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Cyclic fatigue resistance of M*two* NiTi rotary instruments used by experienced and novice operators – an *in vivo* and *in vitro* study

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Summary

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Background

The aim of the present study was to evaluate the cyclic fatigue resistance of M*two* NiTi rotary instruments after clinical use by 1 experienced and 1 novice operator.

Material/Methods

Cyclic fatigue testing of instruments was performed on tapered artificial canals with a 5 mm radius of curvature and 60° angle of curvature. Twenty M*two* instruments for each size were selected and divided into 2 groups: group A consisted of 10 instruments of each size used for shaping 10 root canals in molar teeth of patients by an experienced operator; group B consisted of 10 instruments of each size used for shaping 10 root canals in molar teeth of patients by a novice operator. Instruments were rotated until fracture occurred and the numbers of cycles to failure (NCF) were recorded. Data obtained were subjected to an independent sample *t*-test to determine statistical differences. The significance was determined at a 95% confidence level.

Results

No statistically significant difference ($P<0.05$) was noted between the instruments of groups A and B for all sizes. More instruments with visible signs of plastic deformation were identified for the novice operator.

Conclusions

The clinical use of M*two* NiTi rotary instruments by a novice operator did not significantly affect the cyclic fatigue resistance when compared with the control group of the same instrument sizes used by an experienced operator. It can be concluded that novice operators can use these instruments safely under the recommended technical guidelines.

Keywords: cyclic fatigue, NiTi rotary instruments, experienced operator, novice operator

Background

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Cleaning and shaping of the root canals is the most important step in root canal treatment and is considered a key to success in root canal therapy [1,2]. It includes the removal of organic substrate from the root canal system by chemo-mechanical methods and the shaping of the root canal system into a continuously tapered preparation. This should be done while maintaining the original path of the root canal. Furthermore, the shape of the prepared canals should ensure adequate filling of the canals [1]. Stainless steel instruments usually deform before they break. A suspect instrument usually exhibits severe deformation of the flutes, indicating that the elastic limit of the metal has been exceeded and the instrument should be discarded [3]. Instrument separation is still a concern with NiTi instruments, as despite their superior bending flexibility unexpected fracture has been reported [3–6]. It has been found that metal fatigue mechanisms leading to breakage occur microscopically within the elastic limit of the metal and therefore are not detectable to the eye [6]. Visible inspection is thus not a reliable method for evaluation of used NiTi instruments.

The clinical skills and experience of the operator seems to be an important clinical factor with respect to instrument fracture [7,8]. The results of several studies indicate the necessity of mastering new techniques and the importance of improving operator competence through training and experience [7–9]. In fact, these studies have reported that proper training is necessary to minimize the incidence of complications such as instrument separation [7,10]. Furthermore, a study by Mandel et al. [7] reported that the incidence of instrument failure also decreased during the instrumentation of the subsequent samples, which showed that there is a ‘learning process’ during instrumentation for each operator. Equally important is the operator experience and preclinical training. It has also been reported that when the clinicians follow the suggested technical guidelines, the reliability of the instrumentation technique was reported [11–14]. Furthermore, the operator’s experience was an important factor in terms of the duration of each canal preparation. In the group of novice operator, the time necessary for canal instrumentation decreased during preparation of the second half of the samples, thus confirming the importance of a learning curve and the importance of improving competency through learning and experience.

The aim of this study was to evaluate the cyclic fatigue resistance of M*two* NiTi rotary instruments after clinical use by 1 experienced and 1 novice operator. The null hypothesis tested was that a novice operator when using NiTi rotary instruments negatively influences the fatigue life of the instruments.

Material and Methods

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Twenty M*two* instruments of the following sizes (size 10, 0.04 taper; size 15, 0.05 taper; size 20, 0.06 taper; size 25, 0.06 taper) were selected and divided into 2 groups: group A consisting of 10 instruments of each size used for shaping 10 root canals in molar teeth of patients by an experienced operator; group B consisting of 10 instruments of each size used for shaping 10 root canals in the molar teeth of patients by a novice operator.

