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Research Article

Comparative Evaluation of Canal Transportation and Centering Ability of Three Different File Systems using Cone Beam Computed Tomography: An *In Vitro* Study

Malaika Varma*, Pankaj Kumar Gupta, Neha Jaju, Sonal Dhote and Sneha Rathaur

Department of Conservative Dentistry and Endodontics, Rungta College of Dental Sciences and Research, Bhilai, India

***Corresponding Author:** Malaika Varma, Department of Conservative Dentistry and Endodontics, Rungta College of Dental Sciences and Research, Bhilai, India.

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Abstract

Background: Root canal instrumentation plays a pivotal role in the success of endodontic treatment by enabling thorough cleaning and shaping of the root canal system. However, mechanical preparation can lead to undesirable alterations such as canal transportation, loss of working length, and deviation from the natural canal curvature. These procedural errors can compromise treatment outcomes. With advancements in endodontic instrumentation, NiTi rotary systems have evolved to offer improved flexibility and cutting efficiency while minimizing iatrogenic errors. Understanding how different file systems influence canal shaping is essential for clinical decision-making. Cone Beam Computed Tomography (CBCT), with its high-resolution 3D imaging, allows for accurate evaluation of canal morphology and the effects of instrumentation.

Aim: To compare and evaluate the canal transportation and centering ability of three different rotary file systems, ProTaper Next, NeoEndo Flex, and Jizai using Cone Beam Computed Tomography in an in-vitro setting.

Materials and Methods: An *in vitro* study was conducted using 105 extracted human mandibular premolars with single canals. Teeth were randomly divided into three groups (n=35 each) and instrumented using ProTaper Next, NeoEndo Flex, and Jizai rotary file systems. Pre- and post-instrumentation CBCT scans were obtained. Canal transportation and centering ability were measured at 3 mm, 6 mm, and 9 mm from the apex in both mesiodistal and buccolingual planes. Data were statistically analyzed using one-way ANOVA, with a significance threshold set at $P < 0.05$.

Results: In the mesiodistal plane, ProTaper Next demonstrated significantly better centering at 6 mm, while Jizai outperformed other systems at 9 mm ($P = 0.044$ and $P = 0.018$, respectively). NeoEndo Flex consistently exhibited the lowest centering ability across all levels. In the buccolingual plane, although differences were not statistically significant, Jizai showed improved centering at 6 mm and 9 mm, and ProTaper Next at 3 mm. Regarding canal transportation, Jizai files maintained the canal anatomy most effectively across all levels. At 3 mm in the buccolingual direction, Jizai showed the highest transportation ($P = 0.025$), while both ProTaper Next and NeoEndo Flex showed negative values, indicating canal straightening. Overall, Jizai showed the best shaping ability, followed by ProTaper Next and then NeoEndo Flex.

Conclusion: Jizai rotary files demonstrated the highest centering ability and the least canal transportation, indicating better preservation of canal anatomy. ProTaper Next also showed promising results, whereas NeoEndo Flex was less effective. CBCT proved to be an accurate and reliable tool for assessing canal shaping outcomes.

Keywords: Endodontic Treatment; NiTi Rotary System; Canal transportation; Centering ability; ProTaper Next; Jizai; NeoEndo Flex; Cone Beam Computed Tomography

Introduction

The primary objective of root canal treatment is the effective elimination of bacteria and dentinal debris through mechanical instrumentation, thorough disinfection, and optimal obturation of the root canal system [1,2]. Ideally, canal shaping should create a continuously tapered preparation from the coronal to apical end while preserving the original curvature and minimizing apical foramen enlargement [3,4]. Simultaneously, procedural errors such as instrument fracture, canal transportation, ledge formation, or perforation must be avoided [5,6].

Numerous studies involving extracted teeth and simulated canals have demonstrated that rotary nickel–titanium (NiTi) instruments facilitate faster, more centered, and conservative canal shaping compared to traditional stainless steel instruments [7,8]. However, shaping complex anatomies, especially curved canals, remains challenging, as all instrumentation techniques can potentially alter the original canal trajectory [9]. The advent of rotary NiTi systems has revolutionized modern endodontics by enabling faster and more predictable canal preparation with fewer procedural errors and minimal deviation from the canal's natural path [8]. Their effectiveness is enhanced in straight canals due to reduced instrument stress and improved centering ability [10]. Recent advancements in NiTi rotary systems have shown significant advantages over manual instrumentation, including fewer canal aberrations, improved shaping, and reduced preparation time [8].

