



Fracture Resistance of Teeth with Truss Endodontic Access: An In Vitro Study and Literature Review

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Abstract

Objective This article evaluates the fracture resistance of teeth with different endodontic access cavities and conducts literature review on the effects of truss endodontic cavity.

Material and Methods Eighty human mandibular first molars were assigned randomly to four groups ($n = 20$); group 1: truss access cavity (TrussAC); group 2: conservative access cavity (ConsAC); group 3: traditional access cavity (TradAC); and group 4: served as control (no access). Accesses were prepared in groups 1 to 3, respectively. Endodontic treatment was performed on all accessed teeth and composite restoration placed. Teeth in all groups were loaded until fracture using a mechanical testing machine. The maximum load at fracture and patterns of fracture were recorded. Additionally, a literature search was performed on studies related to TrussAC and its importance.

Statistical Analysis Fracture strengths were compared using one-way analysis of variance complemented by Bonferroni test. Fracture patterns were analyzed using chi-square test.

Results TradAC showed significantly lower mean load at fracture than TrussAC, ConsAC, and intact teeth. Fracture resistance of teeth with TrussAC and ConsAC was not significantly different. All three test groups showed significantly more frequent unrestorable fractures. The literature review revealed that TrussAC did not improve the fracture strength significantly; however, pulp chamber debridement was significantly impaired.

Conclusion TrussAC improved the fracture strength of endodontically treated teeth, but not significantly as compared to ConsAC. Restorable fractures were more in intact teeth compared with all prepared ones.

Keywords

- ▶ conservative access cavity
- ▶ dental pulp
- ▶ endodontics
- ▶ endodontic access cavity
- ▶ traditional access cavity

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Introduction

Endodontic treatment is the standard care for a nonvital or endodontically involved tooth. However, endodontically treated teeth are weakened and generally are more prone to fracture.^{1,2} Loss of tooth structure, either due to caries or endodontic procedures, including the loss due to endodontic access cavity preparation is considered a major risk factor for fractures.³ Minimally invasive treatments are trending in modern dentistry. Thus, in endodontics, the concept of contracted access cavity was born because a tooth's susceptibility to fracture was found to be proportional to the amount of tooth structure removed.⁴

Traditional access cavity (TradAC) designs for all types of teeth have been the same since decades with only slight alterations. TradAC involves removal of tooth structure to allow access to the canals, facilitating complete cleaning, shaping, and obturation, while preventing procedural complications. However, excessive tooth structure is removed in a TradAC. Moreover, this affects the tooth's strength to resist fracture when subjected to loading in function. Thus, with a reduced and properly designed endodontic access cavity, the prognosis of a tooth that undergoes endodontic treatment can be improved.^{5,6}

Meanwhile, in a minimally invasive procedure called conservative access cavity (ConsAC), tooth structure including the peri-cervical dentine can be preserved.⁴ There are no particular rules to prepare a ConsAC. The main aim is to conserve maximum tooth structure while locating all the canal orifices.

Truss access cavity (TrussAC) on the other hand has been recently introduced to further preserve the tooth structure.⁷ Cone beam computed tomography information of the tooth together with magnification is used to prepare strategically located truss access.⁸ These accesses are placed directly above the respective root canals, and through these holes, cleaning, shaping, and obturation is performed. Hence, complete root canal treatment (RCT) is performed either through existing restorative cavities or by creating small entries leaving lateral pulp horns and the rest of the pulp chamber unroofed.⁷ Many studies have been performed to determine fracture resistance of teeth with ConsAC^{1,4,9,10}; however, there is limited and conflicting evidence available on the fracture resistance of teeth with TrussAC.¹¹ Thus, this study aimed to determine the effect of three different access cavity designs on fracture resistance of endodontically treated mandibular molars.

Materials and Methods

In this *in vitro* experimental study, 80 recently extracted first permanent mandibular molars were obtained from dental clinics of School of Dental Sciences, Universiti Sains Malaysia (USM), Kota Bharu, Kelantan, Malaysia. Teeth were extracted due to periodontal conditions. The sample size calculation was done using input parameters, effect size 0.04 with 80% power, and α of 0.05 as per a previous study⁷ to obtain a sample size of 20 in each group. Ethics Committee for Human Research, USM (Ref. USM/JEPeM/17040221) approved this study.