Canal preparation

Nonsurgical root canal treatment was performed on patients by 2 operators using a standardized clinical protocol: 1 operator was very proficient in the use of NiTi rotary files, had 8 years of experience in using the M*two* instruments, and was deemed to be an expert; the second operator had no experience in the use of NiTi rotary instruments and had only been trained for the use of M*two* instruments on resin blocks and extracted teeth.

Maxillary and mandibular human molar teeth from patients undergoing root canal treatment were included in the study. Direct and angulated preoperative radiographs of each tooth were obtained using a long-cone technique. Radiographs were evaluated in normal room lighting, using a view box and 3.5× loupes (Carl Zeiss, Jena, Germany). According to Schneider, only teeth with mature apices and possessing at least 1 root with a curvature of 10° or more were included [15]. Molars with abrupt apical curvatures (with a radius of curvature ≤2 mm in the last 3 mm) were excluded. Approximate working length was determined from the preoperative radiographs. After administration of local anesthesia, access openings were prepared and the canal orifices were located and irrigated with 5.25% NaOCl (Ogna, Muggiò – MI, Italy). The canals were initially scouted using size 08 and 10 hand K-type files. The canal working length was determined using an electronic apex locator (Root ZX, Morita, Dietzenbach, Germany) and then confirmed radiographically. The M*two* NiTi rotary instruments were used in a 16:1 handpiece (Anthogyr, Sallanches, France) in conjunction with a high torque endodontic electric motor (E-Go, Sweden & Martina, Padova, Italy) at 300 rpm. Following our previous study, NiTi M*two* instruments were used in a simultaneous technique without early coronal enlargement [16]. Each instrument was taken to working length with light apical pressure and as soon as the clinician felt a binding sensation, the instrument was withdrawn 1–2 mm so that it could be worked in a brushing action to selectively remove the interferences and to advance towards the apex. The instruments were used with lateral pressure in order to obtain a circumferential preparation and only allowed to rotate at length for a few seconds. Canals were irrigated between each instrument with 2.5 mL of 5.25% NaOCl (Ogna, Muggiò – MI, Italy) using an endodontic syringe (Navi Tip, Ultradent Products Inc, South Jordan, UT, USA) placed as far into the root canal as possible without binding. The final flush was performed with 5 mL of 17% EDTA (Ogna, Muggiò – MI, Italy), which was rinsed using 5 mL of saline solution. Prior to use, the M*two* instruments were cleaned of all visible debris using an ultrasonic cleaner and sterilized by steam autoclave (Domina Plus, DentaLX s.r.l, Vicenza, Italy) at 134°C for 10 min.

Each instrument was carefully examined under a stereomicroscope at 10× magnification (Global G6, St. Louis, MO, USA) between use in each root canal for signs of plastic deformation or separation. Instruments with any sign of deformation and/or separation were excluded from the study and replaced in order to maintain a constant number of instruments that were tested for each size in each group (n=10).

Fatigue testing

The testing device used in the present study has been validated in several other studies published in the literature [18–20,23]. Ten instruments for each instrument size of each group were tested in a tapered artificial canal with an angle of curvature of 60° and radius of curvature of 5 mm. The centre of the curvature was 6 mm from the tip of the instrument and the curved segment of the canal was approximately 6 mm in length. Each artificial canal was milled in stainless steel blocks with a tapered shape corresponding to the dimensions of the instruments tested, thus providing the instruments with a suitable trajectory. The artificial canal was mounted on a stainless steel block that was connected to a main frame to which a mobile plastic support for the hand-piece was also connected. The dental hand-piece was mounted upon a device that allowed for precise placement of each instrument inside the artificial canal, ensuring 3-dimensional alignment and positioning of the instruments to the same depth. The artificial canal was then covered with tempered glass to prevent the instruments from slipping out and to allow for observation of the instrument.

