

ACCURACY OF CBCT, DIGITAL AND CONVENTIONAL RADIOGRAPHY IN EVALUATING THE SHAPING PERFORMANCE OF A NOVEL NITI ROTARY SYSTEM (AN IN VITRO STUDY)

Sherif A. Ammar*, Nihal E. Sabet** and Hagar A. Bastawy***

ABSTRACT

Aim: This study was designed to evaluate and compare the shaping abilities of ProTaper Gold and the ProTaper Universal systems using cone beam computed tomography (CBCT), digital and conventional radiography.

Materials and Methods: Forty mesiobuccal root canals of extracted mandibular first molars with curvature ranging between 25-60° according to Schneider's technique were selected and prepared using either ProTaper Gold (group I) or ProTaper Universal (group II). Root canals were scanned using CBCT, digital and conventional radiography before and after preparation for measurement of canal transportation and centering ratio at three levels (3, 6 and 9 mm) from the apex.

Results: ProTaper Gold instruments resulted in lower mean canal transportation and higher mean centering ratio compared to ProTaper Universal instruments at 3, 6 and 9mm levels when conventional, digital radiographic or CBCT radiography were used, with a statistically significant difference, at 9 mm when the conventional and digital radiographic methods were used; and at 3 mm when CBCT radiographic method was used.

Conclusions: ProTaper Gold instruments are more able to maintain the original canal configuration than did ProTaper Universal instruments considering canal transportation and centering ability. CBCT proved to present more details than conventional and digital periapical radiographs at the three tested levels.

KEYWORDS: Protaper Gold, Protaper Universal, Cone Beam Computed Tomography (CBCT), Digital radiography, Conventional radiography.

* Teaching Assistant of Endodontics, Endodontic Department, Faculty of Dentistry, Egyptian Russian University

** Professor of Endodontics, Cairo University

*** Associate Professor of Endodontics, Endodontic Department, Faculty of Dental Medicine for girls, Al-Azhar University, Cairo, Egypt.

INTRODUCTION

Mechanical preparation of the root canal system is one of the most important stages of endodontic treatment. The aim of instrumentation is to remove vital and necrotic tissues from the root canal system, along with infected root dentin creating the space that allows irrigants and antibacterial medicaments to more effectively eradicate bacteria and eliminate bacterial by-products. Therefore, canal instrumentation can be considered as the essential phase that eliminates infection ⁽¹⁾.

Several rotary systems have been introduced and improved recently, with the development of new rotary file designs, techniques and manufacturing methods in order to overcome difficulties in root canal preparation, simplify the procedures and reduce instrumentation time. Ni-Ti instruments are much more flexible with a modulus of elasticity that is about one-fifth of the value of stainless-steel files also special thermal and mechanical treatments introduced the new M-wires and CM-wires with higher flexibility and fatigue resistance ⁽²⁾. Therefore, Ni-Ti rotary instruments produce a more centered canal preparation³, with less transportation than stainless steel instruments ⁽³⁾.

ProTaper Universal (PTU) is a widely used rotary instruments manufactured from the conventional super elastic Ni-Ti wire, is characterized by good cutting efficiency and a progressive taper that allows for less contact with canal walls and good torsional resistance. Being made of the conventional Ni-Ti wire, PTU files produced more canal transportation and straightening of curved canals compared to the more flexible M- wires and CM- wires ⁽⁴⁻⁶⁾.

ProTaper Gold (PTG) system has the same design as PTU system with a triangular cross section and a variable progressive taper. ProTaper Gold has been metallurgically enhanced through post machining heat-treatment of CM-wire, which is known to enhance flexibility, improves the centering abilities of the files in the canal

and decreases the canal transportation during preparation of curved canals ^(4,7,8). The heat-treated files also demonstrated enhanced fatigue resistance compared to conventional NiTi files as claimed by the manufacturer ⁽⁹⁾.

Several evaluation methods for specimens were adopted as tooth sectioning ⁽¹⁰⁾, which was not accurate, then the conventional and digital radiographic techniques, which presented a 2D image of a 3D object ^(11,12). CBCT has emerged as a powerful tool for evaluation of root canal morphology because it is accurate as anatomic sectioning and gives 3D information of teeth and jaws ^(11,13).

