

Analysis of Root Canals Prepared By Reciprocation Or Continuous Rotation

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Abstract: Objective: A new preparation technique using a single file was introduced based on the reciprocating movement. The present study was designed to compare the shaping ability of different rotary instruments operated either with continuous rotation movement or with reciprocating movement. **Methods:** Thirty-five extracted mandibular molars with 2 separate mesial canals and a canal curvature of more than 20° were randomly assigned to one of five groups (seven teeth each). Group1, rotary conventional preparation using full sequence ProTaper. Group2, reciprocation preparation using one ProTaperF2. Group3, rotary conventional preparation using full sequence BioRace. Group4, reciprocation preparation using one BioRace BR3. Group5, reciprocate preparation using one Reciproc R25. Specimens were scanned before and after root canal preparation using micro-computed tomography system. Cross-sectional images of each canal were obtained at 2,4,6, and 8mm from the apex. The following parameters were assessed: change in canal volume, change in perimeter, change in surface area, canal transportation, and centering ratio. **Results:** There were no statistically significant differences between the shaping of root canal by ProTaper F2 or BioRace BR3 using single file reciprocating technique or conventional full sequence in continuous rotation regarding the studied anatomical outcomes. Single file Reciproc R25 showed significantly higher cutting ability compared to single file ProTaper F2, single file BioRace BR3, and full sequence BioRace, but no difference in the amount of canal transportation or centering ability between Reciproc R25 and other groups. **Conclusion:** Shaping outcomes with single file preparation techniques and conventional full sequence preparation technique were similar. Reciproc R25 showed significantly higher cutting ability compared to all other systems.

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1. Introduction

Over the last decade, nickel titanium have become part of armamentarium of root canal therapy and been increasingly used by generalists and specialists to facilitate the cleaning and shaping of root canals. In an effort to improve preparation safety and quality, new instrument designs and advanced preparation techniques have been developed, one of which is the single file preparation concept. Yared in 2008 introduced a novel canal preparation technique using a single file ProTaperF2 based on the reciprocating movement of this instrument. Recent *in-vitro* studies which evaluated different mechanical aspects of this technique reported promising findings regarding apical extrusion of debris, improved cyclic fatigue life, cutting efficiency and shaping ability, except for the reduced cleaning ability on oval canals, where ProTaper F2 left more residual pulp tissue at the apical 3mm (De-Deus *et al.*, 2010a; De-Deus *et al.*, 2010b; De-Deus *et al.*, 2010c; You *et al.*, 2010; Paque *et al.*, 2011). Afterward Reciproc and Wave One were introduced as new rotary systems utilizing the single file technique.

The use of single file technique has many advantages: first, it reduces instrument fatigue. Both F2 ProTaper and R25 Reciproc showed improved resistance to flexural fatigue and cyclic fatigue when operated in reciprocating movement. Second, reciprocating movement reduces instrumentation time. Third, single file technique provides simplicity, cost effectiveness and safety. Fourth, it eliminates possible side effect of debris and protein contamination (Yared, 2008; De-Deus *et al.*, 2010c; You *et al.*, 2010; Paque *et al.*, 2011; Burklein *et al.*, 2012; Plotino *et al.*, 2012; Gavini *et al.*, 2012). However, there is a need for extensive laboratory and clinical studies of several parameters as transportation, centering ability, incidence of instrument fracture and working safety.

The present study was designed to compare the shaping ability of different rotary instruments operated either with continuous rotation movement or with reciprocating movement. High definition micro-computed tomography (μ CT) was used to compare the following parameters: changes in canal volume, changes in canal perimeter, change in surface area, canal transportation, and centering ability. The null

hypothesis was that there is no difference in root canal shaping ability between continuous rotations and reciprocating movement kinematic regarding any of the investigated outcomes.

