A comparative analysis of mechanical properties of different reciprocating Niti endodontic instruments

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Abstract

Despite it is not questionable that static tests give readers only a partial view of the performance of an endodontic instrument they are currently accepted as valid ones to evaluate and compare mechanical properties of endodontic instruments.
Therefore, aim of the present study was to evaluate a new single-file reciprocating instrument (Direct R-Gold 25, Direct Endo, Paris, France) and compare by using the three above-mentioned tests them with the same features of other reciprocating instruments which have been commercialized since many years and consequently have been widely investigated: Wave One Gold Primary (Dentsply-Maillefer, Baillagues, Switzerland), Reciproc and the Reciproc Blue (VDW, Munchen, Germany).
For each of the four tested instruments (in size 25) 60 instruments were selected and randomly divided into three groups (n=20). Each group was subjected to a different in vitro mechanical test. Prior to test, each instrument was carefully examinated under magnification. Instruments with visible defects and flute deformation were discarded. Stiffness, cyclic fatigue, torsional resistance tests were performed using methodologies validated in previous studies. For each test data were recorded, then the mean values and the standard deviations were statistically analyzed using a 1-way ANOVA test followed by the post hoc Tukey test with significance set to a 95% confidence level.
Results showed that Direct R Gold was significantly more resistant in terms of torsional resistance when compared with all the other instruments. In terms of cyclic fatigue resistance no statistically relevant differences were found amongst the three thermally treated instruments (Direct R Gold, Reciproc Blue and WaveOne Gold) which were all significantly more resistant than Reciproc. Flexibility of Direct R Gold and Reciproc was significantly lower than the other tested instruments.
Since the tip and taper dimensions are almost the same for every instrument tested, and since the Direct R gold has the same cross-sectional design as Reciproc and Reciproc Blue, the explanation of these results must be due to the proprietary thermal treatments of the instruments. Direct R-Gold heat treatment allowed a significant increase in both torsional and fatigue resistance, which is a clinically relevant advantage in a single-file technique where only one instrument is used and, as a consequence, it is subjected to all instrumentation stresses.

Introduction

The goal of any endodontic therapy is to obtain a chemo-mechanical disinfection and debridement of the root canal, by proper shaping and cleaning procedures, and to obtain a stable apical and coronal sealing, to avoid the re-infection of the root canal system (1-2). These objectives were indicated many decades ago and are still valid; on the contrary the way they are reached drastically changed with the introduction of Nickel-Titanium (NiTi) rotary instruments, which completely revolutionized the root canal treatment (RCT). NiTi rotary files increased the predictability, speediness, and effectiveness of the RCT, due to the improved properties of the alloy (3). Moreover, in the last decade new thermal treatments have been developed to improve flexibility and fatigue resistance of the instruments, resulting in a differentiation between heat-treated (HT) and non heat-treated (NHT) instruments, with the first type of instruments being pre-bendable and showing less bounce back (4). All these improvements currently allow a more efficient and safe instrumentation of curved canals. Another important improvement in the shaping procedure has been the introduction of the reciprocating motion (RM). The idea was to simplify shaping by using a single-file technique, while keeping safety, thanks to a motion which is less stressful than continuous rotation, because the instruments is not continuously engaged, but works by alternating engagement and disengagement of the blades (5).
RM has been defined as a repeated backward and forward (CW/CCW) movement; this kind of cinematic can be applied to every endodontic file. There are many kinds of RM:
- complete reciprocation (oscillation),

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- partial reciprocation (rotational effect),
- hybrid reciprocation (combined movements).

According to the review of the literature of Grande &Plotino (6-7) it can be stated the reciprocating motion enhance the metallurgical in vitro performances of the NiTi files without significantly affecting in any way the cutting efficiency of the same files.

