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Research Article

Shaping ability of rotary instrumentation techniques and their limitations in simulated root canals

Abstract

The aim of this *in vitro* study was to describe the shaping ability of rotary nickel-titanium (NiTi) instruments (Mtwo, VDW, Munich, Germany) with beneficial properties in combination with two different endodontic devices (Mtwo direct and Endo IT professional) and to compare them with Mity NiTi K-Files (Loser, Leverkusen, Germany) in combination with preparation by hand in severely curved simulated root canals of acrylic blocks.

Thirty blocks simulating a severely curved root canal were divided into three groups (n=10 for each). All canals were prepared with NiTi files to an ISO size of 40 using an apical-coronal preparation technique. Mtwo NiTi files were used for the automatic systems, while Mity K-Files were used for the preparation by hand. We evaluated the frequency of instrument failure, the preparation time, loss of working length, loss of weight, elbow-zip effects, and changes in root canal anatomy. The data were analysed statistically using one-way ANOVA followed by a post hoc Bonferroni test ($p < 0.05$).

No instrument failures were observed. The preparation time was significantly longer when preparing by hand (16.64 min) than for both automatic systems, which did not differ significantly. Loss of working length could be detected for all systems (0.3–0.4mm for Mtwo instruments and 1.3mm for Mity K–Files), in which differences between the systems were not statistically, but possibly clinically, significant.

Irrespective of the torque-controlled motor, the shape of the canal anatomy was not retained with the Mtwo instruments nor with the Mity K-Files by hand preparation. The Mtwo files in combination with the automatic preparation of root canals with both systems caused an audible material loss in comparison to the Mity K-File. This was especially evident when comparing the material removal on the inner side and outside of the root canal curvature.

Within the limitations of this study, the results indicate that the torque-limited rotation handpiece Mtwo direct can be seen as an alternative to the electric low-torque control motor and is superior to hand preparation due to shorter preparation times and lower working length losses.

Introduction

Giraki et al. [1], examined the Mtwo direct cordless endodontic handpiece (Sirona Dental Systems, Bensheim, Germany) in combination with Mity Roto 360° NiTi files (Loser, Leverkusen, Germany) and compared it with the same files in combination with a conventional endo motor (Endo IT professional device, VDW, Munich, Germany), as well as with Mity K-Files (Loser, Leverkusen, Germany) used in the hand preparation technique. The Endo IT motor is a low-torque control motor with individually adjusted torque limits for each instrument [2,3]. Mtwo direct, on the other hand, is an air-driven torquelimited rotation handpiece. Its torque settings are specially adapted for Mtwo instruments (VDW) and are marked on this handpiece for every Mtwo instrument [4].

In summary, the two automatic systems did not differ significantly, but due to the long working length losses, neither the Mtwo direct handpiece nor the Endo IT professional motor could be recommended in combination with Mity Roto 360° files when an apical-coronal preparation method is used in severely curved root canals [1]. These results could be partially explained by some characteristics of the design of the Mity Roto 360° files, e.g., its rounded tip and its radial lands, which may have been disadvantageous in combination with an apical-coronal preparation technique [1] due to its low cutting efficiency [5].

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Therefore, the aim of this *in vitro* study was to describe the shaping ability of another rotary NiTi instrument (Mtwo, VDW, Munich, Germany) with beneficial properties in combination with the same endodontic devices (Mtwo direct and Endo IT professional) used in the study of Giraki et al. [1]. A further aim was to compare them again with nickel-titanium files (Mity K-Files) in combination with preparation by hand in severely curved simulated root canals.

The parameters studied were the same; that is, frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-zip effects, and changes in root canal anatomy were assessed. For reasons of standardisation and comparability with Giraki et al. [1], the preparation was performed on curved root canal equivalents in transparent plastic blocks made of acrylic (VDW, Munich, Germany).

Our first hypothesis was that there would be a difference between the two torque-controlled devices in terms of frequency of instrument failure, preparation time, loss of working length, loss of weight, elbowzip effects, and changes in root canal anatomy.

Our second hypothesis was that there would be no difference between the endodontic handpiece and the preparation by hand with K-Files in terms of frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-zip effects, and changes in root canal anatomy.

