Cyclic Fatigue of TruNatomy Nickel-Titanium Rotary Instrument in Single and Double Curvature Canals: A Comparative Study

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ABSTRACT

Aim: The aim of this study is to measure the cyclic fatigue resistance of TruNatomy (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) instruments in single and double curvature canals and compare it with those of ProTaper Next and 2Shape.

Materials and methods: Sixty NiTi rotary files were used in this study and distributed into three groups ($n = 20$ for each group). Group I: TruNatomy (size 26, taper 0.04), group II: ProTaper Next (size 25, taper 0.06), and group III: 2Shape (size 25, taper 0.06). Then, each group was subdivided into two subgroups ($n = 10$ for each subgroup) according to the curvature of the canals (single or double). Lengths of all the used files were 25 mm. The files were tested in custom-made artificial canals with a single curvature (60° curvature, 5-mm radius) and a double curvature (coronal curve: 60° curvature, 5-mm radius and apical curve: 70° curvature and 2-mm radius). Each file was operated in a continuous rotation movement until the file fractures. Time for file separation and length of fractured fragment were recorded. The number of cycles to failure of each file was calculated.

Statistical analysis: Data were statistically analyzed using the Shapiro-Wilk test, one-way ANOVA, and the *post hoc* Tukey test.

Results: The normal distribution of data was detected by the use of the Shapiro-Wilk test. The results of the ANOVA test revealed a significant difference in cyclic fatigue resistant among three groups of the tested files ($p < 0.05$). The *post hoc* Tukey test showed that in both single- and double-curved canals, the number of cycles to failure of the TruNatomy group was significantly higher than other groups ($p < 0.05$). No statistical difference in fragment length among the tested files in both curvatures ($p > 0.05$).

Conclusion: In both curvatures, TruNatomy instruments were more resistant to cyclic fatigue than 2Shape and ProTaper Next instruments.

Keywords: 2Shape, Cyclic fatigue, Double curvature, ProTaper Next, TruNatomy.

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INTRODUCTION

While nickel-titanium (NiTi) rotary endodontic files have a greater advantage over the instrumentation with stainless steel that enabling improved canal shaping with minimizing canal transportation, separation through torsional and cyclic fatigue remains a risk with the NiTi instruments.^{1,2} Over the last decay, rotary NiTi files have undergone major changes. In an effort to improve their mechanical properties, resistance to cyclic fatigue and flexibility, various treatments have been implemented for NiTi instruments.³ New NiTi instruments should undergo many investigations for their mechanical properties or cyclic fatigue resistance before and immediately after their release in the market to prevent instrument separation and the adventure in therapeutic prognosis.⁴

The number of loading cycles needed to trigger a fatigue crack and to propagate the crack to a specific amount was considered as the fatigue life of rotary endodontic files. In NiTi alloys, the growth rates of that cracks were notified to be greater than in other metals of the same strength.⁵ Therefore, it is not surprising that in recent years, several studies have been advertised with a focus on the resistance of cyclic fatigue of many NiTi files that are used in root canal treatment. All of these studies have attempted to simulate the instrument's rotation inside a curvature to mark how long it will last before the fracture occurs.⁵ The TruNatomy endodontic rotary system was developed in 2019 by Dentsply Sirona, Maillefer, Ballaigues, Switzerland. Instruments being sophisticated as an

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advanced type of the heat-treated NiTi rotary system with many specific characteristic features. The manufacturer claimed that the TruNatomy endodontic system contains many advantages that include greater flexibility, better cyclic fatigue resistance because of the special heat treatment, and the unique 0.8-mm wire design instead of 1.2-mm wire design of the other rotary files with variable tapered in addition to off-centered parallelogram cross-section design.⁶ As a result of those features, the TruNatomy instrument is used widely in the curved canal in which minimum tooth

amount needed to be removed only with respecting the original canal anatomy and in cases of a constricted endodontic cavity for the preservation of the dentinal tissue to help in maintaining the strength of the tooth.⁶ The larger tip diameter of TruNatomy prime and medium (0.26 mm, 0.36 mm) may be considered as a disadvantage that leads to reduce the fatigue life span of instruments.⁷ For the TruNatomy endodontic rotary system, there is no sufficient information available of resistance to cyclic fatigue. Therefore, it is important to examine the newly introduced NiTi rotary system to give a reliable information for clinicians to improve the prognosis of root canal treatment.⁸ This *in vitro* study have been aimed to measure the cyclic fatigue of TruNatomy and compare it with those of ProTaper Next and 2Shape in the simulated single- and double-curved canal.