Cone Beam Computed Tomography (CBCT) is the imaging modality of choice in contemporary endodontics, offering three-dimensional visualization of root canal anatomy [11]. This is particularly important in detecting and assessing oval canals, which constitute 25%–50% of all canals and are often missed on two-dimensional radiographs due to their buccolingual orientation [12]. CBCT allows for accurate assessment of canal shape, positioning, and changes following instrumentation, making it ideal for evaluating parameters such as canal transportation and centering ability are key indicators of the effectiveness and safety of endodontic instruments [13].

ProTaper Next (PTN; Dentsply Maillefer, Switzerland) is a fifth-generation NiTi rotary file system made from M-Wire alloy, known for its enhanced flexibility and resistance to cyclic fatigue. It features an offset center of mass and rotation, which produces an asymmetric rotary motion designed to improve shaping efficiency and reduce canal transportation [14]. NeoEndo Flex (NeoEndo, UK) is another heat-treated file system with a convex triangular cross-section and proprietary thermal treatment, providing superior flexibility and enhanced centering ability [15]. The Jizai file system (Mani, Japan) is a recent innovation, featuring a heat-treated design with a unique cross-sectional shape and flute pitch intended to reduce file binding, over-instrumentation, and enhance adaptability. It can also be pre-bent while retaining its shape, allowing better negotiation of curved canals [16].

Thus, the aim of this study was to evaluate and compare the canal transportation and centering ability of three different file systems, ProTaper Next, NeoEndo Flex, and Jizai using CBCT imaging in both the mesiodistal and buccolingual directions.

Materials and Methods

This *in vitro* study was conducted in the Department of Conservative Dentistry and Endodontics at Rungta College of Dental Sciences & Research, Bhilai. Cone Beam Computed Tomography (CBCT) imaging was performed at the Department of Oral Diagnosis, Medicine and Radiology at the same institution. A total of 105 extracted human mandibular premolars with single root canals were collected and used for the study. These were randomly divided into three groups, with 35 samples in each group. Each group was instrumented using a different rotary file system. The selected teeth were non-carious, with fully developed and intact roots, and had complete root end closure. Teeth that were fractured, resorbed, hypoplastic, exhibited accessory or lateral canals, showed coronal decay or restorations below the cementoenamel junction, were dilacerated, or had calcified canals were excluded from the study.

All selected teeth were cleaned using ultrasonic scalers. Preoperative radiographs were taken in both buccolingual and mesiodistal directions using radiovisiography (RVG). Only teeth with no prior endodontic treatment and with a buccolingual canal dimension 2 to 2.5 times greater than the mesiodistal dimension at 5 mm from the apex were included. The selected teeth had similar working lengths and a canal curvature ranging from 0° to 15°, with a radius of curvature not less than 5–6 mm. Standard endodontic access cavities were prepared using a #4 round bur followed by an Endo-Z bur. Canal patency was established with a #10 K-file, and working length was determined by inserting the file until it was just visible at the apical foramen, then subtracting 1 mm from this measurement. The root canals were then negotiated with a #15 K-file to the working length and irrigated with 5 mL of normal saline.

All samples were mounted in modelling wax blocks, and a pre-operative CBCT scan was taken. The samples were then randomly assigned to one of the three groups and instrumented according to the manufacturer's instructions for each file system, using a torque-controlled endomotor. Instrumentation involved three to four pecking motions per file until the working length was achieved. Following each pecking motion, canals were irrigated with 3% sodium hypochlorite. Post-operative CBCT scans were obtained for all samples, ensuring that each tooth was positioned in the same orientation as during the pre-operative scan. Cross-sectional images were evaluated at 3 mm, 6 mm, and 9 mm from the apex in both mesiodistal and buccolingual directions. Canal transportation was assessed by measuring the shortest distances from the canal edge to the external root surface before and after instrumentation. The distances measured were labeled as A1, B1, C1, D1 (pre-operative) and A2, B2, C2, D2 (post-operative) in the mesial, distal, buccal, and lingual directions, respectively.

