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CORRELATION BETWEEN FRACTURE RESISTANCE IN ENDODONTICALLY TREATED MOLAR TEETH AND DIFFERENT ACCESS CONFIGURATIONS (AN IN VITRO STUDY)

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ABSTRACT

Background: This in vitro study evaluated the influence of different access cavity configurations on the fracture resistance of endodontically treated mandibular molars.

Materials and Methods: Thirty-six extracted human mandibular molars were divided into three main groups (n=12 per group) based on the endodontic access cavity preparation (traditional, conservative, truss). Standardized endodontic treatment was performed on all teeth, followed by core build-up. Specimens were subjected to compressive testing using a universal testing machine to determine the fracture resistance of the molars within each experimental group. Means and standard deviations were calculated for each group, and data were analyzed using two-way ANOVA followed by Tukey post hoc test.

Results: Comparative analysis between conservative, truss and traditional endodontic access cavity designs revealed a potential trend towards increased fracture resistance for the conservative and truss access cavity designs, though this difference had no statistical significance ($p > 0.05$).

Conclusion: Minimal invasive access cavity preparations did not significantly enhance fracture resistance compared to traditional methods. There are other factors beyond endodontic access cavity configurations, such as restorative materials and overall tooth integrity, might exert a more substantial influence on fracture resistance. Further investigation is needed to optimize treatment outcomes and reduce fracture risk in endodontically treated teeth.

KEYWORDS: Fracture resistance, Traditional access cavity, conservative access cavity, Truss

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INTRODUCTION

Achieving optimal access cavity preparation is essential for successful endodontic treatment. Traditionally, this has involved extensive removal of tooth structure, including the complete removal of the pulp chamber roof, to ensure adequate access for instrumentation and obturation. While this approach has been a standard endodontic practice, it has been increasingly recognized that excessive tooth removal can compromise the structural integrity of the tooth, increasing its susceptibility to fracture [1,2].

Clark et al.[3] suggested a method to minimize peri-cervical dentin removal during endodontic access. Their approach involves preserving a portion of the pulp chamber ceiling (0.5 to 3 millimeters) encircling the entire pulp chamber. This technique is thought to reduce cuspal flexure, consequently, lowering the risk of tooth fracture.

Following this rationale, the concept of minimally invasive dentistry has affected the endodontic treatment, leading to the development of conservative access cavity preparation techniques. These approaches aimed to preserve critical tooth structure, such as the peri-cervical and peri-cingular dentin, while maintaining adequate access for treatment [3,4]. By minimizing tooth removal, it is hypothesized that fracture resistance can be enhanced[5,6].

The advent of surgical microscopy has significantly enhanced visual clarity and illumination during endodontic procedures, facilitating the preservation of dental tissues through minimally invasive access cavity preparation (4–6).

Different conservative access cavity preparation techniques have been proposed, including conservative and truss approaches. These methods aim to preserve tooth structure by minimizing cavity dimensions while maintaining adequate access for endodontic procedures. By reducing the extent of tooth removal, these techniques have been suggested to enhance the fracture resistance and potentially decrease the need for complex restorative interventions. [7]

Conservative access cavity design involves creating a small cavity on the occlusal surface of the tooth. Despite its reduced size, it provides adequate access to all the canal orifices. The truss design is characterized by a direct access from the occlusal surface to the mesial and distal canal orifices, while preserving the intervening dentin. This approach aims to maintain structural integrity while enabling access for endodontic procedures [8].

Therefore, this study aimed to evaluate the impact of both traditional and minimally invasive endodontic access cavity designs, including conservative and truss endodontic access cavities, on the fracture resistance of endodontically treated molars.

MATERIALS AND METHODS

A total of thirty-six intact, mature human molars were used among the experimental groups. Teeth were extracted from patients undergoing routine dental procedures at the Oral Surgery Department, Ain Shams University after the approval of the Ethical Committee of Faculty of dentistry, Ain Shams University. The inclusion criteria mandated fully developed, mature molars with intact crowns and roots, confirmed through radiographic examination to exclude anatomical anomalies or incomplete root formation. Teeth exhibiting carious lesions, root resorption, or pre-existing cracks were excluded.

A total of thirty-six extracted human molars were divided into three primary groups based on access cavity design. Figure (1)

- Group 1: Traditional endodontic access cavities (TEC) were prepared (n=12).
- Group 2: Conservative endodontic` access cavities (CEC) were prepared (n=12).
- Group 3: Truss endodontic access cavities (TREC) were prepared (n=12).

