Evaluation of canal transportation after root canal instrumentation: a comparative in vitro study with cone-beam computed tomography

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ABSTRACT
Aim: Reciproc and WaveOne (WO) system was used to evaluate the canal centering ability and apical transportation by cone-beam computed tomography.

Materials and Methods: Forty extracted human single-rooted mandibular premolars were used in the present study. Preinstrumentation scans of all teeth were taken; canal curvatures were calculated; and the samples were randomly divided into two groups with 20 samples in each group, where Group 1-Reciproc system and Group 2-WO reciprocation system. Postinstrumentation scans were performed using DICOM software and the two scans were compared to determine centering ability and canal transportation at 3, 6, and 9 mm from the root apex.

Results: Using Student's unpaired t-test results were as follows, for centering ability Group 1 showed nonstatistically significant difference at 3 mm and 9 mm, whereas a statistically significant difference (P < 0.05) at 6 mm was obtained. For canal transportation, Group 1 showed a statistically significant difference (P < 0.05) at 3 mm and 6 mm, and nonsignificant difference was obtained at 9 mm, but for Group 2, nonstatistically significant difference (P > 0.05) was obtained at 3 mm, 6 mm, and 9 mm.

Conclusion: WO single reciprocation file has better centering ability, maintains original canal curvature, and causes lesser canal transportation as compared to reciproc.

Keywords: Cone-beam computed tomography, M wire, root canal anatomy, root canal curvature

INTRODUCTION
Successful root canal therapy depends on effective debridement of the root canal by eliminating debris and microorganisms and shaping of the root canal system without deviating from the original anatomy. Ideally, during root canal preparation, the instruments should always conform to and retain the original shape of the canal. The ability to keep the instruments centered is crucial in curved canals and to deliver an accurate enlargement to the root canal without any unnecessary weakening to the root structure. A prepared root canal should have a continuously tapered funnel shape while maintaining the original outline form of the canal. When curvatures are present, preparation becomes more difficult and there is a tendency for all preparation techniques to divert the prepared canal away from the original axis. Endodontic mishaps are unfortunate occurrences that can occur during root canal treatment which includes ledging, zipping, blockage, strip perforations, and canal transportations. Factors that affect canal centering ability are design of the instrument which includes cross-section, taper, tip size, and flexibility.

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Canal transportation is one of the most common mishaps during the instrumentation of curved root canals. When transportation occurs, it has two components: direction and deviation. The direction is an excessive dentine removal in a single direction off the main tooth axis of the canal. Deviation is any undesirable departure from original canal path, which is the distance in millimeters from the pre- and post-instrumented canal as a function of file action.\(^2\)

Transportation in the apical third of the root canal promotes the harboring of debris and residual microorganisms as a result of insufficient cleaning of the root canals and overreduction of sound dentin and destruction of the integrity of the root. The etiology associated with an increased risk of canal transportation include insufficiently designed access cavities, use of inflexible instruments, instrumentation technique, tip design, insufficient irrigation during mechanical enlargement, unseen canal curvatures in two-dimensional radiography, skill of operator, and degree and radius of a root canal curvature both induce a stress on the instruments.\(^3\) Radial lands support edge of the cutting angle and helps to distribute the pressure of the blades more uniformly around the circumference of a curved canal and thus reduces apical transportation.\(^4\)

The more severely curved and the shorter the radius of curvature, the greater the risk of transportation. Ideal instrumentation should have equal dentin removal from the canal walls, so that it could avoid excessive thinning of root structure.

Recently, Reciproc and WaveOne (WO) represent single NiTi file systems which are made of a special NiTi-alloy called M-Wire that is made by a special thermal treatment procedure.\(^5\) The advantages of this M-Wire NiTi are increased flexibility and better resistance to cyclic fatigue.\(^6\) Thus, it is important to estimate the canal centering ability of single-file systems before they can be taken for a viable replacement of full-sequence rotary file systems.\(^7\)

