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Research Article

Impact of contracted endodontic cavity on shaping ability of protaper next files system by using cone beam computed tomography: an ex-vivo study

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Abstract

Background: The aim of the study was to evaluate and compare the effect of different access cavity designs, using CBCT, on root canal transportation and centeralization performed on 2 rooted maxillary premolars. **Methods**: Twenty maxillary premolars were randomly divided into 2 groups. In group 1, traditional endodontic cavities (TECs) were prepared. In group 2, contracted endodontic cavities (CECs) were prepared. Mechanical preparation was done by Protaper Next files in both groups. CBCT imaging was performed pre and post root canal preparation for calculations of root canal transportation and centering ability. **Results:** Data were analyzed using Mann-Whitney U test and Kruskal-Wallis test. For transportation, teeth with CECs showed the statistically significantly highest median amount of transportation, while as for centering ability, results showed no significant difference between both groups at 6 mm and 9 mm of the root level. At root level of 3 mm, teeth with CECs showed the statistically significantly lowest median amount of centering ability. **Conclusion**: Under the conditions of this study, Protaper Next prepared canals with different access cavity designs without significant shaping errors. TEC showed less transportation than CEC, while both TEC and CEC had no effect on the file centering ability at the middle and coronal third of the root.

Keywords: Protaper Next, CBCT, Traditional Access, Contracted Access, Canal Transportation, Centering Ability, Nickel-titanium Instruments

Introduction

An adequate endodontic access cavity is a key step to achieve proper cleaning, shaping and filling of all root canals within a tooth[(1)]. Moreover, an appropriate access may promote canal detection and enhance instrumentation efficacy by avoiding coronal interferences[(2)]. As an alternative to the traditional endodontic access cavities (TECs), minimally invasive endodontic cavities or contracted endodontic cavities (CECs) have been described[(3–5)], emphasizing the importance of preserving the tooth structure, including pericervical dentin. In contracted access cavities, coronal interference may cause endodontic instruments to work primarily on the internal surface of the root canal, resulting in root canal transportation which negatively affects long term prognosis because of the excessive removal of dentin and straightening of the original root canal curvature [(6,7)]. Recently, new generations of NiTi rotary instruments with higher flexibility and greater cutting efficiency have been introduced. HyFlex EDM (HFEDM) is submitted to controlled memory (CM) treatment, which has been proven to considerably increase flexibility and cyclic fatigue resistance. HFEDM is presently the only instrument produced by electrical discharge machining, the design is characterized by a variable cross section, with a transition from roughly triangular near the shaft (conveying flexibility and fatigue resistance) to rectangular at the tip (granting torsional resistance)[8]. Despite the different instrument designs and metallurgical advancements, root canal preparation is negatively influenced by the anatomical variation of root canals[7].

The root form and canal anatomy of maxillary first premolars are highly variable. The most common anatomical features include two roots, narrow furcation entrances, deep mesial concavities and the presence of the palatal furcation groove of the buccal root, which is a developmental depression located at the palatal aspect of the buccal root [9]. Lack of knowledge about the extent and thickness of the dentin in this area might lead to excessive thinning of the dentinal wall during endodontic procedure [10].

Cone Beam Computed Tomography (CBCT) technology can help guide CECs preparation through the valuable information it provides for pre-access analyses, knowledge of the number root canals present in addition to their orientation within the tooth as well as their orientation relative to each other which could allow for a more precise access cavity and thus, the preservation of dentin with CECs preparation. Additional information such as the presence of complex anatomy (i.e isthmus presence, broad canals buccolingually, developmental anomalies) can be planned for and taken into consideration all with the goal of increasing the efficacy and accuracy of CECs preparation [11].

Therefore, the aim of the present study was to evaluate and compare the effect of access cavity designs, using CBCT, on root canal transportation and centeralization performed on 2 rooted maxillary premolars. TECs were used as a reference for comparison. The null hypothesis tested was that there would be no influence of the type of endodontic cavity on any of the investigated outcomes.

Material and methods

Sample size calculation

The sample size was calculated based on previous studies comparing TECs and CECs[12,13], both with 10 teeth per group. Accordingly, for analysis with a = 0.05 and 80% power, at least 10 teeth were allocated for each of the following groups: TECs and CECs.

