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The Effect of Access Cavity Design on Fracture Strength of Endodontically Treated Maxillary Premolars: Traditional Versus Conservative Preparation. An In Vitro Study

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Abstract

Background: The purpose of this study was to evaluate and compare the fracture strength of maxillary premolars prepared through the traditional endodontic cavity (TEC) and the conservative endodontic cavity (CEC) approaches.

Methods: Twenty-two extracted permanent human maxillary premolars were chosen and allocated into two groups (n = 11). In group A (TEC), teeth were prepared by removing the pulp chamber roof and employing a straight-line approach. In group B (CEC), teeth were prepared to maintain the soffit and peri cervical dentin. Following access preparation, all teeth received standard endodontic treatment and were restored with direct composite resin restorations. The specimens were then mounted in self-curing acrylic resin and underwent a fracture resistance test utilizing a universal testing machine, with fracture loads recorded in Newtons. Data were evaluated using the Shapiro-Wilk and independent t-test, with a significance threshold set at $p \leq 0.05$.

Results: Teeth prepared using the CEC approach exhibited significantly higher fracture strength compared to those prepared using the TEC approach ($p < 0.001$).

Conclusion: The CEC approach significantly improves the fracture strength of maxillary premolars compared to the TEC approach.

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1 Introduction

Endodontic treatment is a comprehensive, multi-step process designed to maintain the functionality of a tooth by preventing or addressing damage to the pulp and periapical tissues [1,2]. The primary goal is obtained by eliminating pathogens using various chemo mechanical techniques, followed by root canal filling to prevent potential reinfection.

Teeth with vital pulp generally show higher fracture resistance, particularly when exposed to occlusal forces, compared to those with root canal therapy [3]. Research indicates that 59.6% of teeth treated with root canal procedures are extracted due to fractures undermining the tooth's structural integrity. Conversely, only 8.6% of extractions are linked to failures in the endodontic treatment itself [4].

One crucial factor influencing fracture resistance and durability of the teeth treated with endodontic therapy is the amount of remaining dentin. The risk of fracture of these teeth is higher in comparison to those that remain intact, largely because the procedure involves removing a portion of the internal tooth structure [5].

The traditional endodontic access cavity (TEC) was developed based mainly on the principle of "straight line access", requiring the removal of sufficient tooth material to establish a direct path to apical foramen or initial canal curvature. This technique aids in more efficient cleaning and shaping, improves access for irrigants and medicaments, and minimizes the likelihood of file deformation or separation resulting from cyclic fatigue [6,7].

Recently, conservative endodontic cavities have emerged as an alternative design to preserve more tooth structure [5]. These cavity designs are thought to enhance the mechanical stability and longevity of treated teeth [5,8]. The innovative conservative endodontic cavity (CEC) approach deviates from the conventional practice of removing coronal walls and fully exposing the pulp horns to establish a direct path to the canals [5].

This study aimed to evaluate and compare the fracture strength of maxillary premolars following preparation using the traditional endodontic cavity (TEC) design versus the conservative endodontic cavity (CEC) design.

2 Materials and Methods

2.1 Specimen Selection and Preparation:

Ethical approval for this study (ETH-19) was granted by the Research Ethical Committee of the Faculty of Dentistry at MSA University.

Twenty-two intact human maxillary premolars, recently extracted and with fully developed apices, were chosen for this study. Teeth were excluded if they showed signs of caries, previous restorations, visible fractures or cracks, abnormal crown morphology, or had undergone previous root canal treatment.

To prepare the teeth, debris and any calculus were removed with ultrasonic scaling, followed by polishing. The teeth were kept in labeled containers with 10% formalin until further use. Crown height was recorded by measuring from occlusal surface to cementoenamel junction, including all aspects of each tooth. Additionally, a digital caliper was used to measure each tooth to ensure consistent dimensions across all specimens. The specimens were then categorized into 2 equal groups based on the endodontic access cavity design:

- Group (A): Traditional Endodontic Access Cavity (TEC)
- Group (B): Conservative Endodontic Access Cavity (CEC)

After grouping, radiographs were taken in both buccolingual and mesiodistal directions for each specimen.

2.2 Access Cavity Preparation:

2.2.1 Group (A): Traditional Endodontic Access Cavity (TEC)

The teeth assigned to this group were prepared in accordance with the established concepts of traditional endodontic access cavity preparation [6]. A round bur attached to a high-speed handpiece with water coolant was utilized to create the initial access, facilitating entry into the pulp space and exposing the canal orifices. An endo-access bur was employed to further enlarge the access until it made contact with the pulp chamber walls, establishing an unobstructed straight-line access. Radiographs were then obtained to verify the direct access. **(Fig. 1A and 1B).**

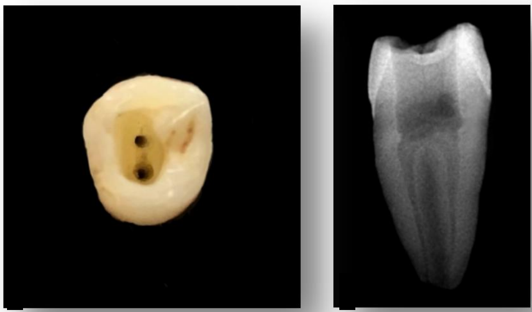

Figure 1A and 1B. Show the traditional access cavity preparation and the corresponding radiograph.

