ORIGINAL ARTICLE

Impact of Traditional vs. Conservative Endodontic Access Cavity on Shaping Ability of Reciprocating and Continuous Rotation File Systems Using Cone Beam Computed Tomography (CBCT)

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Received: 08 July 2023 / Accepted: 12 September 2023

Abstract

Purpose: This in-vitro study was conducted to illustrate the influence of Traditional Endodontic Access Cavity (TEAC) and Conservative Endodontic Access Cavity (CEAC) procedures on the capacity of AF F One (Fanta Dental Materials Co., Shanghai, China) and AF Blue R3 (Fanta Dental Materials Co., Shanghai, China), a continuous rotation and reciprocation endodontic rotary file systems respectively, to shape the root canals of maxillary premolar teeth without transportation or centering deviation.

Materials and Methods: Randomly, forty maxillary premolar teeth were categorized into four groups. Group 1 was accessed and instrumented conventionally with AF F One, Group 2 was accessed and instrumented conventionally with AF Blue R3, Group 3 was accessed and instrumented conservatively with AF F One, and Group 4 was accessed and instrumented conservatively with AF Blue R3. With the use of Cone-Beam Computed Tomography (CBCT) imaging (Planmeca ProMax, Helsinki, Finland), before and after instrumentation pictures of the root canals were captured for the purpose of calculating the transportation and centering ability.

Results: After checking the normality of data distribution, which was accomplished using the Shapiro-Wilk test, an independent sample t-test was performed to compare the data of various groups with a 95% level of confidence. Equivalent in terms of transportation and centering capacity, the two distinct endodontic instruments have comparable shaping capacities. No statistically significant difference ($P > 0.05$) was seen among the endodontic access cavity approaches for the two file systems investigated.

Conclusion: Compared to TEAC preparation, CEAC preparation has no effect on the capacity of the endodontic files to shape the root canal system.

Keywords: Minimally Invasive Dentistry; Endodontic Access Cavity; Root Canal Transportation.

DOI: https://doi.org/10.18502/fbt.v12i4.19807

1. Introduction

Conventional methods, Traditional Endodontic Access Cavity (TEAC), of preparing an access cavity have not been modified for many years. However, extreme removal of coronal tooth structure, particularly at pulp chamber walls (Figure 1a), may raise the tooth's vulnerability to fracture throughout function [1].

This will result in the eventual extraction and loss of teeth, hence diminishing confidence in root canal therapy as a viable therapeutic option.

As a result of the advancement of diagnostic radiology and dental microscopy, together with the substantial enhancement in flexibility, cyclic fatigue, and fracture resistance of endodontic file systems and the latest developments in obturation techniques, dental practitioners are now able to be more conservative without compromising tooth structure, which is straightforward for modern dentistry new trends [2].

Minimally Invasive Dentistry refers to “the maximal preservation of healthy dental structures” [3]. In endodontic, tooth components such as peri-cervical dentin (7–14 mm at the level of the alveolar crest) are valuable if preserved during access cavity (Figure 1b) to avoid the fracture of the tooth after restoration [4, 5].

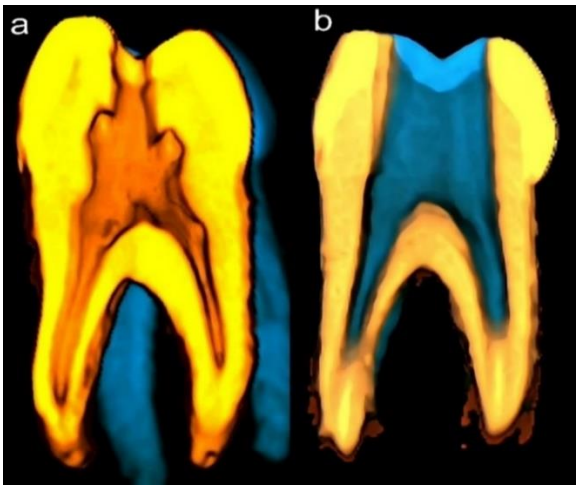

Figure 1. Cone beam computed tomography image (sagittal view) shows (a) conservative endodontic access cavity and (b) traditional endodontic access cavity

