Microcomputed tomographic evaluation of shaping ability of two thermo mechanically treated single-file systems in severely curved roots

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Abstract

Context: Canal shaping abilities such as canal transportation, centering ability, and preparation time are important and have to be considered before using any Nickel–Titanium file system.

Aim: This in vitro study aimed to evaluate and compare the amount of canal transportation, centering ability, and time required for the shaping of severely curved canals with WaveOne Gold (WOG) Primary Reciprocating file and One Curve (OC) Rotary file using the micro computed tomography (µCT).

Materials and Methods: Thirty intact mesial roots of extracted human mandibular first molars having severe curvature (25°–35°) were selected. Samples were divided into two groups. Samples in Group I and II were shaped with WOG primary reciprocating files and OC rotary files, respectively, to the working length. Time required to prepare each canal was recorded. µCT pre- and post-instrumentation scans of all samples were taken. The cross-sectional images at 3, 6, and 9 mm from the radiographic apex were selected for analysis. Statistical analysis was performed using the Kruskal–Wallis and unpaired t-test.

Results: At 3 mm, OC showed statistically lower canal transportation with mean value (0.17 ± 0.10) than WOG (0.55 ± 0.42). Furthermore, OC showed statistically significant better centering ability (0.59 ± 0.25) than WOG (0.39 ± 0.20) at 3 mm level. However, the differences between both instruments were not statistical significant at 6 and 9 mm level for canal transportation and centering ratio. WOG reciprocating file required less time for canal preparation than OC file.

Conclusions: OC rotary file showed less canal transportation and better canal centring ability than WOG file, during the preparation of severely curved canals. However, WOG required less time for canal preparation.

Keywords: Canal centering; micro-computed tomography; one curve; transportation; WaveOne gold

INTRODUCTION

Schilder emphasized that the root canal should have a continuously tapering conical form, from the access cavity till the apex, with the narrowest cross-sectional diameter at the apex and the largest at the orifice, preserving the apical foramen but not altering the original canal curvature as this is the most appropriate canal shape for irrigation and obturation. However, these objectives are difficult to achieve because of the highly variable root canal anatomy. Achieving a proper taper in a curved canal becomes difficult as there are the chances of canal transportation and loss of centering ability of endodontic files.
Canal transportation has undesirable effects which might endanger the success of root canal treatment. The convex outer surface of the root canal wall may be over-prepared leading to the other areas of the canal wall being left unprepared. This invariably impacts negatively on the elimination of bacteria. In addition, root canal transportation may result in loss of the apical stop which might lead to extrusion of irrigants and obturation materials that will inevitably cause periapical tissue irritation and eventually poor prognosis.

With the introduction of nickel–titanium (NiTi) instruments, a significant improvement of the quality of root canal shaping with predictable results and less iatrogenic damage has been observed, even in severely curved root canals. Over the ages, conventional NiTi instruments have undergone thermomechanical treatments, led to the development of M-wire files, Controlled memory files, R-phase, C wire, and T-wire files, etc. All have shown improved flexibility and cyclic, torsional fatigue resistance compared to conventional NiTi files. Unlike multiple file systems, it has been proposed that the single-file shaping technique may simplify instrumentation protocols and avoid the risk of cross contamination. Single file system is more cost effective, reduced canal preparation time, and the learning curve is considerably reduced.

In the comprehensive literature review, although the authors found comparative study on the canal shaping ability of Wave one primary reciprocating file and One shape rotary file, but no study was cited on its heat-treated version, i.e., WaveOne Gold (WOG) and One Curve (OC). Hence, the study was conducted to compare canal shaping parameters such as canal transportation, centering ability, and preparation time with two single file systems, i.e., WOG primary reciprocating file and OC rotary file using micro-computed tomography (μCT).