Materials and Methods

The materials and methods were similar to already published data [1] regarding sample preparation, instrument failure, preparation time, measuring the differences in working length, measuring the loss of weight, elbow-zip effects, and canal anatomy.

Due to the fact that in the current study for automatic preparation we used Mtwo NiTi instruments instead of Mity Roto 360° instruments, there were some differences concerning the root canal preparation, as described in the following section.

Root canal preparation

All canals were prepared by one person using an apical to coronal preparation technique with NiTi files to an ISO size of 40. The automatic preparation was done by two torque-controlled endodontic devices (Mtwo direct handpiece and Endo IT motor in combination with a contra-angle E-Type handpiece 4:1) with a constant rotation speed of 280 rpm and Mtwo NiTi instruments. Torque values were set manually depending on the files used, in accordance with the manufacturers' specifications. The mechanised preparation was performed in a dynamic model. Instrument sequencing was standardised for Mtwo NiTi files as follows: 10/.04, 15/05, 20/.06, 25/.06, 30/.05, 35/.04, and 40/.04. The preparation by hand was done with Mity NiTi K-Files. Instrument sequencing with Mity K-Files was 15/02, 20/02, 25/02, 30/02, 35/02, and 40/02. The working length that was achieved was verified with a Gutta-Percha of ISO size 40 (ROEKO, Langenau, Germany).

Before being used, all instruments were loaded using FileCare® EDTA (VDW, München, Germany). After each preparation step, each canal was rinsed with 2ml Aqua dest. (Phönix GmbH, Sundern, Germany). Mity files were applied a maximum of two times per canal. Room temperature was constant at 21°C.

Statistical analysis

The study variables (frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-zip effect, changes in canal anatomy) were statistically analysed using one-way analysis of variance (SPSS Statistics, Version 2.0, IBM, Ehningen, Germany).

Significant differences were determined using the post hoc Bonferroni test. Means and Standard Deviations (SD) were also evaluated.

Results

Instrument failure rate

There were no instrument failures during preparation.

Preparation time, loss of working length, loss of weight, and elbow-zip effect

Table 1 shows the results for the parameters of preparation time, loss of working length, loss of weight, and elbow-zip effect. Significant differences among the three groups exist only for the parameter preparation time, which was significantly longer for the preparation by hand [Control Group 2 (CG2)] than for the automatic preparation [Study Group (SG) and Control Group 1 (CG1)]. Although the loss of working length for the Mity K-Files (CG2) on average seemed to be higher (1.3mm) than for the Mtwo NiTi instruments (0.3–0.4mm, SG and CG1), the differences between the three groups are not statistically significant.

Canal anatomy

Table 2 and Figures 1-4 show the results of the comparison of material removed from the inside and the outside of the root canal curvature. The most important results are described as follows.

Overall, both automatic systems showed a similar inhomogeneous preparation pattern that differed from the

Table 1: Comparison of analyses results (mean values and standard deviations) acquired in the study. The values with the same letters are statistically significant.

Criterion	Study group (MTwo NiTi/ MTwo direct)	Control group 1 (MTwo NiTi/ Endo IT)	Control group 2 (Mity K-file/ hand-preparation)
Loss of working length (mm)	0.30±0.25	0.40±0.21	1.30±0.85
Preparation time (min)	8.15±0.78[a]	7.57±2.32[b]	16.46±2.74[a, b]
Loss of weight (mg)	5.83±0.71	6.34±0.69	5.59±1.27
Elbow-zip effect (EZE) 0 = no EZE 1 = weak EZE 2 = strong EZE	0.0±0.0	0.0±0.0	0.10±0.32

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Table 2: Comparison of material removal from the inner side (in) and outside (out) of the root canal curvature (mean values and standard deviations). The values with the same letters are statistically significant.

