ORIGINAL RESEARCH

Comparative Evaluation of Root Canal Centering Ability of ProTaper, Mtwo, WaveOne, and Reciproc Using Cone-beam Computed Tomography: *In Vitro* Study

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Abstract

Aim: To compare the centering ability of rotating (ProTaper and Mtwo) and reciprocating (WaveOne and Reciproc) file systems using cone-beam computed tomography (CBCT).

Materials and methods: Eighty extracted human mandibular molars with curvature within 15–45° were selected and randomly divided into four groups ($n = 20$): group I (ProTaper), group II (Mtwo), group III (WaveOne), and group IV (Reciproc). The selected teeth were arranged in a template, and pre-instrumentation and post-instrumentation CBCT scans were taken using Kodak Carestream CS 9300 machine. The centering ability was measured in four planes namely, at furcation, 3 mm apical to furcation (coronal), 6 mm apical to furcation (middle), and 3 mm coronal to the apex (apical), wherein dentin thickness was measured from pre- and post-instrumentation CBCT scans and recorded for each canal (mesiobuccal and mesiolingual) separately and statistically analyzed.

Results: Mtwo and Reciproc remained better centered followed by WaveOne and least by ProTaper in different-level comparisons. In the mesiodistal dimension (MD) at the 3 mm, 6 mm, and 3 mm apical level, Mtwo and Reciproc showed better centering, meanwhile, in the buccolingual dimension, only in the 3 mm apical level, Mtwo and Reciproc remain better centered. A significant difference was seen between the group and type of canal.

Conclusion: Mtwo and Reciproc showed better centered preparation than ProTaper and WaveOne. Significant differences were seen between the groups and types of canal.

Clinical significance: Root canal instrumentation should maintain the original canal anatomy. The proper enlargement keeping in mind the remaining strength in the tooth structure is essentially decided by how the selected instrument is centered. The alloy used for instrument manufacture and its design (taper, cross-section, and tip) will influence the centered preparation. The type of instrument and the instrumentation techniques should be chosen based on root canal anatomy.

Keywords: Centering ability, Cone-beam computed tomography, Nickel–titanium rotary files.

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Introduction

Endodontic treatment success depends on proper shaping and cleaning of the root canal system. Enlargement and maintaining the shape of the root canal system are both a part of mechanical instrumentation, and it is crucial to increase the efficacy of irrigants and antibacterial medications in eradicating germs and eliminating bacterial by-products, creating enough room for three-dimensional obturation. Root canal instrumentation should provide a centered preparation, thereby preserving root dentin. With the introduction of nickel–titanium instruments, root canal instrumentation has become easier when compared with using hand instruments, correlated with faster instrumentation times and improved cutting effectiveness.[1] Superelasticity of alloy provides better centered preparation with fewer procedural errors.[2]

Gambill et al. defined centering ratio (centering ability) as the measurement of the ability of the instrument to stay centered in the canal. It is influenced by the alloy used for manufacturing instruments and the design of the instruments (cross-section, taper, and tip).[3]

The multiple NiTi-file systems that are commercially available feature unique cross-sectional shapes, rake angles, taper, flute depths, and numbers of spirals or flutes per unit length that could all have an impact on file behavior. To obtain faster preparations with no deviations, it is important to choose and combine instruments and instrumentation procedures, depending on their ability to shape, especially in curved canals.[4] Even with the advancement of materials and techniques, proper cleaning of the root canal system is still difficult.

M-wire alloy, which improves cycle fatigue and increases flexibility, is used to create the commercially available Reciproc

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and WaveOne, two single-use reciprocating devices. WaveOne single-file reciprocating system has a reverse helix and noncutting-modified guiding tip.[5] Reciproc single-file reciprocating system has S-shaped cross-sectional design with a noncutting tip and sharp cutting edges. Last but not least, ProTaper rotary system has a progressively tapered design with a convex triangular cross-section, noncutting-modified guiding tip, and changing helical angle and pitch. Mtwo file system has fixed taper, S-shaped cross-section with no radial lands, positive rake angle, and minimal core width, which provide optimal cutting and shaping ability.[6]

Intraoral periapical radiographs provide a limited two-dimensional image of complex anatomical structures. In turn, three-dimensional (3D) CBCT can produce sequential axial images of root canals from the coronal to the apical region, or vice versa. It is incredibly helpful in pinpointing the precise locations of anatomical structures, revealing details of the internal root canal anatomy, and helping identify points of communication between root canals and the periodontal space.