**MATERIALS AND METHODS**

Thirty extracted human mandibular first molars (for periodontal reasons) with intact pulp chambers, fully formed roots, two separate mesial canals with independent foramina, severe (25°–35°) curvature, and curvature radius < 10 mm were selected. Ethical clearance was obtained from the institute. Teeth having calcified canals and defects such as caries, cracks, perforation, and resorptive defects were excluded. In all specimens, distal root with the respective part of the crown was sectioned at furcation level and discarded. Standard access cavities were prepared. Each root sample was radiographed in bucco-ligual and mesio-distal direction to confirm the root curvature ranging from 25° to 35° according to Schneider’s technique and the presence of two distinct and separate root canals before instrumentation, respectively. Working

length of each mesiobuccal canal was measured using the visual method (until the tip of #10 instrument is just visible out of apex) and recorded by reducing 0.5 mm from the total length of file in the respected canal. Tooth length was standardized at 18 mm by grinding the occlusal surfaces with a diamond disk (Buehler, IL, USA). To ease in the holding of specimen during the instrumentation, each sectioned mesial root was embedded into transparent acrylic resin block (DPI RR Cold Cure, India) up to cementoenamel junction. The prepared specimens were randomly divided into two experimental groups.

**Pre- and post-instrumentation scanning**

Pre- and post-instrumentation scan of the entire specimens was taken with a μCT unit (Zeiss Xradia 520 Versa, Jena, Germany) at 25 μm resolution. The beginning and the end point of the scanning (on z-axis) were recorded to allow repeated scanning of the specimen at the same horizontal level. The same settings were used for all subsequent scans. Raw scanned data were reconstructed into the images by using the dedicated software.

**Root canal instrumentation**

**Group I**
WOG Primary Reciprocating File (#25 7%) (Dentsply Maillefer, Ballaigues, Switzerland) (n = 15).

Canals were shaped in the pecking motion to the respective working lengths using the X smart plus reciprocating motor (X-SMART PLUS; Dentsply Maillefer, Ballaigues, Switzerland) with the manufacturing configuration setup. New file was used for each canal. Irrigation and recapitulation were done with 1 mL of 5.25% NaOCl (Chloraxid, Cerkamed Poland) using 30G needle (Endo-top, Cerkamed Poland) and #10 K file (Mani Inc. Japan), respectively. Flutes of file were cleaned with NaOCl-soaked moist gauze piece. 2 mL of 5.25% NaOCl was used as the final irrigant.

**Group II**
OC Rotary File (#25 6%) (Micro Méga, Besançon, France) (n = 15).

New file was used for each canal. Canal preparation (in-out motion) till working length and irrigation protocol similar to Group I was followed.

**Shaping assessment**

The cross sections of the mesiobuccal canals at 3, 6, and 9 mm from the apex of the root were viewed. The distances from the external walls were measured, as shown in Figure I.

**Canal transportation**

Degree of canal transportation was calculated at each level according to the following formula: \((A_1 - A_2) - (B_1 - B_2)\)
as described by Gambill et al.,\textsuperscript{[8]} where $A_1$ is the shortest distance between the mesial edge of the root and the mesial edge of the uninstrumented canal; $B_1$ is the shortest distance between the distal edge of the root to the distal edge of the uninstrumented canal [Figure 1a]; $A_2$ is the shortest distance between the mesial edge of the root and the mesial edge of the instrumented canal; $B_2$ is the shortest distance between the distal edge of the root and the distal edge of the instrumented canal [Figure 1b]. According to this formula, the result of “0” indicates no canal transportation. The result other than “0” means that transportation has occurred in the canal.

**Canal centering ability**

According to Gambill et al.,\textsuperscript{[8]} the mean centering ratio indicates the ability of the instrument to remain centered in the canal. This ratio was calculated by the following formula $(A_1–A_2) ÷ (B_1–B_2)$. Whenever, these numbers were not equal, the lower figure was considered to be the numerator of the ratio. The result of 1 indicates perfect centering ability.

**Preparation time**

A stop watch was used to measure the total instrumentation time for each canal and was recorded in seconds. It included the actual instrumentation time in the canal, irrigation, recapitulation, intermittent cleaning the flutes of instrument, and final irrigation.

Root canal preparations were completed by one operator while the measurements on the $\mu$CT data prior to/after instrumentation, and statistical analysis were carried out by a second examiner blinded to all experimental groups.

Data pertaining to canal transportation, centering ability, and preparation time were analyzed by using the Kruskal–Wallis test. The unpaired $t$-test was used for pair wise comparison at three different levels. For the statistical analysis, the SPSS software version program (SPSS software version 13 SPSS Inc. Chicago, IL, USA) was used.

**RESULTS**

During canal preparation, neither deformation nor fracture of any instrument was noted.

