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In vitro evaluation of root canal transportation after use of BT-Race files

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ABSTRACT

Objective: To evaluate the effect of repeated use on the shaping ability of the BT-Race instrument.

Methods: Thirty-six canals in resin blocks were allocated into six groups. Glide paths were flooded with alcohol while canals were prepared using a crown-down technique to a final apical size of 35/.04. Pre- and post-instrumentation images were taken using macroscopic magnifier, layered by PaintShop Pro9 software, and canal transportation was measured using Solidwork CAD 2014 in apical, middle and coronal levels. Data were analyzed using a General Linear Model with a 0.05 significance level.

Results: When the number of uses only was considered, there were no statistically significant differences in transportation ($F = 0.453$; $p = 0.808$). No statistically significant differences were found in transportation in the interdependence influence of the locations and the number of uses of the files ($F = 0.746$; $p = 0.691$). There were statistically significant differences in this measure between the locations when all groups about number of uses ($F = 22.358$; $p < 0.0005$) were considered. The largest measures were seen at five and seven millimeters from the apex and the shortest ones in the apical area. The direction of transportation was toward the outer side of the curvature in the apical level and toward the inner side in the middle and coronal parts.

Conclusion: BT-Race file respects the canal morphology well and was safe to use repeatedly with few incidences of transportation.

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Avaliação in vitro do transporte de canais radiculares após utilização das limas BT-Race

Palavras-chave:
Endodontia
Instrumentação
Reutilização
Capacidade conformação
Instrumentos NITI rotativos

RESUMO

Objetivo: Avaliar o efeito do uso repetido dos instrumentos BT-Race na capacidade de conformação de canais.

Métodos: Trinta e seis blocos de resina com canais simulados foram divididos em 6grupos. A permeabilidade foi mantida enquanto os canais foram preparados, irrigando-os com álcool e usando uma técnica crown-down até um calibre final de 35/0,04. Foram obtidas imagens pré e pós-instrumentação, usando uma lupa macroscópica, e sobrepostas com auxílio do software PaintShop Pro9. O transporte dos canais foi determinado a nível apical, médio e coronal utilizando o software Solidwork CAD2014. Os dados foram analisados utilizando um modelo geral linear com um nível de significância de 0,05.

Resultados: Considerando apenas o número de utilizações, não se observaram diferenças estatisticamente significativas no transporte dos canais (F = 0,453; p = 0,808). Também não se observaram diferenças com significado estatístico no transporte na influência interdependente das localizações e número de utilizações das limas (F = 0,746; p = 0,691). Existem diferenças estatisticamente significativas nas medidas entre localizações diferentes quando são considerados todos os grupos em relação ao número de utilizações (F = 22,358; p < 0,0005). As maiores medidas obtiveram-se a 5e 7milímetros do ápex e as menores na zona apical. A nível apical a direção de transporte verificou-se para o lado exterior da curvatura e nas porções médias e coronal em direção ao lado interior.

Conclusão As limas BT-Race respeitam a morfologia dos canais, podendo ser usadas repetidamente de forma segura provocando pouco transporte dos canais.

Introduction

Root canal's instrumentation is an essential step of root canal treatment procedure since it determines the efficacy of all subsequent procedures.[1] This treatment phase is associated with root canal disinfection and canal tapering shape, with maintenance of the foramen position without any deviations from the original path of the canal.[2] These shaping goals have been set as major objectives by various preparation techniques, and instruments that were introduced for canal instrumentation[3] of this concept is difficult to reach in curved canal where procedural errors are very common to take place.[4] Stainless steel files induce great lateral forces in curved canals due to its stiffness that lead to alter the canal morphology.[5] Flexible NITI endodontic files did improve the root canal preparation by their ability to shape the narrow and curved root canals without producing any aberrations[6] besides creating more centered canal preparations than stainless steel hand files.[7] Evaluating the performance of endodontics files was always correlated to their ability to shape the curved root canals and their capability to preserve the original anatomy of them.[8–10] Although many evaluating parameters were reported in the literature when shaping ability of instrument was evaluated, yet transportation is the most frequently used. Such evaluations are important to clinicians and researchers; their consideration is valued in the selection of a particular rotary NiTi instrument.[11]

BT-Race (FKG, La Chaux-de-Fonds, Switzerland) is a newly introduced endodontic file system. It mainly consists of three sequences of files. BT1(10/.06), BT2(35/.00), and BT3(35/.04), but BT4(40/.04) and BT5(50/.04) are also available. BT-Race is sterile and for a single use, to avoid patient cross-contamination, reduce both cyclical fatigue and torsion stress on instruments and, reduce the possibility of breakage.[12] Single used files are frequently used to prepare multiple canals in a single furcated tooth; these files perform a significant amount of work.