2. Material and Methods

Specimen Selection and Preparation

Thirty-five extracted human mandibular molars were selected from a collection of freshly extracted teeth. After extraction, teeth were stored in 0.1% thymol until use. Inclusion criteria stipulated that the tooth had intact mature root apices, the mesial root canals had two orifices and two foramina, and in addition the root canals had a curvature more than 20°. Caries and restorations were removed and a standard access cavity achieved by using Endo-Access burs (Dentsply Maillefer, Ballaigues, Switzerland). Apical patencies of all mesial root canals were confirmed with a K-File no. 10 (Dentsply Maillefer). Standardized digital radiographs (Kodak RVG 6100 Digital Radiography System, USA - Focus, Instrumentarium Imaging, Finland) were taken in a mesiodistal and buccolingual dimensions before the instrumentation. The radiographs in the mesiodistal dimension were taken to confirm the presence of two distinct and separate root canals. K-files no. 10 were inserted into the buccal and lingual canals to assess the degree of root canal curvatures in the buccolingual dimension (Pruett *et al.*, 1997). The working length (WL) was measured until the no. 10 K-File tip was visible at the apical foramen minus 1 mm and then standardized at 18 mm by adding composite resin (Tetric® Ceram, Ivoclar Vivadent Inc, USA) to the crown of the tooth or reducing the occlusal surface. The specimens were randomly assigned into five groups of seven teeth each. Randomization was stratified to ensure that mesiobuccal and mesiolingual canals were distributed equally to each group. The homogeneity of the five groups with respect to the canal curvature was examined using analysis of variance, and all groups were well balanced.

µCT Pre-instrumentation Scanning Procedures

Before scanning, the specimens were mounted with their flat occlusal surface against a custom made resin disc to allow reproducible orientation in the pre- and post instrumentation µCT scans (SkyScan 1172, SkyScan, Aartselaar, Belgium). Scanning parameters and reconstruction settings were as follows: image pixel size: 17.27 µm, source: 100KV/100 µA, rotation: 360°, rotation step: 0.6°, averaging by frames: 2, filter Al+Cu 1mm: On.

Root Canal Preparation

All canals were manually pre-flared with hand instruments Flexo files No. 10, 15 and 20 (Dentsply Maillefer) (Patino *et al.*, 2005). For coronal flaring,

canals were stepped-down using Gates-Glidden burs (Dentsply Maillefer) nos. 4 through 2 sequentially. In preparation of the coronal 3 mm, each bur was carried about 1 mm into the root canals (Peters *et al.*, 2001). Root canals were copiously irrigated throughout the instrumentation using 5ml 2.5% NaOCl by a G30 nickel titanium irrigation needle (SybronEndo, CA, USA). In addition, a lubricant (MD-Chelcream, Meta Biomed Co., Ltd, Korea) was used during instrumentation.

Group 1: Canal Preparation with ProTaper Universal Instruments (Dentsply Maillefer, Ballaigues, Switzerland) in Continuous Rotation

Rotary instrumentation was accomplished according to the manufacturer instructions using S1, SX, S2, F1 and F2 in a torque-controlled system (ATR Tecnika, Pistoia, Italy) at 250 rpm as follows: (1) S1 file (two third of the WL); (2) SX file was used to one half of the WL; (3) S1 and S2 file was used to the full WL; and (4) F1 and F2 files were used to the full WL. All shaping files (SX, S1 and S2) were used in a brushing motion, away from the furcation area. As soon as they reached the WL, all finishing files (F1 and F2) were withdrawn from the root canal.

Group 2: Canal Preparation with Single ProTaper F2 Instrument (Dentsply Maillefer, Ballaigues, Switzerland) in Reciprocating Movements

The root canal preparation was performed with one ProTaper F2 nickel titanium rotary instrument in clockwise (CW) and counterclockwise (CCW) reciprocating movements. The setting of the ATR Tecnika motor was four-tenths and two-tenths of a circle with 400-rpm rotational speed. During preparation the instrument was used with slow pecking motions and light apical pressure. If some resistance was felt that would have required more apical pressure, the instrument was removed, and the flutes were cleaned in a NaOCl soaked gauze, this was repeated until WL was reached (Yared, 2008).

Group 3: Canal Preparation with BioRace Instruments (FKG Dentaire, Switzerland) in Continuous Rotation

Rotary instrumentation was accomplished according to the manufacturer instructions using BR0, BR1, BR2 and BR3 in a torque-controlled system (ATR Tecnika, Pistoia, Italy) at 250 rpm as follows: (1) The BR0 (#25/0.08) was used in the coronal aspect of the canal with 4 steady strokes, (2) BR1 (#15/0.05), (3) BR2 (#25/0.04), (4) BR3 (#25/0.06) instruments were used to working length.

