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Zahra Nematollahi
DDS, University of California Los Angeles, School of Dentistry, Los Angeles, USA

Farshad Khosraviani
DDS, University of California Los Angeles, School of Dentistry, Los Angeles, USA

Ehsan Esnaashari
Assistant Professor, Endodontics Department, Member of Dental Material Research Center, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

Mansoureh Abbasi
Assistant Professor, Endodontics Department, Member of Dental Material Research Center, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

Sara Shahbazi
DDS, Azad University, Dental Branch, Tehran, Iran

Corresponding Author:
Ehsan Esnaashari
Assistant Professor, Endodontics Department, Member of Dental Material Research Center, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

Centering ability and root canal transportation of ProTaper gold and V taper gold using cone-beam computed tomography: An *in vitro* study

Zahra Nematollahi, Farshad Khosraviani, Ehsan Esnaashari, Mansoureh Abbasi and Sara Shahbazi

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Abstract
Introduction: This study aimed to evaluate the central ability and root canal transportation of two types of rotary files in curved molar canals using cone-beam computed tomography (CBCT) in mesiodistal (MD) and buccolingual (BL) directions.
Method and Material: A total of 40 mesiobuccal root canals of mandibular first molars with an angle of 25-35 degrees and radius curvature of 5 millimeters were randomly divided into two groups of 20 canals each. Group A was prepared with Pro Taper Gold (PTG), and Group B with V Taper Gold (VTG). Pre- and post-instrument CBCT scans were recorded. Images were reconstructed, then cross-sections were detected corresponding to distances of 3, 6, and 9 mm from the anatomic apex using Gambill's method. Statistical analysis was performed with T-test and repeated measure ANOVA. P-value was set at 0.05.
Results: There was a significant difference in centering ratio and canal transportation at all three levels of 3-, 6-, and 9- mm, mesiodistally. PTG has higher centering ability in 6 mm and 9 mm sections with more canal transportation at 3 mm and 6 mm.
In the BL direction, no statistically significant difference in central ability was observed among the PTG and VTG groups. The centering ability of both groups became higher from the apex to the coronal part. The last and the most canal transportation in both PTG and VTG groups was reported at 6 mm level and 9 mm level, respectively.
Conclusion: Both rotary instruments efficiently cleaned and shaped curved canals. ProTaper Gold had better centering ability, while V Taper Gold showed less canal transportation.

Keywords: Canal transportation, centering ability, cone-beam computed tomography, ProTaper gold, V taper gold

Introduction
Root canal shaping plays a vital role in a successful endodontic treatment due to its effect on the following process of root canal irrigation, obturation, and overall success, especially in curved canals, which negatively influence outcomes by procedural errors including ledge, zip, and strip perforation, and canal transportation [1-3].
A higher central ratio and less canal transportation of instruments are critical factors in providing a correct enlargement without excessive root structure weakening. Several studies have reported that Ni-Ti files have significantly more centering ability with less canal transportation than stainless steel instruments because of their higher flexibility and better cutting efficiency [1, 4]. Some advantages of NiTi instruments, including less iatrogenic irregularities, less endodontic treatment time, and favorable treatment outcomes, have been reported [5, 6]. However, unexpected fracture due to cyclic fatigue and torsional loading is a significant disadvantage of NiTi rotary instruments [4, 7].
The ProTaper Universal (PTU) rotary system comprises conventional superelastic NiTi files with a convex triangular cross-sectional design that provides various percentage tapers over its length to active cutting motion and more dentin removal coronally [8]. ProTaper Gold (PTG) has the same geometric design as PTU files but increases flexibility and cyclic fatigue resistance with triangular cross-sections due to their proprietary metallurgy [9].

Some characteristics of PTG are a convex triangular cross-section, a progressive taper, and a noncutting tip design to maintain the original shape of the root canal [10].

