSTRACT

Background: The purpose of this in vitro study is to compare the shaping ability of ProTaper Next (PTN) and Twisted Nickel (TF) Titanium rotary instruments in the maxillary and mandibular first and second molars with curvature of 25 to 90 degrees using digital radiography.

Materials and Method: Forty maxillary and mandibular first and second molars extracted for orthodontic or periodontal reasons were selected. The crown of each tooth was removed at the level of the CEJ using a diamond disc. A #10 stainless steel K-type hand file was kept at the working length and digital radiographs were taken for each specimen. The root canals were then divided in two groups: Group A- PTN and Group B- TF, the root canals were instrumented by these systems to their full length according to the manufacturer's instructions. Postoperative radiographs were taken with the last file used inside the root canals. The digital radiographs were enhanced The angle and radius of the root canal curvature were determined according to Pruett's method using the software Scion Image and the distance between these two central axes at working length was measured. Dentine removal was measured at five reference points.

Results: The analysis of removed dentine showed that both the titanium rotary instruments cut uniformly at all the reference points. The instrumentation symmetry indicated that both systems maintained the original curvature of the root canal. The mean loss of working length was 0.495+0.437 mm for PTN and 0.435+0.267 mm for TF. The mean apical transportation for PTN was 0.343mm for TF was 0.252mm, the difference between these values were not significant.

Conclusions: Within the limitations of this study, it can be concluded that although both the system are based on different principles, PTN and TF were statistically equal in shaping curved canals and they respected the original canal anatomy, without any aberrations or failures.

Keywords: Shaping ability, Nickel Titanium, Twisted file, Protaper Next, NiTi Rotary file system.

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INTRODUCTION

The goal of root canal therapy is to remove the infected pulp and to prevent or resolve apical periodontitis through proper cleaning, shaping, disinfection and sealing of the root canal system. Schilder stated that the most important phase of endodontic treatment is cleaning and shaping of the root canal system.[1] Besides other anatomical variations root canals are rarely straight and have a varying degree of curvature along their length, hence the instruments used for cleaning and shaping them can become stressed as the degree of curvature increases.

Root canal instruments have evolved over time, from annealed piano wire instruments made by Fouchard in 1746, to the use of Nitinol orthodontic wire to fabricate endodontic files by Walia et al in 1988.[2] Now a days, there are numerous rotary nickel titanium (NiTi) file systems available, with differing designs in terms of their taper and flute design.

NiTi instruments have the unique mechanical properties of shape memory and super elasticity as a result of austenite to martensite transition.[3] This reversible transformation imparts the file with advantageous bending and torsional properties due to its low modulus of elasticity. This helps the instrument to recover from a much higher strain without breaking as compared to stainless steel files[4], which facilitates instrumentation of curved root canals with less risk of canal transportation. Thus NiTi instrument overcomes the limitations imposed by stainless steel instruments.

Many rotary instrument systems have been introduced so far with the aim to prepare root canals efficiently by preserving the original root canal anatomy of the tooth. Out of many NiTi files available, ProTaper Next & Twisted files have been introduced recently for shaping of the root canals. The ProTaper Next (PTN) system (Dentsply Maillefer, Ballaigues, Switzerland) is the successor of the ProTaper Universal system (Dentsply Maillefer). It has an innovative off centred rectangular cross section that gives the file a snake-like swaggering movement as it advances into the root canal. The rotation of this cross section generates enlarged space for debris removal. These instruments are manufactured from M-wire alloy that improves file flexibility and resistance to cyclic fatigue whilst retaining cutting efficiency

The Twisted File (TF) system (Sybron Endo Orange, CA) have a triangular cross section with constant tapers (.04, .06, .08, .10, and .12) available in 5 tip sizes (25-50). TF instruments are manufactured using a raw NiTi wire in an austenite crystalline structure that transforms into a different phase (R-phase) by a process of heating and cooling. In the R-phase, NiTi can be twisted and converted back to an austenite structure by heating and cooling again. TFs are superior to file systems manufactured by the traditional grinding method due to their cyclic fatigue resistance, flexibility, and better cutting efficiency, and the fact that they maintain the original canal shape with minimal transportation (TF Technical Bulletin, Sybron Endo). The manufacturing characteristics such as R-phase heat treatment, twisting the metal, and special surface conditioning produce a more flexible NiTi rotary instrument.[5,6] Since the TF manufacturing process is new and differs from the traditional grinding process, all mechanical properties of rotary instruments produced with this process must be investigated.