Group 4: Canal Preparation with Single BioRace BR3 Instrument (FKG Dentaire, Switzerland) in Reciprocating Rotation

Root canal preparation was performed with one BioRace BR3 nickel titanium rotary instrument in CW and CCW reciprocating movement as in Group 2.

Group 5: Canal Preparation with Single ReciprocR25 Instrument (RECIPROC, VDW, Germany) in Reciprocating Movement

The root canal preparation was performed according to the manufacturer instructions using one ReciprocR25 Ni-Ti rotary instrument in CW and CCW movement. The R25 was used in a torque-controlled system with predetermined setting (VDW, SILVER, VDW, Germany). R25 instrument was used in a slow in-and-out pecking motion. The in-and-out movements' amplitude did not exceed 3 mm and applied with a very light pressure. The instrument was cleaned in the interim stand after 3 pecks with NaOCl soaked gauze.

All Groups: After instrumentation all canals were irrigated with 5 ml of 17% ethylenediaminetetraacetic acid, followed by 5 mL of 2.5% NaOCl by using a 30- gauge irrigating tip (SybronEndo, CA, USA).

μ CTPos-t instrumentation Scanning Procedures and Evaluation

After preparation the specimens were repositioned against the same acrylic disc on the sample base and scanned under the same parameters and settings used in the first scan. All uninstrumented and instrumented cross-section images were studied by Data Viewer software version 1.4.2.2 (SkyScan) and the images at distance 2, 4, 6, 8 and 10mm from the most apical point of each specimen were selected for later process. The cross-section (preinstrumented and postinstrumented) images were studied and assessed in CT analyzing software version 1.11.8.0+. Subsequently the quantitative assessments of matched root canals were evaluated.

Evaluation Parameters

Changes in Root Canal Volume: The volume of interest was limited to 10 mm from the apical foramen (Peters *et al.*, 2000; Moore *et al.*, 2009). The changes in volume were calculated by subtracting the scores for preinstrumentation canals from those recorded for postinstrumentation counterparts.

Changes in Perimeter: The difference between root canal cross-section perimeter after and before instrumentation at 2, 4, 6 and 8mm sections was calculated in order to assess the peripheral dentin removal (Loizides *et al.*, 2007).

Changes in Area: The difference between root canal cross-section area after and before instrumentation at 2, 4, 6 and 8mm sections was calculated to evaluate the root canal enlargement (Loizides *et al.*, 2007).

Evaluation of Canal Transportation: To compare the extent and direction of canal transportation, a technique developed by (Gambill *et al.*, 1996) was used. The following formula was used for the calculation of transportation:

$$|(M1-M2)-(D1-D2)|$$

Where (M1) is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, (D1) is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented canal, (M2) is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, (D2) is the shortest distance from the distal edge of the root to the distal edge of the instrumented canal. A result of 0 from the canal transportation formula indicates no canal transportation. The direction of transportation was assessed from the results obtained for the canal transportation of each specimen. A negative result indicated transportation toward the distal side, a positive result meant transportation toward the mesial side.

Evaluation of Centering Ability: The mean centering ratio is a measure of the ability of the instrument to stay centered in the canal (Gambill *et al.*, 1996). This ratio was calculated for each section using the following ratio:

$$(M1-M2) \text{ to } (D1-D2) \text{ or } (D1-D2) \text{ to } (M1-M2)$$

The numerator for the centering ratio formula was the smaller of the two numbers (M1-M2) or (D1-D2), if these numbers were unequal. A result of 1 indicated perfect centering ability and the closer the result to zero the worse the ability of the instrument to keep itself in the canal central axis.

The duration of the root canal preparation was recorded using stopwatch; instrument changing, irrigation, and intermediate cleaning of the instrument were counted.

Statistical Analysis

Data of changes in volume, changes in perimeter, change in surface area, canal transportation and centering ration were normally distributed as determined by Kolmogorov-smirnov test and Shapirowilk test. Statistical analysis were performed Analysis of Variance (ANOVA) test using SPSS software package (Version 16, SPSS Inc., Chicago, Illinois, USA), to compare the change in volume, change in perimeter, change in surface area, canal transportation and centering ratio. When the changes were statistically significant, further analysis was performed with Pairwise Multiple comparison procedure (Tukey HSD, Games-Howell test). The alpha - type error set at ≤ 0.05 .