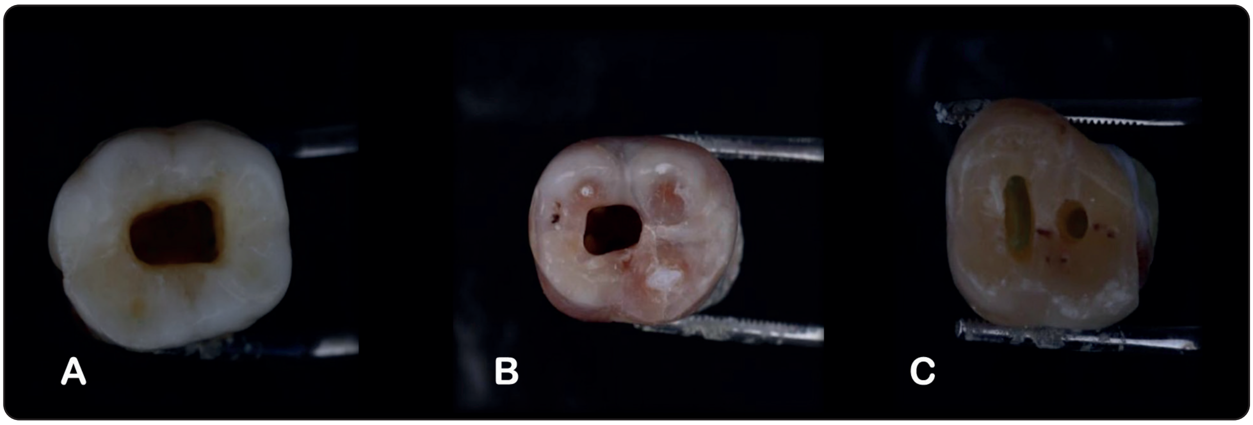

Fig. (1): Showing different access cavities A) A photograph showing TEC in a first mandibular molar B) A photograph showing CEC in a first mandibular molar C) A photograph showing TREC in a first mandibular molar

Access Cavity Design Preparations

Traditional Endodontic Access Cavity Preparation (TEC)

A standardized traditional endodontic access cavity preparation was performed on twelve extracted molars (n=12). To enhance canal accessibility, a trapezoidal access cavity outline was used in this study for molars exhibiting mesiobuccal, mesiolingual, and distal canals following the principles of TEC [(4)]. The mesio-buccal canal entrance is commonly situated beneath the mesio-buccal cusp tip, while the mesio-lingual canal is slightly buccal to the mesio-lingual cusp tip. Mesial canals, are generally equidistant from the mesio-distal midline of the tooth. The distal canal is situated just distal to the buccal developmental groove, the distal canal entrance tends to be oval-shaped. [(4)]

TEC was prepared using carbide round bur size 2 (FGSS, friction grip, short shank bur) to penetrate the central fossa of the pulp chamber roof and a round end tapered diamond bur, to completely remove the pulp chamber roof, mounted on a high-speed handpiece with water coolant. This technique involved complete removal of the pulp chamber roof, exposing the pulp horns, and establishing a straight-line access to the root canals. Meticulous examination using a dental probe ensured the elimination of any residual dentin lips or edges. Figure (2)

Conservative Endodontic Access Cavity Preparation (CEC)

A conservative access cavity preparation technique was implemented on twelve extracted molars (n=12). CEC was prepared using a carbide round bur size 2 (FGSS, friction grip, short shank bur) on a high-speed handpiece with water coolant under the guidance of a dental operating microscope (Labomed Dental Microscope Prima DNT).

CEC was performed by accessing the mesial quarter of the central fossa and then extending the cavity apically and distally. While maintaining a portion of the chamber roof, the removal of mesial-distal, buccal-lingual, and circumferential pericervical dentin was minimized. This approach ensured the preservation of a portion of the pulp chamber roof and peri-cervical dentin while facilitating canal orifice identification as described by Clark and Khademi [(3)]. Figure (2)

Truss Endodontic Access Cavity Preparation (TREC)

A truss endodontic access cavity preparation technique (TREC) was implemented on twelve extracted molars (n=12). In the truss group, separate access cavities were prepared for each root without removing the central portion of the pulp chamber roof. TREC was prepared using carbide round bur size 1 (FGSS, friction grip, short shank bur) on a