The objective of Conservative Endodontic Access Cavity (CEAC) preparation is to practicably preserve more dental components as possible that enable the localization of the canal orifices (Figure 1); however, there are no specific guidelines for preparing the CEAC [6]. In previous studies, CEACs were designed keeping a tooth's central fossae and cusp tip in mind as less than the half distance between the central groove and cusp tip were prepared [1, 7].

The enhanced quality and characteristics of nickel-titanium (Ni-Ti) endodontic files have indeed enabled them to withstand large loads without fracturing or deviating from the existing canal anatomy [8].

(Ni-Ti) metallurgy advancements become the key characteristic of the third generation of endodontic instrumentation files. From 2007, manufacturers started to emphasize the use of heating and cooling techniques to minimize cyclic fatigue and enhance fracture resistance when endodontic instruments are used in canals with a greater degree of curvature [9].

AF F One (Fanta Dental Materials Co., Shanghai, China) is a single file system developed with an AF-R Wire technology (controlled memory wire) and has a unique S-shaped cross-sectional design with a flat side-cut and a non-cutting tip which is useful for curved and restricted root canals, easily bypassed if the file is separated, debris removed efficiently in coronal direction and allows more room for irrigation during instrumentation as the manufacturer claims [10].

Reciprocation, "any repetitive up-and-down or back-and-forth motion", in endodontics is another development in canal preparation techniques that gives way to the fourth generation of root canal shaping file systems [11, 12]. AF Blue R3 (Fanta Dental Materials Co., Shanghai, China) is an example of this generation manufactured with a rectangular cross-section [10].

Above all, endodontic irrigation has permitted the cleaning of infected and remnant debris of inaccessible coronal and radicular tooth portions without the requirement for substantial removal of the pulp chamber and root canal system [13].

This research aimed to study the impact differences between conventionally and conservatively prepared access cavity of maxillary first premolar teeth on the shaping ability of AF F One and AF Blue R3, a continuous and reciprocating file system, respectively, with the aid of cone beam computed tomography

(CBCT). The following statements served as the study's null hypotheses:

First, the shaping ability of continuous rotation and reciprocation endodontic file systems would not be impacted by the access cavity preparation design of maxillary first premolar teeth.

Second, the ability of the root canal of maxillary premolar teeth to be shaped does not vary across filing systems used.

2. Materials and Methods

2.1. Sample Size Estimation

Previous studies suggest that the sample size for each group should be at least 10 teeth [1, 14], using an alpha (α) level of 0.05 and study power equal to 80%. consequently, 40 samples were chosen and each group has 10 samples.

2.2. Sample Selection and Grouping

Forty human two-rooted maxillary premolar teeth were collected after receiving approval from Baghdad University/ College of Dentistry's local ethics committee (no. 2022/547) and stored in 0.1% thymol to be used within six months to prevent dehydration and bacterial growth [15].

These teeth were extracted for orthodontic considerations and had an average size and degree of root curvature (20°-40°).

Standardization of tooth size was established using a digital caliper (Mitutoyo, Japan). While for canal curvature, radiographic images were taken buccolingually, and with the aid of the Image J software program, two lines were drawn, one line was parallel to the initial part of the root canal, and another line was created from the root apex to coincide with the initial line at the level where the canal actually started to depart its straight aspect; the actual angle formed was recorded; and the curvature angle of the canal was defined [16].

Visual and radiographic examination ruled out teeth with decay, prior restorative or endodontic management, open apices, or root resorption (internal or external).

