Original Article

Ex Vivo Comparison of Mtwo and RaCe Rotary File Systems in Root Canal Deviation: One File Only versus the Conventional Method

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Abstract

Objectives: Cleaning and shaping of the root canal system is an important step in endodontic therapy. New instruments incorporate new preparation techniques that can improve the efficacy of cleaning and shaping. The aim of this study was to compare the efficacy of Mtwo and RaCe rotary file systems in straightening the canal curvature using only one file or the conventional method.

Materials and Methods: Sixty mesial roots of extracted human mandibular molars were prepared by RaCe and Mtwo nickel-titanium (NiTi) rotary files using the conventional and only one rotary file methods. The working length was 18 mm and the curvatures of the root canals were between 15-45°. By superimposing x-ray images before and after the instrumentation, deviation of the canals was assessed using Adobe Photoshop CS3 software. Preparation time was recorded. Data were analyzed using three-way ANOVA and Tukey's post hoc test.

Results: There were no significant differences between RaCe and Mtwo or between the two root canal preparation methods in root canal deviation in buccolingual and mesiodistal radiographs (P>0.05). Changes of root canal curvature in >35° subgroups were significantly more than in other subgroups with smaller canal curvatures. Preparation time was shorter in one file only technique.

Conclusion: According to the results, the two rotary systems and the two root canal preparation methods had equal efficacy in straightening the canals; but the preparation time was shorter in one file only group.

Keywords: Instrumentation; Root Canal Preparation; Transportation

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INTRODUCTION

One of the main objectives of root canal preparation is cleaning and shaping of the root canal system, while retaining the original shape of the canal without creating iatrogenic events, such as instrument fracture, apical transportation, ledge or perforation [1].

Deviation from the original canal path and occurrence of apical transportation are some of the procedural errors during root canal preparation. Stainless steel hand instruments are especially more prone to produce these mishaps, due to the stiffness of the file and intense lateral pressure on the walls of the

canals [2]. In the recent decades, many new systems and techniques have been introduced for the preparation of root canals with Ni -Ti rotary instruments. Also, a number of rotary Ni-Ti instruments with different designs and shapes have been developed for easier root canal preparation and reducing the operating time. Many of these systems have been investigated with regard to their efficacy in cleaning and shaping of root canals, safety and function [3,4]. These systems reportedly maintain the main canal form with the least canal transportation [5]. Yared used F2 ProTaper for single file canal preparation in reciprocating motion, despite the fact that this system has not been designed for this motion [6].

In 2008, both WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc (VDW, Munich, Germany) were internationally launched as single-file shaping techniques. These files need specifically engineered and programmed motors to drive in reciprocating motion [7].

This study introduces a method of canal preparation with only one rotary file discarded after a single use. This method needs only one file, reduces the cost and time of canal preparation, increases the accuracy of work and does not need a special expensive engine motor in contrary to the WaveOne and Reciproc systems.

RaCe (reamer with alternating cutting edges) rotary files have a noncutting tip and a triangular cross-section. Alternating cutting edges avoid the screwing effect and have the advantage of operating with extremely low torque. This instrument can produce centered canal shapes and adequately clean and shaped canals [8].

Mtwo instruments have a S-shaped cross-sectional design, a noncutting safety tip, positive rake angle with two cutting edges and increasing pitch length from the tip to the shaft. This design prevents the screwing effect in continuous rotation and reduces the extrusion of debris beyond the apex [5]. Some previous studies reported that Mtwo (VDW, Munich, Germany) and RaCe (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) rotary file systems maintained the root canal curvature, were associated with few instrument fractures, were more rapid than the manual techniques and were easy to use [3-5].

The aim of this study was to compare the efficacy of Mtwo and RaCe rotary file systems in straightening the canal curvature using only one file or the conventional method.

MATERIALS AND METHODS

In this experimental study, 60 recently extracted human mandibular first and second molars were collected and kept in normal saline. Mature teeth without visible apical resorption or cracks and with separate mesial and distal roots were selected.