All teeth were inspected for the absence of previous restorations, fractures, or abrasion under a microscope (Leica Microsystem Imaging Solutions, Cambridge, United Kingdom) at a 20 \times magnification. Soft tissue remnants and calculus were cleaned off the surfaces of the selected teeth with a hand curette. The teeth were then disinfected by soaking for 10 minutes in sodium hypochlorite (NaOCl) (5.25%; Clorox Inc, Oakland, United States), followed by rinsing with distilled water. Subsequently, the mesiodistal and buccolingual dimensions of the teeth were measured using a digital caliper at the cervical margin. Teeth included in the study had mesiodistal and buccolingual dimension of 10.61 mm (\pm 0.45 mm) and 10.25 mm (\pm 0.45 mm), respectively. The mean mesiodistal and buccolingual pulp chamber distance were 3.76 and 4.39 mm, respectively, measured from pre-operative computed tomographic images. Teeth were stored in 10% formalin solution until use.

Eventually, 20 teeth were allocated to each group as follows:

- Group 1: Teeth with TrussAC prepared.
- Group 2: Teeth with ConsAC prepared.
- Group 3: Teeth with TradAC prepared.
- Group 4: Control group; intact teeth.

TrussAC, ConsAC, and TradAC were prepared on all teeth respectively using an endo access bur size 2, 21 mm (Dentsply Maillefer, United States) mounted on a high speed handpiece, water spray was used as coolant. In group 1, truss accesses were prepared above the mesial and distal roots utilizing pre-operative computed tomographic images as a guide, ensuring the canal orifices could be located, leaving a truss in between the mesial and distal cavities. Hence, a small access and tiny entries left the pulp chamber roof and lateral pulp horns intact^{7,12} (**→ Fig. 1A**). In group 2, the ConsAC preparation was initiated at the central fossa (mesial quarter) and extended distally and apically until all canals were located. Peri-cervical dentin removal mesiodistally, buccolingually, and circumferentially was minimized ensuring pulp chamber roof was partly maintained and all root canal orifices could be localized visually from the same angulation⁴ (**→ Fig. 1B**). TradAC preparation was performed on teeth in group 3 following the TradAC principles as reported in earlier studies^{1,7} (**→ Fig. 1C**). RCT was then done in all access cavity groups. A K-file size 10 (FlexOFiles; Dentsply Maillefer, Switzerland) was used to check canal patency. Working length was determined by introducing a file till it was visible beyond the apical foramen, 1 mm was then subtracted and determined as the working length. Instrumentation was then performed using NiTi rotary files (S5 Sendoline, Sweden) until final apical size 30, 0.06 taper following manufacturers' instructions. Irrigation with 2.5% NaOCl solution (Lenntech, Delfgauw, Netherlands) was performed during instrumentation. Finally, 5 mL of 17% ethylenediaminetetraacetic acid solution (Promega Corporation, Wisconsin, United States) followed by 10 mL of normal saline solution (RMBIO, Missoula, Montana, United States) was used. Obturation was subsequently performed using gutta-percha (Dentsply Maillefer, Switzerland) and AH Plus sealer (Dentsply Maillefer, Switzerland) using warm vertical condensation technique. Throughout the endodontic



Fig. 1 Access cavity designs for each group: (A) Truss access cavity; (B) Conservative access cavity; (C) Traditional access cavity.

procedure the teeth were handled using a moistened gauze to avoid dehydration of the samples.

After completion of endodontic treatment, the access cavities were cleaned using a spoon excavator followed by a moistened cotton pellet to remove all the debris. Phosphoric acid 37% (Magic Acid Coltene, Brazil) was used for etching (enamel for 30 and dentine for 15 seconds). Subsequently, the cavity was rinsed with water/air spray for 30 seconds, and air-dried gently to avoid desiccation. An adhesive (OptiBond S; Kerr Corporation, California, United States) was then applied, thinned by gentle air blowing, and polymerized using a light-emitting diode for 10 seconds. Finally, composite resin (Zmack Comp, Italy) was placed incrementally (2 mm increments) to restore the access cavities and each increment polymerized for 40 seconds following the manufacturers' instructions. Subsequently, composite restoration was polished using a composite polishing kit (Shofu, United States).

