ORIGINAL RESEARCH

Comparative Evaluation of Canal-shaping Abilities of RaceEvo, R-Motion, Reciproc Blue, and ProTaper Gold NiTi Rotary File Systems: A CBCT Study

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Abstract

Aim: To evaluate the canal transportation, canal-centering ability, and touched and untouched surfaces of the root canal dentin after instrumentation with various newer file systems in continuous rotation and reciprocating motion using cone-beam computed tomography (CBCT) imaging.

Materials and methods: This *in vitro* study was conducted on one hundred recently extracted human mandibular molars, which were selected and instrumented using the following rotary NiTi file systems: RaceEvo, R-Motion, Reciproc Blue, and ProTaper Gold. The canal preparations for all four (04) experimental groups were done according to the manufacturer's instructions; the CBCT imaging was done for all the teeth compared at different levels of 2 mm, 5 mm, 8 mm from the apex, before and after the canal preparations. The data thus collected were evaluated for variation where $p < 0.05$ was calibrated as significant using "ANOVA and Mann–Whitney" statistical tests.

Result: When the file systems were compared at different levels of the canal i.e. 2 mm, 5 mm, 8 mm from the apex, we observed a statistically significant difference for all the experimental groups ($p = 0.021, 0.023, 0.032$) respectively for the canal transportation (CT), ($p = 0.045, 0.040, 0.037$) respectively for the canal centering ability (CCA), ($p < 0.001$) respectively for the touched (TS) and untouched (US) surfaces. R-Motion showed the least CT, greater CCA, with maximum TS, and the least US dentinal surfaces in the root canal preparations followed by RaceEvo, Reciproc Blue, and ProTaper Gold.

Conclusion: R-Motion exhibited better canal centering ability, lower canal transportation due to its improved cutting efficiency down to the apex while preserving the dentin of the root canal walls and also exhibits lesser stress on dentin. The newer rotary file systems of R-Motion and RaceEvo described in this study could be recommended for clinical use during endodontic treatment.

Clinical significance: The newly introduced R-Motion and RaceEvo showed better preparations of the root canal compared to other file systems and could be used as a reliable alternative to the ProTaper file systems which is considered as the gold standard in rotary endodontics.

Keywords: Canal-centering ability, Canal transportation, Cone-beam computed tomography, Continuous rotation, ProTaper Gold, RaceEvo, R-Motion, Reciproc Blue, Reciprocating motion.

The Journal of Contemporary Dental Practice (2021): 10.5005/jp-journals-10024-3217

Introduction

The most common of all the clinical procedures done in dental clinics is the root canal treatment (RCT). RCT has replaced the extraction of decayed teeth (that can be restored within limits), which was the most common practice in yester years. RCT chiefly constitutes three important steps, the first being a thorough diagnosis followed by proper preparation and finally restoration. These steps are dependent on the clinical expertise of the dentist.[1]

In the past years, for the preparation of the canal for the RCT, manual techniques were followed with files that were made of various metals. During the instrumentation, the apical enlargement is a critical step that will decide the success of the RCT. This step allows for thorough irrigation and the proper seal. A uniformly tapered canal is essential to complete the restoration. However, this step is prone to a few problems like "apical transportation, zip, elbow, and ledge formation."[2] The main disadvantages of the manual method were instrument breakage and fatigue in the clinician along with other detriments. The manual method was also dependent on the tactile sensibility of the clinician.[3] Overcoming these disadvantages, the rotary system was introduced. This system uses fewer files, is convenient to use, easily learned, time-saving, and fewer reports of breakage of the file. The most prominent of the advantages of the rotary file systems is the use of nickel–titanium metal that is more elastic and less prone to breakage even in curved canals.[4] The rotary NiTi file systems are further classified as follows:

- Continuous rotation—ProTaper Gold and RaceEvo
- Reciprocating motion—Reciproc Blue and R-Motion

Race®Evo and R-Motion® are two innovative new file systems, which seem to provide solutions for reshaping the canals during

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How to cite this article: Mustafa M. Comparative Evaluation of Canal-shaping Abilities of RaceEvo, R-Motion, Reciproc Blue, and ProTaper Gold NiTi Rotary File Systems: A CBCT Study. J Contemp Dent Pract 2021;22(12):1406–1412.