The roots with multiple or abrupt apical curvatures with less than 3 mm radius were excluded. The teeth were immersed in 5.25% sodium hypochlorite solution for 30 minutes and then stored in 1% chloramine T solution for one week. The teeth were kept in saline during the course of study. After access cavity preparation, apical patency of both mesiobuccal and mesiolingual root canals was examined using a #10 K-file.

All teeth with mesial roots with mesiodistal curvature over 15° were included. Then, based on the degree of mesiodistal canal curvature (<25°, >25° and <35°, and >35°) three groups (n=20) were created. Finally, each group was divided into four subgroups (n=10 mesial canals each).

The access cavity was sealed with Cavit (DeTrey/ Dentsply, Konstanz, Germany) after placing a cotton pellet in it and then the root apex was covered with a small piece of wax. Then, the roots were embedded in molds filled with self-polymerizing acrylic resin. To determine the working length, a #15 K-file was inserted into the canal 1 mm short of the radiographic apex.

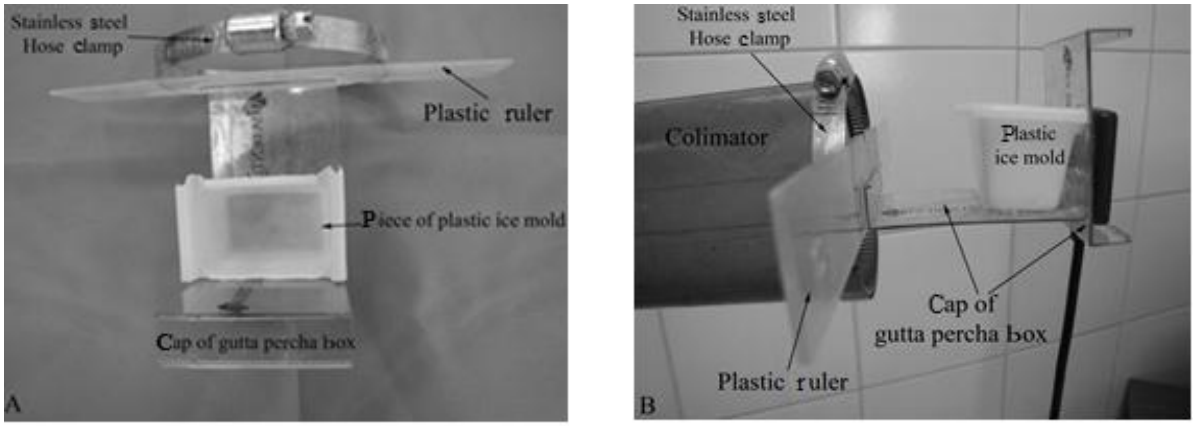

Fig. 1. The platform: (A) Superior view (B) Lateral view

Occlusal surfaces of the teeth were flattened using a 0.5 mm-thick diamond disk (D & Z, Berlin, Germany) to achieve a working length of about 18 mm and a reliable reference point during canal preparation. The radiographs were taken using a digital radiography sensor (Kodak RVG 5100 Digital Radiography System, Eastman Kodak Co., Trophy Radiology, Marne-la-Vallée, France) and a platform (Fig. 1), which stabilized the mounted teeth and enabled the superimposition of pre- and post-instrumentation radiographs [9]. Next, #15 K-file was inserted into the canal and the initial radiograph was taken using a digital radiography sensor and a radiographic device (X-genius, de Gotzen, Roma, Italy) with 70 kVp, 8 mA and 0.3 seconds exposure settings and a cylindrical 12-inch tube. The initial radiographs were obtained in both buccolingual and mesiodistal directions.

Root curvatures were determined using Schneider's method [10] and Adobe Photoshop CS3 Extended (Middle East version 10.0) software program. Root Canal preparation was done using RaCe (FKG, Lachaux-de-Fonds, Switzerland) and Mtwo (VDW, Munich, Germany) systems in the conventional method or with the use of only one file. Initially, all the mesial canals were prepared with #10 and #15 K-files and Well-Prep (Vericom Co., Anyang, Korea) was used as a lubricant.