The instruments were rotated at a constant speed of 300 rpm using a 6:1 reduction hand-piece (Sirona Dental Systems GmbH, Bensheim, Germany) powered by a torque-controlled motor (Silver; VDW GmbH, Munich, Germany). To reduce the friction of the file as it contacted the artificial canal walls, special high-flow synthetic oil designed for lubrication of mechanical parts (Super Oil, Singer Co. Ltd, Elizabethport, NJ, USA) was applied. All instruments were rotated until fracture occurred. Fracture was easily detectable because the instruments were visible through the glass window. The time to fracture for each file was recorded visually with a 1/100-s chronometer and the number of rotations was calculated to the nearest full number. The time to fracture in seconds was multiplied by the number of rotations per minute (RPM)/60 (number of rotations per seconds) to obtain the number of cycles to failure (NCF) for each instrument. Mean values were then calculated. The length of the fractured tip was also recorded for each instrument, and the mean values were then calculated for each instrument type in each group.

Statistical analysis

All data were recorded and subjected to statistical evaluation by using the independent sample *t*-test. Significance was determined at the 95% confidence level.

Results

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Six instruments were discarded and replaced during clinical use. One instrument of tip size 20, 0.06 taper used by the novice operator demonstrated visible signs of plastic deformation in the apical 4 mm of the instrument. Three instruments with tip size 10, 0.04 taper, all used by a novice operator, and 2 instruments tip size 15, 0.05 taper, 1 used by the experienced and 1 by the novice operator, showed a loss of 1–1.5mm of the file tip due to fracture.

Mean values and standard deviations of the number of cycles to failure and apical fragment length obtained during cyclic fatigue testing for each instrument size in the 2 different groups are displayed in Table 1. No statistically significant difference (P<0.05) was noted between instruments of groups A and B in all sizes, showing that the use of M*two* NiTi engine-driven instruments by a novice operator did not statistically significantly reduce the resistance to subsequent cyclic fatigue testing of the instruments.

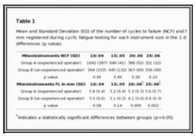

Table 1
Mean and Standard Deviation (SD) of the number of cycles to failure (NCF) and fragment length (FL) in mm registered during cyclic fatigue testing for each instrument size in the 2 different groups and statistical differences (p value).

No statistically significant difference (P>0.05) in the mean length of the fractured fragments was evident between groups for size 10, 0.04 taper and 15, 0.05 taper, while a significant difference was noted for size 20, 0.06 taper and size 25, 0.06 taper.

Discussion

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The aim of this study was to evaluate the influence of clinical experience on the fatigue life of M*two* instruments. The null-hypothesis tested in the present study can be rejected using a defined rotary instrumentation technique. Experience of the operators with the use of M*two* rotary NiTi instruments had no influence on the fatigue life of the file after their clinical use. The results of the present study indicate that all instruments had similar fatigue life when discarded after 10 times of clinical use, instrumenting 10 canals of molar teeth, whether used by an experienced or a novice operator. This demonstrates that within the limitations of the study, novice operators can use M*two* rotary instruments safely in clinical practice with up to 10 root canals with a reduced potential for breakage caused by cyclic fatigue.

Only 1 previous study investigated the influence of operator experience on metal fatigue of NiTi rotary instruments [8]. The results of that study showed no statistically significant differences in number of cycles to failure for ProTaper between instruments used by an experienced endodontist and undergraduate students. The students' only experience with the instruments was training on 2 extracted molars. This is in agreement with the results of the present study, which show that the experience of the operator did not influence the residual fatigue life of M*two* instruments.

Previous studies have analyzed the influence of operator experience on instrument failure, suggesting that the effect of operator experience as an independent variable was the most consistent and predictable parameter in instrument failure, while other parameters remained identical [7,11–13]. Results by Yared et al. [14] are indicative of the need to improve competence through learning and experience to prevent deformation and fracture of ProTaper instruments. The results of the study by Shen et al. indicated that the NiTi rotary instrument system was successfully introduced into an undergraduate endodontic program [21]. Furthermore, the same authors found that the risk of NiTi rotary instrument fracture in the canal is low when a new instrument is used by experienced endodontists [22]. In the present study, more instruments with visible signs of plastic deformations and fractures were observed for the novice operator rather than the experienced one. Five instruments used by the novice operator were discarded because they demonstrated visible signs of plastic deformation or fracture, thus confirming the importance of training to prevent failure of NiTi root canal rotary instruments [7,8,11–13].

