ORIGINAL RESEARCH

Analysis of Shaping Abilities of Rotary File Systems in Oval Canals with Moderate Root Curvature: A Randomized Controlled *Ex Vivo* Study

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Abstract

Aim: The purpose of this study was to evaluate and compare the canal transportation tendencies and centering ability of the TruNatomy shaper (TN) and XP-endo shaper (XPS) rotary systems in oval-shaped canals with moderate root curvature (15°–25°), using cone-beam computed tomography (CBCT) imaging.

Materials and methods: Sixty single-rooted permanent human teeth were chosen after considering the inclusion and exclusion criteria. The teeth were divided into two groups ($n = 30$). The test group was instrumented with TN files and the other with XPS according to manufacturer's instructions. CBCT images were taken before and after instrumentation to record the root canal distances from mesial, distal, buccal, and lingual borders of the root at 3, 5, and 7 mm distances from the root apex using a specific formula. Statistical analysis was done using the Statistical Package for the Social Sciences software program, version 20.0. The data were analyzed using the unpaired *t* test.

Results: Both TN and XPS were safe for use in oval-shaped canals with moderate root curvature. However, the XPS showed higher buccolingual transportation as compared with TN at 3 mm from the apex and higher mesiodistal transportation at 3 and 5 mm levels from the apex as compared with TN.

Conclusion: Canal transportation has been detected in both systems; however, the values obtained were within the safe range (<0.3 mm). Overall, no significant difference was observed between TN and XPS ($p > 0.05$) in their canal transportation tendencies and centering ability.

Clinical significance: The study assesses the canal centering and transportation tendencies of the recently launched TN rotary system in extracted teeth with a combination of morphologies. The findings of the study are significant clinically as minimum transportation of the canal, minimal dentin removal, efficient disinfection, and three-dimensional obturation of the root canal are considered important factors in deciding the prognosis of endodontic therapy.

Keywords: Canal transportation, Centering ability, Cone-beam computed tomography, Oval-shaped canals, TruNatomy shapers, XP-endo shapers.

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Introduction

The main goal of a root canal procedure is adequate disinfection while maintaining the shape of the root canal as close to its initial anatomy as possible. This can often be a challenge in curved and oval-shaped canals resulting in undesirable outcomes, such as transportation of the apex, ledging, perforation, and damage to apical foramen leading to irritation of periapical tissues.[1] Insufficient access preparation in an oval-shaped canal can result in incorrect guidance of the rotary instrument along the root canal resulting in loss of control during the preparation.[2,3] The difficulty is further increased when associated with a curvature at the apical region. Numerous studies have reported that instrumentation of oval-shaped canals leaves behind unprepared recesses that harbor bacterial and necrotic pulp tissue remnants. All of these serve as potential sources of persistent infection and treatment failure.[4–8]

Numerous nickel–titanium (Ni–Ti) rotary system files are available in the market with superior canal centering ability. Since the 1900s, these instruments have undergone revolutionary changes in their construction and physical characteristics.[9] TruNatomy shapers (TNs) are a new generation of Ni–Ti rotary files heat treated with a unique design to shape root canals into a continuously tapering preparation with maximum preservation of peri-cervical dentine.[10] It also provides exceptional flexibility with superior canal centering ability.[11]

