

Research article**Comparison of CBCT and Digital Radiography for Detection and Quantification of Apical Transportation in Curved Root Canals Prepared with ProTaper Universal and Safe Siders System**

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ABSTRACT

Objectives: This study sought to compare apical transportation in curved root canals prepared with ProTaper Universal and SafeSiders system using cone beam computed tomography (CBCT) and digital radiography.

Methods: This in vitro, experimental study was conducted on 40 maxillary first molars with 20-40° mesiobuccal root curvature. After access cavity preparation, a #15 K-file was used for working length determination, 1mm short of apical foramen. The teeth were divided into two groups (n=20) for preparation with ProTaper Universal or SafeSiders. Digital radiographs and CBCT scans were obtained of teeth before and after preparation, and apical transportation and centering ability at 1, 2, 3 and 4 mm levels from the apex were compared between the two groups. The data were analyzed using the Mann Whitney test, Friedman test and one-sample t-test.

Results: On CBCT scans and digital radiographs, all samples showed transportation in mesiodistal and buccolingual directions. The two groups were not significantly different in terms of apical transportation or centering ratio at 1, 2, 3 and 4 mm levels from the apex ($P>0.05$). Although the two imaging modalities were not different in terms of detection of apical transportation ($P>0.05$), they were significantly different in measurement of the amount of apical transportation and centering ratio ($P<0.0001$).

Conclusion: ProTaper Universal and SafeSiders were not different in terms of apical transportation and centering ability. Both digital radiography and CBCT were useful for detection of transportation; but CBCT was more accurate in quantification of the amount of transportation.

Keywords: RVG; CBCT; ProTaper Universal

INTRODUCTION

One of the main objectives of root canal preparation is to clean the root canal system while maintaining its original shape [1]. In curved root canals, all endodontic instruments have a high risk

of causing apical transportation and changing the canal path [2]. Enlarging the curved canals may result in ledge formation, apical transportation or root perforation [3]. Apical transportation may

create a space for accumulation of debris and residual microorganisms and lead to inadequate cleaning of the root canal system, loss of root integrity and decreased resistance to fracture, compromising the outcome of treatment [4]. Moreover, apical transportation greater than 0.3 mm compromises the outcome of endodontic treatment since it significantly decreases the sealing ability of root canal filling materials [5].

Stainless steel hand files were the first endodontic instruments used for cleaning and shaping of the root canal system, which had drawbacks such as being time consuming [6], requiring several files and drills [7], high risk of apical transportation [8] and difficult clinical use in narrow root canals especially in teeth with difficult accessibility [9]. Nickel-titanium rotary files were later introduced with advantages such as lower risk of apical transportation, faster root canal preparation, maintaining the original canal center, rounder preparation of canals and less removal of dentin [9]. However, these conventional rotary instruments also had drawbacks such as high rate of fracture of files due to torsional loads and cyclic fatigue [10]. Moreover, they required the simultaneous use of hand instruments as well for creation of a glide path in narrow root canals of teeth with difficult accessibility, which was tiresome and exhaustive [11].

Reciprocation compared to rotational motion is more similar to hand filing movements. Thus, it decreases the risks associated with continuous rotation in curved canals.

SafeSiders is a recently introduced reciprocating system with high fracture strength and optimal flexibility for use in narrow canals. This system has eight stainless steel and three NiTi files as well as a Pleezer reamer to coronal flaring of root canal away from the furcation area [12]. According to its manufacturer, it creates a balanced force, which maintains the original center of the canal [13]. ProTaper Universal is a well-known rotary system with shaping (SX, S1 and S2) and finishing (F1, F2 and F3) files, which is unique in that it has variable tapers along the longitudinal axis of the file [14-

16]. Al-Ali et al, [17] in 2016 compared the effect of SafeSiders and ProTaper rotary systems on root canal shape and found that SafeSiders had a larger and more efficient cutting surface. Maia Filho et al, [18] in 2015 compared the shaping ability of ProTaper Universal and Reciproc and found that ProTaper Universal caused the greatest amount of apical transportation compared to reciprocating systems while no significant difference was noted in terms of change in curvature. Ceyhanli et al, [12] in 2014 reported that SafeSiders had higher rate of transportation at 1 mm from the apex compared to ProTaper.