Region	Reading point	Study group (MTwo NiTi/ MTwo direct)	Control group 1 (MTwo NiTi/ Endo IT)	Control group 2 (Mity K-file/ hand-preparation)
apical	1 in	0.65±0.26	0.92±0.33^{a}	0.45±0.28^{a}
	1 out	4.02±0.86	4.40±1.33	3.42±1.13
	2 in	1.20±0.62^{a}	1.60±0.60^{b}	0.45±0.36^{a,b}
	2 out	3.80±0.80	4.15±0.85	5.27±1.05
middle	3 in	4.2±0.98	5.17±1.13^{a}	2.85±0.68^{a}
	3 out	2.05±0.66	1.97±0.61	2.70±0.88
	4 in	5.62±0.81^{a}	6.70±1.07^{b}	3.75±1.15^{a,b}
	4 out	0.95±0.48	1.32±0.50	1.20±1.22
	5 in	6.00±0.51^{a}	7.00±0.90^{b}	4.37±0.94^{a,b}
	5 out	0.72±0.21	1.17±0.58^{a}	0.25±0.26^{a}
coronal	6 in	3.20±0.68^{a}	3.62±0.69^{b}	2.00±0.84^{a,b}
	6 out	2.27±0.76	2.55±0.62^{a}	1.30±0.32^{a}
	7 in	2.87±0.61	3.47±0.49	2.92±0.79
	7 out	4.15±0.66	4.07±0.81	3.70±0.94

preparation pattern of the Mity K-File in that a significantly higher material removal was predominantly recorded in the automatic systems compared to the manual system.

Outside curvature

Overall, for all systems, a larger change in canal anatomy was observed in the apical region of the root canal than in the middle area (Figures 2–4). The amount of material removal in the apical part of the external curve did not differ significantly within the systems (Table 2).

The lowest amount of material removal within all systems was in the middle area of the outer curvature (Figures 2-4). Significantly higher material removal is shown only for the measuring point 5 of the Mtwo group with the Endo IT motor (CG1: 1.17mm) compared to the Mity-K group (CG2: 0.25mm).

The coronal part of the external curve also showed higher material removal for all groups compared to the mean part. The material removal by CG1 (2.55mm) was significantly higher at measuring point 6 compared to the CG2 (1.30mm).

Inside curvature

For the apical and middle channel section, it behaved almost opposite on the inner curve to the outer curve: For all groups, less material was removed from the apical region (SG: 0.65–1.2mm; CG1: 0.92– 1.6mm; CG2: 0.45mm) than the middle (SG: 4.2–6mm; CG1: 5.17–7mm; CG2: 2.85–4.37mm) and coronal areas (SG: 2.87–3.2mm; CG1: 3.47–3.62mm; CG2: 2–2.98mm) of the root canals (Figures 2–4). However, this was equally larger for both automatic systems (SG and CG1) than for the manual system (CG2), especially at measuring point 2.

In contrast to the outer curve, the inner curve for all groups (SG: 4.2–6mm; CG1: 5.17–7mm; CG2: 2.85–4.37mm) also showed the strongest material removal in the middle section of the canal with the strongest curvature (Figures 2–4). The root canal preparation was significantly stronger for both automatic systems in combination with the Mtwo instruments (SG and CG1) than for the manual system (CG2) (Table 2). In the coronal canal part, the changes in canal anatomy at the inner curvature were comparable to those at the outer curvature. Once again, both automatic systems removed significantly more material at measuring point 6 than the Mity K-File in combination with manual preparation (CG2).