V Taper Gold, as a new product of NiTi rotary systems, has the characteristics as follows according to the manufacturer (11) AF™-R wire tech for three shaping files (Vx, V1, V2), AF™-H wire tech for three finishing files (T1, T2. T3), high elasticity of Ni-Ti material, suitable for curved root canal preparation, unique design for variable taper six files, using in the speed of 300-350 rpm and torque of 2.6 N.

To our knowledge, no study has yet compared PTG and VTG for centering ability and canal transportation. Hence, this *in vitro* study investigated the two factors above, followed by root canal preparation with ProTaper Gold and V Taper Gold in curved mesiobuccal canals of permanent mandibular teeth using cone-beam computed tomography (CBCT). The null hypothesis was that PTG and VTG instruments are similar in centering ability and canal transportation.

Method and Material

The protocol for this *in vitro* study was approved by the Research Ethics Co mmittee of Azad University, Dental Branch, Tehran, Iran.

Tooth Selection

Forty intact mandibular molars without defects, root canal calcification, internal or external root resorption, prior endodontic or prosthetic treatments, and no aberrant canal morphology that has been extracted for periodontal reasons were selected for this experimental study. Mesiobuccal roots were checked and excluded in case of cracks, fractures, caries, or external resorption.

Using buccolingual and mesiodistal periapical radiographs, teeth with calcification or internal resorption were excluded. Teeth were stored in 5.25 % sodium hypochlorite for one hour to disinfection, then stored in normal saline until use. To gain standardization, crowns were cut using a diamond disc, and roots measuring 16±1 mm were included in this *in vitro* study. Tooth with 25-35 curvature degrees from the mesiodistal and buccolingual aspect and 5 mm radius curvature (Pruett method) were included in this study to access the considerate teeth number.

The first CBCT (NewTom VGi, QR SRL Company, Verona, Italy) was carried out to detect the canal morphology and curvature before instrumentation. Teeth with angles of curvature within 25°–35° in mesiodistal (MD) and buccolingual (BL) dimensions and 5- mm radius curvature were selected according to Pruett's method [12].

Tooth Preparation

A #10 K-file (0.02) (Mani Inc, Utsunomiya, Tochigi, Japan) was used to initial patency of working length (WL), visible at the apical foramen, and the WL was determined 0.5 mm short of this length. The teeth were embedded in molding wax with upright roots in rows of 20.

Forty MB canals of these 40 samples were randomly divided into two groups of A and B and prepared by an expert operator with a torque-controlled motor (Silver Reciproc; VDW, Munich, Germany) in both rotary systems.

In group A (n = 20), the root canals were prepared using ProTaper Gold (Tulsa Dental Specialties, Dentsply, Tulsa, USA) with a speed of 300-350 rpm and 2N Torque. The following sequence of rotary files was applied in preparation; SX (19/0.04), S1 (18/0.02), and S2 (20/0.04) files to flare and shape the orifice, coronal, and middle thirds of the mesiobuccal canals with brushing movements to reach straight-line access. Then, preparation continued with F1 (20/0.07) and F2 (25/0.08) files with non-brushing movements to WL. Each file was used to prepare four channels and then discarded.

In group B (n = 20), V Taper Gold (Fanta Dental Material, Shanghai, China) rotary files (21/0.04 and 25/0.04) with speeds of 300-350 rpm and 2.6N Torque were used for root canal preparation. Three shaping files of Vx, V1 (#10), and V2 (#15) were used with brushing movement at first. Then, three finishing files of T1 (#20), T2 (#25), and T3 (#30) were applied with non-brushing movement according to the manufacturer's instructions [10]. Each file was used to prepare four channels and then discarded.

After applying each file in both systems, recapitulation was carried out using a #10 K-file, and the canals were rinsed with 2ml of 2.25 % NaOCl. Each file was used in the preparation of four canals.