The aim of this study was to evaluate and compare the shaping abilities of ProTaper Gold and the ProTaper Universal systems using CBCT, digital and conventional radiographic techniques.

MATERIALS AND METHODS

Forty extracted human mandibular first molars were selected that fulfilled the following criteria; mature apices without noticeable root defects, mesial roots having 2 separate mesial canals and apical foramina, with an average length of 12-15 mm and angle of curvature ranging between 25°-60° according to Schneider's technique ⁽¹⁴⁾.

Surface and calcified debris were removed using an ultrasonic scaler and then teeth were disinfected in sodium hypochlorite 5.25% for 15 minutes. After complete cleaning, teeth were autoclaved to ensure sterility and then stored in saline until used. All crowns were sectioned at 2 mm above the cemento-enamel junction using diamond disc under constant water cooling and then the access cavity was refined with Endo-Z bur. All samples were hemi-sectioned at the furcation level with a safe sided diamond disc.

Meisobuccal canals were checked for apical patency with a # 10 K-file until it was just visible from the apex, then 1 mm was subtracted from this

length to establish the working length. # 15 K-file was introduced to the working length to create a glide path.

Using a digital calliper and a permanent marker, the mesial roots were marked at three parts; apical, middle and coronal (3mm, 6mm and 9mm) from the apex respectively, then placed in a mount made of a silicon-based impression material to maintain a fixed film/sensor-object-source position during the conventional and digital radiography⁽⁹⁾. The radiographic mount is composed of a paralleling film/sensor holder which held the samples parallel to the long axis of the roots and as near as possible to the roots, therefore, the X-ray tube and the central X-ray beam were aligned perpendicular to the roots.

Samples were randomly divided into two experimental groups (I and II) according to the NiTi file system used during canal instrumentation (n=20), where group I: samples were instrumented with ProTaper Gold (PTG), while group II: samples were instrumented with ProTaper Universal (PTU).

Pre-instrumentation conventional and digital radiographs were taken with #15 K-files inside the canals at the working length by placing the mounts in the paralleling device. The exposure parameters for the conventional and digital radiographs were (0.4s; 60 KV, 6 mA) and (0.16s; 60 KV, 6 mA) respectively. The conventional radiographs were digitalized by scanning them, then they were imported to EzDent-i software for measurements. Then pre-instrumentation (CBCT) scans were made with exposure time 0.04 seconds, operating at 90 kV and 15 mA with slice thickness of 0.125 mm. Image reconstruction was performed using Romexis 3D software. Pre-instrumentation mesial and distal dentin thickness were measured at the three levels (3, 6 and 9mm from the apex) to determine canal transportation and centering ratio.

Root canals were instrumented either with The ProTaper Gold or ProTaper Universal instruments in an electric motor “Endo-Mate DT, NSK, Nakanishi

Inc., Tokyo, Japan” with a 16:1 reduction handpiece at speed of 300 rpm with a torque of 3 N/cm for SX, S1, and S2 instruments, 1.5N/cm for F1 files and 2N/cm for F2 files following the manufacturer instructions. In both groups (I and II), root canal preparation was done starting with Sx file up to file F2 as master apical file (MAF) to complete apical preparation.

After each instrument use, irrigation with 2 ml of freshly prepared 2.6% sodium hypochlorite (NaOCl) solution dispensed through a 31-gauge Navi-Tip flexible irrigation needle, where the needle was inserted as deep as possible into the root canal without binding. Ethylenediaminetetraacetic acid (EDTA) gel was used as a lubricating agent.

After instrumentation, the samples were radiographed/scanned under the same conditions as the initial radiographs/scans. The amount of canal transportation was assessed at each pre-determined level by measuring the shortest distance from the edge of uninstrumented canal to the periphery of the root (mesial and distal) and then comparing these measurements with the same measurements obtained from the instrumented images⁽¹⁵⁾.

The following formula was used for the calculation of transportation:

$$[(A1 - A2) - (B1 - B2)]$$

According to this formula, a result other than 0 indicates that transportation has occurred in the canal⁽¹⁵⁾. A positive value represented transportation to the outer canal wall (mesial wall), while a negative value represented transportation of the prepared canal to the inner wall (distal wall). Pre and post-instrumentation standardized CBCT axial view images were used to calculate the canal transportation at the pre-determined levels.

