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Evaluation of cutting ability and plastic deformation of reciprocating files

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Abstract: This *in vitro* study evaluated the cutting ability of reciprocating files and the deformations caused by their multiple use. Five Reciproc® R25 files were divided into five groups for 10 simulated root canal preparations each. The resin blocks were weighed and photographed (12.5X and 20X) before and after preparation. The canals were prepared according to the manufacturer's instructions. Enlargement of the root canals was evaluated by comparison of pre- and post-preparation images using a computer software. The preoperative and postoperative weight differences determined the cutting ability of repeatedly used instruments. The data were analyzed using Lilliefors and Friedman statistical tests. The cutting ability and enlargement of the canals gradually decreased after each use, with significant differences observed at the 8th and 9th repetitions, respectively. There was no evidence of file deformation. The cutting ability and enlargement of the simulated canals gradually decreased when a reciprocating file was used up to 10 times.

Keywords: Endodontics; Dental Instruments; Root Canal Preparation; Root Canal Therapy.

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Introduction

A new mark for instrumentation was established when files designed to be used in continuous rotation were combined with an oscillating system, which led to a drastic reduction in fracture rates.[1] Therefore, due to the growing demand for wider preparation of the apical third of the root canal,[2,3,4,5] the Reciproc® system was designed (VDW™ GmbH, Munich, Germany). The Reciproc file is made of a NiTi alloy with structural changes by thermal processes also known as M-Wire. These modifications allowed for more elastic and flexible files, such as the R25 file with #25 tip but with 0.08 taper over the first three apical millimiters.[6] A centralized preparation of the root canal walls, even in canals with high degrees of curvatures, can be carried out by a single instrument. The instrumentation protocols have been simplified and the time for root canal shaping decreased significantly.[7]

This system works in a reciprocating rotation motion combined with asymmetric displacement. Such kinematics minimizes the risk of torsional stress fractures, as the counterclockwise rotation angle is lower than the elastic limit of the instrument.[6,8] The manufacturer indicates single use of files despite greater resistance to cyclic fatigue. However, single use means that the same instrument can be used in three or four canals, which could be complex and tortuous.[6] High resistance to cyclic fatigue is a fact,[8,9,10] but it is unknown whether a reciprocating file used as a single instrument for preparation keeps its shaping characteristics after prolonged use.

The aims of this study were to evaluate the cutting ability of Reciproc® R25 files, as well as to analyze deformation of instruments used up to 10 times.

Methodology

Preparation of specimens and samples

Fifty transparent epoxy resin blocks containing simulated root canals were selected (IM do Brasil Ltda., São Paulo, Brazil) with a single curvature varying from 38º to 40º and a diameter equivalent to a #15 file, and 0.02 taper, identified with a permanent marker.

The resin blocks were weighed on an analytical balance with an accuracy of 10^{-5} g (Mettler Toledo International Inc. XP205, Greinfensee, Uster, Switzerland). Each block was weighed three times, with a difference of no more than 0.05 mg between the weighing and the average noted. The resin blocks were individually photographed using a digital camera (Canon EOS REBEL T3i, Canon USA Inc., New York, USA) and 105 mm F2.8 EX DG Macro lens (Sigma Corporation of America, New York, USA). The blocks were positioned on an acrylic resin base at a focal length of 32 cm. The images were stored in JPEG format at 5184 X 3456 pixels.

Five Reciproc® R25 files from the same manufacturing lot (1107001365) were selected for the study. Deformation was assessed using an endodontic ruler (Indústria de Produtos Odontológicos S/A, Londrina, Brazil) placed on a mini bench vise at a distance of 22 cm from the lens of a light microscope (DF-MU® M19, DFVasconcellos, Valencia, Brazil), using a Nikon Coolpix 4500 digital camera (Nikon Corporation, Tokyo, Japan) and lens (4.0 megapixels; 4x optical zoom lens).

Each file was photographed inside the groove of the endodontic ruler in its most apical half, rotated 180° and then photographed again. The procedure was then repeated for the coronal half. The photographs were taken at 12.5 X and 20 X magnifications. The images were inspected for morphological changes or distortions that may have occurred prior to each use. The images were stored in JPEG format at 2272 X 1704 pixels.

Preparation of the simulated root canals

A #10 file with 0.02 taper (C-Pilot™ VDW GmbH™, Munich, Germany) was used for clearing, obtaining patency, and visually determining the working length at 1 mm short of the apex.

The first file was coupled to a Sirona 6:1 handpiece of the Silver VDW Reciproc (VDW GmbH™, Munich, Germany) and prepared using pecking motion kinematics and light apical pressure, according to the manufacturer's instructions. After three pecking movements, the file was cleaned with gauze and the simulated canal irrigated with 5 mL of water. Root canal patency was maintained through its entire length using a C-Pilot™ #10 file. This cycle was repeated until the instrument reached the working length. The files were dried with gauze and once again placed on the endodontic ruler for a new sequence of photographs.

