Comparative Evaluation Of Cyclic Fatigue Resistance Of Protaper NEXT And Reciproc R Rotary Files In Simulated Canals With Angle Of Curvatures At 45° And 60°: An Invitro Study

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Abstract

Aim: To evaluate the cyclic fatigue resistance of Pro Taper NEXT & Reciproc R rotary files in simulated canals with angle of curvatures at 45º and 60º.

Materials and Methods; This study was conducted at HKE' s S.Nijalingappa institute of dental sciences and reasearch institute, Kalaburagi. After considering the inclusion and exclusion criteria the selected samples were divided into two groups, as G1(ProTaper NEXT) and G2(RECIPROC R), further these two groups are divide into 2 subgroups.

Results: The mean cyclic fatigue was significantly high in Reciproc R procedure as compared to ProTaper NEXT. Therefore Reciproc R procedure was better as compared to ProTaper NEXT.

Conclusion: Cyclic fatigue resistance of Reciproc R was higher than the ProTaper NEXT.

Keywords: Cyclic Fatigue Resistance, Reciproc R, Protaper Next, Nickel Titanium Instruments

INTRODUCTION:

The root canal morphology is not always straight and simple as it appears on the radiographs. Various curves are present along the length of the canal and the preparation of these curved root canals becomes very challenging for a clinician. These curved canals may also restrict the mechanical and chemical preparation of the curvature or may lead to some procedural errors affecting the prognosis.[1]

Root curvature is a frequent occurrence in the human dentition, especially in molars, being one of the various anatomical complexities characterizing the root canal system and introduces factors that, if not properly controlled during canal preparation, may lead to undesirable technical results. The parameters radius and angle of curvature, as defined by Pruett et al, are generally employed to describe the geometrical characteristics of curved root canals. The radius of curvature describes, for canals with the same angle of curvature, how abrupt is the canal deviation from a straight line: the smaller the curvature of radius the more abrupt the canal deviation. Abrupt curvatures, especially those localized in the apical one-third of a canal, present the greatest difficulty because they do not allow much alteration of the curvature radius via canal coronal enlargement, since their influence is expressed through a very short lever arm.

For this reason, the high incidence of secondary curvatures in human mandibular molars, 30%, and the fact that they are usually localized in the apical one-third of the canal, at a mean distance of 2.2 mm from the foramen, make root canal instrumentation even more difficult.[2]

Increasing the resistance to file separation has been the main goal of manufacturers in developing the latest NiTi rotary instruments, aiming at improving safety through innovative design and manufacturing processes. Thermal treatment of NiTi alloys, such as M-Wire, R-phase wire , and controlled memory wire , has been used to optimize the mechanical properties of the files. Thermomechanical processing is a frequently used method to optimize the microstructure and transformation behavior of NiTi alloys, which, in turn, have great influence on the reliability and mechanical properties

of NiTi files. The fracture of instruments used in rotary motion occurs through 2 different mechanisms: fracture caused by torsion and fracture caused by flexural fatigue, even if there is no conclusive agreement in which is the most important factor influencing the mode of fracture. The torsional fracture occurs when an instrument tip or another part of the instrument becomes locked in a canal, while the shank continues to rotate. The tip fractures when handpiece torque exceeds the ultimate strength of the metal . Instruments fractured through excess torsional loads often carry indications such as plastic deformation.[3]

Reciproc file system; are available in sizes 25/.08, 40/.06, 50/.05, have a regressive taper, a S-shaped cross section with 2 cutting edges, and a non-cutting instrument tip. Reciproc is made from M-Wire, this material is a modified NiTi alloy produced by a special heat treatment, which ensues after the instruments have first been ground according to the proven method.Instruments made of this material can be easily pre-curved and display a memory-effect, meaning that they have the ability to return to their initial shape. These properties therefore warrant an accurately shaped preparation of complex channel configuration.[4]

ProTaper NEXT files available, in different lengths, for shaping canals, namely X1, X2, X3, X4, and X5 . In sequence, these files have yellow, red, blue, double black, and double yellow identification rings on their handles, corresponding to sizes 17/04, 25/06, 30/07, 40/06, and 50/06, respectively. The tapers listed are NOT fixed over the active portion of any given PTN file. Appreciate the PTN X1 and X2 files have both an increasing and decreasing percentage tapered design on a single file; whereas the PTN X3, X4, and X5 files have a fixed taper from D1-D3, then a decreasing percentage tapered design over the rest of their active portions. PTN files are the convergence of 3 significant design features, including progressive percentage tapers on a single file, M-wire technology, and the 5th generation of continuous improvement, the offset design. As a single example, the PTN X1 file has a centered mass and axis of rotation from D1-D3, whereas from D4-D16, the X1 file has an offset mass of rotation. Starting at 4%, the X1 file has 10 increasing percentage tapers from D1-D11; whereas, from D12-D16, there are decreasing percentage tapers to enhance flexibility and conserve radicular dentin during shaping procedures. The PTN files are used at 300 rpm and a torque of 2.0-5.2 N cm, based on the method of use. However, the authors prefer a torque of 5.2 N cm, as this level of torque has been validated as profoundly safe if clinicians perform meticulous glide path management procedures and utilize a deliberate outward brushing motion when progressively shaping canals. In the PTN technique, all files are used in exactly the same way and the sequence always follows the ISO color progression and is always the same regardless of the length, diameter, or curvature of a canal.[5]