All teeth were then mounted with the roots 2 mm below the level of cementoenamel junction embedded in self-cured resin. Silicon impression material was used to simulate the periodontal ligament ((Panasil Light Body; Kettenbach GmbH & Co KG, Eschenburg, Germany). Next, the specimens were mounted in a universal testing machine (AGS-X, Shimadzu, Japan). The teeth were loaded using a spherical steel tip of 3 mm diameter at a speed of 1 mm/min. Forces were then applied vertically on their central fossa, parallel to the tooth's

long axis. The load at which the teeth fractured was recorded in Newton (N) as indicated by the load testing machine software.¹³ Fracture levels were then determined by examining the specimens using a stereomicroscope (Stereo Discovery, Zeiss, Germany). The following was used to classify fracture patterns:

Restorable: Fracture above the bone simulation level (acrylic resin).

Unrestorable: Fracture extending below the bone simulation level.

Normality of distribution was determined using the Kolmogorov-Smirnov test. One-way analysis of variance complemented with Bonferroni test was used for data analysis. Chi-square test was used to analyze the types of fractures. Significance level was set at $p = 0.05$.

A literature search was then performed on January 6, 2020 using PubMed and Google Scholar to find relevant articles using keywords, "Truss access cavity preparation," "Fracture strength with truss access cavity," "Truss access approach," and "Influence of truss access on fracture strength"; obtained literature was reviewed and summarized.

Results

The highest mean fracture resistance was found in group 4, followed by group 1, group 2, and group 3 demonstrating the lowest mean fracture resistance (→ **Table 1**). Besides, pairwise

Table 1 Fracture strength (N) analysis with comparison among groups using one-way ANOVA complemented with Bonferroni test

Groups (n = 20)	Mean	SD	One-way ANOVA test results p-value	Bonferroni test test results p-value		
				ConsAC	TradAC	Control
TrussAC	2068.07	357.39	< 0.001 ^a	0.524	< 0.001 ^a	0.042 ^a
ConsAC	1954.41	224.30			< 0.001 ^a	0.007 ^a
TradAC	1254.77	122.82				< 0.001 ^a
Control	2435.66	237.67				

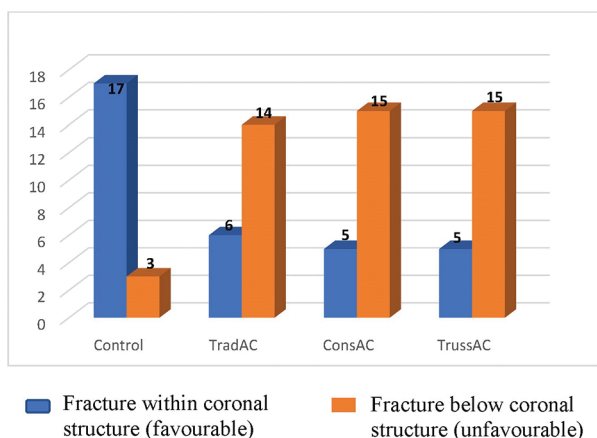
Abbreviations: ANOVA, analysis of variance; ConsAC, conservative access cavity; SD, standard deviation; TradAC, traditional access cavity; TrussAC, truss access cavity.

^aStatistically significant ($p < 0.05$).

Table 2 List of studies and cases that determined the effects TrussAC

Author (year)	Purpose of study	Methodology	Outcomes
Corsentino et al ⁷ (2018)	Assess influence of access cavity design (TradAC, ConsAC, TrussAC) and remaining tooth substance on fracture strength	Sound mandibular molar teeth were selected. After access cavity preparation, and removal of no, one, or two marginal walls, teeth were endodontically treated and restored. The specimens were then loaded to fracture in a universal loading machine	TrussAC and ConsAC do not increase the fracture strength of endo treated teeth, rather the loss of mesial and distal ridges reduced fracture strength of teeth significantly
Özyürek et al ¹⁴ (2018)	Assess the effects of endodontic access cavity preparation design (TradAC, TrussAC) and different restorative base material on the fracture strength	Intact mandibular molar teeth were randomly assigned to TradAC or TrussAC group (with one marginal wall missing), restored with either SDR or EverX posterior as base material. Samples loaded after restoration until fracture	TrussAC did not increase the fracture strength of teeth. No difference in the fracture strength between teeth with TradAC or TrussAC when the same base material was used
Neelakantan et al ¹² (2018)	Assess the influence of using TradAC and TrussAC access cavity design on the efficacy to debride the pulp space	Intact mandibular molar teeth randomly assigned to TradAC or TrussAC group, endodontically treated and evaluated histologically after sectioning to determine remaining pulp tissue	The amount of pulp tissue remnants was significantly lower in the pulp chamber of TradAC group
Abou-Elnaga et al ¹⁵ (2019)	Assess the influence of TradAC, TrussAC, and ATR on fracture resistance	Intact mandibular 1st molars were randomly assigned to TradAC, TrussAC, and ATR. After access cavity preparation, and removal of both marginal walls, teeth were endodontically treated and restored. The specimens were then loaded to fracture	The fracture resistance was not significantly different between the groups
Auswin and Ramesh ¹⁶ (2017)	A case report on TrussAC new conservative approach	Right first molar root canal treatment using TrussAC preparation	This minimal invasive approach in access opening prevents unnecessary tooth structure removal
Mooktiar et al ¹⁷ (2019)	A TrussAC preparation case series	Three permanent teeth with an indication for endodontic treatment were treated via the TrussAC design	This minimal invasive approach in access opening avoids the need for conventionally placed crowns

