ORIGINAL RESEARCH

Fatigue Resistance of Two Nickel–Titanium Rotary Instruments before and after *Ex Vivo* Root Canal Treatment

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Abstract

Aim: The aim of the present study is twofold: to evaluate cyclic fatigue resistance differences of two different nickel–titanium rotary instruments, brand new and after an *ex vivo* instrumentation of single root extracted teeth.

Materials and methods: Twenty new S One 20.06 were randomly divided into two groups. The first group ($n = 10$) was immediately subjected to a cyclic fatigue test (S One Group I). The second group ($n = 10$) (S one Group II) performed a cyclic fatigue test after three *ex vivo* root canal treatment with a single-file technique. The same process has been carried out for 20 M-Two 20.06 instruments.

Results: Mean time to fracture (TtF) for Group I was 51.14 ± 1.28 for S One and 32.62 ± 0.17 for M-Two 20.06 and for Group II was 46.00 ± 0.99 for S One and 27.75 ± 1.58 for M-Two 20.06. The reduction in TtF values from Group I to Group II was 11% for S One and 15% for M-Two. Statistical analysis found significant differences in all the groups examined (p value < 0.05). Mean fragment length (FL) for Group I was 3.07 ± 0.17 for S One and 3.05 ± 0.14 for M-Two 20.06 and for Group II was 3.05 ± 0.07 for S One and 3.05 ± 0.14 for M-Two 20.06. Statistical analysis was pursued, and no significant difference was found (p value > 0.05).

Conclusion: The S-One showed significantly more resistance to cyclic fatigue stress than M-Two for both new and used instruments. This validates the hypothesis that the AF H wire enables the S One files to endure more the cyclic fatigue stresses.

Clinical significance: This study demonstrates the cyclic fatigue resistance of a new endodontic instrument after repetitive usage.

Keywords: Cyclic fatigue, Endodontics, Heat treatment, NiTi rotary instrument.

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Introduction

The introduction of Nickel–Titanium (NiTi) rotary instrument in endodontics significantly reduced operative time and improved cutting efficiency.[1,2]

This improves root canal cleaning allowing deeper penetration of solutions, such as sodium hypochlorite (NaOCl) and ethylene diamine tetraacetic acid.[3]

Although the above-mentioned advantages are present, the major drawback is represented by unexpected file breakage during intracanal instrumentation.[4]

In the present literature there are several studies that evaluate the two patterns of fracture of NiTi rotary instruments, the torsional and fatigue failures.[5–7]

One of the most remarkable among those is cyclic fatigue stress. This type of stress results in the formation of micro-cracks along the surface of the instrument that eventually occur in the file separation.[8] More precisely, when an instrument rotates inside a curvature, half of the instrument that engages the outer of the curvature is in tension, while the other half of the instrument on the inner of the curvature is in compression.[9] The repetition of compression and tension, caused by continuous rotation inside the canal, generates fatigue along the instrument surface, eventually leading to separation.[10]

In the literature, many studies investigated the parameters that influence cyclic fatigue resistance, such as cross-sectional design, metal mass, heat treatments, and type of motion: continuous or reciprocating. It is clear that lower the mass, higher the flexural resistance will be.[11] Moreover, the heat treatments influence the flexural resistance by shifting the transition temperature of NiTi.

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Resistance of the instrument is influenced not only by its characteristics but mainly by the number of uses. Indeed, several manufacturers recommend "single use" of the instruments.[12] The concept of "single use" in these recommendations is still unprecise, not specifying if single canal, single tooth, or single patient. In the literature, many studies investigated this parameter, demonstrating that repetitive usage of the same instruments reduces the mechanical resistance, producing internal micro-cracks without any visible signs of external deformations.[13]

M-Two endodontic instruments (Sweden and Martina, Padova, Italy) are a type of file widely studied in the present literature. The alloy is not heat treated, and for this reason, at room temperature, the alloy is completely austenitic.[14]