**Canal transportation and centering ability**

As shown in Table 1, both rotary systems had shown canal transportation and loss of centering ability at all the levels of assessment. To compare at 6 and 9 mm from the apex, the difference in the transportation was statistically not significant. However, it was statistically significant at the level of 3 mm from the apex. WOG files transported more than OC files with the mean values of 0.55 $\pm$ 0.42 and 0.17 $\pm$ 0.10, respectively. At 3 mm from the apex, WOG file lost canal centering ability more (0.39 $\pm$ 0.20) than OC file (0.59 $\pm$ 0.25), which is statistically significant.

**Preparation time**

As shown in Table 2, OC file required more time (229.44 $\pm$ 30.42 s) to prepare the canal as compared
to WOG file (204.40 ± 18.25 s), but the difference is not statistically significant.

**DISCUSSION**

To study the parameters of this study, different experimental designs and methods such as the use of resin blocks of different geometry to simulated root canals and then superimposing pre- and post-operative instrumentation photographic images, superimposing radiographic images of root canal before and after instrumentation, use of an analytical reassembly technique-Bramante technique, stereomicroscopic evaluation, scanning electron microscopic study of the walls of instrumented root canals, and CT and µCT have been used. Among all these, µCT helps to visualize and study the exact morphology of the root canals before and after instrumentation in three dimensions without destruction of the specimens.

During this study, both the single-file systems have different features such as alloy type, crosssection design, taper, and kinematics but same tip size 25 to predictably clean and seal the foramen.

Both file systems showed canal transportation at all the levels of assessment. Research showed an increased tendency toward canal transportation as the diameter of file is increased. Another important factor responsible for apical transportation is taper of the file, which is directly proportional to the amount of apical transportation. The transportation is caused by the tendency of the instrument to return to its original straight shape when inserted into a curved root canal. WOG Primary file transported more in the apical region of the canal may be due to its 7% taper and resulting larger core diameter as compared to OC file having constant taper of 6% throughout its length. The results of our study are in accordance with previously mentioned factors responsible for canal transportation.

The study protocol excluded the use of lubricant such as ethylenediaminetetraacetic acid (EDTA) during preparation because dentin demineralization caused by EDTA irrigation increased root canal transportation in canals. For centering ability, the results obtained in this study are in agreement with the findings of previous reports. They found that constant tapered instruments produced good centering ability in the apical part of curved roots compared to variable tapered instruments. WOG primary file is thicker and stiffer than OC file owing to its larger taper. Owing to the variable cross-section design along the length of working part makes OC file more flexible. Hence, better centering ability of OC file may be related to variable cross section along the blade. WOG file has offcentred parallelogram cross throughout its length.

However, our results regarding the canal transportation and loss of centering ability of WOG are comparable with studies conducted by Razcha et al. and Poly et al. They found the better performance of rotary files than WOG reciprocating files.

Preparation time depends on the technique and the number of instruments used, the operator’s experience and on further details of the study design. In this study, WOG file required less time to prepare the canal to full working length rather than OC file. The WOG file is used with reciprocating motion using the preprogrammed motor. Counter-clock wise movement advances the instrument, engaging and cutting the dentine. Clockwise movement disengages the instrument from the dentine before it can (taper) lock into the canal. It is claimed that the instrument advances continuously toward the apex of the root canal. On the contrary, OC file during its continuous rotary movement, binds into dentine due to taper-lock. There is no mechanism to unlock taper lock which is seen in the reciprocating movement. The reduction in preparation time with both the single-file systems is a clinically relevant finding.

Larger volumes of irrigant and additionally its activation are responsible for apical transportation as the diameter of file is increased. Another important factor responsible for apical transportation is taper of the file, which is directly proportional to the amount of apical transportation. The transportation is caused by the tendency of the instrument to return to its original straight shape when inserted into a curved root canal. WOG Primary file transported more in the apical region of the canal may be due to its 7% taper and resulting larger core diameter as compared to OC file having constant taper of 6% throughout its length. The results of our study are in accordance with previously mentioned factors responsible for canal transportation.

**CONCLUSIONS**

Within the limitation of this study, it can be concluded that, OC file due to its less taper and change in the taper...
A cross-sectional design showed less transportation and better canal centering at the apical third as compared to WOG single-reciprocating file. However, WOG primary file required less time to prepare root canal.

Further, clinical studies are required to correlate these findings.

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**Conflicts of interest**
There are no conflicts of interest.

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