There are various devices to test cyclic fatigue resistance of Nickel titanium rotary instruments to rotate until fracture using different geometric curvatures. Hence in this study one such method is used to test the cyclic fatigue resistance of two rotary file system.

MATERIALS AND METHODS:

This study was conducted at HKE' s S.Nijalingappa institute of dental sciences and reasearch institute, Kalaburagi. Sample size was twenty four. Duration of study was 18 months (2019 to 2021).

Sample Collection: Instruments were procured directly from the distributor (Denstply company). All instruments were inspected using an stereomicroscope under 20x magnification for any sign of visible deformation. If any deformation was found then it was discarded and only files with intact flute surfaces and with no signs of deformation were used in this study.

Inclusion criteria: Files showing intact flute surface and Files with no signs of unwinding or craze lines

Exclusion criteria: Instruments with following sign were discarded

1. Unwinding 2. Curving 3. Bending

Procedure: After considering the inclusion and exclusion criteria the selected samples of 12 Protaper Next and 12 Reciproc R files were divided into two groups as,G1(ProTaper Next) and G2 (Reciproc R),which was further divided into 2 subgroups as,

1. G1(A1)-for block with 1.5mm wide canal with 45^0 angulation -5mm radius of curvature.
2. G1(A2)- for block with 1.5mm wide canal with 60^0 angulation-5mm radius of curvature
3. G2(A1)- for block with 1.5mm wide canal with 45^0 angulation-5mm radius of curvature
4. G2(A2)- for block with 1.5mm wide canal with 60^0 angulation -5mm radius of curvature

A simulated artificial metal canal block (300 series stainless steel) measuring 36.8x25.4x9.5mm was fabricated with 45^0 and 60^0 angle of curvature and a 5mm radius of curvature to the centre of 1.5mm wide canal. To ensure the accuracy of the size of each canal a copper duplicate of each instrument was milled increasing the original size of the instrument by 0.2 mm using a computer numerical control (CNC) machining bench was used. The copper duplicates were constructed according to the curvature parameters that were chosen for the study. With these negative moulds the artificial canals were made using a die-sinking EDM (electrical-discharge machining) process (Agietron Hyperspark 3; AGIE Sa, Losone, Switzerland) in a stainless-steel block. The block was hardened through annealing.

The depth of each artificial canal was machined to the maximum diameter of the instrument +0.2 mm, allowing the instrument to rotate freely inside the artificial canal. The centre of curvature was 5mm from the tip of the instrument and the curved segment of the prepared artificial canal was also 5mm in length.The above fabricated metal block was

caliberated using computer aided visual measuring machine further ruler/scale and protracter was also used for inspecting.
A swiveling acrylic top face cover was placed on the metal block which permits visualization of the files rotating in the canal and removal of broken instrument between tests. File stopper was placed at 19mm on the metal block to standardize instrument placement.
Endomotor handpiece was mounted on a platform under the adjustable device to allow proper fixation of handpiece which allowed a precise and reproducible placement of each instrument inside the artificial canal. This placement ensured three dimensional alignment and positioning of the instruments to the same depth.
Before starting the procedure every file was lubricated with synthetic (mineral) oil. ProTaper NEXT instruments were rotated in symmetrical motion and Reciproc R were reciprocated wherein counterclockwise rotation of the reciprocating instrument is (150^0) than clockwise rotation (30^0),thus allowing a complete turn (360^0) to occur after about three to four reciprocating movements, 350rpm and 4Ncm of torque until fracture occurred. For every instrument time was recorded by the same operator with a chronometer/chronograph to an accuracy of 0.1 sec. After positioning the instrument in the canal and as soon as rotation start timing was initiated and timing was stopped when instrument breakage was observed. The data for number of cycles of the instrument to fracture (NCF) was calculated.
NCF=RPM X time to failure (sec)/60sec. The recorded and calculated data was subjected to statistical evaluation.

RESULTS:

Study reveals that, there was statistically very highly significant difference of mean cyclic fatigue between canals with 45^0angulation and 60^0angulation in ProTaper NEXT procedure (P<0.001).

