Comparative evaluation of the shaping ability of rotary systems of varying metallurgy in curved canals and its analysis using cone-beam computed tomography: An in vitro study

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ABSTRACT
Background: This study compared the shaping ability of four nickel-titanium rotary file systems of varying metallurgy along curved canals.
Aim: The aim of the present study is to compare the shaping ability of rotary systems of varying metallurgy in curved canals and its analysis using cone-beam computed tomography (CBCT).
Materials and Methods: Forty mesiobuccal canals of mandibular first molars with an angle of curvature ranging from 20° to 40° were divided according to the instrument used in canal preparation into four groups of 10 samples each: Hyflex CM (Group I), Vortex Blue (Group II), Flexicon (Group III), and K3XF (Group IV). All samples were instrumented according to the manufacturer’s guidelines and prepared to size 30, 0.06-taper master apical file. Canals were scanned and evaluated using an NNT CBCT unit before and after preparation at different levels from the apex. The data were subjected to statistical analysis.
Statistical Analysis: The intergroup comparison in terms of canal transportation and the time taken for canal preparation was done by the one-way analysis of variance (ANOVA) test with Bonferroni post hoc test. The intragroup comparison in terms of canal transportation was done by the repeated measures ANOVA test with the post hoc Bonferroni test. For the canal-centering ability, the Kruskal–Wallis test with Mann–Whitney U-test was used for the intergroup comparison and the intragroup comparison was done by Friedman’s test with Wilcoxon signed-rank test.
Results: Hyflex CM and Vortex Blue files showed significantly least canal transportation and highest canal-centering ability values as compared to Flexicon and K3XF file systems.
Conclusion: The metallurgy and file design of Hyflex CM and Vortex Blue file systems resulted in superior shaping ability, with the instruments remaining more centered in the canal than Flexicon and K3XF.

Keywords: Canal transportation, cone-beam computed tomography, curved canals, nickel-titanium

INTRODUCTION
Biomechanical preparation in curved canals with the earliest stainless steel files leads to canal straightening and canal transportation.[1] To overcome these iatrogenic errors, hand- and engine-driven nickel-titanium files with proprietary thermomechanical processing were introduced.[2] Canal shaping is collectively determined by the file design, the manner in which the file is used and the method of manufacturing.

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Hyflex CM Wire (Coltene/Whaledent, Alstatten, Switzerland) is made by a unique heating process that controls the material’s memory enhancing its flexibility. Their decreased nickel content makes it less aggressive in cutting dentin and makes it stay centered within the canal during instrumentation.[3]

K3XF files (Sybron Endo, Orange, CA) are manufactured by the proprietary R-phase technology responsible for enhanced flexibility and increased cyclic fatigue resistance of the files.

Vortex Blue (Dentsply, Tulsa Dental Specialties, Tulsa, OK) files are made of M-wire and show a unique “blue color” indicative of a hard titanium oxide surface layer which is known to improve the cutting efficiency and wear resistance.

Flexicon™ rotary files are made with the FireWire technology to make it extremely flexible and resistant to torsional strain.

Newer noninvasive devices for radiographic investigation have been introduced to produce undistorted three-dimensional (3D) images of the oromaxillofacial region. Cone-beam computed tomography (CBCT) can render cross-sectional and 3D images that are highly accurate and quantifiable.[4]

Therefore, the aim of this study was to compare the shaping ability of the rotary systems of varying metallurgy in curved canals and its analysis using CBCT.

The null hypotheses to be tested are as follows: (1) there is no difference in canal-shaping ability and time taken to complete instrumentation, among four rotary file systems, i.e., Hyflex CM, Vortex Blue, Flexicon, and K3XF of varying metallurgies when used in curved canals and (2) there is no difference in canal-shaping ability at the different levels of root canals tested, i.e., 3 mm, 5 mm, 7 mm, and 9 mm from the root apex.

MATERIALS AND METHODS

The study design was approved by the Institutional Ethics Committee.

