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Original Article

Dentistry Section

Impact of Access Cavity Design and Root Canal Taper on Fracture Resistance of Permanent Mandibular Molars: An In-vitro Study

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ABSTRACT

Introduction: Minimal invasive endodontics in the form of conservative access designs and minimal root canal taper preparation have been devised to preserve tooth structure and increase fracture resistance.

Aim: To assess the influence of two different access cavity designs and two different final preparation tapers on fracture resistance of mandibular molars.

Materials and Methods: In this in-vitro study, performed over a period of two months, a total of 54 extracted human permanent mandibular first and second molar teeth with completely formed apices were selected and for infection control, the teeth were stored in 10% buffered formalin solution for two weeks before the experiment. The teeth were then randomly allocated into three groups, Group C where no tooth preparation was carried out, Group TAC in which Traditional Access Cavity design was performed and Group TREC where Truss Access Cavity was performed. The groups TAC and TREC were further subdivided into subgroup A and B with two different tapers 0.04 and 0.06 taper preparations. Mesial canals of the teeth were chosen for testing the minimal root canal taper preparations. After apical gauging the distal canals, obturation and postendodontic restoration was carried out in all teeth of both the test groups. The teeth in all three groups were subjected to fracture testing in a universal testing machine. The data were recorded. One-way Analysis of Variance (ANOVA) and Tukey's Post-hoc test were used for statistical analysis.

Results: The fracture resistance between group C and groups TAC and TREC and their subgroups were found to be statistically significant ($p<0.05$). However, there was no statistically significant difference ($p>0.05$) observed between the two test groups TAC and TREC and their subgroups.

Conclusion: The conservative truss access design in combination with a reduced root canal taper preparation has shown to have produced better fracture resistance values in comparison to other groups and their subgroups although the results were not statistically significant.

Keywords: Conservative access preparation, Minimal invasive endodontics, Truss cavity

INTRODUCTION

Teeth managed endodontically are known to be weak due to caries removal, access cavity preparation and excessive use of rotary instrumentation. Vertical root fracture is a serious clinical concern and has multiple precipitating factors. Hence, in an effort to reduce such complications minimal enlargement and flare preparation of root canal space has been recommended. Since, increased cavity sizes and access cavities increase cuspal deflection, the extent of cuspal flexure after endodontic procedures also becomes a factor to be considered for potential failure [1]. A study by Clark D and Khademi J states that molar fracturing can be described as retrograde vertical root fracture and that the ultimate purpose of access must be to avoid the fracturing potential of endodontically treated teeth. Since, the traditional access design focuses more on operator needs and less on restorative needs the newer trends which lays emphasis on biologic and structural aspects for teeth in adapting to the concepts of minimally invasive dentistry have been widely acclaimed in recent times [2].

In order to maintain optimal strength and fracture resistance, the Pericervical Dentine (PCD), undermined dentine, Dentinoenamel Junction (DEJ), axial wall of DEJ, cervical enamel in physiologic young teeth which have been considered of high value with respect to tissue type becomes important. The PCD is the dentine near the alveolar crest and the critical zone identified to be roughly 4 mm above the crestal bone and 4 mm below the crestal bone is important when it comes to ferrule, fracturing and dentine tubule proximity [2].

In the endodontic domain the essence of MID could be attained by shifting to access opening designs that are crafted to preserve sound tooth structure especially cervically as loss of tooth structure in this area of the teeth could make them more susceptible to fracture and by the use of minimally tapered rotary instruments in the root canal space as an attempt to avoid straightening the canals, causing irreparable defects like cracks and stripping of the root walls [3]. Although undermined enamel does not aid in reinforcing the tooth with regard to fracture potential but naturally occurring undermined dentine in the form of soffit aids in adding mechanical strength and value to the teeth [4]. Since, the fracture of teeth often results in extraction it can ultimately leave the dentist and patients to question the prognosis of such endodontically treated teeth.

Although the primary objective of these newer designs is 'directed dentine conservation' [2] several approaches to the Contracted Endodontic Cavities (CEC) technique have been discussed and demonstrated. The 'Ninja' and 'Truss' endodontic cavities (NEC) and (TREC) designs are inclusive of such demonstrations [5]. The TREC is more a strategic design where cavities are prepared over each canal orifice from occlusal surface leaving a dentine truss between the cavities. The approach also proves to be more conservative in that the entire pulp chamber deroofing is avoided [5,6].

