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Cyclic Fatigue Resistance of Mtwo Rotary Instruments with two Different Instrumentation Techniques

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ABSTRACT

Introduction: The objective of this *in vitro* study was to evaluate whether cervical preparation with Mtwo files in a crown-down technique influences instrumentation time and the cyclic fatigue resistance of these instruments. **Methods and Materials**: Two instrumentation techniques were evaluated (manufacturer and crown-down). Each group consisted of 10 kits containing four Mtwo instruments (10/0.04, 15/0.05, 20/0.06, and 25/0.06), which were used to prepare three standard simulated curved resin canals. The mean instrumentation time and the corresponding number of cycles for each instrumentation (NCI) were recorded. The instruments were rotated at a constant speed of 300 rpm in a stainless-steel canal (diameter of 1.5 mm) at a 90° angle of curvature and 5-mm radius. The center of the curvature was 5 mm from the tip of the instrument. The cyclic fatigue resistance of the files was determined by counting the number of cycles to failure (NCF). Data were analyzed by the Mann-Whitney test. **Results**: The mean instrumentation time and NCI of files 10/0.04 and 15/0.05 were significantly lower ($P<0.05$) when the crown-down technique was used compared to the manufacturer's method for the same tip size/taper file. There was no significant difference in the mean NCF between the two techniques. **Conclusion**: The crown-down technique did not interfere with resistance to cyclic fatigue. However, the shorter instrumentation time of files 10/0.04 and 15/0.05 could reduce the fracture risk in the case of reuse of these instruments.

Keywords: Crown Down; Cycles to Failure; Cyclic Fatigue; Instrument Fracture; Root Canal Instrumentation

Introduction

The separation of nickel-titanium instruments continues to be a matter of concern. These instruments do not allow plastic deformations and their failures occur intrinsically, which are not noticeable under visual inspection [1]. The leading causes of separation are cyclic fatigue and torsional stress [2, 3].

Cyclic flexural fatigue occurs when an instrument rotates freely in a curved canal and is subjected to successive loads of compression and tension at the same point [2]. Torsional stress is generated when the tip of the instrument locks into the root canal wall, while the shank is still being rotated. This occurs mainly during the shaping of curved and narrow canals when the file is susceptible to high torsional loads [2, 4].

Several factors can influence the longevity of files, for instance, rotations per min (rpm), instrument motion, thermomechanical treatment of the alloy, thickness, and conicity of the instrument, and high working temperature caused by the absence of a lubricant. Other interfering factors are the use of oxidizing chemicals, canal diameter and curvature, the sterilization cycles employed, and the instrumentation technique used [5-11]. The cross-sectional area and file design, which are inherent characteristics that influence the distribution of tension, may affect failure resistance [12-14].

MTwo files (VDW, Munich, Germany) are among the rotary systems most resistant to cyclic fatigue [15]. Their "S" cross-section with a double-cut blade promotes a more efficient dentin cut and, consequently, better cleaning of the canal [16, 17]. This system does not use the crown-down technique. According to the manufacturer, thinner-caliber files precede thicker files as they progress apically. Each instrument creates access to the apex for the following instrument and is used up to the working length (WL) to prepare the entire canal.

The objective of this study was to evaluate whether the use of the crown-down technique, through cervical pre-enlargement, increases the resistance of Mtwo files to cyclic fatigue. The hypothesis is that cervical pre-enlargement reduces the time of use of the thinner files during instrumentation, thus increasing their resistance to cyclic fatigue.

Materials and Methods

Materials

Eighty new Mtwo rotary endodontic instruments (size/taper: 10/0.04, 15/0.05, 20/0.06 and 25/0.06; 25 mm in length) were randomly divided into two groups according to the instrumentation techniques used: manufacturer and crown-down. All surfaces were previously inspected under a stereomicroscope (SteREO Discovery, V12, Zeiss, Germany) under 16× magnification to observe the presence of defects or distortions. None of the files were excluded. Each file kit instrumented three artificial canals in standard resin blocks (IM Brazil Ltda., São Paulo, SP, Brazil) to simulate the preparation of a molar (*n*=30 simulated canals per group). Considering that each kit was composed of four instruments (10/0.04, 15/0.05, 20/0.06, and 25/0.06) and 10 kits per group were used, a total of 40 instruments per group were evaluated. The simulated canals had a curvature angle of 60° and a curvature or radius of 5 mm [18].

