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Effect of Contracted Access Cavity Preparation on Transportation in Curved Root Canals in Molars: An In-Vitro Study

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ABSTRACT

Background: Conservation of the tooth structure is one of the main pillars for tooth longevity. Achieving both conservation and proper visualization and instrumentation is challenging in Endodontics**.** ***Aim of the study:*** Study the effect of contracted access cavity preparation on transportation in curved roots in mandibular molars. ***Materials and methods:*** Mandibular human molar teeth were collected. Cone Beam Computed Topography (CBCT) was taken preoperatively and postoperatively and was superimposed. Teeth were divided into four groups. Group A (10˚-21˚), subdivided into A1, undergoes traditional access cavity (TAC), and A2 undergoes contracted access cavity (CAC). While group B (≥21˚) is sub-divided into B1, which undergoes (TAC), and B2 undergoes (CAC). Then, dentin thickness was measured at 5mm from the apex on superimposed radiographs. Gambill's equations were used to obtain results for transportation. ***Results:*** Contracted access cavity (0.09±0.01) had a significantly higher value than traditional access cavity (0.05±0.01) (p<0.001). ***Conclusion:*** Contracted access cavity increases the occurrence of transportation in curved roots.

Keywords: contracted access cavity, conservative dentistry, curved canals, transportation, superimposed CBCT.

INTRODUCTION

Access cavity preparation is a crucial step in root canal therapy. It allows the dentist to gain access to the root canal system for cleaning and shaping.[1] Traditionally, access cavity preparation involves removing a significant portion of the healthy tooth's structure, creating a funnel-shaped cavity that extends beyond the pulp chamber, reaching the pulp horns and the canal orifices.[2] Advantages of traditional access cavity preparation include improved visibility and ease of accessing the root canal. The larger cavity provides a more direct pathway for instrumentation, irrigation, and obturation, making identifying and treating complex root canal anatomies easier, particularly in molars

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with multiple roots and curved canals.[3]

While this approach has been widely practiced for many years, it has drawbacks. Excessive dentin removal weakens the tooth structure, making it more susceptible to fractures, especially in teeth with significant coronal destruction. The removal of healthy tooth structure weakens the tooth, making it more susceptible to fractures, especially in molars exposed to significant occlusal forces during chewing. The weakened tooth may also be more prone to structural failures, such as cracks or fractures, which can jeopardize the tooth's overall health and longevity.[4]

Consequently, the preservation of tooth structure has gained increasing attention, leading to the introduction of contracted access cavity preparation techniques. The focus is minimal dentin removal while providing sufficient access to the root canal system. The rationale behind this technique is to maintain the tooth's structural integrity and reduce the risk of tooth fractures.[1,5]

Nevertheless, the impact of contracted access cavity preparation on procedural errors in curved root canals, particularly in molars, remains an area of interest and active investigation. One significant procedural error associated with curved root canals is transportation.[6] Transportation is defined as "Removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation; may lead to ledge formation and possible perforation."[7]

Despite the increased risk of procedural errors associated with contracted access cavity preparation, it is essential to consider the potential benefits this technique offers. Preserving tooth structure remains a crucial advantage, as it enhances the tooth's resistance to fracture and may extend its longevity.[1] Furthermore, studies have suggested that the risk of procedural errors decreases with increased operator experience and improved familiarity with the contracted access cavity preparation technique.[8]

To overcome the challenges of contracted access cavity preparation in curved root canals, advancements in endodontic instruments and techniques have been introduced. Nickel-titanium rotary instruments with greater flexibility and resistance to fracture have shown promise in negotiating curved root canals more effectively.[5] Additionally, when adopting a conservative approach, such as contracted access cavity preparation, preserving tooth structure becomes a priority, which may lead to reduced visibility and limited access to the root canal system. Therefore, the role of illumination and magnification in contracted access cavity preparation cannot be overruled, as they significantly contribute to the success and precision of the procedure.[9]

In conclusion, the effect of contracted access cavity preparation on procedural errors in curved root canals in molars is a critical area of investigation in endodontics. As the dental community seeks to refine treatment techniques and optimize patient outcomes, understanding the potential benefits and limitations of contracted access cavity preparation is essential. Through a comprehensive review of the existing literature, this study explores the effect of contracted access cavity preparation on procedural errors encountered during root canal treatment in molars with curved root canals. This study compares this conservative approach's outcomes and potential complications against traditional access cavity preparations.