Literature has limited information about the shaping ability of BT-Race instruments; only one study was available,[13] which revealed that BT-Race has a respectable ability to maintain root canal curvature.[13]

The aim of this in vitro study is to evaluate repeated use of BT-Race file to resemble multi-rooted canals; for this, the research questions raised are: Does the new rotary files systems BT-Race induce root canal transportation and how does repetitive use[1–6] affect the ability of BT-Race file to induce root canal transportation?

Material and methods

A total of thirty-six curved root canals in clear resin blocks (Dentsply-Maillefer) were used for this study. Each was mounted with an angle of apical curvature of 60° and was of 16-mm canal length. The blocks were given numbers from one to thirty-six (B1–B36) and then assembled into six groups (G1–G6). Each group consisted of six blocks. Six kits of the

Table 1 – Mean and standard deviation of transportation of the canal center at 4 locations.

Location mm	Once ($n = 6$)	Twice ($n = 6$)	Three times ($n = 6$)	Four times ($n = 6$)	Five times ($n = 5$)	Six times ($n = 6$)	Total ($n = 35$)
1	0.022 ± 0.019	0.029 ± 0.015	0.027 ± 0.022	0.037 ± 0.029	0.036 ± 0.022	0.041 ± 0.014	0.032 ± 0.021
3	0.040 ± 0.035	0.027 ± 0.022	0.048 ± 0.024	0.036 ± 0.016	0.040 ± 0.023	0.035 ± 0.005	0.038 ± 0.023
5	0.088 ± 0.044	0.083 ± 0.028	0.098 ± 0.039	0.087 ± 0.046	0.089 ± 0.045	0.059 ± 0.028	0.085 ± 0.039
7	0.078 ± 0.032	0.049 ± 0.023	0.057 ± 0.040	0.064 ± 0.051	0.042 ± 0.020	0.051 ± 0.022	0.057 ± 0.034

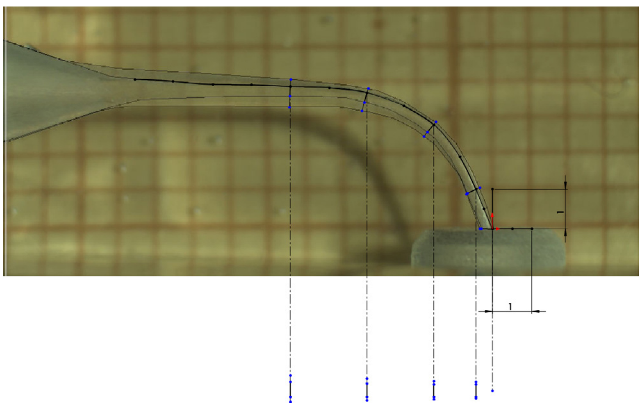

Fig. 1 – Model transferred onto the Solidwork software (SolidWorks 2014 ×64 Edition).

BT-Race file system were also given numbers from one to six (F.S.1.–F.S.6). Each kit was used to prepare the corresponding number of the block's group where each file was used six times each, one time in each block within each group.

In all canals, working length (WL) was set up to the level of the apical foramen using a #10 hand K-file (Dentsply Maillefer, Ballaigues, Switzerland) and glide path was established using a #10 hand K-file (Dentsply Maillefer, Ballaigues, Switzerland). The canals were then instrumented by BT-Race files using crown-down technique, driven by the Rooter Endodontic motor (FKG, La-Chaux De Fonds, Switzerland); the rotational speed was set at the recommended rotation of 800 rpm and 1.5 N/cm torque. Preparation was performed by the same operator, using the files in a gentle in-and-out motion until the full working length was reached. The instrumentation sequence was as follows: BT1 (size 10, 0.06 taper); BT2 (size 35, 0.00 taper); and BT3 (size 35, 0.04 taper). Between the uses of each rotary instrument in order to keep the glide path open, all canals were frequently irrigated with 99% ethyl alcohol using a 30-G side-vented needle and repeatedly recapitulated with K-file ISO 10.