In the subgroup 1, the mesial canals were prepared using Mtwo files and the conventional method. Mtwo files including 10/0.04, 15/0.05, 20/0.06 and 25/0.06 were used, respectively in single-length technique according to the manufacturer's instructions. In the subgroup 2, mesial canals were prepared with only one rotary Mtwo File 25/0.06. In this technique, after the initial preparation with #10 and #15 K files, Mtwo File 25/0.06 was introduced into the canal. The coronal two-thirds of the canal was prepared with active working on the walls without excessive pressure on the tip of the file. After this pre-flaring and determination of the new working length, the file was used for preparation of the entire length of the canal. If the rotary file did not reach the working length, #20 K-file was used with watch-winding and pulling motion until it reached the working length. Then, the preparation was continued with Mtwo File 25/0.06 until reaching the apex. Canal irrigation was done with %5.25 sodium hypochlorite using Max-i-Probe 30-gauge needle (Dentsply, Elgin, Illinois, USA). Finally, the canals were irrigated with %17 EDTA (Ariadent, Asia Chemi Teb Co., Tehran, Iran) followed by %5.25 sodium hypochlorite to remove the smear layer. In the subgroup 3, the canals were prepared using RaCe rotary files numbers 40/0.10, 35/0.08, 25/0.06, 25/0.04 and 25/0.02, respectively.

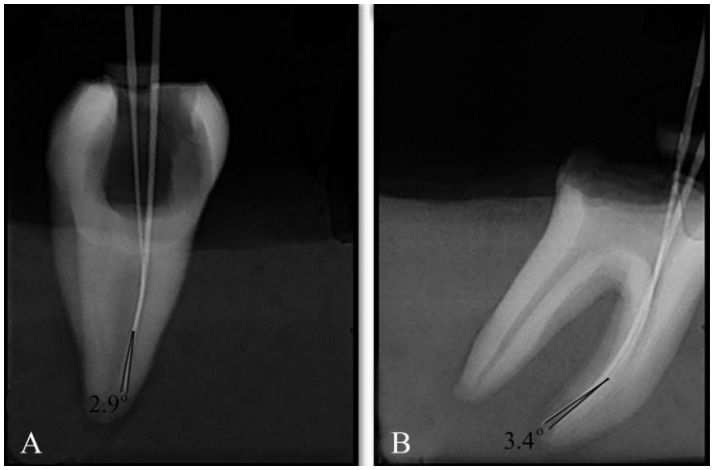

Fig. 2. Superimposition of pre- and post-preparation images in (A) buccolingual direction and (B) mesiodistal direction.

When the file #25/0.06 reached to the working length, the canal preparation was considered complete. In the subgroup 4, the canals were prepared with only one rotary RaCe file # 25/0.06 using the new method described for the subgroup 2. A postgraduate student prepared all canals. In all groups, each file was used for preparing two roots or four root canals and in case of any change in the appearance of the file it was discarded. To compare the changes in canal curvatures, a #25 K-file was introduced into each canal and the radiographs were obtained in buccolingual and mesiodistal directions. Digital radiographs were saved in JPEG format. Pre- and post-preparation images were superimposed using Adobe Photoshop CS3 Extended (Middle East version 10.0) software. Changes in canal curvatures were recorded as deviation from the original canal curvature. If the two files were seen separately at the apical third on the superimposed radiograph, it was considered as a deviation from the original path that is apical transportation [11] (Fig. 2A and 2B).

Preparation time for each canal including instrumentation, irrigation and changing the instruments was recorded using a digital chronometer. The number of fractured instruments was recorded for all the systems and techniques.

The measurements were made blindly and the data were recorded using SPSS version 16 software (Microsoft, IL, USA). Data analysis was done with three-way ANOVA and Tukey's post hoc test.

RESULTS

The Kolmogorov-Smirnov test confirmed that the data had normal distribution. The homogeneity of variances was tested with Levene's test and there were no significant differences among the variances of the groups. Table 1 shows deviations in the buccolingual dimension.