MATERIALS AND METHODS

The materials and instruments used are shown in **table (1)**.

Sample collection and handling:

Twenty-four extracted mandibular molars were obtained from the teeth bank at Misr International University. These teeth were sourced for various purposes, such as educational and research initiatives, clinical training, or dental implant studies. These extracted molars are crucial in advancing dental education, research, and clinical training at the university.

Extracted teeth were cleansed of visible blood and gross debris and maintained in sterile saline. Saline solution is preferred because it is isotonic, meaning it has a similar salt concentration to bodily fluids, which helps prevent damage and desiccation of the dental tissues. This hydration step is essential in preventing the teeth from drying out, which can lead to irreversible damage. The hydrated extracted teeth are placed in a securely sealed, closed container. This container is designed to be airtight, maintaining a controlled environment that prevents contamination or the introduction of microorganisms. Before handling extracted teeth, strict infection prevention and control measures are observed.

METHODOLOGY

Sample preparation:

In this study, an essential part of the methodology involves systematically categorizing and analysing teeth. To ensure accurate identification and record-keeping, each tooth was meticulously assigned a numerical code marked on the lateral side of its roots using a black marker.

Digital periapical X-rays were taken for all the teeth. These radiographic images were taken with a dental X-ray positioner, a crucial tool in our protocol that ensured the standardization of the imaging process. This standardization was vital in enabling us to make accurate and reliable comparisons across all teeth under examination.

The root angulations obtained through this method were then meticulously assigned to the corresponding tooth numbers, a key step in the categorization process. This detailed categorization allowed to group teeth based on their distinct angulations. Consequently, teeth were classified into specific groups, each characterized by its unique root angulation.

Table (1): Shows the materials and instruments used.

Item	Description	Manufacturer
1. Putty	Condensation silicon	Zetaplus by Zhermack SpA, Italy
2. Contra angle handpiece	High speed stainless steel	NSK/Nakanishi INC.
3. K-files	Manual stainless steel endodontic file	Mani INC, Tochigi,Japan
4. XP-Endo Shaper files	Rotary endodontic file made of MaxWire alloy	(XPS; FKG Dentaire, La Chaux-de-Fonds, Switzerland)
5. Dental microscope	Magnification aid	Zumax
6. CBCT machine		Cranex ® SOREDEX, Finland.

Schneider's method was applied to identify the root curvatures.[10] A well-established and recognized technique for measuring root curvatures. This method involved the creation of two key reference lines on the digital periapical X-rays. The first line connected point A, which represented the midpoint of the orifice, with point B, corresponding to where the root began to exhibit a flare in its morphology. Subsequently, a second line connected point B with point C, situated at the apex of the root. The angle formed by the intersection of these two lines effectively captured the root angulation. **Figure (1)** visually represents this process.

Samples grouping:

Teeth are divided into 2 main groups: group A and group B. Teeth were assigned to the groups randomly according to canal curvatures that had previously been attained.

Group A (N=12) contains teeth with moderately curved roots (10˚- 20˚). At the same time, Group B (N=12) has teeth with severely curved roots (≥21˚).[10]

Each group is randomly sub-divided into 2 subgroups:

A1 Undergoes Traditional access cavity,

A2 Undergoes Conventional access cavity, B1 Undergoes Traditional access cavity, and B2 Undergoes Conventional access cavity.

N=6 in each sub-group.

Teeth in each subgroup are then placed in a rectangular pattern 5.5*7 cm, made from condensation silicon putty (Zetaplus by Zhermack SpA, Italy). Teeth were put into