The amount of canal transportation was calculated using the difference in these measurements. The centering ability of the file systems was determined using the formula (A1-A2)/(B1-B2) or (B1-B2)/(A1-A2) for the mesiodistal direction and (C1-C2)/(D1-D2) or (D1-D2)/(C1-C2) for the buccolingual direction. The mean and standard deviation of canal transportation and centering ability were calculated at all three levels for each group. Canal transportation equal to 0 indicates that no transportation occurred, a negative value indicates that transportation occurred in the distal direction, and a positive value indicates transportation in the mesial direction. Values equal to 1 indicated perfect centering ability of the instrument, while values closer to 0 indicated a reduced ability of the instrument to maintain in the central axis of the root canal.

The 2 parameters, canal transportation and centering ability, were obtained for each tooth based on CBCT scan measurements. The statistical parameters, such as the mean and standard deviation of canal transportation and centering ability, were obtained for the 3 groups. Statistical analysis was performed with SPSS software 14.0 (SPSS Inc, Chicago, IL). Because the Kolmogorov-Smirnov test did not reveal a normal distribution of results, the significance of difference of the mean canal transportation and centering ability between the 3 groups, in both directions at each distance, was tested statistically using the One-Way ANOVA test. The level of statistical significance was set at $P < 0.05$.

Results

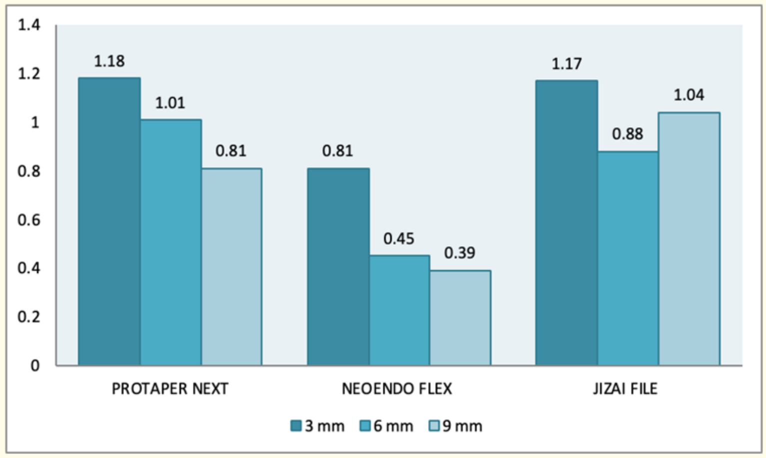
Table 1 and Graph 1 presents the mesiodistal centering ability of the ProTaper Next, NeoEndo Flex, and Jizai file systems at 3 mm, 6

File System	3 mm		6 mm		9 mm	
	Mean	SD	Mean	SD	Mean	SD
Protaper next	1.18	1.249	1.01	0.9108	0.81	1.091
Neoendo flex	0.81	2.028	0.45	1.073	0.39	0.985
Jizai file	1.17	0.502	0.88	0.903	1.04	0.727
P-value	0.462		0.044		0.018	

Table 1: Mesio-Distal Centering Ability of Protaper Next, Neoendo Flex and Jizai File System.

ANOVA

$P \leq 0.05$ is statistically significant



Graph 1: Mesio-distal centering ability of protaper next, neoendo flex and jizai file system.

mm, and 9 mm from the apex. At 3 mm, the mean centering ability values were highest for ProTaper Next (1.18 ± 1.249) and Jizai file (1.17 ± 0.502), while NeoEndo Flex had the lowest (0.81 ± 2.028) (P = 0.462). At 6 mm, NeoEndo Flex showed the lowest centering ability (0.45 ± 1.073) compared to ProTaper Next (1.01 ± 0.9108) and Jizai file (0.88 ± 0.903), with a statistically significant difference (P = 0.044). At 9 mm, Jizai file exhibited the highest centering ability (1.04 ± 0.727), while NeoEndo Flex had the lowest (0.39 ± 0.985), and the difference was statistically significant (P = 0.018).

