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Comparative Evaluation of Canal Transportation and Centering Ability of ProTaper Universal and Reciproc Blue in Curved Mesiobuccal Canals Using Cone-Beam Computed Tomography: An In Vitro Study

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Abstract
Background: *Preservation of the original root canal anatomy during biomechanical preparation is essential for successful endodontic treatment. Canal transportation and centering ability are important parameters used to evaluate the shaping performance of endodontic instruments, particularly in curved root canals. Advances in nickel-titanium (NiTi) metallurgy and instrument kinematics have led to the development of systems designed to improve canal centering and minimize procedural errors.*
Aim: *To compare the canal transportation and centering ability of ProTaper Universal and Reciproc Blue file systems in curved mesiobuccal canals of permanent molars using cone-beam computed tomography (CBCT).*
Materials and Methods: *Twenty extracted permanent molars with mesiobuccal canal curvatures ranging from 20° to 30° were selected and randomly divided into two groups (n = 10). Group I was instrumented using Reciproc Blue (R25, 25/.08), while Group II was prepared using ProTaper Universal (F2, 25/.08). Pre- and post-instrumentation CBCT scans were obtained using standardized imaging parameters. Canal transportation and centering ability were evaluated at 3 mm, 6 mm, and 9 mm from the apex using the method described by Gambill et al. Statistical analysis was performed using the independent samples t-test, with significance set at $p < 0.05$.*
Results: *Reciproc Blue demonstrated lower mean canal transportation values than ProTaper Universal at all evaluated levels. At 3 mm, transportation values were 0.360 ± 0.246 and 0.570 ± 0.316, respectively ($p = 0.115$). At 6 mm, the values were 0.194 ± 0.154 and 0.360 ± 0.227 ($p = 0.072$), while at 9 mm they were 0.410 ± 0.247 and 0.480 ± 0.239 ($p = 0.528$). Reciproc Blue also exhibited higher centering ability than ProTaper Universal at all levels. The difference was statistically significant at 9 mm from the apex, where centering ratios were 1.570 ± 0.424 and 1.070 ± 0.368, respectively ($p = 0.011$).*
Conclusion*: Both instrumentation systems maintained the original canal anatomy with acceptable shaping performance. However, Reciproc Blue demonstrated lower canal transportation and superior centering ability compared with ProTaper Universal. The enhanced flexibility associated with blue heat-treated NiTi alloy and reciprocating motion may contribute to improved preservation of canal curvature during instrument.*
Keywords: *Canal transportation; Centering ability; Cone-beam computed tomography; Reciproc Blue; ProTaper Universal; Root canal preparation; Nickel-titanium instruments.*

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I. INTRODUCTION

Successful endodontic treatment depends on effective cleaning, shaping, and obturation of the root canal system. Among these procedures, biomechanical preparation plays a crucial role by facilitating the removal of infected tissue and microorganisms while creating a continuously tapered canal shape that permits adequate irrigation and obturation. An ideal root canal preparation should maintain the original canal anatomy and curvature without causing procedural errors such as canal transportation, ledge formation, perforation, or apical zipping. [1]

Preparation of curved root canals remains one of the greatest challenges in endodontics because endodontic instruments have an inherent tendency to return to their original straight configuration. This tendency may result in excessive dentin removal from specific canal walls, leading to canal transportation. Canal

transportation has been defined as the undesirable deviation of the physiological canal path during instrumentation and may compromise the apical seal, reduce cleaning efficiency, and negatively affect treatment outcomes. [2]

The introduction of nickel-titanium (NiTi) instruments significantly improved root canal preparation because of their superior flexibility and shape-memory characteristics compared with stainless steel instruments. [3] Continuous advancements in metallurgy and instrument design have led to the development of rotary and reciprocating systems with enhanced flexibility, fatigue resistance, and shaping ability.

ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) is one of the most widely used rotary NiTi systems. It incorporates progressively increasing and decreasing tapers along the cutting blades, which enhance cutting efficiency and facilitate coronal enlargement. However, the progressive taper design and continuous rotary motion may increase the tendency for canal transportation, particularly in severely curved canals. [4]

Reciproc Blue (VDW, Munich, Germany) is a single-file reciprocating system manufactured using a proprietary blue heat-treatment process. This thermal treatment alters the metallurgical characteristics of the NiTi alloy, resulting in increased flexibility and improved resistance to cyclic fatigue. [5] The reciprocating motion has also been reported to reduce torsional stress and enhance the instrument's ability to remain centered within the root canal. [6]

Accurate evaluation of shaping outcomes requires reliable imaging techniques. Cone-beam computed tomography (CBCT) has become an established method for assessing canal morphology before and after instrumentation. Compared with conventional radiography, CBCT provides three-dimensional, non-destructive, and reproducible evaluation of canal transportation and centering ability at different levels of the root canal. [7]

Although both ProTaper Universal and Reciproc Blue are extensively used in contemporary endodontic practice, limited evidence is available regarding their comparative shaping performance in curved mesiobuccal canals of permanent molars. Therefore, the present in vitro study was undertaken to compare the canal transportation and centering ability of ProTaper Universal and Reciproc Blue using CBCT analysis.

II. MATERIALS AND METHODS

This in vitro study was conducted on twenty extracted human permanent molars. Teeth exhibiting intact mesiobuccal roots with canal curvatures ranging from 20° to 30° were selected. Teeth with root fractures, internal or external resorption, previous endodontic treatment, calcified canals, or immature apices were excluded from the study.

The selected specimens were randomly allocated into two experimental groups (n = 10) according to the instrumentation system used:

Group I: Reciproc Blue (R25, 25/.08) Group II: ProTaper Universal (F2, 25/.08)

Conventional access cavities were prepared and working length was established using a size 10 K-file. Root canal preparation was performed according to the manufacturers' recommendations. In Group I, instrumentation was completed using Reciproc Blue R25 in reciprocating motion. In Group II, canals were prepared using the ProTaper Universal sequence up to F2 in continuous rotary motion.

Pre-instrumentation CBCT scans were obtained using the Carestream Dental CS 9600 imaging system with a 6 × 8 cm field of view, 90 kVp tube voltage, 6 mA current, and voxel size of 0.2mm. Specimens were positioned with the root perpendicular to the X-ray beam. Axial sections were evaluated at 3 mm, 6 mm, and 9 mm from the root apex representing the apical, middle, and coronal thirds, respectively. Following instrumentation, post-operative CBCT scans were acquired using identical exposure parameters.

Canal transportation and centering ability were assessed according to the method described by Gambill et al. Canal transportation was calculated using the formula:

Canal Transportation = (m1 − m2) − (d1 − d2) and

(b1 − b2) − (l1 − l2)

Centering ability was calculated using the formula:

(m1 − m2)/(d1 − d2) or (d1 − d2)/(m1 − m2) and

(b1 − b2)/(l1 − l2) or (l1 − l2)/(b1 − b2)

where m1, d1, b1, and l1 represented the shortest distances from the canal wall to the external root surface before instrumentation, whereas m2, d2, b2, and l2 represented the corresponding distances after instrumentation.

Statistical analysis was performed using IBM SPSS Statistics version 21.0. Data normality was evaluated using the Shapiro–Wilk test. Descriptive statistics were expressed as mean and standard deviation. Intergroup comparisons were performed using the independent samples t-test. Statistical significance was established at $p < 0.05$.

III. RESULTS

The mean centering ability and canal transportation values of the two file systems were compared at 3 mm, 6 mm, and 9 mm levels from the apex.

Centering Ability

At the 3-mm level, Reciproc Blue demonstrated a higher mean centering ratio (0.330 ± 0.267) than ProTaper Universal (0.206 ± 0.200); however, the difference was not statistically significant (p = 0.255).

At the 6-mm level, Reciproc Blue exhibited a mean centering ratio of 1.590 ± 0.428 compared with 1.220 ± 0.442 for ProTaper Universal. Although Reciproc Blue showed better centering performance, the difference did not reach statistical significance (p = 0.073).

At the 9-mm level, Reciproc Blue demonstrated significantly greater centering ability (1.570 ± 0.424) than ProTaper Universal (1.070 ± 0.368). This difference was statistically significant (p = 0.011).

Canal Transportation

At the 3-mm level, mean canal transportation was 0.360 ± 0.246 for Reciproc Blue and 0.570 ± 0.316 for ProTaper Universal. The difference was not statistically significant (p = 0.115).