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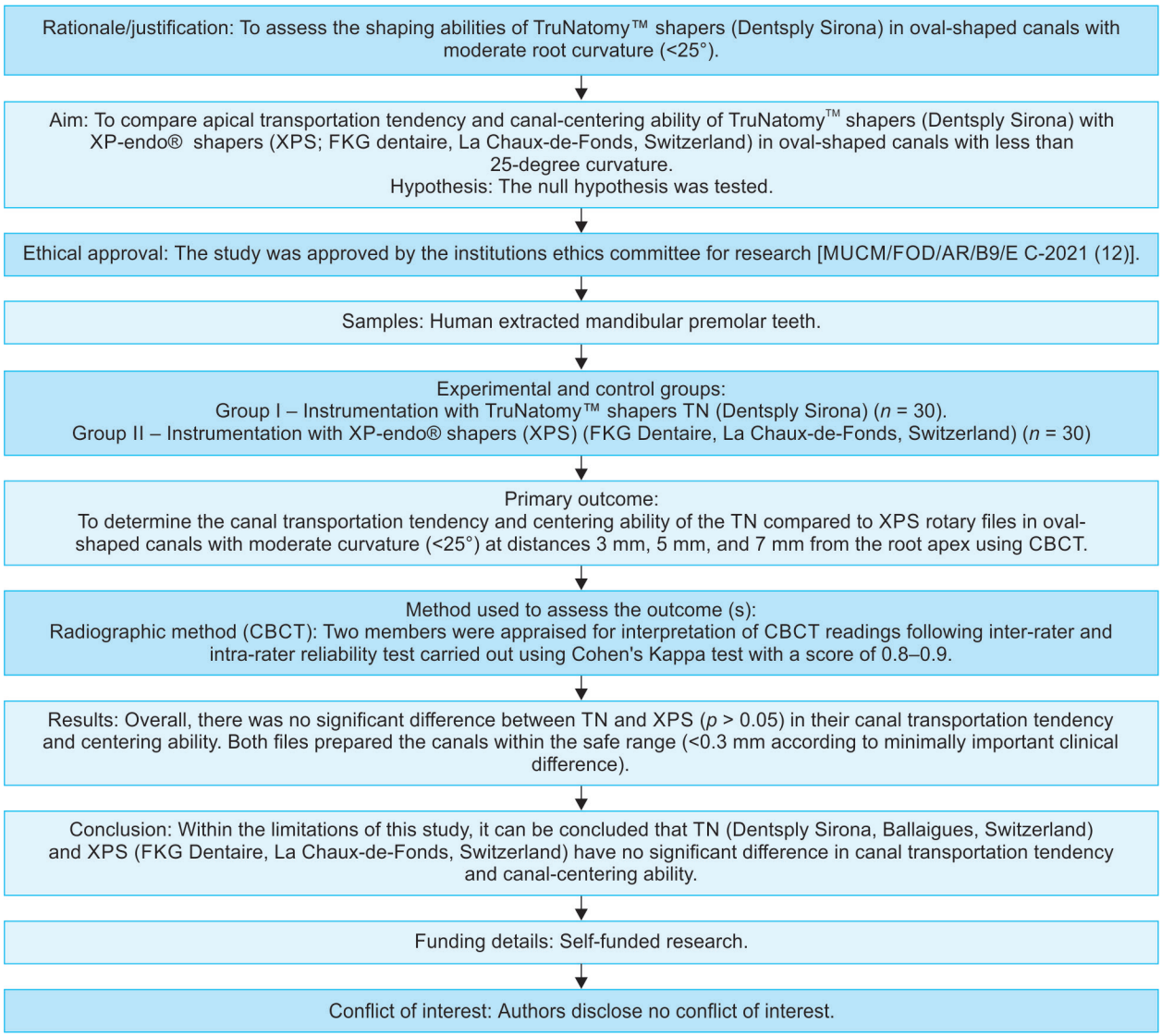
XP-endo shaper (XPS) is a single rotary system made of MaxWire alloy that contributes to its shape memory and superelastic properties. It has a snake-shape triangular cross-section with an apical diameter of 0.27 mm and a fixed taper of 0.01. It also has

Flowchart 1: PRILE flowchart 2021



a special booster tip with six cutting edges, allowing efficient canal shaping after a manual glide path of at least #15 K-file followed by increasing the apical size to achieve an ISO size of 30.[12]

There are limited studies assessing the shaping abilities of TN in oval-shaped canals with moderate canal curvature. Therefore, this study aimed to determine the canal transportation tendency and centering ability of the TN and XPS rotary files in oval-shaped canals with moderate curvature (15°–25°). The null hypothesis states that there is no difference in the canal transportation and canal centering ability of TN files using cone-beam computed tomography (CBCT) imaging on extracted teeth with oval-shaped canals with moderate curvature (15°–25° curvature).