Clinically, M*two* instruments have a defined sequence that is reproducible and easy to be utilized by novice operators. Novice operators with minimal training typically have the tendency to exert excess apical pressure and/or use rotary instruments for a long period of time in the canal. Consequently, the instrument may be subjected to higher-levels of stress. In the present study, the most discarded instruments were files of small dimensions (size 10, 0.04 taper and size 15, 0.05 taper). This was expected because small files are likely to be subjected to more stress. This result is in agreement with a previous study that showed small files are very flexible and have high resistance to cyclic fatigue [23].

The results of the present study contradict with the previous study by Inan et al. [24]. Although metal fatigue tends to be the predominant cause for fracture, M*two* instruments of smaller dimensions (size 10, 0.04 taper and size 15, 0.05 taper) showed more torsional fracture than larger instruments. From a clinical point of view, although some instruments were shorter in the working part, this was not registered during intra-canal preparation, but rather was measured after clinical use. As a consequence, root canal preparation was not adversely affected and the treatment was completed normally without the operator suspecting possible fracture of the instrument. The dimensions of the tip and the design of the blades in cross-section of these instruments make them likely to bend at the tip and for a small fragment (1–1.5 mm) to break off for reasons other than stress. Demonstration of this assumption is that during clinical use, M*two* size 10 and 15 are frequently discarded because of a fractured tip; however, these fractured tips are small and almost never remain inside the root canal [24].

The results reported in the study by Inan & Gonulol, in which the authors evaluated the deformation and separation incidence of M*two* rotary NiTi instruments discarded after normal clinical use, are in accordance with the results of the present study [24]. In fact, the authors reported that most of the size 10, 0.04 taper and size 15, 0.05 taper instruments fractured at the tip, and that the length of the fractured fragments was 1 mm or less. Many of these fragments were so small that a clinician might not be aware that a fracture occurred. The authors also concluded that these very short fragments of NiTi rotary instruments (0.5–1.5 mm) might not be noticed during preparation and obturation, and that they may unknowingly be either bypassed or forced into the isthmuses or canal fins [25]. For this reason, it may be misleading to only report the percentage of fractured files discarded after use; it would be more useful for clinicians to report how many of these instruments represented an immediate impediment to continuation of the root canal treatment. All instruments should be checked carefully before each use, between instrumentation of different canals, especially the small sizes, where it is difficult to detect minor defects and fractures. If no damage is observed, these files can be safely re-used, while paying attention not to exceed the manufacturer's recommended maximum number of uses to reduce the risk of fracture [16].

Analysis of the data regarding the length of the fractured segment revealed a statistically significant difference between the groups for the instrument sizes 20,.06 taper and size 25,.06 taper. This result is difficult to explain with respect to clinical use of the instruments; rather it is related to the cyclic fatigue test and the fact that bigger instruments may fracture in a more coronal point inside the curvature. It has been reported in previous studies that in cyclic fatigue tests a progressive increase in the mean length of the fragments occurred with an increase in instrument size [16,26].

Conclusions

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The clinical use of M*two* NiTi rotary instruments by a novice operator did not significantly reduce the cyclic fatigue resistance of M*two* NiTi rotary instruments when compared to instruments used by an experienced operator. Within the limitations of this study, it was demonstrated that a novice operator can use these instruments safely under clinical conditions. More visible signs of plastic deformations were observed for instruments used by the novice operator. A similar study with more experienced and novice operators is needed to confirm the results reported in this study.

Footnotes

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Disclosures

There are no disclosures for the present study.

Source of support: Departmental sources

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