Even though there are various methods to assess centering ability, CBCT provides a 3D image. With the help of CBCT, it is possible to compare the pre- and post-instrumentation scans of the canal system. Using this technology, the amount and direction of canal transportation at any level can be viewed without loss of specimen.

Considering the significance of correlating instrument characteristics and root canal anatomical aspects to ensure endodontic treatment success, the study aimed to evaluate the centering ability of ProTaper, Mtwo, WaveOne, and Reciproc using CBCT at different levels.

Materials and Methods

The study was conducted by a single operator at the Department of Conservative Dentistry and Endodontics, Amrita School of Dentistry, following approval and ethical clearance (REF/003/TPRC/2015) from the Amrita Institute of Medical Sciences and Research Centre Ethics Review Board.

Selection of Teeth and Preparation of the Specimen

Eighty extracted human mandibular molars with curvature within 15–45° that were extracted due to periodontal problems were selected. Teeth with multiple rapid apical curvatures and calcified canals were excluded from the study.

The specimens were disinfected with 5.25% sodium hypochlorite, and teeth were stored in normal saline until use. Digital radiographs were taken to assess the root morphology. The teeth were mounted on a template, and pre-instrumentation CBCT scans were taken using Kodak Carestream CS 9300 machine.

Coronal access was achieved using a no. # 4 round bur, and the apical patency of the mesiobuccal and mesiolingual canals was confirmed with a size 10 K file (Mani, Japan).

The working length of mesiobuccal and mesiolingual canals was determined by the #15 k file (Dentsply, Maillefer) 1 mm short of the radiographic apex.

The eighty selected teeth were randomly divided into four groups (n = 20) for instrumentation with different file systems:

Group I – ProTaper universal, instrumented up to size F2.
Group II – Mtwo, instrumented up to 25.6%.
Group III – WaveOne, instrumented up to primary file.
Group IV – Reciproc, instrumented up to Reciproc R 25.

All instruments were driven using the X-Smart Plus (Dentsply Maillefer) by following the manufacturers' instructions.

The apical diameter of master apical instrumentation was standardized to ISO size 25 as preparation to size 25 is exceptionally safe in all canals.[7] The canals were rinsed with 1 mL of 2.5% sodium hypochlorite and 3 mL of 17% EDTA solution using a 30-gauge needle, and a no. 10 K file was used to confirm patency. After canal shaping, post-instrumentation CBCT scans were performed with similar values and positions as pre-instrumentation scans.

Evaluation of Centering Ability

Cone-beam computed tomography images were analyzed by CS 3D imaging software. Centering ability was measured in the followingfour planes:

- At furcation.
- 3 mm apical to furcation (coronal).
- 6 mm apical to furcation (middle).
- 3 mm coronal to the apex (apical).

In each plane, buccal, lingual, mesial, and distal dentin thickness was measured from pre- and post-instrumentation CBCT scans. The measurements were recorded for each canal (mesiobuccal and mesiolingual) separately.

Centering ability was calculated using the formula

$$(X1 - X2)/(Y1 - Y2) \text{ or } (Y1 - Y2)/X1 - X2)$$

A value of "1" indicates perfect centering.

Statistical Analysis

Initially, a pilot study was conducted, and the mean value obtained from the study was used to determine the sample size.

The data were exported to SPSS version 20 software (Chicago, IL, USA) and statistically analyzed using paired t-test and ANOVA test. Multiple comparison tests were done using Tukey's Post-hoc test .

Results

Pre- and post-instrumentation values were put into the centering ability formula and the results were tabulated on an Excel sheet. A value of one indicates perfect centering.

In the MD (Tables 1 to 3) at the level of furcation, all the groups showed lower centering in both the mesiobuccal (MB) and the mesiolingual canal (ML). At the 3 mm, 6 mm, and 3 mm apical levels in both MB and ML canals, Mtwo remains better centered followed by Reciproc, and the least centering ratio is shown by ProTaper and WaveOne.