The mean centering ratio indicates the ability of the instrument to stay centered in the canal. It was calculated for each pre-determined level by using the following ratio:

$$(A1 - A2) / (B1 - B2) \text{ or } (B1 - B2) / (A1 - A2).$$

If these numbers are not equal, the lower figure is considered as the numerator of the ratio. According to this formula, a result of 1 indicates perfect centering ⁽¹⁵⁾.

Statistical analysis:

Data were presented as mean values and standard deviation (SD). Data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). For parametric data; One-way ANOVA test was used to compare among the different groups. For non-parametric data; Mann-Whitney U test was used to compare between two instruments. Kruskal-Wallis test was used to compare among the different groups. Mann-Whitney U test with Bonferroni adjustment was used for pair-wise comparisons when Kruskal-Wallis test was significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed using IBM® SPSS® Statistics Version 21 for windows (SPSS Inc., Chicago, IL).

RESULTS

Shaping abilities of the two tested instruments using CBCT, digital and conventional radiography

Canal Transportation (Table 1)

With the conventional and digital radiographic methods, the results showed that, ProTaper Gold instruments produced significantly less canal transportation compared to ProTaper Universal instruments at the coronal level ($P \leq 0.05$). However, Mann Whitney U test showed no statistically significant difference between the two tested instruments at the apical and middle levels ($P > 0.05$) (Fig 1,2).

With CBCT radiographic methods, the results showed that, ProTaper Gold instruments produced significantly less canal transportation compared to ProTaper Universal instruments at the apical level ($P \leq 0.05$). However, Mann Whitney U test showed no statistically significant difference between the two tested instruments at the middle and coronal levels ($P > 0.05$).

TABLE (1): Descriptive analysis of canal transportation (mm) between the two tested instruments.

Radiographic technique	Level	Group I (PTG)		Group II (PTU)		P-Value
		Mean	SD	Mean	SD	
Conventional radiograph	Apical (3mm)	0.05	0.03	0.09	0.1	0.242
	Middle (6mm)	-0.01	0.07	-0.06	0.13	0.565
	Coronal (9mm)	-0.01	0.12	-0.13	0.14	0.001*
Digital radiograph	Apical (3mm)	0.06	0.06	0.09	0.06	0.121
	Middle (6mm)	-0.05	0.14	-0.04	0.16	0.841
	Coronal (9mm)	-0.05	0.16	-0.16	0.16	0.023*
CBCT	Apical (3mm)	0.006	0.010	0.013	0.011	0.005*
	Middle (6mm)	-0.01	0.06	-0.07	0.11	0.429
	Coronal (9mm)	-0.06	0.11	-0.12	0.16	0.052

* Significant at $P \leq 0.05$

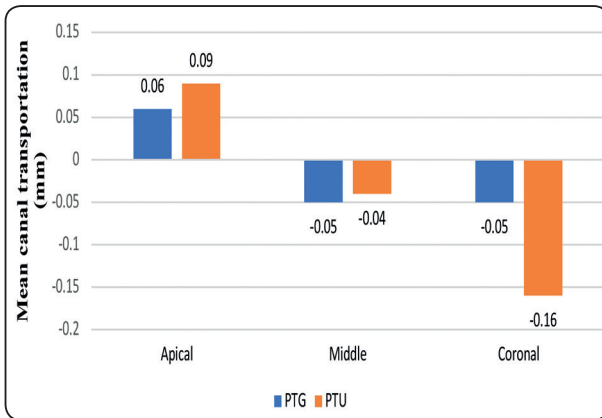


Fig. (1): A bar chart comparing the mean canal transportation after using ProTaper Gold and ProTaper Universal instruments using digital radiography.

Centering Ratio: (Table 2)

With the conventional radiographic method, the results showed that, ProTaper Gold instruments produced significantly more centered canal preparation compared to ProTaper Universal instruments at the apical and coronal levels ($P \leq 0.05$). However, Mann-Whitney U test showed that, there was no statistically significant difference between the two tested instruments at the middle level ($P > 0.05$).