For randomization, a website (https://www.ramdomizer.org) is used to distribute the samples into four categories (n = 10 per each). The endodontic access cavity design and endodontic file system were utilized to determine allocation in one of the following groups of the study:
1- Group (TF) was traditionally accessed and instrumented with AF F One.

2- Group (TR) was traditionally accessed and instrumented with AF Blue R3.

3- Group (CF) was conservatively accessed and instrumented with AF F One.

4- Group (CR) was conservatively accessed and instrumented with AF Blue R3.

The teeth were mounted vertically on a customized mold (made of acrylic and additional silicon impression material) to be in a fixed position during pre and post-instrumentation CBCT scanning.

2.3. Access Cavity Preparation

With the aid of a customized arm of a dental surveyor with high-speed handpiece, preparation of the traditional access groups was done by the penetration of the central fossae of the teeth occlusal surface; then the access cavity is extended Bucco-Lingually (BL) to the margin of the blue dot planned previously (Figure 2b) according to radiographic images (Figure 2a) taken from the Riosensor software (Ray medical, Gyeonggi-do, Korea) in mesio-distal (MD) direction for the standardization of pulp chamber size and access cavity planning to avoid the vision-based and stepped access cavity which may differ according to variable anatomy and morphology of teeth. In addition, checking the pulp chamber roof with a probe may help verify that the access cavity has been properly shaped to provide endodontic files unobstructed root canal entrance [17, 18].

In the conservative endodontic cavity groups, BL extension was done to the margin of red dot planned previously (which was done by contracting the traditional access cavity 1mm from both buccal and palatal access cavity extension) (Figure 2b), maintaining part of the chamber, with the occlusal enamel cavosurface beveled at 450 to avoid endodontic file contact [7].

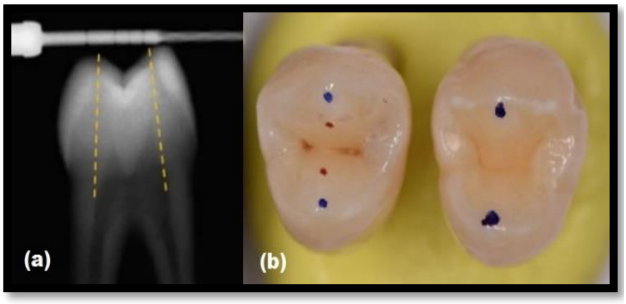

Figure 2. Access cavity dimension planning. (a) Lateral periapical x-ray shows an interrupted yellow line representing the straight-line endodontic access. (b) Occlusal surface with blue and red dots represents the traditional and conservative endodontic access cavity extensions, respectively

Finally, the average BL extension for the conventional access cavity was 4mm, whereas the average for the conservative access cavity was 2mm.

An expert endodontist carried out all of the aforementioned procedures.

2.4. Root Canal Instrumentation

According to manufacturer instructions, following root canal negotiation with file K10 (Fanta Dental Materials Co., Shanghai, China), use an open file (Fanta Dental Materials Co., Shanghai, China) to prepare the coronal third and get straight-line access. After irrigation, further negotiation of the canal with file K10 in a watch wind motion to full working length, to get a patent canal pathway.

Furthermore, with irrigation use AF F One file (#25/04, #25/06) accordingly in a pecking motion (in and out motion for a depth of 3 mm) for 3 times using program set (AF F One) on Fanta micromotor (Fanta Dental Materials Co., Shanghai, China), then irrigate again and repeat till reaching full working length, while for the AF Blue R3 groups, a glide path with C-path 1-2-3 (Fanta Dental Materials Co., Shanghai, China) at full working length. Then start shaping with AF Blue R3 (#25/04, #25/06) using the program set (AF Blue R3) on Fanta micromotor with a gentle push till you see the file proceeding apically, when you feel and see that it stops, retrieve it and clean blades (irrigating with sodium hypochlorite). Repeat until reaching full working length.