All blocks were photographed before and after preparation using macroscopic magnifier (Leica Microsystems) with a total of 6× magnification with an image analysis program (Leica Application Suite© 2008 Leica Microsystems, Switzerland. Ltd.). Then both images for each block were overlapped accurately using Paint Shop Pro 9 (JascSoftware® U.S.A.). They were then transferred as one image to the SolidWorks program (SolidWorks 2014 ×64 Edition) and a drawing model was generated (Fig. 1).

The possibility of canal transportation was assessed at four locations along the canal walls on both sides of the simulated canal (outer and inner); those sites were selected to signify the apical, middle, and coronal levels. The measurements of 1 mm and 3 mm were used to demonstrate the apical level, 5 mm indicated the middle level, and 7 mm specified the coronal level.

Table 2 – The directions of the means of transportation of the canal center at 4 locations.

Blocks	1 mm	3 mm	5 mm	7 mm
35 Blocks	−0.032	−0.037	+0.085	+0.058

Transportation of the canal's center was determined by subtracting the amount of resin removed at the outer wall (convex) from that removed at the inner wall (concave) divided by two. A positive result means that transportation occurs mainly on the inner surface of the canal curvature and negative value indicates that transportation occurs mainly on the outer surface of the canal curvature.

SPSS software V.22 was used for data analysis, and multivariate statistical analysis (GLM – General Linear Model) was applied to compare the transportation between the six groups when time of uses and the transportation in the four locations in the canals were considered. The statistical Greenhouse–Geisser was considered toward the rejection of covariance homogeneity after application of Mauchly's test. The Bonferroni correction was used for multiple comparisons analysis with a significance level of 0.05.

Results

One file fractured; BT2 number 4 was broken during the sixth time attempting to prepare block number thirty-four.

Means and standard deviations of canal center transportations are shown in (Table 1). When all locations were considered, there were no statistically significant differences in transportation between the six groups of files ($F = 0.453$; $p = 0.808$). BT-Race rotary NiTi instruments showed transportation in both canal sides. However, there was more transportation toward the inside of the curve in the coronal and middle levels (−values), rather than further toward the outside of the curve at the apical level (+values) (Table 2).

On the other hand there were statistically significant differences in this measure between the locations when all groups about number of uses ($F = 22.358$; $p < 0.0005$) –were considered (Table 1).

No statistically significant differences were found in transportation in the interactive influence of the locations and the number of uses of the files ($F = 0.746$, $p = 0.691$) – (Fig. 2).

In average, the transportation was greater and statistically significant at 5 mm from the apex than other locations ($p < 0.05$). The major mean difference of transportation was found between 5 mm from the apex and 1 mm (0.052 mm; $p < 0.0005$). The second largest transportation was found at

Table 3 – Pairwise comparisons based on estimated marginal means of transportation (mm) between locations.

(I) Location	(J) Location	Mean difference (I-J)	Std. error	Sig.[a]	95% Confidence interval for difference[a]	
					Lower bound	Upper bound
1 mm	3 mm	−0.005	0.006	1.000	−0.023	0.013
	5 mm	−0.052	0.009	0.000	−0.078	−0.026
	7 mm	−0.025	0.008	0.029	−0.047	−0.002
3 mm	1 mm	0.005	0.006	1.000	−0.013	0.023
	5 mm	−0.046	0.005	0.000	−0.061	−0.031
	7 mm	−0.019	0.006	0.026	−0.037	−0.002
5 mm	1 mm	0.052	0.009	0.000	0.026	0.078
	3 mm	0.046	0.005	0.000	0.031	0.061
	7 mm	0.027	0.006	0.001	0.009	0.045
7 mm	1 mm	0.025	0.008	0.029	0.002	0.047
	3 mm	0.019	0.006	0.026	0.002	0.037
	5 mm	−0.027	0.006	0.001	−0.045	−0.009

[a] Adjustment for multiple comparisons: Bonferroni correction.