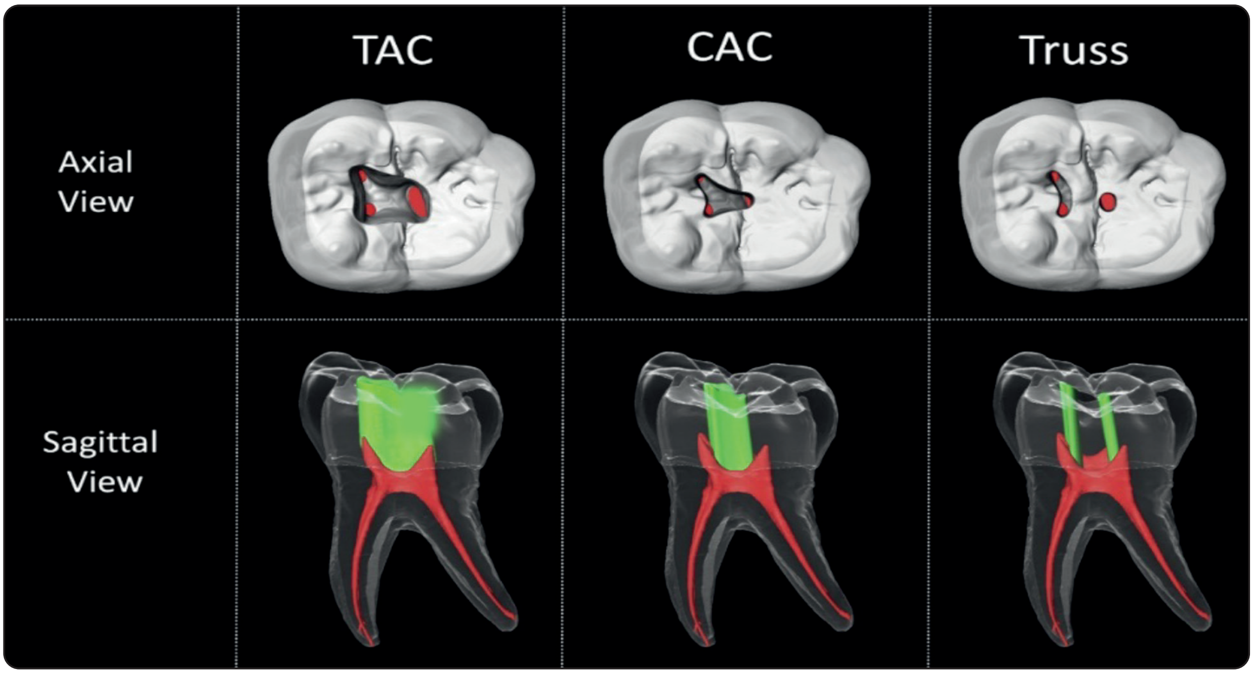

Fig. (2) A photograph showing the axial and sagittal views of traditional and conservative access cavities

high-speed handpiece with water coolant under the guidance of a dental operating microscope (Labomed Dental Microscope Prima DNT)

Raqdiographic measurements were taken using a probe to determine the distance between the marginal ridges or buccal and lingual cusps of the molars and the perpendicular projections of their canal orifices. This information guided the placement of the bur. A single buccolingial access was created for the mesial canals, followed by a circular access to reach the distal canal orifice. The mesial canal access was oval-shaped, formed by joining two access slots perpendicular to the occlusal surface and enlarging it to a minimum diameter of 1.2 mm. The distal canal access was circular, starting with a single slot perpendicular to the occlusal surface and enlarging it to a diameter of 1.2 mm. Diameters were measured using a digital caliper. The two accesses were separated by a dentin bridge. The mesial and distal walls of the teeth were prepared using tapered diamond burs with rounded angles. The access path might be further refined with ultrasonic instruments. Figure (2)

Endodontic Treatment

All teeth underwent a standardized endodontic treatment protocol. This included access cavity preparation according to the assigned, followed by root canal instrumentation and obturation.

Root canal preparation began with initial negotiation to a working length established 0.5 mm short of the anatomic apex utilizing K-files of sizes 10 and 15 (MANI, INC, Tochigi, Japan). Rotary instrumentation was subsequently performed using E-flex Blue rotary files (Changzhou, Sufary Medical Technology Co., Ltd., China) with a sequential use of 17/08, 20/04, 25/04, and 30/04 tapers in the mesiobuccal and mesiolingual canals. The distal canal was instrumented to a final apical size of 35/04. Copious irrigation with 2 mL of 5.25% sodium hypochlorite was administered between instrumentation steps. Final irrigation protocols included the sequential use of 2 mL of 5.25% sodium hypochlorite, saline, and 17% ethylenediaminetetraacetic acid (EDTA).