Cone beam computed tomography is the gold standard for detection of apical transportation [19]. However, periapical radiographs are more commonly used for this purpose in the clinical setting. Alencar et al, [20] in 2010 compared the efficacy of CBCT and periapical radiography for detection of procedural errors during endodontic treatment and reported that although CBCT was superior for diagnostic purposes, the difference between the two imaging modalities was not significant.

Considering the limited number of studies comparing the efficacy of CBCT and digital radiography for detection of apical transportation and quantification of its magnitude [20] as well as the controversy in the results of previous studies on the frequency of apical transportation by use of SafeSiders and ProTaper Universal systems, this study aimed to compare the rate of apical transportation in curved canals prepared with these two systems using CBCT and digital radiography. The two imaging modalities were also compared for detection and quantification of the amount of apical transportation.

MATERIAL & METHODS

This in vitro, experimental study was conducted on 40 extracted human maxillary first molars with mesiobuccal root curvature between 20-40°(measured using radiovisiography based on a study by Schneider [21]), closed apices, no internal or external root resorption, no cracks and no root

caries or calcification in the root canal system. Teeth with broken instruments in root canals (occurred during instrumentation) were excluded. Sample size was calculated to be 20 samples in each group (a total of 40) assuming an expected mean difference of 9% in mesial and distal measurements between the two preparation methods, standard deviation (SD) of 0.06 and 0.1 in the two groups based on a previous study [22], study power of 90% and type one error of 0.05.

Preparation of samples

The collected teeth were cleaned from debris and tissue residues and immersed in 5.25% sodium hypochlorite solution (Golrang, Tehran, Iran) for 48 hours. Coronal caries was removed and the teeth were inspected under a magnifier to ensure absence of external root resorption, root caries or cracks. Access cavities were prepared using a fissure bur (Brasseler USA®, GA, USA) and checked with an explorer to ensure straight access to mesiobuccal root. Access cavity was then filled with 5.25% sodium hypochlorite solution. Canal path was opened using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland), and a #15 K-file was used to determine working length. The file was introduced into the canal until its tip was visible at the apex. One millimeter was subtracted from this length to determine the working length. Teeth with severely calcified canals larger than #15 K-file were excluded. Cardboard cubes measuring 1.5 cm x 1.5 cm with 2 cm height were fabricated to standardize the placement of samples in the mounting jig. Tooth apices were covered with dental red wax and the roots were mounted in the cube filled with silicon impression material (root mounting). Each sample was allocated a code.

Baseline digital radiography

To standardize all digital radiographs, a silicon impression was made of the digital sensor (Dr. Suni, Apteryx Inc., OH, USA). A mounting jig was fabricated to fix the position of mounted teeth relative to the digital sensor. A prefabricated standard cylindrical mold was used to standardize the distance and angle of placement of mounted

teeth (before and after the intervention for each tooth and among different teeth) relative to the X-ray tube. Each mounted tooth was placed in the jig (Figure 1) and exposed from the buccal surface using a digital radiography unit (Kodak, France) with 0.125mA. After taking radiographs, root curvatures were measured using Dr. Suni software (Dr. Suni, Apteryx Inc., OH, USA).

The working length was standardized by adjusting the reference point for each tooth. To match the groups, samples were divided into two groups based on precise degree of curvature and working length.

Baseline CBCT

To take CBCT scans, remounting was required; tooth crowns had to be embedded in silicon impression material and roots had to be out (in the air) to create the highest contrast (crown mounting) since it would significantly enhance reading of root outline and making measurements on CBCT scans. For this purpose, five cylindrical molds with 5cm diameter and 2.5 cm height were fabricated and silicon impression was packed in one side of the mold such that it was completely sealed. Before setting, tooth crowns were mounted in silicon (10 teeth per each cylinder). The crowns of all teeth were mounted from the buccal side and this side was also marked on the mold. Next, one mold was placed on top of the other with buccal sides on the same direction. The CBCT scans were taken using NewTom VGI CBCT unit (QRL, SRL Co., Verona, Italy) with the exposure settings of 110 kV, 9.5 mA, 0.1 and 0.125 mm voxel size and 6x6 mm field of view in denture base mode. OnDemand software (Cybermed Inc., Irvine, CA, USA) was used for interpretation of scans. The distance from the external root surface to the internal surface of canal wall was measured at 1, 2, 3 and 4 mm levels from the apical foramen in the mesial, distal, buccal and lingual walls (M1, D1, B1, L1; Figure 2).

