

**How to Cite:**

Sharma, S., Sawhny, A., Hora, B. S., Kumari, R., Vizo, V., & Sumbria, S. (2022). Impact of endodontic access cavity design and thermo-cycling on fracture strength of root canal treated mandibular molar teeth: An ex-vivo study. *International Journal of Health Sciences*, 6(S4), 4626–4635. <https://doi.org/10.53730/ijhs.v6nS4.9158>

## **Impact of endodontic access cavity design and thermo-cycling on fracture strength of root canal treated mandibular molar teeth: An ex-vivo study**

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**Abstract**---Aim: Aim of study is to evaluate the fracture resistance of the root canal treated Mandibular 1<sup>st</sup> and 2<sup>nd</sup> molar teeth with Conventional(TEC) access design and Truss(TREC) access design restored with composite resin and subjected to thermocycling.

Method: 60 human 1<sup>st</sup> and 2<sup>nd</sup> molar (mandibular) teeth were randomly categorised into six (6) groups: CON (GroupI), TEC (GroupIII), TREC(GroupV) not subjected to thermocycling whereas CONTC (GroupII),TECTC(GroupIV) and TRECTC(GroupVI) subjected to thermocycling. Biomechanical preparation of the canals were done upto #F3 of Protaper gold rotary files (Dentsply) and obturated using gutta-percha points and restored using SDR bulk-fill composite(Dentsply). All samples were then subjected to thermocycling for 5000cycles between 15°C and 45°C for different time intervals and their fracture toughness tested under an Universal Tester with steel ball of diameter 5mm at a constant 1mm/min speed. Two-way and one-way ANOVA test employed for statistical analysis. Result: The fracture strength of teeth in TREC group had no notable variation with the control group ( $P>0.05$ ) without thermocycling. Both TEC and TREC designs notably reduced the fracture toughness after thermocycling ( $P<0.05$ ). The least fracture resistance was noted in TECTC group. Conclusion: TREC ought to increase the fracture resistance of root canal treated teeth after thermocycling

**Keywords**---root canal access cavity, fracture resistance, minimally intrusive intervention, thermo-cycling.

## Introduction

Endodontically treated teeth have a lower fracture strength than teeth which is vital. This discrepancy could be attributed to the dentine of a tooth with a living pulp compared to endo-dontically treated teeth<sup>1</sup>. However, endo-dontically Treated teeth's restoration of structure, aesthetics, and function is accompanied with various issues<sup>2</sup>, which may be attributed to the severe loss of the structure of tooth (dentin) while preparation of access cavity, which reduces their fracture toughness when in mastication.<sup>3,4</sup> To prevent endodontic complications, the structure of the tooth is eliminated in a restricted manner in traditional root canal access cavity design (TEC) preparation.<sup>5</sup>

After post obturation restoration, however, dentine loss and anatomical tooth structures namely tooth cusps, marginal ridge, and floor of pulp chamber could result in fracture of tooth.<sup>6,7</sup> UnlikeTEC, the Truss access (TREC) design is minimally intrusive, preserves portions of the tooth structures like Peri-cervical dentin ,and can aid root canal treated teeth resist fracture.<sup>8</sup>The influence of access preparation design on fracture strength, on the other hand, has not been well studied and remains controversial.<sup>12,13</sup> The presently advocated minimally invasive access designs are the contracted design (a miniature access preparation on the tooth's occlusal surface which facilitates the dentist to approach all openings of the root canal of tooth) ; Truss access preparation (incorporates an approach which is orifice-directed, preserving centre of the pulp chamber roof) and Ninja design ( Ultraconservative design ).

The above mentioned designs are intended to improve the fracture resistance of root canal treated teeth and reduces tooth's reliance upon sophisticated and

expensive post-endodontic restorations.<sup>14</sup> The principal curvature of the canal framework of conservative access design is not considerably distinct compared to that of the Truss access designs, however the latter notably increases the duration of instrumentation.<sup>18</sup> Despite this, research suggests that the truss design improves the fracture resistance of root canal treated teeth.<sup>19</sup>

Thermo-cycling is a technique that uses hot and cold baths to replicate in-vivo ageing in vitro. To better imitate the clinical context, it imitates heat variations in the mouth.<sup>20</sup> However, recent researches on this subject have not conducted thermo-cycling. As all pertinent older studies evaluated Traditional or Truss designs without simulating in-vivo conditions (eg. by thermal cycling). This research assesses the fracture resistance of the root canal treated mandibular molar teeth filled with composite resin restorative material followed by thermal cycling.

