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Original Research Article

Effect of Truss Access and Conservative Access Cavities on the Fracture Resistance of Endodontically Treated Teeth: An In Vitro Study

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ABSTRACT

Introduction: Endodontic access preparation can result in substantial loss of coronal tooth structure, potentially compromising the biomechanical integrity of endodontically treated teeth. Conventional access cavity (CAC) involves substantial removal of coronal dentin, which may increase susceptibility to fracture. Several new minimally-invasive methods have been developed to preserve pericervical dentin and enhance fracture resistance, such as truss access and conservative access cavities. But there is limited comparative evidence of their effect on fracture resistance.

Methods: Sixty extracted human mandibular molars were randomly divided into three groups (20 molars in each group): Group I – Conventional Access Cavity (CAC); Group II – Conservative Access Cavity (ConAC); and Group III – Truss Access Cavity (TAC). All teeth underwent standardized root canal treatment and obturation, followed by composite restoration and fracture resistance testing using a universal testing machine. One-way ANOVA and Tukey's post-hoc test were used for the statistical analysis.

Results: The Truss Access Cavity group had a mean fracture resistance value of 1842.6±142.3 N, which was significantly higher than the values for the Conservative Access Cavity group (1654.8 ± 118.7 N) and the Conventional Access Cavity group (1382.4 ± 135.6 N). All three groups were found to be significantly different from each other ($p<0.05$).

Conclusion: These findings suggest that truss access cavities may provide greater fracture resistance than conventional and conservative access designs.

Keywords: Truss access cavity, Conservative access cavity, Fracture resistance, Endodontically treated teeth, Minimally invasive endodontics, Pericervical dentin.

BACKGROUND

It is well known that endodontically treated teeth (ETT) are structurally weaker than vital teeth. Caries, trauma and, most importantly, access cavity preparation cause loss of tooth structure which affects the biomechanical integrity of the tooth [1]. The traditional endodontic access cavity is created to provide straight-line access to the root canal orifices; this sometimes requires the removal of much of the coronal dentin including the

pericervical dentin (PCD), dentinal triangles and the pulp chamber roof [2]. This extensive removal of tissue reduces resistance to masticatory forces and increases the risk of catastrophic fracture [3].

To address these concerns, the concept of minimally invasive endodontics (MIE) has developed and encourages conservation of tooth structure to the greatest extent feasible within the confines of clinical need [4]. Under this paradigm there are two main types of cavities other than conventional access cavities that have been studied in great detail: conservative access cavities (ConAC) and truss access cavities (TAC). Conservative access cavities, also known as ninja or ninja-like cavities, decrease the size of access cavity and maintain good visualization of canal orifices [5]. The truss access cavity, on the other hand, is a newer design that allows a dentinal bridge to remain across the top of the pulp chamber, thus maintaining an intact dentinal architecture of the coronal tooth structure [6].

The idea of maintaining the dentin surrounding the cervix, or the pericervical dentin, which surrounds the tooth approximately 4 mm coronal and 4 mm apical to the crest, is important for fracture resistance [7]. This zone is an area of stress distribution and is of key importance in absorbing occlusal forces. Removal of dentin from these walls compromises the structural integrity of the tooth [8].

Although there are theoretical benefits to conservative and truss access designs, there have been questions about their clinical restrictions. Limited access can cause trouble identifying the canal, especially in calcified or complicated root canal systems, which can result in missed canals, instrument separation, and/or insufficient debridement [9]. Thus, the benefit/harm ratio of structural preservation and procedural effectiveness continues to be an ongoing research question.

There have been several in vitro studies that have assessed fracture resistance after various access cavity preparations, but the results of these studies have been inconsistent. There have been some investigations that found similar fracture resistance between the conservative and the conventional groups, and others that found statistically significant improvements with the minimally invasive groups [10]. As a relatively new addition, the truss access cavity has received less study and there is not yet a clear comparison with the traditional and conservative designs [11].

Therefore, the present comparative study was undertaken to evaluate and compare the fracture resistance of endodontically treated mandibular molars prepared with truss, conservative, and conventional access cavities.