Scans Assessment

The samples underwent CBCT with the same exposure settings as those applied before instrumentation; fov 6*6, 110 KVP, 5.52 mA. The OnDemand 3D Dental software (Cybermed, Seoul, South Korea) was used to evaluate root canal transportation and the centering ratio at 3-, 6-, and 9-mm distance from the apex from Mb and BL directions (Fig 1, 2). The three levels, including 3, 6, and 9 mm from the root apex, showed the root canals' apical, middle, and coronal thirds, respectively, before and after preparation. The shortest distance between the canal wall and the external root surface in the mesial, distal, buccal and lingual was assessed and recorded. The measurements were made on CBCT scans as follows;

Canal Transportation: The amount of canal transportation was measured according to the formula by Gambill *et al*. [13]; canal transportation (mm): (a1-a2) - (b1-b2)

a1and b1: the shortest distance from the root mesial edge to the mesial and distal edge of the uninstrumented canal, respectively.

a2 and b2: the shortest distance from the root mesial edge to the mesial and distal edge of the instrumented canal, respectively.

The result of "0" declared no canal transportation, and other than "0" showed that transportation has occurred.

Canal Centering Ability: It was calculated by the following formula; (a1-a2)/(b1-b2) or (b1-b2)/(a1-a2)

A result of "1" showed perfect centering, and the higher figure was considered as more deviation. The root dentinal thickness (RDT) was detected by subtracting the uninstrumented canal from the instrumented canal.

Statistical Analysis

The two rotary systems' centering ability and root canal transportation were analyzed using the ANOVA test to compare systems during different times. For pairwise comparison, Kai-2 and the independent t-test were used. SPSS statistics version 11 (SPSS Inc., Chicago, IL, USA) was utilized for statistical analysis.

P-value was set at 0.05. α=0.05 and β=0.2 were considered.

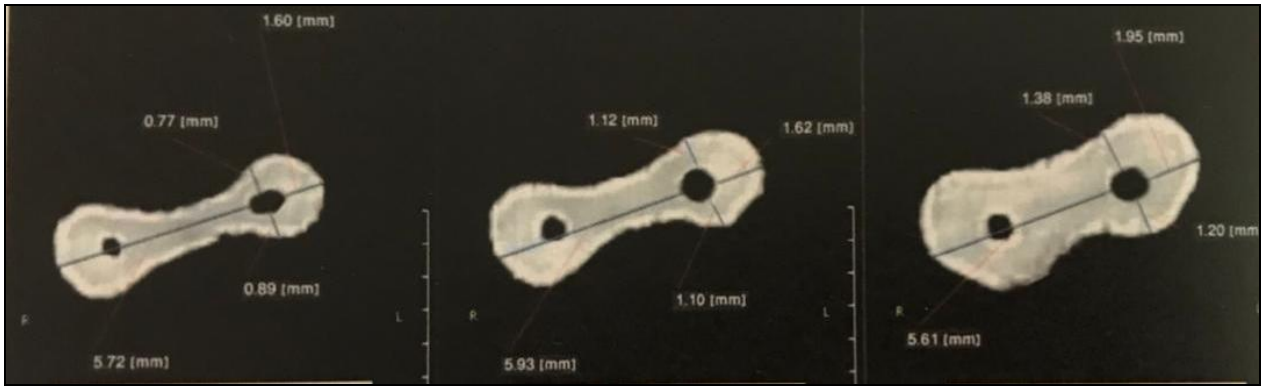

Fig 1: Post-instrumentation CBCT at three 3 mm, 6 mm, and 9 mm levels following preparation with V Taper Gold