3. Results

The mean canal angle was $40.43^\circ \pm 9.67^\circ$ with no significant difference between groups and the mean radius was $5.94\text{mm} \pm 1.26\text{mm}$. Three canals were lost, two canals in Group 2 due to material loss and one canal in group 5 due to perforation. No loss of the working length, blockage or instrument fracture occurred.

Changes in Canal Volume

Means and standard of deviations (SD_s) of the canal volume difference between volume after and before instrumentation are shown in Table 1. A statistically significant difference between the five groups was observed ($p < 0.001$). Reciproc R25 removed significantly greater dentin volume in comparison to ProTaper F2, BioRace BR3 and full sequence BioRace ($p < 0.05$). No significant difference found between other groups (Graph 1).

Changes in Perimeter

Means and SD_s of the difference between perimeter before and after instrumentation for each cross section are shown in Table 2. A statistically significant difference between the groups was observed at 2, 4 and 6mm cross sections ($p \leq 0.05$). Reciproc R25 removed significantly greater amount of peripheral dentin in comparison to BioRace BR3 at 2, 4 and 6mm cross sections and full sequence BioRace at 4 and 6mm cross sections. BioRace BR3

resulted in less peripheral dentin removal in comparison to ProTaper F2 and full sequence BioRace at 6mm cross section ($p < 0.05$). No significant difference found between other groups (Graph 2).

Changes in Surface Area

Means and SD_s of the difference between the surface area before and after instrumentation for each cross section are shown in Table 3. A statistically significant difference was observed at 2, 4, 6mm cross sections ($p \leq 0.002$). Reciproc R25 resulted in greater canal enlargement in comparison to ProTaper F2 at 2 and 4mm cross sections, BioRace BR3 at 2, 4 and 6mm cross sections, and full sequence BioRace at 4 and 6mm cross sections. Full sequence ProTaper resulted in significantly greater canal enlargement in comparison to BioRaceBR3 at 2mm cross section ($p \leq 0.05$). No significant difference found between other groups (Graph 3).

TABLE 1. The Mean Values and Standard Deviations of the Root Canal Volume Difference Between Volume After and Before Instrumentation.

Motion type	Group	N	Mean (mm^3)	Std.Deviation
Continuous rotation	Full sequence BioRace	14	1.531	.361
	Full sequence ProTaper	14	1.960	.534
Reciprocating rotation	Single file BioRace (BR3)	14	1.508	.203
	Single file ProTaper (F2)	12	1.555	.520
	Single file Reciproc (R25)	13	2.137	.372
	Total	67	1.738	.478

GRAPH 1. The Mean of the Root canal Volume Difference Between Volume After and Before Instrumentation.

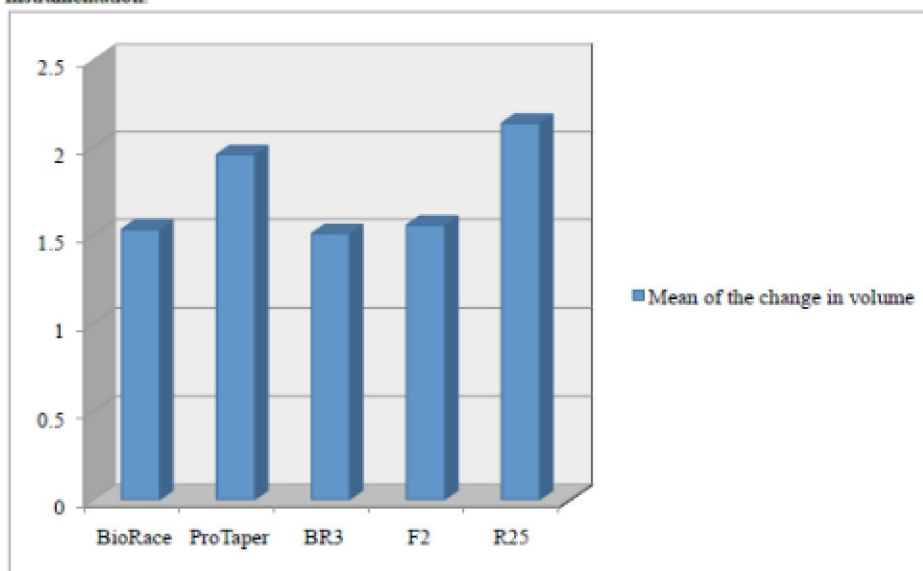


TABLE 2. The Mean Values and Standard Deviations of the Difference Between the Perimeter After and Before Instrumentation for Each Cross Section.