These undoubtfully advantages has brought the manufacturer to produce new endodontic motors and a lot of different instruments thought to be used in counterclockwise reciprocating motion. Whenever a new NiTi instrument is released on the market, it is important to evaluate the file characteristics and compare to similar files already present on the market. Indeed, it is well known the influence of each characteristic on a particular performance of the NiTi rotary file (6-7). To be more precise, the cyclic fatigue is influenced by two main characteristics: the metal mass at the point of maximum stress and the percentage of martensite. Lower the mass, higher the cyclic fatigue resistance and higher the martensite percentage, higher the cyclic fatigue resistance as well. Similarly, the bending properties on the file are influenced in the same way as the cyclic fatigue resistance. The torsional resistance is instead influenced mainly by the cross-sectional design and specifically by the distribution of the mass around the rotation center of the file. The greater the mass gathered far from the rotation center, the greater is the torque to fracture. On the other hand, several studies demonstrate that the martensite percentage, does not or negatively affect the torsional resistance (8). Finally, the cutting efficiency has been demonstrated depending mainly on the cross-sectional, tip and flute design. The s shaped cross section is the most cutting efficient, as demonstrated by Plotino et al (7).

Therefore, the influence of each single characteristic of a file is well-known from the literature, despite that the performance of a file is influenced by the interaction between all these different factors and this result is still impossible to predict.

Despite it is not questionable that static tests give readers only a partial view of the performance of a new instrument (8), it is likewise not questionable that the scientific method is based on repeatable and comparable studies, and nowadays these kinds of parameters can only by obtained using the static test used. Therefore, it is possible only using the cyclic fatigue, bending and torsional resistance tests. This comparison could help the general dentist as well as the endodontists, who undoubtfully already knows the other instruments tested, to preliminary evaluate the potential performances of the newly released one.

Therefore, aim of the present study was to evaluate the stiffness, the cyclic fatigue and torsional resistance of a new (9) single-file reciprocating instrument (Direct R-Gold, Direct Endo, Paris, France) and compare them with the same features of other reciprocating instruments which have been commercialized since many years and consequently have been widely investigated : Wave One Gold Primary (Dentsply-Maillefer, Baillagues, Switzerland), Reciproc and the Reciproc Blue (VDW, Munchen, Germany).

Materials and Methods

For each of the four tested instruments (in size 25) sixty instruments were selected and randomly divided into three groups (n=20). Each group was subjected to a different in vitro mechanical test, according to the current dental literature. Prior to test, each instrument was carefully examinated under magnification. Instruments with visible defects and flute deformation were discarded.

Bending Resistance (Stiffeness) Test

Twenty instruments for each brand underwent the bending resistance test (Fig. 1a). The stiffness tests were performed using a device already validated in a previously published study (10). The device consists of a load cell, an electronic display, and a mobile holder to allow repeatable positioning of the instruments on the load cell. The stiffness tests were performed by bending each file at a 45° angle at 3 mm from its tip and recording the applied force (g). The higher the value, stiffer (less flexible) the instrument. The measurements indicated by the electronic display connected to the load cell were recorded, and then the mean values and the standard deviations of the bending force were statistically analyzed using a 1-way ANOVA test followed by the post hoc Tukey test with significance set to a 95% confidence level.

Cyclic Fatigue Test

Twenty instruments for each brand were rotated according to the manufacturers' recommendation in a stainless-steel artificial canal of 16 mm characterized by a 90° angle of curvature and a 2-mm radius of curvature using glycerin as a lubricant to avoid any friction between the files and the artificial canal (Fig. 1b). Resulting speed was always same (300 rpm). Each test was performed by the same expert operator to avoid error due to different operators' skill. Each instrument reciprocated inside the canal until a visible and/or audible sign of fracture was detected (11-12). The time to fracture (TtF) was measured using a digital chronometer with a sensitivity of 0.01 seconds. The higher the value the more resistant the instrument.

The length of the fragments (FL) was measured with a digital caliber and statistically analyzed to evaluate the correct positioning of the instruments inside the artificial canal (13) and to verify the comparability of the results of the cyclic fatigue test.

The mean values and the standard deviations of both TtF and FL were statistically analyzed using a 1-way ANOVA test followed by the post hoc Tukey test with significance set to a 95% confidence level.