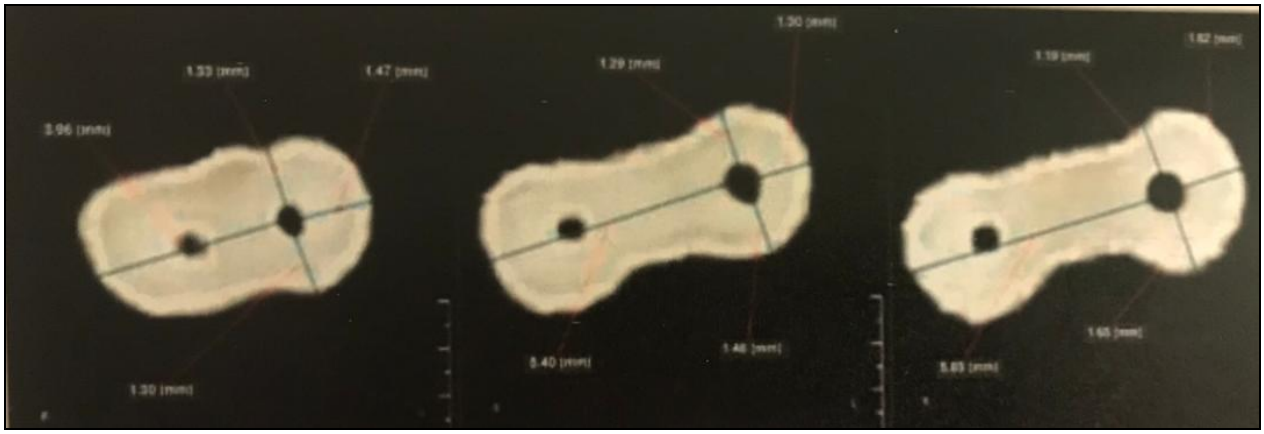

Fig 2: Post-instrumentation CBCT at three 3 mm, 6 mm, and 9 mm levels following preparation with Pro Taper Gold

Results

Centering Ability (%): The amount of centering ability in two MD and BL directions of two different rotary instruments are exhibited in table 1.

In MD direction: There was a significant difference among the tested groups in all three levels of 3-, 6-, and 9- mm. PTG has higher centering ability in 6 mm and 9 mm sections. However, VTG was better in the 3 mm level of the root apex.

In BL direction: No statistically significant difference was observed among the PTG and VTG groups. However, there was a significant difference in various sections of each group. The centering ability of both groups became higher from the apex (3 mm level) to the coronal part (9 mm level).

Table 1: Mean (SD) values for centering ability (%) in mandibular molar mesiobuccal root canals from mesiodistal (MD) and buccolingual (BL) directions following preparation with different files.

Centering Ability	Root Level	3 mm		6 mm		9 mm		Anova Test
		Mean (SD)	Coefficient of Variation	Mean (SD)	Coefficient of Variation	Mean (SD)	Coefficient of Variation	
	ProTaper	0.648	0.194	0.717	0.234	0.882	0.258	0.000
MD	Gold	(0.126)		(0.168)		(0.228)		
	(Control)							
	V Taper	0.975	0.225	1.328	0.164	1.445	0.143	
	Gold	(0.220)		(0.219)		(0.207)		
	(case)							
	T Test	P=0.004						
BL	ProTaper	0.690	0.166	0.849	0.155	0.995	0.127	0.000
	Gold	(0.115)		(0.132)		(0.127)		
	(Control)							
	V Taper	0.977	0.311	1.047	0.198	1.372	0.145	
	Gold	(0.304)		(0.208)		(0.200)		
	T Test	0.140						