Sample selection and grouping

After the approval of a local ethics committee of Faculty of Dentistry, Minia University, a total of 20 extracted sound, intact, mature human 2-rooted maxillary premolars extracted for orthodontic or periodontal reasons were included. These teeth were stored in 0.9% saline solution at 4°C for a maximum of 6 months. Teeth were initially selected based on similar length and degree of canal curvature, and pulp chamber height < 2 mm. Angle of curvature was assessed according to the criteria described by Schneider[14]. Teeth were radiographed using radiovisiography in buccolingual direction. A line was drawn parallel to long axis of the canal. The second line was drawn from the apical foramen to intersect with the first at the point where the canal began to leave the long axis of the tooth. Thus, the acute angle formed was measured and the angle of curvature was determined. Teeth with a degree of curvature ranging between 10° and 24° were included in the study[15]. The images were stored, group allocation was done randomly into two groups (n=10 per group) using a random group allocation online software (https://www.ramdomizer.org) where only the buccal root was considered in the study. The two groups were allocated based on the type of endodontic access preparation; group I: Traditional endodontic access design, group II: Contracted endodontic access design. All teeth were fixed by mounting them vertically halfway in transparent auto polymerizing acrylic resin (Acrostone, Dental & Medical Supplies, Cairo, Egypt) mixed according to the manufacturer's instructions, and then scanned by CBCT before instrumentation.

Group I: Traditional endodontic cavities (TECs)
Endodontic access cavities were drilled with high-speed diamond burs (BR-41 Round bur, Mani, Japan) and an Endo Z drill (Dentsply Maillefer, Ballaigues, Switzerland) following conventional guidelines already described in the literature[16,17]. The roof of the chamber was removed, the pathway to the canal orifices was unimpeded and unobstructed, creating a straight-line access (Fig. 1).

Group II: Contracted endodontic cavities (CECs)
Endodontic access cavities were drilled with high-speed diamond burs (BR-41 Round-bur, Mani, Japan). The teeth were accessed at the central fossa with minimal extension enough to detect canal orifices, in order to preserve pericervical dentin as well as part of the chamber roof[18,19] (Fig. 2a, b).

Root Canal Preparation
The apical patency of all root canals was confirmed using a #10 K-file (Dentsply Maillefer, Baillagues, Switzerland), Working length was determined using a #10 K-file (Dentsply Maillefer, Baillagues, Switzerland), which was introduced into the root canal until it became visible at the apical foramen. Working length was set to 1 mm short of the apex.25/~ HyFlex EDM one file system (Coltene, Whaledent, Cuyahoga Falls, OH, USA) was used for shaping the canals of both groups. All instruments were driven using the X-Smart Plus (Dentsply Maillefer, Baillagues, Switzerland). The files were operated at 400-rpm speed and torque of 2 Ncm. Each of the files was used to shape a maximum of 4root canals, the root canals were irrigated with 2mL 5.25% sodium hypochlorite (CanalPro; Coltene/ Whale-dent, Allstetten, Switzerland) solution. To remove the smear layer, 2mL 17% EDTA (CanalPro; Coltene/Whaledent, Allstetten, Switzerland) was applied for 2 minutes, followed by 2 mL saline and then 2 mL 5.25% sodium hypochlorite was applied as a final irrigation, then dried with paper points. A single experienced endodontist (A.B) performed all access cavities preparation and instrumentation to avoid inter-operator variability, all steps were done under magnification (4.3X magnification EyeMag Smart Loupes; Carl Zeiss Meditec; Jena, Germany).

Image Capture
Root canal transportation and instrument centralization were measured both pre and post mechanical preparation at the level of 3 mm, 6mm and 9mm from the apex. Images of tooth roots were evaluated in three different planes (axial, coronal, and sagittal) in search of synchronization between the first and second sets of images obtained for each specimen. Navigation in the axial plane started at the most extreme point of the root apex and continued for 3mm, 6mm, and 9mm. CBCT images were obtained using a Vatech Pax-i3D Green scanner (VATECH GREEN Inc., Hwaseong-si, Gyeonggi, Korea) with the following settings: field of view of 50 x 50 mm, voxel of 0.080mm, tube voltage of 94 kVp, tube current of 10 mA and exposure time of 12.2 seconds. Images were examined using the scanner's proprietary software (EZ3d-I, VATECH GREEN Inc., Hwaseong-si, Gyeonggi, Korea).

Evaluation of canal transportation and centering ability
The formula introduced by Gambill et al.,[20] was used to measure the degree of canal transportation. ($[a1 - a2] - [b1 - b2]$), where a1 and a2 were the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented and instrumented canal, respectively; b1 and b2 were the distance from distal edge of the root to the distal edge of the uninstrumented canal and instrumented canal, respectively. The result of "0" indicates no canal transportation and other than "0" means that transportation has occurred.