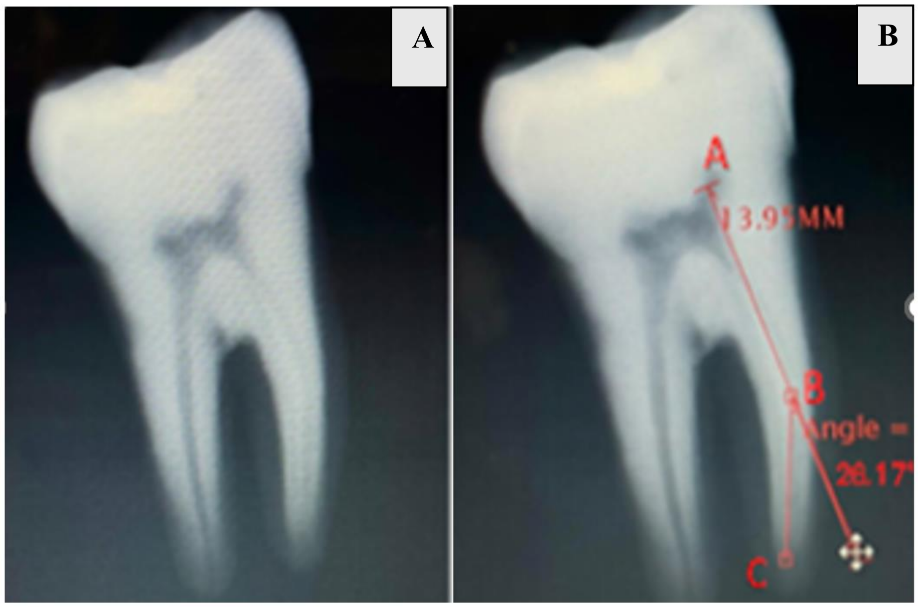

Figure (1):
(A) Preoperative radiograph,
(B) Determining root curvature angulation on digital radiograph using Schneider's method.

Teeth grouping is illustrated below in **Figure (2)**.

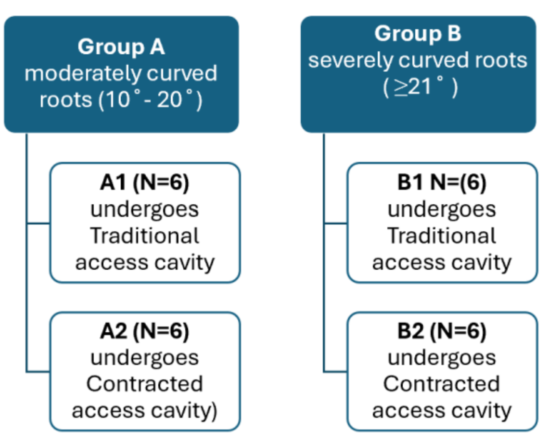

Figure (2): Teeth grouping.

the putty before it was set to create a mold where teeth can be repositioned in the same exact place.

Stapler pins of different shapes are stapled into putty and are used to differentiate between groups on radiographs.

Preoperative scanning:

CBCT is performed on all groups preoperatively. They were taken using Cranex® SOREDEX, Finland.

Preoperative scans were taken with standardization of the following exposure parameters: Field of view 6 x 8 cm, peak kilovoltage of 90 Kv, milliamperage of 10 mA, exposure time of 6.1 seconds, and resolution of 0.2 mm (200 µm) voxel size. Images were obtained using OnDemand 3d App software (Cybermed, South Korea). Preoperative CBCT enabled a reference for dentin thickness preoperatively, which will later be used to determine transportation and centring ratio.

Access cavity preparation:

Groups A1 and B1 undergo Traditional Access Cavity (TAC) as follows: a drop is made into the pulp chamber, and all the pre-dentin is removed to allow straight-line access enabled by the endodontic file.[2]

While Groups A2 and B2 undergo Contracted Access Cavity (CAC) as follows:

Under microscope X10 magnification, the smallest possible drop was access done just to fit the size of the bur. This was made using Mani Round Carbide Bur size #2 in a place in between the orifices of canals. Then, the access was smoothened using a tapered stone with a round end. No additional dentin was removed, preserving peri-cervical dentin.[11]

Figure (3) below demonstrates the difference between contracted vs traditional access cavities.

Root canal preparation:

Orifices are found inside the teeth using magnification and illumination using a Zumax dental microscope with magnification X10. They were pre-detected on CBCT by searching in axial slices with dimensions 0.5 mm/0.5 mm involving coronal to apical direction and apical to coronal one.

