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CLEANING AND SHAPING ABILITY OF TWO HEAT-TREATED ROTARY NI-TI FILES: A CORRELATED HISTOLOGICAL AND CBCT STUDY

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Abstract

Objectives: the aim of the study was to compare the shaping and cleaning abilities of Race Evo and VDW. Rotate rotary files in extracted human mandibular molars. **Materials and Methods:** Sixty mesiobuccal canals, in mandibular first molars, with moderate curvature (15°–30°) were randomly assigned to two groups (n = 30): Group A (Race Evo #25/.04) and Group B (VDW.Rotate #25/.04). Shaping ability was assessed using CBCT at 3, 6, and 9 mm from apex, and cleaning efficacy was evaluated histologically by quantifying residual debris. Data were analyzed with a significance set at $p \leq 0.05$. Kruskal-Wallis and Mann-Whitney tests have been applied for intra- and intergroup comparisons of image analysis results in cleaning assessment. Chi-square test assessed differences in canal transportation and centering. **Results:** Both systems-maintained canal anatomy within acceptable limits. VDW. Rotate exhibited better centering, whereas Race Evo showed fewer residual debris, with no significant differences between groups. A moderate negative correlation was observed between centering and debris in the VDW. Rotate group ($r = -0.374$, $p = 0.027$), suggesting better centering may enhance cleaning. **Conclusion:** Both rotary systems demonstrated comparable shaping and cleaning abilities and can be considered clinically safe and effective.

Keywords: Canal Centering; Cone Beam Computed Tomography; Debris Removal; Heat Treated Ni Ti Files; Race Evo and VDW.Rotate Rotary Files.

INTRODUCTION

Traditional endodontic therapy includes cleaning, shaping, and final obturation of the root canal system. The shaping phase is crucial since the initial root canal anatomy must be conformed and expanded in accordance with the canal's original morphology. Furthermore, the constructed root canal must have a continuously tapering conical configuration. Nonetheless, these objectives are challenging to achieve due to the variety in root canal morphology, involving uneven canal cross-sections, supplementary canals, and apical deltas. Diverse techniques and instruments may be used to eliminate

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blockages and rectify shape faults such as ledging, zipping, loss of working length, and apical transportation.[1]

The use of rotational NiTi equipment in endodontics represented a significant advancement in enhancing the root canal shaping process. This method offers a more expedient and secure technique, with a lower possibility of errors in procedure compared to manual instrumentation. Numerous advancements have been made in the design and materials of NiTi rotary devices to increase their clinical efficacy. Heat-treated alloys mostly exist in the martensitic phase at reduced temperatures and exhibit greater flexibility compared to the austenitic phase of superelastic NiTi alloys. Consequently, the manufacturer does not fully provide the precise temperature and time figures.[2]

Race Evo is a heat treated NiTi file which has a sequenced system with rotational movement (15/0.04, 25/0.04, 30/0.04) and a triangular cross-sectional shape. Although the precise production procedure is unknown, the blue coloration indicates a titanium oxide coating that presumably improves their resistance.[3]

VDW Manufacturers have implemented a heat treatment technique for their file system, VDW. Rotate. This initiative aims to enhance flexibility while maintaining cutting efficiency. It is a sequenced file system including rotational movement (15/0.04, 20/0.05, 25/0.04) and an optimized s-shaped cross-section for enhanced cutting efficiency, which facilitates excellent debris removal.[4]

Utilizing CBCT, the removed dentin volume, surface area, taper, and cross-sectional morphology of the canal may be evaluated without damaging the tooth structure. It has decreased costs and scanning duration, minimized radiation exposure, and facilitated expedited data collecting relative to micro-CT.[5]

Mechanical instrumentation significantly contributes to the decrease of microorganisms in the infected root canal .[6] A study by Siqueira et al. utilized debris as a criterion to evaluate the cleaning efficacy of various instruments, as debris, consisting of dentin chips and residual vital or necrotic pulp tissue adhering to the root canal wall, is deemed infected and may lead to reinfection of the root canal. It has been shown that the cleaning of the root canal is not always readily achieved, particularly during the preparation of small and curved canals. Furthermore, to provide thorough apical cleaning, the devices must engage with every section of the canal wall.[7]

Since few studies evaluated the cleaning and shaping efficiency comparing Race Evo and VDW. Rotate files, so the cleaning ability were scored by measuring debris accumulation at the same thirds using optical microscopy. Additionally, the shaping ability was evaluated by quantifying mesiodistal transportation and centering ability at the apical, middle, and coronal thirds via CBCT. The null hypothesis was that no significant difference between Race Evo and VDW. Rotate files regarding cleaning and shaping ability of the root canal.