All the samples were passively irrigated with a 27-gauge needle using 2ml of 5.25% NaOCl (Chloraxid 5.25%, Cerkamed Medical Company, Poland) between instruments. then, a final irrigation with distilled water was done [19]. Each file was used two times to shape the root canal system and then discarded to avoid any file fatigue and procedural errors

2.5. CBCT Imaging and Image Analysis

The samples were imaged by Planmeca ProMax (Planmeca, Helsinki, Finland) using the parameter of voxel size of 0.075 mm to obtain a three-dimensional image of the teeth. Planmeca Romexis Viewer 4.4.3.R software was used to obtain axial cross-section images of the root canal that were processed by ImageJ software to make the measurements of shaping ability parameters [20].

The samples were placed on a holder specially designed for cast scanning and the position of the sample was marked on the holder to ensure that the sample was positioned on the same plane for CBCT exposure after instrumentation.

The value of canal transportation (in mm) and centering ability (dimensionless) were documented by calculating the shortest route from the canal's inner wall before instrumentation to the root's boundary in the inner of curvature (I1), outer of curvature (O1), buccal (B1), and palatal (P1) directions (Figure 3a); and then equating these measurements to those obtained from the images after instrumentation (I2, O2, B2 and P2 respectively) (Figure 3b) [21].

Canal transportation:

Inner-Outer of curvature (IO) = (I1−O2) − (I1− O2)

Bucco-lingual (BL) = (B1 − P2) − (B1 − P2)

Canal centering ability:

IO = (I1 − I2) / (O1 − O2) or (O1 − O2) / (11− 2)

BL = (B1 − B2) / (P1 − P2) or (P1− P2) / (B1−B2).

A result other than 0 indicated that transportation occurred and its direction to the inner and outer curvature sides is indicated by the positive and negative values, respectively. Moreover, the centering ability of 1 designated an ideal centering [22].

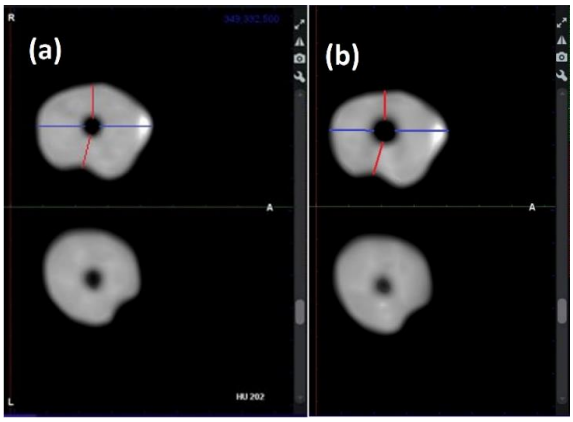

Figure 3. Cone beam computed tomography image of root canal axial cross-section. (a) Shows pre-instrumentation and (b) shows post-instrumentation. Red and blue lines represent the shortest distance from the inner wall of the root canal to the root boundary in bucco-lingual and inner-outer of curvature directions, respectively

2.6. Analysis of Data

The collected data were tested using SPSS v.26 (SPSS Inc., Chicago, IL, USA). Then, after checking the normality of data distribution which was accomplished using the Shapiro-Wilk test, an independent sample t-test was applied to compare the data of various groups with a 95% level of confidence.

3. Results

The table (Table 1) shows the transportation and centering ability of AF F One and AF Blue R3 in both access cavity groups.

There was no statistically significant difference observed between traditional and conservative endodontic access cavity methods and no significant difference in root canal shaping between AF F One and AF Blue R3 file systems in terms of transportation and centering ability ($P > 0.05$). However, the difference was significant in a single group of centering ability in IO direction between TC and CF groups. However, across all experimental groups, the most transportation occurred in the conservative access cavity groups, regardless of the root canal preparation instruments utilized.

4. Discussion

The endodontist's role in disinfecting and shaping the root canal system is crucial. Hence to be considered effective, a root canal preparation technique must meet the three main criteria of being risk-free, rapid, and little altering of the root canals' basic form [23].