Specimen selection and preparation

Human mandibular first molars with intact roots and fully formed apices extracted for periodontal reasons were collected, stored in 10% formalin, and kept moist before the study. Access cavities were prepared and the mesiobuccal canal was localized and explored with the size 10 K-file and was assessed according to the Schneider’s method. Forty teeth with root curvature ranging from 20° to 40° were selected.

The coronal part of the tooth was sectioned using steel disks to obtain the final dimension of 18 mm and working length of 17 mm. Distal half of the tooth was sectioned at the furcation level and discarded. Specimens were randomly divided into four equal experimental groups (n = 10) according to the rotary file system used for canal instrumentation: Hyflex CM, Vortex Blue, Flexicon, and K3XF. Four molds of the shape of a mandibular arch were prepared using rubber-base impression material. Ten specimens of each group were then embedded in clear acrylic poured into the mold.

For all the groups, canals were prepared as per the manufacturer’s instructions and the final apical preparation was standardized to size 30 with 0.06 taper. Canals were irrigated with 3 ml of 5% NaOCl solution after use of each file. Glyde was used as a lubricant during instrumentation. Final irrigation was done with 1 ml of 17% EDTA for 1 min followed by a final flush of 3 ml of NaOCl. The instrument was changed after preparation of three canals.

Scanning and imaging of teeth

The specimens were placed into the NewTom GiANO CBCT unit (New Net Technologies Ltd., Naples, FL) and aligned so that the long axis of the roots was perpendicular to the beam. The teeth were then scanned before and after instrumentation [Figures 1 and 2] to determine the root canal-shaping ability at 3 mm, 5 mm, 7 mm, and 9 mm from the apex. Exposure parameters were kept constant for both the scans, i.e., 90 KVP and 27 mA with a time scan of 9 s. The field of view was 5 × 8 inches and the voxel size was...
100 microns. After obtaining scans from all the specimens, the data were stored in a magnetic optical disc and analyzed using the NNT software (Newtom, Verona, Italy).

**Evaluation of shaping ability**

The shortest distance from the canal wall to the external root surface was measured in the mesial and distal directions for the mesiobuccal root canal on the reconstructed 2D image using the measure length tool. Measurements were recorded before and after instrumentation to calculate the following:

1. The degree of canal transportation at each level according to the following formula:

\[(x_1 - x_2) - (y_1 - y_2)\]

2. The canal centering ratio at each level according to the following formula:

\[(x_1 - x_2)/(y_1 - y_2)\] or \[(y_1 - y_2)/(x_1 - x_2)\]

According to the above formula, a result of 1 indicates perfect centering

where

- \(x_1\) and \(x_2\) are the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented and instrumented canal, respectively.

- \(y_1\) and \(y_2\) are the shortest distance from the distal edge of the root to the distal edge of the uninstrumented and instrumented canal, respectively.

(3) The mean working time was recorded using an electronic stopwatch. Time for instrument changes and irrigation was excluded.

**Statistical analysis**

The intergroup comparison in terms of canal transportation and the time taken for canal preparation was done by the one-way analysis of variance (ANOVA) test with Bonferroni post hoc test. The intragroup comparison in terms of canal transportation was done by the repeated-measures ANOVA test with the post hoc Bonferroni test. For the canal-centering ability, the Kruskal–Wallis test with Mann–Whitney U-test was used for the intergroup comparison and the intragroup comparison was done by Friedman’s test with Wilcoxon signed-rank test. 

\(P = 0.05\) was considered as statistically significant level. The data were evaluated using the IBM SPSS (Statistical Package for the Social Sciences, IBM Corp., Armonk, N.Y., USA) software 21.0 and the results were tabulated.