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MATERIALS AND METHODS

Sample size calculation

This in vitro study included 60 samples divided equally into two groups (Race Evo and VDW.Rotate), with 30 samples per group. Based on Pagliosa et al.[8], 15 samples from each group were used to evaluate canal transportation and 15 to assess debris removal. The sample size was sufficient to detect an effect size of 0.62 with 90% power at a 5% significance level. Calculations have been performed utilizing G*Power software version 3.1.9.7.[9,10]

Inclusion criteria

Sixty mandibular molars were selected with intact mesial roots standardized at 16 mm in length, mature apices, and Vertucci type IV canal configuration. Only mesiobuccal canals with a single mesiodistal curvature of 15°–30° and a 10 mm radius of curvature, as determined using CBCT and Schneider's method, were included.[11] The canals had to be patent to a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and not exceed size #20 as the initial apical file. Only the mesiobuccal canals were included for instrumentation, giving a total of sixty root canals.

Randomization and sample collection

Randomization was done using Microsoft Excel, where blind allocation was conducted by placing coded cards in sealed opaque envelopes.

Study design and ethical approval

The experimental protocol for this study was approved by the Institutional Review Board and the Research and Ethics Committee of the Faculty of Dentistry, Suez Canal University (Research Ethics Committee; REC No. 303/2020). All procedures were conducted in strict accordance with relevant institutional guidelines and regulations. A waiver for ethical approval was granted as the study utilized unidentified, randomly selected molars. These teeth had been previously extracted for clinical purposes, such as periodontal treatment, and were not linked to any specific patient identities

Sample Selection and Preparation:

Sixty mandibular first molars with mature apices were selected, disinfected in 2.5% NaOCl for 1 hour, and stored in saline. Access cavities were prepared, distal roots sectioned, and root length standardized to 16 mm. Working length for mesial roots was set 0.5 mm short of the apex using a #10 K-file.

Embedding in Acrylic Blocks: A custom-made plastic mold (15 cm length x 15 cm width x 4 cm height) with 15 holes arranged in 5 columns and 3 rows was specially constructed and painted with Vaseline as a separating media to facilitate removal of acrylic blocks later. Cold-cured acrylic resin was mixed according to the manufacture instructions and packed in 15 holes of the plastic mold. Samples were vertically embedded in the acrylic resin before complete polymerization with the buccal surface of all teeth facing the same direction and their long axis parallel to the long axis of the mold to ensure standardization

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of the samples for the tomography images before and after root canal instrumentation. To prevent the resin from entering and polymerizing into the apical foramen, the apices of the roots were sealed with temporary filling then acrylic resin was allowed to set. Samples of each group were coded with numbers for ease of identification. Metal pin inserted into the resin at one corner of the mold to act as opacifier for simplifying the recognition of the specific sample after cone beam shooting. This process was repeated, and every 15 blocks were arranged in a fabricated box filled with condensation silicon rubber base impression material with the mesial surface of all samples facing the same direction for standardization purpose.

Root canal preparation and assessment of shaping ability

Each file was used for four canals only, as per the manufacturer's instructions. All samples underwent pre-instrumentation CBCT scanning (90 kVp, 8 mA, 15 s, 150 µm voxel, 5×5 cm FOV) to assess canal anatomy. Cross-sections were taken at three millimeters (apical), six millimeters (middle), and nine millimeters (coronal) from the apex. Measurements of the shortest mesial and distal distances were recorded using Carestream 3D imaging software.