Torsional Resistance Test

Twenty instruments for each brand underwent the torsional resistance test ((Fig. 1c). The torsional resistance test was performed with a custom-made torsiometer-like device previously validated in a published study at 300 rpm in counterclockwise reciprocating motion because it has been demonstrated that rotational speed does not affect the results (8,14). The device was used to avoid the bending of the coronal part of the instrument and to have a straight angle of insertion because it has been demonstrated in recently published studies that it can deeply influence the result of the torsional test. Precisely, the test was performed blocking the tip of the instrument with a vise at 3 mm from the tip and rotating it at 300

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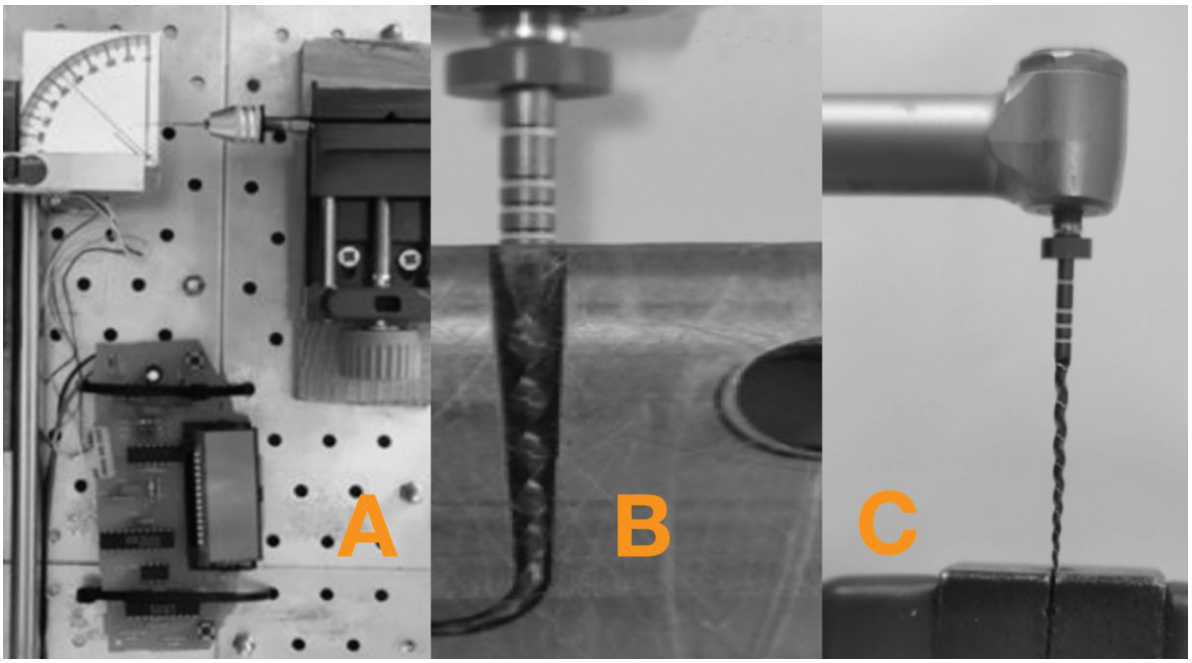

Figure 1. The three tests : A. Stiffness. B Fatigue resistance C Torsional resistance

rpm in the counterclockwise direction with a dedicated electronic motor (Kavo, Biberach, Germany) allowing a real-time (0.1 seconds) recording of the torque with a sensitivity of 0.05 Ncm. The torque at fracture results were collected on a spreadsheet. The higher the value the more resistant the instrument.
The length of the fragments (FL) was measured with a digital caliber and statistically analyzed to evaluate the correct positioning of the instruments' tip inside the torsiometer and to verify the comparability of the results of the torsional test. The mean values and the standard deviations of both FL and the torque at fracture were statistically analyzed using 1-way ANOVA followed by the post hoc Tukey test with significance set to a 95% confidence level.

Results

Results are shown in Table 1. Direct R showed the best mechanical performance in terms of torsional resistance with statistically significant difference with all the other instruments. In terms of cyclic fatigue resistance no statistically relevant differences were found amongst the three thermally treated instruments (Direct R Gold, Reciproc Blue and WaveOne Gold) which were all significantly more resistant than Reciproc. Flexibility of Direct R Gold and Reciproc was significantly lower than the other tested instruments.