In the past, methods for understanding canal transportation and centering ability included radiographic analysis, serial sectioning technique, diafanization, stereomicroscopy photographic assessment, clinical and scanning electronic microscopy, and computer manipulation technique.\(^8\) The above-mentioned methods were invasive in nature and accurate repositioning of pre- and post-instrumented specimens is tough, and there is a disadvantage of loss of sample, whereas radiographs provide two-dimensional image of three-dimensional object.\(^9\)

Cone-beam computed tomography (CBCT) uses a cone-shaped X-ray beam and an area detector which principally determines the size of voxel and produce volumetric data in one acquisition. CBCT is able to provide submillimeter resolution images for the analysis of the root canal area and parameters such as canal transportation and centering ratio.\(^10\)

Subsequently, the aim of this study was to investigate the level of canal transportation and centering ability after instrumentation with Reciproc and WO reciprocation system by utilizing CBCT.

**MATERIALS AND METHODS**

After approval by the ethical institutional board, 40 freshly extracted human single-rooted mandibular premolar teeth for an orthodontic treatment purpose or for periodontal reasons were collected for this study. Teeth without any previous endodontic treatment, fractures, resorptive defects, calcifications, or open apices were selected for the study. They were cleaned of any residual tissue tags, rinsed under running water, and stored in 10% formalin solution. The presence of a single root and root canal in each tooth was confirmed on radiographs. To get the flat reference, the crowns were decoronated with diamond disc (DFS, Germany) and a final dimension of 9-mm length was achieved for each tooth. The root canal length was established by measuring the penetration of a size 10 K-file (MANI, PRIME DENTAL) until it reached the apical foramen and then subtracting 0.5 mm. The angle of curvature was assessed according to the criteria described by Schneider.\(^11\) Teeth were radiographed using radiovisiography in buccolingual direction. A line was drawn parallel to long axis of the canal. Second line was drawn from the apical foramen to intersect with the first at the point where the canal began to leave the long axis of the tooth. The acute angle thus formed was measured and the angle of curvature was thus determined. Further, only teeth with a degree of curvature ranging between 10˚ and 24˚ were included in the study.\(^11\) A template of self-cure acrylic resin (DPI RR COLD CURE) was made, in which the roots were embedded until the cervical region so that a constant position could be obtained.\(^11\) The teeth were coded with permanent marker. The template mounting was horizontally fitted to a chin support with its occlusal plane parallel to plate.

All teeth were scanned by CBCT before instrumentation. The exposure time was 3.0 s, operating at 75 KV and 2.0 mA. The images were stored in the computer’s hard disk for further comparison between preinstrumentation and postinstrumentation data by using CBCT (Kodak 9000 DICOM Software CS 9000 3D).

The teeth were then randomly divided into two groups of 20 each which received the following treatment.
Group-1: Canals were shaped using Reciproc files having a size of 25 and having a taper of 0.08 till the working length in a reciprocating slow in and out pecking motion. Each file was discarded after once used.

Group-2: Canals were shaped a primary WO file (Dentsply-Maillefer, Switzerland) having a size 25 and a taper of 0.08 was used in a reciprocating, slow in-and-out pecking motion according to the manufacturer’s instructions.

X-Smart Plus endomotor (Dentsply-Maillefer, Switzerland) was used. After each instrumentation, the canals were irrigated copiously with 3% Sodium hypochlorite (Vishal Dentocare Pvt. Ltd., India), and the flutes of the instrument were cleaned. Final apical preparation size was 25 for both the groups again all the specimens were scanned by CBCT after instrumentation. Preinstrumentation and postinstrumentation images were compared using DICOM software.

**Canal centering ratio estimation**\[^{12}\]

The canal centering ratio was calculated according to the following ratio:

\[
\frac{X_1 - X_2}{Y_1 - Y_2} \text{ or } \frac{Y_1 - Y_2}{X_1 - X_2}.
\]

The centering ratio is the difference between the instrumented and noninstrumented canal, which measures the ability of the instrument to stay centered. If the numbers are not equal, the lower figure is considered as the numerator.