Source of support: Nil

Conflict of interest: None

root canal therapy. RE works in continuous rotation, and RM works in a reciprocating motion. RE and RM have been very recently introduced in 2021 by FKG Dentaire, Switzerland.[5,6]

The ProTaper gold (PG) (DENTSPLY Sirona, Ballaigues, Switzerland) system is a NiTi file system considered the gold standard in rotary endodontics, which is manufactured by thermal treatment. The gold treatment intends to improve the mechanical properties, especially the cyclic fatigue resistance of the conventional NiTi, which makes the file more durable and very flexible.[7]

"Reciproc® Blue (RB) (VDW GmbH, Munich, Germany) is a NiTi file system that is prepared from innovative heat treatments. The universal and flexible instrument for the majority of cases. This system is an improvised version of Reciproc®. This system also shows better flexibility, designed for one file shaping, easy to learn, higher resistance to cyclic fatigue due to its modified molecular structure which also gives a characteristic Blue color, and also reduces the risk of instrument fracture.[8]

Previous studies have supported the reciprocation file systems as they less engage in the dentin walls of the root canal/s causing lower stress in the file and thereby less file breakage.[9,10] However, some studies have reported supporting the continuous motion of the rotary files for their efficiency.

In order to investigate the shaping effect of these new NiTi systems with different design features and kinematics for root canal preparation, numerous methods have been used to evaluate the canal shape before and after instrumentation. CBCT imaging is a noninvasive technique for the analysis of canal geometry and the efficiency of shaping abilities of different instruments. Using CBCT makes it possible to compare the anatomical structure of the root canal before and after preparation.[7]

In this study, we aim to compare the shaping abilities in terms of canal transportation (CT), canal centering ability (CCA), touched surface (TS), and untouched surface (US) after canal preparations using the novel NiTi instruments RaceEvo (continuous rotation) and R-Motion (reciprocation) in curved root canals and to compare them with the well-known Reciproc Blue and ProTaper Gold rotary system using CBCT. The null hypothesis tested was that there would be no difference among all the file NiTi rotary systems for the analyzed parameters.

Materials and Methods

Ethical Approval

This study was reviewed and approved by the Research Ethics Committee of Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia, with approval no. REC-HSD-015-2020. This study was performed in the Department of Conservative Dental Sciences, College of Dentistry, Prince Sattam Bin Abdulaziz University. This study has an *in vitro* design; therefore, signing of written informed consent was not needed from the individuals whose extracted teeth were assessed.

Inclusion and Exclusion Criteria

The inclusion criteria were the teeth that had identifiable canals with no other pathologies like grossly carious teeth with caries involving root surfaces, internal/external root resorption, calcifications, fracture or crack line, and/or immature apex were excluded.

Sample Selection and Preparation

One hundred (100) human mandibular molars that were extracted for periodontal and orthodontic reasons were taken for this study. The teeth collected were disinfected and stored at 4°C in saline until they were used. The selection of the teeth for canal curvature was based on Schneider's method,[12] the canal curvature ranged between 25° and 30° were included in the study, Access cavities were prepared with an Endo-Access bur (Dentsply Maillefer), and the root canals were negotiated using #10 K-file (Dentsply, Maillefer, Switzerland). Mesial canals of the mandibular molars were selected, only teeth with two separated mesial canals with separate apical foramen were taken for this study, and the distal root was sectioned at the furcation level using a low-speed diamond bur under water and discarded. The working length was determined by inserting #10 K-file to the root canal terminus and subtracting 1 mm from this measurement, which was then confirmed using an electronic apex locator.