Regarding the mean deviation of canal curvature in buccolingual direction (Table 1), there was no significant difference between Mtwo and RaCe (P=0.716) or between the two canal preparation techniques (P=0.586). Comparison of deviation of canal curvature in subgroups (25-35° curvature, greater than 35° and less than 25°) revealed a significant difference (P<0.001), and the highest rate of curvature changes was observed in >35° subgroup. There were no significant differences in the buccolingual dimension for the following interactions: file type and preparation method (P=0.302), preparation method and degree of canal curvature (P=0.743), file type and degree of canal

curvature (P=0.377) and finally the interaction of preparation method, file type and degree of canal curvature (P=0.285). Table 2 shows deviations of canal curvatures in the mesiodistal direction.

There was no significant difference between Mtwo and RaCe (P=0.550) or between the two canal preparation methods regarding the deviation of canal curvature in the mesiodistal direction. However, comparison of deviation of canal curvature in subgroups (25-35° curvature, greater than 35° and less than 25°) revealed significant differences (P<0.001) and the highest rate of curvature changes was observed in the subgroup with curvature >35°.

There were no significant differences in the mesiodistal direction for the interactions mentioned earlier. Table 3 shows the results of comparison of canal preparation times. The mean time of canal preparation with only one rotary file had a significant difference with the conventional method (P<0.001).

No significant differences were observed in terms of canal preparation time with Mtwo and RaCe files (P=0.669), or with regard to the degree of canal curvature (P=0.426). Assessment of the following interactions with three-way ANOVA revealed no significant effects: Preparation method and file type (P=0.229), preparation method and degree of

Table 1. Statistical indicators regarding deviation of canal curvature (in degrees) in buccolingual dimension (n=10)

System	Method	Curvature	Max.	Min.	Mean	SD
RaCe	Conventional	< 25 º	2.34	0	1.182	0.90103
		25 º -35 º	3.42	0	1.906	0.99186
		> 35 º	4.67	2.43	3.851	0.74651
Mtwo	Conventional	< 25 º	2.65	0	1.081	1.0089
		25 º -35 º	3.89	1.19	2.639	0.97923
		> 35 º	4.27	3.26	3.853	0.37895
RaCe	One file only	< 25 º	2.75	0	1.554	0.76557
		25 º -35 º	3.57	1.27	2.332	0.71425
		> 35 º	4.86	2.68	3.769	0.618
Mtwo	One file only	< 25 º	2.16	0	1.19	0.87072
		25 º -35 º	3.25	0	2.14	1.0105
		> 35 º	4.89	3.02	4.021	0.67594

SD: Standard deviation

Table 2. Statistical indicators for deviation of canal curvature (in degrees) in the mesiodistal direction (n=10)

System	Method	Curvature	Max.	Min.	Mean	SD
RaCe	Conventional	< 25 º	1.32	0	0.247	0.52226
		25 º-35 º	2.16	0	0.86	0.79325
		> 35 º	3.34	1.53	2.307	0.61455
Mtwo	Conventional	< 25 º	1.26	0	0.239	0.50479
		25 º -35 º	3.25	1.12	1.849	0.75525
		> 35 º	3.45	2.02	2.524	0.44799
RaCe	One file only	< 25 º	1.56	0	0.298	0.62911
		25 º -35 º	2.01	0	1.208	0.69904
		> 35 º	3.19	2.13	2.662	0.2851
Mtwo	One file only	< 25 º	1.42	0	0.368	0.59779
		25 º -35 º	2.67	0	1.267	0.97675
		> 35 º	3.13	2.13	2.668	0.35894

SD: Standard deviation

canal curvature (P=0.378), file type and degree of canal curvature (P=0.103), file type and the method of canal preparation and degree of canal curvature (P=0.622). Regarding the file fracture, none of the RaCe files broke but an Mtwo file # 25/0.06 broke in the conventional method in canal curvature of >35°.

DISCUSSION

Recently introduced rotary devices are claimed to be superior to previous instruments in canal preparation. It is necessary to precisely analyze canal geometry in three dimensions and to compare the pre- and post-instrumentation shapes to confirm or refute such claims.