Table 1: Comparison Of Cyclic Fatigue Resistance Of Protaper NEXT Rotary Files In Simulated Canals With Angle Of Curvature 45^0 And 60^0

ProTaper NEXT (Group-1)		**t-test value**	**P-value and Significance**
Canals with 45^0 angulation (A1)	Canals with 60^0 angulation (A2)		
Mean ± SD	Mean ± SD		
2.0 min± 0.12	1.27 min± 0.06	t = 9.729	P = 0.000, VHS

NS= not significant, S=significant, HS=highly significant, VHS=very highly significant

Study reveals that, there was statistically very highly significant difference of mean cyclic fatigue between canals with 45^0 angulation and 60^0 angulation in reciproc R procedure (P<0.001).

Table 2: Comparison Of Cyclic Fatigue Resistance Of Reciproc R Rotary Files In Simulated Canals With Angle Of Curvature 45^0 And 60^0

Reciproc R (Group-2)		**t-test value**	**P-value and Significance**
Canals with 45^0 angulation (A1)	Canals with 60^0 angulation (A2)		
Mean ± SD	Mean ± SD		
2.27 min± 0.32	1.42 min± 0.02	t = 5.157	P = 0.000, VHS

Study reveals that, there was statistical significant difference of mean cyclic fatigue between ProTaper NEXT (Group-1) and Reciproc R (Group-2) procedures in 45^0 and 60^0 angulation (P<0.05)

Table 3: Comparison Of Cyclic Fatigue Resistance Between Protaper NEXT (Group-1) And Reciproc R (Group 2) With Angle Of Curvature 45^0 And 60^0

Angle of curvature	**ProTaper NEXT Group-1**	**Reciproc R Group-2**	**t- test value**	**P-value and Significance**
	Mean ± SD	**Mean ± SD**		
45^0 (A1)	2.0 min± 0.12	2.27 min± 0.32	t = 2.846	P = 0.016, S
60^0 (A2)	1.27 min± 0.06	1.42 min± 0.02	t = 8.458	P = 0.000, S

Study reveals that, there was statistically very highly significant difference of mean NCF scores between canals with 45^0 angulation and 60^0 angulation in ProTaper NEXT procedure (P<0.001).

Table 4: Comparison Of Number Of Cycles Of The Instrument To Failure (NCF) With Angle Of Curvature 45^0 And 60^0 In Protaper NEXT Procedure

NCF scores- ProTaper NEXT (Group-1)		**t-test value**	**P-value and Significance**
Canals with 45^0 angulation (A1)	**Canals with 60^0 angulation (A2)**		
Mean ± SD	**Mean ± SD**		
702.17 ± 39.46	**444.5 ± 20.59**	**t = 9.765**	**P = 0.000, VHS**

Study reveals that, there was statistically very highly significant difference of mean NCF scores between canals with 45^0 angulation and 60^0 angulation in Reciproc R procedure (P<0.001).

Table 5: Comparison Of Number Of Cycles Of The Instrument To Failure (NCF) With Angle Of Curvature 45^0 And 60^0 In Reciproc R Procedure

NCF scores-Reciproc R (Group-2)		t-test value	P-value and Significance
Canals with 45^0 angulation (A1)	Canals with 60^0 angulation (A2)		
Mean ± SD	Mean ± SD		
794.50 ± 113.04	493.05 ± 8.71	t = 9.763	P = 0.000, VHS

Study reveals that, there was statistical significant difference of meannumber of cycles of the instrument to failure (NCF) between Protaper next (Group-1,A1 and A2) and Reciproc R (Group-2,A1 and A2) procedures (P<0.05).

Table 6: Comparison Of Number Of Cycles Of The Instrument To Failure (NCF) Between Protaper NEXT (Group-1, A1 And A2) And Reciproc R (Group -2,A1and A2)

Angle of curvature	Protaper next Group-1	Reciproc R Group-2	t-test value	P-value and Significance
	Mean ± SD	Mean ± SD		
45^0 (A1)	702.17± 39.46	794± 113.04	t = 2.135	P = 0.044, S
60^0 (A2)	444.5± 20.59	493.05± 8.71		

DISCUSSION:

Root curvature is a frequent occurrence in the human dentition, being one of the various anatomical complexities characterizing the root canal system, and introduces factors that, if not properly handled during canal preparation, may lead to undesirable technical results. [6]

Artificial canals used by Pruett et al[7] were fabricated from 18-G, stainless steel needles having an internal diameter of 0.83 mm. A 2-mm and 5-mm radius of curvature measured to the inner aspect of the curve of the guide tubes. They have used 30^0, 45^0, and 90^0 angles of curvature, and the point of maximum curvature was 7mmfrom the tip of the instrument. The maximum curvature region was located at approximately 4.5 mm from the tip of the files. [3]

In the present study a simulated artificial metal canal block (300 series stainless steel) measuring 36.8x25.4x9.5mm was fabricated with 45^0 and 60^0 angle of curvature and a 5mm radius of curvature to the centre of 1.5mm wide canal.