Sixty mesiobuccal root canals were randomly assigned into two equal groups: Group A (Race Evo) (FKG Dentaire, Switzerland) and Group B (VDW.Rotate) (VDW GmbH, Germany), with thirty canals each. Glide path preparation was established utilizing #10 and #15 K-files, accompanied by intermittent irrigation with 2.5% NaOCl to ensure debris flushing and chemical debridement. For Group A, Race Evo files (#15/.04, 25/.04) were operated at 800 rpm and 1.5 Ncm torque and sequentially used in the canal until reaching the working length, employing gentle in-and-out motions and EDTA gel as a lubricant. Group B used VDW. Rotate files at 350 rpm with variable torque settings (1.3–3.5 N·cm), progressing through file sizes #15/.04, #20/.05, and #25/.04 in a similar manner. Patency was regularly confirmed utilizing a #10 K-file, and a total of 10 ml of 2.5% NaOCl was delivered per canal, followed by a final 1-minute rinse with 5 ml of 17% EDTA. 5 ml Saline was employed as an intermediate rinse between the applications of NaOCl and EDTA, and a final rinse was performed with 5 ml of saline to ensure removal of EDTA residues.

CBCT analysis was performed pre- and post-instrumentation at 3-, 6-, and 9-mm levels from the apex to assess canal transportation and centering ratio using standardized formulas: [12-14]

$$\text{Canal transportation} = |\ (a_1 - a_2) - (b_1 - b_2)\ |$$

According to this formula, negative results indicate transportation towards the distal portion, a positive result towards the mesial portion and zero denotes absence of transportation.

$$\text{Centering ratio} = \frac{(a_1 - a_2)}{(b_1 - b_2)} \text{or} \frac{(b_1 - b_2)}{(a_1 - a_2)} \text{ (the smaller value is recorded)}$$

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Where:

a1= distance from mesial edge of root to mesial edge of the canal before instrumentation

a2= distance from mesial edge of root to mesial edge of the canal after instrumentation

b1= distance from distal edge of root to distal edge of the canal before instrumentation

b2= distance from distal edge of root to distal edge of the canal after instrumentation

According to this formula, the result of 1 indicates perfect centering.

To eliminate observer bias, all CBCT image analysis and measurements of canal transportation and centering ability were conducted by a single investigator who was blinded to the specific file system used for each specimen. The Cohen's Kappa coefficient was calculated, showing high intra-examiner reliability, thus ensuring the reproducibility of our CBCT findings (0.84).

Assessment of cleaning ability

To evaluate cleaning effectiveness after full mechanical preparation half of the samples (30, 15/each group) were fixed in a 10% formalin solution for 48 hours. Next, the mesial roots were washed in running water for 24 hours and immersed in Morse solution for 4 weeks for decalcification. The completion of decalcification was determined via physical and radiographic endpoints. The physical assessment involved probing the specimen with a fine needle; decalcification was considered total once the needle could pass through the entire tooth. Radiographic verification was achieved by exposing the tooth to 60 KV and 8 mA for 0.1 seconds, with a complete lack of radiopacity indicating the process was finished.[15] Afterwards, the mesial roots were sectioned -equivalent to the thirds cut in the CBCT part- at 3, 6, 9 mm from the apex respectively using sharp blade, washed in running water for 24 hours, and submitted to dehydration in alcohol (70%, 90%, 95%, and 100%), followed by diaphanization in xylene (Merck, Darmstadt, Germany) for further paraffin embedding at 60C. Semi-serial sections (10 semi-serial sections per specimen) of 5-mm thickness were cut using microtome. Semi-serial 5-μm sections have been stained with hematoxylin-eosin (Merck, Darmstadt, Germany) and examined under a digital microscope at ×100 and ×200 magnifications. Using image analysis software, the area of residual pulp tissue and debris was quantified and expressed as a percentage of the total canal area for each third.[16] For the histological samples, single examiner was blinded to the experimental groups to ensure unbiased evaluation. Intra-examiner reliability was confirmed using Cohen's Kappa coefficient (0.88).

Statistical analysis

Statistical analysis has been performed utilizing SPSS. Data normality was assessed via the Shapiro-Wilk test, revealing non-parametric distribution. Kruskal-Wallis and Mann-Whitney tests have been applied for intra- and intergroup comparisons of image analysis results in cleaning assessment. Chi-square test assessed differences in canal transportation and centering. Spearman's correlation coefficient evaluated the relationship between residual debris percentage and degree of transportation, with

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correlation strength interpreted as: none (r = 0), weak (r above 0–0.25), moderate (r above or equal to 0.25–0.75), strong (r above or equal to 0.75–1), and complete (r = 1). A p-value ≤ 0.05 was considered statistically significant.