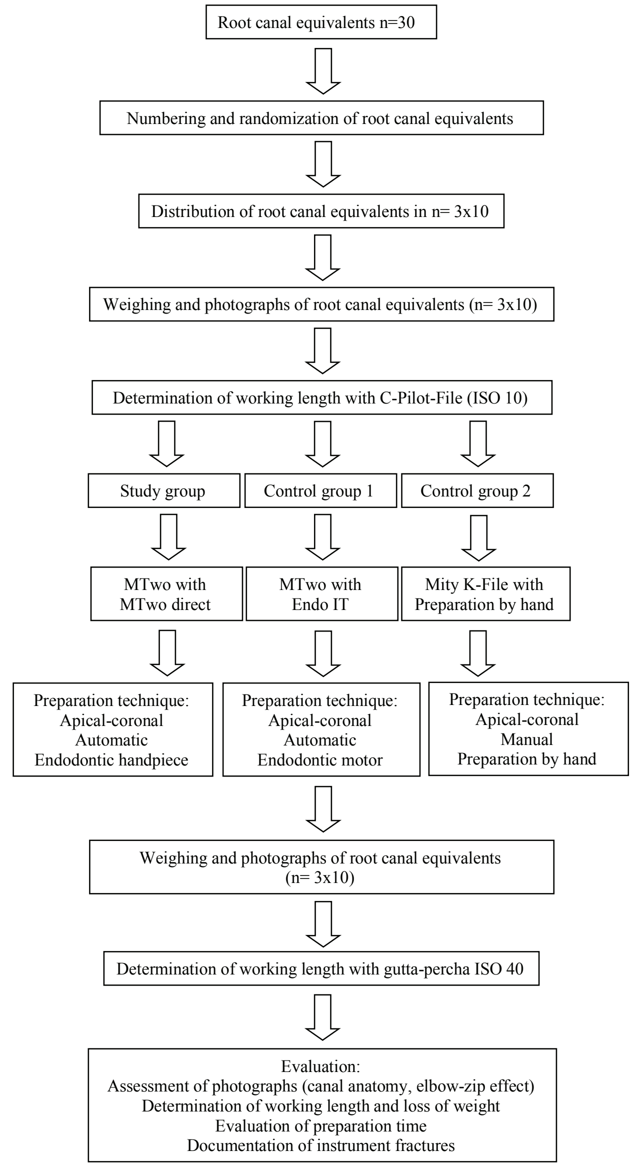

Figure 1: Flow chart of the study.

Discussion

Instrument failure rate

As described in a previous study [1], complex reasons based on a variety of factors such as the material [6] and design [7] of the files used, the application or drive technology [2,8], the dynamic or static testing conditions during preparation [9], the environmental temperature [9] and user experience [2] are associated with breakage of the NiTi instruments.

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Mtwo instruments are characterised by an S-shaped cross-sectional design and have two deeply pronounced, sharp cutting edges that run almost vertically in long spirals. Thus, these instruments are claimed to cut dentine effectively and offer a large chip space for dentin transportation. In addition, the cutting distance increases progressively from the noncutting file tip to the shaft. This design is claimed to have two functions: first, to eliminate threading and binding in continuous rotation, and second, to reduce the transportation of debris towards the apex [10,11]. The fact that none of the Mtwo files fractured may be due to the increasing pitch length from the tip to the shaft of these instruments [10]. As already reported, a varying pitch length along the working part of the instrument reduces the tendency of the file to screw-in [12] minimising the risk of instrument fracture. Also, Bürklein's

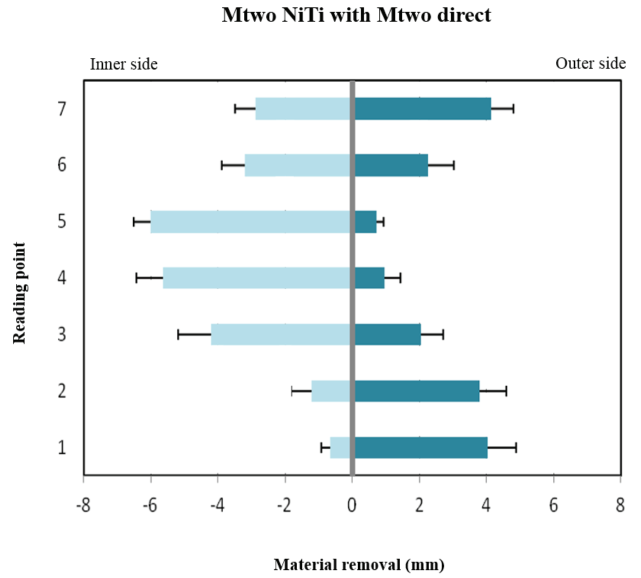

Figure 2: Graphic representation of material removal on the inner and outer root canal curvature (in mm) for the MTwo NiTi with Mtwo direct.