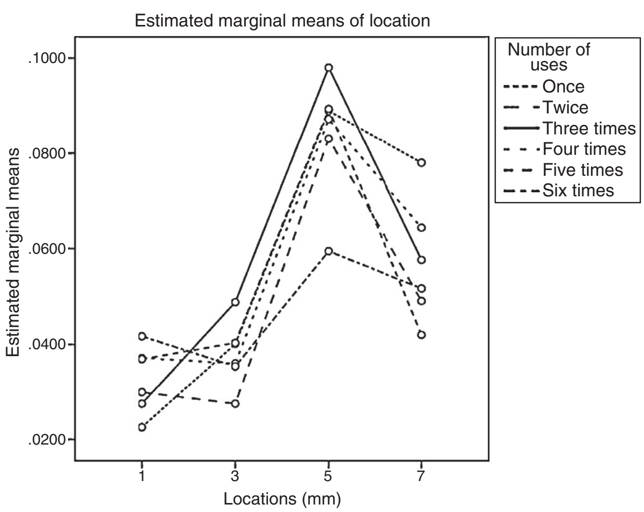

Fig. 2 – Measures of transportation induced by BT files considering locations and number of usage.

7 mm from the apex. In this case, the largest mean difference occurred when compared the location at 1 mm from the apex (0.025 mm; $p < 0.03$) – (Table 3).

Discussion

The purpose of this study was to determine the shaping ability of BT-Race endodontic file systems by measuring canal transportation in simulated root canals in resin blocks. The reliability of resin blocks as an experimental model for assessment of instruments and preparation techniques has been established.[14,15] Although literature has reported that caution should be taken in justification of the results, since there are differences between resin and dentin materials,[16] clinical relevance can be transmitted as result of their outcomes.[17,18]

In this study, transportation of the canal at the apical level of the simulated canals was analyzed in a two-dimensional plan using Solidwork software. A previous study found that highest acceptable amount of canal transportation occurred apically; this measurement is reached up to 0.15 mm and should not be greater than 0.30 mm.[1] Measurements outside of this range are responsible for number of adverse effects on the apical seal.[19] Our study demonstrated that the amount of the canal transportation induced by BT-Race was less than both figures mentioned (Table 1; Fig. 2).

Till date, only one study by Burklein et al. evaluated the shaping ability of BT-Race.[13] The inspected locations, as well as the methodologies, are different. Burklein et al. study, showed that the transportation at 0.5 mm was 0.12 ± 0.08; our study showed that at 1 mm, it was 0.032 ± 0.020. Burklein et al. study compared the BT-Race with Mtwo, PTU, and PTN systems, and showed no significant differences between all four instruments regarding canal transportation. Ours showed no statistically significant difference between the files themselves.

Due to the lack of studies conducted on the BT-Race, results were compared with the published data of the predecessor systems. Despite the fact that different methodologies were used, the outcomes were similar. Saber et al.[20] measured the transportation induced by iRaCe (FKG, La Chaux-de-Fonds, Switzerland) at the apical region, and found it to be (0.06 ± 0.01); this study's data showed (0.032 ± 0.020) as the value of the transportation at the center of the canal. The other Race study showed transportation at apical level of 3 mm (0.10 ± 0.10) and at middle level of 6 mm (0.15 ± 0.13)[21]; this study's results are well within the ranges shown by BT-Race files at 3 mm (0.038 ± 0.022) and at 5 mm (0.085 ± 0.038), and almost equal to Nabavizadeh et al.[22] that revealed 0.034 at 1 mm, and 0.010 at 5 mm for BioRace.

In this study's results, the amount of canal transportations was generally small; the reason for the small amount of transportation induced by BT-Race can be explained by the file flexibility. Previous studies found that a lesser amount of transportation takes place with more flexible files.[23] It was also specified that the centered canal preparation depends on the file design, its flexibility, or the instrumentation technique.[24] The file sequences and BT tip of the BT-Race instrument allow adequate apical preparation sizes, ensure