Although studies [4,5] have been conducted on fracture resistance of conservative cavity designs and root canal instrumentation of increasing tapers [6] no study till date has been conducted in combination of the two in the same experimental teeth. Hence, the

aim of this study was to assess the influence of two different access cavity designs and two different final preparation tapers on fracture resistance of mandibular molars. The null hypothesis is that, there is no difference in the fracture resistance of teeth with two different access cavity designs and two different root canal taper preparation.

MATERIALS AND METHODS

In this in-vitro study, performed over a period of two months between September and October 2020 in the Department of Conservative Dentistry and Endodontics, Bapuji Dental College and Hospital, Davangere, Karnataka, India. A total of 54 extracted human permanent mandibular first and second molar teeth with completely formed apices were selected and the teeth were stored in 10% buffered formalin solution for two weeks before the experiment. At no stage in the procedure, were the teeth allowed to dehydrate. Ethical committee clearance was obtained from the Research Development and Sustenance Committee, Bapuji Dental College and Hospital, Davangere (Ref.No.BDC/Exam/467/20018-2019).

Inclusion and Exclusion criteria: Non carious teeth with mature apices, teeth with no visible fracture lines or cracks and free of any developmental defects, teeth with similar morphology and relative coronal dimensions were included in the study. However, teeth with previous restoration or endodontic manipulation, short thin or curved roots, fused roots, fused mesial canals and canal calcifications, internal or external resorption were excluded.

The teeth where then randomly allocated into three groups. Standardised radiographs (Paralleling Technique) of each tooth in both the buccal-lingual and mesial-distal directions was taken. The anatomic crown height of the 54 teeth was measured from the occlusal surface to the CEJ on all four sides of the teeth; buccolingual and mesiodistal (MD) dimensions were measured at the occlusal surface. Tooth measurements were taken with a digital caliper (Digimatic 500). Teeth with similar dimensions were selected. Therefore, homogenous groups were created based on the averages of tooth dimensions in order to minimise the influence of size and shape variations. The specimens were randomly divided into two test groups (TAC and TREC) and one control group containing 18 teeth each. The two test groups were divided into two subgroups, Subgroup A (n=9): 0.04 taper and Subgroup B (n=9): 0.06 taper.

Study Procedure

1. **Access cavity preparation:** Access cavities were performed with a size 856 diamond point and Endo z bur in a high-speed air rotor with water cooling.

In the intact group, no treatment was performed on teeth, and they remained intact until the fracture resistance test. In the TAC group, traditional endodontic access cavities were prepared following conventional guidelines [7]. TRECs [Table/Fig-1] was performed by keeping part of the pulp chamber roof intact. Then, a single access to the mesial canals was created in the buccal-lingual direction, and another circular one was made to reach the distal canal orifice. The single oval access to the mesial canals was determined by joining the two access slots created following the perpendicular projection to the occlusal surface of the mesial canals and enlarging it up to 1.2 mm for the oval minimum diameter; the circular access over the distal canal was started with one access slot created following the perpendicular projection to the occlusal surface of the distal canal, and it was enlarged circularly to a 1.2 mm diameter. The diameters were measured and checked with a digital caliper. The two accesses on the same occlusal surface were separated by an enamel/dentine bridge [5,8].

[Table/Fig-1]: Truss access design.

2. **Canal instrumentation:** In mesial canals of all specimens of group TAC and TREC, working length was determined by advancing a size 10 K-file into the canal until it was just visible at the foramen and then 1 mm was subtracted from this measurement. The size of the minor constriction was standardised, and any tooth where the size 15 K-file extruded beyond the apical foramen was excluded [9].

Group TAC and TREC: Subgroup A: The mesial canals of teeth were shaped with rotary instruments reaching a final continuous 0.04 taper up to tip size 25 using crown down technique, in the order of files sequence according to manufacturer instructions.

