Comparative Evaluation of Shaping Ability of V-Taper 2H, ProTaper Next, and HyFlex CM in Curved Canals Using Cone-beam Computed Tomography: An In Vitro Study

Abstract

Aim: The aim of this study was to compare the canal transportation and canal centering ability in the preparation of curved root canals after instrumentation with V-Taper 2H, ProTaper Next (PN), and Hyflex CM files using cone-beam computed tomography (CBCT). Materials and Methods: Thirty mesiobuccal canals of mandibular molars with an angle of curvature ranging from 20 to 40° were divided according to the instrument used in canal preparation into three groups of ten samples each: V-Taper 2H (Group 1), PN (Group 2), and Hyflex CM (Group 3). The teeth were instrumented according to manufacturer’s guidelines up to 30° apical preparation. Canals were scanned using a CBCT scanner before and after preparation to evaluate the transportation and centering ratio at 3 mm, 6 mm, and 9 mm from the apex. The amount of transportation and centering ability was assessed. The three groups were statistically compared with analysis of variance and post hoc Tukey test. Results: All instruments maintained the original canal curvature with significant differences between the different files. Data suggested that V-Taper 2H files presented the best outcomes for both the variables evaluated. V-Taper 2H files caused lesser transportation and remained better centered in the canal than PN and Hyflex CM files. However, it was seen that PN caused less transportation in apical level than Hyflex CM. Conclusion: The canal preparation with V-Taper 2H showed lesser transportation and better centering ability than PN and Hyflex CM.

Keywords: Canal transportation, centering ability, Hyflex CM, ProTaper Next, V-Taper 2H

Introduction

The foremost goals of cleaning and shaping are thorough debridement of the root canal system and specific shaping of root canal preparation. Root canal shaping is a key stage of endodontic treatment with a good prognostic success factor if performed properly. Ideally, root canal shaping should create a continuous tapered preparation from the crown to apex while maintaining the original path of the canal and keeping the foramen size as small as practical.[1] However, during preparation, especially when preparing curved canals, iatrogenic errors, such as ledges, zips, perforations, and root canal transportation tend to occur.[2] Regardless of the instrumentation technique, cleaning and shaping procedures invariably lead to dentine removal from the canal walls. However, excessive dentine removal in a single direction within the canal rather than in all directions equidistantly from the main tooth axis causes what is known as “canal transportation.”[3] The ability to keep the instruments centered is essential to provide a correct enlargement, without excessive weakening of the root structure, is the canal centering ability of instrument. However, with the recent advent of new generations of instruments manufactured from nickel–titanium alloys (NiTi), with higher flexibility and greater cutting efficiency, there was a significant improvement of quality of root canal shaping, with predictable results and less iatrogenic damage, even in severely curved canals.[4]

The ProTaper Next (PN) (DentsplyMaillefer, Ballaigues, Switzerland) is one of the novel NiTi file systems; it has an offset design and progressive and regressive percentage tapers on a single file and is made from M-Wire technology. Having various percentage tapers functions to decrease the screw effect and dangerous taper lock by minimizing the contact between a file and
dentin. The advantages of PN files include being able to cut a larger envelope of motion compared with a similarly sized file with a symmetrical mass and axis of rotation. Thus, smaller and more flexible PN files can cut the same size preparation as a larger and more rigid file with a centered mass and axis of rotation.

Hyflex CM rotary instruments (HyF) ( Coltene-Whaledent, Allstetten, Switzerland) are made from a new type of NiTi wire, namely CM wire (controlled memory), that has been subjected to proprietary thermo-mechanical processing. It has been manufactured by a unique process that controls the material's memory, making the files extremely flexible but without the loss of shape memory typical of other NiTi files. The manufacturer claims that these instruments are up to 300% more fatigue and resistant, have no rebound and regain their shape after sterilization.

The V-Taper 2H Rotary NiTi File System (VT) (SS White Dental, New Jersey) creates deep apical shape with a conservative coronal preparation which preserves coronal dentin. One to two files per case are used and have the lowest cost for shaping per root canal procedure. Manufacturers claim that it is strongest file system in the market as per tests conducted by the University of Michigan.

Investigations of the shaping effect of these new NiTi systems with different design features and kinematics are important for understanding how the differences affect their performance; however, the effect of these new NiTi rotary systems on canal transportation and centering ability in root canals has not yet been compared. Thus, the study aimed to evaluate and compare the canal transportation and centering ability of V-Taper 2H, PN, and HyFlex CM in curved canals using cone-beam computed tomography (CBCT).