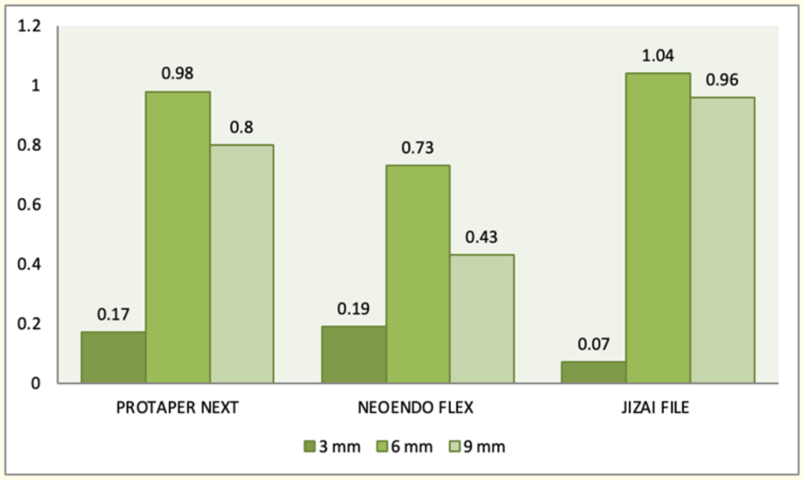
Table 2 and Graph 2 presents the buccolingual centering ability of the ProTaper Next, NeoEndo Flex, and Jizai file systems at 3 mm, 6 mm, and 9 mm from the apex. At 3 mm, the mean centering ability values were similar across all three file systems, with ProTaper Next (0.17 ± 0.488), NeoEndo Flex (0.19 ± 0.525), and Jizai file (0.07 ± 0.393), showing no statistically significant difference (P = 0.497). At 6 mm, Jizai file exhibited the highest centering ability (1.04 ± 0.754), followed by ProTaper Next (0.98 ± 1.156) and NeoEndo Flex (0.73 ± 1.329), though the difference was not statistically

File system	3 mm		6 mm		9 mm	
	Mean	SD	Mean	SD	Mean	SD
Protaper next	0.17	0.488	0.98	1.156	0.80	0.899
Neoendo flex	0.19	0.525	0.73	1.329	0.43	1.767
Jizai file	0.07	0.393	1.04	0.754	0.96	0.582
P-value	0.497		0.475		0.176	

Table 2: Bucco-lingual centering ability of protaper next, neoendo flex and jizai file system.

ANOVA

P ≤ 0.05 is statistically significant.



Graph 2: Bucco-lingual centering ability of protaper next, neoendo flex and jizai file system.

significant (P = 0.475). At 9 mm, Jizai file again demonstrated the highest centering ability (0.96 ± 0.582), while NeoEndo Flex had the lowest (0.43 ± 1.767), but the difference remained statistically insignificant (P = 0.176).

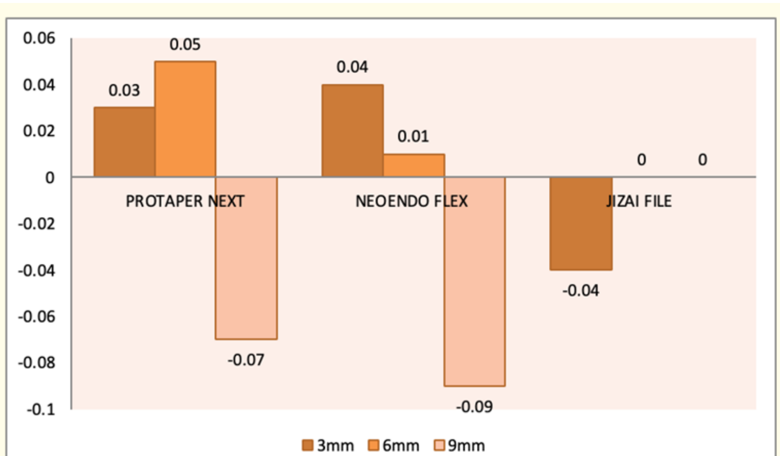
Table 3 and Graph 3 presents the mesiodistal canal transportation values for the ProTaper Next, NeoEndo Flex, and Jizai file systems at 3 mm, 6 mm, and 9 mm from the apex. At 3 mm, NeoEndo Flex exhibited the highest mean canal transportation (0.04 ±