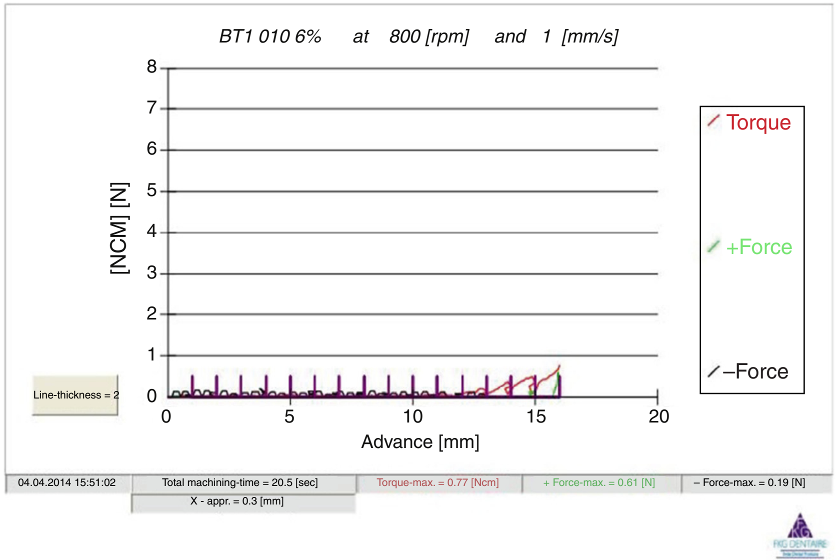

Fig. 3 – Effect of torque. Positive and negative forces on B1.

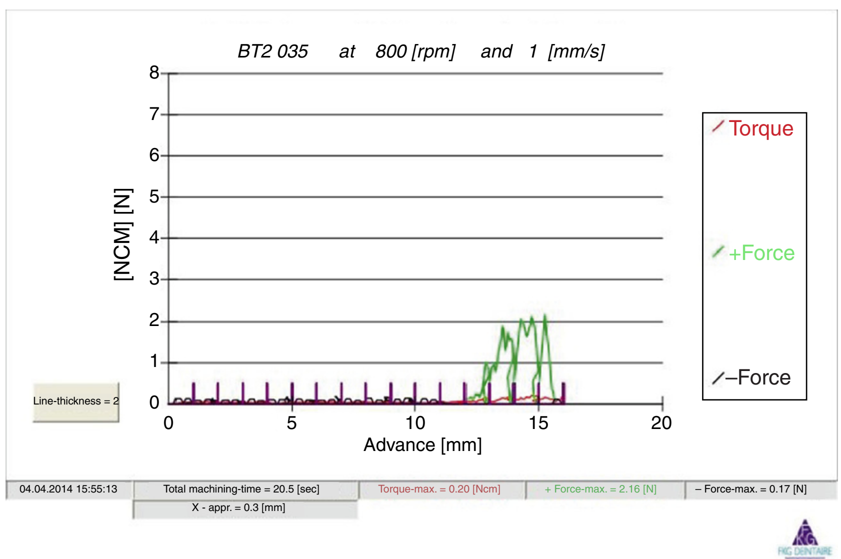

Fig. 4 – Effect of torque. Positive and negative forces on B2.

that the original canal shape is maintained, and keep the files centered in the canal.[12,25] These reasons could be another cause of the small amount of observed transportation.

This study's data showed also that the direction of transportation was in the apical area toward the outside curvature, a finding supported by the previous reports, which also confirmed the same inclination; this was explained as a result of file's superelasticity, which was allowing the instrument to follow the canal curvature.[9,26,27]

Evaluating the changes of the amount of root canal transportation upon reusing the file six times was chosen to mimic the clinical situation of treating one or two molars within the same patient. Single patient NiTi use is the world's endodontic golden standard, specifically for the cross-contamination reason and breakage of instruments as a result of metal fatigue. It is crucial to study instruments in non-clinical reuse circumstances to decide their most extreme capacities and performance. Our result exhibited no statistical difference between amount of canal transportation when the file was used six times. Up to the present time, no study evaluated how several clinical uses of BT-Race instruments would effect root canal transportation; however, one study examined the effects of multiple clinical uses of Protaper universal file on the incidence of root canal transportation.[28] This study reported significant diversity in the amount of transportation between the numbers of file uses. The variances between the instruments' design made the comparison impossible.