Discussion

In the current study, a three methods approach was performed to compare Direct R-Gold, a new HT reciprocating NiTi file recently introduced on the market and designed to be used in a single-file technique with the most commonly used and tested single-file reciprocating instruments commercially available. The instruments tested in this study share some characteristics such as the taper and the tip dimensions, 0.25mm for all of them and the shaping technique. Indeed, each of the tested file is thought to be used in a CCW reciprocating single-file technique. Moreover, the Direct R Gold presents a s-shaped cross-sectional design, which is the same design as the Reciproc and Reciproc Blue instruments (5). According to the manufacturer (9), the Direct R Gold instruments undergo a proprietary treatment, but at the moment no published study on this kind of treatment is present in literature, while many studies are available for the other two HT instruments . It must be underlined that HT are not disclosed by manufacturers and it has been

Table 1. Mean values and SD of Stiffness, Cyclic Fatigue and Torsional Resistance tests of the four instruments tested (significant difference *)

	Direct R Gold		Reciproc		Reciproc Blue		Wave One Gold	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stiffness (g)	146.3	11.0	157.2	8.3	82.2*	3.2	88.5*	12.01
Cyclic fatigue (s)	12.8	0.5	9.27*	1.18	13.31	1.26	11.98	1.20
Torsional resistance (Ncm)	1.54*	0.12	0.66	0.08	0.52	0.07	0.46	0.09

demonstrated that they are different from each manufacturer, and consequently these differences may result in different mechanical in vitro properties and clinical performance (8).

Therefore, despite similarities in design and method of use, comparative tests are needed when new instruments with new HTs are commercialized to compare their performances with the mostly known competitor instruments (15).

Reciproc and Reciproc Blue are instruments from VDW designed for be used in CCW reciprocating single-file technique (4,5). The two instruments shares every design characteristic (tip 0.25 and taper 0.08 variable and present an S-shaped cross-sectional design) but differ from for the heat treatment of the alloy; Reciproc presents M-Wire heat treatment, containing the austenite phase with small amounts of martensite and R-phase at body temperature, and the Reciproc Blue alloy is the Blue Wire, which is characterized by lower transformation temperatures but a greater amount of stable martensite than M-Wire, leading to softer and more ductile NiTi files. As previously mentioned, the different thermal treatment of the alloys can explain the differences in the results of the mechanical tests of the two instruments. In fact, according to the results of the present study, Reciproc showed lower flexibility and cyclic fatigue resistance than Reciproc Blue, whereas the latter showed lower torsional resistance than the former. Wave One Gold is a thermally treated (single file system) CCW reciprocating instrument designed by Dentsply Maillefer. The primary file, tested in the current study, is 25.08 with a rectangular cross-sectional design and a proprietary heat treatment, the Gold Wire. The dimensions are similar to the other instruments, but design and HT are significantly different.

The results of the current study showed that the behavior of the new instrument is slightly different from the old ones. Despite being heat-treated Direct R Gold presents stiffness similar to the NHT Reciproc, while the HT Reciproc Blue and WaveOneGold showed significantly more flexibility. On the contrary results of the cyclic fatigue tests showed no difference in terms of cyclic fatigue lifespan between the Direct R Gold and the other two thermally treated reciprocating instruments (HT Reciproc Blue and WaveOneGold), while NHT Reciproc showed the smallest fatigue resistance. Moreover, the resistance to torsional stress was higher for Direct R Gold than for any other tested instruments, while NHT Reciproc was found to be significantly more resistant than HT Reciproc Blue and WaveOneGold.

Since the tip and taper dimensions are almost the same for every instrument tested, and since the Direct R gold has the same cross-sectional design as Reciproc and Reciproc Blue, the explanation of these results must be due to the proprietary thermal treatments of the instruments. Direct R-Gold heat treatment allowed a significant increase in both torsional and fatigue resistance, which is a clinically relevant advantage in a single-file technique where only one instrument is used and, as a consequence, it is subjected to all instrumentation stresses.

However, to better understand the thermal treatments, the martensitic and austenitic composition of the new instruments other studies like a Differential Scanning Calorimetry could be performed in the next future. Moreover it must be kept in mind another drawback could be the absence of dynamic investigations, such as cutting efficiency (16), shaping ability, centering ability.

Hence we may conclude that, despite the clinical relevance of in vitro studies can be doubtful, the importance of understanding the in vitro performances of new instruments introduced on the market is undoubtedly (8). The evaluation of different in vitro characteristics, such as flexibility, cyclic fatigue and torsional resistance and comparison with widespread file could give provide important preliminar data on the quality positioning of new products and possible advantages in clinical practice

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