Scholars Journal of Dental Sciences (SJDS)
Abbreviated Key Title: Sch. J. Dent. Sci.
ISSN 2394-4951 (Print)
ISSN 2394-496X (Online)

A Unit of Scholars Academic and Scientific Society, India
www.saspublishers.com
DOI:10.36347/sjds.2018.v05i09.008

The Effect of Access Cavity Design on Fracture Resistance of Endodontically Treated First Molars: In Vitro Study

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Original Research Article

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Article History
Received: 02.09.2018
Accepted: 12.09.2018
Published: 30.09.2018

DOI:
10.21276/sjds.2018.5.9.8

Abstract: The aim was to evaluate in vitro the fracture strength of conservative versus traditional access cavity design in molar teeth. The null hypothesis tested was that there is no difference in fracture strength of sound molars, molars with conservative and those with traditional access cavities design. Sample size for maxillary and mandibular molars was calculated using Gpower software. Forty two extracted human intact maxillary and mandibular molars were assigned to Traditional Access Cavity (TAC), Conservative Access Cavity (CAC) and Sound Control groups (SC) (n = 7/group/type). TAC groups were prepared with pulp chamber de-roofing and straight line access. For CAC a soffit and pericervical-dentine were maintained. Working length was determined and canals were left un-obturated and mounted in self-cured acrylic resin molds of PVC for testing. Specimens were then tested with a compression testing machine and fracture force data were recorded in Newton for analysis. Data were normally distributed; therefore One-way ANOVA and post-hoc Tukey tests were used for analysis. The software R & R Studio were used for statistical analysis. Results showed the fracture load for CAC was significantly higher in mandibular molars (P Value = 0.0367250) compared to TAC groups. For maxillary molars fracture load for CAC was not significantly higher (P Value = 0.0951567) compared to TAC group. We concluded that Mandibular molars after preservation of pericervical dentine and soffit were found to have higher fracture strength compared to teeth with traditional straight line access.
Keywords: molars, access, cavity, endodontic, traditional, conservative, pericervical, soffit, dentine.

INTRODUCTION

The primary goal of endodontic treatment is the long-term preservation of a functional tooth by preventing or treating pulpal and periapical injuries [1,2]

Endodontically treated teeth have been found to have worse long-term survival than their non endo. treated teeth.[3] They are prone to failutre due to fracture more than other factors of failure. Fracture was found to be the main cause of extraction of endodontically treated teeth (59.4%), only 8.6% of the failures rate were due to endodontic causes [4].

The idea that endodontically treated teeth are significantly brittle than sound teeth and hence susceptible to fracture as a result of decreased moisture contents has been disproved by various studies. Helfer showed that the moisture content of dentine from endodontically treated teeth was about 9% less than their vital counterpart [5]. Others showed that there was no significant difference in the moisture content between endodontically treated teeth and vital teeth [6,7] indicating that endodontically treated teeth do not become more brittle as a result of intrinsic factors following treatment, suggesting that other factors may be more critical to failure.

It has been suggested that the most essential factor regarding the fracture resistance and survival of root-filled teeth is the amount of remaining dentine, and that endodontically treated teeth are more susceptible to fracture than sound teeth primarily because of internal tooth structure removal during endodontic therapy [8].

Traditional endodontic access cavity involves removal of much amount of dentine, coronaly to gain straight-line access to canals, and radiculary by over-flaring of canals orifices, which may weaken the tooth and increases its susceptibility to fracture and eventual extraction [9]. Moreover, in root canal and post preparation it was found that loss of coronal tooth structure to gain straight-line access has a significant loss of fracture resistance [10].

The emergence of Minimally Invasive Dentistry and the modern imaging devices, illumination and magnification have inspired the emergence of the recent conservative endodontic access cavity design. The trend is preserving sound dentine by avoiding de-roofing of the pulp chamber and avoiding over-flaring of canal orifices as well as avoiding aggressive dentine removal for shaping [11].