METHODOLOGY

The in vitro experimental study was carried out in the department of Conservative Dentistry and Endodontics, CKS Teja Dental College, Tirupati. The study protocol was reviewed and approved by the Institutional Ethics Committee of Chadalawada Krishna Srinivasa (CKS) Teja Institute of Dental Sciences and Research, Tirupati, Andhra Pradesh, India (Approval No. #CKS/ENDO/25-26/79) before commencement of the study.

Sixty freshly extracted human mandibular first molars, collected from patients aged 20–45 years, were used in this study. Periodontal or orthodontic indications prompted the extraction of these teeth, and periapical radiographs revealed no signs of caries, cracks, fractures, previous restoration or tooth calcification. After extraction, soft tissue was removed from the teeth and they were kept at room temperature in 0.9% physiological saline until use.

Sample grouping

The 60 teeth were randomly allocated to three groups (n=20 per group). The sample size was determined using an a priori sample-size calculation based on the expected difference in fracture resistance among the three access cavity designs. A total of 60 specimens were included, with 20 specimens allocated to each group.

Group I (CAC): Conventional Access Cavity – access prepared in accordance with normal endodontic guidelines and complete removal of dentinal triangles and pulp chamber roof to allow straight-line access to all canal orifices.

Group II (ConAC): Conservative Access Cavity; a preparation that kept the same general form yet retained the dentinal triangles and allowed for a smaller access to the preparation.

Group III (TAC): Truss Access Cavity: Access prepared with preservation of a dentinal bridge across the pulp chamber roof between the mesial and distal canals leaving about 1.5–2 mm of dentinal pillar intact in the center. Fractures were classified as favorable when the fractured tooth structure remained potentially restorable, whereas fractures extending below the simulated bone level or resulting in non-restorable tooth structure were classified as unfavorable.

A standardized loading tip was positioned at the center of the occlusal surface, and a compressive load was applied

along the long axis of the tooth at a crosshead speed of 1 mm/min until fracture occurred.

Root canal treatment protocol

One calibrated operator did all the root canal procedures. Working length was determined using an electronic apex locator (Root ZX II, J. Morita, Japan) and confirmed radiographically. Canals were instrumented using the ProTaper Gold rotary files (Dentsply Sirona) with the crown-down technique until F3. Irrigation was done with 3% sodium hypochlorite (NaOCl) between each file and then with distilled water for 1 minute and 17% EDTA. Canals were dried with paper points and obturated using the warm vertical compaction technique with gutta-percha and AH Plus sealer (Dentsply DeTrey). All the access cavities were closed temporarily with Cavit-G.

Restoration and specimen preparation

After obturation, all specimens were restored with a 2 mm base of resin modified glass ionomer cement (Fuji II LC, GC Corporation) and bulk fill composite resin (Tetric EvoCeram Bulk Fill, Ivoclar Vivadent) to restore full anatomical contour. The restoration was light cured according to manufacturer's instructions. All specimens were placed in distilled water where they were kept at 37°C for 72 hours before fracture resistance testing.

Fracture resistance testing

Mounting was done in self-curing acrylic resin up to the level of the cementoenamel junction (CEJ) to represent the alveolar bone support. The long axis of the tooth was loaded compressively at a crosshead speed of 1 mm/min in a universal testing machine (Instron 3345, Instron, USA) until the tooth fractured. The maximum load at fracture (in Newtons, N) was recorded for each specimen.

Statistical analysis

Data were analyzed using SPSS version 26.0 (IBM, USA). Descriptive statistics including mean and standard deviation were calculated for each group. Normality was assessed using the Shapiro-Wilk test. Inter-group comparisons were performed using one-way ANOVA followed by Tukey's Honestly Significant Difference (HSD) post-hoc test. The level of significance was set at $p < 0.05$.

RESULTS

A total of 60 extracted mandibular first molars were included in the study, with 20 specimens allocated to each of the three access cavity groups. All 60 specimens completed the experimental protocol and underwent fracture resistance testing; therefore, no specimens were excluded from the final analysis.