Root canal preparation

The root canals were instrumented using ProTaper Universal (Dentsply Maillefer, Ballaigues,

Switzerland) files up to F2 (#25, 8%) according to the manufacturer's instructions with the recommended motion in group one and SafeSiders (Essential Dental Systems, Hackensack, NJ, USA) up to #25 NiTi file (8%) in group two. SafeSiders stainless steel #35 and 40 files were not used after a pilot study to prevent excessive taper. After use of each file, root canal was rinsed with 2mL of 5.25% sodium hypochlorite.

Post-instrumentation imaging

After completion of root canal preparation, all teeth were subjected to CBCT and digital radiography. To assess apical transportation on CBCT scans, the technique described by Gambill et al. [9] was used. The lowest dentin thickness on each of the axial sections (at 1, 2, 3 and 4mm levels from the apex) in the mesial, distal, buccal and lingual (M2, D2, B2 and L2) was measured in prepared root canals using OnDemand software.

The amount of apical transportation was calculated using the formulae below:

Apical transportation in mesiodistal direction= $(M1-M2) - (D1-D2)$

Apical transportation in buccolingual direction= $(B1-B2) - (L1-L2)$

Also, in order to assess the canal centering ability of the instrument, the following formulae were used:

Canal centering ability in mesiodistal direction: $(M1-M2)/(D1-D2)$ or $(D1-D2)/(M1-M2)$

Canal centering ability in buccolingual direction: $(L1-L2)/(B1-B2)$ or $(B1-B2)/(L1-L2)$.

The formula, with numerator equal or smaller than the denominator is used to assess the centering ability. Thus, the obtained value is always between 0-1; the closer the value to one, the greater the centering ability.

To obtain digital radiographs, the prepared root canal was filled with a radiopaque material i.e. 76% meglumine) Darou Pakhsh, Tehran, Iran). The samples were then subjected to digital radiography. To determine the amount of apical transportation in mesiodistal direction, Auto CAD 2011 software (Autodesk Inc., San Rafael, CA, USA) was used to

analyze the before and after digital radiographs of the teeth [23]. The canal shape before and after preparation was drawn by the software. Also, an index was used to correctly superimpose the pre- and post-preparation images. After ensuring correct superimposition of images, 1, 2, 3 and 4mm levels from the apex were marked on the canal curvature before instrumentation. A line was drawn passing through each 1mm interval perpendicular to the mesial wall after instrumentation. The same was done for distal wall and (D1-D2) and (M1-M2) values were calculated as such (Figure 3). The amount of apical transportation was calculated using the formula $(M1-M2) - (D1-D2)$. The centering ratio was calculated using the formula $(D1-D2)/(M1-M2)$ or $(M1-M2)/(D1-D2)$.

Statistical analysis

Descriptive statistics were used to report changes after preparation in the values in the two groups. To compare the amount of transportation and centering ratio in the two groups, the Mann Whitney test was used. Friedman test was applied to compare the frequency of apical transportation and centering ratio at different levels from the apex within each group. One-sample t-test was used to compare detection of transportation and centering ability between CBCT and digital radiography.

RESULTS

The obtained results by analyzing the distillate of *Polygonum aviculare* with GC/MS device, detected 13 components according to the (Table 1) Both CBCT and digital radiography showed that apical transportation occurred in all teeth in the two groups in both mesiodistal and buccolingual directions.

Apical transportation on CBCT scans

The frequency of apical transportation at different levels from the apical foramen in mesiodistal direction on CBCT scans is presented in Table 1. In Both groups, maximum frequency of apical transportation in mesiodistal direction was 85% and occurred at 2 mm from the apex. At 1,2, 3 and 4

mm levels, maximum frequency of transportation in both groups was towards the mesial and then distal with different quantities mentioned in Table 1 and none of the differences were statistically significant ($P>0.05$). Table 1 also shows the frequency of apical transportation at different levels from the apex in buccolingual direction on CBCT scans. In the SafeSiders group, maximum frequency of transportation was 70% and occurred at 4mm from the apex followed by 65% at 1 mm level. In ProTaper Universal group, maximum frequency of transportation was 55% and occurred at 2 mm from the apex followed by 50% at 1, 3 and 4 mm levels. At 2 and 3 mm levels, maximum frequency of transportation in both groups occurred towards the lingual and then buccal. At 1 and 4 mm levels, maximum frequency of transportation occurred towards the lingual and then buccal in the SafeSiders group, and in a reverse order in ProTaper Universal group. The differences at 1, 2, 3 and 4 mm levels were not significant ($P>0.05$). Table 2 shows the comparison of mean and SD of the amount of apical transportation at different levels from the apex in buccolingual and mesiodistal directions in the two groups on CBCT scans. In the SafeSiders group, maximum mean of transportation was 0.20 ± 0.15 mm at 2 mm level and 0.17 ± 0.21 mm at 1 mm level in mesiodistal and buccolingual directions, respectively. In ProTaper Universal group, maximum mean of transportation was 0.19 ± 0.15 mm at 2 mm level and 0.14 ± 0.19 mm at 1 mm level from the apex in mesiodistal and buccolingual directions, respectively. No significant difference was noted in this regard between the two groups or within each group ($P>0.05$).