The working length of all teeth was determined by inserting k-file file #10 until it appeared at the apex and then measured, and the working length was calculated shorter by 0.5mm.[12]

K-file #15 was used to create a glide pass, and after that, 5ml sodium hypochlorite was irrigated using a side-vented needle. Then, filling the motion with file #20 to the full working length, followed by irrigation again with 5ml of sodium hypochlorite. At last, XP-endo Shaper rotary endodontic files (XPS; FKG Dentaire, La Chaux-de-Fonds, Switzerland) were used to clean the canals.

Postoperative scanning and superimposition:

All teeth were put back in the putty mold, and post-operative CBCT was obtained using the same machine and standardized exposure parameters as preoperatively.

To ensure standardization while comparing dentin thickness, both pre-and post-operative CBCT images are superimposed using the fusion feature in

OnDemand 3d App software (Cybermed, South Korea).

Figure (3): Traditional Access Cavity design (A)Versus Contracted Access Cavity design (B).

Data collection:

Dentin thickness was measured at 5mm from the apex using the superimposed coronal view.[13] To measure dentin thickness at this level, 5mm were measured from the apex, and the cursor was put exactly on the 5mm level. After shifting to the fused axial view, dentin thickness was measured mesially and distally preoperatively and postoperatively at the widest area of the root cross-section. Both pre- and post-operative measures were circumferentially measured at the same exact point to ensure standardization as shown in **Figure (4)**.

Dentin thicknesses are put into the transportation equation by Gambill.[14]

For obtaining results for transportation:

$(M2 - M1) - (D2 - D1)$ were:

- M2: stands for preoperative dentin thickness, measured from the mesial wall of the root mesial wall of the un-instrumented canal wall.

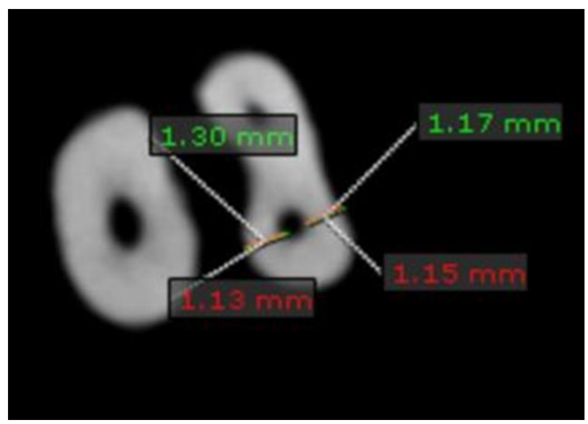

Figure (4): Measuring dentin thickness on superimposed axial view CBCT. Green lines representing pre-operative dentin thickness, and red lines representing post-operative dentin thickness.

- M1: stands for postoperative dentin thickness, measured from the mesial wall of the root to the mesial wall of the instrumented canal wall.

- D1: stands for preoperative dentin thickness, measured from distal wall of distal wall of the root to the un-instrumented wall of the canal
- D2: stands for postoperative dentin thickness; measured from the distal wall of the root to the instrumented distal wall of the canal.

The numerical value of the result of the formula determines whether transportation happened or not; zero indicates no transportation, whereas positive results mean mesial transportation, and negative results mean distal transportation.

RESULTS

Intergroup comparisons, mean and standard deviation values of transportation for different access cavity designs are presented in **Table (2)**.

Table (2): Intergroup comparisons, mean and standard deviation values of transportation for different access cavity designs.

Distance	Root curvature	Transportation (mean±SD)		p-value
		Traditional access cavity	Contracted access cavity	
5 mm	**10° -20°**	0.05±0.01	0.09±0.01	**<0.001***
	>21°	0.05±0.01	0.06±0.01	**0.030***

*; significant (p<0.05)

At 5 mm:

- **10°- 20°:**

Contracted access (0.09±0.01) had a significantly higher value than traditional access (0.05±0.01) (p<0.001).

- **>21°:**

Contracted access (0.06±0.01) had a significantly higher value than traditional access (0.05±0.01) (p=0.030).

DISCUSSION

Root canal treatment (RCT) is a fundamental procedure in modern endodontics, aiming to retrieve compromised teeth by eliminating infection and restoring functionality. While RCT has significant popularity, treating molars with curved root canals remains a dreadful challenge due to their complicated anatomy. The complexity of curved root canals demands meticulous attention to detail during every procedure step, particularly in access cavity preparation.