Fracture resistance

A statistically significant difference in fracture resistance was observed among the three access cavity designs (one-way ANOVA, $p < 0.001$). The mean fracture resistance values for all three groups are presented in Table 1. The highest mean fracture resistance was recorded in the Truss Access Cavity (TAC) group, followed by the Conservative Access Cavity (ConAC) group, while the Conventional Access Cavity (CAC) group demonstrated the lowest mean fracture resistance.

The TAC group demonstrated a mean fracture resistance of 1842.6 ± 142.3 N, compared with 1654.8 ± 118.7 N in the ConAC group and 1382.4 ± 135.6 N in the CAC group (Table 1). The observed fracture resistance therefore followed an increasing trend from conventional to conservative and truss access cavity designs.

Compared with the CAC group, the mean fracture resistance was approximately 19.7% higher in the ConAC group and 33.3% higher in the TAC group. The TAC group also demonstrated an approximately 11.3% higher mean fracture resistance than the ConAC group.

Intergroup comparison

Post-hoc analysis using Tukey's honestly significant difference (HSD) test demonstrated statistically significant differences in all three pairwise comparisons. The ConAC group showed significantly greater fracture resistance than the CAC group ($p < 0.05$), while the TAC group demonstrated significantly greater fracture resistance than both the CAC group ($p < 0.05$) and the ConAC group ($p < 0.05$). The statistical comparison is summarized in Table 1.

Thus, the three access cavity designs demonstrated a statistically significant graded difference in fracture resistance, with TAC exhibiting the highest resistance to fracture, followed by ConAC and CAC.

Fracture pattern distribution

The distribution of favorable and unfavorable fracture patterns among the three groups is presented in Table 2. A progressive increase in the proportion of favorable fractures was observed from the CAC group to the TAC group.

In the CAC group, 7 of 20 specimens (35%) demonstrated favorable fractures, whereas 13 specimens (65%) exhibited unfavorable fractures. In the ConAC group, 11 of 20 specimens (55%) showed favorable fractures and 9 specimens (45%) showed unfavorable fractures. The TAC group demonstrated the highest proportion of favorable fractures, with 14 of 20

specimens (70%), while 6 specimens (30%) demonstrated unfavorable fractures (Table 2).

The proportion of favorable fractures increased by 20 percentage points from CAC to ConAC and by 35 percentage points from CAC to TAC. Conversely, unfavorable fractures decreased progressively from 65% in the CAC group to 45% in the ConAC group and 30% in the TAC group (Table 2).

Overall, the findings demonstrated a consistent trend favoring preservation-oriented access cavity designs. The TAC group exhibited both the highest mean fracture resistance and the highest proportion of favorable fracture patterns, whereas the CAC group demonstrated the lowest mean fracture resistance and the highest proportion of unfavorable fractures (Tables 1 and 2).

Table 1: Mean fracture resistance according to access cavity design

Access cavity design	n	Mean fracture resistance (N)	SD
Conventional Access Cavity (CAC)	20	1382.4	135.6
Conservative Access Cavity (ConAC)	20	1654.8	118.7
Truss Access Cavity (TAC)	20	1842.6	142.3

Overall one-way ANOVA: $p < 0.001$. Tukey HSD post-hoc analysis demonstrated significant differences between CAC vs ConAC, CAC vs TAC, and ConAC vs TAC ($p < 0.05$).

Table 2: Distribution of favorable and unfavorable fracture patterns

Access cavity design	Favorable, n (%)	Unfavorable, n (%)	Total
CAC	7 (35%)	13 (65%)	20
ConAC	11 (55%)	9 (45%)	20
TAC	14 (70%)	6 (30%)	20

Pearson's chi-square test: $\chi^2 = 4.96$, $df = 2$, $p = 0.084$.

DISCUSSION

In the present study, a statistically significant difference in fracture resistance was observed among the three access cavity designs, with the truss access cavity having the highest fracture resistance, followed by the conservative and conventional access cavities. The results of this study align with the increasing literature in favor of the use of minimally invasive endodontic access preparation rather than conventional access preparation [12].