Abbreviations: ATR, artificial truss restoration; ConsAC, conservative access cavity; SDR, smart dentine replacement; TradAC, traditional access cavity; TrussAC, truss access cavity.

**Fig. 2** Bar chart showing the fracture pattern among the four groups.

comparison of fracture resistance between groups showed significant difference between all groups, TrussAC and TradAC ($p < 0.001$), TrussAC and control ($p = 0.042$), ConsAC and TradAC ($p < 0.001$), ConsAC and control ($p = 0.007$), and TradAC and control ($p < 0.001$) except between TrussAC and ConsAC ($p = 0.524$).

In intact teeth (control group), a significantly higher number of restorable fractures were noted ($p = 0.031$). However, in

all test groups, unrestorable fractures were significantly higher than the restorable ones ($p = 0.028$). This data are illustrated in ►Fig. 2. No correlation between the type of cavity and the favorability of fracture was found ($p = 0.521$).

Literature Review

►Table 2 summarizes the list of studies that assessed the influence of TrussAC. A study was performed to determine whether the design of the endodontic access cavity (TradAC, ConsAC, TrussAC) and the amount of remaining tooth structure had any influence on the fracture strength of mandibular molars. It was found that loss of marginal ridges significantly affected the fracture strength rather than the endodontic cavity design itself. When the marginal ridges were intact, the teeth accessed with TrussAC, ConsAC, or TradAC had no significant difference in their fracture strength.⁷ Another similar study aimed to determine if different access cavity designs (TradAC and TrussAC) and use of different restorative base materials influenced the fracture strength of mandibular molars. It was found that the fracture strength did not increase with TrussAC. Furthermore, the fracture strength of teeth with TradAC or TrussAC was not significantly different when the same base material was used.¹⁴ Another study was performed to assess the influence of using TradAC and

TrussAC access cavity design on the efficacy to debride the pulp chamber and mesial root canal systems of mandibular molars. The authors concluded that pulp tissue remnants were seen in both TradAC and TrussAC groups; however, the amount of pulp tissue remnants were significantly lower in the pulp chamber of the TradAC group.¹² Furthermore, a recent study performed on endodontically treated mandibular first molars compared the fracture resistance of teeth with TradAC, TrussAC, and artificial truss restoration. The fracture resistance was not significantly different between the groups.¹⁵ Only one case report and one case series has been published on TrussAC design. However, no posttreatment follow-up is presented.^{16,17} Furthermore, posttreatment radiographic evaluation is not satisfactorily presented, and the methodology was also not adequately explained.¹⁶ Besides, both these reports did not use three-dimensional imaging to plan orifice-directed access cavities (TrussAC) which might lead to failure of detecting additional/accessory root canals.

Discussion

In this study, the fracture resistance of sound teeth and teeth accessed with TrussAC, ConsAC, and TradAC were compared. Endodontically treated teeth fracture most commonly due to loss of tooth structure,³ and following TradAC principles for endodontic access cavity preparation is one of the most important causes of tooth structure loss.¹⁸

In an attempt to reduce the risk of fracture in endodontically treated teeth, ConsAC and TrussAC were introduced.¹⁰ However, to the best of our knowledge, only one previous study has compared the fracture resistance of teeth accessed with TrussAC and ConsAC.⁷ Thus, the present study tested the effect of TrussAC, ConsAC, and TradAC on the fracture strength of teeth treated endodontically. In endodontically treated posterior teeth, vertical fractures most commonly occur in mandibular molars,^{7,19} thus they were selected in this study. Furthermore, to enable loading test and to simulate procedures performed clinically, composite resin was used to restore the endodontic access cavities. It has been observed that fracture strength is reinstated by nearly 72% after endodontic access cavities are restored.³