**RESULTS**

The comparison of mean canal transportation and canal-centering ability was found to be significant at all levels for all groups. The mean canal transportation at all the levels was significantly more and mean canal-centering ability was significantly less for Group III (Flexicon) and Group IV (K3XF) groups in comparison to Group I (Hyflex CM) and Group II (Vortex Blue). The mean canal transportation at 3 mm, 5 mm, 7 mm, and 9 mm was significantly more for Group III (Flexicon) in comparison to Group IV (K3XF). When Group I (Hyflex CM) and Group II (Vortex Blue) were compared, Group I (Hyflex CM) showed superior results but was statistically insignificant.

The most superior and most inferior canal-shaping ability was observed for Group I (Hyflex CM) and Group III (Flexicon), respectively [Tables 1 and 2].

The minimum and maximum time taken for instrumentation was observed for Group III (Flexicon) and Group IV (K3XF), respectively [Table 3].

**Table 1: Comparison of mean canal transportation for the tested groups at the tested levels**

|           | 3 mm      | 5 mm      | 7 mm      | 9 mm      |
|-----------|-----------|-----------|-----------|-----------|
| Group I - Hyflex CM | 0.062 ± 0.019<sup>a</sup> | 0.08 ± 0.014<sup>b</sup> | 0.115 ± 0.023<sup>c</sup> | 0.047 ± 0.017<sup>d</sup> |
| Group II - Vortex Blue | 0.071 ± 0.025<sup>a</sup> | 0.09 ± 0.019<sup>b</sup> | 0.121 ± 0.021<sup>c</sup> | 0.051 ± 0.025<sup>d</sup> |
| Group III - Flexicon | 0.12 ± 0.15 | 0.15 ± 0.024 | 0.186 ± 0.019 | 0.101 ± 0.021 |
| Group IV - K3XF | 0.097 ± 0.023 | 0.122 ± 0.019 | 0.153 ± 0.022 | 0.08 ± 0.015 |

Same superscripts indicate nonsignificant differences in the means ± SD of those groups across the column keeping significance level \(P<0.05\). SD: Standard deviation; CM: Controlled Memory
Table 2: Comparison of mean canal-centering ability for the tested groups at the tested levels

| Group   | 3 mm  | 5 mm  | 7 mm  | 9 mm  |
|---------|-------|-------|-------|-------|
| Group I - Hyflex CM | 0.66±0.24* | 0.48±0.17* | 0.50±0.19* | 0.63±0.25* |
| Group II - Vortex Blue | 0.61±0.18* | 0.55±0.19* | 0.55±0.17* | 0.71±0.38* |
| Group III - Flexicon | 0.45±0.17 | 0.45±0.13 | 0.44±0.14 | 0.71±0.29 |
| Group IV - K3XF | 0.56±0.24 | 0.50±0.22 | 0.39±0.1 | 0.50±0.16 |

Same superscripts indicate nonsignificant differences in the means±SD of those groups across the column keeping significance level $P<0.05$. SD: Standard deviation; CM: Controlled Memory

Table 3: Time taken (s) for canal preparation by Group I (Hyflex Controlled Memory), Group II (Vortex Blue), Group III (Flexicon), and Group IV (K3XF)

| Group   | Mean    | $P$     |
|---------|---------|---------|
| Group I - Hyflex CM | 66.51±10.18 | 0.001* |
| Group II - Vortex Blue | 78.03±12.73 |       |
| Group III - Flexicon | 51.17±7.72 |       |
| Group IV - K3XF | 97.61±17.42 |       |

*Statistically significant difference between all the groups. CM: Controlled Memory

DISCUSSION

In this study, four different rotary file systems of varying metallurgies have been compared to evaluate their shaping ability and time taken to prepare curved root canals.

The results showed that Hyflex CM had the most superior shaping ability when compared to all other groups at all the tested levels, owing to their increased flexibility, constant taper,[3] noncutting tip design,[5] and a double-fluted Hedstrom cross-sectional design, i.e., they have a thinner inner core which keeps it more centered in the canal.[7] These results are in accordance with those of Peters et al.,[6] Bürklein et al.,[8] and Testarelli et al.[9] who reported that Hyflex CM prepared curved canals without any significant shaping errors.