Grouping

The teeth selected for the study were divided into four (04) experimental groups for each rotary file system as mentioned below:

- Continuous rotation
  - Group I ($n = 25$) ProTaper Gold
  - Group II ($n = 25$) RaceEvo
- Reciprocating motion
  - Group III ($n = 25$) Reciproc Blue
  - Group IV ($n = 25$) R-Motion

The canal preparations for all four experimental groups were prepared according to the manufacturer's instructions, and the final apical preparation of the root canal was standardized for all specimens at size 25. The instrumentation was done using Glyde (Dentsply Maillefer) as a lubricating agent. The canals were irrigated with 2 mL of 5% sodium hypochlorite during instrumentation followed by 1 mL of 17% EDTA for 3 min and final irrigation with 2 mL of saline solution. Each instrument was used to prepare three canals, and then, the files were discarded. Teeth were then scanned under the same conditions followed for the initial scan, and the data were analyzed.

Cone-beam Computed Tomography

We compared all the groups before and after the preparation for CT, CCA, TS, and US of dentin after instrumentation:

- The CT was calculated as $(x_1 - x_2) - (y_1 - y_2)$
- The CCA ratio was calculated as $(x_1 - x_2)/(y_1 - y_2)$ or $(y_1 - y_2)/(x_1 - x_2)$

where x_1 is the short distance measured from the mesial end of the root to the mesial end of the unprepared canal, x_2 is the short distance from the mesial end of the root to the mesial end of the prepared canal, y_1 is measured from the distal end of the root to the distal end of the unprepared canal, and y_2 is measured from the distal end of the root to the distal end of the prepared canal.

- The US and TS of root canal dentin were calculated from the superimposition of the images that were recorded before and after the preparation using the AutoCAD 2012-CDW software (Figs 1 and 2).

The specimen was mounted in wax to be imaged using CBCT (CS 9000 3D, Carestream Dental, Atlanta, GA) at a voxel size and slice thickness of 150 µm and 0.150 mm, respectively. The images were recorded before and after the preparation. The scans were performed at three regions from the apex of the root at 2 mm, 5 mm, and 8 mm.

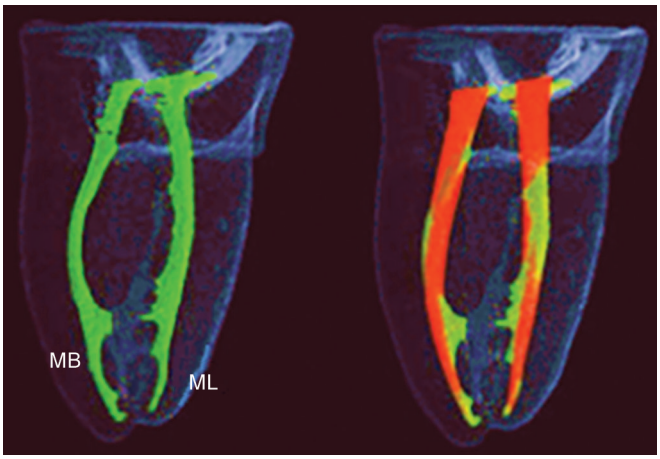

Fig. 1: CBCT imaging of pre (green) and post (red) preparation of the root canals

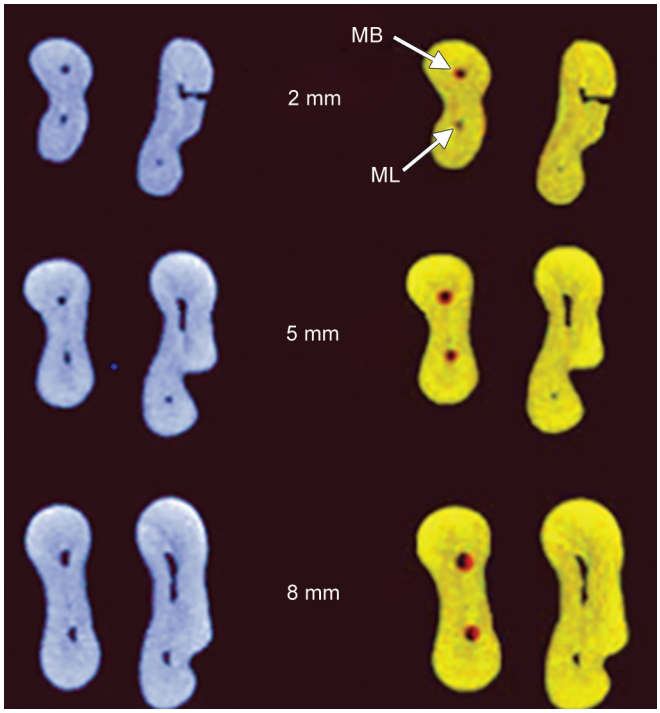

Fig. 2: CBCT imaging of canal centering [pre (green) and post (red) treatment] of the root canals