Materials and Methods

The ethical approval was obtained from the institutional Ethics Committee for Research [MUCM/FOD/AR/B9/E C-2021(12)]. The study was conducted in the Department of Endodontics, Manipal University College Malaysia, Melaka, Malaysia during the period from March 10, 2021 to May 22, 2022. The manuscript of this *in vitro* randomized controlled study has been written according to Preferred Reporting Items for Laboratory Studies in Endodontology (PRILE) 2021 guidelines (Flowchart 1).[13]

Mandibular premolar teeth extracted for orthodontic purposes were collected following consent obtained from the patients. The collected teeth were cleaned with ultrasonic tips to remove gross debris, soaked in a saline solution mixed with 1% ethanol, and then autoclaved.

Sample size calculation was done based on previous research by Hasheminia et al.[14] A sample size of 30 for each file was suggested to achieve 90% power. Non-probability sampling was done, followed by block randomization using sealedenvelope.com. The teeth were selected considering the inclusion criteria composed of extracted human teeth with completely formed apices, single-rooted having an oval-shaped canal with moderate curvature (15°–25°) determined using the CBCT (PLAnMECA Promax 3Ds,

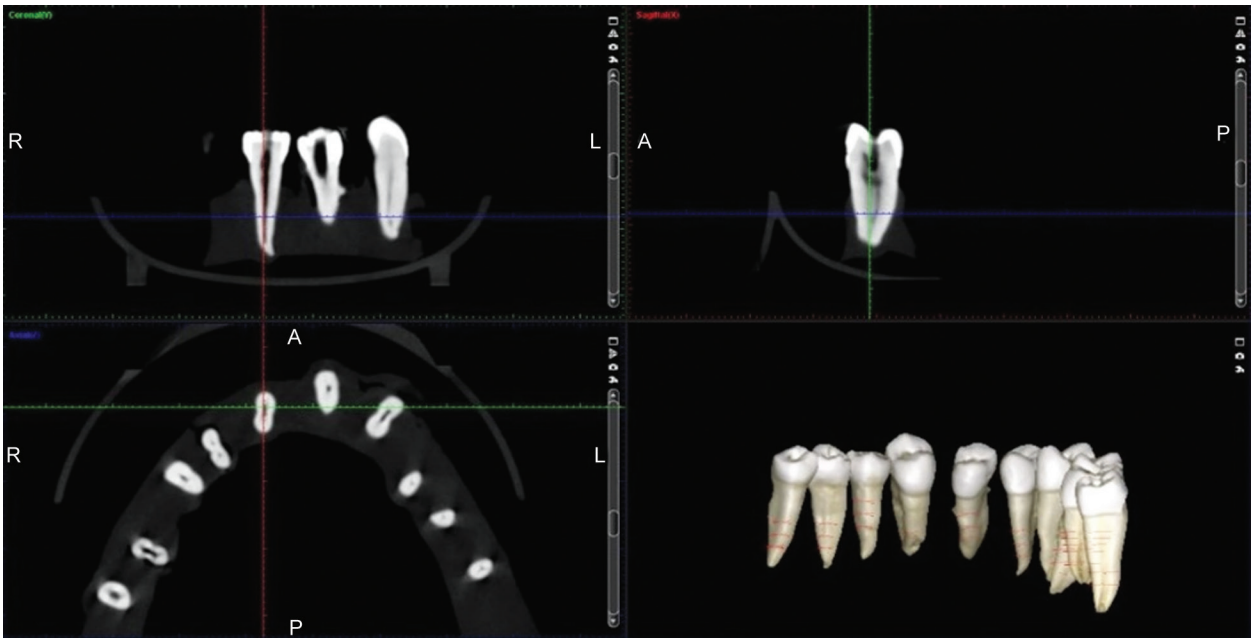


Fig. 1: CBCT image representing the selection of oval-shaped curved root canals

Helsinki, Finland; Fig. 1). Teeth with calcified canals, fractures, cracks, more than a single root/canal, and severely curved root canals (>25° according to Schneider's classification) were excluded.[15] The selected teeth were then randomly divided into two groups ($n = 30$) and mounted onto wax blocks.

The endodontic procedures were performed by two operators. Other two operators, blinded to the endodontic procedures, were appraised for interpretation using CBCT readings. The inter-rater and intra-rater reliability tests were carried out using Cohen's kappa test with a score of 0.8–0.9.