Instrumentation

The instrumentation conditions, especially the depth of movement, were calibrated in a pilot study using a separate batch (*n*=6) of artificial canals. The aim of this calibration was to establish and standardize the torque, time and speed needed by the operator to instrument the canals.

Instrumentation of the simulated canals started with canal negotiation using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) to establish the WL of 17 mm. Patency was maintained during all techniques by introducing a #10 K-file. A

Table 1. Instrumentation protocol of the groups

Manufacturer technique				Crown-Down technique			
Mtwo File	**Speed (RPM)**	**Torque (Ncm)**	**Working Length**	**Mtwo File**	**Speed (RPM)**	**Torque (Ncm)**	**Working Length**
10/0.04	300	1.20	17mm	25/0.06	300	2.30	Until resistance was felt
15/0.05		1.30		20/0.06		2.10	Until resistance was felt
20/0.06		2.10		15/0.05		1.30	Until resistance was felt
25/0.06		2.30		10/0.04		1.20	17mm
				15/0.05		1.30	17mm
				20/0.06		2.10	17mm
				25/0.06		2.30	17mm

Table 2. Values of the mean (SD) of the instrumentation time (s), number of cycles for each instrumentation (NCI), time to instrument failure (s), and number of cycles to failure (NCF)

MTwo	Group	Instrumentation time	NCI	NCF
10/0.04	Manufacturer	31.39* (14.65)	156.95* (73.26)	348.30 (92.86)
	Crown-down	4.12* (1.50)	20.60* (7.51)	367.70 (92.45)
15/0.05	Manufacturer	43.40* (17.96)	217.45* (89.81)	494.00 (64.01)
	Crown-down	25.52* (8.10)	127.60* (40.51)	493.30 (53.64)
20/0.06	Manufacturer	39.98 (18.62)	199.90 (93.11)	550.15 (65.25)
	Crown-down	42.59 (6.75)	212.95 (33.77)	568.70 (81.58)
25/0.06	Manufacturer	26.75 (6.81)	133.75 (34.05)	511.45 (53.76)
	Crown-down	30.69 (4.98)	153.45 (24.93)	533.10 (127.06)

** Statistically significant difference (Mann-Whitney test)*

24% gel of ethylenediaminetetraacetic acid (Biodynamic Chemistry and Pharmaceutical Ltda., Ibiporã, PR, Brazil) was used as a lubricant, and 2 mL of distilled water (Iodontosul-Industrial Odontológica do Sul Ltda., Porto Alegre, PR, Brazil) was applied to remove resin remnants at each file change during instrumentation. All files were used with a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) operated by a torque-controlled motor (Reciproc Silver, VDW, Munich, Germany). The predefined conditions of instrumentation, velocity, and torque for each file are described in Table 1.

All instrumentation procedures were performed by a single operator. In the manufacturer's technique group, the instruments were used in the 10/0.04, 15/0.05, 20/0.06 and 25/0.06 sequence, with simultaneous lateral and penetration movements (brushing) until reaching the WL without pushing the instrument apically. The amplitude of movements did not exceed 3 mm.

In the crown-down group, the files were used in the 25/0.06, 20/0.06 and 15/0.05 sequence for pre-enlargement of the cervical and middle thirds. The instruments were replaced every three gently inward pecking motions until resistance was felt. The preparation of the simulated canals was completed using the sequence of the manufacturer's technique (10/0.04, 15/0.05, 20/0.06, and 25/0.06) at WL. The amplitude of movements did not exceed 3 mm.

The mean instrumentation time(s) of each file to prepare the artificial canals was recorded by a single operator with a 1/100-s chronometer, and the number of rotations was calculated to the nearest full number. The number of cycles during instrumentation (NCI) was then estimated using the formula[1]: NCI= rpm × time to failure (s)/60 s.