Statistical Analysis

The observations thus made were noted and statistically compared considering $p < 0.05$ as significant. ANOVA and Mann–Whitney statistical tests were applied to compare the values. IBM SPSS version 20 was used for this study.

Results

Canal Transportation

It was observed that for CT in the file system in continuous rotation RE showed the least mean values compared to PG, as shown in Figure 3. Similarly, in the reciprocating file systems, RM showed the least CT, as shown in Figure 4. When the file systems were compared at the level of 2 mm, 5 mm, and 8 mm from the apex, we observed a statistically significant difference ($p = 0.021$, 0.023, and 0.032), respectively, for CT. Among all four file systems, the least CT was observed with RM followed by RE, and RB whereas PG showed maximum CT as shown in Table 1.

Canal-centering Ability

It was observed that for CAA in the file system in continuous rotation RE showed the maximum mean values than PG, as shown in Figure 5. Similarly, in the reciprocating file systems, RM showed the maximum CCA, as shown in Figure 6. When the file systems were compared at the level of 2 mm, 5 mm, and 8 mm from the apex, we observed a statistically significant difference ($p = 0.045$, 0.040, and 0.037), respectively, for CCA. Among all four file systems, we observed the maximum CCA for RM followed by RB and RE whereas PG showed the least CCA, as shown in Table 2.

Untouched Surface

When the US of the dentin in the canal was considered, we observed that for the rotary file system in continuous rotation RE showed the least mean values as compared with PG, as shown in Table 3. Similarly, in the reciprocating motion file systems, RM showed the least mean values compared with RB, as shown in Table 4. When all four file systems were compared at the level of 5 mm and 8 mm from the apex, we observed a statistically significant difference ($p < 0.001$) for US.

Touched Surface

When the TS of the dentin in the canal was considered, we observed that for the rotary file system in continuous rotation RE showed the maximum mean values compared with PG, as shown in Table 5. Similarly, in the reciprocating motion file systems, RM showed the maximum mean values compared with RB, as shown in Table 6. When all four file systems were compared at the level of 2 mm, 5 mm, and 8 mm from the apex, we observed a statistically significant difference ($p < 0.001$) for TS.

Discussion

Root canal therapy is an intricate and technique-sensitive procedure, multiple factors influence the outcome of the therapy.[13–16] Various file systems are commercially available in the market. These employ the continuous rotation or the reciprocating motion. Each file system has its own advantages and disadvantages.[17–20] Hence in our study we compared four file systems with two novel file systems by comparing the CT, CA, TS, and the US of dentin after instrumentation employing CBCT images.

The least CT and maximum CCA was seen for the R-Motion reciprocating file system, since this file system is relatively new there were only a few studies to compare our results.[5,6] RM exhibits better cutting efficiency and also has a uniform cross-section. Our observations can be compared to the study of Islam et al.,[9] where they compared the ProTaper Gold, RM, and RE in primary curved root canals, they found that the new file systems RM and RE performed better than the ProTaper Gold, which showed more CT. Our findings were inconsistent with the study of Saleh et al.,[21] where they found better CCA for the rotary file systems in continuous rotation than for file systems in reciprocating motion, this could be due to the variation in the design. Similarly, our finding differs from the study of Arruda et al.,[2] in their study they compared the Protaper Next, R25, and Protaper Universal, and found no significant variation.