In this study, two rotary NiTi file systems available in the market namely Mtwo and RaCe files were evaluated in terms of their ability to maintain the canal curvature, speed of canal preparation and safety of use. This study focused on the comparison of these systems used in the conventional method of canal preparation versus only one rotary file with the aim of reducing the number of files, cost of treatment and the time of canal preparation. Due to the accumulation of debris in file flutes and the problem of cross contamination and the difficult process of cleaning and sterilization, a new technique using only one single-use rotary file may be precious.

In some studies, simulated canals in resin blocks were used. The limitations of resin blocks such as toughness and wear properties, which are different from those of dentin, cause differences in the performance of instruments compared to the natural root canals [12]. The heat generated during instrumentation with rotary files in resin blocks softens the resin; the softened resin clings to the blades of the files and may lead to breakage [13].

In order to compare the shaping ability of different canal preparation techniques or morphological changes and differences between instruments, it is necessary to have similar apical canal diameters [14]. However, we did not have similar apical canal diameters, which might have affected the results and only the size of final apical preparation file (#25/0.06) was acceptable due to minimal risk of apical perforation or apical canal deviation [15]. In this study, mesial root canals of the first and second mandibular molars were used to reduce the variation range of the three-dimensional shape of the canals.

In most cases, these teeth had the greatest root canal curvature [16].

In our study, roots with canal curvatures of 15° to 45° were selected and each of the three groups was divided into four subgroups based on their curvature.

Table 3. Root canal preparation times in seconds (n=10).

System	Method	Curvature	Max.	Min.	Mean	SD
RaCe	Conventional	< 25º	310	240	247.6	23.496
		25º-35º	343	226	270.6	35.334
		> 35º	315	229	267.3	23.935
Mtwo	Conventional	< 25 º	304	216	253.4	30.193
		25º -35º	328	254	283.7	24.162
		> 35 º	308	235	264.8	22.394
RaCe	One file only	< 25 º	154	98	128.6	16.668
		25 º -35 º	153	76	123.5	27.854
		> 35 º	176	83	128.2	30.473
Mtwo	One file only	< 25 º	167	94	128.2	22.135
		25 º -35 º	159	106	136	14.095
		> 35 º	168	109	138.3	17.372

SD: Standard deviation

Assessment of canal straightening in both buccolingual and mesiodistal directions was performed with the purpose of describing the three-dimensional morphological changes during root canal preparation.

Acceptable range for transportation of the apical foramen has not been evaluated; although an earlier study suggests that straightening of canals in the range of 5°-7.7° is acceptable [17]. Another study reported that apical transportation more than 300 micrometers can have an adverse effect on the seal of root canal fillings [18].

Only one file (Mtwo #25/0.06) broke in our study during preparation with the conventional method in a mesiobuccal canal with a curvature of >35°. File fracture is still a serious concern in the use of Ni-Ti rotary instruments because most fractures occur without any visible deformation [19]. Because of the low incidence of file fracture, no conclusion has been drawn regarding the higher tendency of one specific rotary system for breakage [19]. The rate of rotary file fracture has reported to be 3 to 5% [20]. Similar to our study, Paque et al, [21] Schirrmeister et al, [12] and Aguiar and Camara [11] reported no fractures in RaCe files in their studies. However, Merrett et al. reported the fracture of one RaCe file #25/0.06 with no previous observable distortion [22]. Bonaccorso et al. confirmed the risk of fracture of Mtwo files [23]. Uroz-Torres et al. [5] reported the fracture of two Mtwo files #25/0.06 in their study. Possible reasons for these fractures may be related to the usual way of using this system in single-length; thus, the entire length of the file is under stress. This is likely to increase the risk of blocking of the file in the depth of the canal [23]. In fact, torsional fracture occurs when the file shaft rotates and some parts of the instrument are blocked in the canal [24]. However, caution must be taken during the use of Mtwo files because there is a high incidence of permanent deformation in the file in >35° curved canals. Therefore, the files should be carefully evaluated every time they are going to be used and files with permanent deformation must be discarded [25].