Materials and Methods

Sample preparation

Thirty extracted human mandibular first molars with an average length of 20–21 mm curved mesial roots with two separate mesial canals and apical foramina were selected. Teeth were accessed using an Endo-Access bur (Dentsply, Maillefer), and the mesiobuccal canals were localized and explored with a size 10 K-file (Dentsply, Maillefer). Mesiobuccal canal curvatures were assessed according to Schneider’s technique. According to this technique, the angle is obtained by two straight lines. The first is parallel to the long axis of the root canal, and the second passes through the apical foramen until intersecting with the first line at the point where the curvature starts. The formed angle ($\alpha$) was named according to the degree of root canal curvature: straight: 5°; moderate: 10–20°; and severe: 25–70°. Only canals with curvature (20–40°) were included in the study. Distal roots with the respective part of the crown were sectioned at the furcation level and discarded. The determination of the working length was performed at magnification $\times 8$ using a surgical microscope by inserting #10 K-file to the root canal terminus and subtracting 1 mm from this measurement. Specimens were coded and randomly divided into three equal experimental groups ($n = 10$) according to the rotary NiTi file system used in canal instrumentation. Roots were embedded into modeling wax, which was simulated in mandibular arch form. The teeth were randomly divided into three experimental groups. All teeth were scanned by CBCT (i-CAT CBCT Scanner, Imaging Science International, Hatfield, PA, USA) to determine the root canal shape before instrumentation. Three sections from each tooth were checked, i.e., at 3 mm, 6 mm, and 9 mm from the root apex. After initial scans, root canals were instrumented by the same operator using a standardized technique. All root canals of experimental teeth were instrumented to the WL with sizes 10, 15, 20 K-files using a step-back technique followed by rotary instrumentation.

Specimens in Group 1 ($n = 10$) were prepared with VT files, Group 2 ($n = 10$) with PN files, and Group 3 ($n = 10$) with HyF files till apical 30 No. according to the individual files manufacturer’s instructions, respectively.

After the use of each file, canals were irrigated with 3 mL of a 5.25% NaOCl solution in all the groups. Glyde (DentsplyMaillefer) was used as a lubricant during instrumentation, and after root canal instrumentation was completed, 1 mL of 17% ethylenediaminetetraacetic acid was used for 1 min followed by a final flush of 3 mL of NaOCl.

The files were discarded after preparation of three canals.

Image analysis

The roots were positioned in a custom-made specimen holder in which they were aligned perpendicularly to the beam and scanned before and after instrumentation using CBCT scanner [Figure 1]. The teeth were then scanned to determine root canal shape at 3 mm, 6 mm, and 9 mm from the apex. 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. The distance was measured on the reconstructed 2-dimensional image without reduction 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: $(a1 - a2) \times (b1 - b2)$ and (2) the canal centering ratio at each level according to the following ratio: $(a1 - a2)/(b1 - b2)$ or $(b1 - b2)/(a1 - a2)$, where $a1$ is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, $a2$ is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, $b1$ is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented canal, and $b2$ is the shortest distance...
from the distal edge of the root to the distal edge of the instrumented canal.\textsuperscript{10} [Figure 2].

The mean, standard deviation, minimum and maximum values were calculated for all the groups in terms of canal transportation, canal centering ability. One-way analysis of variance with Tukey’s post hoc test was applied to make inter- and intra-group comparison of canal transportation, canal centering ability, using SPSS version no.15 (IBM alogarithms. Armonk, NY, USA). A $P < 0.05$ was considered as statistically significant level.

**Results**

Table 1 provides the mean, standard deviation, and median for canal transportation for three groups at three different distances from root apex.

- It shows that the mean transportation at 3 mm distance from root apex shows statistically significant difference across groups with $P = 0.0009$. The paired-wise comparison of mean between groups using Tukey’s post hoc test suggested that mean for VT group was significantly lower than that of other two groups. The mean values for PN and HyF were insignificantly different as indicated by same alphabets in superscript.

- The mean transportation at 6 mm distance from root apex shows statistically significant difference across groups with $P = 0.0004$. The paired-wise comparison of mean values between groups using Tukey’s post hoc test suggested that mean for PN Group was significantly higher than other two groups. The mean values for VT and HyF were insignificantly different as indicated by same alphabets in superscript.

- The mean transportation at 9 mm distance from root apex shows statistically significant difference across groups with $P < 0.0001$. The paired-wise comparison of mean values between groups using Tukey’s post hoc test suggested that mean for HyF group was significantly higher than other two groups. The mean values for VT and PN were insignificantly different as indicated by same alphabets in superscript.