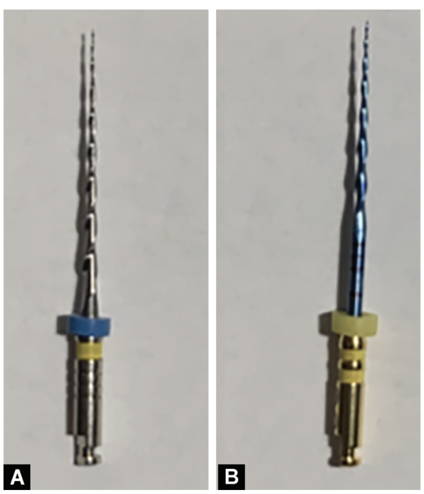
The S One (Fanta Dental Co., Ltd, Shanghai, China) is a new NiTi rotary instrument recently developed and introduced in the market. This instrument presents a new heat-treated alloy, the AF-R wire (Fanta Dental Co., Ltd, Shangai, China), which according to manufacturer studies improves the cyclic fatigue and torsional lifespan.[11]

To date, in the present literature, there are no studies that investigate cyclic fatigue resistance between M-Two and S One, evaluating the influence of repetitive usage over the mechanical file features. Moreover, no published studies evaluate the influence of single canal teeth instrumentation on cyclic fatigue resistance.

The aim of the present study is twofold: to evaluate difference in terms of cyclic fatigue resistance of two brand new different NiTi rotary instruments and to evaluate cyclic fatigue resistance of the same two instruments after *ex vivo* usage.

Materials and Methods

A total of 40 new instruments have been selected for the present study, 20 S One 20.06 and 20 M-Two 20.06 (Fig. 1). The whole study has been conducted in the Department of Oral and Maxillofacial Sciences of Sapienza, University of Rome, Italy. All the files have been previously inspected using an optical stereomicroscope at 20× magnification to detect any signs of external deformation. For each brand, two groups (Group I and II) of 10 instruments were randomly selected, with simple randomization. Group I for both brands were immediately subjected to a cyclic fatigue test. Group II for each brand was initially used to perform three root canal treatments of 30 extracted single-rooted teeth with a single-file technique. After the shaping procedure, instruments were analyzed again with optical stereomicroscope at 20× magnification to identify any sign of visible deformation or fracture. Finally, the used instruments were subjected to a cyclic fatigue test (Group II).[15]



Figs 1A and B: Instrument's design: (A) M-Two 20.06; (B) S One 20.06

Teeth were freshly extracted for orthodontic or periodontal reasons. The age of the patient was between 25 and 55 years old. The single-rooted extracted teeth used in this study were previously analyzed through the use of cone-beam computed tomography (CBCT) in axial, coronal, and sagittal sections (Fig. 2). The CBCT analysis was performed to ensure that the extracted teeth presented the same anatomy and number of canal. All the extracted teeth presented type I according Vertucci's classification. The extracted single-rooted teeth that presented calcification, root fractures, immature apex, and previous endodontic treatment at CBCT images were not included in this study. The selected teeth were cleaned to remove any organic tissue, and then they were autoclaved at 121°C for 20 minutes. To ensure a reproducible working length (WL), the teeth crowns were reduced. The amount of WL of all the single-rooted extracted teeth were 19 mm. A straight access to the coronal orifice was executed. Irrigation with 2 mL of 5% sodium hypochlorite (NaOCl) with a 30-gauge needle was performed. The apical patency was checked with a #10 K-file (Dentsply, Maillefer, Tulsa, USA). The shaping procedures were carried out using an endodontic motor (KaVo, Biberach, Germany) following the manufacturer's instruction (300 rpm and 2.5 Ncm). The shaping procedures of each instrument tested was performed by the same operator. No instruments, after the shaping procedures, showed any sign of deformation or failure.

To perform cyclic fatigue test in the present study, a device already validated in previous studies was used.[16]

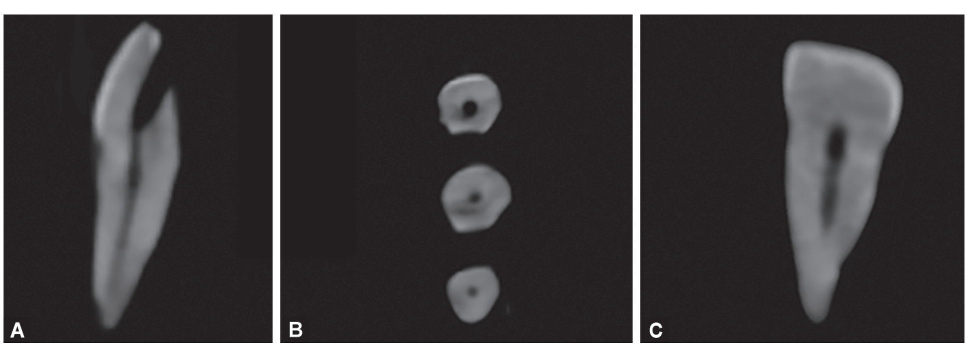
The device consists of a main platform to which is connected the electric hand piece and a stainless-steel block containing the artificial canals (Fig. 3).