At the 6-mm level, Reciproc Blue showed lower transportation values (0.194 ± 0.154) than ProTaper Universal (0.360 ± 0.227). Although the difference approached statistical significance, it did not reach the predetermined significance threshold (p = 0.072).

At the 9-mm level, mean transportation values were 0.410 ± 0.247 and 0.480 ± 0.239 for Reciproc Blue and ProTaper Universal, respectively, with no statistically significant difference observed between the groups (p = 0.528).

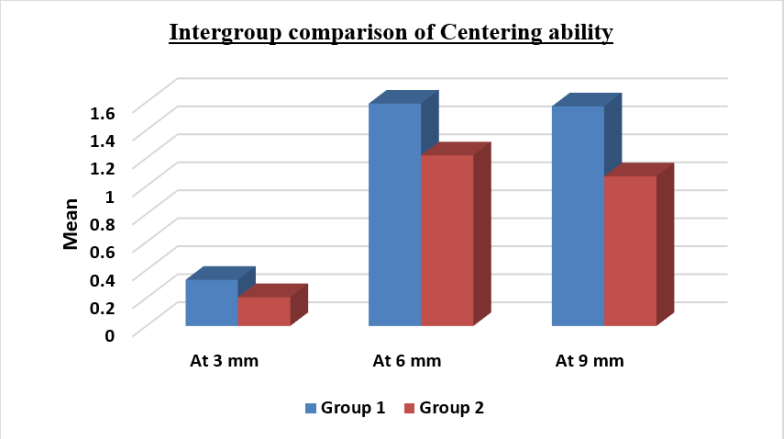
Overall, Reciproc Blue demonstrated lower canal transportation and higher centering ability at all evaluated levels. A statistically significant difference was observed only in centering ability at the 9-mm le

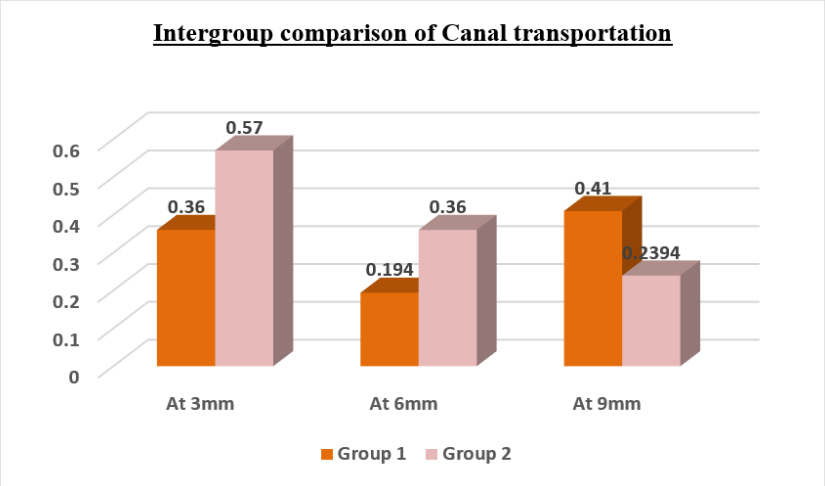
Table 1: Intergroup comparison of Centering ability

		N	Mean	Std. Deviation	Std. Error Mean	P value
At 3 mm	Group 1	10	.3300	.26687	.08439	0.255
	Group 2	10	.2060	.19962	.06313	
At 6mm	Group 1	10	1.590	.4280	.1354	0.073
	Group 2	10	1.220	.4417	.1397	
At 9mm	Group 1	10	1.570	.4244	.1342	0.011*
	Group 2	10	1.070	.3683	.1165	

Table 2: Intergroup comparison of Canal transportation

		N	Mean	Std. Deviation	Std. Error Mean	P value
At 3 mm	Group 1	10	.360	.2459	.0777	0.115
	Group 2	10	.570	.3164	.1001	
At 6mm	Group 1	10	.1940	.15385	.04865	0.072
	Group 2	10	.3600	.22706	.07180	
At 9mm	Group 1	10	.410	.2470	.0781	0.528
	Group 2	10	.480	.2394	.0757	





IV. DISCUSSION

The preservation of original root canal anatomy during biomechanical preparation is a critical determinant of endodontic success. Canal transportation and centering ability are widely accepted parameters for assessing the shaping performance of endodontic instruments, particularly in curved canals where procedural errors are more likely to occur. In the present study, both file systems maintained the original canal curvature; however, Reciproc Blue demonstrated lower canal transportation and greater centering ability than ProTaper Universal, with a statistically significant difference observed in centering ability at the coronal level (9 mm from the apex).