Apical transportation on digital radiographs

Table 3 shows the frequency of apical transportation at different levels from the apex in mesiodistal direction on digital radiographs. In the SafeSiders group, maximum frequency of transportation was 70% at 1, 2 and 3 mm from the apex and 60% at 4mm. In ProTaper Universal group, this value was 80% at 2 and 3 mm and 70%

at 4 mm. At 1, 2, 3 and 4 mm levels, maximum frequency of transportation in both groups was towards the mesial and then distal and this difference was not significant either ($P>0.05$).

Table 4 presents the mean and SD of the amount of transportation at different levels in mesiodistal direction in the two groups and compares this rate at different levels on digital radiographs. The maximum mean of transportation in SafeSiders and ProTaper Universal groups was 0.14 ± 0.13 mm at 4 mm and 0.19 ± 0.15 mm at 3 mm, respectively. No significant difference was noted in this regard either ($P>0.05$).

Centering ability on CBCT scans

Table 5 shows the mean centering ability at different levels from the apex in mesiodistal and buccolingual directions on CBCT scans. In the SafeSiders group, the maximum mean centering ability was 0.34 ± 0.34 at 1 mm from the apex in mesiodistal direction. In buccolingual direction, maximum mean was 0.34 ± 0.36 at 3 mm level. In ProTaper Universal group, maximum mean was 0.35 ± 0.34 at 4 mm level from the apex in mesiodistal direction and 0.40 ± 0.36 at 4 mm from the apex in buccolingual direction. No significant intergroup or intragroup difference was noted in terms of centering ability at 1, 2, 3 and 4 mm levels from the apex on CBCT scans. None of the differences in this regard were significant ($P>0.05$).

Centering ability on digital radiographs

Table 6 shows the centering ratio in mesiodistal direction in the two groups on digital radiographs at different levels from the apex. In the SafeSiders group, maximum centering ratio was 0.41 ± 0.30 mm at 4 mm from the apex. In ProTaper Universal group, maximum centering ratio was 0.34 ± 0.25 mm at 4 mm from the apex. None of the differences in this regard were significant ($P>0.05$).

Comparison of CBCT and digital radiography for detection of apical transportation

In the SafeSiders group, digital radiographs showed transportation in all samples; however, CBCT scans showed transportation in all samples at 2, 3 and 4

mm levels from the apex but at 1 mm level, transportation was detected in 18 out of 20 (90%) samples. In the ProTaper Universal group, digital radiography showed transportation in all samples; however, CBCT showed transportation in 19 (95%) samples at 1, 2 and 4 mm levels; CBCT showed transportation in all samples at 3 mm level from the apex. Overall, Digital radiographs showed apical transportation in all samples while CBCT scans revealed transportation in 37 samples at 1 mm from the apex (P=0.25), 39 samples at 2 mm (P=1), 40 (P>0.05) at 3 mm and 39 (P=1) at 4 mm from the apex.

Considering CBCT as the gold standard modality, sensitivity of digital radiography at different levels was 100% but its specificity was 0% at 1, 2 and 4 mm; its specificity at 3 mm could not be calculated. The positive predictive value of digital radiography was the highest (100%) at 3 mm from the apex. This value was 97% at 2 and 4 mm levels and 92% at 1 mm level from the apex. Comparison of CBCT and digital radiography for measurement of the amount of transportation and centering ratio comparison of the amount of transportation and centering ability in the two groups of CBCT and digital radiography are shown in Figures 4 and 5. One-sample t-test was used to compare the difference in the absolute values of apical transportation and centering ratio on CBCT scans and digital radiographs. Maximum difference in the amount of transportation and in the centering ratio

was 0.13 ± 0.10 mm at 2 mm and 0.40 ± 0.41 mm at 3 mm from the apex, respectively. A significant difference was noted between the two imaging modalities in terms of the amount of transportation and centering ratio at 1, 2, 3 and 4 mm levels from the apex (P<0.0001).