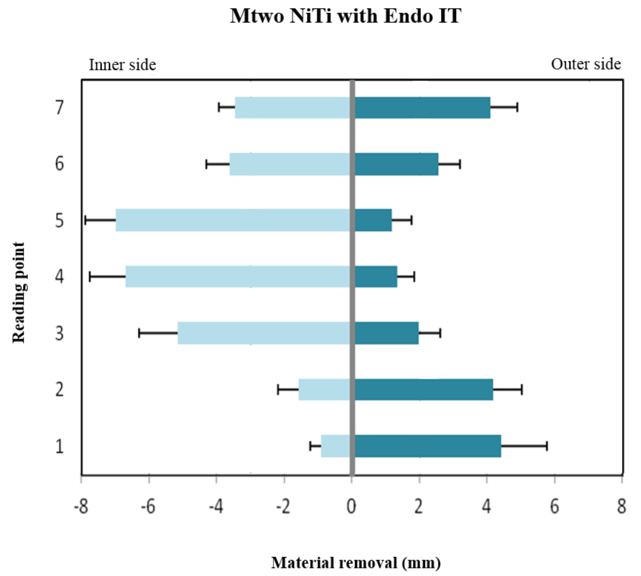

Figure 3: Graphic representation of the material removal on the inner and outer root canal curvature (in mm) for MTwo NiTi with Endo IT.

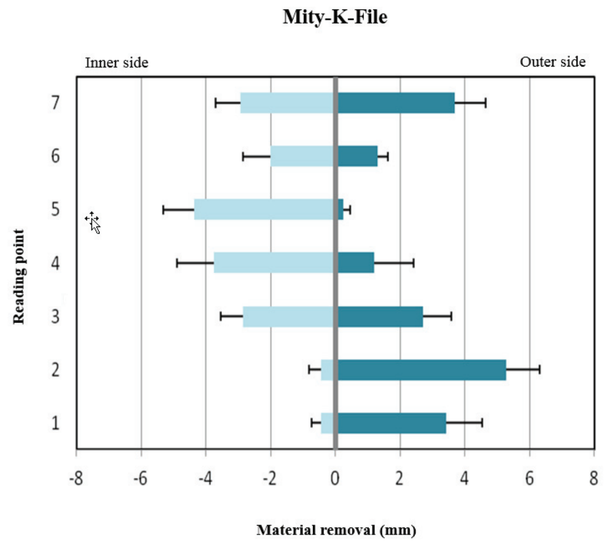

Figure 4: Graphic representation of the material removal on the inner and outer root canal curvature (in mm) for the Mity-K-File with preparation by hand.

study [4] suggested that Mtwo instruments reduce fractures by having a higher proportion of the cutting edges of the instrument in contact with the canal wall at the same time as other instruments. Moreover, Inan et al. [13] pointed out that Mtwo rotary NiTi instruments have core width designed for maximum flexibility and have minimal radial contact with a non-cutting tip [13] which may lead to a reduced risk of fracture. In summary, the fracture-resistance of the Mtwo files could be confirmed by other authors in accordance with the present study [14,15].

In contrast to the present study, in which the type of electronic device for the Mtwo instruments had no effect on the fracture behaviour, Bürklein's investigation revealed a fracture of a Mtwo file with the torque-controlled contra-angle handpiece Mtwo direct [4]. The fracture occurred with the fourth use of a Mtwo file in size 10/.04. In the present study, in contrast to Bürklein et al. [4], all files were used for a maximum of two times, which probably minimised the risk of fracture. The recommendation to carefully examine replace used files regularly in order to keep the risk of fracture as low as possible [10,11].

Preparation time

Engine-based root canal treatment is a valuable time relief for patients and practitioners [16]. The mean time for canal preparation was, therefore, recorded in this study and it included instrument changes within the sequences, as in the other studies described [1, 4].

Despite the increased number of instruments (seven instruments) for both mechanical systems compared to preparation by hand (six instruments), it was shown that mechanical preparation, independent of the system, could be completed significantly faster than preparation by hand. The superiority of mechanical processing systems over preparation by hand with respect to the factor time coincides with our previous study [1] and also other studies [1,17,18].