Group TAC and TREC: Subgroup B: The mesial canals of teeth were shaped with rotary instruments reaching a final continuous 0.06 taper up to tip size 25 using crown down technique, in the order of files sequence according to manufacturer instructions.

The final apical file size and taper of the distal canals of all teeth in the two test groups were determined by apical gauging. Also, instruments were used with an endodontic motor (X-Smart, Dentsply Maillefer) following the manufacturer's instruction.

During the shaping p rocedure, a #10 K-file was taken to the working length to check patency, and intermittent irrigation with 5.25% NaOCl was performed with disposable syringes of 5 mL with 27 G needles.The final flush was done using 17% EDTA and saline. The root canals were then dried using paper points.

3. **Obturation:** Master cone was selected and obturation was then carried out using cold lateral compaction technique and AH Plus sealer with all canals. The orifices were sealed using flowable resin composite and postendodontic core build up was done using resin composite.
4. **Fracture resistance testing:** The 54 specimens were mounted in self-curing resin (SR Ivolen; Ivoclar Vivadent, Schaan, Lichtenstein) with the roots embedded up to 2 mm apical to the CEJ as reported in a previous study [4].The specimens were then placed in the Hounsfield universal testing machine [Table/Fig-2] equipped with a 500 N cell load that applied a continuous compressive strength force at a crosshead speed of 1 mm/min. The teeth were positioned vertically and a cylindrical hardened steel rod attached to the upper crosshead was lowered until the cone shaped point of the rod rested on the teeth. The universal load-testing machine was then connected to a microsoft based Qmat Pro that collected all the information and indicated the load at which each mandibular molar tooth fractured. The load at which the fracture occurred was then measured in kilogram force.

STATISTICAL ANALYSIS

The values obtained from samples were analysed using R software version 4.0.2. The descriptive statistics, including Mean and Standard Deviation (SD) were calculated for each group tested. The data was normally distributed hence, One-way ANOVA (Analysis of Variance) was used for intergroup and repeated ANOVA was used for intragroup analysis data for significant differences. Pair-wise

[Table/Fig-2]: Hounsfield universal testing machine.

comparison between the groups were done using Tukey's Post-hoc test. A p<0.05 was considered statistically significant.

RESULTS

The descriptive statistics between the three groups have been shown in [Table/Fig-3] and the mean and SD of intact tooth group was found to be higher than the two test groups. [Table/Fig-4] reveals that The intact teeth have maximum fracture resistance with a Mean±SD of 262.9±58.75 kilograms force.

[Table/Fig-5] reveals that intact teeth group in comparison to TAC and Truss group showed statistical significance (p<0.05). However,

Groups	N	Mean (Breakforce in kilograms)	Std. Deviation
Intact teeth	18	262.9	58.75
TAC	18	167.4	50.27
Truss	18	184.8	55.93
Total	54	205.0	68.39

[Table/Fig-3]: Comparison of mean fracture resistance values (break force in kg) between the study groups.

Groups	N	Mean (Breakforce in kilograms)	Std. Deviation
Intact teeth	18	262.9	58.75
TAC (0.04)	9	174.4	44.16
TAC (0.06)	9	160.3	57.51
Truss (0.04)	9	186.2	42.44
Truss (0.06)	9	183.3	69.58
Total	54	205.0	68.39

[Table/Fig-4]: Comparison of mean fracture resistance values (break force in kg) between the study groups and the subgroups.

TAC group was found to show statistically significant difference in comparison to intact teeth group (p<0.05) but showed statistically non significant difference in comparison to Truss group. Similarly, the Truss group showed statistically significant difference (p<0.05) in comparison to intact teeth. However, it did not show statistically significant difference when compared to TAC group.

[Table/Fig-6] shows multiple comparisons between the groups and subgroup. The intact teeth group was found to produce statistically significant difference when compared to TAC (Subgroup A), TAC (Subgroup B), Truss (Subgroup A) and Truss (Subgroup B) with (p<0.05).

The traditional (Subgroup A) showed statistically significant difference when compared to intact teeth with (p<0.05). It did not show statistically significant difference when compared to Traditional (Subgroup B), Truss (Subgroup A), and Truss (Subgroup B).

Also, Traditional (Subgroup B) was found to give a statistically significant difference with intact teeth group with (p<0.05) and did not show statistically significant difference with the remaining group.