In our study, the time of canal preparation was lower for Mtwo files in both canal preparation methods; but there was no statistically significant difference between Mtwo and RaCe in this regard. In both systems when only one rotary file was used, the preparation time was significantly less than that in the conventional method due to the use of fewer files and less time required for changing the files. In a previous study, Mtwo system maintained the original canal curvature significantly better than K3 or RaCe systems and it was significantly faster than them regarding canal preparation [26]. Faster canal preparation may be related to the design of Mtwo file with a S-shaped cross-section and positive rake angle that can effectively cut dentin [5].

In our study, the double radiography technique was used to evaluate the deviation from the main canal curvature. In the buccolingual and mesiodistal directions, there were no significant differences between the two files or preparation techniques. Schafer et al. [26] compared the performance of RaCe and Mtwo files and showed lower frequency of canal transportation with Mtwo files. Martin-Mico et al. [27] reported that Mtwo, RaCe and ProTaper systems had tendency to straighten the canal with no significant difference with one another. Based on our study, the tendency for canal transportation increased as the curvature exceeded 35°. Both Mtwo and RaCe systems showed some degrees of canal transportation, which were consistent with the results of previous studies by Weine et al, [28] Lim and Webber [29] and Kosa et al [30].

Schafer et al, [25] and Burklein and Schafer [31] reported that the degree of canal straightening was between 1 to 2.69° in canals with curvatures of 25° and 35°. Differences in the results of various studies may be related to

the different preparation methods and use of resin blocks instead of the extracted teeth.

Our results showed that there was no difference between the only one rotary file and the conventional methods of canal preparation for preservation of initial canal curvature. But the time of canal preparation was significantly shorter in only one rotary file technique compared to the conventional method and it may not be necessary to buy special or newly designed expensive rotary files with reciprocating motion.

Further studies using other NiTi rotary file systems are required to evaluate other factors related to cleaning and shaping of the root canals.

CONCLUSION

According to the results of this experimental study, the technique based on using only one rotary Mtwo or RaCe file was faster than the conventional method; but the tendency to deviate the canal curvature was similar in both techniques.

REFERENCES

1- Peters OA, Peters CI. Cleaning and shaping of the root canal system. Mosby Inc. 2006:290-357.

2- Peters OA, Peters CI, Schönenberger K, Barbakow F. ProTaper rotary root canal preparation: effects of canal anatomy on final shape analysed by micro CT. Int Endod J. 2003 Feb;36(2):86-92.

3- Guelzow A, Stamm O, Martus P, Kielbassa AM. Comparative study of six rotary nickel-titanium systems and hand instrumentation for root canal preparation. Int Endod J. 2005 Oct;38(10):743-52.

4- Sonntag D, Ott M, Kook K, Stachniss V. Root canal preparation with the NiTi systems K3, Mtwo and ProTaper. Aust Endod J. 2007 Aug;33(2):73-81.

5- Uroz-Torres D, Gonzalez-rodriguez MP, Ferrer-Luque CM. Effectiveness of a manual glide path on the preparation of curved root canals by using Mtwo rotary instruments. J Endod. 2009 May;35(5):699-702.

6- Yared G. Canal preparation using only one NiTi rotary instrument: preliminary observations. Int Endod J. 2008 Apr;41(4):339-44.

7- Ruddle CJ. Canal preparation: single-file shaping technique. Dent Today. 2012 Jan;31 (1):124,126-9.

8- Pessoa OF, da Silva JM, Gavini G. Cyclic fatigue resistance of rotary NiTi instruments after simulated clinical use in curved root canals. Braz Dent J. 2013;24(2):117-20.

9- Sydney GB, Batista A, de Melo LL. The radiographic platform: a new method to evaluate root canal preparation In vitro. J Endod. 1991 Nov;17(11):570-2.

10- Schneider SW. A Comparison of canal preparation in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971 Aug;32 (2):271-5.