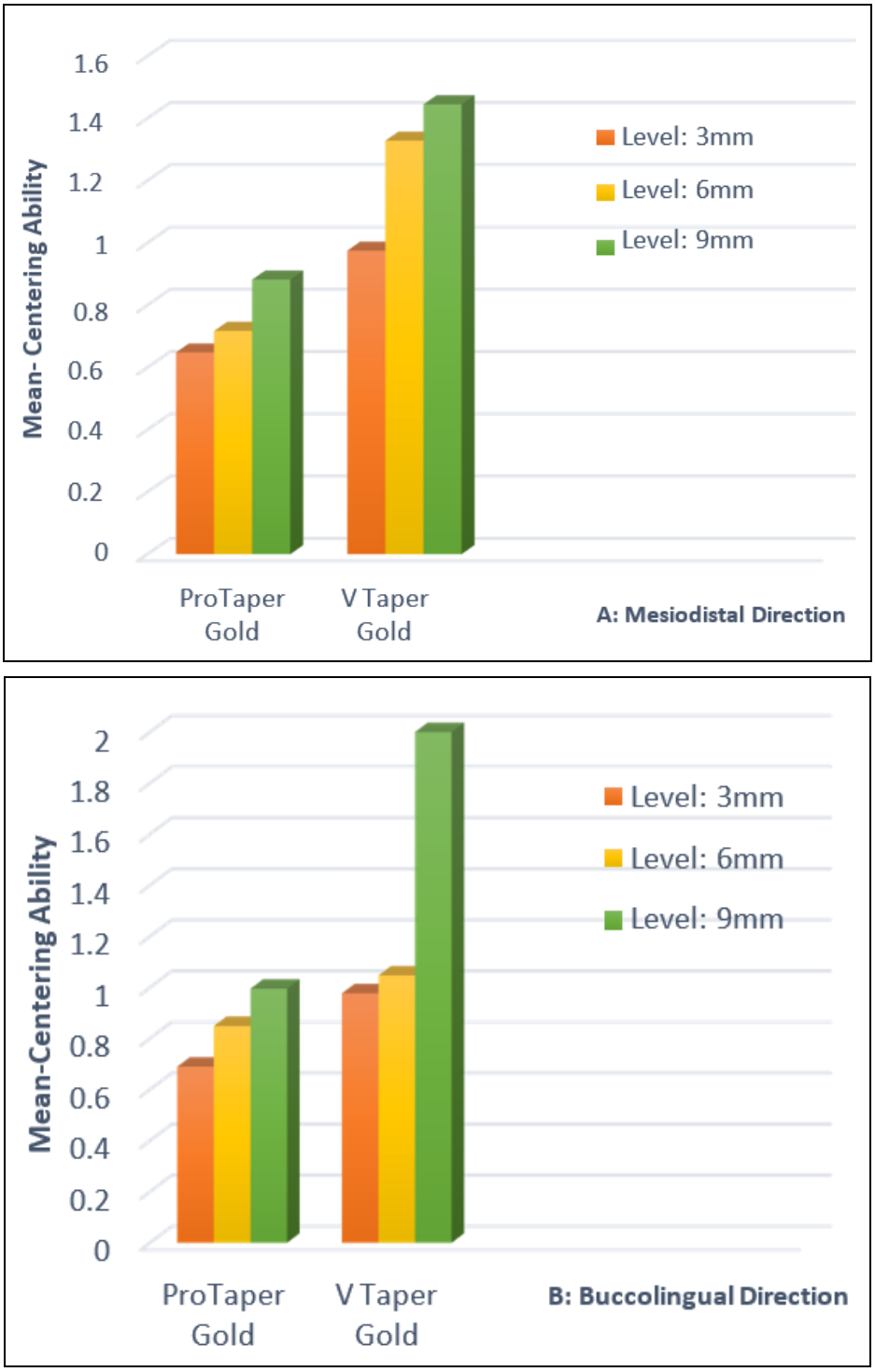

Fig 3: Mean Central Ability in root canals following preparation with different files from A) mesiodistal and B) buccolingual directions

Canal Transportation: The amount of canal transportation values in MD and BL directions are shown in table 2.

In MD direction: Tested groups showed a significant difference in all levels of 3 mm, 6 mm, and 9 mm. Canal transportation was higher in the PTG group at the 3 mm and 6 mm level of root apex, while greater canal transportation was observed in the VTG group at the 9 mm level.

In BL direction: The least and the most canal transportation in both PTG and VTG groups was reported at 6 mm level and 9 mm level, respectively. However, there was no significant difference between the two groups at various root levels.

Table 2: Mean (SD) values of apical transportation (mm) in root canals from mesiodistal (MD) and buccolingual (BL) directions following preparation with different files.