Passive ultrasonic irrigation with a with a side vented irrigation needle with size 30 gauge at a 1 mm working length activation distance was employed for irrigant agitation. Files were lubricated with Metapaste (Meta Biomed. Korea).

Following thorough drying with absorbent paper points, root canals were obturated with master cone size 35/04 (Meta,Gyeonggi, South Korea) and resin sealer (Ad seal, Gyeonggi, South Korea) using warm vertical compaction technique. A single heated plugger, adapted to the apical canal dimensions, was inserted into the canal until reaching the predetermined working length. Vertical compaction was applied for 10 seconds, followed by a controlled heat activation and deactivation cycle to facilitate plugger removal. The coronal third of the canal was subsequently backfilled. Thermoplasticized gutta-percha was incrementally injected and condensed into the coronal portion of the canal using an Obtura gun. Each 2-3mm increment was condensed to minimize shrinkage and ensure adequate apical resistance.

Placement of Restoration

Following obturation, the canal dentin surfaces were etched with 37% phosphoric acid (Meta Biomed, Korea) for 15 seconds, thoroughly rinsed with distilled water, and dried. An adhesive system (All-bond Universal BISCO, USA) was applied using a microbrush, excess resin removed with sterile paper points, and subsequently light-cured for 20 seconds at an intensity of 500 mW/cm^2 using a light-emitting diode curing unit (3M ESPE Elipsr Deep cure LED-L curing light, USA). Following adhesive polymerization, the root canals were backfilled with a dual-cure, fiber-reinforced composite resin core material (Build-it® FR™ Core Material, Pentron Clinical Technologies) delivered via an auto-mix cartridge and syringe. The material was then light-cured coronally for 20 seconds to initiate setting.

Fracture Testing

Each tooth was marked 2 mm below the cementoenamel junction with a periodontal probe. The roots were then coated with a 0.3 mm thick layer of light body silicon impression material (elite HD+, Zhermack dental, Italy) up to the mark to simulate the periodontal space. The specimens were then mounted in self-curing acrylic resin in a mold with the occlusal surface facing upward. To mimic the alveolar bone, all specimens were secured within cylindrical polyvinyl chloride (PVC) blocks (diameter and height: 25 mm) using a self-curing resin. The teeth were embedded such that the root apex was positioned 3 mm below the cementoenamel junction. The resin was mixed as per the manufacturer's guidelines and poured into the PVC molds. Each tooth was centrally aligned within its respective cylinder, maintaining a parallel orientation with the walls of the cylinder. The PVC models were then adjusted to accurately position the testing apparatus' loading arm directly above the tested teeth. Force was applied vertically along the long axis of the tooth, directed at the occlusal slopes of both buccal and lingual cusps. Figure (3)

To assess fracture resistance, the prepared teeth underwent compressive testing using a universal testing machine (Instron, MA, USA). Each tooth was positioned and subjected to a compressive force applied at a thirty-degree angle to its longitudinal axis. A stainless-steel loading fixture tip was centered over the occlusal surface. The force was directed at a steady rate of one millimeter per minute until the tooth fractured. The force required to induce fracture in each specimen was recorded in newtons. (N)

Statistical Analysis

Statistical power was determined using G*Power software for Windows. The significance level was set at P=0.05. To assess the influence of different access cavity designs on fracture resistance, a two-way analysis of variance (ANOVA) was conducted at a significance level of $P \leq 0.05$.