Perimeter after-Perimeter before					
Cross section	Motion type	Group	N	Mean (mm)	Std. Deviation
Cross section at 2mm	Rotation	Full sequence BioRace	14	.501	.330
		Full sequence ProTaper	14	.583	.304
	Reciprocating	Single file BioRace (BR3)	14	.358	.198
		Single file ProTaper (F2)	12	.459	.191
		Single file Reciproc (R25)	13	.641	.199
		Total	67	.508	.266
Cross section at 4mm	Rotation	Full sequence BioRace	14	.533	.310
		Full sequence ProTaper	14	.823	.249
	Reciprocating	Single file BioRace (BR3)	14	.547	.363
		Single file ProTaper (F2)	12	.710	.312
		Single file Reciproc (R25)	13	.901	.252
		Total	67	.700	.327
Cross section at 6mm	Rotation	Full sequence BioRace	14	.886	.376
		Full sequence ProTaper	14	.926	.338
	Reciprocating	Single file BioRace (BR3)	14	.521	.240
		Single file ProTaper (F2)	12	.901	.414
		Single file Reciproc (R25)	13	1.177	.323
		Total	67	.877	.393
Cross section at 8mm	Rotation	Full sequence BioRace	14	.987	.377
		Full sequence ProTaper	14	.974	.340
	Reciprocating	Single file BioRace (BR3)	14	.761	.397
		Single file ProTaper (F2)	12	1.077	.447
		Single file Reciproc (R25)	13	1.180	.3758
		Total	67	.991	.401

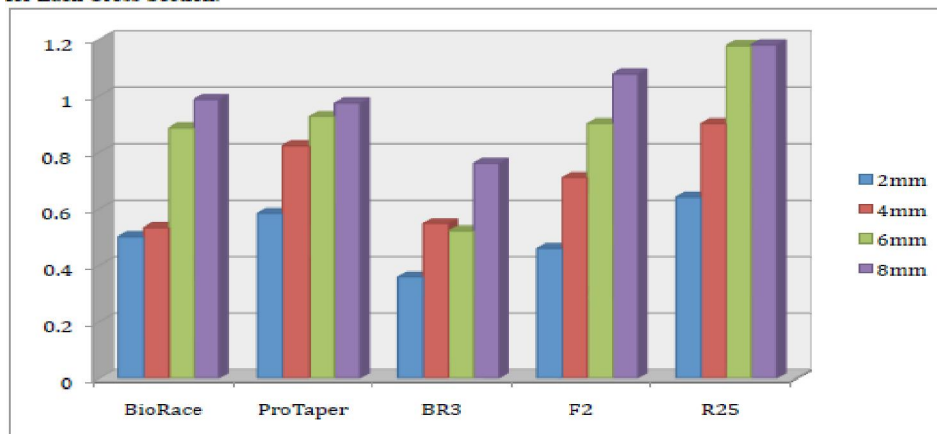
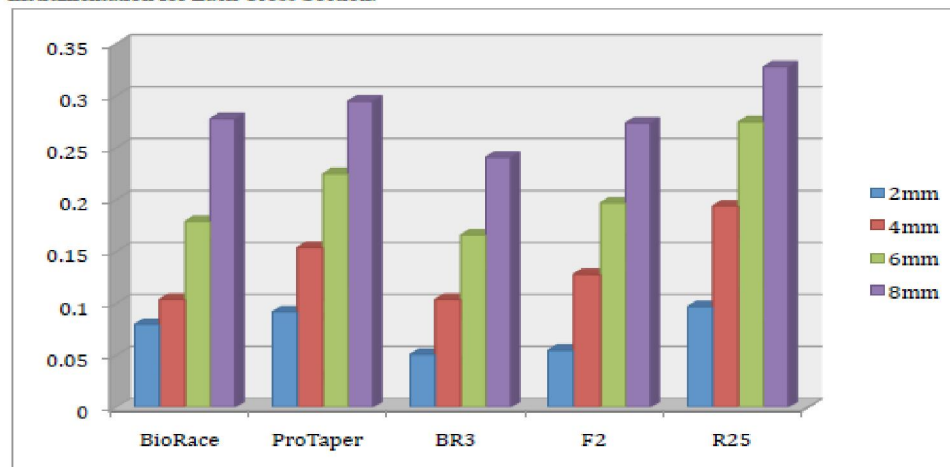
GRAPH 2. The Mean Values of the Difference Between the Perimeter After and Before Instrumentation for Each Cross Section.**GRAPH 3.** The Mean Values of the Difference Between the Surface Area After and Before Instrumentation for Each Cross Section.