In addition, modern dentistry frequently employs the use of conservative and least invasive procedures such as the conservative endodontic access cavity. The purpose of the current research was to evaluate the Conservative Endodontic Access Cavity (CEAC) in comparison to the Traditional Endodontic Access Cavity (TEAC) by analyzing the transportation and shaping capabilities of various endodontics file systems using continuous rotation and reciprocation movement.

The adoption of conservative access cavity preparations has given rise to numerous of research into the association between access cavity design and the tooth's fracture resistance. such as [24, 25]. Fewer studies are concerned with other aspects of the endodontic treatment that could be affected by this design of access such as detecting canal orifices, removing pulp tissue remnants, efficiency of irrigation, ability to shape the canals, and filling procedures.

In addition, correct shaping of the canal system, keeping it well centered avoiding undesirable transportation, and maintaining the original canal configuration is very crucial to the endodontic treatment's effectiveness [26].

The human maxillary premolar teeth were used in this study for the easier standardization of the cavity size between teeth with simpler anatomy in comparison to maxillary or mandibular molars [27]. Also, the degree of curvature was standardized between 20 and 40° using Schilder's method as they have been previously described as severe and may be more susceptible to transportation within the canal [28, 29].

The teeth were put in an acrylic resin block, so that the teeth are in the same fixed position during scanning for pre-instrumentation and post-instrumentation records, also the radio-density of the acrylic resin would not obscure the details of the root canals [30].

Regarding file systems used in this study, they have different cross-section and operates in different motions. AF F One is a continuous rotation file system and has a flat-side S-shaped cross section. While AF Blue R3 operates in reciprocating motion and has a rectangular cross-sectional

Table 1. Canal transportation (in mm) and centering ability (dimensionless) values at coronal, middle, and apical levels

Level	File system	Measurement	Direction	Traditional Mean mm (SD)	Conservative Mean mm (SD)	P value
apical	AF F One	Transportation	IO	.030 (.046)	.029 (.046)	.683
			BL	.032 (.049)	.046 (.049)	.876
		Centering ability	IO	0.651 (.142)	.557 (.148)	.665
			BL	.581 (.156)	.539 (.252)	.160
	AF Blue R3	Transportation	IO	.012 (.045)	.034 (.053)	.556
			BL	.020 (.042)	.059 (.064)	.118
		Centering ability	IO	.684 (.178)	.551 (.138)	.239
			BL	.623 (.193)	.500 (.203)	.721
middle	AF F One	Transportation	IO	-.043 (.063)	-.031 (.090)	.137
			BL	.014 (.047)	.053 (.033)	.566
		Centering ability	IO	.693 (.222)	.494 (.107)	.004
			BL	.653 (.222)	.590 (.173)	.477
	AF Blue R3	Transportation	IO	-.002 (.037)	-.032 (.046)	.440
			BL	.016 (.059)	.048 (.051)	.819
		Centering ability	IO	.679 (.193)	.551 (.201)	.692
			BL	.556 (.174)	.563 (.181)	.978
coronal	AF F One	Transportation	IO	-.030 (.066)	-.035 (.084)	.472
			BL	.023 (.062)	.040 (.063)	.694
		Centering ability	IO	.584 (.180)	.560 (.258)	.127
			BL	.608 (.127)	.631 (.187)	.059
	AF Blue R3	Transportation	IO	-.014 (.064)	-.045 (.060)	.588
			BL	.018 (.051)	.052 (.068)	.538
		Centering ability	IO	.542 (.139)	.488 (.185)	.409
			BL	.607 (.175)	.501 (.177)	.678

design. However, both files were manufactured using AF-H heat treatment technology making them more flexible and resistant to fracture [31].

For standardization of the methodology, the whole work was performed by a single operator and the access cavity preparation was done using a modified dental surveyor with dental loupe 2.5x (Carl Zeiss Meditec AG, Jena, Germany).