This study investigated the role of the access cavity design (traditional versus conservative) in relation to fracture strength in maxillary and mandibular first molars teeth.

The significance of the study may contribute to the scanty literature available on this subject, and also may throw light on regional and ethnical variations of dental microstructure in relation to fracture strength in molar teeth. The aim of this in vitro study was to assess and evaluate the effects of conservative endodontic access cavity design on fracture strength of extracted intact maxillary and mandibular first molars.

The hypothesis tested was that

The Null hyposthesis:

H0: It is true that $\mu_{sc} = \mu_C = \mu_T$

There is no difference in the mean load required to fracture sound molars, molars with conservative access cavity and molars with traditional access cavities.

The Alternative Hypothesis:

H1: it is not true that $\mu_{sc} = \mu_C = \mu_T$

- The mean load required to fracture intact molars is higher than that required for both root canal treated molars with conservative or traditional access cavities.
- The mean load required to fracture molars with conservative access cavities is higher than that required for molars with traditional access cavities.

MATERIALS AND METHODS

Sample size Calculation/Estimation

Studies of the same design comparing fracture strength for traditional access cavity (TAC) and Conservative access cavity (CAC) were rare, so semi-similar studies that used molars as sound control (SC) groups were selected to calculate the effect size, so as to calculate a sample size.

From these studies [12-15] an effect size of (0.75) was calculated. Gpower software Version 3.1.9.2 [http://www.gpower.hhu.de/en.html] was used to calculate the sample size for mandibular molars and maxillary molars for this study:

Effect size = 0.75
Power = 80%
Significance level = 0.05
Number of groups = 3

We had got a calculated total sample size of 21 for each type (21 mandibular molars and 21 maxillary molars: (N=21/type) for each tooth type, and (N=7/group) for each TAC, CAC and SC groups. (Figure_1).

F tests – ANOVA: Fixed effects, omnibus, one-way

Analysis:	A priori: Compute required sample size	
Input:	Effect size f	= 0.75
	α err prob	= 0.05
	Power (1-β err prob)	= 0.80
	Number of groups	= 3
Output:	Noncentrality parameter λ	= 11.8125000
	Critical F	= 3.5545571
	Numerator df	= 2
	Denominator df	= 18
	Total sample size	= 21
	Actual power	= 0.8134127

Fig-1: screen shot of Gpower sample calculation

Sample Collection

Samples were collected from multiple hospitals and dental centers in Khartoum, Sudan. Twenty one extracted human, mature, intact, mandibular first molars, another twenty one maxillary first molars were included in this study: 21 molars (N = 21/type) were assigned to TAC, CAC and SC groups (N=7/group). Teeth were selected almost equally comparable in size and anatomy and randomly assigned to each group.

Preservation and Storage

After debridement and removal of staining, calculus, and attached soft tissue with hand scaling instruments, the teeth were stored in 10% formalin (Trust chemical laboratories/India) until used, and between preparation and testing for fracture strength teeth were stored in distilled water to prevent dehydration.

Specimen Preparation

To standarise preparation and to minimise confounding factors and variables; all preparations were carried out by one operator (the author), as well as caliper and paper clips were used to standarise cavity dimension for preparation.

The endodontic cavities were drilled with tapered high-speed diamond burs and a pathway to the pulp space and the canal orifices achieved, the pathway was unimpeded and unobstructed for TAC group to create straight-line access.

Conventional coronal flaring for TAC and minimal flaring for CAC was used to open canals orifices and enlarge the coronal aspect of the root canal.

Irrigation with sodium hypochlorite 2.5% was used thoroughly between each instrument change and throughout canal preparation, using a 30 gauge needle.

Working length was determined visually using ISO size 10 K-file to negotiate canals to full working length and then the apical part of canals was negotiated with a series of progressively increasing size hand K-files #15 and #20, 25 and 30.(Manikin, Tochigi, Japan).