The following formula was used for the calculation of centering ability. $(a1 - a2)/(b1 - b2)$ or $(b1 - b2)/(a1 - a2)$. If the numbers are not equal, the lower figure was considered as the numerator and a result of

"1" indicates perfect centering. A second examiner (R.H) who was blinded to all experimental group performed the measurements.

Statistical Analysis

Data were explored for normality using Kolmogorov-Smirnov test and showed non-parametric distribution. Data were described using minimum, maximum, median and inter-quartile. Comparisons were carried out between two studied independent not-normally distributed sub-groups using Mann-Whitney U test and between more than two studied independent not-normally distributed subgroups using Kruskal-Wallis test. Post-hoc pair-wise comparisons when Kruskal-Wallis test was significant was carried out using Dunn- Sidak test for multiple comparison.

An alpha level was set to 5% with a significance level of 95%, and a beta error accepted up to 20% with a power of study of 80%. Statistical analysis was performed with SPSS (Statistical Package for Social Science) program for statistical analysis (IBM Corp. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.; Released 2012).

Results

During mechanical preparation, neither instrument fracture nor loss of working length were encountered in any of the teeth.

Transportation

At 3mm, 6mm and 9mm root level from the apex; there was statistically significant difference between the 2 endodontic cavity designs, Mann-Whitney comparisons between both cavity designs revealed that teeth with CECs showed the statistically significantly highest median (IQR) amount of transportation at all levels. For each cavity design; there was no statistically significant difference between amounts of transportation between 3mm, 6mm and 9mm. Table (1)

As regarding the total amount of absolute transportation (median of the three root levels for each group); there was a statistically significant difference between the 2 groups CECs showed the statistically significantly highest median amount of transportation 0.12 (0.07-0.16) while TECs showed the lowest amount of transportation 0.05 (0.03-0.06, p=0.000). Table (2)

Centering ability

At 3 mm, 6 mm and 9 mm root level from the apex; there was no statistically significant difference between the 2 endodontic cavity designs. For each cavity designs; there was no statistically significant difference in term of centering ability between 3mm,6 mm and 9mm (Table 3). As regards the total amount of absolute centering ability (median of the three root levels for each group); there was no statistically significant difference between the 2 groups (p=0.824). Table (4)

Table 1: Median (IQR) and minimum-maximum values of buccal roots transportation (mm) at different root levels for both endodontic cavity designs.

	Group		Test of significance *p* value
	TECs (n=10)	**CECs (n=10)**	
3 mm			
- Min-Max	0.01-0.09	0.01-0.41	$Z_{(MW)}$= 2.138
- Median (IQR)	0.05 (0.03-0.05)	0.16 (0.06-0.16)	*p*=0.033*
6 mm			
- Min-Max	0.03-0.13	0.08-0.27	$Z_{(MW)}$= 2.901
- Median (IQR)	0.05 (0.03-0.06)	0.12 (0.12-0.15)	*p*=0.004*
9 mm			
- Min-Max	0.00-0.15	0.02-0.31	$Z_{(MW)}$= 1.978
- Median (IQR)	0.05 (0.00-0.06)	0.09 (0.07-0.12)	*p*=0.048*
Test of significance *p* value	$\chi^2_{(df=2)}$=0.623 *p*=0.732 NS	$\chi^2_{(df=2)}$=0.790 *p*=0.674 NS	

n : Number of specimens
Min-Max: Minimum – Maximum
MW: Mann-Whitney U test
KW: Kruskal Wallis test
*: Statistically significant (p<0.05)
NS: Statistically not significant (p>0.05)

Table 2: Median (IQR) and minimum-maximum values of the entire buccal roots levels in term of transportation(mm) for both endodontic cavity designs.

	TECs (n=30)	**CECs (n=30)**	**Test of significance *p* value**
- Min-Max	0.00-0.15	0.01-0.41	$Z_{(MW)}$=-4.059
- Median (IQR)	0.05 (0.03-0.06)	0.12 (0.07-0.16)	*p*=0.000*

n : Number of specimens
Min-Max: Minimum – Maximum
MW: Mann-Whitney U test
* : Statistically significant (p<0.05)
NS: Statistically not significant (p≥0.05)

Table 3: Median (IQR) and minimum-maximum values of buccal roots in term of centering ability (mm) at different root levels for both endodontic cavity designs.