Canal Transp	Root Level	3 mm		6 mm		9 mm		Anova
		Mean (SD)	Coefficient of Variation	Mean (SD)	Coefficient of Variation	Mean (SD)	Coefficient of Variation	
MD	ProTaper Gold (Control)	0.017 (0.01)	0.588	0.016 (0.011)	0.687	0.005 (0.011)	2.2	0.000
	V Taper Gold (case)	0.0005 (0.008)	16	0.011 (0.006)	0.545	0.024 (0.010)	0.416	
	T Test	0.014						
BL	ProTaper Gold (Control)	0.016 (0.08)	0.5	0.01 (0.009)	0.9	0.049 (0.226)	4.612	0.063
	V Taper Gold (case)	0.005 (0.016)	3.2	0.003 (0.012)	4	0.021 (0.008)	0.380	
	T Test	0.536						

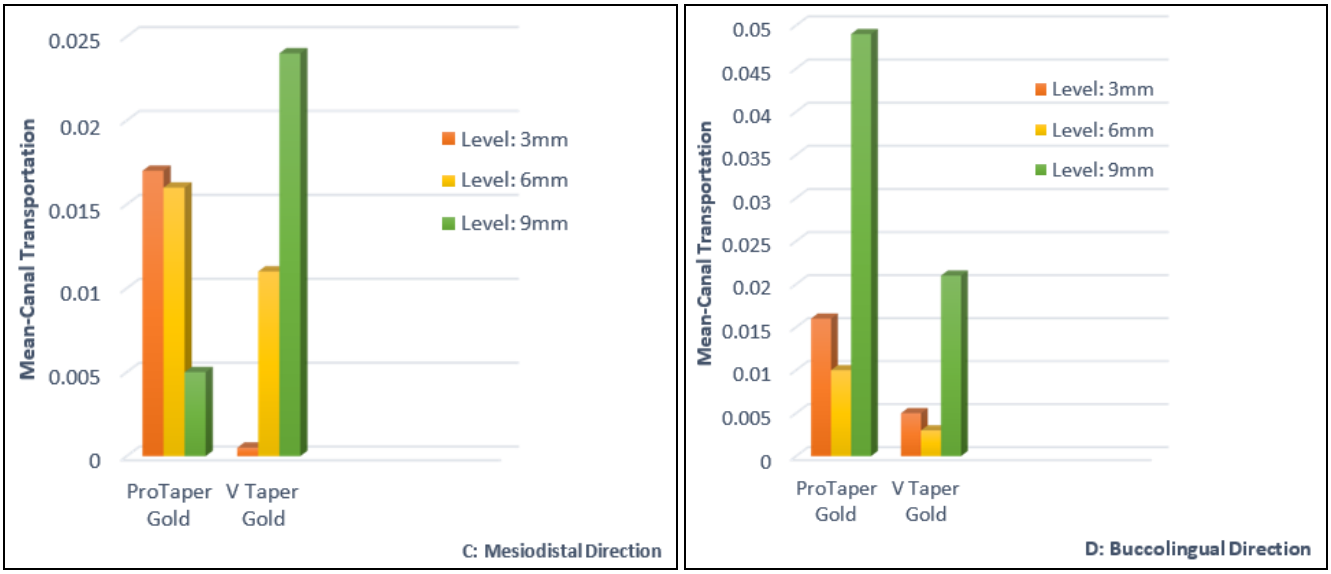

Fig 4: Mean Canal Transportation in root canals following preparation with different files from A) mesiodistal and B) buccolingual directions.

Discussion

The purpose of mechanical preparation in root canal treatment is to clean all canal walls while maintaining the original anatomy which is a challenge in curved canal preparations [14]. The current study was based on the hypothesis that two instruments of various brands would not show a significant difference in considering to root canal transportation centering ability in the preparation of mandibular molars. Indeed, the results of our study showed statistically significant differences across the instruments evaluated, not confirming the null hypothesis exactly.