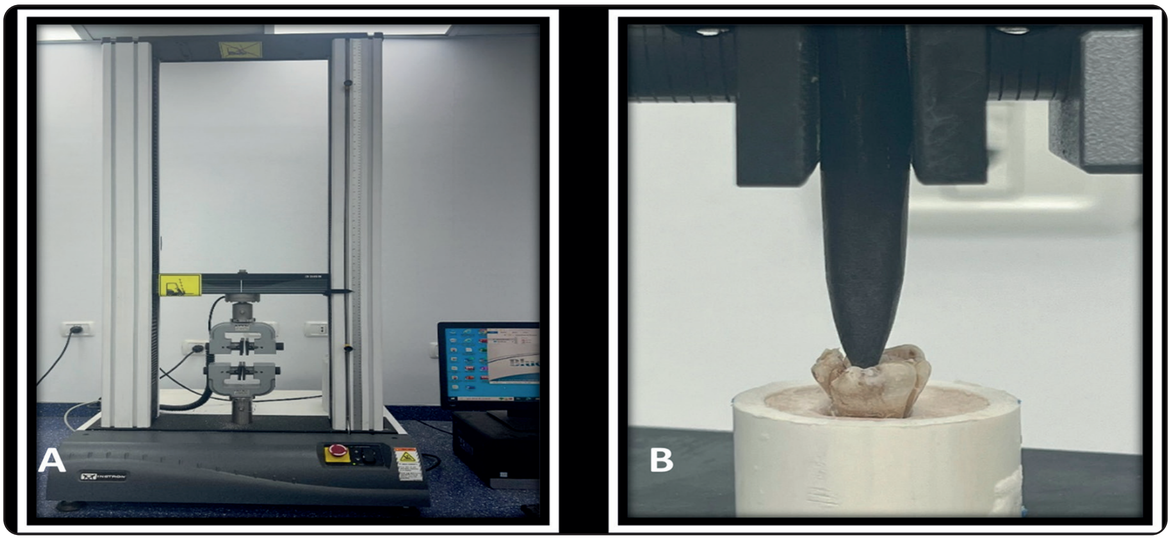

Fig. (3) (A) Universal testing machine used for fracture resistance evaluation. (B) Compressive load application to the occlusal surface of endodontically treated mandibular molars during testing.

RESULTS

The results of intergroup comparisons presented in Table (1) showed no significant difference between fracture resistance values measured with different access cavity designs (p=0.099). The highest values were measured in the conservative access group (2282.71±185.21) (N), followed by ultra-conservative (2064.64±309.92) (N), while the lowest values were found in the traditional access group (1989.01±154.42) (N). Mean and standard deviation values for fracture resistance are presented in Figure (4).

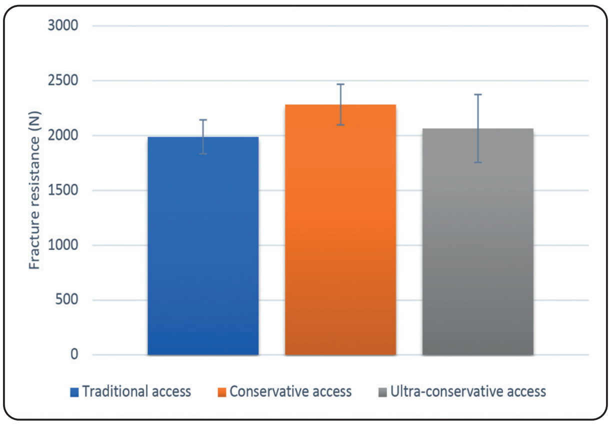

Fig. (4) Bar chart showing mean and standard deviation values (error bars) of fracture resistance (N).

TABLE (1) Intergroup comparison.

Fracture resistance (N) (Mean±SD)			*f-value*	*p-value*
Traditional access	***Conservative access***	***Ultra-conservative access***		
1989.01±154.42^{A}	2282.71±185.21^{A}	2064.64±309.9^{2}A	**2.71**	**0.099**

Values with **different superscripts** are significantly different.

DISCUSSION

Endodontically treated teeth (ETT) exhibit a compromised structural integrity due to the cumulative effects of pre-existing pathology, restorative interventions, and the necessary removal of dental tissue during endodontic access cavity preparation. The fracture susceptibility of ETT is a complex interplay of multiple factors, as evidenced by previous research demonstrating a strong correlation between coronal dentin loss and long-term tooth survival. [1,2] Consequently, preserving tooth structure during access cavity preparation and instrumentation has emerged as a critical principle in contemporary endodontic practice. Subsequently, minimally invasive access cavity designs, including conservative and ultraconservative truss approaches, have been introduced. To maximize tooth structural integrity, various studies have suggested the need for the preservation of the pulp chamber roof and cervical dentin [3,9]. Previous research has proposed that conservative access cavity preparation with less dentin removal may reduce the risk of fracture in endodontically treated teeth compared to the traditional approach [10–12].