CBCT is clinically related and provides a valid, accurate, and a none-invasive technique that enables the examination during different steps of the work, pre and post instrumentation [32]. Even though micro-CT is the gold standard, several studies have shown that CBCT's 3D images of teeth before and after root canal treatment can give useful insights.

The results of the current study showed no statistically significant differences ($P > 0.05$) in root canal transportation and centering ability among most of the TEAC and CEAC groups thus the first null hypothesis was accepted.

However, a significant statistical difference in centering ability appeared between the TF and CF groups in the middle third in the IO direction. This is probably due to the existence of occlusal interferences with CEAC and severe root curvature, which are more probably caught in the middle third, causing a bending of the instruments and an unbalanced transmission of force [33, 34].

In general, the results of this study showed a similar result to previous studies [35-39]. Despite the use of micro-CT in most of these studies, their values appeared comparable to the values obtained in the present study.

On the other hand, the current results disagree with other studies [29, 33, 40-42]. This could be explained by the differences in the methodology, study samples, root curvature, and the file systems used.

The sample used by Alovisi *et al.* was the mesiobuccal up to 30° curved root of the mandibular first molars and the used file system was Wave One gold primary file (0.25 taper 7%) with different designs and taper to the two files used in the current study [29]. While in the study by Rover *et al.*, the tooth sample was maxillary first molar and the instrumentation was performed using the Reciproc file system R25 in buccal canals and R40 in the palatal canal [33]. In another study by Pereira *et al.*, despite the similarity

in tooth samples, the instrumentation files were different, including protaper universal, reciproc, reciproc blue, and hyflex EDM [42]. In addition to the study by Korany *et al.*, mandibular molar teeth were accessed using a truss access cavity and instrumented with Reciproc blue, Hyflex CM files, Endostar E3 basic files, and Wave one [40]. In the last, study of Lima *et al.*, mandibular molars teeth were prepared with XP-endo Shaper and Reciproc [41]. These differences in tooth sample and file system size and tapering could be behind the discrepancy with the results of the current study.

Although there was no statistical difference in transportation and centering ability with different types of access, the means appear slightly higher in the conservative access samples but still within the acceptable range (below 0.15 mm) [43].

An explanation for such a difference could be due to the coronal interference for the shaping files occurring more within the conservative access cavity. This may lead to an increase in the bending forces while the file engages more within the canal deviating the files toward the outer walls [29], and this explains the negative value of transportation of IO direction.

Also, the difficulty in clearing away the debris that accumulated throughout the shaping process may have also had an impact on the instrument's cutting performance.

Furthermore, the presence of crown obstructions, which contributed to a more straightening of the curved root canal (transportation toward the outer aspect of canal curvature), maybe account for the increased time of instrumentation and (in and out) motion seen in the CEAC group [1, 44].

However, both file systems used in this study had super elasticity to overcome this problem as they were both produced by the heat treatment techniques. The manufacturer's own research shows the heat-enhanced metallurgical characteristics can improve the flexibility of NiTi files and create files with controlled shaped memory to reduce the chances of transportation.

Fanta AF F One has a flat-sided S-shaped cross-section, allowing irrigant fluids to reach more space during instrumentation and improving flexibility without sacrificing fracture resistance [45], as these cross-section features reduce the metal mass of the instrument which results in more flexibility [46].

Regarding the AF Blue R3 system, reciprocation movement tends to maintain the initial canal curvature better compared to continuous rotation movement [47]. Furthermore, glide path preparation used with this system also improves the centering abilities [48].

5. Conclusion

Results from this in vitro study suggest that the enhanced flexibility of continuous rotation and reciprocation file systems may answer why they performed equally in shaping the root canal in both endodontic access cavity methods.

Acknowledgments

The research was partially funded by Baghdad University, College of Dentistry.

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