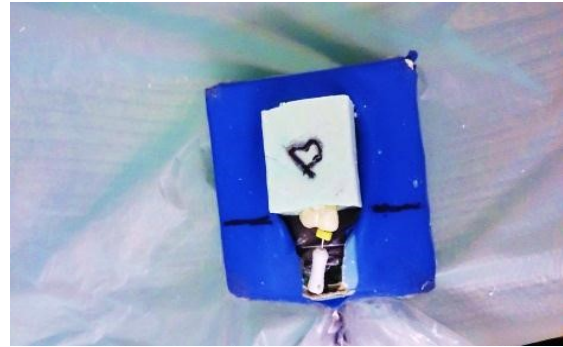


Figure 1. Placement of a sample in the mounting jig prior to digital radiography

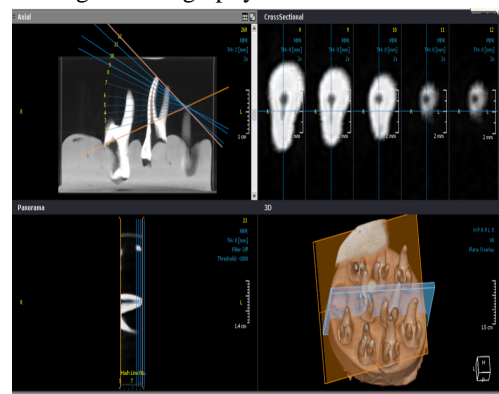


Figure 2. Axial sections were made at 1, 2, 3 and 4 mm levels from the apex of the respective root

Table 1. Frequency of apical transportation in mesiodistal and buccolingual direction at different levels from the apex on CBCT scans in SafeSiders and ProTaper Universal groups (M: Mesial, D: Distal, B: Buccal, L: Lingual)

Transportation Group	Buccolingual Direction											
	At 1mm Number (%)			At 1mm Number (%)			At 1mm Number (%)			At 1mm Number (%)		
	B	L	Center	B	L	Center	B	L	Center	B	L	Center
Safe Siders	6 (30%)	13 (65%)	1 (5%)	8 (40%)	11 (55%)	1 (5%)	8 (40%)	10 (50%)	2 (10%)	4 (20%)	14 (70%)	2 (10%)
ProTaper Universal	10 (50%)	8 (40%)	2 (10%)	7 (35%)	11 (55%)	2 (10%)	9 (45%)	10 (50%)	1 (5%)	10 (50%)	8 (40%)	2 (10%)
	At 1mm Number (%)			At 1mm Number (%)			At 1mm Number (%)			At 1mm Number (%)		
	B	L	Center	B	L	Center	B	L	Center	B	L	Center
SafeSiders	6 (30%)	13 (65%)	1 (5%)	8 (40%)	11 (55%)	1 (5%)	8 (40%)	10 (50%)	2 (10%)	4 (20%)	14 (70%)	2 (10%)
ProTaper Universal	10 (50%)	8 (40%)	2 (10%)	7 (35%)	11 (55%)	2 (10%)	9 (45%)	10 (50%)	1 (5%)	10 (50%)	8 (40%)	2 (10%)

Table 2. The mean and standard deviation of the amount of apical transportation (in millimeters) in buccolingual and mesiodistal directions at different levels from the apex in the two groups on CBCT scans

Transportation Group		Mesiodistal					Buccolingual				
		1mm	2mm	3mm	4mm	P value	1mm	2mm	3mm	4mm	P value
SafeSiders	Mean(SD)	0.12(0.13)	0.20(0.15)	0.17(0.11)	0.14(0.12)	0.177	0.17(0.21)	0.11(0.08)	0.11(0.09)	0.09(0.06)	0.251
	Median (1 st and 3 rd percentile)	0.07(0.01, 0.22)	0.18(0.05, 0.28)	0.13(0.08, 0.24)	0.13(0.04, 0.17)		0.11(0.05, 0.20)	0.08(0.04, 0.16)	0.08(0.04, 0.16)	0.08(0.13, 0.03)	
ProTaper Universal	Mean(SD)	0.17(0.17)	0.19(0.15)	0.16(0.09)	0.14(0.10)	0.389	0.14(0.19)	0.12(0.11)	0.11(0.10)	0.13(0.12)	0.951
	Median (1 st and 3 rd percentile)	0.10(0.05, 0.25)	0.14(0.09, 0.29)	0.18(0.07, 0.24)	0.14(0.04, 0.22)		0.05(0.01, 0.23)	0.09(0.02, 0.23)	0.07(0.02, 0.20)	0.10(0.04, 0.19)	
P value		0.341	0.947	0.841	0.659		0.327	0.968	0.862	0.414	