### **Methodology and Materials**

This ex-vivo study received ethical clearance from the Rama Dental College Hospital and Research Centre in Kanpur. Based on previous studies<sup>6,21</sup>, the sample size was calculated to be 10 for each group assuming Alpha = 0.05, Beta = 0.1 and study power of 90%. 60 lower 1<sup>st</sup> and 2<sup>nd</sup> human molar teeth with mature root apices from patients of 20-60 years age group were collected from Oral and Maxillofacial Surgery department, Rama Dental College, Kanpur. There were no visible carious lesions, restorations, cracks or fractures on the teeth. After cleaning the surface of the tooth with a hand-scaler and clearing the root and crown surface using rubber cups and pumicing powder, all samples were kept in 0.1% thymol solution at room temperature, to prevent dryness for a maximum of six months. All samples of teeth were then digitally photographed from the buccal and mesio-distal directions using a film holder for posterior teeth (Dentsply, Germany). The height of the anatomical crown from the occlusal surface of all four surfaces to the CEJ was calculated. Using a digital calliper the buccal and mesio-distal extent of the tooth from occlusal surface was measured. The average distance mesio-distally and bucco-lingually of pulp chamber was 3.82mm and 4.45mm, approximately, and the average distance from tooth's occlusal surface to the pulp chamber's roof was 4.25mm for the tooth.

We then randomized the teeth into four experimental groups (n = 10) and two control groups as follows:

Group I: Unprepared control Group (CON) which is not accompanied by Thermal cycling.

Group II: Unprepared control group accompanied by Thermal cycling (CONTC).

Group III: Access Cavity with Traditional Design (TEC) unaccompanied by Thermal cycling.

Group IV: Access Cavity (TECTC) with Traditional Design subjected to Thermal cycling.

Group V: Access Cavity (TREC) with Truss Design unaccompanied by Thermal cycling.

Group VI: Access cavity (TRECTC) with Truss Design subjected to Thermal cycling.

For standardization purposes and to reduce the impact of size and shape variation of teeth on outcome, Teeth of similar shapes and sizes were assigned to each group.<sup>21</sup>

### **Traditional and Truss Access Design Preparation**

Access opening in all experimental batches were done using round diamond points and Endo Access Bur (Dentsply), mounted on high speed handpiece with water coolant. In Traditional design (TEC) the access preparation starts from the Central fossae and proceeds apically and distally to deroof the pulp chamber. When the TEC was ready, the canal opening can be completely visualised (Figure 1).

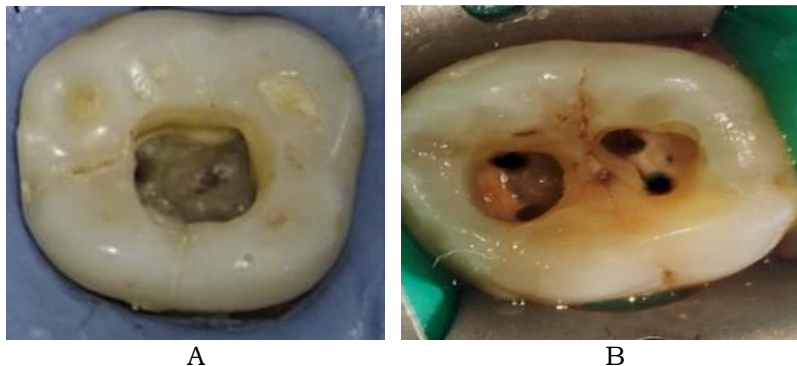


Figure (1) Teeth with (A) TEC design and (B) TREC design

In Truss access opening (TREC) portion of the roof of pulp chamber was maintained. Circular access openings were made to approach the mesial root canals in bucco-lingual direction and other access opening was done to gain access to the distal root canal orifice. The distinct mesial access openings were then joined to form an elliptical access cavity of 1.25 mm diameter. Efforts were made to standardize the measurements and depths of access cavities for each teeth in the group and specimens that were not upto the criteria were replaced.

### **Root Canal treatment**

After access cavity was prepared, a #15 K file was introduced into the canal upto the apical foramen and then working length was taken 1mm short of the apical foramen. Root canal filing was done till #F3 of the ProTaper Gold Rotary files (Dentsply) mounted in an endomotor. The canal was irrigated with 5.25% sodium hypochlorite and normal saline. After complete biomechanical preparation, the root canals were dried using paper points, they were then obturated with corresponding gutta-percha points (Dentsply Sirona, Germany) and Apexit Plus root canal sealer (Ivoclar Vivadent). According to manufacturer's instructions, root canal sealer was introduced into the canal. Next, a sealer coated gutta-percha master cone was introduced into the tooth root canal and canal obturation was done using cold lateral compaction technique. Finally, the tooth access cavity was restored.