AIMS AND OBJECTIVE

The aim of this study is to comparatively evaluate the shaping ability of PTN and TF in the maxillary and mandibular first and second molars with canal curvature more than 25 degrees using digital radiography.

MATERIALS AND METHOD

Human maxillary and mandibular first and second molars extracted for orthodontic and periodontal reasons having curved canals with more than 25^0 curvature were included in the study. Whereas teeth with Open apex, Carious/Fluoresced teeth, Fractured/cracked teeth, Restored teeth, Teeth with MB2 canals were excluded from the study.

Specimen Preparation

More than 80 maxillary and mandibular first and second molars extracted for orthodontic or

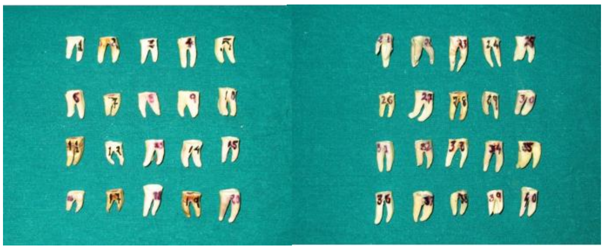

Fig 1: Specimens for the study.

Fig 2: Radiographic mount.

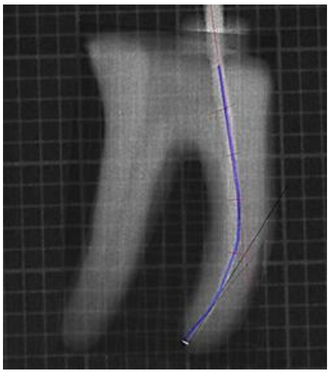

Fig 3: Superimposition of pre and post operative radiographs.

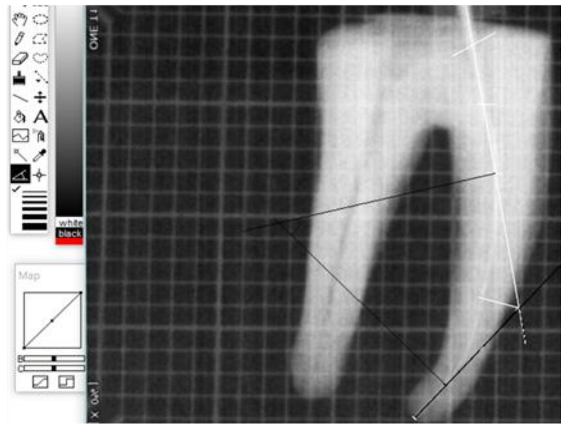

Fig 4: Pruett's method of measuring canal curvature.

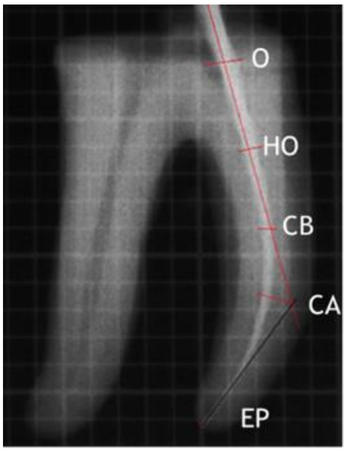

Fig 5: Dentin removal measured at five reference points.

periodontal reasons were collected, then they were cleaned and stored in a 10% formalin solution until use. The crown of each tooth was removed at the level of the cementum enamel junction using a diamond disc. A single mesial canal was instrumented in each tooth specimen. The working length was determined by subtracting 1 mm from the length at which the file tip extruded apically. A #10 stainless steel K-type hand file (Dentsply/ Maillefer, Ballaigues, Switzerland) was placed at working length and standardized digital radiographs were taken of each tooth specimen, which was placed in a radiographic mount made of silicone-based impression material (Speedex, Coltène/Whaledent) to maintain a fixed film-object-source position. (FIG-2)