2.2.2 Group (B): Conservative Endodontic Access Cavity (CEC)

For the CEC group, the initial access into the premolars was created 1 mm buccally from the center of the occlusal surface using a round bur attached to a high-speed handpiece with water cooling. The bur was maintained in alignment with the long axis of the tooth throughout the preparation procedure. After gaining entry into the pulp chamber, an endodontic probe was employed to identify the canals through tactile feedback. The cavities were then further extended in an apical direction while maintaining a portion of the pulp chamber's roof and lingual shelf. The end of the probe was used to confirm the presence of a 'soffit,' which refers to the roof that covers the coronal part of the pulp chamber. A radiograph of each tooth was obtained after conservative access cavity preparation. **(Fig. 2A and 2B).**

Figure 2A and 2B. Show the conservative access cavity preparation and the corresponding radiograph.

2.3 Root Canal Treatment:

The canals were initially explored with K-type files (#10) to reach the apical foramen. Mechanical preparation was then carried out to the working length using the ProTaper Gold rotary system (Dentsply), progressing to an apical size of #30 with a 0.09 variable taper. During instrumentation, sodium hypochlorite (5.25 %) was intermittently delivered as a root canal irrigating solution between file changes using a 30-gauge needle. Following the canal preparation, a final irrigation was performed with an EDTA solution at a concentration of 17%. The root canals were subsequently dried using sterile absorbent paper points and obturated using the single-cone gutta-percha technique of root canal obturation, with a cone matched to the final apical preparation size, in conjunction with an epoxy resin-based sealer (AH Plus, Dentsply). The gutta-percha was sectioned at the orifice of each canal, and the access cavity was thoroughly cleaned. Acid etching was performed with 37% phosphoric acid for 30 seconds, then a 30-second rinse followed by gentle air drying. A light-curing adhesive (Adper, 3M bond) was applied, thinned with air, and cured for 30 seconds using a light-emitting diode. All 22 endodontic access cavities were restored using a composite resin material (Z250, 3M ESPE) applied with the incremental layering method, with each layer cured for a duration of 40 seconds.

2.4 Fracture Strength Test:

The specimens were mounted in cylindrical holders, with their roots placed into self-curing acrylic resin (Acrostone, England) up to 3 mm below the cementoenamel junction to mimic the level of the alveolar bone. Each specimen was carefully positioned to ensure that its long axis remained parallel to the walls of the holders. The specimens underwent testing with an Instron Universal Testing Machine, applying a load at a 30° angle relative to the tooth's long axis. A sustained compressive force was delivered at a rate of 0.5 mm/min utilizing a spherical crosshead featuring a 6-mm diameter tip until fracture was observed. The load at which the fracture occurred was documented and recorded in Newtons (N).

2.5 Statistical Analysis

All numerical data were expressed as mean values with 95% confidence intervals, along with standard deviations, and the minimum and maximum values. Shapiro-Wilk test was applied to assess whether the data followed a normal distribution. The data exhibited a parametric distribution, and the independent samples t-test was applied for analysis. A significance threshold of $p \leq 0.05$ was applied for all statistical tests. Statistical data analysis was conducted using R statistical computing software (v.4.1.3).

3 Results

A comparison of the results in Table 1, as well as Figures 3 and 4, indicates that the fracture resistance of endodontically treated maxillary premolars restored with composite resin restorations ranged from 302.54 N to 680.79 N. It can be observed that the resistance to fracture was lowest when using the traditional approach (TEC), with values ranging from 302.54 to 461.77 N. In contrast, the maximum force required to fracture the specimens was observed using the conservative approach (CEC), with forces ranging from 427.76 N to 680.79 N.

Table 1. Descriptive statistics of fracture strength (N) in both groups.

	Mean	95% CI		SD	Min	Max
		Lower	Upper			
TEC	346.13	327.60	364.67	31.37	302.54	461.77
CEC	574.24	523.75	624.74	85.44	427.76	680.79

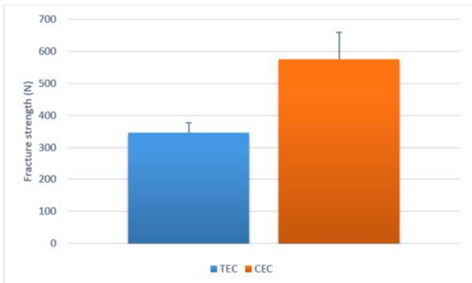

Figure 3. Bar chart showing mean and standard deviation (error bars) for fracture strength (N) of (TEC) and (CEC) groups.