With the digital radiographic method, the results showed that, ProTaper Gold instruments produced more centered canal preparation compared to

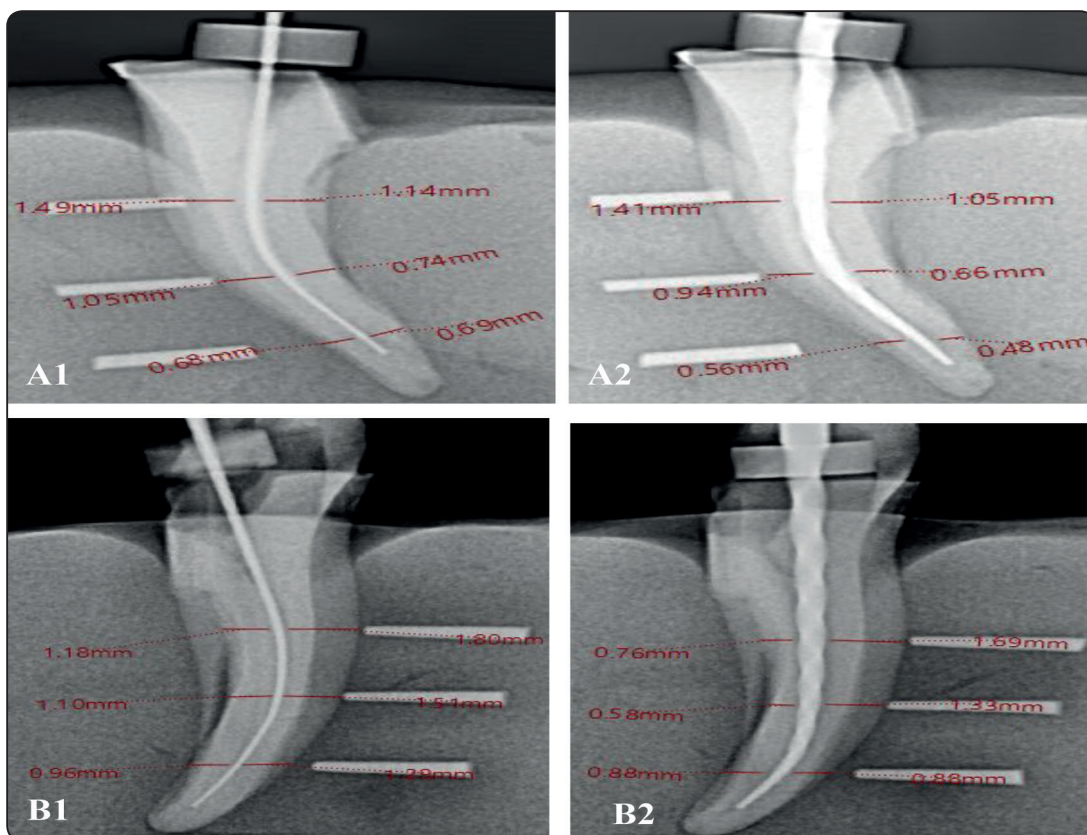


Fig. (2): A1-Digital radiographic pre-instrumentation image of a specimen showing pre-instrumentation measurements at 3,6 and 9mm from the apex. A2- Digital radiographic post-instrumentation image of a specimen prepared with ProTaper Gold (PTG) showing post-instrumentation measurements at 3,6 and 9mm from the apex. B1- Digital radiographic pre-instrumentation image of a specimen showing pre-instrumentation measurements at 3,6 and 9mm from the apex. B2- Digital radiographic post-instrumentation image of a specimen prepared with ProTaper Universal (PTU) showing post-instrumentation measurements at 3,6 and 9mm from the apex.

ProTaper Universal instruments at the apical, middle and coronal levels. However, Mann-Whitney U test showed that, there was no statistically significant difference between the two tested instruments at the three level ($P > 0.05$).

With CBCT radiographic method, the results showed that, ProTaper Gold instruments produced significantly more centered canal preparation compared to ProTaper Universal instruments at the apical level ($P \leq 0.05$). However, Mann Whitney U test showed no statistically significant difference between the two tested instruments at the middle and coronal levels ($P > 0.05$).