### **Post Endodontic Tooth Restoration**

All prepared tooth walls in each group except for those in Group I and Group II were etched, 30 seconds for enamel and 15 seconds for dentin with 37% phosphoric acid (Ivoclar N Etchant Gel). All Specimens were then washed for 20-30 seconds, dried using absorbent paper, and then applied twice with an adhesive bonding agent (Tetric N Bond Universal, Ivoclar Vivadent). A gentle blow of air was applied for 5 seconds to evaporate the adhesive solvent and then cured for 10 seconds via the LED curing unit (Ivoclar). The access cavity was restored with SDR Flowable Bulk Fill Composite (Dentsply, Sirona). Application of composite resin restorative material was done using oblique incremental build-up technique with light curing of 40 seconds to the occlusal surface level while maintaining the occlusal anatomy.

### **Periodontium Simulation**

To replicate the periodontal ligament, all of the samples were placed 2 mm apical to the cemento-enamel junction in custom-made cylinders manufactured with self-cure acrylic resin and a 0.2mm thick vinyl poly-siloxane lining. The samples were then thermo-dynamically cycled.

### **Thermal Cycling**

The control, TEC, and TREC batches' teeth were all preserved in distilled water. The teeth samples from the CONTC, TECTC, and TRECTC groups were placed in water baths of various temperatures, and thermo-cycling was performed as follows: 35°C for 30 seconds, 15°C for 2 seconds, 35°C for 30 seconds, 35°C for 30 seconds, and 45°C for 2 seconds for 5000 cycles, to mimic thermal changes occurring in the oral cavity over a 6-month period. After that, the teeth samples were tested for fracture strength using the Universal Tester.

### **Fracture strength test**

All teeth were kept in distilled water at room temperature for 24 hours before the testing began. UNIVERSAL TESTING MACHINE was used to test all of the specimens. The specimens were loaded at a 30 degree angle from the tooth's long axis at their central fossa. A ball-ended steel compressive head of 5-mm diameter was applied with a continuous compressive force at 1 mm/min crosshead speed. Each tooth's load upon break was measured in Newtons (N).

### **Statistical analysis**

The data was analyzed using SPSS version 22 (IBM Corp2013; version 22.0; Armonk, NY). Anderson-Darling test was used to evaluate the normal data distribution. The impact of access cavity designs and thermal cycles, as well as their interaction to the tooth fracture resistance was analysed using Two-way ANOVA test. In addition, comparison amongst the groups were carried out using Duncan's test and One-way ANOVA test, and the impact of the thermal cycle on fracture resistance was analysed using t-test. The group was at the significance level of  $p < 0.05$ .

## Results

Normal data distribution was revealed by Anderson-Darling Test. Two-way ANOVA test revealed thermo-cycling notably affects the resistance to fracture of root canal treated teeth with different access preparation designs ( $p < 0.05$ ). The fracture resistance of the teeth in Group I and II remained unaffected even after Thermo-cycling but the fracture resistance of teeth with Traditional (TEC) and Truss (TREC) access designs were notably reduced after thermo-cycling, such that least resistance to fracture was observed in the TECTC batch as revealed by the Duncan's test and One-way ANOVA test. As revealed by the Student T-test, no notable variance in fracture resistance of teeth in control group (with/without thermal cycling) and TREC/Truss access cavity batch (without thermal cycling) was recorded. Also a notable variance of fracture resistance was noted among TEC, TECTC and TRECTC batches (Table I).

(Table I) Cross-Sectional Diameters, Bucco-lingual [BL], Mesio-distal [MD] and Comparison of Fracture Strength (N) of Teeth (n=10)

Groups	n	BL	MD	MD*BL	Fracture(N) (SD)	P Value*
CON	10	10.017	10.956	110.0324	1616.302 <sup>a</sup> ±106.5	>0.05
CONTC	10	10.318	11.25	116.4863	30	
TREC	10	10.342	11.241	116.3963	1595.7a±72.708	<0.05
TRECTC	10	10.286	11.397	116.254	1601.2a±143.073	
TEC	10	10.264	11.328	116.5389	1264.928b±209.3	<0.05
TECTC	10	10.16	11.007	112.2544	05	
P value	60	>0.05	>0.05	>0.05	1369.9b±253.903 886.23c±157.559	>0.05

Note: P value: oneway ANOVA test. P value\*: student t test (comparison with Thermo-cycling and without Thermo-cycling). a,b,c inter group comparison using Tuckey's test. Abb: Control, CON; CONTC, control with thermo-cycling; TREC, truss root canal access cavity; TRECTC, truss root canal access cavity with thermo-cycling; TEC, traditional access cavity; TECTC, traditional access cavity with thermo-cycling.