Access cavity was prepared using Endo-Access burs #2 (Dentsply Tulsa, Tulsa, Oklahoma) on each tooth. The working length was determined radiographically by inserting a size of #15 K-file (Mani, Utsunomiya, Japan) until the apical foramen and subtracting 1 mm from the obtained measurement.

A preoperative image was obtained with the CBCT using the Romexis software (version 3.0.1.R) to record the distances from mesial (a1), distal (b1), buccal (c1), and lingual (d1) borders of tooth root at 3, 5, and 7 mm distances from the root apex of each tooth. The images were acquired with exposure parameter setting (90 kV, 8 mA, and 12.28 s) and image acquisition of 0.20 mm voxel size.

Root Canal Preparation

A glide path was created in both groups by using the #15 K-file followed by irrigation with 5 mL of NaOCl.

Control group: XPS (FKG Dentaire, La Chaux-de-Fonds, Switzerland) ($n = 30$): the XPS was used at 900 RPM and 1 N.cm torque according to the manufacturer's instructions. The canals were shaped to a size 30, 0.04 taper. The file was inserted into the canal with a motion of five long gentle strokes until the working length was reached.

Test group: TN (Dentsply Sirona) ($n = 30$): The files were run at 500 RPM with 1.5 N.cm according to the manufacturer's instructions. The Orifice Modifier (size 20, variable taper) was used with 2–3 gentle apical strokes (2–5 mm) into the canal followed by the TN Prime shaping file (tip size 26, 0.04 regressive taper) till the working length.

Each rotary file was used for five teeth and then discarded. During instrumentation, the canal was irrigated with 5 mL of 2.5% NaOCl, and the file flutes were cleaned from debris. Following instrumentation, a final irrigation protocol was carried out using 2-mL 2.5% NaOCl (30 s) → 2-mL 15% EDTA solution (2 min) → 2-mL 2.5% NaOCl (30 s) → 2-mL saline solution.[16]

Subsequently, a postoperative scan using CBCT was carried out using the same parameters mentioned before. The measurements were taken by recording the root canal distances from mesial (a2), distal (b2), buccal (c2), and lingual (d2) borders of tooth root at levels 3, 5, and 7 mm from each root apex (Fig. 2).

Canal transportation and centering ability were determined by substituting values acquired from measurements of canal transportation into the formula below:

Canal Transportation

The determination of apical transportation formula (Fig. 3) is as follows:[14]

$$(a1 - a2) - (b1 - b2)$$
$$(c1 - c2) - (d1 - d2)$$

where $a1$, $b1$, $c1$, and $d1$ are the minimum distances between the mesial, distal, buccal, and lingual extents of the root canal before instrumentation, whereas $a2$, $b2$, $c2$, and $d2$ represent after instrumentation.

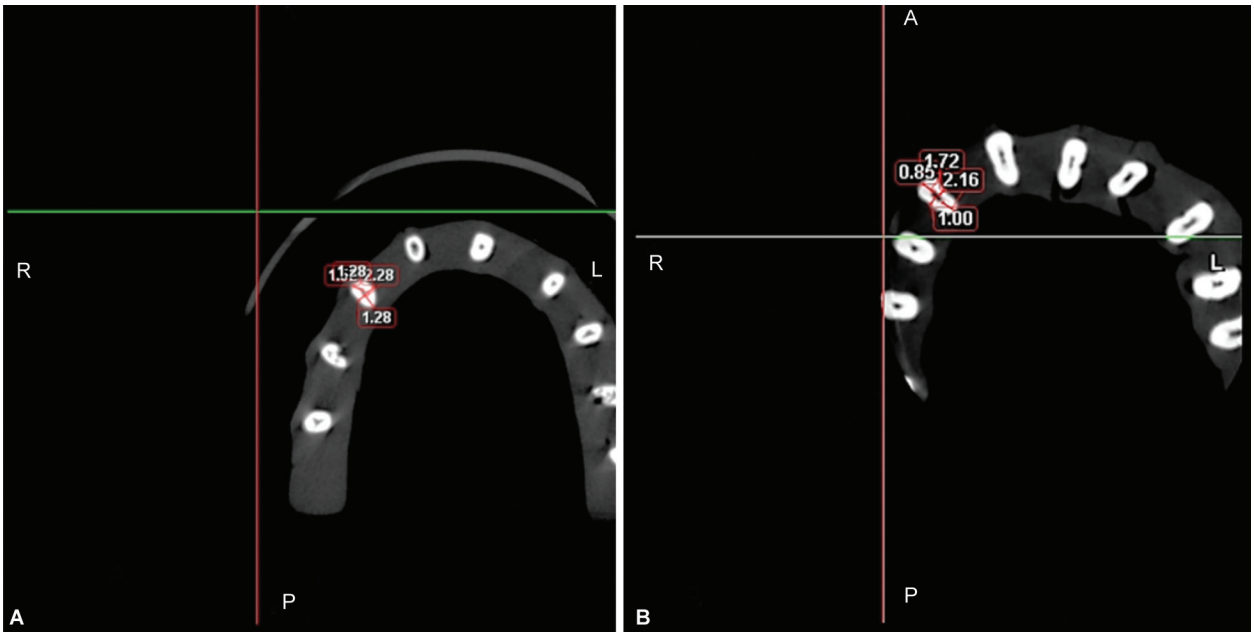
According to these formulas, 0 signifies no canal transportation, whereas a positive or negative value represents mesial, buccal, distal, or lingual transportation.