**Apical transportation assessment**

By using this formula \([X_1 - X_2 - Y_1 - Y_2]\) as introduced by Gambill et al. canal transportation was calculated,\[^{12}\]

where,

- \(X_1\) is the minimum distance from the external edge of the root to the mesial periphery edge of the uninstrumented root canal.
- \(Y_1\) is the minimum distance from the external edge of the root to the distal periphery edge of the uninstrumented root canal.
- \(X_2\) is the minimum distance from the external edge of the root to the mesial edge of the instrumented root canal.
- \(Y_2\) is the minimum distance from the external edge of the root to the distal edge of the instrumented root canal.

After putting the values in the formula a result of ‘1’ indicates perfect centering capacity and the value closer to zero or other than zero indicates canal transportation has taken place in the canal.

**RESULTS**

The student’s unpaired \(t\)-test with 0.05 level of significance was used for statistical analysis. Table 1 compares a mean and standard deviation of Reciproc and WO for centering ratio at the level of 3 mm, 6 mm, and 9 mm. When Reciproc was used at 3 mm and 9 mm, nonstatistical significant difference was obtained, whereas at 6 mm, there was statistical significant difference. However for WO, nonstatistical significant difference was observed at all the levels Figures 1-2.

When estimation of canal transportation was done at 3 levels between both the groups [Table 2] there was a significant
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Table 1: Canal centering ability at 3 mm, 6 mm and 9 mm for both the groups

| Centering Ability | Mean±SD | 3 mm | 6 mm | 9 mm |
|-------------------|---------|------|------|------|
| Group 1 (Reciproc) | 0.054(±0.039) | 0.037(±0.037) | 0.10342(±0.067) |
| Group 2 (WaveOne) | 0.041(±0.047) | 0.0389(±0.033) | 0.1092(±0.045) |
| P | 0.073 | 0.041 | 0.018 |

Table 2: Canal transportation at 3 mm, 6 mm and 9 mm for both the groups

| Mean±SD | 3 mm | 6 mm | 9 mm |
|---------|------|------|------|
| Group 1 (Reciproc) | 0.045(±0.0043) | 0.0531(±0.005) | 0.052(±0.051) |
| Group 2 (WaveOne) | 0.0412(±0.00561) | 0.056(±0.052) | 0.0546(±0.00451) |
| P | 0.035 | 0.052 | 0.61 |

The variable pitch flutes along the length of the instrument considerably an additional advantage of anti-breakage control is a safety bonus, which would help the instrument to unwind to avoid separation. CBCT analysis has been found to be the gold standard method for the analysis of canal geometry following instrumentation, for analysis of variables such as volume, surface area, cross-sectional shape, and taper of the root canal system.

It can also be used to compare the morphological structure of root canal before and after instrumentation. In the present study, preinstrumentation and postinstrumentation images were acquired by CBCT, a process that allows analysis of the root canal area without the need for invasive procedures on tooth structure. Furthermore, the results of this study revealed that the quality of the three-dimensional images captured by CBCT scanning is a distinct and explicit way for understanding root canal instrumentation.

In the present study, to control the differentiation in root length, the teeth were decoronated keeping a standard root length of 18 mm. Canals prepared with Reciproc showed maximum value for canal transportation at 3 mm and 6 mm levels the reason behind may be attributed to the reduction in instrument flexibility, strength, and indicating a probabilities to straighten curved canals.

Capar et al. compared canal transportation, canal curvature, centering ratio, surface area, and volumetric changes in curved mesial root canals of 120 mandibular molars after instrumentation with ProTaper next (PTN) X, one-shape (OS), Protaper Universal (PTU) F, Reciproc, Twisted File Adaptive (TFA), or WO. They reported no statistical significant difference in canal transportation and centering ratio between PTU, WO, and PTN and Reciproc files presented greater volumetric changes in comparison with OS, TFA, and PU.
Technological advancement has contributed to the improvement of technical procedures, but still there is a faint line between research findings published and its clinical significance. Further studies should be conducted in severely curved canals with a bigger sample size.

CONCLUSION

Within the limitations of the present study, it was found that WO single reciprocation file produced significantly less transportation and remained centered and respects original canal morphology better than Reciproc with an apical instrumentation diameter of #25. More researches are required to conclude these results to clinical conditions.

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Conflicts of interest
There are no conflicts of interest.

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