TABLE 3. The Mean Values and Standard Deviations of the Difference Between the Surface Area After and Before Instrumentation for Each Cross Section.

Surface area after- Surface area before					
Cross section	Motion type	Group	N	Mean (mm ²)	Std. Deviation
Cross section at 2mm	Rotation	Full sequence BioRace	14	.080	.041
		Full sequence ProTaper	14	.092	.046
	Reciprocating	Single file BioRace (BR3)	14	.051	.028
		Single file ProTaper (F2)	12	.055	.027
		Single file Reciproc (R25)	13	.097	.030
		Total	67	.075	.040
Cross section at 4mm	Rotation	Full sequence BioRace	14	.104	.047
		Full sequence ProTaper	14	.154	.042
	Reciprocating	Single file BioRace (BR3)	14	.104	.066
		Single file ProTaper (F2)	12	.128	.046
		Single file Reciproc (R25)	13	.194	.0297
		Total	67	.136	.0576
Cross section at 6mm	Rotation	Full sequence BioRace	14	.179	.088
		Full sequence ProTaper	14	.225	.068
	Reciprocating	Single file BioRace (BR3)	14	.166	.051
		Single file ProTaper (F2)	12	.197	.077
		Single file Reciproc (R25)	13	.275	.057
		Total	67	.208	.078
Cross section at 8mm	Rotation	Full sequence BioRace	14	.278	.079
		Full sequence ProTaper	14	.295	.064
	Reciprocating	Single file BioRace (BR3)	14	.241	.066
		Single file ProTaper (F2)	12	.274	.106
		Single file Reciproc (R25)	13	.328	.078
		Total	67	.283	.082

TABLE 4. The Mean Transportation Values and Standard Deviations.

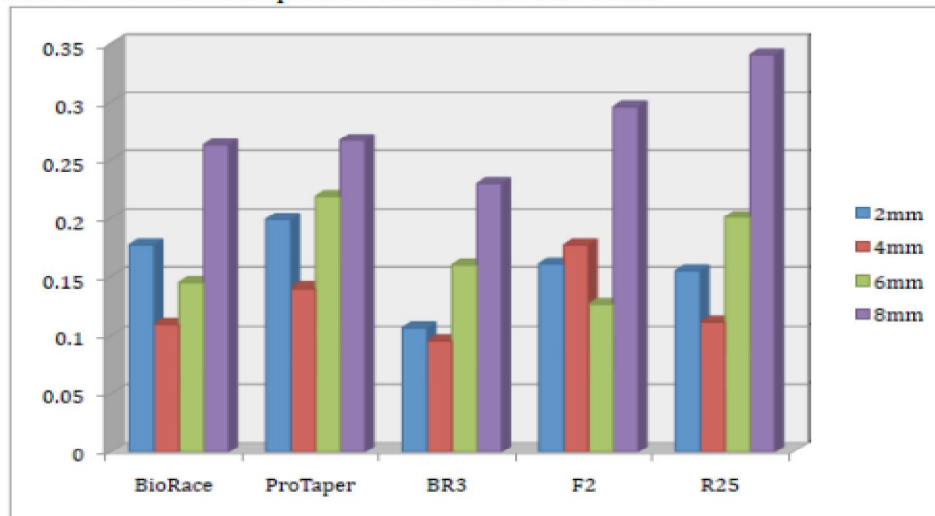
Mean Transportation					
Cross section	Motion type	Group	N	Mean (mm)	Std. Deviation
Cross section at 2mm	Rotation	Full sequence BioRace	14	.177	.190
		Full sequence ProTaper	14	.199	.116
	Reciprocating	Single file BioRace (BR3)	14	.107	.067
		Single file ProTaper (F2)	12	.161	.082
		Single file Reciproc (R25)	13	.155	.095
		Total	67	.160	.120
Cross section at 4mm	Rotation	Full sequence BioRace	14	.110	.071
		Full sequence ProTaper	14	.141	.105
	Reciprocating	Single file BioRace (BR3)	14	.096	.050
		Single file ProTaper (F2)	12	.177	.135
		Single file Reciproc (R25)	13	.112	.078
		Total	67	.126	.093
Cross section at 6mm	Rotation	Full sequence BioRace	14	.145	.128
		Full sequence ProTaper	14	.219	.114
	Reciprocating	Single file BioRace (BR3)	14	.160	.099
		Single file ProTaper (F2)	12	.127	.132
		Single file Reciproc (R25)	13	.201	.133
		Total	67	.171	.123
Cross section at 8mm	Rotation	Full sequence BioRace	14	.263	.093
		Full sequence ProTaper	14	.267	.114
	Reciprocating	Single file BioRace (BR3)	14	.230	.176
		Single file ProTaper (F2)	12	.296	.156
		Single file Reciproc (R25)	13	.341	.185
		Total	67	.278	.149