Adobe Photoshop CS6 software (Adobe Systems Inc., San Jose, CA) was used to enhance the edges of the initial and final instrumentation radiographs. The angle and radius of the root canal curvature were determined according to the methodology of Pruett et al. using the computerized digital image processing software Scion Image (Scion Corp., Frederick, MD, USA). Out of these, 40 roots whose angles of curvature were 25º or more were included in this study. (FIG-1)

Root canal instrumentation

The root canals were then divided in two groups (n=20): Group A- PTN and Group B- TF, which were instrumented by PTN and TF systems respectively. A manual glide path up to K-file #20 (Dentsply/Maillefer) was prepared. In both the groups, a 16:1 reduction handpiece powered by a

Table 1: Mean Dentin Removal (in mm).

Dentin removal in (mm)	O	HO	BC	AC	EP
Inner Canal Wall					
Pro Taper Next	0.173	0.168	0.135	0.110	0.035
Twisted File	0.169	0.145	0.12	0.105	0.033
P- Value	>0.05	>0.05	>0.05	>0.05	>0.05
Outer Canal Wall					
Pro Taper Next	0.180	0.174	0.135	0.121	0.05
Twisted File	0.176	0.173	0.138	0.119	0.47
P- Value	>0.05	>0.05	>0.05	>0.05	>0.05

Table 2: Man-Whitney U test results.

Table - 2			
Instrument	Canal Straightening (Degrees)	Loss of working length (mm)	Apical Transportation (mm)
PTN	14.61538	0.495	0.343868
TF	10.35318	0.435	0.252296
Man-Whitney U test	191.5	198	152.5
p - Value	0.82588	0.48405	0.10204

torque controlled electric motor was used to prepare the canals according to the manufacturer's instructions.

The preparation for PTN was done with 4-5N/cm torque and a speed of 300 RPM. The sequence of files used for instrumentation of PTN group was as follows: X1#17/04, X2#25/06, X3#30/07. These files were used till the working length according to the manufacturer's instructions. For the TF group, the preparation was done at 3-4N/cm torque and a speed of 500- 625 RPM. Instruments were withdrawn if resistance was felt. The sequence of the instrumentation was as follows: #25/08, #25/06 and #30/06 at WL.

The root canals were flushed after the use of each instrument with a 2.5% NaOCl solution using a plastic syringe inserted as deep as possible into the root canal without binding and the canals were recapitulated with a K-file #15 (Dentsply/Maillefer). Each set of files was rejected after five uses.

Assessment of root canal preparation

Postoperative radiographs were taken with the final file at working length (i.e. X3 in case of PTN and in case of TF #30/06) inside the root canals. The digital radiographs were downloaded in .TIFF format from the digital radiographic system and imported into Adobe Photoshop CS6 (Adobe Systems, San Jose, CA, USA), which was used to superimpose post and the corresponding pre-instrumentation image. The central axes of the two images were superimposed. Small translation and rotation movements were used to achieve a perfect fit between the two images. The images were then transferred to the Image analysis software Scion Image (Scion Corp., Frederick, MD, USA), which was used to measure the distance between these two central axes at working length and measure apical transportation at 0.5 mm short of the WL. (FIG-3) The angle of curvature of each root canal was determined by following the methodology of Pruett et al. (FIG-4) Based on the canal curvatures assessed before and after instrumentation, canal straightening was determined as the difference between them, by subtracting the pre-operative canal curvature from postoperative canal curvature.

Dentine removal from the inner side of the curvature and the outer side of the curvature was measured at five reference points namely, the canal orifice (O), the point half-way from the beginning of the curve to the orifice (HO), the point where the canal deviates from the long axis of its coronal portion and is called the beginning of the curvature (BC), the point where the long axes of the coronal and the apical portions of the canal intersect and is called the apex of the curve (AC), the point where the preparation ends (EP). (FIG-5)

Parameters used to evaluate the working safety were: the loss of working length and the fractured instruments. Variations of working length were established by subtracting the preoperative from the postoperative length, while the number of separated instruments was recorded during instrumentation.