In the buccolingual dimension (Tables 4 and 5), at the level of furcation, 3 mm and 6 mm levels, all the groups showed lower

Table 1: Group comparison

	ProTaper	*Mtwo*	*WaveOne*	*Reciproc*
MB	0.47 ± 2.26	0.66 ± 3.44	0.13 ± 248	0.62 ± 1.79
ML	0.45 ± 2.55	0.65 ± 8.14	0.04 ± 2.32	0.53 ± 3.02

Table 2: Comparison of centering ability mesiodistally in MB canal

	Furcation	*3 mm*	*6 mm*	*Apical 3 mm*
Group I	0.54 ± 2.69	0.38 ± 1.30	0.61 ± 0.9	0.33 ± 2.30
Group II	0.78 ± 1.51	1.33 ± 1.8	2.36 ± 5.39	1.02 ± 1.94
Group III	0.49 ± 0.82	0.45 ± 6.14	0.35 ± 1.66	0.44 ± 1.42
Group IV	0.49 ± 1.50	0.93 ± 2.62	1.14 ± 2.48	0.91 ± 1.77

Table 3: Comparison of centering ability mesiodistally in ML canal

	Furcation	*3 mm*	*6 mm*	*Apical 3 mm*
Group I	0.64 ± 1.21	0.50 ± 1.48	0.14 ± 1.43	0.55 ± 1.43
Group II	0.15 ± 3.23	1.03 ± 1.8	1.18 ± 3.20	1.17 ± 1.85
Group III	−0.07 ± 0.52	0.93 ± 2.62	0.42 ± 0.74	0.27 ± 1.54
Group IV	−0.06 ± 2.84	0.59 ± 1.11	0.92 ± 3.06	0.69 ± 0.68

Table 4: Comparison of centering ability buccolingually in MB canal

	Furcation	*3 mm*	*6 mm*	*Apical 3 mm*
Group I	0.21 ± 1.30	−0.07 ± 2.06	0.37 ± 0.55	0.35 ± 4.50
Group II	0.48 ± 3.65	0.85 ± 1.06	−0.32 ± 5.39	1.23 ± 3.28
Group III	−0.12 ± 2.29	0.41 ± 1.16	0.18 ± 0.82	0.08 ± 0.79
Group IV	0.01 ± 0.57	0.69 ± 1.24	0.07 ± 1.09	0.85 ± 1.06

Table 5: Comparison of centering ability buccolingually in ML canal

	Furcation	*3 mm*	*6 mm*	*Apical 3 mm*
Group I	0.31 ± 2.70	0.34 ± 1.93	0.24 ± 4.74	0.38 ± 2.64
Group II	0.41 ± 5.11	0.75 ± 1.39	−0.34 ± 3.60	1.77 ± 11.10
Group III	−0.27 ± 4.02	0.36 ± 1.80	0.26 ± 1.11	0.06 ± 3.46
Group IV	−0.34 ± 6.92	0.48 ± 1.40	0.50 ± 1.43	1.50 ± 1.79

centering. At the 3 mm apical level, Mtwo and Reciproc show better-centering ability, and the least is shown by WaveOne.

Paired *t*-test was done to find whether there is any significant difference within the groups and no statistically significant difference was observed. A significant difference was seen between the group and type in ANOVA ($p = 0.016$), Tukey's post-hoc test was done for multiple comparisons, which showed a significant difference ($p < 0.05$) between group III (WaveOne) and group IV (Reciproc).

On intergroup comparison, among all the groups, Mtwo remains better centered.

The inference from the study highlights the fact that Mtwo remains best centered followed by Reciproc and Waveone and ProTaper.

Discussion

Shaping of the root canal system should produce a continuously tapered shape maintaining the canal curvature with minimal procedure errors. According to Wu et al., more than 300 µm of apical transportation can negatively affect the sealing of the root canal system.[6] Mtwo and ProTaper are continuous rotation-file systems and both differ in instrument design. Mtwo instruments have constant taper with an s-shaped cross-section, positive rake angle, and noncutting tip, which eliminates threading into canal walls and provides a well-centered preparation.[8] ProTaper system has a variable taper and convex triangular cross-section.

Reciproc and WaveOne are single-file systems, based on the balanced force technique by Roane et al. Reciprocating motion produces increased enlargement at the external side of the canal, thereby providing a centered preparation.[9]

Burklein et al. demonstrated that Reciproc and WaveOne with Mtwo and ProTaper rotary instruments could maintain the original canal curvature well with no significant differences.