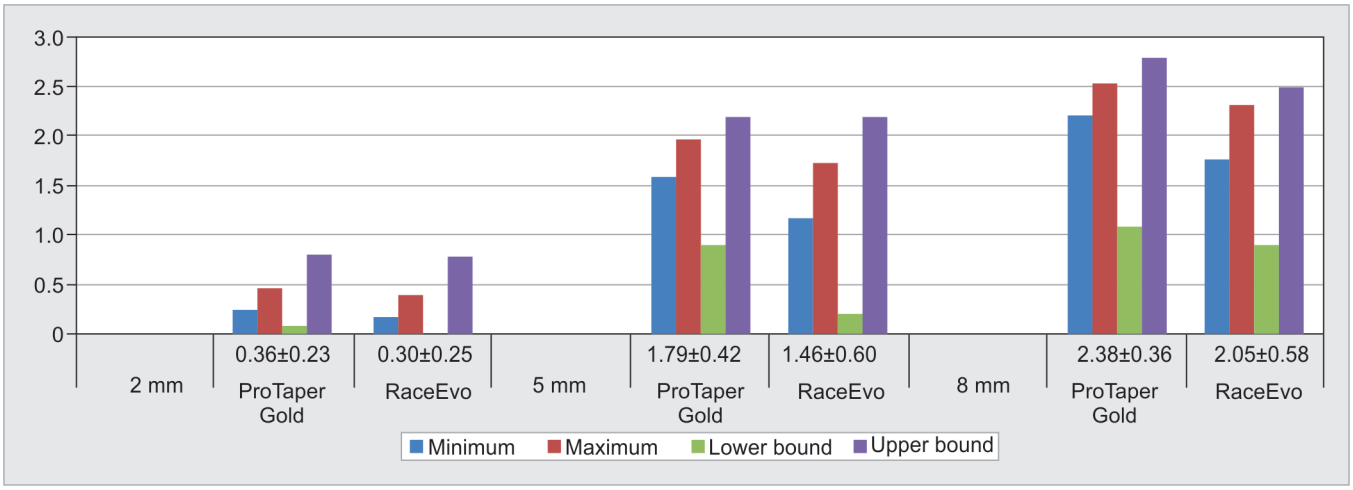

Fig. 3: Comparison for canal transportation among the file systems (ProTaper Gold) and (RaceEvo) in continuous rotation

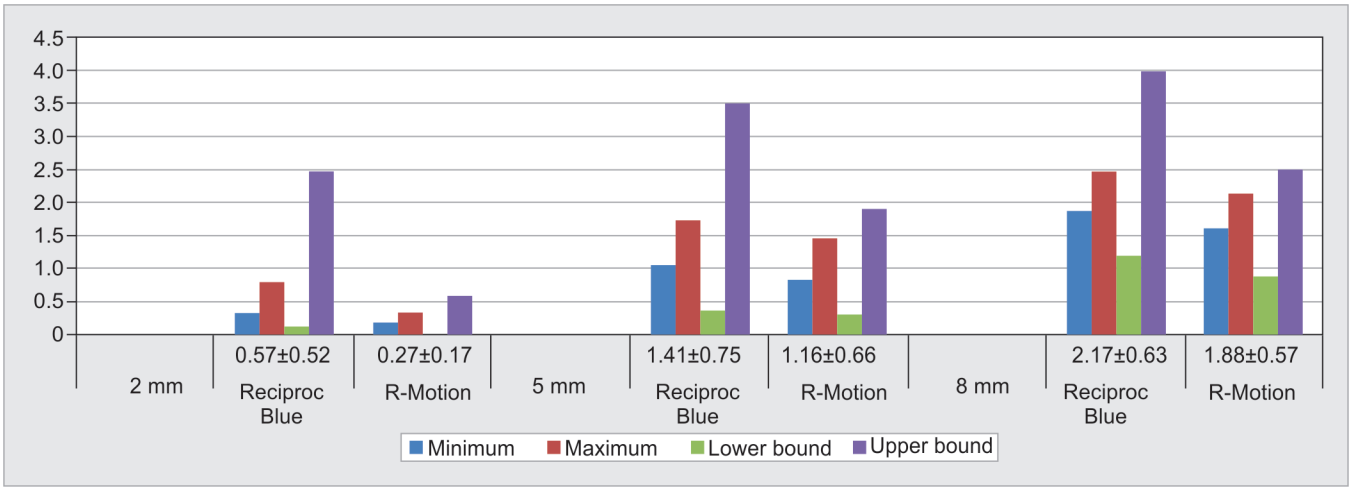

Fig 4: Comparison for canal transportation among the file systems (Reciproc Blue) and (R-Motion) in reciprocating motions