Access cavity preparation is a critical phase that provides direct access to the canal orifice. Traditionally, this step involved creating a funnel-shaped cavity by removing a healthy tooth structure to achieve straight-line access. This approach enhances visibility and allows for efficient cleaning, shaping, and obturation. However, the compromise for improved access has been the significant weakening of tooth structure. Potentially, this leads to structural failures like fractures, especially in molars subjected to substantial occlusal forces, and consequently can result in the loss of the tooth.

In response to the challenges introduced by traditional access cavity preparation, a more conservative approach called contracted access cavity preparation has emerged. The concept behind this design is to preserve more of the natural tooth structure while ensuring adequate access to the root canal system. By minimizing dentin removal, the risk of tooth fractures is reduced, and the overall structural integrity of the tooth is better maintained.

Despite the potential advantages of contracted access cavity preparation, concerns have arisen regarding its impact on procedural errors, especially in curved root canals. Procedural errors may include a range of challenges like ledges, transportation, instrument separation, difficulty finding canals, and cleaning and obturating efficiently. Not to mention, these errors could be more serious with curved root canals. The reduced visibility associated with contracted access cavities might potentially exacerbate these errors.

This in-vitro study aims to investigate the effect of contracted access cavity design on the occurrence of procedural errors in molars with curved root canals. This will happen by comparing the outcomes of contracted access cavity design to those of traditional access cavity design, with different canal angulations. The main outcomes to be compared are transportation, centring ratio, and instrument separation.

The null hypothesis suggests no difference in transportation, centring ratio, and instrument separation when comparing contracted access cavities with traditional access cavity designs in curved roots. In the present study, extracted human molars are used, which offers a significant advantage in replicating clinical scenarios.[15]

The mesio-buccal root canal was chosen to work on because mesial root canals generally exhibit curved shapes with diverse curvatures in both the mesio-distal and bucco-lingual planes. These degrees might not be easily apparent through periapical radiographs, increasing the risk of issues like canal transportation, creating ledges, and causing perforations. Therefore, this makes MB root more complex in anatomy and thus more susceptible to errors.[16,17]

To facilitate canal preparation, a glide path was done using a size 15 K-File. This aims to eliminate intracanal irregularities and enables easy canal preparation.[18] This study used single-file rotary instruments (XP-shaper) because previous records show that enlarging the apical preparation can result in excessive dentin removal and a higher likelihood of causing canal transportation.[19] Also, XP shaper is stated to preserve original canal anatomy therefore, it is less likely to cause transportation.[20]

CBCT imaging was taken pre- and postoperatively and used to measure dentin thickness before and after instrumentation, as it has been proven to be a precise method for measuring dentin thickness.[21] This was in line with the research methodology done by Bahaa M et al.[22] The superimposition feature is a standardized means of comparing radiographs, which is essential when linking pre and post-operative CBCT imaging.[23]

Even though Micro-CT remains the established standard for such investigations, as it allows for image acquisition with voxel sizes ranging from 5 to 50 mm, the finer voxel dimensions enable the quantification of dentin that has been extracted but remain a costly means of evaluation and very difficult to find available.[24]

Measurements of dentin were taken before and after instrumentation at a 5mm level from the apex in correspondence to the following areas, respectively: apical, middle third, and cervical third. This agrees with the following research.[25-27]

The current results for transportation showed that at 5mm level with angulations 10˚-20˚ and >21˚ Contracted access had a significantly higher value than traditional access. This was in line with the results of Rover et al.[13] and can be referred to by the coronal obstructions that put so much stress on the canal walls by the file. While Wang D et al. did not find any statistical difference between traditional and contracted access cavity design on transportation. This could be explained due to the usage of CBCT for analysis of the current results, instead of micro-CT used in the research done by Wang et al.[27]

At 5mm from the apex with root curvature of 10˚-20˚, the traditional access cavity showed statistically higher values than the contracted access cavity. This, again, could be explained due to the small sample size of the group.

CONCLUSION

According to the limitations of the current study, the following can be concluded:

1. Contracted access cavities significantly affect the occurrence of errors happening inside the root canal.
2. Contracted access cavity negatively affects transportation.

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CONFLICTS OF INTEREST: The authors declare no conflict of interest.

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