File system	3 mm		6 mm		9 mm	
	Mean	SD	Mean	SD	MEAN	SD
Protaper next	0.03	0.237	0.05	0.230	-0.07	0.225
Neoendo flex	0.04	0.322	0.01	0.290	-0.09	0.293
Jizai file	-0.04	0.112	0.00	0.160	0.00	0.158
P-value	0.263		0.593		0.244	

Table 3: Mesio-distal canal transportation of protaper next, neoendo flex and jizai file system.

ANOVA

P ≤ 0.05 is statistically significant



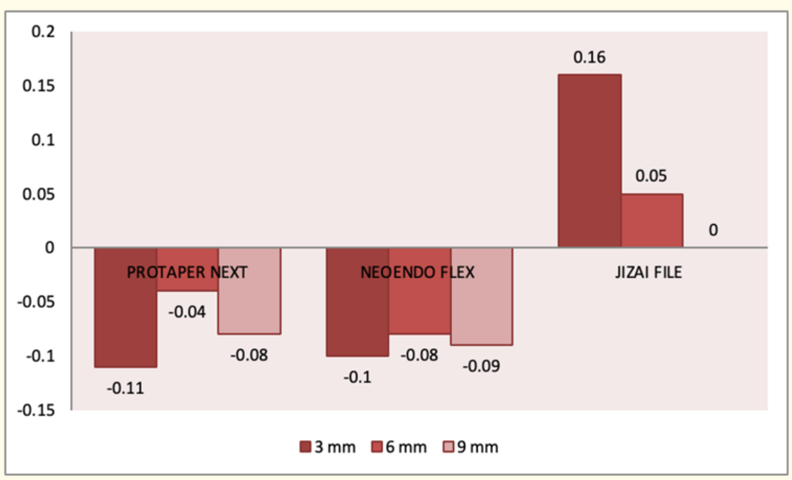
Graph 3: Mesio-distal canal transportation of protaper next, neoendo flex and jizai file system.

0.322), followed by ProTaper Next (0.03 ± 0.237), while Jizai file showed the least transportation (-0.04 ± 0.112), with no statistically significant difference (P = 0.263). At 6 mm, ProTaper Next demonstrated the highest transportation (0.05 ± 0.230), followed by NeoEndo Flex (0.01 ± 0.290) and Jizai file (0.00 ± 0.160), with no significant difference (P = 0.593). At 9 mm, ProTaper Next and NeoEndo Flex exhibited negative transportation values (-0.07 ± 0.225 and -0.09 ± 0.293, respectively), whereas Jizai file showed no transportation (0.00 ± 0.158), with the difference remaining statistically insignificant (P = 0.244).

File system	3 mm		6 mm		9 mm	
	Mean	SD	Mean	SD	Mean	SD
Protaper next	-0.11	0.479	-0.04	0.203	-0.08	0.256
Neoendo flex	-0.10	0.505	-0.08	0.336	-0.09	0.341
Jizai file	0.16	0.438	0.05	0.185	-0.00	9.159
P-value	0.025		0.058		0.304	

Table 4: Bucco-lingual canal transportation of protaper next, neoendo flex and jizai file system.

ANOVA: P ≤ 0.05 is statistically significant



Graph 4: Bucco-lingual canal transportation of protaper next, neoendo flex and jizai file system.