Canal Transportation

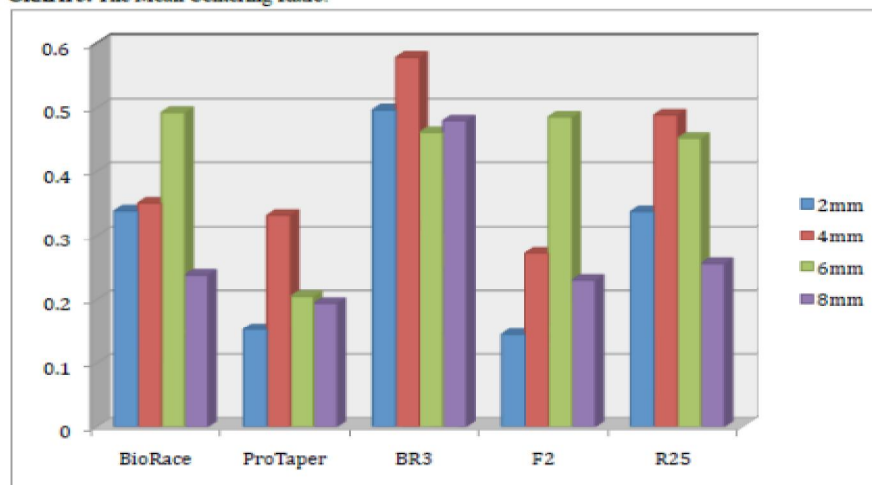
Mean values and SDs of transportation values shown in Table 4. No statistically significant was observed between groups at all cross sections ($p > 0.05$). All rotary nickel titanium instruments tended to transport the original path in the same direction. At 2 and 4mm cross sections transportation was toward the outer curve, at 6 and 8mm cross section transportation was toward the danger zone (Graph 4).

Centering Ratio

Mean values and SDs of centering ration are shown in table 5. A statistically significant difference was observed between BioRace BR3, and both ProTaper F2at 2 and 4 mm, and full sequence ProTaper at 2 and 8mm cross sections ($p \leq 0.05$). No significant difference found between other groups (Graph 5).

GRAPH 4. The Mean Transportation Values for Each Cross Section.**TABLE 5.** The Mean Centering Ratio Values and Standard Deviations.

Centering Ratio					
Cross section	Motion type	Group	N	Mean	Std. Deviation
Cross section at 2mm	Rotation	Full sequence BioRace	14	.339	.290
		Full sequence ProTaper	14	.153	.231
	Reciprocating	Single file BioRace (BR3)	14	.497	.284
		Single file ProTaper (F2)	12	.145	.189
		Single file Reciproc (R25)	13	.338	.320
		Total	67	.298	.292
Cross section at 4mm	Rotation	Full sequence BioRace	14	.351	.262
		Full sequence ProTaper	14	.332	.337
	Reciprocating	Single file BioRace (BR3)	14	.580	.197
		Single file ProTaper (F2)	12	.272	.257
		Single file Reciproc (R25)	13	.489	.285
		Total	67	.408	.287
Cross section at 6mm	Rotation	Full sequence BioRace	14	.493	.274
		Full sequence ProTaper	14	.205	.228
	Reciprocating	Single file BioRace (BR3)	14	.462	.241
		Single file ProTaper (F2)	12	.486	.400
		Single file Reciproc (R25)	13	.453	.276
		Total	67	.417	.299
Cross section at 8mm	Rotation	Full sequence BioRace	14	.238	.166
		Full sequence ProTaper	14	.194	.239
	Reciprocating	Single file BioRace (BR3)	14	.480	.320
		Single file ProTaper (F2)	12	.230	.274
		Single file Reciproc (R25)	13	.256	.166
		Total	67	.281	.256

GRAPH 5. The Mean Centering Ratio.