11- Aguiar CM, Camara AC. Radiological evaluation of the morphological changes of root canals shaped with ProTaper for hand use and the ProTaper and RaCe rotary instruments. Aust Endod J. 2008 Dec;34(3):115-9.

12- Schirrmeister JF, Strohl C, Altenburger MJ, Wrbas KT, Hellwig E. Shaping ability and safety of five different rotary nickel-titanium instruments compared with stainless steel hand instrumentation in simulated curved root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006 Jun;101(6):807-13.

13- Kum KY, Spängberg L, Cha BY, Il-Young J, Msd, Seung-Jong L, et al. Shaping ability of three profile rotary instrumentation techniques in simulated resin root canals. J Endod. 2000 Dec;26(12):719-23.

14- Bergmans L, Van Cleynenbreugel J, Beullens M, Wevers M, Van Meerbeek B, Lambrechts P. Progressive versus constant tapered shaft design using NiTi rotary instruments. Int Endod J. 2003 Apr;36(4):288-95.

15- Mullaney TP. Instrumentation of finely curved canals. Dent Clin North Am. 1979 Oct;

23(4):575-92.
16- Vaudt J, Bitter K, Neumann K, Kielbassa AM. Ex vivo study on root canal instrumentation of two rotary nickel-titanium systems in comparison to stainless steel hand instruments. Int Endod J. 2009 Jan;42(1):22-33.
17- Hülsmann, Michael. Entwicklung einer Methodik zur standardisierten Überprüfung verschiedener Aufbereitungsparameter und vergleichende In-vitro-Untersuchung unterschiedlicher Systeme zur maschinellen Wurzelkanalaufbereitung. Quintessenz-Verlag, 2000:93-134.
18- Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved root canals. Part I: Effects of apical transportation on seal of root fillings. J Endod. 2000 Apr;26(4):210-6.
19- Gambarini G, Grande NM, Plotino G, Somma F, Garala M, De Luca M, et al. Fatigue resistance of engine-driven rotary nickel-titanium instruments produced by new manufacturing methods. J Endod. 2008 Aug; 34(8):1003-5.
20- Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. J Endod. 2005 Dec;31 (12):845-50.
21- Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. Int Endod J. 2005 Jan;38(1):8-16.
22- Merrett SJ, Bryant ST, Dummer PM. Comparison of the shaping ability of RaCe and FlexMaster rotary nickel-titanium systems in simulated canals. J Endod. 2006 Oct;32(10): 960-2.
23- Bonaccorso A, Cantatore G, Condorelli GG, Schäfer E, Tripi TR. Shaping ability of four nickel-titanium rotary instruments in simulated S-shaped canals. J Endod. 2009 Jun; 35(6):883-6.
24- Yared GM, Bou Dagher FE, Machtou P. Cyclic fatigue of Profile rotary instruments after simulated clinical use. Int Endod J. 1999 Mar;32(2):115-9.
25- Schafer E, Erler M, Dammaschke T. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 1. Shaping ability in simulated curved canals. Int Endod J. 2006 Mar;39(3):196-202.
26- Schafer E, Erler M, Dammaschke T. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J. 2006 Mar;39(3): 203-12.
27- Martin-mico M, Forner-Navarro L, Almenar-Garcia A. Modification of the working length after rotary instrumentation. a comparative study of four systems. Med Oral Patol Oral Cir Bucal. 2009 Mar 1;14(3):E153-7.
28- Weine FS, Kelly RF, Bray KE. Effect of preparation with endodontic handpieces on original canal shape. J Endod. 1976 Oct;2(10): 298-303.
29- Lim KC, Webber J. The effect of root canal preparation on the shape of the curved root canal. Int Endod J. 1985 Oct;18(4):233-9.
30- Kosa DA, Marshall G, Baumgartner JC. An analysis of canal centering using mechanical instrumentation techniques. J Endod. 1999 Jun; 25(6):441-5.
31- Bürklein S, Schäfer E. The influence of various automated devices on the shaping ability of Mtwo rotary nickel-titanium instruments. Int Endod J. 2006 Dec;39(12): 945-51.