Table 3. Frequency of apical transportation in mesiodistal direction at different levels on digital radiographs in SafeSiders and ProTaper Universal groups

Transportation Group	At 1mm Number (%)			At 2mm Number (%)			At 3mm Number (%)			At 4mm Number (%)		
	M	D	Center	M	D	Center	M	D	Center	M	D	Center
SafeSiders	14 (70%)	6 (30%)	0 (0%)	14 (70%)	6 (30%)	0 (0%)	14 (70%)	6 (30%)	0 (0%)	12 (60%)	8 (40%)	0 (0%)
ProTaper Universal	12 (60%)	8 (40%)	0 (0%)	16 (80%)	4 (20%)	0 (0%)	16 (80%)	4 (20%)	0 (0%)	14 (70%)	6 (30%)	0 (0%)

Table 4. The mean and standard deviation of apical transportation in mesiodistal direction at different levels from the apex in the two groups on digital radiographs

Transportation Group		1mm	2mm	3mm	4mm	P value
SafeSiders	Mean (SD)	0.12 (0.11)	0.07 (0.13)	0.14 (0.11)	0.14 (0.13)	0.618
	Median (1 st and 3 rd percentile)	0.07 (0.17, 0.04)	0.13 (0.18, 0.06)	0.09(0.24, 0.04)	0.12 (0.22, 0.03)	
ProTaper Universal	Mean (SD)	0.18 (0.20)	0.17 (0.17)	0.19 (0.15)	0.19 (0.12)	0.540
	Median (1 st and 3 rd percentile)	0.15 (0.19, 0.08)	0.15 (0.20, 0.07)	0.16 (0.24, 0.09)	0.18 (0.24, 0.09)	
P value		0.149	0.495	0.314	0.149	

Table 5. The mean and standard deviation of centering ability in buccolingual and mesiodistal directions in the two groups on CBCT scans

Centering ability Group		Mesiodistal					Buccolingual				
		1mm Mean (SD)	2mm Mean (SD)	3mm Mean (SD)	4mm Mean (SD)	P value	1mm Mean (SD)	2mm Mean (SD)	3mm Mean (SD)	4mm Mean (SD)	P value
Safe siders	Mean (SD)	0.34(0.34)	0.30(0.38)	0.28(0.54)	0.27(0.28)	0.613	0.24(0.31)	0.20(0.28)	0.34(0.36)	0.30(0.35)	0.242
	Median (1 st and 3 rd percentile)	0.26(0.1, 1.058)	0.07(0.0, 0.079)	0.13(0.0, 0.30)	0.15(0.0, 0.57)		0.13(0.0, 0.29)	0.06(0.0, 0.41)	0.24(0.0, 0.64)	0.14(0.0, 0.63)	
ProTaper Universal	Mean (SD)	0.23(0.30)	0.22(0.28)	0.26(0.27)	0.35(0.34)	0.196	0.36(0.38)	0.25(0.29)	0.25(0.31)	0.40(0.36)	0.424
	Median (1 st and 3 rd percentile)	0.11(0.0, 0.35)	0.13(0.0, 0.45)	0.17(0.0, 0.40)	0.29(0.0, 0.65)		0.15(0.0, 0.74)	0.04(0.0, 0.55)	0.14(0.0, 0.41)	0.37(0.0, 2.072)	
P Value		0.301	0.659	0.478	0.478		0.369	0.841	0.369	0.414	

Table 6. The mean and standard deviation of centering ability in mesiodistal direction in the two groups on digital radiographs

Centering ability Group	1mm Mean (SD)	2mm Mean (SD)	3mm Mean (SD)	4mm Mean (SD)	P value
SafeSiders	0.32 (0.27)	0.30 (0.23)	0.37 (0.27)	0.41 (0.30)	0.346
ProTaper Universal	0.33 (0.33)	0.33 (0.32)	0.32 (0.30)	0.34 (0.25)	0.616
P value	0.968	0.968	0.495	0.565	