Statistical Analysis

The Mean dentin removal, straightening of root canal curvature, apical transportation, loss of working length results for each group did not follow a normal distribution, the **Mann - Whitney U-test** was used for pairwise comparisons. The level of statistical significance was set at $p<0.05$. All statistical analyses were performed by means of SPSS 17.0 software (SPSS Inc., Chicago, IL, USA)

RESULTS

The mean amount of dentine removal on the outer and on the inner side of the curvature at the five reference points is shown in *Table 1*. Mean canal widths after the instrumentation were regular at all the reference points along the canal curvature and no significant differences were found between the two systems. The canal curvatures were assessed before and after instrumentation, canal straightening was determined as the difference between them. Mean values for canal straightening, loss of working length and apical transportation with their statistical analysis is shown in *Table 2*. Although, both the Loss of working length and the apical transportation showed a slightly higher value for PTN but statistically they were not significant. During root canal preparation no instrument fracture or blockage in the canal was observed.

DISCUSSION

One of the main objectives of root canal therapy is to prepare the root canal with a shape that tapers from the coronal portion to the apical area while maintaining the original canal curvature[7]Traditional stainless steel instruments are found to produce more procedural errors, as these instruments are less flexible (especially the larger sizes), as a result, instruments precurved to manage the curvature, straighten up when placed in a curved root canal which increases the likelihood of creating canal aberrations [28].

Whereas the NiTi instruments may create less zipping or apical perforation defects, as they have two to three times more flexibility than stainless steel instruments and are considerably more resistant to clockwise torsional stress[27] Innovations are made in the NiTi instruments to increase their efficiency and safety, such as surface engineering (implantation or electropolishing), improvements in the manufacturing processes, microstructure control (e.g. heat treatment or innovative manufacturing techniques) or the use of new alloys.[25]

In the present study the aim was to comparatively evaluate the shaping ability of PTN and TF in curved canals. The prime reason to choose these two rotary files was that PTN which is manufactured by cutting/grinding the NiTi blank and has the M wire technology. Whereas TF which is manufactured by twisting the NiTi alloy is also in the R phase.

This study was performed to evaluate the shaping ability of different NiTi instruments in curved root canals. Many different experimental designs and methods have been used for this purpose. A few of them are listed below.

- Comparative analysis of radiographic images of root canals before and after their instrumentation by superimposing them using a double exposure system.[8, 9]
- Use of simulated root canals of varying geometry in resin block.[10-12]
- Computed tomography (CT) [13,14] and the advanced microcomputed tomography (MCT) [15-20], that enable visualization and study of the morphology of the root canals before and after instrumentation in 3 dimensions and in a quantitative manner.

The microcomputed tomography (MCT), is a noninvasive method that provides the ability to accurately visualize the 3-dimensional reconstruction and the formation of virtual cross sections in any desired orientation without resulting in teeth destruction[15-20]. But, it has got drawbacks such as, in early studies using MCT, the data had insufficient quality, resolution and projection errors. The prolonged scanning and reconstruction time up to 4 hours per specimen was another factor that limited the efficiency of this method[15, 16]. Moreover, this method requires costly and sophisticated hardware and software that has to be supported and serviced by experienced personnel. Such conditions can be met only in well-equipped and organized research centres[13, 16, 22]. The conventional computed tomography (CT) can also provide a 3 dimensional cross section of the tooth. But it has disadvantages such as inadequate resolution to detect subtle changes in root canal morphology[21, 22].

So in this study, the digital radiographic image processing and analysis procedures were used. This radiographic method for the study is not complex, time-consuming, and difficult to use. Furthermore, as of today, digital subtraction radiography (DSR) and digital radiographic image processing and analysis procedures in general, have become established modalities in endodontic research.[23] In this study digital radiographs were standardized by placing each tooth in a radiographic mount made of silicone-based impression to maintain a fixed film-object-source position. The root canals were parallel and as near as possible to the surface of the sensor. The X-ray tube, and thus the central X-ray beam, was aligned perpendicular to the root canal.[24]

To determine the degree of root canal curvature, usually a single parameter is used, described by Schneider's method. But the shape of any root canal curvature is more accurately described using two parameters such as described in Pruett's method: angle of curvature and radius of curvature.