This in vitro experimental study aimed to investigate the influence of minimal invasive access cavity preparations, in comparison to the traditional access cavity on the fracture resistance of endodontically treated mandibular molars. This controlled laboratory setting provided an optimal environment for isolating variables and ensuring consistent experimental conditions, which would be impractical and ethically challenging to replicate in a clinical setting.[13]

It is essential to consider that in vitro fracture testing methodologies may not completely simulate the complex and dynamic loading conditions experienced by teeth in the oral cavity. [14] While fracture in clinical settings often arises from fatigue-induced failure over time, static loading conditions are commonly employed in laboratory studies. Furthermore, axial cyclic loading tests may not accurately capture the multifaceted strain patterns generated during the masticatory process.[15,16]

Mandibular molars were selected as the study teeth due to their documented predisposition to vertical root fracture, a common complication following endodontic treatment in posterior teeth[17]. Their wider occlusal surfaces are subjected to greater occlusal forces, increasing the risk of fracture

Prior to fracture resistance testing, all teeth underwent standard endodontic treatment procedures, including root canal preparation and obturation. To simulate clinical conditions, composite resin core material was placed within the endodontic access cavities [16]. The restorative phase is integral to the overall strength and longevity of endodontically treated teeth. Previous research has indicated that appropriate restorations can enhance fracture resistance by up to 72% compared to intact teeth [18].

To minimize the influence of inter-operator variability on study outcomes, a single, experienced clinician performed all specimen preparation procedures. This standardization ensured consistency in experimental methodology and enhanced the reliability of the results.[19]

Regarding the effect of access cavity configurations on fracture resistance, the results of the present study revealed that the conservative and truss endodontic access cavities had higher fracture resistance compared to the traditional access cavity group. This may be attributed to the fact that conservative and Truss access cavities remove less tooth structure than traditional access cavities, which may help to maintain the structural integrity of the teeth. Additionally, conservative and truss access cavities preserve a portion of the pulp chamber roof, peri-cervical denin and marginal ridges, which can help to distribute occlusal forces more evenly and reduce the risk of fracture. [3,9] Besides, conservative access cavities demonstrate superior fracture resistance compared to truss group. This enhancement is attributed to several factors: wider access openings facilitating optimal cleaning and instrumentation, well-formed ferrules providing a robust foundation and higher surface area for better adhesion to the restoration. However, there was no statistically significant difference in fracture resistance between the three tested access cavity preparations (P<0.5).

These results aligned with several studies that reported comparable fracture strength between teeth prepared with TEC, CEC and TREC [7,13,20–22]. However, a contrasting body of literature suggested that reducing access cavity size through conservative and truss access preparation could significantly enhance the fracture resistance by preserving residual dentin [11,19,23]. These discrepancies in study outcomes might be attributed to variations in methodological approaches, including tooth type, instrumentation and obturation techniques, restorative materials, and fracture testing protocols [7,11,12,16,17,19,20,23].

Beyond affecting the fracture resistance, the dimensions and configuration of the endodontic access cavity significantly impact the clinical efficacy of root canal treatment. While minimal invasive access cavity preparations, including CEC and TREC, have been advocated for preserving dental hard tissue, their potential limitations in terms of canal accessibility and biomechanical preparation have been reported in the literature [19,25,26]. These challenges may hinder the thorough removal of pulp tissue and debris, compromising the quality of root canal disinfection and obturation, ultimately affecting treatment outcomes. [20,26]. Subsequently, based on the previous research has indicating that minimally invasive access cavity designs may potentially compromise the effectiveness of pulp chamber debridement. To mitigate this risk, passive ultrasonic irrigation was employed in the present study to enhance the cleaning and disinfection of the root canal system. [24]

Within the limitations of this in-vitro investigation, the employment of CEC and TREC did not result in a statistically significant enhancement of fracture resistance compared to TEC. Hence, further clinical investigations are needed to evaluate the long-term impact of various minimally invasive access cavity designs on the fracture resistance of endodontically treated teeth.

CONCLUSION

In conclusion, the present study showed no statistically significant difference in fracture resistance resulted by the minimal invasive endodontic access cavity preparations compared to the traditional approach. These results contradict the assumption that the extensive tooth structure removal during access cavity formation is the primary factor influencing fracture risk in endodontically treated teeth. While the preservation of tooth structure remains a desirable objective, the results of this study suggested that other factors, such as restorative materials, occlusal loading conditions, and the overall structural integrity of the tooth, may exert a more pronounced influence on fracture resistance. Further research is needed to investigate the complex interplay of these variables and to identify the optimal treatment strategies for preserving the long-term function and esthetics of endodontically treated teeth.

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