## Discussion

The long term outcome of root canal treatment relies upon extent of the tooth structure remaining and final coronal structure rebuilding<sup>22</sup>. The survival rate of root canal treated teeth is significantly influenced by loss of dentin<sup>21</sup>. Root canal treatment steps involves access opening and biomechanical preparation of root canal system consequently leading to extreme tooth structure loss thus diminishing the tooth strength against occlusal forces.<sup>23,24</sup> Currently, Truss design is preferred compared to Traditional access design as the previous one better protects structure of tooth thus improving its strength<sup>25,26</sup>. Nonetheless, there is no agreement on the type of access design and the final restoration of the posterior tooth after root canal treatment. The previous researches conducted by various researchers showed no studies comparing Truss and Traditional access designs after thermal cycling. Thus this research assessed the resistance to

fracture of composite restored root canal treated lower molars with Traditional or Truss designs when subjected to Thermo-cycling. The outcome revealed that the Truss design notably increases fracture resistance of the root canal treated mandibular molars which was controversial when compared to outcomes of other researches.

Platino-et al demonstrated that fracture toughness of root canal treated teeth was not influenced by Truss configuration.<sup>16</sup> The study outcomes uncovered that resistance to fracture of control group (tooth without any access cavity or intact teeth) was almost alike compared to teeth prepared with Truss design in the experimental batch.<sup>11,28</sup>

Since, the research outcomes showed that the resistance to fracture was evidently diminished in root canal treated tooth such that the teeth with Traditional design with thermo-cycling (TECTC) batch showed least resistance to fracture compared to the Teeth with Truss access design with thermo-cycling (TRECTC) batch. Factors affecting the loading capacity of Root canal treated teeth; like adjoining Teeth, Occlusal surface contacts, Tooth placement in jaws, the forces acting on tooth in clinical setting cannot be recreated in the external experimental environment.<sup>29</sup> The technique for loading outside oral cavity is likewise not quite the same as it is static in vitro dynamic inside oral cavity.<sup>30</sup> We made an honest effort to reproduce the periodontium and prevent drying and its unfavourable consequences for teeth samples while the research was being conducted by keeping the teeth in 100 percent humid condition.<sup>31</sup> To mimic the clinical in-vivo conditions, the compressive force was applied at 30° angle with tooth axis running longitudinally.

In any case, a few different factors, for example, forces acting laterally that are additionally present in vivo can't be re-enacted outside the oral cavity. Thermal cycling hasn't been carried out in previous similar researches; nonetheless, it appears to essentially affect the fracture toughness of root canal treated teeth. It has also been accounted that thermo-cycling can lead to extension of the micro-cracks in enamel and dentin formed due to tooth structure removal during access preparation<sup>34</sup>. Bigger sized access openings (Traditional Form) has higher probability of micro-cracks, and would eventually lead to diminished resistance to fracture. Interestingly, in contracted access designs, the pericervical dentin is more safeguarded, and the chances of micro-cracks reaching the level of access opening would be diminished because of its more modest dimension, which could be a potential justification for greater resistance to fracture of the tooth structure. Enamel being hard and brittle structure is composed of hydroxyapatite crystals implanted in protein and water matrix known as prisms of enamel or enamel prisms. Close to DEJ, a web of inner deformities is found that is principally formed of less calcified fissures, such as enamel tufts. These imperfections are the reason for crack propagation during massive or persistent loading. Reduction in teeth's resistance to fracture after thermal cycling in our review might be as a result of micro-cracks spread following preparation of access cavity and enamel tufts presence, because self-mending doesn't happen in vitro.

## Clinical Significance

In the clinical oral environment various thermo-mechanical loads acts on the teeth. Ideally tooth structure should be removed as minimally as reasonable. In addition, conservative / contracted access cavity design in teeth which is not extensively carious can increase the Fracture toughness of teeth treated endodontically.

## Conclusion

The fracture strength of mandibular molars teeth treated endodontically having Truss(TREC) design didn't differ substantially from the fracture strength of healthy teeth under the thermal cycle, according to the results of this in vitro investigation.. The TREC and TEC designs have significantly reduced the fracture toughness of the teeth after thermo-cycling. Future studies are needed to evaluate tooth fracture resistance by TEC and conservative access cavity designs after thermo-mechanical repeated loading.

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