Balance-force action was used to create a pathway to working length and canal preparation continued in sequence until #25 apical size achieved for mesial canals of mandibular molars and maxillary molars. Distal canals of mandibular molars and palatal canals of maxillary molars were negotiated to working length of #30 sizes.

Traditional Access Cavity (TAC) preparation guidelines

External outline form was established projecting the internal anatomy of the pulp onto the external surface, by complete deroofing of the pulp chamber to gain straight line access to canals orifices [16].

The convenience form used was to allow for unobstructed access to the canals orifices, direct access to the apical foramen, cavity expansion to accommodate filling techniques, and cavity enlargement to have control on instrumentation and obturation (Figures_2, _3).

For maxillary molars, access was made in the mesial fossa without involving the distolingual cusp and was kept mesial to the oblique ridge. Access cavities had a rhomboid shape to allow for locating MB-2, and were not extended into the mesial marginal ridge and they were widest buccolingually.

For mandibular molars, the entry point used was just mesial to the central pit with access cavity located in the mesial half of the tooth to create straight line access for the mesial canals. The distal extension was allowed to gain straight line access to the distal canals.

Conservative Access Cavity (CAC) preparation guidelines

Clark and Khadem conservative access model was used as a general guide [8]. Coronal access preparation objective used was to remove as little tooth structure as necessary to locate canals orifices and to maintain a soffit which has been defined as a small piece or tiny lip of dentinal roof of 0.5-3.0 mm around the entire pulp chamber[8].

Access was accomplished by cutting near functional cusps, while staying 1-2 mm away from non-functional cusps, and the distal half of the occlusal surface was avoided [11].

Radicular apical preparation was just wide enough to clean canals and remove the biofilm, without aggressive dentine removal for shaping. (Figures _2, _3)

Fig-2: Prepared Mandibular Molars

Flaring of canals orifices that connects the coronal to the apical preparations was kept to minimal to preserve the pericervical dentine which is defined as an area roughly 4 mm coronal to crestal bone and 6 mm apical to crestal bone [17].

In this study design canals were left prepared without obturation, contrary to normal clinical setting. This is to eliminate and exclude confounding variables such as types, methods and efficiency of obturation and restorations [13].

Fig-3: Prepared Maxillary Molars

Specimen mounting and loading for test

All teeth including the sound control groups, after instrumentation were mounted on polyvinyl chloride (PVC) cylinders (25 mm diameter x 25 mm height), with the roots embedded in self-curing resin (Acrostone, England) 3 mm apical to the cemento-enamel Junction to simulate the alveolar bone level (Figures _4, _5,).

Fig-4: Mandibular Molars embedded in self-cure resin for Testing

The resin was mixed according to the manufacturer's instructions and was inserted in the PVC cylinders immediately after mixing, and then the teeth were centrally-positioned with the long axis of the tooth parallel to the PVC cylinders walls.

The PVC molds were adjusted to place the loading arm of the testing machine over the center of the cavity preparation, with the load applied to the occlusal inclines of the buccal and lingual cusps vertically down the long axis of the tooth.

Fig-5: Maxillary Molars embedded in self-cure resin for Testing

All teeth were then subjected to gradual continuous nondestructive occlusal loading until failure, in a servohydraulic compression testing machine (Avery compression machine, UK), at the Material Lab Tesing, civil engineering department, College of engineering, University of Khartoum, Sudan.

Failure was defined as a 25% or more drops in the applied load and this was noticed to be frequently preceded by a crack sound (Figure 6).


Fig-6: A sample tooth loaded for testing

The force required to fracture each tooth was then recorded in Kilo force and later converted to Newtons for statistical analysis.

STATISTICAL ANALYSIS

The sample data in each tooth type (mandibular molars, maxillary molars) were evaluated for normality distribution and was found to be normally distributed or at least with few skewness using "Shapiro-Wilk normality test" (Figures _7, _8,), and therefore the parametric tests (one-way ANOVA and post-hoc Tukey tests) were justified to compare data between groups and within groups.