Canal-centering Ability

The determination of canal centering ability formula (Fig. 3) is as follows:[14]

$$a1 - a2/b1 - b2 \text{ or } b1 - b2/a1 - a2.$$

The fraction with the lesser value was selected for statistical analysis in these formulas. According to the formulas, a value of 1 signifies



Figs 2A and B: Postoperative scan representing measurements taken at (A) 3 mm from the apical foramen and (B) 5 mm level from the apical foramen

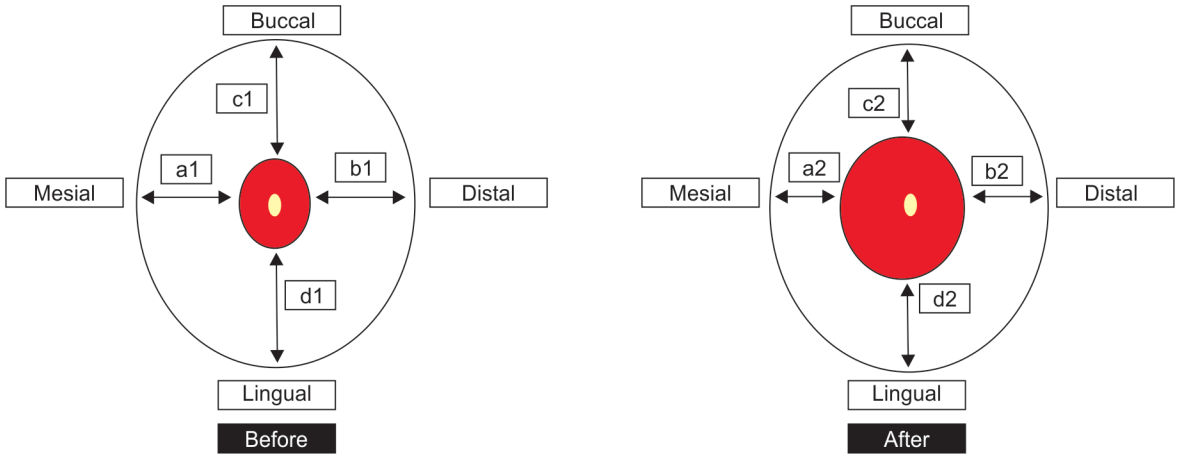


Fig. 3: A schematic representation of measurements in cross-section. The yellow dot indicates the center of the root canal

Table 1: Comparison of canal transportation between TruNatomy shapers and XP-endo shapers

Distance from tooth apex	*Mesiodistal transportation (mm), mean (SD)*			*Buccolingual transportation (mm), mean (SD)*		
	T	*X*	*p-value*	*T*	*X*	*p-value*
3 mm	−0.002 (0.219)	−0.051 (0.287)	0.463	−0.110 (0.377)	−0.216 (0.436)	0.317
5 mm	0.001 (0.306)	−0.048 (0.231)	0.487	−0.031 (0.460)	−0.023 (0.368)	0.941
7 mm	0.027 (0.217)	0.031 (0.170)	0.947	−0.042 (0.330)	−0.032 (0.424)	0.920

T, TruNatomy shapers; *X*, XP-endo shapers. *Unpaired *t* test ($p < 0.05$)

complete centering, whereas other values represent possible deviations in the canal pathway.