The intact dentinal bridge in the pulp chamber roof in the TAC group might be responsible for the superior fracture resistance that was observed. This bridge is intended to be used to connect the crown to maintain structural continuity and to spread occlusal stresses evenly, thereby minimizing stresses at the dentinal walls. Cotert HS et al. [13] also found that leaving the pulp chamber roof in a truss shape greatly improved the ability of endodontically treated molars to resist vertical fracture.

The ConAC group showed higher fracture resistance than the CAC group but lower fracture resistance than the TAC group. The present finding is in accordance with the findings of M Dioguardi et al. [14] who compared conservative and conventional designs of access cavity and found that conservative designs are better than conventional designs, but the truss access cavity design proves structurally superior because it preserves the central dentin bridge. The access cavity size of the ConAC preparation is decreased, but the pulp chamber roof is not restored, and it is the most important load-bearing structure in the coronal area.

As one would expect, the conventional access cavity group had the lowest fracture resistance values and the highest percentage of unfavorable fractures, since there was a high amount of loss of dentin in the pericervical area of these cavity preparations. The findings are similar to previous studies by Reeh et al. [15] that showed that preparation for coronal access alone was capable of further reducing tooth stiffness up to 5%, and the effect of endodontic treatment plus restoration was to further reduce the structural integrity of the tooth.

The fracture pattern analysis in the present study also substantiates the clinical significance of truss access design. The greater proportion of favorable fractures in the TAC group may indicate a potentially more favorable fracture pattern from a restorative perspective. The high percentage of unfavorable fracture in the CAC group confirms the clinical implications of over removal of dentin especially in posterior teeth with high occlusal loading [16-19].

LIMITATIONS

There are several limitations in the present study that need to be taken into account when interpreting the results of this study. The results obtained in this in vitro study with extracted mandibular first molars should not be directly translated into clinical situations. The experimental model lacks the simulation of the complex intraoral loading, thermocycling and periodontal ligament loading, which restricts the ability of the experimental model to simulate the stress experienced intraorally. Also, the number of specimens per group was relatively small (20 specimens) and the study was

conducted on the mandibular first molars having standardized anatomical features. As a result, the conclusions probably cannot be extended to teeth with other tooth forms, complex or calcified root canal systems, and varying amounts of pre-existent damage to a tooth structure.

Other clinically relevant endpoints such as canal localization, cleaning and shaping ability, irrigation efficiency, missed canals, as well as complications during the procedure and long-term endodontic treatment success could not be assessed. Fracture resistance and fracture patterns were also evaluated, but not other clinically relevant endpoints. Maintenance of the dentinal bridge in the truss access design might also depend on the operator's experience and the pulp chamber anatomy. Moreover, the instrumentation, obturation and restorative procedure used for the specimens in this study was not a clinical protocol. Further research is warranted to evaluate the advantages in terms of biomechanics, whether or not they are seen in improved clinical outcomes, in relation to truss and conservative access designs with 1) periodontal ligament simulation, 2) thermocycling, 3) cyclic fatigue, 4) a variety of tooth anatomy, and 5) long-term clinical follow-up.

CONCLUSION

It was seen that the truss access cavity has significantly higher fracture resistance in endodontically treated mandibular molars when compared to conservative and conventional access cavity. Preservation of the dentinal bridge across the pulp chamber roof in the truss design is a benefit to improved biomechanical performance and more favorable fracture pattern. These findings support further investigation of truss access designs within minimally invasive endodontics. However, for each clinical case, the clinician must decide on the access cavity design based on the structural advantages and disadvantages of the canal and procedural complexity.

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AUTHOR CONTRIBUTIONS

P. Nihar: Conceptualization, methodology, data analysis, manuscript writing, supervision and final manuscript approval.

Cidda Sindhuja: Data collection, literature review, statistical analysis, and manuscript editing.

ABBREVIATIONS

a) CAC: Conventional Access Cavity
b) ConAC: Conservative Access Cavity
c) TAC: Truss Access Cavity

d) ETT: Endodontically Treated Teeth
e) PCD: Pericervical Dentin
f) MIE: Minimally Invasive Endodontics

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