RESULTS

Intra-group Comparison

As shown in Table (1), Figure 1 (A-L) in the Race Evo group, the apical third showed the highest transportation, mostly mesial (66.7%), while distal and no transportation were equal (16.7%). In the middle third, distal transportation was dominant (63.3%), and in the coronal third, distal (43.3%) and mesial (30%) were more common than no transportation (26.7%). In the VDW. Rotate group, the apical third also showed the highest transportation, mainly mesial (60%), followed by no transportation (33.3%). The middle third showed a higher incidence of distal transportation (56.7%), while the coronal third had more no transportation cases (40%), with less mesial and distal movement.

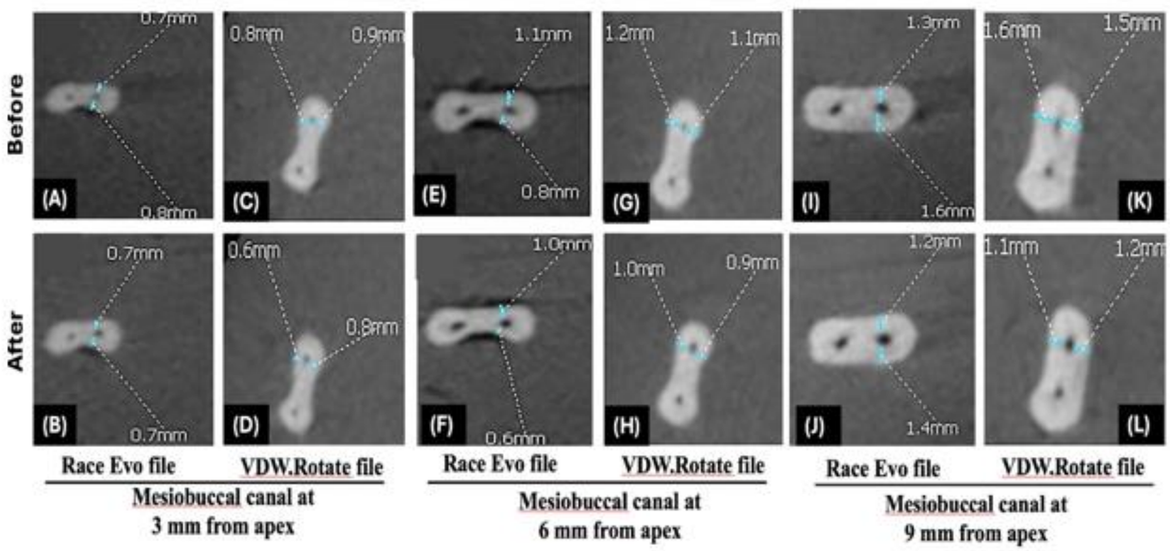

Figure 1: A CBCT image showing (A) Mesiobuccal canal at 3 mm from apex before preparation by using Race Evo file. (B) canal after preparation. (C) Mesiobuccal canal at 3 mm from apex before preparation by using VDW.Rotate file. (D) canal after preparation. (E) Mesiobuccal canal at 6 mm before preparation by using Race Evo file. (F) canal after preparation. (G) Mesiobuccal canal at 6 mm before preparation by using VDW.Rotate file. (H) canal after preparation. (I) Mesiobuccal canal at 9 mm before preparation by using Race Evo file. (J) canal after preparation. (K) Mesiobuccal canal at 9 mm before preparation by using VDW. Rotate file. (L) canal after preparation

Inter-group Comparison

The intra- and inter-group comparison of root canal transportation types for race evo and vdw.Rotate rotary files at apical, middle, and coronal levels were presented in Table (1).