All preparation of the specimen was performed by one expert operator to eliminate differences in results caused by a difference in skills of the operator. In this study, the fracture strength of the TradAC group was found to be the lowest in comparison to the control, TrussAC, and ConsAC groups. Likewise, a previous study comparing the fracture resistance of teeth with TradAC and ConsAC showed similar results.¹ When cavities are prepared with TradAC principles, the cavity floor is also the pulp chamber floor.⁷ Since, the centrally located tooth structure in mandibular molars is subjected to heavy masticatory loads, in ConsAC, preserving a part of the pulp chamber roof helps in distributing the occlusal forces, thereby reducing the amount of forces reaching the pulpal chamber floor.¹⁰ An additional aim in conservative access is to preserve the peri-cervical dentin, which is very important for the lifetime and the optimal function of teeth. However, studies that compared the fracture resistance of

teeth accessed with ConsAC and TradAC found no significant difference.^{7,9,14} Furthermore, Abou-Elnaga et al¹⁵ reported that in teeth prepared with TradAC and TrussAC, fracture resistance did not differ significantly. Contrasting findings among studies comparing TradAC, ConsAC, and/or TrussAC could be due to difference in the type of teeth used, methodology of the study, and type of restorative material used.

Additionally, in this study, fracture resistance of teeth accessed with ConsAC and TrussAC did not differ significantly. These results are in line with other studies that tested the fracture resistance of teeth accessed with TrussAC.⁷ However, fracture resistance of teeth with TradAC was significantly lower than those with TrussAC in this study. This result is in line with a recent study that compared the fracture resistance of teeth with TrussAC and TradAC with and without artificial aging.²⁰ The authors concluded that TrussAC did not reduce the fracture strength as compared with sound teeth, nevertheless, when subjected to thermal stress the fracture strength of teeth accessed with both TrussAC and TradAC was significantly reduced.²⁰ Besides, the efficacy of the entire root canal therapy can be influenced by a reduced access cavity.¹⁰ TrussAC can particularly affect the ability of detecting root canals and influence complete removal of debris and pulp tissue remnants.¹²

Moreover, looking at the pattern of fractures in intact teeth, unrestorable ones were significantly lower than restorable ones. On the contrary, in TradAC, ConsAC, and TrussAC groups, restorable ones were significantly lower than unrestorable ones. Similarly, previous studies also reported a higher number of unrestorable fractures in accessed teeth, irrespective of the access cavity design type used.¹ Extended preparation in TradAC design greatly reduces the amount of sound dentine,²¹ thus increasing the tooth deformability resulting in fractures that are unfavorable to restore. Although ConsAC and TrussAC preserve more peri-cervical dentin and pulpal chamber roof, there is still a decrease in the fracture strength due to loss of tooth structure, leading to more unfavorable fractures.³

The limitations of this study include the use of static instead of dynamic force to determine the fracture strength. Additionally, the pH, temperature, and other intraoral factors were not simulated; hence, results should be extrapolated to the clinical situation cautiously.

Conclusion

Considering the limitations, it is concluded that, lower fracture strength was observed in teeth with TradAC (group 3) as compared with TrussAC (group 1) or ConsAC (group 2). Furthermore, when accessed using TrussAC, the fracture strength was not greater than in teeth with ConsAC. Moreover, unrestorable fractures were more than restorable ones in all accessed teeth.

The literature review showed that accessing teeth with TrussAC had no significant effect on the fracture strength, rather the fracture strength was significantly reduced with the loss of one or more marginal ridges. Furthermore, TrussAC resulted in a higher amount of pulp tissues remnants in the

pulp chamber which may lead to failure of endodontic treatment. These conclusions are based solely on in vitro studies and clinical translation may not be completely pertinent.

Authors' Contributions

M.I.K. contributed in preparation of the manuscript. A.F.A.A. conducted the study as part of the DDS program. S.D.M. and N.R.N.A.G. contributed in supervision of the project and proof reading of the manuscript. M.S.H. contributed in supervision of the project, design of the project, and proof reading of the manuscript. T.Y.N. contributed in concept, design of the study, obtained funding, supervision, and proof reading of the manuscript.

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Conflict of Interest

No conflicts of interest exist.

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