Statistical Analysis

Data were tabulated and analyzed using IBM Statistical Package for the Social Sciences (SPSS) software program, version 20.0 (IBM, Chicago, Illinois). An unpaired *t* test was used to compare the findings concerning canal transportation and canal centering ability in both file systems. The significance level was set at $p < 0.05$ in all cases.

Results

Canal Transportation

According to the results of this study, Table 1 shows the mean value and standard deviation of canal transportation tendency of TN and XPS, respectively, at levels 3 mm, 5 mm, and 7 mm. TN showed a maximum mean value of mesiodistal transportation at 7 mm (0.027 ± 0.217) and maximum buccolingual transportation at 3 mm (−0.110 ± 0.377). In comparison, XPS showed maximum mesiodistal transportation at 3 mm (−0.051 ± 0.287) and 5 mm (−0.048 ± 0.231)

Table 2: Comparison of centering ability between TruNatomy shapers and XP-endo shapers

Distance from tooth apex	*Centering ratio (mm), mean (SD)*		
	T	*X*	*p-value*
3 mm	0.361 (0.336)	0.461 (0.376)	0.287
5 mm	0.502 (0.343)	0.409 (0.287)	0.259
7 mm	0.397 (0.344)	0.480 (0.332)	0.345

T, TruNatomy shapers; *X*, XP-endo shapers. *Unpaired *t* test ($p < 0.05$)

and maximum buccolingual transportation at 3 mm (–0.216 ± 0.436) from the root apex. However, both the files showed no statistically significant difference ($p > 0.05$) at all levels (3, 5, and 7 mm).

Canal-centering Ability

Table 2 shows the mean value and standard deviation of centering abilities of both rotary systems, respectively, at levels 3 mm, 5 mm, and 7 mm. TN showed a maximum centering ratio at the 5-mm level (0.502 ± 0.343). In contrast, XPS showed a maximum centering ratio at the 7-mm level (0.480 ± 0.332). However, there were no statistically significant differences ($p > 0.05$) between both files at levels of 3, 5, and 7 mm from the root apex.

The TN and XPS groups showed no statistically significant difference in terms of canal transportation tendency and canal centering ability. The XPS showed higher buccolingual transportation at 3 mm from the apex and higher mesiodistal transportation at 3 and 5 mm levels from the apex as compared with TN. However, the canal transportation tendency was less than 0.3 mm at all levels for both systems, which is well within the safe range.

Discussion

Endodontic therapy focuses on preserving the configuration of the root canal closest to its original anatomy. Hence, the files must be maintained in the center of the canal during instrumentation to avoid canal transportation, which may result in procedural errors.[1,17] This study aimed to assess the canal transportation tendency and canal centering ability of a novel file, TN, compared with XPS, the reference standard, in oval-shaped canals with moderate curvature.

The flattened geometry of oval-shaped canals, which ranges from 25 to 50%, presents difficulties in the guidance of root canal shaping, especially in the buccal and lingual extensions that harbor bacteria and residual debris, potentiating endodontic failure.[2] Teeth comprising both oval and curved canal morphology might pose a challenge, emphasizing the importance of the files' ability to clean and shape the canals. Thus, this study addresses this challenge, the shaping abilities of the newly launched TN rotary system in teeth with a combination of morphologies, oval-shaped with moderate root curvature (15°–25°) was assessed.

XPS was chosen as the reference standard due to its low canal transportation tendency and better canal-centering ability, which is evident in various studies. Studies conducted in simulated root canals by Alfadley et al.[12] Yanes et al.[18] and Shukri et al.[19] concluded that XPS preserved the original shape of the simulated curved root canals with minimal transportation than the other compared rotary systems. Another study by Werdina et al.[20] reported that XPS had the best centering ability near the apical end of the simulated curved root canal. Studies conducted by Velozo et al.[6] and Poly et al.[21] suggested that increased instrumentation time with the XPS improved the shaping abilities in oval-shaped canals.