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Table 1: Intra- and Inter-group Comparison of Root Canal Transportation Types for Race Evo and VDW. Rotate Rotary Files at Apical, Middle, and Coronal Levels

Race Evo n=15	No transportation	Mesial transportation	Distal transportation	X^2	P-value*
Apical	16.7%	66.7%	16.7%	15.705[a]	
Middle	16.7%	20.0%	63.3%	8.420[b]	
Coronal	26.7%	30.0%	43.3%	2.417[c]	
VDW. Rotate n=15					
Apical	33.3%	60%	6.7%	20.804[a]	
Middle	30%	13.3%	56.7%	9.361[b]	
Coronal	40%	26.7%	33.3%	3.577[c]	
Apical third					
Race Evo	16.7%	66.7%	16.7%	3.058	0.217[NS]
VDW. Rotate	33.3%	60%	6.7%		
Middle third					
Race Evo	16.7%	20.0%	63.3%	1.654	0.437[NS]
VDW. Rotate	30%	13.3%	56.7%		
Coronal third					
Race Evo	26.7%	30.0%	43.3%	1.250	0.535[NS]
VDW. Rotate	40%	26.7%	33.3%		

[a, b, c] superscript letters indicate intra-group comparisons between different canal levels (apical, middle, coronal). Different letters denote a statistically significant difference at $P \leq 0.05$, while the same letters indicate no significant difference. S = Statistically significant at $P \leq 0.05$; NS = Not significant

Assessment of Centering Ratio

Intra-group Comparison

As shown in Table (2), for both file systems, there were no significant differences in centering ratio across the apical, middle, and coronal thirds. **Race Evo** showed higher rates of Non-centered canals, especially in the apical and middle thirds (up to 83.3%). **VDW. Rotate** had better centering in the coronal third.

Inter-group Comparison

As shown in Table (2), no significant differences have been found between the two files at any level. However, **VDW. Rotate** showed a better centering ability compared to **Race Evo**, which exhibited more Non-centered canals.

Table 2: Intra- and Inter-group Comparison of Centering Ratio Between Race Evo and VDW. Rotate Rotary Files Across Apical, Middle, and Coronal Thirds

Race Evo n=15	Non- centered	Centered	X^2	P-value*
apical	83.3%	16.7%	0.00	1[NS]
middle	83.3%	16.7%	0.884	0.347[NS]
coronal	73.3%	26.7%	0.884	0.347[NS]
VDW .Rotate n=15			X^2	P-value*
apical	66.7%	33.3%	0.077	0.781[NS]
middle	70%	30%	0.287	0.592[NS]

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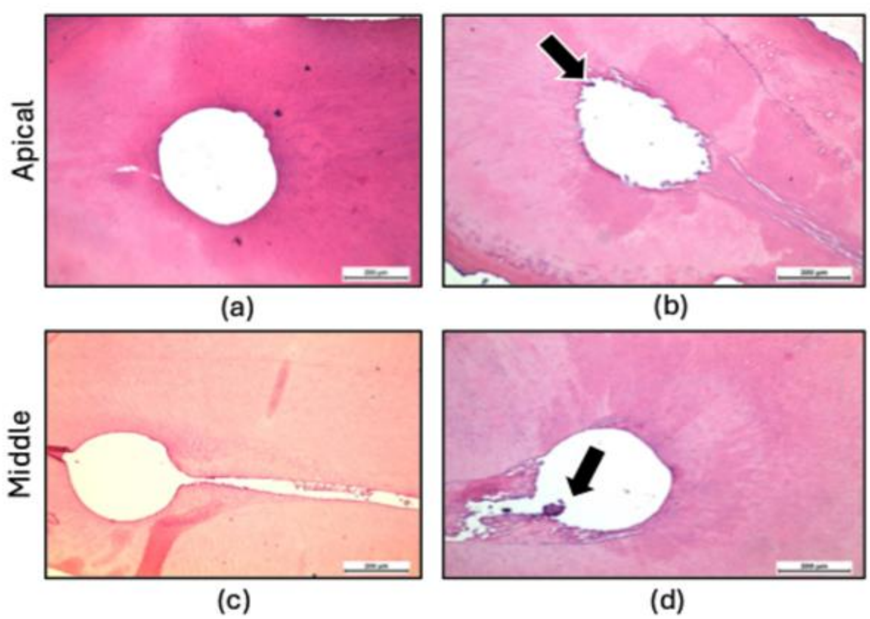
coronal	60%	40%	0.659	0.417^{NS}
Apical third			X^2	P-value*
Race Evo	83.3%	16.7%	2.222	0.136^{NS}
VDW. Rotate	66.7%	33.3%		
Middle third			X^2	P-value*
Race Evo	83.3%	16.7%	1.491	0.222^{NS}
VDW. Rotate	70%	30%		
Coronal third			X^2	P-value*
Race Evo	73.3%	26.7%	1.200	0.273^{NS}
VDW. Rotate	60%	40%		

* P-value for intergroup comparison.   NS= Non-significant P > 0.05.