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Bürklein [4] was able to demonstrate that preparing simulated root canals with an Endo IT motor was significantly faster than with a Mtwo direct contra-angle handpiece, but used Mtwo files in the crowndown technique. It is possible that an apical to coronal preparation technique, as used in the present study, allows an additional time gain compared to the crown-down technique, especially for use with the Mtwo handpiece.

Loss of working length

The preparation of the complete working length is a key prerequisite for the success of root canal treatments [19]. In the present study, working length losses were between 0.3 and 0.4 mm on average for the automatic systems and 1.3 mm for the preparation by hand. The differences between the three systems were not significant. This is opposite to our previous study where the Mity Roto 360° files in combination with the same automatic devices and the same preparation technique as used in the present study showed significantly higher working length losses (2.44 mm and 2.81 mm on average) [1]. Therefore, better results for Mtwo instruments may be explained by characteristics of the MTwo files (see section “instrument failure”). It can be concluded that using Mtwo NiTi files with both automatic systems it was possible to control the working distance well. The finding of small mean changes in working distance agrees with other studies using rotary NiTi instruments [20-22]. Clinical significance of small changes of working length seems to be negligible, as already described by Schäfer et al. [10].

Loss of weight

The observed weight loss after preparation is a model for examining the cutting performance and the removal of debris from the file systems [23]. The cutting performance of the file is good when the weight loss is high, and the working length loss is simultaneously low [23]. In the present study, both factors are applicable for Mtwo files, as well as for the Mity K-File, which confirms the good cutting performance of all systems used. The Mtwo files had numerically slightly higher weight losses (5.83–6.34mg) with lower working length losses (0.3–0.4mm); the Mity K-files had higher working length losses (1.3mm) with lower weight losses (5.59mg). However, the differences were not statistically significant, which initially suggests a comparable cutting efficiency of the two instruments. However, in the present study it was shown that when using NiTi hand instruments (CG2) for the same result compared to the rotating NiTi systems (SG and CG1), more than twice the time was required (Table 1), which represents a relevant disadvantage for their clinical use (see "preparation time").

Elbow-zip effect

In this study, no elbow-zip effects occurred with the Mtwo NiTi files in combination with the automatic preparation, independent of the device used. A weak elbow-zip effect with the Mity K-Files in combination with the preparation by hand could be registered, but this difference was not statistically significant within the three groups.

On the one hand, this could be due to the single length preparation method recommended by the manufacturer for Mtwo instruments, in which a canal is already instrumented with the first instrument in its entire length and then always prepared to working lengths with instruments of ascending ISO sizes [10]. Another reason for the minimisation of elbow-zip effects in simulation blocks for a root canal equivalent could also be the S-shaped cross-section design of the Mtwo files, which allows high flexibility and effective debris removal with good canal centring by a non-cutting tip [10]. The cutting tip of the Mity K-Files, however, may contribute to a stronger "screw-in" effect in the outer canal wall [1], which may lead to elbow-zip effects by a lower apical centration and a stronger straightening of curved root canals.

Canal anatomy

Preserving the original root canal shape is one of the main goals of root canal preparation. Considering the canal anatomy factor, independent of preparation mode, material loss in the present study was rather uneven over the entire canal length with the Mtwo instruments, independent of the electronic device used, as well as with the Mity K-Files. This uneven preparation pattern partly leads to a displacement of the canal axis (transportation). Possible causes for the extent of root canal straightening are varying consistencies in combination with different cutting efficiencies and specific instrument cross-sections, as well as the different flexibilities of the preparation instruments [14,23-27].

In the present study, for all three groups, significantly higher material removal on the outside than the inner curvature was evident in the apical area. This preparation pattern was confirmed by other investigations using NiTi instruments, especially Mtwo files, in which increased removal at the outer curvature of the apical third was accompanied by little or no removal at the inner curvature [27-29].

In the middle canal area with the strongest curvature, the highest material removal was found against the inner curvature; the Mtwo instruments showed significantly higher values for material removal than the Mity K-Files. This observation is consistent with other studies [14,23] and can be partially explained by the high cutting efficiency of the Mtwo instruments: Peters et al. [30], demonstrated that active cutting systems resulted in slightly greater canal transportation than file systems with a passive cutting process [30]. In addition, there is the increasing conicity of the Mtwo instruments, which probably led to higher material removal in the middle and coronal part of the canal than was the case with the Mity K-Files with a constant conicity of two percent.