Table 1: Comparison of all the file systems in continuous rotation (ProTaper Gold and RaceEvo) and reciprocating motions (Reciproc Blue and R-Motion) for canal transportation

Level from apex	*Sum of squares*	*df*	*Mean²*	*f*	*p value*
2 mm					
Among groups	1.012	3	0.324	3.500	**0.021**
Within-group	7.32	76	0.111		
Total	9	79			
5 mm					
Among groups	3.65	3	1.366	3.414	**0.023**
Within-group	29.54	76	0.398		
Total	33.98	79			
8 mm					
Among groups	2.78	3	0.789	2.956	**0.032**
Within-group	22.45	76	0.369		
Total	25.58	79			

CT was also seen with RB, this is in contrast to the CBCT study of Hage et al.,[17] in which they found a significant variation for CCA and CT when the glide path was used. It was stated that RB showed superior properties as it uses M-Wire alloy that is considered a clear improvement in terms of flexibility compared to other NiTi alloys.[8,14] Similar observations were made in the study of Keskin et al.;[24] for RB, however, they used resin blocks with S-shaped canals. In the study of Üstün Y et al.,[13] they observed no significant difference for the two file systems Reciproc R25 and ProTaper Universal retreatment (PTUR) instruments, that are contrary to this present study.

Cyclic fatigue is seen better for the reciprocation file systems irrespective of the brands.[6,10,11] RM has improved file tips, sharp cutting edges, cross-sections that are rounded triangular, greater flexibility, and thinner core size. Hence, RM performs better in any type of canal with lesser CT and greater CCA as compared with the PG files.[22–26] Additionally, the variation in transportation levels between RM and PG may be explained by the lesser screwing effect design of RM that affords the endodontist greater control efficiency during the advancement in root canals.[6,14] Berutti et al.[10] stated that reciprocating preserved the original canal anatomy, with not as much modification of the canal curvature compared with the PG files. However, they conducted their study on the training resin blocks instead of natural teeth.