Evaluation of Cleaning Ability

Histological Evaluation and Image Analysis Results

As shown in Table (3) and Figure 2 (a-f), intra-group comparison revealed no significant difference in remnant percentage among the three canal thirds in the Race Evo group (P = 0.799), with the apical third showing the highest mean (1.25 ± 0.08), followed by the middle (1.20 ± 0.27) and coronal (0.89 ± 0.11) thirds. In contrast, the VDW.Rotate group showed a statistically significant variance among the thirds (P = 0.039), where the apical third had the highest mean (1.37 ± 0.58), followed by the middle (1.31 ± 0.35), and the coronal third had the lowest (0.63 ± 0.10). Inter-group comparisons indicated no significant differences in remnant percentage between the two systems across the apical (P = 0.654; Figures 1a-d), middle (P = 0.821) (Figures 1E-H), or coronal thirds (P = 0.110; Figures 1I-L). Although the Race Evo system achieved a lower overall mean remnant percentage across the three thirds, the variance between the two groups wasn't statistically significant (P = 0.872).



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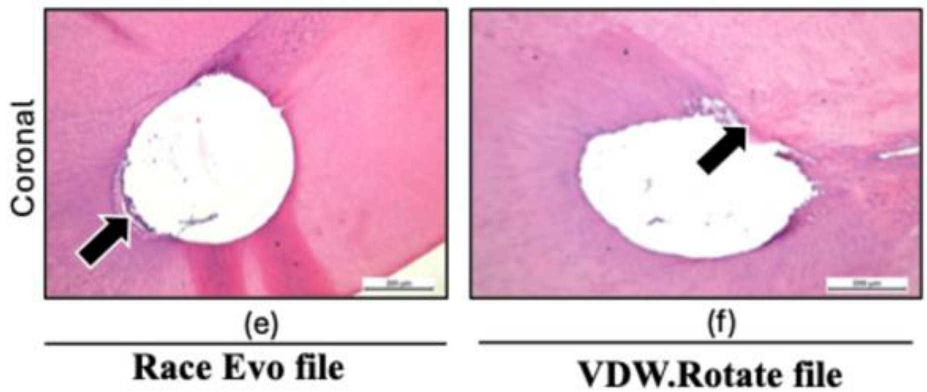

Figure 2: A photomicrograph showing: (a) the apical part of root canal prepared by (Race Evo) appears clean rounded root canal, no remnant of pulp tissue.(b) the apical part of root canal prepared by VDW.Rotate showed remnant of pulp tissue (arrow), (c) the middle part of root canal prepared by (Race Evo) appears clean with rounded configuration, no remnant of pulp tissue, (d) the middle part of root canal prepared by VDW.Rotate with remnant of pulp tissue (arrow).(e) the coronal part of root canal prepared by (Race Evo) revealed remnant of pulp tissue. (f) the coronal part of root canal prepared by VDW.Rotate showed remnant of pulp tissue (arrow)

Table 3: Intra- and inter-group comparison of remnant percentage (Mean ± SD and %) between the three canal thirds for both Race Evo and VDW .Rotate rotary files

	Coronal	Middle	Apical	Overall, across the three thirds	P-value*
Race Evo	0.89 ± 0.11^{a}	1.20 ± 0.27^{a}	1.25 ± 0.08^{a}	1.07 ± 0.26	**0.799^{NS}**
VDW.Rotate	0.63 ± 0.1^{b}	1.31 ± 0.35^{a}	1.37 ± 0.58^{a}	1.17 ± 0.23	**0.039^{S}**
P-value*	**0.11^{NS}**	**0.821^{NS}**	**0.654^{NS}**	**0.872^{NS}**	

-* Overall *p*-value for comparison between the three thirds (Kruskal-Wallis test). Small letters for intra-group comparison between different thirds (Mann-Whitney test) and the means with various superscripts are statistically significant various at $P \leq 0.05$.

Different capital superscript letters denoting significance between the three thirds in the two tested groups.

Correlation between remnant percentage and the degree of transportation

Group 1 (Race Evo rotary file): -

As shown in table (4), There was insignificant variance in the correlation between the three levels and the overall canal assessment. There was a weak negative correlation in all thirds.