The accuracy of the radiographic techniques in evaluating canal transportation and centering ratio: (Table 3) and (Fig 3,4)

Canal Transportation

Within group I (PTG), Kruskal-Wallis test showed that there was a statistically significant difference among the three radiographic methods in the mean canal transportation when ProTaper Gold instruments were used ($P \leq 0.05$). Mann-Whitney U test with Bonferroni adjustment test revealed that, the CBCT radiographic method showed the statistically highest mean canal transportation. However, there was no statistically significant

TABLE (2): Descriptive analysis of centering ratio between the two tested instruments.

Radiographic technique	Level	Group I (PTG)		Group II (PTU)		P-Value
		Mean	SD	Mean	SD	
Conventional radiograph	Apical (3mm)	0.73	0.19	0.54	0.30	0.021*
	Middle (6mm)	0.68	0.24	0.55	0.23	0.087
	Coronal (9mm)	0.62	0.23	0.42	0.26	0.014*
Digital radiograph	Apical (3mm)	0.58	0.18	0.52	0.25	0.448
	Middle (6mm)	0.53	0.20	0.49	0.20	0.553
	Coronal (9mm)	0.55	0.23	0.38	0.28	0.051
CBCT	Apical (3mm)	0.97	0.05	0.88	0.07	<0.001*
	Middle (6mm)	0.72	0.23	0.65	0.26	0.401
	Coronal (9mm)	0.63	0.21	0.50	0.32	0.122

* Significant at $P \leq 0.05$

TABLE (3): Descriptive analysis of the accuracy of conventional, digital and CBCT radiographic methods.

Radiographic technique	Group I (PTG)				Group II (PTU)			
	Transportation		Centering ratio		Transportation		Centering ratio	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Conventional radiograph	0.01 ^a	0.05	0.68 ^a	0.17	-0.03	0.05	0.50 ^a	0.19
Digital radiograph	-0.01 ^{a,b}	0.07	0.55 ^b	0.11	-0.03	0.06	0.47 ^a	0.15
CBCT	-0.02 ^b	0.03	0.78 ^a	0.11	-0.06	0.05	0.68 ^b	0.12
P-value	0.043*		<0.001*		0.144		<0.001*	

*: Significant at $P \leq 0.05$, Different superscripts in the same row are statistically different.

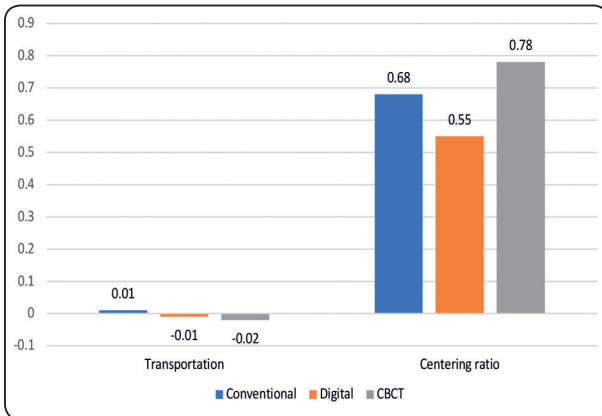


Fig. (3): A bar chart comparing the mean values of conventional, digital and CBCT radiographic methods in measuring transportation and centering ability in PTG group.

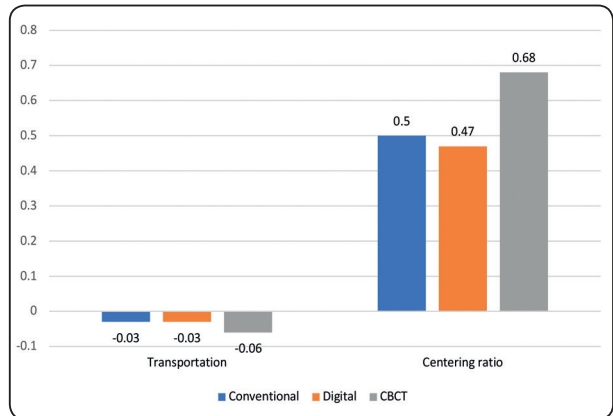


Fig. (4): A bar chart comparing the mean values of conventional, digital and CBCT radiographic methods in measuring transportation and centering ability in PTU group.

difference in the mean canal transportation produced by conventional and digital radiographic methods or digital and CBCT radiographic methods when ProTaper Gold instruments were used.

Within group II (PTU), Kruskal-Wallis test showed that, there was no statistically significant difference among the three radiographic methods in the mean canal transportation when ProTaper Universal instruments were used ($P > 0.05$).