The complex anatomy of multirooted teeth is often a challenge for endodontic treatment. Mandibular molars have significant curvature in the mesiobuccal canal in both mesiodistal and buccolingual planes and often have concavities on the mesial and distal surfaces of the root. These factors make the tooth susceptible to transportation. In this study, the crowns were maintained to simulate the clinical situations, in which the interference of cervical dentin projections creates tensions on the files during root canal instrumentation. Peters et al. stated that anatomical variations of the tooth before preparation have more influence on preparation than the technique used.[10] Computed tomography and CBCT are 3D high-resolution imaging methods by which before and after instrumentation can be assessed at different levels without destructing the specimen. Studies by Oliveira et al. and Samia M. Elsherief et al. found CBCT an effective method of assessing the centering ability of root canal system.[11,12]

In the present study, the specimens were arranged in a template for CBCT scans, and before and after instrumentation scans were measured at four different levels by using CS 3D imaging software. The kinematics of movements and the file sequences influences the centering ability. Studies show that instruments with less cross-sectional area, taper, and noncutting tips will show better canal-centering ability. Reciproc and WaveOne files were compared with Mtwo and ProTaper files because both systems are the direct full-sequence counterparts of the single-file reciprocating systems.

When comparing the four groups in this study, all instruments had a low centering ratio with no significant difference, except in a few sections. There was no statistically significant difference within the groups at different levels. In the mesiodistal direction, at the furcation level, none of the groups showed a better centering ratio. At the 3 mm and 6 mm level, both Mtwo and Reciproc had shown to be better centered, and at the 3 mm apical level, Mtwo remains better centered. In the buccolingual direction, at furcation, 3 mm and 6 mm levels, all the groups showed a lower centering ratio. At the 3 mm apical level, Mtwo remains better centered in the mesiobuccal canal and Reciproc remains better centered in the ML canal. This result is confirmed by the result of a study by Agarwal et al., where they compared the reciprocating motion and continuous rotation. There was no significant difference in canal transportation at 3 mm, 6 mm, and 9 mm levels, ProTaper showed greater canal transportation and less centering.[13] The observation from this study was in agreement with the studies by Schafer et al. and Yang et al., where they found that canals prepared with Mtwo remained better centered.[13,14] The positive rake angle, small core diameter, noncutting tip, and constant taper of the Mtwo produce a good centering ability.[14] Noncutting tips act as a guide to allow easy penetration with minimal apical pressure.[6]

S-shaped cross-section of Mtwo instruments showed higher torsional strength and higher resistance to torsional breakage compared with the instruments with a triangular cross-section.[15]

ProTaper showed a lower centering ratio when compared with other groups in this study. A Convex triangular cross-section and variable taper reduced flexibility, and increased tip stiffness of ProTaper file system could predispose to greater canal transportation.

The results of the present study conformed to the study by Gergi et al., where ProTaper was found to produce more apical transportation, and also studies by Burklein et al., You and Cho, 2012, and Capar et al., where Reciproc maintained the original curvature of severely curved canals.[16–19] Reciprocating motion of WaveOne

and Reciproc maintains a better centered preparation compared with continuous rotation.

In the present study, WaveOne has shown a low centering ratio. The multiple-taper and file cross-section changes from the apical part with a modified triangular convex and neutral rake angle may be attributed to the lower centering ratio of WaveOne file. The study by Marzouk et al. compared the effect of reciprocating and rotating motion on canal transportation and found that reciprocating motion during instrumentation resulted in increased canal transportation when compared with continuous rotation motion.[5]

The lack of significance between the groups in the present study may be due to an insufficient number of samples as canal preparation is dictated more by the anatomy than the difference in instrumentation.[20] There was a difference when the MB and ML canals centering was compared, which could be because of the difference in curvature. Even though there are various methods to access centering ability, microCT provides precise results, but as the sample size was large in this study, CBCT was used for assessment.

Conclusion

Within the limitation of this study, it was concluded that both rotating and reciprocating motion affect centering ability. Among the four systems, Mtwo and Reciproc have shown to have the better centering ability when compared with ProTaper and WaveOne. At 3 mm and 6 mm from furcation and 3 mm apical levels, Mtwo showed better centering than other systems. Cone-beam computed tomography was found to be a very effective tool in assessing the centering ability of files. Since a wide variety of factors affect centering ability, the clinician should be selective in choosing the file system that best fits the individual needs of each tooth.

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