Similarly, Truss (Subgroup A) and Truss (Subgroup B) groups also showed statistically significant difference only with intact teeth group (p<0.05) and not with other groups.

DISCUSSION

The present study was aimed to understand if minimal invasive access design in combination with reduced taper root canal preparation 0.04 and 0.06 taper has increased the fracture resistance of teeth in comparison to traditional access design with similar taper root canal preparation and intact control group.

The minimal invasive endodontics approach has gained popularity in current times as it aids in maintaining a balance in functional, biological, adhesive, mechanical and aesthetic parameters through maximum preservation and conservation of tooth structure [3,10].

In the present study, a statistically significant result was obtained between the intact teeth group and the two test groups TAC and Truss endodontic access design. It is important to understand, however, that restoring teeth after access cavity preparation has been shown to enable teeth to regain 72% of their fracture resistance [11,12] and that, it is not the cavity design per se. The traditional access design based on GV Black's extention for prevention and the Truss design based on the concept of directed dentine as described by Clark D and Khademi J [2] that highlights preserving PCD and a portion of coronal pulp chamber, the soffit are not the main reason for reduced fracture resistance but rather the loss of mesial and distal ridges as observed by Corsentino G et al., and Silva AA et al., [5,13].

In this study irrespective of tapers, Truss access design has performed better than the traditional access design, however, a statistically significant difference could not be obtained and this could be attributed to smaller samples in each of the groups and their subgroups. The better performance can to a certain extent attributed to dentine preservation as claimed by Clark D and Khademi J, Plotino G et al., [2,14]. However, several studies that followed to test this proposition as tabulated in [Table/Fig-7] did not report any

Break force Tukey's HSD					95% Confidence interval	
(I) Group	(J) Group	Mean difference (I-J)	Std. Error	Sig.	Lower bound	Upper bound
Intact teeth	TAC	95.46889*	18.36514	<0.001	51.1358	139.8020
	Truss	78.10444*	18.36514	<0.001	33.7714	122.4375
TAC	Intact Teeth	-95.46889*	18.36514	<0.001	-139.8020	-51.1358
	Truss	-17.36444	18.36514	0.614	-61.6975	26.9686
Truss	Intact Teeth	-78.10444*	18.36514	<0.001	-122.4375	-33.7714
	TAC	17.36444	18.36514	0.614	-26.9686	61.6975

[Table/Fig-5]: Multiple comparison of statistical significance between the study groups.
*The mean difference is significant at the 0.05 level.
*p<0.05 Statistically significant, p>0.05 Non significant

Break force Tukey's HSD		Mean difference (I-J)	Std. error	p-value	95% Confidence interval	
(I) Group	(J) Group				Lower bound	Upper bound
Intact Teeth	Traditional (0.04)	88.41167*	22.87774	0.003	23.6233	153.2001
	Traditional (0.06)	102.52611*	22.87774	<0.001	37.7377	167.3145
	Truss (0.04)	76.66389*	22.87774	0.013	11.8755	141.4523
	Truss (0.06)	79.54500*	22.87774	0.009	14.7566	144.3334
Traditional (0.04)	Intact Teeth	-88.41167*	22.87774	0.003	-153.2001	-23.6233
	Traditional (0.06)	14.11444	26.41694	0.983	-60.6968	88.9257
	Truss (0.04)	-11.74778	26.41694	0.992	-86.5590	63.0634
	Truss (0.06)	-8.86667	26.41694	0.997	-83.6779	65.9445
Traditional (0.06)	Intact Teeth	-102.52611*	22.87774	<0.001	-167.3145	-37.7377
	Traditional (0.04)	-14.11444	26.41694	0.983	-88.9257	60.6968
	Truss (0.04)	-25.86222	26.41694	0.863	-100.6734	48.9490
	Truss (0.06)	-22.98111	26.41694	0.906	-97.7923	51.8301
Truss (0.04)	Intact Teeth	-76.66389*	22.87774	0.013	-141.4523	-11.8755
	Traditional (0.04)	11.74778	26.41694	0.992	-63.0634	86.5590
	Traditional (0.06)	25.86222	26.41694	0.863	-48.9490	100.6734
	Truss (0.06)	2.88111	26.41694	1.000	-71.9301	77.6923
Truss (0.06)	Intact Teeth	-79.54500*	22.87774	0.009	-144.3334	-14.7566
	Traditional (0.04)	8.86667	26.41694	0.997	-65.9445	83.6779
	Traditional (0.06)	22.98111	26.41694	0.906	-51.8301	97.7923
	Truss (0.04)	-2.88111	26.41694	1.000	-77.6923	71.9301