Group 2 (VDW. Rotate rotary file): -

As shown in table (4), there was a statistically significant correlation among the apical, coronal and overall canal assessment and a no significant correlation in the middle third.

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There was a moderate negative correlation among the apical, coronal and overall canal assessment and weak negative correlation in the middle third.

Table 4: Correlation value (r) between remnant percentage and the degree of transportation in the different groups studied

	Race Evo			VDW. ROTATE		
	r**	P	Correlation type	r**	P	**Correlation type**
Coronal	-0.107	0.861^{NS}	Weak Negative	-0.336	0.031^{S}	Moderate Negative
Middle	-0.194	0.427^{NS}	Weak Negative	-0.234	0.354^{NS}	Weak Negative
Apical	-0.130	0.705^{NS}	Weak Negative	-0.374	0.027^{S}	Moderate Negative
Overall	-0.163	0.521^{NS}	Weak Negative	-0.305	0.043^{S}	Moderate Negative

r** represents Spearman's correlation coefficient

DISCUSSION

Canal shaping is a crucial aspect of endodontic treatment because it influences the outcome of subsequent phases of canal irrigation, obturation, and overall success of the treatment. The goal of instrumentation is to produce a continuously tapered preparation that maintains the canal anatomy, keeping the foramen as small as possible without deviation from the original curvature. The presence of pulp remnants is often associated with the anatomical complexity of mesiobuccal canals in molars, such as isthmi and oval configurations.[16,17]

The American Association of Endodontics defines transportation as “removal of the canal wall structure on the outside of the curve in the apical half of the canal due to the file tendency to restore their original shape during canal preparation”.[18] This inappropriate dentin removal adversely affects treatment prognosis as it increases the risk of straightening, ledge formation, debris extrusion, and postoperative discomfort.[19]. Several factors affect canal transportation including canal curvature, instrument design, taper, cross-sectional geometry, tip configuration, and instrumentation technique.[20]

Nickel–titanium rotary instruments have greatly improved the quality of root canal shaping because of their superelasticity, shape memory, and cutting efficiency.[21] These features allow them to negotiate curved canals more effectively than stainless steel files. Extracted human permanent mandibular molars were chosen in this study as they are among the most common teeth requiring endodontic treatment and usually exhibit remarkable curvatures and mesiodistal flattening.[22] Mesiobuccal canals were specifically selected since they are often narrow and curved in two planes, making them highly prone to iatrogenic errors.[23,24] This design ensured that the tested systems were evaluated under challenging clinical-like conditions.

To achieve standardization, all teeth were shortened to a length of 16 mm. Root canal curvature was determined using the Schneider’s method which has been widely adopted because it provides reproducible results and lower measurement errors compared with other techniques.[11] In this study, moderate to severe curvatures between 15–30˚ with a

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radius of 5–10 mm were included to simulate real clinical scenarios where instrumentation is most difficult.[25]

Cone-Beam Computed Tomography (CBCT) was used to assess canal transportation and centering ability. CBCT is considered a highly accurate imaging modality for root canal morphology because it is reproducible, non-destructive, and provides three-dimensional evaluation, although micro-CT remains the gold standard.[26] In this study, CBCT images were taken at 3, 6, and 9 mm from the apex, corresponding to apical, middle, and coronal thirds where curvatures have a high vulnerability to iatrogenic mishaps.[27] The formulas of Gambill et al. were applied, which are widely recognized for objective and standardized assessment of canal transportation and centering ability.[12]

This comprehensive approach enabled objective comparison of the shaping accuracy and cleaning efficiency between the two file systems, providing valuable insights into their clinical performance.

The results of the present study showed that both Race Evo and VDW.Rotate systems produced canal transportation, most pronounced in the apical third. Importantly, however, none of the instruments exceeded the 0.3 mm margin considered clinically critical for maintaining apical sealing.[28] Accordingly, both systems can be safely used in curved canals without significantly compromising canal anatomy. These results are consistent with previous studies confirming that newer NiTi systems preserve canal anatomy within safe limits.[29,30]

When comparing canal transportation at different levels, no significant differences were found between the middle and coronal thirds, but the apical third consistently showed more deviation. The direction of transportation varied, with mesial deviation more common in the apical third and furcal deviation more common in the middle and coronal thirds. These findings are consistent with Wu MK[28] and Haupt et al.[31] A possible explanation is that the greater taper of NiTi files is associated with increased risk of straightening and coronal transportation.[32] This observation highlights the importance of careful instrument selection and controlled preparation techniques in curved canals.