BT-Race file system has a "non-screw-in design" that introduces them into the root canal with low magnitude of positive force and torque, and allows them to be removed smoothly from the canal with low magnitude of negative force and torque, This could be seen in (Figs. 3–5) as provided from the

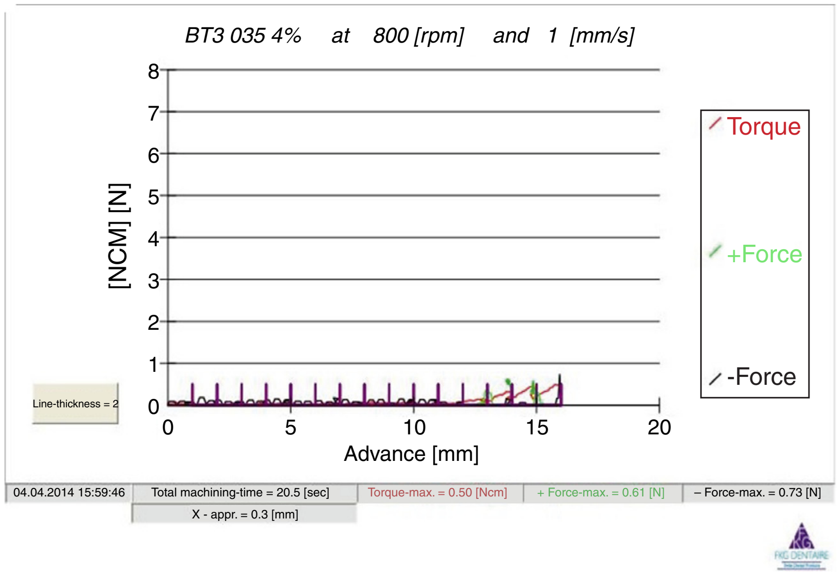

Fig. 5 – Effect of torque. Positive and negative forces on B3.

FKG based on our request. This ability can be added to the reason why BT-Race instruments can be used frequently without significant changes in amount of transportation.

It is important to note that the instruments do maintain their cutting efficiency throughout the experiment; transportation decreases were not due to decreases in blade cutting ability. Our study showed that the files were able to maintain their cutting efficiency even after 6 times usage, since they could remove the resin materials on both the inner and outer sides of the tested simulated canals.

The single use BT-Race file is ideal for use in one case only; the manufacture claims that it is ideal for molars with 4/5 canals.[12] In our study, a fracture happened after the instrument was used six times; this could be due to significant amount of work done above the recommendation by the manufacturer (more than 5). In addition, the inherent resistance of the resin material used in the block may cause unwinding of the instrument flutes and, consequently, fracture of the files.[29–31] Burklin et al. also reported one BT-Race file fractured (BT2)[13] and deduced that to the cylindrical design of the instrument that makes it prone to fracture. The electro-polished surface feature of the file is responsible for decreasing the effects of torsional and cyclic fatigue,[25] which could explain its resistance to fracture. Despite the limitations of this study, a small amount of transportation was induced by BT-Race file; repetitive use[1–6] did not affect the ability of BT-Race to maintain the shaping ability of curved root canal as there were no statistically difference between the amount of transportation and the number of uses. A standard protocol for testing the shaping ability of NiTi rotary instruments is required to confirm consistency of methodology and to obtain comparable results when assessing the transportation of new instruments and techniques.

Conclusion

Under the condition of this study, BT-Race files (FKG, La Chaux-de-Fonds, Switzerland) respect the original canal curvature well. It can be used to prepare multi-rooted teeth with minimal amount of transportation.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Conflicts of interest

The authors have no conflicts of interest to declare.

REFERENCES

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod. 2004;30:559–67.
2. Schilder H. Cleaning and shaping the root canal. Dent Clin N Am. 1974;18:269–96.
3. Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Top. 2005;10:30–76.
4. Lam TV, Lewis DJ, Atkins DR, Macfarlane RH, Clarkson RM, Whitehead MG, et al. Changes in root canal morphology in simulated curved canals over-instrumented with a variety of stainless steel and nickel titanium files. Aust Dent J. 1999;44:12–9.
5. Craig RG, McIlwain ED, Peyton FA. Bending and torsion properties of endodontic instruments. Oral Surg Oral Med Oral Pathol. 1968;25:239–54.