The procedure was repeated for all files until deformation was identified or complete preparation of the tenth simulated root canal was achieved.

At the end of preparation, each resin block was rinsed under running water, dried with compressed air, and the canal dried using a capillary tip (0.48 mm and 0.35 mm, Ultradent Products Inc., Salt Lake City, USA) and paper points. The resin blocks were weighed on an analytical balance using the same aforementioned method. Preoperative and postoperative weight measurements were recorded. The resin blocks were then photographed to obtain postoperative images, as previously described.

The images were analyzed using the UTHSCSA Image Tool 3.0 software (University of Texas Health Science Center at San Antonio, San Antonio, USA). For each image, the acrylic base rulers, where the simulated root canal blocks were positioned, aided the calibration of the images on the software, so that 1 mm on the ruler corresponded to 128 pixels in the image. The values of the canals before and after preparation as well as the data for the weight of the resin blocks were recorded for statistical analysis.

According to the Lilliefors test, the variables did not conform to normality. File performance, in terms of area and weight, was evaluated using the nonparametric Friedman's test, combined with the establishment of the least significant difference (LSD) of multiple comparisons.

Results

During its seventh use, a fracture occurred in instrument C, which required exclusion of its data from the study.

The results demonstrated a reduction in the simulated root canal width after multiple instrument use, mainly following the ninth repetition (Table 1)

Similarly, a slight reduction in cutting ability occurred after repetitive use, mainly seen after the eighth use of the file (Table 2).

The image analysis of Reciproc® files after each use did not reveal plastic deformation in any of the files, regardless of image magnification.

Discussion

Cyclic fatigue tests are the most important method for analyzing resistance of endodontic files. Few variations of this type of test are available, with the basic principle that files are driven into a simulated metallic root canal until instrument fracture. The option of using the same file in several canals is an alternative method, which is closer to clinical reality.

According to the manufacturer, the single use of the instrument is recommended. Several factors may influence the stress suffered by the file during each use, such as the manufacturing process, instrument design, preparation technique, dental anatomy, and operator experience. In addition, the reuse of an

Table 1. Average area (mm^2) and widening (mm^2) of the simulated root canals after each use of the Reciproc® R25 file.

Sample		1	2	3	4	5	6	7	8	9	10	p-value
Average area	Pre	7.7	7.3	7.2	7.54	7.48	7.63	7.44	7.36	7.28	7.42	$p < 0.008$
	SD	0.39	0.23	0.15	0.37	0.52	0.53	0.32	0.71	0.49	0.29	
	Post	11.16	10.5	10.17	10.5	10.33	10.4	10.09	9.91	9.62	9.71	
	SD	0.6	0.41	0.2	0.56	0.74	0.67	0.47	0.95	0.77	0.47	
Difference		3.46	3.2	2.97	2.96	2.85	2.77	2.65	2.56	2.34*	2.29*	
	SD	0.23	0.2	0.13	0.22	0.24	0.15	0.16	0.25	0.3	0.2	
N		4	4	4	4	4	4	4	4	4	4	

SD: standard deviation.
*Statistically significant

Table 2. Mean weight (mg) and mean difference in weight after each file use (mg) in the simulated root canals after each use of the Reciproc® R25 file.

Sample		1	2	3	4	5	6	7	8	9	10	p-value
Average	Pre	3310.4	3381.2	3316	3274.4	3289	3249.6	3193.8	3181.1	3237	3354.9	$p < 0.00007$
	SD	62.27	124.63	150.46	163.53	100.62	64.3	140.32	155.71	138.64	233.47	
Weight	Post	3306	3377.6	3312.9	3271.6	3286.3	3247.2	3191.7	3179.3	3235.5	3353.5	
	SD	62.64	124.15	149.83	162.91	100.58	64.66	139.85	155.58	138.85	233.24	
Difference		-4.375	-36.375	-3.08	-28.775	-2.625	-24.275	-2.085	-1.7475*	-1.525*	-1.425*	
	SD	0.63	0.6	0.68	0.69	0.38	0.6	0.5	0.43	0.25	0.26	
N		4	4	4	4	4	4	4	4	4	4	

SD: standard deviation.
*Statistically significant.

instrument is a key factor for consideration.[11] Some studies have demonstrated the mechanical effects of reusing files.[12,13,14,15,16] Reusing the same Reciproc® R25 file in several simulated root canals is an alternative method, which more closely mirrors clinical practice and would therefore provide more realistic results.The manufacturer does not recommend file sterilization. The files were not sterilized between uses because the mechanical properties of the files made of M-Wire alloy are not influenced by this process.[17,18,19] Even after 10 sterilization cycles, the files can keep high resistance to cyclic fatigue.[19]

Our results demonstrated that the enlargement obtained with the files occurred in decreasing order, with a reduced ability to promote root canal widening the more the instrument is used. This was not, however, statistically significant until its ninth use.