Moreover, in the coronal area, changes in the canal anatomy after preparation with the Mtwo files compared to the Mity K-File were greatest in the area of the inner curve at measuring point 6, independent of the electronic device. In accordance with the present work, numerous studies have shown that Mtwo instruments offer the greatest cutting efficiency within different machine systems [14].

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Within the limitations of this study, the results indicate that the torque-limited rotation handpiece Mtwo direct is safe and suitable for preparing curved root canals with the Mtwo instruments used in the singlelength technique. Thus, this device can be seen as an alternative to an electric low-torque control motor and superior to hand preparation due to shorter preparation times and lower working length losses.

Review of the research hypotheses

The pre-formulated first research hypothesis was adopted and the alternative hypothesis was rejected. These relate to similar results concerning all parameters examined in the present study for both electronic devices used. The second research hypothesis was rejected and the alternative hypothesis was adopted.

These relate primarily to the extended preparation time in manual processing.

References

1. Giraki M, Harapetian E, Rüttermann S, Gerhardt-Szep S (2019) Hand-operated and rotary mity instruments in combination with an endodontic handpiece and endodontic motor preparation: A comparison of shaping ability in simulated curved root canals. J Dent Probl Solut 6: 013-020. Link: https://tinyurl.com/y5zkg8cm

2. Yared G, Bou Dagher F, Kulkarni K (2003) Influence of torque control motors and the operator's proficiency on ProTaper failures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 96: 229-233. Link: https://tinyurl.com/y2fxys3k

3. Hülsmann M, Peters O, Dummer P (2005) Mechanical preparation of root canals: shaping goals, techniques and means. Endodontic Topics 10: 30-76. Link: https://tinyurl.com/y52v4cd2

4. Bürklein S, Schäfer E (2006) The influence of various automated devices on the shaping ability of Mtwo rotary nickel-titanium instruments. Int Endod J. 39: 945-951. Link: https://tinyurl.com/yxudjqsh

5. Thompson SA, Dummer PM (1998a) Shaping ability of Mity Roto 360 degrees and Naviflex rotary nickel-titanium instruments in simulated root canals. Part 1. J Endod 24: 128-134. Link: https://tinyurl.com/y2mx59q5

6. Shen Y, Coil JM, Zhou H, Zheng Y, Haapasalo M (2013) HyFlex nickel-titanium rotary instruments after clinical use: metallurgical properties. Int Endod J 46: 720-729. Link: https://tinyurl.com/y5pv6rkj

7. Parashos P, Gordon I, Messer HH (2004) Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. J Endod 30: 722-725. Link: https://tinyurl.com/y6y9687x

8. Giraki M, Bauer A, Barthel C, Rüttermann S, Gerhardt-Szep S (2016) Problems with a Cordless Endodontic Hand Piece when Preparing Severely Curved Root Canals. J Dent Probl Solut 3: 040-044. Link: https://tinyurl.com/y34zsqtp

9. Palma PJ, Messias A, Cerqueira AR (2018) Cyclic fatigue resistance of three rotary file systems in a dynamic model after immersion in sodium hypochlorite. Odontology 107: 324-332. Link: https://tinyurl.com/yyr3nrxk

10. Schäfer E, Erler M, Dammaschke T (2006) Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 1. Shaping ability in simulated curved canals. Int Endod J 39: 196-202. Link: https://tinyurl.com/y66crwhy

11. Bürklein S, Hiller C, Huda M, Schäfer E (2011) Shaping ability and cleaning effectiveness of Mtwo versus coated and uncoated EasyShape instruments in severely curved root canals of extracted teeth. Int Endod J 44: 447-457. Link: https://tinyurl.com/y5l94hrz

12. Diemer F, Calas P (2004) Effect of pitch length on the behavior of rotary triple helix root canal instruments. J Endod 30: 716-718. Link: https://tinyurl.com/y62yk4x4