MATERIALS AND METHODS

Total 60 of NiTi rotary files were used in this *in vitro* study and distributed into three groups ($n = 20$ for each group). Group I: TruNatomy, Dentsply Sirona, Maillefer, Ballaigues, Switzerland (tip size 26, with 0.04 taper); group II: ProTaper Next, Dentsply Maillefer, Ballaigues, Switzerland (size 25 with taper 0.06); and group III: 2Shape, Micro Mega, France (size 25, taper 0.06). Then, each group is split into two subgroups ($n = 10$ for each subgroup) according to the canal's curvature (single or double) (Fig. 1). Cyclic fatigue testing was applied for all instruments by a specific stainless steel block that was custom-made with a single curvature canal (60° angle of curvature/5-mm radius, curvature's center was found at 5 mm from the canal's end, curve's length was 5.25 mm) and the double-curved simulated canal (60° of curvature's angle coronally with a radius of 5 mm, the center of the curvature will locate at a distance of 8 mm from canal's end and 5.25-mm curve length, with the curve apically has a curvature's angle of 70° with 2-mm radius, curvature's center was found at 2 mm from the canal's end and the curve was 2.4 mm in length) as measured by Plotino.⁹ The canals were 3D drawn in AutoCAD 2018 and then transferred to DWG, DXF 2005 file extension in order to be understood and constructed by an electrical discharge wire cutting machine. The two artificial canals were milled in stainless steel (Fig. 2). Both artificial canals had a working length of 18 mm; the canal's inner diameter was 1.5 mm.¹⁰ Tempered glass was used to cover the artificial canals to prevent the instrument from slipping out, allow

the instrument to be examined during operation, and to provide easy observation of the fracture through the cover glass when instrument separation occurs.¹¹

All the instruments were examined by stereomicroscope (MEIJI Techno, Japan, model No. HG175398) to detect any deformation for exclusion. Electric motor (NSK ENDO-MATE DT) was used for operating instrument according to the manufacturer's instruction of speed and torque for each system. The handpiece of the electric motor was mounted on a surveyor that keeps the hand-piece in its position during operation, permits precise placement of each rotary file within the simulated canal, and ensures instrument insertion to the same depth each time (Fig. 3).¹² All tested files were rotated until a separation occurred. The time was registered as soon as a fracture has been identified visually and/or audibly. To prohibit human error and for standardization of this study, video recording was used at the same time for cross-checking the time of separation of the file.¹³ By multiplying the time reported in minutes with a motor speed recommended by the manufacturer, the number of cycles to failure (NCF) was determined. The length of fractured fragment (FL) for each file was obtained using digital Vernier.¹⁴ By using the Shapiro-Wilk test, one-way ANOVA, and the *post hoc* Tukey test and independent *t*-test, NCF and FL data were analyzed. All of the statistical analyses were completed with the SPSS version 21 software edition (IBM-SPSS Inc., Chicago, USA), and the level of statistical significance was fixed on 0.05.

RESULTS

Normal distributions of the data were evaluated using the Shapiro-Wilk test; descriptive statistics (mean $\pm$ standard deviations SD) were recorded. The results of the ANOVA test revealed a significant difference in resistance to cyclic fatigue among three groups of the tested instruments ($p < 0.05$). The *post hoc* Tukey test demonstrated that in both artificial canals, NCF of the TruNatomy group was significantly superior to other groups ($p < 0.05$). The ANOVA test presented no significant differences in the number of cycles to failure between ProTaper Next and 2Shape in both simulated canals, single and double curved (Table 1). Independent *t*-tests revealed that in all tested files the NCF mean was less in the double-curved canal than that in the single-curved canal (Table 2) ($p < 0.05$). No statistical difference was found in fragment length among the tested instruments in both simulated canals ($p > 0.05$).

Fig. 1: Sample grouping

Fig. 2: Cyclic fatigue testing device

DISCUSSION

The intracanal separation of the rotary instrument is a significant incidence since the fractured part of the instrument can limit the mechanical instrumentation, prevent the access of irrigation solution from reaching the apex of the root canal system, and subsequently prevent enough elimination of microorganism. Investigation of the cyclic fatigue resistance of root canal instruments is an important topic that was greatly discussed in many studies.¹⁵ Even if the extracted teeth more closely resemble the clinical situation, it was not a precise model because there were no two root canals identical typically.¹⁶ Simulated canals made from stainless steel were used excessively in laboratory researches to examine the resistance of NiTi rotary instruments to cyclic fatigue for better experiment Standardization.¹⁷ Two test stainless steel models are present: dynamic and static types. In a dynamic one, stress is spread on the shaft's length of the instrument during the insertion and removal axially; however, in static models, concentration of the stress was on specific single area of the instrument's shaft. The static test model was used in this study because the dynamic models could be not