Reciproc represents a convergence of the best design features from the 2nd and 3rd generation of files, coupled with a reciprocating motor that drives the file in *unequal* bidirectional angles. The CCW engaging angle is 5 times the CW disengaging angle and is designed to be less than the elastic limit of the file. Strategically, after 3 CCW and CW cutting cycles, the file will have rotated 360º or one circle. This novel reciprocating movement allows file to more readily progress, efficiently cut and effectively auger debris out of the canal. This instruments also provides decrease in instrument fracture associated with the reduction of instrument fatigue. These instruments are manufactured from M-Wire technology to improve the fracture resistance of the instruments. M-Wire is a new Ni-Ti alloy that is prepared by a special thermal process, claimed to increase flexibility and resistance to cyclic fatigue. It is reported that instruments made from M-Wire with a ProFile (Dentsply/Maillefer) design exhibit nearly 400% more resistance to cyclic fatigue than do super-elastic wire instruments of the same size. The cross section of these files is S shaped for greater flexibility, more efficient cutting and channelling of debris. the blades are non landed and are designed to cut in a counterclockwise direction with asymmetric reciprocating motion.[8] A smaller-sized and more flexible PTN file can cut the same-size preparation as a larger and stiffer file with a centered mass and axis of rotation.[9] Hence in this study Reciproc R and ProTaper NEXT were used.

There was statistically significant difference of mean cyclic fatigue between canals with 45^0 angulation and 60^0 angulation in ProTaper NEXT procedure (P<0.001). Similar results were shown in the study conducted by Cheng Peng et al , ProTaper NEXT files tended to be more resistant when operated in 45°and 60° canals, Considering that the majority of root canals are closer to being 45°or 60° artificial canals.[10]

Another study conducted by Huseyin Sinan et al revealed that PTN X2 instruments exhibited greater cyclic fatigue resistance in the apical curvature of an artificial canal with a double curvature[11],which is in accordance with the present study.

The mean cyclic fatigue was significantly high in Reciproc R procedure as compare to ProTaper NEXT. Therefore Reciproc R procedure was better as compared to ProTaper NEXT.

Alberto Dagna,et al conducted a study in which 4 artificial canals (canal 1 had 60° angle and 8-mm radius, canal 2 had 45° angle and 8-mm radius, canal 3 had 60° angle and 5-mm radius, and canal 4 had 45° angle and 5-mm radius) and concluded that Reciproc R exhibited significantly higher cyclic fatigue resistance than other instruments such as ProTaper[12], which is in accordance with the present study.

Study reveals that, there was statistically very highly significant difference of mean NCF scores between canals with 45^0 angulation and 60^0 angulation in Reciproc R procedure(P<0.001). Which is Similar results were shown in the study conducted by Alberto Dagna,et al where in the most difficult curvature (canal 1-60^0) generated the lowest NCF and the easiest curvature (canal 4-45^0) showed the highest NCF values in all systems[12].

Study reveals that, there was statistically very highly significant difference of mean NCF scores between canals with 45^0 angulation and 60^0 angulation in Protaper next procedure (P<0.001). Which is in accordance to the study conducted by kariem Mostafa Elbatouty et al showed statistically significant higher mean ncf values in canals having 5mm radius with 45^o angle of curvature than 60^0 angulation with 5mm radius[13].

There are no studies comparing NCF values between ProTaper NEXT and Reciproc R instruments.
Cyclic fatigue test investigated in this study is the in vitro resistance to fracture caused by the accumulation of metal fatigue, which is determined by the tension/compression cycles at the point of maximum flexure. The clinical relevance of the results of such tests is difficult to assess because this condition differs from intracanal instrumentation in which the fracture occurs because of several factors that act together at the same time, including torsional stress. This represents a pure mechanical test to extrapolate only one characteristic of the instruments (bending failure) . As NiTi rotary instruments are widely used, the need for a standardization of testing of their properties including cyclic fatigue is required to ensure the uniformity of methodology and comparable results for a safer, efficient clinical use.[3]

CONCLUSION:

Reciproc R fractured required higher time than the Protaper Next, hence Reciproc R file is better as compared to ProTaper NEXT in terms of cyclic fatigue at 45^0 and 60^0 angle of curvature. NCF values at 45^0 for ProTaper NEXT were higher when compared to Reciproc R and at 60^0 Reciproc R files had more values compared to ProTaper NEXT.

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