13. Inan U, Aydin C, Demirkaya K (2011). Cyclic fatigue resistance of new and used Mtwo rotary nickeltitanium instruments in two different radii of curvature. Aust Endod J 37: 105-108. Link: https://tinyurl.com/y3b6unbh

14. Schäfer E, Oitzinger M (2008) Cutting efficiency of five different types of rotary nickel-titanium instruments. J Endod 34: 198-200. Link: https://tinyurl.com/y32c4uyh

15. Grande NM, Plotino G, Pecci R, Bedini R, Malagnino VA, et al. (2006) Cyclic fatigue resistance and three-dimensional analysis of instruments from two nickel–titanium rotary systems. Int Endod J 39: 755-763. Link: https://tinyurl.com/y3c3wp8z

16. Schäfer E, Lohmann D (2002) Efficiency of rotary nickel-titanium FlexMaster instruments compared with stainless steel hand K-Flexofile--Part 1. Shaping ability in simulated curved canals. Int Endod J 35: 505-513. Link: https://tinyurl.com/y5ogmgrn

17. Glossen CR, Haller RH, Dove SB, del Rio CE (1995) A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. J Endod 21: 146-151. Link: https://tinyurl.com/yydmvsx6

18. Sonntag D, Delschen S, Stachniss V (2003) Root-canal shaping with manual and rotary Ni-Ti files performed by students. Int Endod J 36: 715-723. Link: https://tinyurl.com/yy3qn3dx

19. Cohen S, Burns R. Pathways of the pulp: Mosby Inc; 1998.

20. Kum KY, Spangberg L, Cha BY, Il-Young J, Msd Seung-Jong L, et al. (2000) Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. J Endod 26: 719-723. Link: https://tinyurl.com/y59hdu2p

21. Thompson SA, Dummer PM (2000) Shaping ability of Hero 642 rotary nickel-titanium instruments in simulated root canals: Part 2. Int Endod J 33: 255-261. Link: https://tinyurl.com/y4kr7jh7

22. Schäfer E, Vlassis M (2004) Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 37: 239-248. Link: https://tinyurl.com/y5rc9zvv

23. 23. Szep S, Gerhardt T, Leitzbach C, Luder W, Heidemann D (2001) Preparation of severely curved simulated root canals using engine-driven rotary and conventional hand instruments. Clin Oral Investig 5: 17-25. Link: https://tinyurl.com/yxj2hkzp

24. Thompson SA, Dummer PM (1998b) Shaping ability of Mity Roto 360 degrees and Naviflex rotary nickel-titanium instruments in simulated root canals. Part 2. J Endod 24: 135-142. Link: https://tinyurl.com/y6tyjjrw

25. Alam MS, Bashar AK, Begumr JA, Kinoshita JI (2006) A study on FlexMaster: a Ni-Ti rotary engine driven system for root canal preparation. Mymensingh Med J Jul 15: 135-141. Link: https://tinyurl.com/y5ehun48

26. Al-Omari MA, Dummer PM, Newcombe RG, Doller R (1992) Comparison of six files to prepare simulated root canals: Part 2. Int Endod J 25: 67-81. Link: https://tinyurl.com/y2sb73lt

27. 27. Sadeghi S (2011) Shaping ability of NiTi rotary versus stainless steel hand instru¬ments in simulated curved canals. Med Oral Pathol Oral Cir Bucal 16: 454-458. Link: https://tinyurl.com/y4c9b7ec

28. Ayar LR, Love RM (2004) Shaping ability of ProFile and K3 rotary Ni-Ti instruments when used in a variable tip sequence in simulated curved root canals. Int Endod J 37: 593-601. Link: https://tinyurl.com/y33scpdh

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29. Hubscher W, Barbakow F, Peters OA (2003) Root-canal preparation with FlexMaster: canal shapes analysed by micro-computed tomography. Int Endod J 36: 740-747. Link: https://tinyurl.com/y4s3xbf8

30. Peters OA, Peters CI, Schonenberger K, Barbakow F (2003) ProTaper rotary root canal preparation: effects of canal anatomy on final shape analysed by micro CT. Int Endod J 36: 86-s92. Link: https://tinyurl.com/y2lvpn9m

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