Table 4 and Graph 4 presents the buccolingual canal transportation values for the ProTaper Next, NeoEndo Flex, and Jizai file systems at 3 mm, 6 mm, and 9 mm from the apex. At 3 mm, Jizai file exhibited the highest mean canal transportation (0.16 ± 0.438), whereas ProTaper Next (-0.11 ± 0.479) and NeoEndo Flex (-0.10 ± 0.505) showed negative values, with a statistically significant difference (P = 0.025). At 6 mm, Jizai file had the highest transportation (0.05 ± 0.185), followed by ProTaper Next (-0.04 ± 0.203) and NeoEndo Flex (-0.08 ± 0.336), but the difference was not significant (P = 0.058). At 9 mm, all three file systems showed minimal transportation, with ProTaper Next (-0.08 ± 0.256), NeoEndo Flex (-0.09 ± 0.341), and Jizai file (-0.00 ± 9.159), with no statistically significant difference (P = 0.304).

Discussion

The evaluation of canal transportation and centering ability has been a significant area of endodontic research, as these factors influence the overall success of root canal treatment [17,18]. Evaluation of the postoperative canal shape plays a crucial role in assessing the safety and effectiveness of endodontic systems [9]. Two key parameters used to determine the quality of root canal preparation are canal transportation and centering ratio. Across various studies, different rotary and reciprocating file systems have been assessed to determine their shaping efficiency, apical transportation, and centering capabilities. The unique features of NiTi instruments, such as reduced modulus of elasticity, increased flexibility, and superelastic behavior which enable them to negotiate curved canals with minimal lateral force exertion on the canal walls, thereby preserving the original canal anatomy [19]. In contrast, stainless steel instruments, owing to their rigidity, are associated with procedural errors such as canal transportation, ledging, and zipping, especially in anatomically complex cases. Modern NiTi systems are continually evolving, incorporating innovations in cross-sectional design, variable tapers, helical angles, and cutting-edge kinematics to enhance shaping efficiency and safety [20]. However, one of the most significant advancements in recent years has been the modification of the alloy's metallurgical properties through thermal treatment processes. Heat-treated NiTi instruments exhibit a controlled phase transformation behavior, improving their resistance to cyclic fatigue and enhancing flexibility, particularly in severely curved canals [21].

The present study aimed to evaluate the canal transportation and centering ability of three NiTi rotary file systems, ProTaper Next, NeoEndo Flex, and Jizai using cone-beam computed tomography (CBCT). Mandibular premolars with a single canal were selected, considering the challenges posed by their often oval-shaped canals. Therefore, long oval single canals were selected with a buccolingual size 2 to 2.5 times larger than the mesiodistal canal 5 mm from the apex. Literature reports the flatness of oval canals ranging from 25% to 50%, predominantly in the buccolingual dimension, making their visualization difficult on two-dimensional radiographs [22,23]. The complex morphology of these oval canals presents a significant challenge in achieving thorough chemomechanical preparation, as areas of uninstrumented dentin may persist [24,25]. The selection of ProTaper Next, Jizai, and NeoEndo Flex for this study was based on their distinct metallurgical compositions and design characteristics, which influence their ability to maintain centering and minimize canal transportation. ProTaper Next incorporates M-wire technology, improving flexibility and cyclic fatigue resistance while maintaining efficient cutting. Its off-centered rectangular cross-section produces a unique swaggering motion, which may help maintain the original canal anatomy [26,27]. Jizai, a system utilizing controlled memory (CM) NiTi alloy, offers superior flexibility and adapts more closely to canal curvatures, potentially reducing unnecessary dentin removal and limiting transportation [16,28].NeoEndo Flex, manufactured using heat-treated NiTi, enhances flexibility and cyclic fatigue resistance, making it effective in preserving canal anatomy, especially in severely curved canals. Differences in alloy composition, heat treatment, and cross-sectional design among these files are key factors affecting their shaping efficiency [15,29].