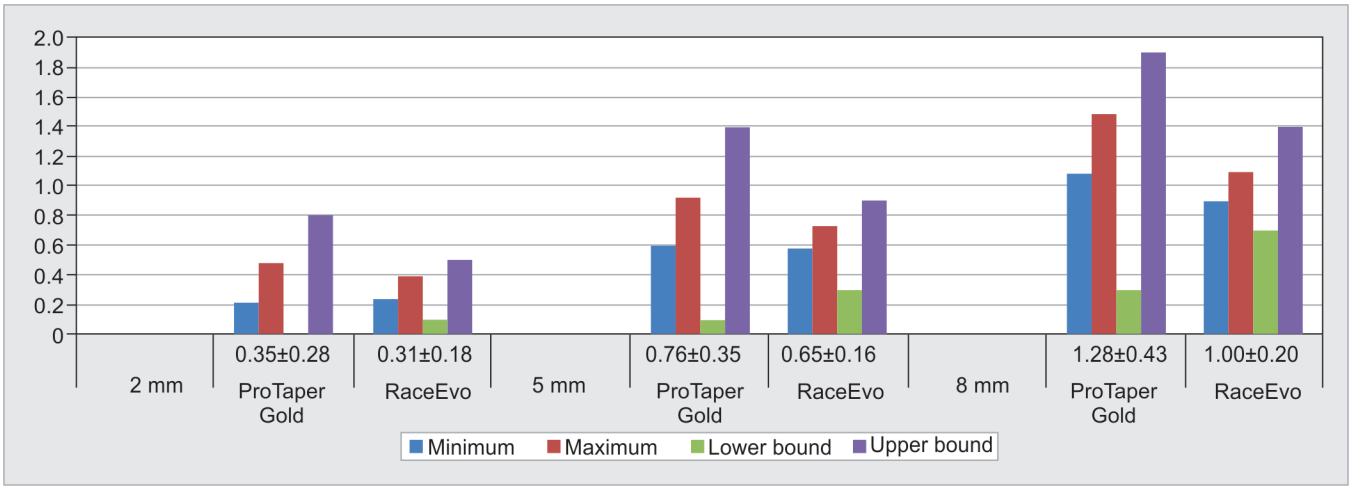

Fig. 5: Comparison of canal-centering ability among the file systems (ProTaper Gold) and (RaceEvo) in continuous rotation

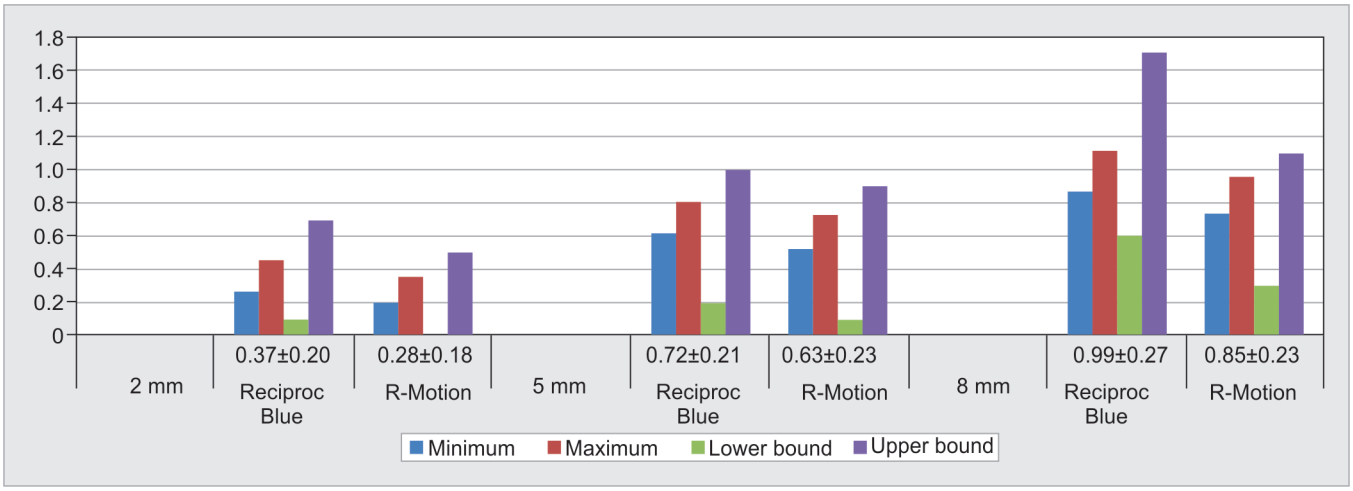

Fig. 6: Comparison for canal-centering ability among file systems (Reciproc Blue) and (R-Motion) in reciprocating motions

Table 2: Comparison of all the file systems in continuous rotation (ProTaper Gold and RaceEvo) and reciprocating motions (Reciproc Blue and R-Motion) for canal centering ability

Level from apex	*Sum of squares*	*df*	*Mean²*	*f*	*p value*
2 mm					
Among groups	2.014	2	0.223	3.589	**0.045**
Within-group	6.896	77	0.158		
Total	9	79			
5 mm					
Among groups	4.753	2	1.302	3.42	**0.040**
Within-group	28.357	76	0.345		
Total	33.0	78			
8 mm					
Among groups	2.861	2	0.898	2.53	**0.037**
Within-group	21.842	76	0.223		
Total	24.593	78			

Table 3: Comparison of the untouched surfaces of the canal at various levels among the file systems (ProTaper Gold) and (RaceEvo) in continuous rotation

Level from apex	*File system*	*Mean% ± SD*	*p value*
2 mm	ProTaper Gold	25 ± 2.88	**0.152**
	RaceEvo	23 ± 2.10	
5 mm	ProTaper Gold	41 ± 1.48	**0.001**
	RaceEvo	35 ± 2.73	
8 mm	ProTaper Gold	29 ± 1.56	**0.001**
	RaceEvo	28 ± 2.12	