- The mean transportation for VT group shows statistically significant difference across distances as indicated by $P = 0.0006$. The pair-wise comparison of mean values using Tukey’s post hoc test suggested that the mean at 9 mm was significantly higher than

| Canal transportation distance from root apex (mm) | Mean±SD (median) | $P^*$ |
|-------------------------------------------------|-----------------|-------|
| 3                                               | v-Taper         | ProTaper next | Hyflex cm |
| 3                                               | 0.05±0.009\textsuperscript{a,1} (0.05) | 0.06±0.008\textsuperscript{a,1} (0.06) | 0.06±0.013\textsuperscript{b,1} (0.06) | 0.0009 (S) |
| 6                                               | 0.06±0.012\textsuperscript{a,1} (0.06) | 0.09±0.016\textsuperscript{b,2} (0.09) | 0.07±0.009\textsuperscript{a,1} (0.07) | 0.0004 (S) |
| 9                                               | 0.07±0.008\textsuperscript{a,2} (0.07) | 0.07±0.011\textsuperscript{a,1} (0.07) | 0.09±0.015\textsuperscript{b,2} (0.09) | <0.0001 (HS) |
| $P^*$                                           | 0.0006 (S)      | 0.0004 (S)   | 0.0002 (S) |

Alphabets in superscripts indicate significance of pair-wise comparison for each distance across group; Numbers in superscripts indicate significance of pair-wise comparison for each group across distances from root apex. Same alphabets or numbers indicate statistical insignificance.

*Obtained using one-way ANOVA; S=Significant, HS=Highly significant, ANOVA=Analysis of variance, SD=Standard deviation.
that of other two distances. The mean values at 3 mm and 6 mm were insignificantly different as indicated by same numbers in superscript

• The mean transportation for PN group shows statistically significant difference across distances as indicated by \( P = 0.0004 \). The pair-wise comparison of mean values using Tukey’s post hoc test suggested that the mean at 6 mm was significantly higher than that of other two distances. The mean values at 3 mm and 9 mm were insignificantly different as indicated by same numbers in superscript

• The mean transportation for HyF group shows statistically significant difference across distances as indicated by \( P = 0.0002 \). The pair-wise comparison of mean values using Tukey’s post hoc test suggested that the mean at 9 mm was significantly higher than that of other two distances. The mean values at 3 mm and 6 mm were insignificantly different as indicated by same numbers in superscript [Figure 3].

Table 2 provides the mean, standard deviation, and median for canal centering ability for three groups at three different distances from root apex.

• It shows that the mean centering ability at 3 mm distance from root apex shows statistically significant difference across groups with \( P = 0.0002 \). The paired-wise comparison of mean values between groups using Tukey’s post hoc test suggested that mean for PN group was significantly lower than that of other two groups. The mean values for VT and HyF were insignificantly different as indicated by same alphabets in superscript

• The mean centering ability at 6 mm distance from root apex shows statistically significant difference across groups with \( P = 0.0017 \). The paired-wise comparison of mean values between groups suggested that mean for VT group was significantly higher than other two groups. The mean values for PN and HyF were insignificantly different as indicated by same alphabets in superscript

• The mean centering ability at 9 mm distance from the root apex shows statistically significant difference across groups with \( P = 0.0117 \). The paired-wise comparison of mean values between groups suggested that mean for VT group was significantly higher than other two groups. The mean values for PN and HyF were insignificantly different as indicated by same alphabets in superscript

• The mean centering ability for VT group shows statistically significant difference across distances as indicated by \( P = 0.00015 \). The pair-wise comparison of mean values using Tukey’s post hoc test suggested that the mean at 9 mm was significantly lower than that of other two distances. The mean values at 3 mm and 6 mm were insignificantly different as indicated by same numbers in superscript

• The mean centering ability for PN group shows insignificant difference across distances as indicated by \( P = 0.211 \)

• The mean centering ability for HyF group shows statistically significant difference across distances as indicated by \( P < 0.0001 \). The pair-wise comparison of mean values using Tukey’s post hoc test suggested that the mean at 3 mm was significantly higher than that of other two distances. The mean values at 6 mm and 9 mm were insignificantly different as indicated by same numbers in superscript [Figure 4].

Discussion

This study sought to evaluate canal transportation and centering ability of files in severely curved root canals. The importance of preserving the natural root canal anatomy after its instrumentation has been discussed and researched upon.\(^{11}\) Failure to respect the canal anatomy may result in zipping, ledging, or perforations. Professionals need to balance well between the concepts of controlled instrumentation and removal of contaminated dentin.
Table 2: Descriptive statistics for canal centering ability according to distance from root apex and groups

| Canal centering ability - distance from root apex (mm) | v-Taper | ProTaper next | Hyflex cm | P* |
|---------------------------------|---------|---------------|-----------|----|
| 3                               | 0.80±0.072 (0.81) | 0.58±0.144 (0.57) | 0.75±0.090 (0.73) | 0.0002 (S) |
| 6                               | 0.72±0.098 (0.68) | 0.52±0.103 (0.51) | 0.60±0.134 (0.60) | 0.0017 (S) |
| 9                               | 0.62±0.128 (0.64) | 0.49±0.065 (0.50) | 0.51±0.076 (0.52) | 0.0117 (S) |
| p*                              | 0.0015 (S) | 0.211 (NS)    | <0.0001 (HS) |    |

Alphabets in superscripts indicate significance of pair-wise comparison for each distance across group; Numbers in superscripts indicate significance of pair-wise comparison for each group across distances from root apex. Same alphabets or numbers indicate statistical insignificance. *Obtained using one-way ANOVA; NS=Not significant, S=Significant, SD=Standard deviation, ANOVA=Analysis of variance, HS=Highly significant.