The shaping ability of Vortex Blue was found to be slightly inferior though statistically insignificant with that of Hyflex CM, probably because of the thicker asymmetric convex triangular cross section of the former.[7]

On comparison of Hyflex CM with Flexicon, inferior shaping ability of the latter was observed at all tested levels owing to their asymmetric parabolic cross-section, thicker inner core, and active cutting tip of Flexicon.[10]

The inferior shaping ability of K3XF as compared to Hyflex CM could also be due to the asymmetrical cross section and a variable core diameter of K3XF rendering them less flexible.

However, in contrast, Kumar et al.[11] observed no significant differences in the shaping ability of Hyflex CM and Twisted Files. The latter are made of the same R-Phase alloy as that of K3XF used in our study. This could be due to the different cross-section and manufacturing method of K3XF and Twisted Files.

The shaping ability of Vortex Blue was found to be significantly superior than those of Flexicon and K3XF at all tested levels owing to the proprietary blue treatment and the M-wire technology of the former. Moreover, these files have a constant taper,[5] noncutting tip design,[7] and negative rake angle[12] which contribute to their good centrality.

On comparing Flexicon with K3XF, significantly superior results were obtained for K3XF at all tested levels. K3XF is manufactured by R-Phase technology has a noncutting tip and is a modified U-shaped file with three radial lands.[13] However, the shaping ability of Flexicon files may be compromised owing to their positive rake angle, nonlanded surface, thicker inner core, asymmetrical cross-sectional design, and an active tip.

These observations are in consent with those of McSpadden,[14] El Batouty and Elmallah,[15] and Oliveira et al.[16] who stated radial lands distribute the pressure of blades more uniformly around the canal circumference, minimizing canal transportation.

There have been no studies published till date comparing canal-shaping ability of Hyflex CM, Vortex Blue, Flexicon, and K3XF, having different metallurgical properties. Therefore, the findings of this study cannot be corroborated or contradicted.

In the present study, the intragroup comparison showed the most inferior canal-shaping ability at 7 mm across all groups, probably because the canals used in this study possessed maximum curvature at these levels. The most superior canal-shaping ability at 9 mm across all the groups could be because the specimens used in this study had straighter canals at this level.

The time taken for biomechanical preparation by Flexicon was the least due to its active cutting tip in contrast to the noncutting tip of the other files used in the study. Its thicker cross section and positive rake angle also produce more aggressive cutting action on dentin than the rest.[7]

Hyflex CM demonstrated more time taken than Flexicon but was faster than Vortex Blue owing to greater flexibility, positive rake angle, and lesser number of instruments.
being used than Vortex Blue. Hyflex CM included usage of five instruments instead of six instruments used by Vortex Blue.

Hyflex CM also took lesser time than K3XF probably due to greater flexibility and higher speed of rotation of former, i.e., 500 rpm in contrast to 300–350 rpm in case of K3XF.

These results are in accordance with those of Arora et al.[17] who found out that lesser number of instruments being used for canal preparation and greater speed of rotation leads to faster preparation of the canals.

Vortex Blue was faster than K3XF probably due to its proprietary blue treatment which significantly increases its cutting efficiency.

Therefore, two null hypotheses of the present study were rejected as the results indicate that all tested rotary instruments produced some amount of canal transportation. Furthermore, there were statistically significant differences in the amount of canal transportation at all the tested levels for each rotary file system.

There is no study published till date to corroborate and contradict the finding of this study. Thus, further research is required to extrapolate the findings of the present study to clinical use.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

- Although all the tested files showed some degree of apical canal transportation it was well within the acceptable limit (0.3 mm) of canal transportation
- Hyflex CM and Vortex Blue rotary file systems showed statistically significant least canal transportation and highest canal-centering ability values as compared to Flexicon and K3XF file systems
- Flexicon rotary file system significantly showed the fastest preparation of canals, while K3XF file system took the maximum time.

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Conflicts of interest
There are no conflicts of interest.

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