4. Discussion

The aim of the study was to evaluate and compare the shaping ability of different nickel titanium instruments operated either at continuous or reciprocating rotation in curved root canals of extracted human teeth.

The use of extracted teeth provides standardization to a certain extent and provides conditions similar to clinical situation. Mesial root canals of mandibular molars have anatomical characteristics, which makes them suitable to compare mechanical alternation produced by different instrumentation techniques. Mesial canals are often curved in two planes. In addition, if these canals were separated, their original shape tends to be similar (Williamson *et al.*, 2009; Paque *et al.*, 2011). In addition to that, several attempts have been made in the present study to ensure comparability of the five experimental groups. Therefore, all teeth included had no double curvature; the teeth were also balanced with respect to the angle of the canal curvature.

In the present investigation, Pro Taper (F2) and BioRace (BR3) instruments were selected mainly because of their resemblance in cross section. Both of them have a triangular cross section that enables them to cut in clockwise and counter clockwise direction. The full sequence of each system was selected for comparison. Reciproc was selected because it represents the group of new instruments that utilizes the single file technique.

All the instrumentation schemes tested caused canal transportation, although there were no significant differences between them. All the instrumentation schemes tested transported the canal toward the furcation area at the coronal cross sections and toward the outer curve at the apical cross section. This finding is in agreement with others (Weine *et al.*, 1975; Weine *et al.*, 1976; Al-Omari *et al.*, 1992; Ayar & Love, 2004). Overall, the least transportation occurred with the single file BioRace (BR3) and the full sequence BioRace. The reduced transportation ability associated with the BioRace (BR3) operated either in continuous or reciprocating rotation may be attributed to less taper, increased flexibility, and decreased cutting ability. In terms of centering ability, none of the tested instrumentation schemes showed a perfect centering ability when preparing moderately to severely curved root canals.

On the literature, there are few studies evaluated reciprocating rotation in comparison to the continuous rotation or evaluated different single file instruments. Some of these studies are in agreement with our findings regarding the similar ability of single file technique and the full sequence technique in maintaining the original canal anatomy (Paque *et al.*, 2011; You *et al.*, 2011; Burklein *et al.*, 2012). Other

studies reported that single file technique used in reciprocating rotation enhanced the canal centering ability (Franco *et al.*, 2011; Berutti *et al.*, 2012).

A similarity was observed between shaping of root canal to ProTaper F2 or BioRace BR3 by using single file in reciprocating technique or conventional full sequence in continuous rotation regarding the anatomical outcomes that were investigated. This similarity arises because the final canal enlargement is greatly determined by the final file reach to the working length.

The Reciproc R25 showed a greater cutting ability than the single file ProTaper F2, the single file BioRace (BR3), and the full sequence BioRace, but no difference was noted in the amount of transportation or the centering ratio between the Reciproc (R25) and the other groups. These findings may be attributed to the reciprocating rotation, the instrument design, the cutting direction or the CCW and CW rotation angles.

One of the limitations of the present study is the high cost and the time consuming scanning and reconstruction procedures, which limited the sample number, in addition to the specific inclusion criteria used in the present study. More studies are required to determine the effect of different cutting angulations, cutting directions on the shaping ability of single nickel titanium instrument operated in reciprocating rotation.

5. Conclusion

The single file technique operated in reciprocating rotation showed a similar shaping quality to the full sequence technique operated in continuous rotation with reduced preparation time. Therefore, reciprocating rotation might be a good alternative method for root canal shaping.

The current study revealed similarity between the shaping of the root canal with the ProTaper (F2) or the BioRace (BR3) using a single file reciprocating technique or the conventional full sequence in continuous rotation regarding the anatomical outcomes that were investigated.

The increased tendency for dentin removal observed with Reciproc (R25) did not affect the canal transportation or the centering ability.

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