Centering Ratio:

Within group I (PTG), Kruskal-Wallis test showed that there was a statistically significant difference among the three radiographic methods in the mean centering ratio when ProTaper Gold instruments were used ($P \leq 0.05$). Mann-Whitney U test with Bonferroni adjustment test revealed that the digital radiographic method showed the statistically lowest mean centering ratio. However, there was no statistically significant difference in the mean centering ratio produced by conventional and CBCT radiographic methods when ProTaper Gold instruments were used.

Within group II (PTU), Kruskal-Wallis test showed that there was a statistically significant difference among the three radiographic methods in

the mean centering ability when ProTaper Universal instruments were used ($P \leq 0.05$). Mann-Whitney U test with Bonferroni adjustment test revealed that CBCT radiographic method showed the statistically highest mean centering ratio. However, there was no statistically significant difference in the mean centering ratio produced by conventional and digital radiographic methods when ProTaper Universal instruments were used.

DISCUSSION

High quality instrumentation of the root canal is crucial for the prevention or healing of apical diseases. According to Hülsmann et al ⁽¹⁾, “there are seven goals of root canal instrumentation: removal of vital and necrotic tissue from the main root canal space, creation of sufficient space for irrigation and medication, preservation of the integrity and location of the apical anatomy, avoidance of iatrogenic damage to the canal system and root structure, facilitation of canal filling, avoidance of further irritation and/or infection of the periradicular tissues, and preservation of sound root dentin to allow long-term function of the tooth”. Respecting all of these goals may be challenging especially when preparing root canals with moderate or severe curvatures.

ProTaper Universal (PTU) instruments, which is a rotary system of conventional NiTi wire that has been widely used^(6,16). Recently, ProTaper Gold (PTG) instruments were introduced, where they have design features with identical geometries as PTU but are more flexible as it has been developed through a patented proprietary thermomechanical process and advanced metallurgy⁽⁹⁾. ProTaper Gold (PTG) and ProTaper Universal instruments are distinctly different in their metallurgy. Therefore, the aim of the present study was to evaluate and compare the shaping abilities of ProTaper Gold and the ProTaper Universal systems using CBCT, digital and conventional radiographic techniques.

The current study was performed on the mesiobuccal root canals of extracted first mandibular molars, due to their anatomical characteristics, where most of them are round, narrow and curved⁽¹⁷⁾. Angle of curvatures ranging from 25°- 60° according to Schneider's technique⁽¹⁴⁾, are considered endodontic cases with moderate to severe curvatures according to American Association of Endodontics (AAE).

Three levels were chosen representing the apical, middle and coronal thirds of the root canal. The first level was established at 3mm from the apex representing the apical third of the canal at which apical transportation and zips often occurs⁽¹⁸⁾. While, the second and third levels were established at 6 and 9 mm representing critical levels at middle and coronal thirds respectively that are prone to stripping⁽¹⁶⁾. The apical preparation was completed to F2 file (0.25 tip size) as it has been reported that, the amount of canal transportation increases with apical preparation larger than # 25⁽¹⁹⁾.

Traditionally, morphometric evaluation of root canal instrumentation was performed by serial axial sectioning of the samples⁽¹⁰⁾. However, this methodology compromises the integrity of the samples as it requires the samples' cutting. Moreover, previous authors reported difficulties in assessment because evaluation of an individual factor, such

as changes in the internal canal dimensions due to instrumentation, required destruction of the tooth. This usually meant a loss of all data, except for that relating to a few predetermined levels.^(20,21)

The benefits to the patient should outweigh the potential risks of higher exposure to X-rays, especially with respect to the age of the patient as children and young adults are more sensitive to radiation damage⁽²²⁾. Therefore, Vatech 1.5 HD image plate system was used in the present study, which provided reliable endodontic measurements even at very low exposures and better or even comparable image quality than the conventional film systems⁽²³⁻²⁵⁾.

Non-invasive CBCT scanning was used as it provides an accurate, reproducible, 3-dimensional evaluation of changes in root canal morphology before and after preparation without destruction of the samples⁽²⁶⁾.