In an assessment of the centering ratio, lower values presented better center preparation in root canal. The present study showed statistical differences among the two groups at three various levels in MD direction with more centering ability in 6 mm and 9 mm sections for PTG. Also, VTG had a higher centering ability at the 3 mm level. However, no significant difference was observed in the BL direction. The results indicated that the two instruments were well centered in the root canal at various levels from the root apex. Manufacture processing with heat-treated file systems can explain this because of its influence on making them more flexible and less straightening during instrumentation [15].

In our study, canal transportation among the two groups showed a significant difference in MD direction with more transportation of PTG at 3- and 6- mm levels. However, it implied similar deviation from the original canal pathway in all the root canals in the BL direction. Canal transportation results in various endodontic challenges, such as insufficient debridement and excessive removal on concave surfaces. Root canal transportation usually occurs due to the rigid nature of endodontic instruments, which results in nonuniform stress distribution in the contact points of the instrument and the root canal. Then, the instrument force to regain its straight form in the canal leads to higher forces on the external surface of the curve [16]. Wu *et al.* [17] reported that apical transportation values of more than 0.3 mm might have a negative effect on the seal of material obturation. In our study, none of the systems showed canal transportation value was over the critical point of 0.300 mm.

Many techniques are used to compare pre- and post-instrumentation canal shape in order to assess shaping ability and canal transportation involving radiography, serial sectioning technique, photographic assessment, scanning electron microscope, computer manipulation technique, and micro-computed tomography [18, 19] but CBCT as the latest one has some advantages such as; being noninvasive, low-dose radiation compact instrumentality, the possibility of detailed images analysis with different settings [20].

Several studies compared the centering ability and canal transportation of PTG with other instruments [8, 15, 21-26], while there has been no assessment on VTB instruments up to now.

Less canal transportation of PTG instruments is due to proprietary heat treatment technology in comparison with other ProTaper files such as ProTaper Universal and ProTaper Next [27]. The good finding related to PTG in our study has been reported in previous studies [24].

Silva *et al.* [8] claimed that different instrumentation systems

in simulated curved canals in clear resin blocks significantly influenced canal transportation which may be due to different methodologies. They reported that PTG had similar performance to Pro Taper Universal in straight canals but less canal transportation in curved portions. In comparison with root dentin, limitations of resin block, including different micro-hardness and negative effects of heat generation during instrumentation, should be considered as effective factors in softening the resin material and binding of instrument cutting blades [28].

In an evaluation of centering ability and root canal transportation by Antony SDP *et al*. [15], no difference was observed between Profit S3 (PS3), One Curve (OC), and PTG. Also, Elnaghy *et al*. [24] reported no significant difference between PTG and Pro Taper Universal NiTi rotary systems in root canal shaping abilities of mesial canals of mandibular first molars at three levels of 3-, 5-, and 7 mm. Arsalan H. *et al*. [10] reported that there was no significant difference in centering ability and canal transportation among PTG, ProTaper universal, and Reciproc groups at three levels of 3 mm, 5 mm, and 7 mm. These results were not in agreement with our study.

Sing *et al*. [25] demonstrated that PTG had a greater significant difference in apical transportation values when compared to two-shape (2S) and WaveOne Gold at all levels of 3,5 and 7mm, mesiodistally. In Jain A *et al*. [29] study, the PTG file system showed better centering ability at 3 mm (apical third) and 9 mm (coronal 3rd) levels than the 6 mm level (middle third). In the present study, PTG showed more transportation at 3- and 6-mm sections.

This *in vitro* study has some limitations, including the lack of adequate information regarding VTB rotary instruments in the literature. Also, no previous study has been performed on centering ability and canal transportation from the BL direction. Therefore, comparing the results of this evaluation with other studies was impossible. More studies are suggested to assess different aspects of VTP instruments in the clinical environment.

Conclusion

Both PTG and VTG rotary instruments were efficient in cleaning and shaping mandibular molar curved canals. PTG had better centering ability, while VTG showed less canal transportation.

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