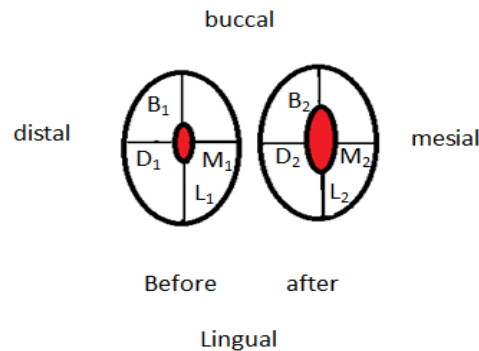


Figure 3. (a) Measurement of M1, D1, B1 and L1 as well as M2, D2, B2 and L2 (b) Green line indicates canal path after preparation; red line indicates canal path before preparation; black and white lines on red line indicate 1mm intervals; purple and blue lines are the indices used for correct superimposition of images.

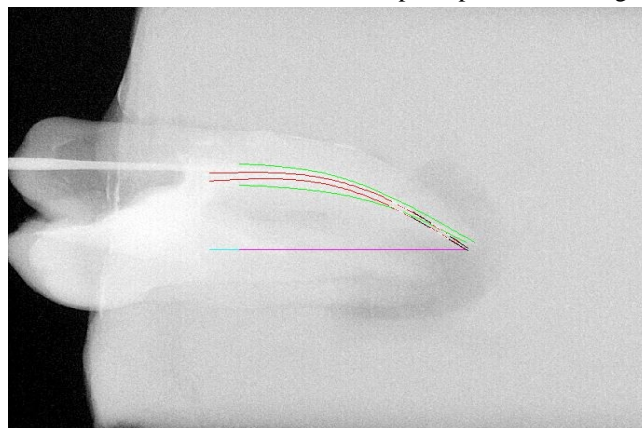


Figure 4. Comparison of transportation in mesiodistal direction in the two groups at 1, 2, 3 and 4 mm levels on CBCT scans and digital radiographs

DISCUSSION

Advances in NiTi rotary instruments and their improved flexibility have resulted in more efficient preparation of curved root canals [15,24,25]. Use of more flexible tools decreases iatrogenic errors such as transportation. In the recent years, several rotary systems such as ProTaper Universal have been introduced [15,16]. However, rotary NiTi files have drawbacks such as torsional and flexural fracture [14].

Recent studies have focused on developing new techniques to overcome the shortcomings of NiTi rotary systems and use of reciprocating motion has been recommended to decrease the frequency of fracture [26,27]. Studies on shaping ability of root canal preparation systems with reciprocating motion are limited [28,29]. SafeSiders files have a continuously smooth surface along the file length, which decreases involvement with dentin and confers fracture resistance during canal preparation. Decreased diameter of cross-section

and smooth surface in one side of the file further adds to its flexibility and narrowing. The manufacturer believes that the advantage of reciprocating motion in this system is applying a balanced force, which maintains the original canal center; 30° rotation eliminates cyclic fatigue, torsional stress and file fracture [13].

According to the American Association of Endodontists, apical transportation is defined as removal of canal wall structure in external curvature of the apical half of the canal path due to the innate tendency of the files to return to their original linear shape [4]. Centering ability refers to no deviation from the central path of the canal [9] and depends on the design of instrument and canal shape [30].

Several methods have been used to compare the performance of different root canal preparation systems. Micro-CT enables three-dimensional visualization of objects. It is suitable for use in endodontics since it enables measurement of the amount of dentin removed from the root canal wall non-invasively. On the other hand, CBCT is a high-resolution scanning system for clinical use in endodontics to evaluate root canal morphology, fracture and changes following preparation. CBCT has lower radiation dose than micro-CT; however, the spatial resolution of CBCT is lower than that of micro-CT, which can be problematic when enhancing the image. Micro-CT has been designed for use *in vitro* while CBCT is ideal for *in vivo* application. In CBCT, the most suitable voxel size is determined based on the size of the respective area, and before and after preparation images must allow their proper superimposition [31]. Although CBCT may not seem reliable for quantification of the results of root canal shaping due to technical limitations, several studies have confirmed its reliability for this purpose [20, 32-35].

In the current study, CBCT and digital radiography were used to compare apical transportation and centering ability in curved mesiobuccal roots of maxillary molars following preparation with ProTaper Universal and

SafeSiders. Both modalities showed transportation in all samples, which was in line with the results of previous studies irrespective of the type of file and technique of imaging [12,22,23,36].