Cyclic fatigue test

Cyclic fatigue testing was performed using the same files as those submitted to stress in the artificial canals blocks. One artificial canal made of a stainless-steel tube was used to evaluate cyclic fatigue. The device simulated a canal measuring 1.5 mm in diameter, with a 90° curvature angle, 5-mm radius, and center of curvature 5 mm from the tip of the instrument [18]. A supporting device was used to keep the artificial canal and the contra-angle static, only allowing free rotation of the file (Figure 1). A lubricating oil (WD-40, AP Winner Ind. Com. De Prod. Quimicos Ltda., Ponta Grossa, PR, Brazil) was applied to minimize the heat generated by the friction of the metal surfaces. The instruments were rotated at a constant speed of 300 rpm using a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) operated by a torque-controlled motor (Reciproc Silver, VDW, Munich, Germany).

Each instrument was rotated until fracture occurred. The time to fracture of the instrument was recorded visually with a 1/100-s chronometer, and the number of rotations was calculated to the nearest full number. The number of cycles of the instrument to failure (NCF) was established using the following formula [1]: NCF=rpm × time to failure (s)/60 s.

Statistical analysis

Data were analyzed with the SPSS 13.0 software (Statistical Package for the Social Sciences, Chicago, USA). Descriptive statistics were obtained, and the nonparametric Mann-Whitney test was used for comparison between groups. The level of significance was set at 0.05.

Results

Table 2 shows the mean instrumentation time, NCI and NCF for the two techniques studied. The mean instrumentation time and NCI of files 10/0.04 and 15/0.05 were significantly lower when the crown-down technique was used compared to the manufacturer's method for the same files ($P<0.05$). These differences were not observed for files 20/0.06 and 25/0.06 ($P>0.05$). The pre-stressed files using the crown-down method did not affect NCF in the cyclic fatigue resistance tests. No significant difference was found in NCF between the two techniques.

Discussion

The hypothesis of this study was partially rejected. The change in the instrumentation sequence of the Mtwo files through the crown-down technique significantly reduced the time of use of the 10/0.05 and 15/0.05 files but did not influence their overall resistance to cyclic fatigue.

Pre-enlargement of the cervical and middle thirds before shaping generates space for the rotating files to work with less contact with the dentinal walls of curved root canals. In this respect, pre-enlargement has been shown to reduce the incidence of fractures and stress concentration during rotation of the file [19]. A previous clinical trial evaluated the fracture incidence of the Mtwo instruments with prior cervical pre-enlargement using manual files and Gates-Glidden burs. The results showed a fracture incidence of 1.98% only for the 10.04 and 15.05 files when 556 teeth were prepared [19]. This

Figure 1. Supporting device for the artificial canal and the cyclic fatigue test. *A)* Counter-angle x file ratio x stainless steel apparatus used in the cyclic fatigue test; *B)* File tip out of the canal; *C)* Characteristics of the artificial canal geometry.

fracture incidence increased significantly in another clinical trial when the Mtwo files were used according to the manufacturer's technique. A total of 593 instruments were used for shaping and 8.9% of them fractured, with a higher incidence for the 10/0.04 and 15/0.05 files [20].

A high incidence of deformations and fractures has been reported for these 10/0.04 and 15/0.05 files [19, 20]. The high fracture susceptibility can be attributed to the fact that these files are more exposed to mechanical stresses since they encounter a narrower anatomy during the initial steps of instrumentation. Also, the files have a higher tendency to separate because of their lower resistance to torque during use [19].

In our study, there was a reduction in the time of use, but no differences were found in the resistance to cyclic fatigue. Theoretically, a shorter instrumentation time would favor a higher NCF. Further studies with a larger sample size as that used in the clinical studies cited are needed to confirm the use of the crown-down technique to reduce the incidence of fractures.