As Schneider method ignores the radius of curvature, an important parameter in the evaluation of curved root canals. In our study, Pruett´s method was used to determine the angle of curvature. Based on the canal curvatures assessed before and after instrumentation, canal straightening was determined as the difference between them, which is in accordance with Nabavizadeh et al (2014), Carlos Estrela et al (2008), Shiva Sadeghi et al (2009), David Torres et al (2012)[29,30,31, 39].

In our study, the range of straightening of root canal curvature was 14.6153 +7.86 º in PTN group and 10.353 +7.35 º in TF group. Recently, a study by David Uroz-Torres (2012) using TF and Mtwo in root canals with moderate and severe curvature (25-76º) showed that straightening ranged from 8.4º to 13.7º degrees[39, 41]. They had used the same Pruett's method for measuring the canal curvature49.

The analysis of removed dentine showed that both the instruments cut uniformly at all the reference points with no significant differences between them. More transportation was seen at the orifice (O) and the half-way orifice (HO) points. The PTN file removed similar amounts of dentin as compared to TF, Which is contradictory to the studies done by Love RM et al (2013) and Cumhur Aydin et al (2012) where TF showed a better ability to remove from the inner side of the curvature at the apical level. In the study by Michal Lęski et al (2015) it was observed that PTN removed less resin from the inner aspects of the canals in apical area[34, [37, 38]. But in all these studies stimulated canals of the resin blocks were used where as in our study natural extracted teeth were used, which is in accordance with the result of studies done by Veltri M et al (2005) and El-Rahman et al (2008) where the compared instruments produced the highest change in dentin thickness coronally and decreased towards the apical level, presenting the least change.[32, 35]

In the present study none of the canals became blocked with debris. Thus, the only change in the working length was because of minor canal straightening during canal enlargement or lack of length control by the operator. So we can say that both the types of instruments controlled the working distance well. This finding is in agreement with Veltri M et al (2005), El-Rahman et al (2008) David Uroz-Torres(2012), Burklein S and Shafer E (2013) who all noticed only small mean changes in working distance with different rotary NiTi instruments[32,33,35].

In this study the apical transportation was 0.343mm for PTN and 0.252mm for TF which was in accordance with studies done by David Uroz-Torres(2012), Saber SEDM (2014), Ismail Capar (2014) and Michal Lęski et al (2015) [34, 36, 39, 40]. It is a known fact that apical transportation of more than 0.5 mm can have a negative impact on the seal of the obturation and that apical transportation increases in curved root canals with an increase of file size.[25] Some authors[42] recommended usage of EDTA with rotary instruments. However, EDTA was not used in the present study, as it to causes softening of dentin resulting into deviation of the canal or loss of curvature[43].

The final apical preparation was done with size 30 of PTN and TF for all the canals because larger preparations might result in canal straightening and undesirable weakening of the tooth structure, whereas preparations with smaller sized instruments may leave tissue remnants and infected dentin behind.[25, 26] The Straightening of the root canal curvature, apical transportation and loss of working length results for each group did not follow a normal distribution, the Mann-Whitney *U*-test was used for pairwise comparisons.[35]

CONCLUSION

Within the limitations of this study it can be concluded that, PTN and TF maintained root canal curvature well and were safe to use. A single set of files of both the file systems tested in this study were effective in shaping at least five curved canals in extracted teeth. TF, are better in shaping the curved canal but it was not statistically significant. There is no statistical difference between dentine removals of the both NiTi rotary systems. We may conclude that PTN and TF are both capable of respecting the original canal anatomy, with no aberrations or failures resulting and preparing root canals with moderate and severe curvature, with a few degrees of canal straightening minimal apical transportation and loss of the working length. Further investigations are required to assess and compare the cleaning effectiveness of these rotary NiTi systems three-dimensionally.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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