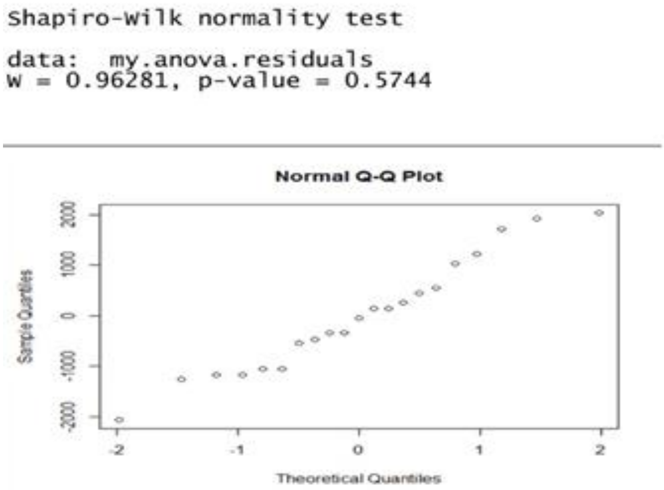

Fig-7: Mandibular Molars Group Normality Test

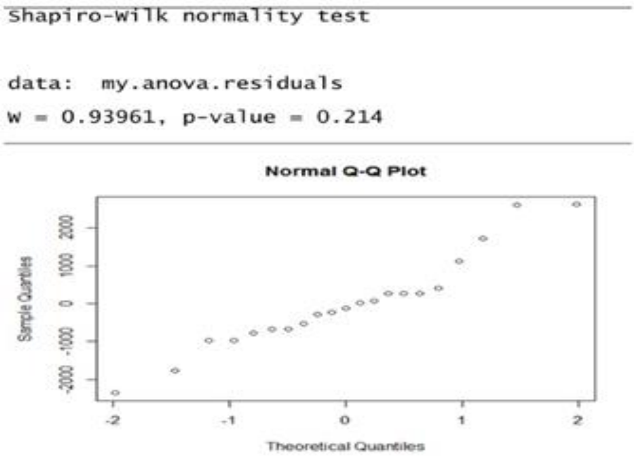

Fig-8: Maxillary Molars group Normality Test

The mean fracture load values in Newton were calculated for both tooth type in groups TAC, CAC and SC sound control group. All tests were two-tailed and interpreted at the 5% significance level.

The software R & Rstudio for statistical computing and graphics were used for statistical analysis and for most of the graphics in this study.

RESULTS

The mean fracture load was highest in the maxillary molars across the two teeth types (maxillary versus mandibular).

Mandibular molars findings

Fracture strength of CAC *was statistically significantly higher* in mandibular molars (P Value = 0.0367250 < 0.05) compared to TAC groups, without differing significantly from the sound control groups. (Table 1,3 and Figure_9).

Table-1: Fracture load (mean & STD) for mandibular molars groups

Fracture strength in Newton	TAC	CAC	SC	P Value (One way ANOVA)	Post-hoc Tukey test P Values
Mean	1537.714	3260.571	3844.571		SC-CAC 0.6366993 TAC-CAC 0.0367250 * TAC-SC 0.0052510 **
ST. Deviation	±429.9309	±1600.579	±1228.786	0.00534 **	

* Indicates statistical significance, ** indicates highly statistical significance
Shows the P Values in ANOVA and Tukey multiple comparisons of means

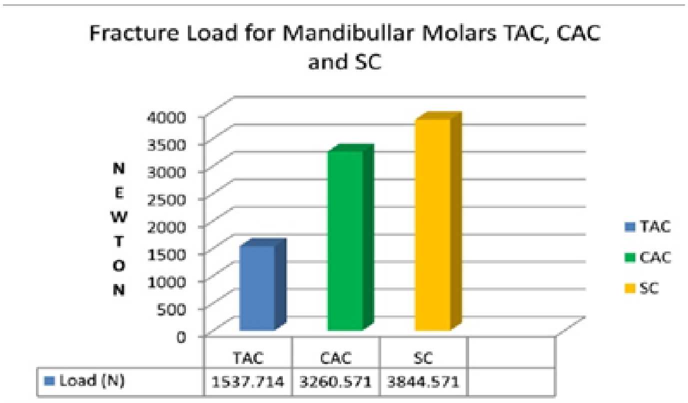

Fig-9: Fracture Load for Mandibular Molars Group

Among mandibular molars; fracture pattern in both TAC and CAC groups was either complete crown breakage or wall fractures extending to and below the cemento-enamel Junction.