Assessment of the amount of transportation at 1, 2, 3 and 4 mm levels from the apex in both groups was a major strength of this study since no previous study has performed such assessments, although no significant difference was noted in terms of the amount of transportation at different levels. Another strength of the current study was assessment of direction of transportation, which has been rarely done [37].

Assessment of direction of transportation by digital radiography in the current study revealed that it was towards the mesial at all levels from the apex in both groups. The direction of transportation in mesiodistal and buccolingual directions was shown to be mainly towards the mesial and lingual in SafeSiders group by CBCT. This direction in ProTaper Universal group was towards the mesial and buccal at 1 and 4 mm levels from the apex and towards the mesial and lingual at 2 and 3 mm levels. However, the difference was not significant in this respect. Apical transportation in mesiodistal direction at all levels in ProTaper group had a higher amount than in SafeSiders on digital radiographs. However, CBCT showed that in mesiodistal direction, transportation at 2 and 3 mm levels in SafeSiders group was more than in ProTaper Universal group. At 4 mm level, the two groups were the same in this respect; this difference was not significant.

The centering ability in mesiodistal direction on digital radiographs at 1 and 2 mm levels from the apex in ProTaper group was greater than in SafeSiders but not significantly; CBCT showed that this value in mesiodistal direction at 1, 2 and 3 mm levels was higher in SafeSiders but in buccolingual direction at 1, 2 and 4 mm levels, this rate was higher in ProTaper group (but not significantly). Moreover, during root canal preparation with ProTaper Universal system, two files broke and two samples were excluded and

replaced while no file broke in SafeSiders system. Filho et al. [18] showed that ProTaper Universal had the highest rate of transportation compared to reciprocating systems; however, no significant difference was noted in terms of change in curvature, which was in agreement with our results. In a study by Venkateshbabu et al, [38] canal transportation was noted following the use of SafeSiders at 4 to 9 mm levels from the apex, but SafeSiders showed greater centering ability compared to the other two groups. Similarly in the current study, the central canal path was changed following root canal preparation. Al-Ali et al. [17] found a significant difference between SafeSiders and ProTaper groups in terms of total volume of change and sum of changes in cross-section, which was different from our results. In their study, canals in each group were prepared according to the protocol recommended by the manufacturer while in our study, after performing a pilot study on a curved transparent acrylic resin model, it was decided not to use #35 and #40 stainless steel files to prevent excessive taper and also for the purpose of standardization with ProTaper group. Difference between our results and those of Al-Ali et al. [17] may be attributed to differences in size of SafeSiders files used. In a study by Ceyhanli et al, [12] the amount of transportation at 1 mm level from the apex was greater in SafeSiders than in ProTaper group; their results were different from ours since the amount of transportation was not significantly different between the two groups in our study. In the aforementioned study, canal preparation with ProTaper continued to F3 file and preparation with SafeSiders continued to #30, 4% NiTi file; however, in the current study, we used F2 as the final file or #25, 8% file of SafeSiders for the purpose of standardization, which may explain the difference in the results of the two studies.

Comparison of the ability of CBCT and digital radiography for detection and quantification of the amount of transportation was another strength of this study. Da Silva Ramos et al. [19] showed similar accuracy of CBCT and micro-CT for this

purpose. Thus, in our study, CBCT was considered as the gold standard, and digital radiography was compared with CBCT. Our results revealed a significant difference between the two imaging modalities in detection of the amount of transportation and centering ability at different levels from the apex. In other words, digital radiography was found to be reliable for detection of transportation in mesiodistal direction after root canal preparation; however, it was not as accurate and reliable as CBCT for measurement of the amount of transportation or centering ratio. No previous study made such a comparison between digital radiography and CBCT. Sensitivity, specificity, positive predictive value and negative predictive value of digital radiography were calculated (compared to CBCT) and revealed that digital radiography did not have high diagnostic accuracy for detection of cases without transportation, which may be due to small number of samples without transportation in our study. Future studies with larger sample sizes are required to better elucidate this topic. Furthermore, the two preparation techniques should be compared in terms of efficient elimination of smear layer, cleaning efficacy of the root canal system, easy use and preparation time to find the most suitable technique for use in the clinical setting.

CONCLUSION

Within the limitations of this study, the results showed that ProTaper Universal and SafeSiders were not different in terms of apical transportation and centering ability. Both digital radiography and CBCT were useful for detection of transportation, but CBCT was more accurate in quantification of the amount of transportation.

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