To ensure a precise and reproducible placement of each instrument inside the stainless steel canals, the electric hand piece was mounted on a mobile device.

The artificial stainless-steel canal presents a 90 degree angle of curvature and 3 mm radius of curvature.

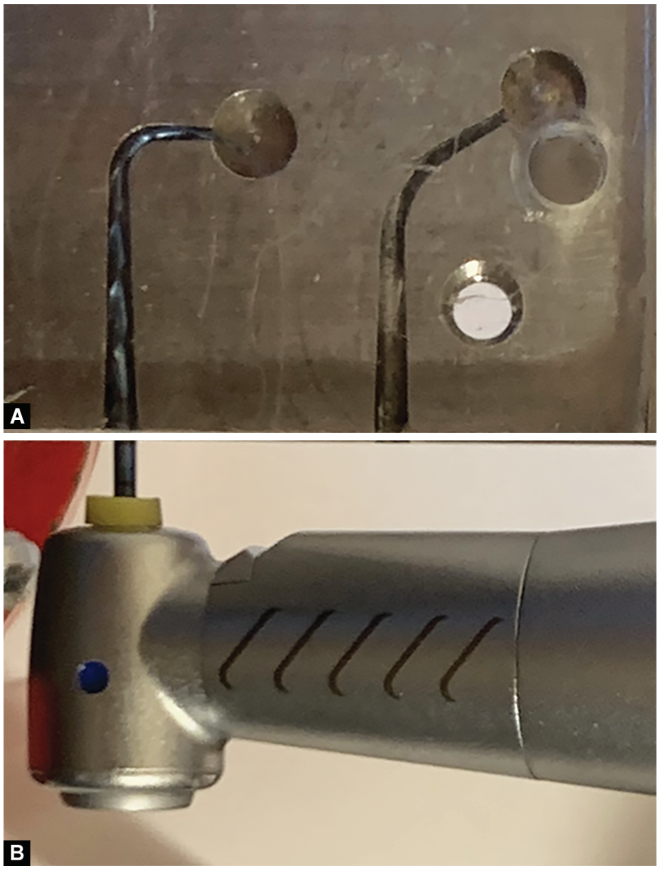
All the instruments were rotated at the same speed and torque values of 300 rpm and 2.5 N cm, respectively.

Time to fracture (TtF), in seconds, for each instrument was recorded. The time was stopped as soon as the fracture was detectable and registered with a 1/100 seconds chronometer.



Figs 2A to C: Cone-beam computed tomography evaluation of single-rooted teeth: (A) Sagittal section; (B) Axial section; (C) Coronal section

Data were statistically analyzed using the SPSS 17.0 software (SPSS Incorporated, Chicago, IL, USA). Mean and standard deviation were calculated. The *t* test for each of the tested group was performed with level of significance set at p value < 0.05.



Figs 3A and B: Testing device for cyclic fatigue test

Results

Table 1 shows mean TtF values for both Groups I and II of the S-One and the M-Two 20.06. Results from cyclic fatigue tests found that the S-One presents significant higher cyclic fatigue resistance in both Group I (51.14±1.28) and Group II (46.00± 0.99) (p value < 0.05).

Table 2 shows the TtF values for both Groups I and II regarding the same instrument. The table presents the reduction of resistance to fatigue of used instruments, expressed as a percentage. The S-One (11%) presents a lower percentage reduction compared to the M-Two (15%). Statistical analysis found significant differences (p value < 0.05).

Table 3 shows the fragment lengths (FLs) of all the tested instruments. Statistical analysis was pursued, and no significant difference in all the tested groups was found between the two instruments (p value > 0.05).

Discussion

In the literature, there are no studies that compare the fatigue lifespan of S One and M-Two.

M-Two endodontic instruments (Sweden and Martina, Padova, Italy) present an "S-shaped" cross-sectional design with two blades along the cutting surface of the instruments. The pitch length is variable and increases from the tip to the handle.[17]

The S One (Fanta Dental Co., Ltd, Shanghai, China) is a new NiTi rotary instrument with the same cross-sectional design of the M-Two. Also, for these files, the pitch length is variable and increases from the tip to the handle.