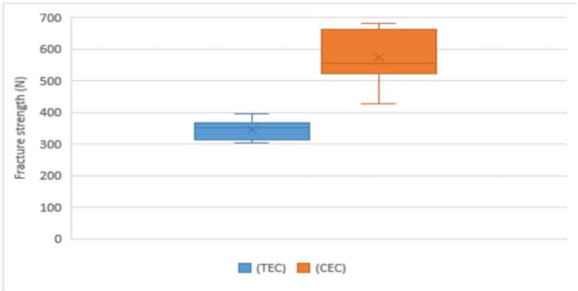

Figure 4. Box plot showing fracture strength (N) values of (TEC) and (CEC) groups.

Results showed that conservative group (CEC) exhibited a significantly greater fracture strength value compared to traditional group (TEC) (p<0.001). **(Table 2)**

Table 2. Intergroup comparisons, mean and standard deviation (SD) of fracture strength values (N).

Fracture strength (N) (mean±SD)		Mean difference (95%CI)	t-value	p-value
TEC	CEC			
346.13±31.37	574.24±85.44	228.11 (170.87:285.35)	8.31	<0.001*

*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

4 Discussion

Over time, the design of access cavities has evolved [9]. The traditional design prioritizes the full removal of tissue, requiring unroofing of the pulp chamber for optimal access. However, achieving this often results in the loss of a significant portion of the tooth structure [9]. To mitigate such an issue and improve the long-term outcomes for teeth undergoing endodontic treatment, more conservative access cavity designs have been proposed [10].

The findings of this study indicated that teeth prepared with CEC designs exhibited significantly greater fracture resistance compared to those prepared with TEC designs. Specifically, the conservative technique (CEC) showed a higher minimum and maximum fracture force (427.76 N and 680.79 N, respectively) than the traditional technique (TEC), where fracture forces ranged between 302.54 N and 461.77 N.

The notable disparity in values between both groups highlights the critical role of preserving a larger amount of healthy tooth structure in maintaining mechanical stability. These results suggest that a conservative approach to cavity preparation could enhance the longevity and the resistance to fracture in teeth undergoing endodontic treatment, as observed by Krishan et al. (2014) [11]. However, their study highlighted potential limitations regarding the effectiveness of canal preparation in distal canals of molars with conservative access cavities.

Unlike the present study, which found a clear advantage for CEC preparation in premolars, Moore et al. (2016) [12] did not identify any significant differences between both endodontic access cavity designs in maxillary molars. This contrast may be due to the anatomical and functional differences between molars and premolars, particularly in terms of structural vulnerability.

Gaikwad et al. (2016) [13] concluded that preserving the peri cervical dentin and soffit structurally reinforced molars compared to straight-line access designs. The present study supports this by demonstrating that the CEC approach, which emphasizes dentin preservation, significantly enhances fracture resistance in premolars as well. Similarly, Plotino et al. (2017) [14] and Marinescu et al. (2020) [15] observed the incidence of higher fracture loads in teeth prepared with conservative cavity designs, supporting the conclusion that minimally invasive techniques offer a biomechanical advantage across different tooth types.

Although Roperto et al. (2019) [16] and Xia et al. (2020) [17] reported no statistically significant differences between traditional and conservative endodontic cavity designs in their respective studies, the current research contradicts these findings, with CEC-prepared teeth showing superior fracture resistance in maxillary premolars. These contradictions might be attributed to the variations in methodology, which could influence fracture outcomes.

Additionally, research conducted by Chlup et al. (2017) [18] and Pereira et al. (2021) [19] reported no significant differences between the CEC and TEC groups in premolars. This suggests that while some studies may not show significant differences, the benefits of conservative access cavity designs in enhancing fracture resistance are still evident under specific conditions in certain tooth types. Santosh et al. (2021) [20] concluded that the mean fracture load value for the TEC group was significantly lower than that of the CEC group in the first and second mandibular molars. The key Findings of the present study also corroborate this conclusion.

Overall, this research contributes to the expanding body of literature endorsing the use of minimally invasive endodontic access cavity designs to enhance resistance to fractures in teeth that have undergone endodontic treatment. The findings suggest that while traditional techniques offer effective debridement and a straight-line path, they compromise structural integrity more significantly than conservative designs. Further clinical studies are recommended to explore the long-term outcomes of CEC preparation in various tooth types and patient populations.

5 Conclusion

Given the constraints of this study, the following conclusion can be made: teeth endodontically treated with the conservative endodontic access cavity design are significantly better in respect to resisting occlusal forces than those treated with the traditional endodontic access cavity design.

Authors' Contributions

Sherif Samy Seddik was the main investigator.

Maged Mohamed Negm was the main supervisor.

Ali Youssef Elgendy was the co-supervisor.

All authors have reviewed the manuscript and provided their approval.

Conflict of interest

The authors confirm there are no conflicting interests.

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