TN is a recently launched Ni–Ti rotary system equipped with smaller diameter initial wire blanks with heat-treated wire providing more flexibility and resistance to cyclic fatigue, making precurving of the files possible with reduced risk of breakage. These factors offer superior canal-centering ability.[22] According to Kim et al.,[23] Kiran et al.,[17] and Kumar et al.,[24] TN files showed significantly less canal transportation canal and preserved more peridentin in simulated canals.

The findings of this study showed no significant statistical difference in canal transportation tendency between TN and XPS at all levels. This was in concordance with the studies by Kabil et al.[25] and Morales et al.,[26] where no significant difference was observed between TN and XPS in extracted teeth with curved root canals. These results could be attributed to the properties of TN and XPS, which were designed to maximize the efficacy of the root canal shaping procedure, as stated previously. Although canal transportation has been detected in both systems, the values obtained were within the safe range (<0.3 mm).[27] Concerning canal-centering ability, the findings were according to the study by Medeiros et al.[7] reporting no significant difference in the canal-centering ability of two other rotary files in oval-shaped canals. This could be attributed to the properties of the Ni–Ti alloy, which is used to fabricate the files.

Studies evaluating the shaping capabilities of rotary file systems frequently use contemporary imaging techniques, microcomputed tomography, and CBCT. Micro-CT is an excellent imaging tool that is used as a reference standard in many studies.[28,29] The high-resolution detectors and microfocus spot X-ray sources allow enhanced image development within the range of 5–50 mm voxel size.[30] However, these systems are high priced, requiring extended scanning and reconstruction times. CBCT imaging is a valuable tool in sectional imaging for endodontic diagnosis. In three-dimensional images, it allows possible visualization of all structures in one image and their superimpositions; this offers superiority in contrast to two-dimensional radiographs.[31,32]

Several studies have used simulated root canal resin blocks to show the shaping abilities of rotary systems and methods of canal space preparation.[33–35] However, dentin and resin are not of the same hardness; the significance of the research outcomes may be an issue of concern. The use of extracted human teeth in this study may be seen as an advantage for accurate simulation of a clinical situation. The levels 3 mm, 5 mm, and 7 mm were chosen to represent the apical, middle, and coronal third regions of the root canal where the curvatures are usually present with a high risk of procedural errors.[36]

According to the results of this study, TN showed more mesiodistal transportation than XPS. This may be accredited to the resistance encountered by both files. During instrumentation, tapers of TN and XPS increase to 0.04 as the final taper[7] increase in taper can lead to a decrease in flexibility.[9] However, since TN has fewer cutting edges than XPS, it encounters less resistance, ensuring greater precision and adaptation to the root canal morphology.[11]

At 3 mm from the apex, this study revealed that XPS showed drastically higher buccolingual transportation than TN. This may be attributed to the reduction in flexibility as the taper increases, resulting in the inability of the file to conform to canal morphology. The apical 3 mm being more constricted and curved can lead to more evident transportation. The results of this research showed

both files had canal transportation toward the lingual side; this may be due to the morphology of the oval-shaped canals encountered in this study, which presented with a broader buccal aspect and narrower lingual aspect; thus, canal transportation may be more readily appreciated on the lingual aspect.

The (observational error) incremental measuring error of the CBCT machine used in this research was calculated with the formula, (±sqr [3] × voxel size = 1.7 mm × 0.2 mm, according to Pythagoras) and found to be 0.34 mm. The error is based on the measurement points' positioning and depends on the machine's voxel size (± one voxel size). This could have influenced the quality of the images used for the measurements.[37] Also, the simulation of body temperature could not be achieved in the experiment, which could have affected the performance of the XPS file in this study.[12]

As the shaping abilities of TN are yet to be explored to a greater extent by other researchers, this study can contribute as a foundation for future research. More clinical research should be conducted for more conclusive and accurate results.

Conclusion

Within the limitations of this study, it can be concluded that TN and XPS have no significant difference in canal transportation tendency and canal centering ability. The XPS showed higher buccolingual transportation at 3 mm from the apex and higher mesiodistal transportation at 3 and 5 mm levels from the apex as compared with TN. However, the canal transportation tendency was less than 0.3 mm at all levels from the root apex for both systems, which is well within the safe range.

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