The statistical results in terms of FL (Table 3) demonstrate the reliability of the testing device, ensuring the same insertion depth for each tested instrument inside the stainless-steel canal. Therefore, we can assume that there is no difference in the portion of the instrument subjected to the flexural stresses.[18]

Several variables, such as instrument taper and tip size, cross-sectional design, and manufacturing techniques could influence resistance to cyclic fatigues lifespan.[19]

Table 1: Time to fracture (TtF) in seconds. Group I and Group II of S One and M-Two (p < 0.05)

	S One	*M-Two*		*S One*	*M-Two*
Mean	51.14	32.62	Mean	46.00	27.75
SD	1.28	0.17	SD	0.99	1.58
p value	0.02		*p* value	0.00	

Table 2: Time to fracture (TtF) in seconds and resistance reduction in percentage. (p value < 0.05)

	S One			*M-Two*	
	Group I	*Group II*		*Group I*	*Group II*
Mean	51.14	46.00	Mean	32.62	27.75
SD	1.28	0.99	SD	0.17	1.58
p value	0.04		*p* value	0.04	
%	11		%	15	

Table 3: Fragment length (FL) in millimeter. Group I and Group II of S One and M-Two (p value < 0.05)

	Group I			*Group II*	
	S One	*M-Two*		*S One*	*M-Two*
Mean	3.07	3.05	Mean	3.05	3.05
SD	0.17	0.14	SD	0.07	0.14
p value	0.83		*p* value	0.95	

To avoid the influences of the motion, each of the tested instrument was rotated in continuous motion, at the same speed 300 rpm and at the same torque value set at 2.5 N cm.[20]

As mentioned earlier, the two Ni–Ti rotary instruments have the same tip 20 and constant 0.06 taper. The same dimension parameter such as tip, taper, and cross-sectional design, in terms of metal mass, allowed the comparison of the performance of the two files.[21]

Therefore, one of the main differences between the two files is the heat treatment of the S-One. The AF H Wire (Fanta Dental Co., Ltd, Shangai, China) is a new heat treatment recently introduced by the manufacturer. According to the present literature, heat treatments could improve the lifespan of cyclic fatigue.[22] According to the manufacturer internal studies, the AF H wire presents superior properties with regard to resistance to flexural stresses. As demonstrated by the results of the present study, the S-One showed significantly more cyclic fatigue resistance than M-Two for both new and used instruments (Table 1). This validates the hypothesis that the AF H wire enables the S One files to endure more the cyclic fatigue stresses and highlights the primary role of heat treatments in fatigue lifespan of the instruments.[23]

In the literature, many studies investigated the role of repetitive instrumentation of multi-rooted teeth using same endodontic instrument.[24] Despite that, until now, no studies demonstrated the influence of single-rooted canal on endodontic performance of the NiTi rotary instruments. For this reason, in the present study, single-rooted teeth with simple anatomical features (Vertucci I Class) were used.[25]

Although the *ex vivo* instrumentation do not represent the exact clinical characteristic of root canal treatment, S-One (11%) showed significantly (p value < 0.05) less resistance reduction expressed in percentage compared to the M-Two (15%). This result could be related to lower fatigue accumulation.[26] The percentage of reduction may be related to many factors: a lower operative torque, an improved cutting efficiency, and debris removal capability, thus generating less friction.

According to Vadhana et al.,[27] the M-Two presents higher cyclic fatigue resistance compared to other NiTi rotary instruments. Since the S One performs even better in cyclic fatigue resistance test than the M-two, it can be stated that the S One can be considered a promising instrument.

Conclusion

In conclusion, within the limit of this study, the fatigue resistance of the tested instruments is consistently reduced by clinical use even after the shaping of a single-rooted canal. Indeed, Although the influence of a maxillary or mandibular molar on cyclic fatigue resistance is well known, a single canal teeth instrumentation could reduce flexural resistance significantly. For these reasons, and to increase root canal instrumentation safety, a used instrument should be discarded and therefore not used again.

Clinical Significance

This study demonstrates the cyclic fatigue resistance of a new endodontic instrument after repetitive usage. Therefore, the S One could be considered safer than a worldwide spread instrument such as M-Two, not only while a new instrument but also after repetitive usage. Despite that, the present study shows a significant reduction after use for both instruments. Therefore, these NiTi rotary files should be used in a single-use way.

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