Samples were mounted in a custom-made silicon-based impression material to standardize the pre and post-instrumentation measurements. Additionally, paralleling device was used to maintain a fixed film/sensor object distance and to ensure standardization of the direction of the X-ray beam, where it is perpendicular on the root canal^(27,28).

In the present study, both PTG and PTU instruments resulted in canal transportation at all examined levels (3, 6 and 9mm from the root apex). PTG instruments recorded lower mean canal transportation compared to PTU instruments at 3, 6 and 9mm levels when conventional, digital radiographic or CBCT radiography were used, with a statistically significant difference, at the coronal level (9 mm) when the conventional and digital radiographic methods were used; and at the apical level (3 mm) when CBCT radiographic method was used. PTG system presented overall less canal transportation compared to PTU system. As PTU and PTG systems have an identical geometrical design (convex triangular cross-sectional design,

unique progressive variable taper along the flutes, noncutting tip design which allow easy penetration with minimal apical pressure) ^(26,29) and operation mode, this result may be solely explained by their different manufacturing processes (the proprietary heat treatment technology), which clearly affect their stress-strain distribution patterns and bending behaviours, making PTG files more flexible and decreasing their tendency to straighten in curved canals ^(4,30).

The results of canal transportation of PTG instruments were comparable to the results obtained with previous studies, in which PTG instruments were reported to have significantly less mean of canal transportation at all levels than PTU instruments ^(4,30). The results of the present study was supported by previous studies that compared transportation by M-wire and CM wire systems with those made of conventional NiTi and reported that CM wires produce less mean canal transportation than conventional NiTi wires ⁽⁴⁻⁸⁾.

On the other hand, contradictory findings were reported by Elnaghy and Elsaka ⁽²⁹⁾, who reported that PTG and PTU systems showed no statistically significant difference in the mean transportation at the apical level when CBCT radiographic method was used. This could be attributed to the use of different canal curvature range (25°- 30°) than the current study.

It has been concluded that apical transportation greater than 0.3 mm may have a negative effect on the apical seal during obturation ⁽³¹⁾. In the present study, none of the instrumented samples reached the above-mentioned critical level of transportation on all studied levels. This was consistent with previous study using PTG and PTU instruments ⁽²⁹⁾.

The results of canal transportation that were recorded in the present study were supported by the results of centering ratio, where PTG instruments produced significantly higher mean centering ratio compared to PTU instruments at the apical

level when conventional or CBCT radiographic methods were used. Many studies have shown that instruments that are more flexible produce more centered root canal preparations ^(4,18,32).

Many authors reported that the PTG instruments maintained the original root anatomy in curved canals and were able of producing centered preparations ^(4,7,30).

On the contrary, many authors reported that, there was no statistically significant difference between PTG instruments and PTU instruments in the mean centering ratio ^(29,33). This could be attributed to the use of different canal curvature range and different evaluation methods than the current study.

The quality and quantity of information obtained from radiographic investigations are very important as these data affect diagnosis, treatment plan and prognosis in endodontic therapy ⁽¹¹⁾. In clinical work; conventional and digital radiographs did not provide enough data on the pathological conditions ⁽¹²⁾. The use of CBCT allow gathering information at low radiation dose which equals two exposures by intra-oral radiography and 1/100 to 1/30 by medical X-ray CT in short as 18 seconds of exposure time ⁽³⁴⁾. In the present study, CBCT was used to evaluate the dentin thickness and root canals of the selected mandibular molars. This technique permits visualization of the root canal system in three planes (axial-coronal- sagittal) that provide the most accurate pre and post- instrumentation measurements of the root canal transportation, centering abilities of the instruments used during treatment and analyse the amount of dentin removed during endodontic treatment ^(13, 35, 36). These measurements were compared to the measurements obtained from the conventional and digital radiography.

The present study revealed that, there was a statistically significant difference among the three radiographic methods when ProTaper Gold instruments were used, where the CBCT radiographic method showed the statistically

significant highest mean canal transportation. The results of the present study were in agreement with previous studies which found that CBCT provides a more accurate detection of hard tissue minimal changes^(11,13).

CONCLUSIONS

Within the limitations of this study the following could be concluded:

1. ProTaper Gold instruments are more able to maintain the original canal configuration than did ProTaper Universal instruments considering canal transportation and centering ability.
2. CBCT proved to present more details than conventional and digital periapical radiographs.

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