[Table/Fig-6]: Multiple comparison of statistical significance between the study groups and subgroups.
*The mean difference is significant at the 0.05 level.
*p<0.05 Statistically significant, p>0.05 Non significant

S. No.	Author's name and year	Place of study	Sample size	Techniques compared	Parameters assessed	Conclusion
1.	Moore B et al., 2016 [12]	Toronto, Canada	59	Load at failure compared between Contracted Endodontic Cavities (CECs) and Traditional Endodontic Cavities (TECs)	Impacts of CECs on instrumentation efficacy and axial strain responses in maxillary molars	In maxillary molars tested in-vitro, CECs did not impact instrumentation efficacy and biomechanical responses compared with TECs.
2.	Chlup Z et al., 2017 [15]	Czechia, Europe	60	Comparison of access cavity of TEC and minimum invasive CEC	Influence of CEC and TEC on the fracture resistance of lower (mandibular) and upper(maxillary) premolars	No statistically significant difference between TEC and CEC in maxillary and mandibular premolars, respectively, althoughthe average loads at fracture for CEC were generally higher
3.	Ivanoff CS et al., 2017 [16]	Tennessee, USA	45	Comparison of fracture resistance of mandibular premolars restored with mesio occlusal composites after access with TEC or CEC designs	Fracture resistance in teet restored with mesio occlusal composites	Modifying access outline did not improve fracture resistance
4.	Rover G et al., 2017 [17]	Santa Catarina, Brazil	30	Comparison of Fracture resistance of CEC and TEC on maxillary molars	Influence of CEC on root canal detection, instrumentation efficacy, and fracture resistance assessed in maxillary molars	No increase fracture resistance
5.	Corsentino G et al., 2018 [5]	Italy	100	Impact of access cavity preparation (Traditional –TEC, Consevative – CEC and TREC – Truss) and the remaining tooth substance on the fracture strength of endodontically treated teeth	Intact (control) TEC CEC TREC TEC+3 walls CEC+3 walls TREC+3 walls TEC+2 walls CEC+2 walls TREC+2 walls	TRECs do not increase the fracture strength of endodontically treated teeth in comparison with CECs and TECs. Moreover, the loss of mesial and distal ridges reduced the fracture strength of teeth significantly.
6.	Ozyurek T et al., 2018 [18]	Turkey	100	Fracture strengths of mandibular molar teeth prepared using TEC and CEC methods and restored using SDR (Dentsply Caulk, Milford, DE) and EverX Posterior (GC Dental, Tokyo, Japan) base composite materials	TEC+EverX Posterior CEC+EverX Posterior TEC+SDR CEC+SDR	CEC preparation did not increase the fracture strength of teeth with class II cavities compared with TEC preparation.
7.	Sabeti M et al., 2018 [6]	Iran	78	Effect of the access cavity design and taper preparation of root canals on ETT fracture resistance of maxillary molars.	1. Fracture resistance of CEC and TEC in one set of samples 2. Fracture resistance of 0.04 taper and 0.06 taper in a different set of samples	Increasing the taper of the root canal preparation can reduce fracture resistance. Moreover, access cavity preparation can reduce resistance; however, CEC in comparison with TAC had no significant impact.
8.	Present study	India	54	Compared the influence of two different access cavity designs and two different final preparation tapers on fracture resistance of mandibular molars	1. TAC and 0.04 Taper 2. TRUSS and 0.04 Taper 3. TAC and 0.06 Taper 4. TRUSS and 0.06 Taper.	The conservative Truss access design in combination with a reduced root canal taper preparation has shown to have produced better fracture resistance values in comparison to other groups and their subgroups although the results were not statistically significant

[Table/Fig-7]: Comparison of data of previous study with the present study [5,6,12,15-18].

statistically significant difference in fracture resistance of contracted/conservative cavities in comparison to TAC. The results of the present study is in accordance with these studies [5,6,12,15-18].