6. Bryant ST, Thompson SA, al-Omari MA, Dummer PM. Shaping ability of Profile rotary nickel-titanium instruments with ISO sized tips in simulated root canals: Part 1. Int Endod J. 1998;31:275–81.
7. Bergmans L, Van Cleynenbreugel J, Wevers M, Lambrechts P. Mechanical root canal preparation with NiTi rotary instruments: rationale, performance and safety. Status report for the American Journal of Dentistry. Am J Dent. 2001;14:324–33.
8. de Oliveira Alves V, da Silveira Bueno CE, Cunha RS, Pinheiro SL, Fontana CE, de Martin AS. Comparison among manual instruments and PathFile and Mtwo rotary instruments to create a glide path in the root canal preparation of curved canals. J Endod. 2012;38:117–20.
9. 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;32:960–2.
10. Berutti E, Paolino DS, Chiandussi G, Alovisi M, Cantatore G, Castellucci A, et al. Root canal anatomy preservation of WaveOne reciprocating files with or without glide path. J Endod. 2012;38:101–4.
11. Busquim SSK, França RC, Siqueira EL, dos Santos M. Evaluation of canal transportation and centering ability of two nickel-titanium rotary instruments. CLRD. 2014;20: 10–5.
12. endo F-S. BT-RaCe, instructions for use; 2014 [cited 2014 12 September]. Available from: http://www.fkg.ch/sites/default/files/fkg_bt_race_brochure_en.pdf.
13. Burklein S, Mathey D, Schafer E. Shaping ability of ProTaper NEXT and BT-RaCe nickel-titanium instruments in severely curved root canals. Int Endod J. 2015;48:774–81.
14. Weine FS, Kelly RF, Lio PJ. The effect of preparation procedures on original canal shape and on apical foramen shape. J Endod. 1975;1:255–62.
15. Dummer PM, Alodeh MH, Al-Omari MA. A method for the construction of simulated root canals in clear resin blocks. Int Endod J. 1991;24:63–6.
16. Dhingra A, Kochar R, Banerjee S, Srivastava P. Comparative evaluation of the canal curvature modifications after instrumentation with One Shape rotary and Wave One reciprocating files. J Conserv Dent. 2014;17:138–41.
17. Ahmad M. The validity of using simulated root canals as models for ultrasonic instrumentation. J Endod. 1989;15:544–7.
18. Khalilak Z, Fallahdoost A, Dadresanfar B, Rezvani G. Comparison of extracted teeth and simulated resin blocks on apical canal transportation. Iran Endod J. 2008;3: 109.
19. 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;26:210–6.
20. Saber SEDM, Nagy MM, Schäfer E. Comparative evaluation of the shaping ability of ProTaper Next, iRaCe and Hyflex CM rotary NiTi files in severely curved root canals. Int Endod J. 2015;48:131–6.
21. Maitin N, Arunagiri D, Brave D, Maitin SN, Kaushik S, Roy S. An ex vivo comparative analysis on shaping ability of four NiTi rotary endodontic instruments using spiral computed tomography. J Conserv Dent. 2013;16:219–23.
22. Nabavizadeh M, Abbaszadegan A, Khojastepour L, Amirhosseini M, Kiani E. A comparison of apical transportation in severely curved canals induced by Reciproc and BioRaCe Systems. Iran Endod J. 2014;9:117–22.
23. Garcia M, Duran-Sindreu F, Mercade M, Bueno R, Roig M. A comparison of apical transportation between ProFile and RaCe rotary instruments. J Endod. 2012;38:990–2.
24. 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;36:288–95.
25. Gilberto Debelian D, Trope M. BT-Race – Biologic and Conservative Root canal instrumentation with the final restoration in mind: Endodontic Practice US; 2014 [cited 2015 September].
26. Taşdemir T, Aydemir H, Inan U, Ünal O. Canal preparation with Hero 642 rotary Ni–Ti instruments compared with stainless steel hand K-file assessed using computed tomography. Int Endod J. 2005;38:402–8.
27. Pasternak-Júnior B, Sousa-Neto M, Silva R. Canal transportation and centering ability of RaCe rotary instruments. Int Endod J. 2009;42:499–506.
28. Ounsi HF, Franciosi G, Paragliola R, Goracci C, Grandini S. Effect of repeated use on the shaping ability of Protaper Universal rotary files. Int Dent SA. 2010;12:30–5.
29. Iqbal MK, Kohli MR, Kim JS. A retrospective clinical study of incidence of root canal instrument separation in an endodontics graduate program: a PennEndo database study. J Endod. 2006;32:1048–52.
30. Schafer E, Florek H. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 1. Shaping ability in simulated curved canals. Int Endod J. 2003;36:199–207.
31. Kum KY, Spangberg L, Cha BY, Il-Young J, Seung-Jong L, Chan-Young L. Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. J Endod. 2000;26:719–23.