Maxillary molars findings

A- There was *no statistically significant difference* in fracture strength between CAC group (3374.429 ±1263.884 N) and TAC group (1822.571 ±308.246 N) with a P Value = (0.0951567) > 0.05.

B- Fracture strength of CAC (3374.429 ±1263.884 N) *did not differ significantly* from that of the SC control group (4357.000 ±1857.468 N) with a P Value = (0.3598322) > 0.05.

C- Fracture strength of TAC (1822.571 ±308.246 N) was *significantly lower* than that of SC control group (4357.000 ±1857.468 N) with a P Value = (0.0052701) < 0.05. (Tables 2,3 and Figure_10).

Among TAC group complete crown breakage and fracture extending to and below the cemento-enamel junction was observed. Among CAC group crown breakage as well as wall fractures were observed.

Table-2: Fracture load (mean & STD) for maxillary molars groups Shows the P Values in ANOVA and Tukey multiple comparisons of means

Fracture strength in Newton	TAC	CAC	SC	P Value (One way ANOVA)	Post-hoc Tukey test P Values
Mean	1822.571	3374.429	4357.000		SC-CAC 0.3598322 TAC-CAC 0.0951567 TAC-SC 0.0052701 **
ST.Deviation	±308.246	±1263.884	±1857.468	0.00681 **	

** indicates highly statistical significance

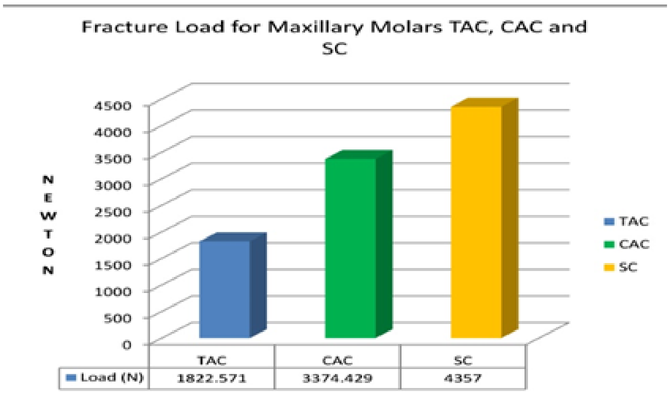

Fig-10: Fracture load for Maxillary Molars group

Table-3: Fracture load (mean and STD) for Mandibular and Maxillary Molars groups prapared with TAC, CAC access cavities

Tooth Type	Mean fracture load in Newton		
	TAC (Traditional)	CAC (Conservativs)	SC (Sound Control)
Mand.Molars (N=7)	1537.714 ±429.931 r	3260.571 ±1600.579 R	3844.571 ±1228.786 R
Max.Molars (N=7)	1822.571 ±308.25 a c	3374.429 ±1263.88 c B	4357.00 ±1857.47 AB

Similar letter case indicates nonsignificant differences (P >0.05); different letter case indicates a significant difference (p < 0.05).

DISCUSSION

This in vitro study was undertaken to assess the fracture strength of extracted intact human maxillary and mandibular molars with conservative access cavity (CAC) compared to those with traditional access cavity (TAC) using counterpart sound teeth as control groups (SC).

This study showed that

Fracture strength of CAC was statistically significantly higher in mandibular molars (P Value = 0.0367250) compared to TAC groups, without differing significantly from the sound control groups.