For the untouched surface of dentin, the least mean values were seen for the RM. The maximum untouched walls were seen for ProTaper gold whereas for the RM file system TS was maximum. The remaining dentin after the preparation is crucial for the fracture resistance of the canal. As our files systems have been relatively recently introduced, we found no studies to compare our results. Zuolo ML et al.[27] stated that BioRace shows more untouched canal areas. BioRace is a continuous rotary file system that is comparable to ProTaper Gold used in our study. The dentin surfaces that are not touched may lodge the bacterial biofilms. This may cause relapse of the infection in the RCT treated

Table 4: Comparison of the **untouched** surfaces of the canal at various levels among the file systems (Reciproc Blue) and (R-Motion) in reciprocating motions

Level from apex	*File system*	*Mean% ± SD*	*p value*
2 mm	R-Motion	20 ± 2.17	**0.059**
	Reciproc Blue	22 ± 1.10	
5 mm	R-Motion	34 ± 1.16	**0.001**
	Reciproc Blue	36 ± 1.38	
8 mm	R-Motion	21 ± 2.00	**0.001**
	Reciproc Blue	24 ± 2.47	

Table 5: Comparison of the **touched** surfaces of the canal at various levels among the file systems (ProTaper Gold) and (RaceEvo) in continuous rotation

Level from apex	*File system*	*Mean% ± SD*	*p value*
2 mm	ProTaper Gold	37 ± 2.88	**0.001**
	RaceEvo	40 ± 2.10	
5 mm	ProTaper Gold	40 ± 1.48	**0.001**
	RaceEvo	42 ± 2.73	
8 mm	ProTaper Gold	48 ± 1.56	**0.001**
	RaceEvo	49 ± 2.12	

Table 6: Comparison of the **touched** surfaces of the canal at various levels among the file systems (Reciproc Blue) and (R-Motion) in reciprocating motions

Level from apex	*File system*	*Mean% ± SD*	*p value*
2 mm	R-Motion	45 ± 2.17	**0.001**
	Reciproc Blue	39 ± 1.1	
5 mm	R-Motion	49 ± 1.16	**0.001**
	Reciproc Blue	41 ± 1.38	
8 mm	R-Motion	55 ± 2.00	**0.001**
	Reciproc Blue	54 ± 2.47	

tooth and failure. The untouched dentinal surfaces in our study ranged from 20% to 41% at different regions of the canal. The reciprocating file system has a file design that better adapts to the canal walls.[28,29]

The reciprocating system has better taper than hand files. This will aid in better touch of the walls in the canal. The volume of the touched surface of the canal depends on the tooth anatomy and also the instrument cross-section, taper, metal properties, and file size. The motion of the file system also influences the outcome as the reciprocating system files have a greater taper they touch most of the canal surface.[30–31]

Some limitations are noted in this present study, the canal curvatures of the extracted/sample teeth that were used in the study were not uniform, although utmost care was taken to exclude extremely curved canals. The results of this study might have been also a factor of dexterity of the investigator.

This is one of the first studies to compare the novel NiTi rotary file systems, namely: RaceEvo and R-Motion compared with ProTaper Gold and Reciproc Blue. Further studies are recommended to corroborate the findings of this present study.

Conclusion

Within the limits of the study, R-Motion rotary file system exhibited better CCA and lesser CT due to its improved cutting efficiency down to the apex, which is essential for the removal of the infected dentinal surface while preserving the dentin of the root canal walls and also exhibiting lesser stress on dentin; hence it can be recommended for its application in endodontic treatment. The newly introduced R-Motion and RaceEvo rotary file systems showed better root canal preparations compared to Reciproc blue and ProTaper Gold and could be used as a reliable alternative as it maintains the original canal anatomy of the root canal system. Nevertheless, further studies are required to support the findings of this present study.

Acknowledgment

The author would like to thank the Deanship of Scientific Research, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia, for their financial support for conducting this study.

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