	Group		Test of significance *p* value
	TECs (n=10)	**CECs (n=10)**	
3 mm			
- Min-Max	0.25-2.50	0.09-2.00	$Z_{(MW)}$= 1.216
- Median (IQR)	1.06 (0.55-1.08)	0.83 (0.50-0.83)	*p*=0.224 NS
6 mm			
- Min-Max	0.19-5.33	0.29-3.45	$Z_{(MW)}$= 0.000
- Median (IQR)	1.44 (0.57-1.75)	1.40 (0.43-2.33)	*p*=1.000 NS
9 mm			
- Min-Max	0.33-3.00	0.21-4.88	$Z_{(MW)}$= 0.607
- Median (IQR)	1.10 (1.00-1.10)	1.60 (0.31-3.25)	*p*=0.544 NS
Test of significance *p* value	$\chi^2_{(df=2)}$=0.909 *p*=0.635 NS	$\chi^2_{(df=2)}$=1.789 *p*=0.409 NS	

n : Number of specimens
Min-Max: Minimum – Maximum
MW: Mann-Whitney U test
KW: Kruskal Wallis test
*: Statistically significant (p<0.05)
NS: Statistically not significant (p≥0.05)

Table 4: Median (IQR) and minimum-maximum values of the entire buccal roots levels in term of centering ability(mm) for both endodontic cavity designs.

	TECs (n=30)	CECs (n=30)	Test of significance *p* value
- Min-Max - Median (IQR)	0.19-5.33 1.08 (0.57-1.59)	0.09-4.88 0.83 (0.43-1.79)	$Z_{(MW)}$=0.222 *p*=0.824 NS

n : Number of specimens
MW: Mann-Whitney U test
NS: Statistically not significant (p≥0.05)
Min-Max: Minimum – Maximum
* : Statistically significant (p<0.05)

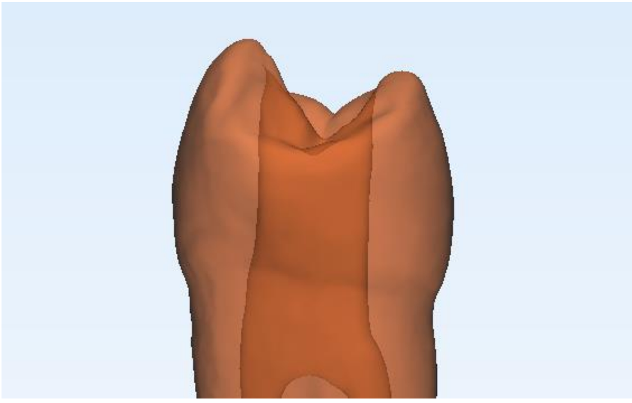

Figure (1): Traditional endodontics access.

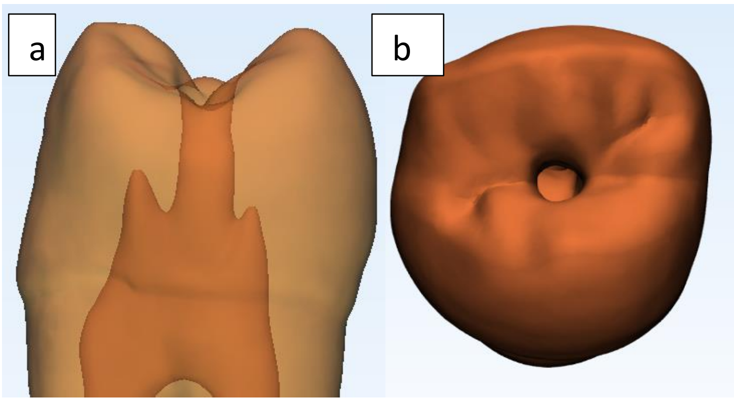

Figure (2): Contracted endodontics access, a: proximal view, b: occlusal view.

Discussion

The emergence of minimally invasive dentistry[18,19] has led to the modern concept of conservative endodontic access cavity; which targets the preservation of sound dentine by avoiding both complete de-roofing of the pulp chamber and avoiding over-flaring of canal orifices as well as avoiding aggressive dentine removal for shaping[20], especially around the pericervical dentin (located 4 mm above and below the crestal bone)where it acts as a buttress against structural flexure and ultimate fracture[21]. The leaning to cut smaller-sized access cavities was influenced by the use of lighting and magnification, highly flexible instruments and better imaging devices such as CBCT[11], while it is crucial to shift the modern operative approach toward a conservative philosophy[22], however it is also obligatory to ensure sufficient endodontic access to enable optimal shaping as it is claimed that contracted endodontic cavities may cause operative difficulties during canal shaping, due to the coronal interferences that could lead to root canal transportation.