To accurately assess these shaping parameters, CBCT imaging was employed, offering three-dimensional visualization of the root canal system. Unlike conventional two-dimensional radiographs, CBCT provides geometrically accurate, distortion-free images, allowing precise measurements of canal volume, surface area, cross-sectional outline, and taper [30,31]. Several previous studies have validated CBCT as a reliable measurement tool for evaluating canal preparation techniques, reinforcing its importance in this study. In the present study, in the mesiodistal plane, ProTaper Next files maintained better centering ability, with statistically significant difference observed at 6 mm and Jizai files maintained better centering ability, with statistically significant difference at 9 mm ($P = 0.044$, $P = 0.018$, respectively). Conversely, NeoEndo Flex exhibited the lowest centering ability across all levels. In the buccolingual dimension, no statistically significant differences were observed among the three file systems at any level, though Jizai files exhibited higher centering ability at 6 mm and 9 mm and ProTaper Next exhibited higher centering ability at 3 mm. Regarding canal transportation, Jizai files showed the least deviation from the original canal anatomy, with minimal transportation at all levels. Interestingly, ProTaper Next and NeoEndo Flex demonstrated negative transportation values at 9 mm in both dimensions, suggesting some degree of canal straightening. At 3 mm in the buccolingual plane, Jizai exhibited the highest transportation (P = 0.025), while ProTaper Next and NeoEndo Flex showed negative values. At 9 mm in the buccolingual plane, Jizai files exhibited the least transportation. Overall, Jizai files exhibited the best centering ability and minimal canal transportation, followed by ProTaper Next, while NeoEndo Flex demonstrated the lowest performance in maintaining canal anatomy. These results suggest that Jizai files may offer advantages in preserving the original canal shape, particularly in curved canals where centering ability is critical.

The influence of thermal treatment on file behavior was discussed in Study by Fayaz Ahmed., *et al*, which compared ProTaper Next, ProTaper Gold, Dia-X Files, and Neoendo Flex Files. This study found that ProTaper Gold and Dia-X files demonstrated better centering ability than Neoendo and ProTaper Next which was in accordance with our study [32]. Another study by Singla., *et al*. evaluated and compared the canal transportation (CT), centering ability (CA), and volumetric changes in curved canals prepared with Hyflex EDM (HEDM), ProTaper Gold (PG), and NeoEndo Flex using CBCT and found that Hyflex EDM (HEDM) and NeoEndo Flex caused less canal transportation (CT) than ProTaper Gold (PG), with significant differences at 4 mm and 7 mm from the apex which was in contrast to our study [33]. In the present study, ProTaper Next exhibited intermediate performance, which is consistent with studies by Giuseppe Troiano., *et al*. and Ekta Pansheriya., *et al*, both highlighting ProTaper Next's ability to stay centered and minimize apical transportation in curved canals. Giuseppe Troiano., *et al*, using simulated J-shaped canals, showed that ProTaper Next removed less material and stayed centered more effectively than WaveOne Classic which was in accordance to our study [34]. Ekta Pansheriya., *et al*. also confirmed ProTaper Next's minimal apical transportation compared to Mani Silk and V-Taper, making it a favorable choice in curved canals [35].

The findings of the present study align with and expand upon existing literature examining the shaping abilities of various NiTi rotary systems. Jizai files demonstrated superior canal centering and minimal transportation in the present study, corroborating the results reported by Yash., *et al*, who found Jizai to outperform WaveOne Gold and HyFlex EDM in maintaining canal anatomy [36]. Studies by Arya Navnath., *et al*. and Simar Kaur., *et al*. evaluated newer file systems, including XP-endo Shaper (XPS), TruNatomy (TRN), HyFlex CM (HCM), OneCurve, and Jizai. Arya Navnath., *et al*. found that TRN removed the least dentin and preserved canal structure better than XPS and HCM, with XPS exhibiting the highest transportation at 5 mm from the apex [37]. However, Simar Kaur., *et al.* observed no significant differences among Jizai, TruNatomy, and OneCurve, with a slight advantage for the latter two in centering ability, contrasting our results [38].

Conclusion

Within the limitations of the present study, it can be concluded that all three file systems - ProTaper Next, NeoEndo Flex, and Jizai were effective in preparing the canals, however, significant differences were observed in their shaping abilities. Jizai files demonstrated superior centering ability and minimal canal transportation, indicating better preservation of the original canal anatomy, especially in the apical and middle thirds. ProTaper Next showed good performance in the coronal third, whereas NeoEndo Flex exhibited the least favorable results across all parameters. These findings suggest that Jizai files may be a more suitable choice for cases requiring enhanced control in curved canals. Further clinical studies are recommended to validate these *in vitro* findings.

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