Enlargement of the canal is fundamental to promote adequate decontamination of the dentin walls and to create an appropriate shape in order to obturate the root canal system. Enlargement of the apical third is more critical due to the curvatures, increasing the risk of fractures.[11]

The R25 Reciproc® instrument has a 0.08 taper on its upper 3 mm. Therefore, the diameter corresponds to #33, #41 and #49 files, respectively. Thus, even in a file with tip #25, an appropriate enlargement is performed. Along the first apical millimeter, the R25 file produces an enlargement four times higher than the #25 manual file. Until the introduction of the system, instruments with a 0.08 taper were used only as orifice openers. Reciproc® provides an R40 instrument with a 0.06 taper. The diameter at its tip is #40 and the upper 3 mm correspond to #46, #52 and #58 files. In canals with a severe degree of curvature, the use of an R40 instrument may not be indicated due to its strong tendency of working on the outer wall of the apical curvature, promoting canal transportation. In canals with a moderate degree of curvature, however, enlargement with this instrument may be performed safely, as it works within the appropriate kinematics. When enlargement of the apical third is necessary for sanification of the root canal, it is possible to enlarge it with a manual #35 instrument with a 0.02 taper, or Mtwo (VDW™ GmbH, Munich, Germany), #30/05 and # 35/04 instruments.

Using the same protocol with a Reciproc® R40 and BioRace system (FKG Dentaire, LaChauxde-Fonds, Switzerland), Alves *et al*.[20] demonstrated a 99.9% reduction of *Enterococcus faecalis* in the apical third, highlighting the importance of root canal enlargement for sanification.

In the present study, R25 revealed a decrease in its cutting ability with an increasing number of uses. Up untilits eighth use, no significant difference was observed. Clinically, however, it is important to highlight that after its fifth use, a greater number of movements were required to reach the working length, in addition to a higher pressure to advance through the simulated canal. Newman *et al*.[21] demonstrated that manual stainless steel files, tested in a sharpening motion on bovine cortical bone, presented at least a 50% loss in their cutting ability after the first use. The specimens and kinematics were different and such an effect was not observed when using NiTi instruments, such as Reciproc®.

As shown by Aydin *et al*.,[22] deformations and fractures of NiTi files are an important concern in terms of their clinical performance. When Varela-Platiño *et al*.[23] used a ProTaper® (Dentsply/Maillefer, Ballaigues, Switzerland) instrument in a reciprocating movement and continuous rotation at 20X magnification, instrument fractures and deformations were observed. However, when Franco *et al*.[24] used a light microscope to compare FlexMaster (VDW™ GmbH, Munich, Germany) in continuous and reciprocal rotation, no file deformations were observed. In the present study, after each use of the R25 file, there were no apparent signs of instrument deformation.

The low incidence of fractures after reuse of the R25 file can be explained by its high flexibility, which is provided by the M-Wire alloy, in addition to the reciprocating movement, which was demonstrated by Wan *et al*.,[9] Gavini *et al*.,[8] and Castelló-Escriva *et al*.,[10] who compared Reciproc® instruments in reciprocating and continuous rotation. They concluded that files in reciprocating movement require a higher number of cycles before cyclic fatigue fracture occurs. In an *in vitro* study by Gambarini *et al*.,[25] reciprocating cycles with short displacement increased file longevity due to lower stress. This corroborates the results obtained by Arias *et al*.,[26] who reported that cyclic fatigue is associated with repetitive stress. De Deus *et al.*[27] found that under continuous rotation, ProTaper® instruments fractured after an average of 160 cycles at 250 rpm and 120 cycles at 400 rpm. With a reciprocating movement, the fracture occurred at an average of 126 rpm to 400 rpm, which equates with 630 cycles. The reciprocating movement showed a significantly higher resistance to fatigue than did continuous rotation.

There is no doubt that reciprocating movement is revolutionary and, when associated with the M-Wire alloy, significantly reduces the risk of instrument fracture. In addition, it is well known that deformation can occur after each file use; however, the methodology adopted in the present study did not demonstrate sufficient evidence to advocate file disposal. Further studies are therefore needed for clarification.

Conclusion

There was no evidence of file deformation when Reciproc® R25 was used up to 10 times.The cutting ability and enlargement of the simulated canals gradually decreased when Reciproc® R25 was reused.

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