Maxillary premolars were selected as several studies have reported that the presence of grooves on the furcation aspects of the buccal roots of maxillary premolars varied between 62 and 100% based on different evaluation methods[10-23]. Excessive removal of dentin with thin canal walls present in maxillary premolars may lead to unnecessary weakening of the tooth and subject it to higher risk for root fracture.

Hence, in this study, we compared the shaping ability of one endodontic instrument with two different access cavity designs in the maxillary premolars using a well-established technique[24]. Two parameters were used in this comparison, canal transportation, and centering ability using CBCT scanning, which was used because it provides an accurate, reproducible, 3-dimensional evaluation of changes in both dentin thickness and root canal volume before and after preparation without the destruction of specimens [20,25].

While Micro-CT remains the golds standard and the reference tool for these studies, since it enables the image to be acquired within the range of 5- to 50 mm voxel size, the small voxel size permits the assessment of accumulation of hard tissue debris, untouched root canal walls and the sum of dentin removed[26], these systems are however costly and involve longer scanning and reconstruction times compared to CBCT, bearing in mind that due to the high radiation dose of micro-CT machines, these is no in vivo scanning available.

There was no significant difference between 76 mm voxel size at CBCT and 20mm voxel size at micro CT in the study of the tooth anatomy in en dodontic therapies[27] using maxillary molars on t he cadaver, CBCT was used in the current study for radio graphic analysis as it provides precise and reproducible calculations of root canal chan ges before and after instrumentation[28-30].

In this study, shaping outcomes after instrumentation with HyFlex EDM single file were analyzed. The proposed main benefits of the single instrument 'system' are cost-effectiveness, elimination of possible cross-contamination and a reduced instrument fatigue associated with single use. The tested hypothesis were rejected, as the transportation observed in the CECs group was statistically higher than that observed in the TECs group at each analyzed level. It has been suggested that 0.15 mm apical transportation is acceptable [31]. However, if apical transportation exceeds 0.3 mm, it will have a negative impact on root canal filling. In this study, Although the median (IQR) of both groups was within the accepted limit, some specimens of the CECs group particularly at the apical part of the canal exceeded this critical level, and the maximum value of 0.41 mm was considered not to be within the acceptable limit. This may have been caused by coronal interferences that led to excessive pressure of the instrument against the outer aspect of the root canal curvature and to the increased number of pecking motions required to reach the WL. The result of the present study revealed that the type of access influenced the shaping outcome in term of transportation and this result is in line with the findings of Alovisi et al., 2018[32] where they demonstrated significantly more canal transportation in CECs when compared to TECs, even when using controlled memory instruments. Similar results could be observed in a study by Rover et al., 2017[33] where canal transportation was significantly higher for the CEC group in the palatal canal of upper molars at 7 mm from the apical end than TEC group even when using M-Wire NiTi technology, probably because of the straight line access in the TEC group. Regardless of the NiTi file system used, studies have showed the negative influence of CECs on the original canal anatomy in lower molars[12-13].

In the analysis of centering ability, no significant difference was seen between TECs and CECs at the three tested levels (3mm, 6mm and 9mm), as well as no significant difference was noted between the three levels of the root of each group. These results may be due to the controlled memory of HyFlex EDM file that can be pre-bent to follow the anatomy of the canal which was considered to be highly flexible and can be tailored to the original shape of the canal, in addition to the rectangular cross section of HyFlex EDM, which may provide a better centralization of the rotary file in the curved canal, this comes in agreement with Ozyurek et al., research[34].

Finally, while the available evidence suggests that the most important factor impacting the survival of root-filled teeth is the amount of remaining dentin[35-38] which highlights the significance of conserving dentin as a critical factor responsible for the fate of root-filled teeth, endodontic access cavity designs should be subjected to assessment of associated benefits and risks, as the elimination of intracanal bacteria to levels compatible with periredicular tissue healing is paramount for root canal treatment success, the effect of minimally invasive endodontic approaches on the disinfection of root canals as well as the fracture resistance of endodontically treated teeth should be further assessed and considered before adopting the new design.

Conclusion

Based on the results of this in vitro study, HyFlex EDM single file performed similarly in CECs and TECs with regard to centering ability, while for transportation CECs negatively influenced the original canal anatomy.

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Declared none.

Conflict of interest

The authors confirm that this article content has no conflict of interest.

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