The morphological design and cross-sectional features of the Mtwo system are similar to that of the ProDesign Logic (Easy Dental Equipment, Belo Horizonte, MG, Brazil), One Shape (Micro Mega, Besancon, France), and Reciproc systems (VDW, Munich, Germany). De Menezes *et al.* [18] showed that the ProDesign Logic 25/0.06 system used in continuous rotation resulted in shorter modeling time and higher resistance to cyclic fatigue than WaveOne Gold 25/0.07 (Dentsply Maillefer, Ballaigues, Switzerland). Dagna *et al.* [21] found better cyclic fatigue resistance results of the Reciproc 25/0.08 file when compared to ProTaper Universal 25/0.08 (Dentsply Maillefer, Ballaigues, Switzerland), WaveOne 25/0.08 (Dentsply Maillefer, Ballaigues, Switzerland), and One Shape 25/0.06. However, One Shape showed good mechanical strength due to its design that eliminates the threading and binding of this instrument during continuous rotational movement. It is believed that the morphological design and the S-shaped cross section have rendered these files more flexible and resistant to cyclic fatigue.

The shaping ability of the manufacturer and crown-down techniques using Mtwo files has also been studied [22]. This study showed no differences in the apical and middle thirds of the canal. However, the crown-down technique respected more the anatomy of the coronal portion of the root canal.

There is no consensus on the reuse of rotary instruments. Most manufacturers claim single use only for rotary instruments [23, 24]. However, some studies have evaluated the reuse of these instruments. In a clinical study, Ehrhardt *et al.* [19] suggested the use of Mtwo files only twice because of the high fracture risk of the thinner files (10/0.04 and 15/0.05), especially in more complex root canal anatomies. According to Uroz-Torres *et al.* [25], this system can be used up to 5 times in canals with moderate (25-44°) to severe (45-76°) curvature angles. Plotino *et al.* [26] suggested that the Mtwo files can be safely reused up to 10 times in molars if operated by a specialist in endodontics. In this study, a manual #15 file was used to create a glide path before instrumentation with the Mtwo files, favoring canal negotiation and enhancing the efficacy and safety of mechanized instruments. The shorter instrumentation time of Mtwo instruments could reduce the fracture risk in the case of reuse of these instruments.

Fractures are a complex and multifactorial clinical situation [25]. Factors such as neglecting the perception of a severe to moderate curvature, instrumentation technique, tip/taper ratio of the instrument and taper of the canal, metallurgical properties of the instruments, speed, torque and mechanical stress caused by the operator can trigger an early fracture during first use [25]. In this respect, this study aimed to evaluate the influence of cervical pre-enlargement on the cyclic fatigue resistance of Mtwo files in curved canals. The use of simulated artificial root canals even before the cyclic fatigue test to pre-stress the files has been well documented [9, 18, 26]. The ideal experimental model continues to be the instrumentation of curved canals in natural teeth [27]. However, standardization is difficult due to anatomical variations [28, 29] that can generate false results, compromising the evaluation of the different systems [30].

Despite the advances in mechanized instrumentation, there is no international standard to evaluate the cyclic fatigue of nickel-titanium rotary instruments. Specification No. 28 of the American National Standards Institute/American Dental Association (ANSI/ADA)[31] and ISO 3630/1 [32] only describe test conditions and parameters for measuring torsion and cyclic flexural fatigue in stainless-steel manual instruments. In this respect, cyclic fatigue studies have been conducted using artificial canals that were made by bending glass [33, 34] or cylindrical metal tubes [18, 35, 36] with different internal diameters and maximum curvature point using different radii and angles of curvatures.

Rotary instruments with a similar tip/taper ratio, but from different manufacturers, follow different trajectories when subjected to cyclic fatigue tests in artificial devices, providing unreliable and inconsistent results [27]. These discrepancies are mainly related to differences in file flexibility due to the thermal treatment of each instrument and the ratio between the diameter of the instrument and the internal diameter of the canal [37]. In this study, only one artificial canal made of stainless steel was used to ensure standardization of the fatigue test for all files [18, 27]. Even without individual preparation of the artificial canal for each Mtwo instrument, comparisons are possible since only one system was used.

Conclusion

Cervical pre-enlargement did not affect NCF in the cyclic fatigue resistance tests. However, the instrumentation time of files 10/0.04 and 15/0.05 was significantly shorter when the crown-down technique was used. Studies with a larger sample size are needed to confirm the use of the Mtwo system by the crown-down technique, which is not only beneficial but also more user-friendly, in addition to preserving the anatomy of the canal.

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