CBCT was selected for evaluation because it provides a reliable, non-destructive, and three-dimensional assessment of canal morphology before and after instrumentation. Previous studies have demonstrated that CBCT allows accurate measurement of dentin removal and canal deviation at different root levels while preserving specimen integrity. Patel et al. highlighted the usefulness of CBCT in endodontic research for evaluating shaping outcomes and canal morphology changes. [1]

The reduced canal transportation observed with Reciproc Blue may be attributed primarily to its thermally treated nickel-titanium alloy. Reciproc Blue instruments undergo proprietary blue heat treatment that increases flexibility and cyclic fatigue resistance by promoting a martensitic crystal structure. De-Deus et al. reported that Reciproc Blue exhibits significantly greater flexibility and fatigue resistance than conventional Reciproc instruments, thereby improving its ability to follow the original canal curvature [2]. Increased flexibility reduces the tendency of the file to straighten within curved canals and consequently minimizes transportation.

Another factor contributing to the favorable performance of Reciproc Blue is its reciprocating motion. Yared introduced the concept of single-file reciprocation and suggested that alternating clockwise and counter-clockwise movements reduce torsional stress and instrument binding within the canal. [3] This motion allows more balanced dentin removal and may explain the superior centering ability observed in the present study.

In contrast, ProTaper Universal demonstrated comparatively greater canal transportation and lower centering ability. Although ProTaper Universal has been widely accepted because of its cutting efficiency and progressive taper design, its continuous rotary motion and larger taper may increase the tendency for canal

deviation in curved canals. Peters reported that instrument design, taper, and flexibility are major determinants of shaping outcomes and canal transportation[4]. The progressive taper of ProTaper Universal, while advantageous for efficient canal enlargement, may generate increased restoring forces against the canal walls, particularly in curved regions.

The present findings are consistent with those reported by Silva et al., who evaluated Reciproc Blue, WaveOne Gold, and ProTaper Next in simulated curved canals and observed superior maintenance of canal anatomy with thermally treated reciprocating systems.[5] Similarly, Sawardeker et al. , using micro-computed tomography, reported that advanced NiTi systems with improved metallurgy demonstrated superior centering ability and reduced canal transportation in curved mesiobuccal canals of maxillary molars.[6]

The results of the present study also agree with the observations of Gambill et al. who established canal transportation and centering ratio assessment methods and demonstrated that more flexible NiTi instruments maintain canal curvature more effectively than less flexible systems.[7] Furthermore, Delgoshayi et al. reported that differences in metallurgy and design significantly influence shaping performance and canal transportation during instrumentation of curved root canals.[8]

Although Reciproc Blue demonstrated superior shaping characteristics, the differences in canal transportation between the groups did not reach statistical significance. This finding may be attributed to the relatively small sample size and the inherent anatomical variability of extracted teeth. Similar observations have been reported in previous in vitro studies where trends favoring heat-treated instruments were identified despite the absence of statistically significant differences. [5–8]

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The limitations of the present study include its in vitro design and limited sample size. Clinical conditions such as periodontal ligament simulation, patient-related variables, and operator factors cannot be completely reproduced in laboratory investigations. Future studies employing micro-computed tomography and larger sample populations may provide more detailed insights into the shaping behavior of contemporary NiTi systems.

V. CONCLUSION

Within the limitations of this in vitro CBCT study, both Reciproc Blue and ProTaper Universal were capable of preparing curved mesiobuccal canals while maintaining the original canal anatomy. However, Reciproc Blue exhibited lower canal transportation and superior centering ability compared with ProTaper Universal at all evaluated levels. A statistically significant improvement in centering ability was observed at 9 mm from the apex. The enhanced flexibility associated with blue heat-treated nickel-titanium alloy and reciprocating kinematics appears to contribute to the superior shaping performance of Reciproc Blue. Therefore, Reciproc Blue may be considered a reliable option for instrumentation of curved root canals where preservation of canal anatomy is critical.

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