There was no statistically significant difference in fracture strength between CAC group and TAC group in maxillary molars with a P Value of (0.0951567).

Fracture strength of Maxillary Molars CAC group did not differ significantly from that of the SC control group with a P Value of (0.3598322), whereas that of the TAC group was statistically significantly lower than the control group with a Pvalue (0.0052701).

Root-canal treated teeth are more susceptible to fracture than sound teeth essentially due to dentinal tooth structure removal during endodontic therapy [2, 8, 9].

The emergence of minimally invasive dentistry [18, 19] has led to the recent concept of conservative endodontic access cavity; the aim is to preserve sound dentine by avoiding un-roofing of the pulp chamber and avoiding over-flaring of canal orifices as well as avoiding aggressive dentine removal for shaping [20].

This trend to cut smaller-sized access cavities was influenced by the use of the operating microscope, lighting and magnification, highly flexible instruments and better imaging devices such as CBCT and micro-CT [21].

This new philosophy of conservation discourages the use of Gates-Glidden burs and large round burs so as to avoid walls gouging and loss of precious dentine, especially around the Pericervical dentine where it acts as a buttress against structural flexure and ultimate fracture.

Generally minimally invasive endodontics concepts are resisted due to risks of minimal cleansing and removal of biofilm, more time and effort required and not yet an in-vivo clinical evidence that it increases fracture strength [22].

In our study, the results for mandibular molars are consistent with previous work of Krishan R. *et al*. 2014 [13] for mandibular molars and also in agreement with Plotino G. *et al*. 2017 [23] who found fracture load was significantly higher for CAC group in all posterior teeth including maxillary molars.

The current study results for maxillary molars are consistent with the findings of Moore B *et al*. 2016 [24] and Rover G. *et al*. 2017 [25] studies, both have shown no differences in fracture strength of maxillary molars accessed with TAC compared to CAC. Our results for maxillary molars are also in agreement with a recent study [26] which found CAC, compared with TAC had no significant effect on fracture resistance. Interestingly, the study [26] found that increasing the taper of canal preparation can reduce fracture resistance in maxillary molars.

These findings could be supported with the observation that endodontically treated maxillary molars have a lower incidence of fracture than mandibular molars [27].

The shape and size of the access opening is governed by the extent of caries or previous restorations, and the CAC model may appear inappropriate, but CAC model even if applied partially may increase the fracture strength of endodontically treated molars.

When the interproximal caries reaches the CEJ and/or the DEJ with loss of pericervical dentine, restorative materials such as bonded composite resins were shown to restore fracture strength of teeth up to 72% of that of intact teeth [28].

Clinically, the main challenge for conservative access cavity in molar teeth is the accessibility to the treated tooth, as any limited accessibility would deem full conservative access difficult if not impossible.

CONCLUSION

A balance is required between cleaning and preserving tooth structure and if tooth condition permits, preservation of per cervical dentine, avoidance of aggressive flaring and retaining even some soffit as practically as possible needs to be taken into consideration. It worth noting that in-vitro microbiological studies do not yet show a definitive answer of a certain required preparation size and taper that achieves antimicrobial efficacy.

In conclusion, in this in-vitro study; preserving dentine coronaly (soffit) and cervically (pericervical dentine) increased the fracture strength significantly in mandibular molars prepared with CAC model whereas there was no statistically significant difference in fracture strength between conservative access cavity (CAC) and traditional access cavity (TAC) models in maxillary molars.

ACKNOWLEDGEMENTS

We thank Dr. Hashim Khalid (Orthodontist) of National Ribat University & Al-Mazen dental center, Dr. Isra of AL-Rakha hospital of Omdurman, Dr. Mohammed of Omdurman teaching hospital and sister Nafissah of Haj Al-safi Health center for their assistance in collecting the specimens. We wish to acknowledge and thank Prof. Magdey and Eng. Yahyah of Civil Engineering Department, College of Engineering, University of Khartoum for their assistance in carrying out the tests.

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