Regarding centering ability, both systems demonstrated similar values across all levels, with no statistically significant difference. However, VDW.Rotate showed non-significant superior centering, especially in the coronal third. This can be attributed to by its off-centered S-shaped cross-section. This geometry creates a larger "envelope of motion" compared to the triangular cross-section of Race Evo, providing increased "chip space" for the coronal displacement of debris. This coronal auguring effect is further enhanced by the system's constant taper, which ensures more consistent mechanical contact with the canal walls in the coronal third than variable-taper designs. Furthermore, both systems utilize advanced heat-treated NiTi alloys. Race Evo's proprietary thermal processing allows for high-speed rotation (up to 1000 RPM) with minimal screw-in effect, while VDW.Rotate's Blue-wire metallurgy provides the flexibility necessary to negotiate curvatures of 15–30° without significant restoring forces.[33,34]

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Still, none of the instruments was able to reproduce the original canal configuration perfectly, which is in agreement with Shen Y et al. who reported that some degree of deviation is inevitable in curved canals.[35]

Cleaning ability was assessed histologically in the present study. Race Evo left similar debris percentages across all canal thirds, while VDW.Rotate showed significantly less debris in the coronal third compared with the apical and middle thirds. When the two groups were compared, the differences were not statistically significant, suggesting that both systems perform similarly in terms of cleaning effectiveness. These findings are consistent with previous studies indicating that no single instrumentation system is capable of complete debris removal, particularly in the apical region.[36,37]. The comparable results may be explained by the fact that both instruments are manufactured using heat-treated NiTi alloys, which enhance efficiency, flexibility, and safety.[38]

An additional observation was that in the VDW.Rotate group, a moderate negative correlation was found between canal transportation and cleaning ability, suggesting that improved centering may enhance debridement. In contrast, Race Evo showed only weak correlation between these parameters. This supports the notion that file design and kinematics can influence shaping and cleaning outcomes independently, and that centering ability alone does not guarantee superior cleaning performance.

Overall, the findings of this study indicate that both Race Evo and VDW.Rotate are effective systems for shaping curved canals, maintaining canal anatomy, and achieving adequate debridement. While VDW.Rotate demonstrated slightly superior centering, Race Evo left numerically fewer remnants, though the differences were not statistically significant. Thus, the null hypothesis of this study was accepted.

The laboratory setting of this study serves as a limitation, as it may not accurately replicate clinical conditions. Additionally, the use of a single operator ensured procedural consistency but may affect the generalizability of the findings across different clinicians. The relatively small sample size may also have limited the statistical power of the results. Moreover, irrigant activation was not performed, which could have influenced the cleaning outcomes. Therefore, future research should be directed toward studies with larger sample sizes, incorporation of irrigant activation protocols, and in vivo investigations to confirm the present findings. These steps will provide stronger evidence and may support the development of file systems that further minimize canal transportation while improving cleaning efficiency.

Further limitation of this study was the use of the CBCT, which—while effective in determining canal shifts in the mesiodistal and buccolingual planes —may lack the high resolution provided by Micro-computed tomography (Micro-CT).

Micro-CT is currently considered the gold standard for evaluating shaping ability due to its non-destructive nature and superior accuracy in measuring volumetric changes. Therefore, future research should incorporate a direct voxel-by-voxel correlation using Micro-CT to provide a more detailed assessment of canal transportation and centering ability.

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5. CONCLUSION

Both systems showed canal transportation and non-centering. While Race Evo produced more coronal deviation, VDW.Rotate resulted in more apical deviation, all within clinically acceptable limits. Both systems demonstrated adequate cleaning, with VDW.Rotate leaving fewer remnants in the apical and middle thirds. A weak negative correlation was found between transportation and cleaning efficiency. Minor transportation was associated with enhanced debridement in specific canal regions; however, this relationship requires further investigation to determine if it is a byproduct of increased file to wall contact. Overall, both systems provided safe shaping and acceptable cleaning outcomes, supporting their use in curved canals.

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