Human mandibular molars were used in this study. The mesial roots of mandibular molars were chosen for this study because these contain canals that usually curve in two planes.\(^{[12]}\)

Noninvasive CBCT scanning was used because it provides an accurate, reproducible, three-dimensional evaluation of changes in both dentin thickness and root canal volume before and after preparation without the destruction of specimens.\(^{[10,13,14]}\) However, micro-computed tomography (CT) and spiral CT techniques are additional techniques for assessing canal transportation and centering ability \textit{in vitro}.\(^{[15]}\) However, the cost-effectiveness and lack of availability of these methods led us to use CBCT scanning in the current study which was easily accessible. Three levels (i.e., 3 mm, 6 mm, and 9 mm from the root apex) were chosen representing the apical and middle thirds of root canal in which curvatures highly susceptible to iatrogenic mishaps usually exist.

Very few researches have been done on VT files. VT files are a series of patented, variable-taper NiTi rotary files that permit deeper apical shapes with fewer instruments. The files yield a conservative access path that retains more healthy tooth structure at the heart of the tooth, i.e., at pericervical area. VT rotary files feature a parabolic cross-section design that combines high efficiency and flexibility while being safe and resistant to fracture. In this study, VT showed more canal centering ability and less canal transportation than other tested files. This can be attributed to its reduced shaft diameter and less cross-sectional area. This is in accordance with highlights from various literature that the canal centering ability is better within Ni–Ti instruments, instruments with less cross-sectional area and instruments with noncutting tips.\(^{[16,17]}\)

According to the present study, PN caused less transportation at apical section than the middle section and better-maintained canal curvature, even though PN produced more transportation at middle section compared with HyF and VT files. The PN files are newly invented files whose microstructure is mainly comprised martensite phase which denotes that files are more flexible and ductile.\(^{[18]}\) The less transportation at apical section can be attributed to the progressive taper of file apically and decreasing taper coronally which makes the files more flexible at the apical section. In addition, PN has a unique swagging motion like a snake due to its off-centered rectangle cross section. It has been found that files with square to rectangle cross section designs have the highest screw-in force and flexural stiffness.\(^{[19]}\) Therefore, PN which has rectangle cross section, high screw in force, and decreasing coronal taper causes more canal transportation at coronal end.

According to a study conducted by Wu \textit{et al.} in which shaping ability of ProTaper Universal, PN, and WaveOne was compared, it was seen that PN showed better shaping ability than ProTaper Universal and WaveOne at the curved section of root canals, and PN maintained the best apical constriction. However, all the files had a tendency to straighten the apical curvature in multicultured canals.\(^{[20]}\)

HyF files are manufactured with a unique process that controls the materials memory making the files extremely flexible. This increases the ability of the file to follow the anatomy of the canal very closely, and reduces the risk of ledging, transportation, and perforation. In the present study, in the coronal and the middle thirds of the canals, HyF files caused more canal transportation than in apical area.

The results are in accordance with a study conducted by Kumar \textit{et al.} where it was seen that in the coronal and the middle thirds of the canals, HyF files caused slightly less transportation and more centered preparation.\(^{[21]}\)

Saber \textit{et al.} compared the shaping ability of PN, iRaCe, and HyF rotary NiTi files during the preparation of severely curved root canals, which showed that the use of PN resulted in significantly greater canal straightening than iRaCe and HyF, with no significant differences between iRaCe and HyF.\(^{[22]}\)

Overall in all the three sections, VT files showed better centering ability within canal and less transportation, PN showed less apical transportation than HyF. This is the first study on canal shaping ability of VT files. Within the parameters of this study, VT instruments produced significantly less transportation and remained centered...
around the original canal to a greater degree than did the other techniques.

**Conclusion**

Within the parameters of this study, it could be concluded that all the tested files showed some degree of apical canal transportation, but it was well within the acceptable limit (0.3 mm) of canal transportation. In addition, VT files remained better centered than other files due to its decreased shaft and coronal diameter.

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**Conflicts of interest**

There are no conflicts of interest.

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