useful in identifying the clinical situations, as clinicians are not able to control the pecking movement exactly.¹⁸ In this *in vitro* study, the cyclic fatigue resistance of the recently developed TruNatomy was assessed and compared with ProTaper Next and 2Shape rotary systems. TruNatomy (Prime) instrument that is used in this study has a tip size of 26 and 0.04 taper and was compared to the ProTaper Next (tip size 25 with 0.06 taper) and 2Shape (tip size 25 with 0.06 taper) learning that it contains a different taper. Moreover, many studies in the articles have also made such a comparison for the resistance of cyclic fatigue for instruments with various taper.¹⁹ TruNatomy exhibited more cyclic fatigue resistance than the other groups in both curvature canals. This could be generated from different reasons; it is well assumptive that instrument dimensions, cross-sectional design, and manufacturing mechanization influence cyclic fatigue resistance of endodontic rotary files. The recently advanced TruNatomy endodontic files are subjected to a post-manufacturing thermal process that yields an instrument with superelastic NiTi metal characteristics.⁷

TruNatomy instruments have a unique design with off-centered parallelogram cross-section and it might be considered that this design when put in comparison with ProTaper Next rectangular cross-section and 2Shape (tripe helix: two primary cutting edges and one secondary cutting edge) could participate to the greater cyclic fatigue resistance of the TruNatomy rotary instruments. In addition, the TruNatomy instruments are made of a slim design of 0.8-mm NiTi wire, which might have led to increased cyclic fatigue resistance.⁷⁻²⁰ A thermomechanical manipulation of endodontic rotary files creates an instrument with several austenite finishing temperatures that influence mechanical features of endodontic instruments mostly cyclic fatigue and bending properties. Alloy heat treatment is responsible for improving the crystal structure arrangement that leads to better flexibility and strength of the NiTi rotary files. However, it leads to decreased internal stress and defects of the instrument surface due to the process of grinding.²¹ The outcome of this study was in the same line with the recently published article in which TruNatomy instruments showed superior cyclic fatigue resistance in comparison with Twisted file and ProTaper Next systems.²² However, results from this study were in contrast to the result of other recently published articles

Fig. 3: File position inside the block

Table 1: Mean and SD of NCF for the three groups. ANOVA presented a significant difference *p* value (*p* < 0.05). Outcomes of Tukey's test are demonstrated

Curvatures	Endodontic files	NCF				
		Mean ± SD	ANOVA <i>p</i> value	Multiple comparison test		
Single curved	TruNatomy	2115.790 ± 652.67	0.000	TN	PTN	0.000
	PTN	740.5000 ± 118.26			2Shape	0.000
	2Shape	617.4000 ± 131.90		PTN	2Shape	0.763
Double curved	TruNatomy	1226.550 ± 179.61	0.00	TN	PTN	0.000
	PTN	338.5000 ± 111.20			2Shape	0.000
	2Shape	251.3100 ± 69.40		PTN	2Shape	0.298

SD, standard deviation; PTN, ProTaper Next; TN, TruNatomy; ANOVA, analysis of variance

Table 2: Independent *t*-test between both curved simulated canals

Endodontic files	<i>T</i>	<i>df</i>	<i>Sig.</i>	Mean difference	SE difference	Lower	Upper
TruNatomy	4.154	18	0.000/S	889.24000	214.066	439.50281	1338.97719
PTN	8.288	18	0.000/S	375.00000	45.2468	279.93989	470.06011
2Shape	7.769	18	0.000/S	368.79000	47.4672	269.06502	468.51498

t, student *t*-test; *df*, degree of freedom; SE, standard error; *Sig.*, significance

in which the TruNatomy instrument demonstrated a lower cyclic fatigue resistance in comparison with other tested instruments. This may be related to the difference in methodology since the mentioned study investigated the cyclic fatigue resistance at body temperature (37°C).⁷ The results showed that the NCF for the investigated endodontic rotary files within the double-curved canal was lower than the single-curved canal because NiTi rotary files were more stressed by the double curvature canals (S-shaped) than by the single curvature canals and consequently, the separation occurs.²³ The current study revealed there is no statistical significant difference for the mean of fragment's length of the fractured piece of tested files among the examined endodontic rotary instruments. Separation of instrument occurs at or just below the center of the curvature, which assures file position in a precise alignment.^{24,25}

CONCLUSION

TruNatomy had higher cyclic fatigue resistance than ProTaper Next and 2Shape in both simulated canals, single and double curvature. TruNatomy rotary files have a greater number of NCF than the other investigated files. Number of cycles to failure for the examined endodontic rotary instruments within double-curved canal was lower than the single-curved canal.

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