However, several other studies that followed to test this proposition such as Moore B et al., where CEC showed mean failure loads at (1703-558 N; range, 1205-3021 N) and TEC that showed failure loads at (1384-377 N; range, 966-2381 N) [12], Chlup Z et al., where mean failure loads for mandibular premolars where 1079.0±383.2 N for CEC and for TEC was 946.6±384.1 N, Ivanoff CS et al., (CEC-601.7±307.9 N and TEC- 600.9±360.3 N), Rover G et al., [18] (CEC-996.30-490.78 N and TEC 937.55-347.25 N), Corsentino G et al., (TEC 1149.8 N/mm^2 and TREC-1237.1 N/mm^2) and Ozyurek T et al., (CEC and TEC with class 11 cavities restored with Ever X Posterior and SDR (TEC+EverX Posterior-971.03±114.28 N, CEC+EverX Posterior -1008.25±216.83 N, TEC+SDR-1451.92±205.39 N, CEC+SDR- 1674.07±238.36 N), Sabeti M et al., (Conservative access cavity- 1705.691250 (591.51) N, Traditional access cavity-1471.113125 (435.34) N) did not report any statistically significant difference in fracture resistance of contracted/conservative cavities in comparison to TEC [5,6,13,16-19]. The results of the present study (Mean fracture resistance values expressed as break force-{TAC - 167.4 Kg and TREC - 184.8 Kg) are in accordance with these studies.

Similarly between Traditional 0.04 and 0.06 tapers and Truss 0.04 and Truss 0.06 tapers, 0.04 taper, in both groups has performed better than 0.06 taper but then again a statistically significant result could not be obtained because of smaller sample size.

With regard to the tapers 0.04 and 0.06 that was tested in the current study, studies by Sabeti M et al., and Zogheib C et al., have shown similar results and it was concluded by Sabeti M et al., that, increasing tapers 0.06 to 0.08 files increased stress in root dentine and reduces the fracture resistance[6,19].

Although previous studies have emphasised that the root canals are significantly weakened by instrumentation alone [20-22]. A study by Zandbiglari T et al., has shown that greater taper instruments greatly weaken the teeth [23]. The amount of remaining dentine thickness and its preservation impacts the resistance of prepared root canals to fracture is henceforth a serious consideration; however, the compromised efficiency of disinfection of root canals through such minimal access preparations cannot be overlooked.

Teeth like the mandibular molars are more prone to vertical root fracture [24] and severe tooth structure loss has been proposed as an important cause for tooth fracture [2,4,6].The conservation of tooth structure through newer access designs and minimal canal preparation with lesser tapers and maintaining smaller apical diameters had been the focus of the present study that aimed to incorporate the minimal invasive approach in endodontics [3,10].

Based on the results of the present study the null hypothesis is partially rejected as the intact control group (Group C) has shown statistically significant difference when compared to Traditional (0.04 taper), Traditional (0.06 taper), Truss (0.04 taper) and Truss (0.06 taper). However, although the Truss group (Group TREC) and its subgroups A and B were found to have mean values of fracture resistance slightly above the Traditional group (Group TAC) and its subgroups A and B, a statistically significant difference was not obtained, this could be attributed to smaller samples in each of the groups and their subgroups.

Limitation(s)

The limitations of the present in-vitro study are that exact oral conditions could not be simulated. Also, smaller sample size could have resulted in not producing a statistically significant difference between the test groups. Further studies with larger sample sizes and its application into clinical settings are necessary and recommended.

CONCLUSION(S)

Within the limitations of the present in-vitro study and based on the results, following conclusions can be drawn. There was a statistically significant difference between the intact teeth group and the two test groups and their subgroups. There was no statistically significant difference between the test groups and their subgroups. However, the conservative Truss access design in combination with a reduced root canal taper preparation has shown to have produced better fracture resistance values in comparison to other groups and their subgroups indicating a need for more studies to be carried out with larger sample sizes.

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