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Original Research Article

Cone Beam Computed Tomographic Evaluation of Fracture Strength of Maxillary Molars with Three Different Access Cavity Designs. - An Invitro Study

G.Sudharsan[1], K. Palani Selvi[2], Vidhya Raguganesh[3], P. Hemalatha[4]

[1] MDS, Conservative Dentist and Endodontist, Private Dental Practitioner, Paramakudi, Tamil Nadu, India
[2]MDS, Conservative Dentist and Endodontist, Madurai, Private Dental Practitioner , Madurai,Tamilnadu, India
[3]BDS, Private Dental Practitioner, Chennai,Tamilnadu, India
[4] MDS, Head of the Department of Conservative Dentistry and Endodontics, Best Dental College, Madurai, Tamilnadu, India

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Corresponding author: Dr. G.Sudharsan
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Abstract

Aim: To evaluate the fracture strength of endodontically treated extracted maxillary molars with three different access cavity designs– Traditional Endodontic Cavity (TEC), Conservative- “TRUSS” Endodontic Cavity (CEC) and Ultra conservative “NINJA” Endodontic Cavity (NEC)access preparations and to correlate it to the volume percentage of enamel and dentin removed which was measured using Cone Beam Computed Tomography.

Materials And Methods: Sixty intact human maxillary molars extracted for periodontal reasons were selected and the samples were randomly grouped (n= 20) into Group I – Traditional (TEC), Group II – Conservative (CEC) and Group III - Ninja (NEC) endodontic access cavities. All the tooth samples were subjected to a Pre- operative CBCT imaging (NEWTOM cone beam computer tomography). Using Digital Imaging and Communications in Medicine data (DICOM) software the total enamel and dentin crown volume for each tooth were calculated. Then, access cavities of all teeth were prepared in respected groups and then subjected to a post-operative CBCT imaging. The volume percentage of coronal enamel and dentin removed by the 3 access cavity preparations were calculated using DICOM software again. The biomechanical preparations and obturation were done, followed by a post-endodontic coronal restoration with light cure composite resin. The samples were then tested for the fracture resistance using the Instron Universal Testing Machine. The loads at which the tooth crowns were fractured were recorded in Newtons. The data obtained were statistically analyzed.

Results: The results showed that as the Volume of the tooth structure removed during the cavity preparation is inversely proportional to the fracture resistance of the teeth. Hence the Group III NEC group showed statistically significant mean difference values with minimal loss of volume % of tooth structure removed (7.92%),suggesting that this can influence positively in the increase in fracture resistance (1403.08 N) of the tooth following a coronal restoration.

Conclusion: Within the limitations of this study it can be concluded that the Group III Ultra-conservative ”NINJA” access showed increased fracture resistance of endodontically treated maxillary molars with the least mean volume percentage of tooth structure removed when compared to TEC and CEC groups.

Keywords:
Traditional Access cavity, Truss access, Ninja access, Cone beam computed tomography, Post-Endodontic Restoration, Fracture resistance.

Introduction

The endodontic triad consists of biomechanical preparation, microbial control and complete obturation of the canal space[1]. The importance of access cavity preparation is to facilitate straight – line access which describes a preparation that provides a straight or outwardly flared, unimpeded path from the occlusal surface to the apex[2]. Recently, Clark and Khademi modified a new model of endodontic access cavity design, focusing on the minimal removal of tooth structure and this was known as the conservative endodontic access cavity design[3]. The orifice directed design is also known as the 'Truss' access cavity. It is an approach to conservative access cavity where separate cavities are prepared to approach canals. In maxillary molars, the mesio and disto buccal cavities are been approached in one cavity and another separate cavity for the palatal canal. The aim of preparing such conservative cavities is to preserve the dentin i.e., leaving a truss of dentin between the two cavities that has been prepared[4]. For Ninja access cavity outline oblique projection is made towards the central fossa of the root orifices in an occlusal plane. This endodontic access is parallel with the enamel cut of 90º or more to the occlusal plane, it is easier to find the root canal orifices even from the different visual angulations[5]. A cone beam computed tomography technology can guide better the conservative and ninja preparation by providing relevant information for pre – access analyses[6].

Materials and Methods:

Sixty intact human maxillary molars extracted for periodontal reasons were selected. The selected teeth were cleaned and disinfected using 5.25% sodium hypochlorite for 10 minutes and rinsed with distilled water. The samples were randomly grouped into 3 groups (n= 20) according to the access cavity design (Fig. 1) as follows: Group I - Traditional endodontic access cavity (TEC), Group II - Conservative endodontic access cavity (CEC), Group III -Ninja endodontic access cavity (NEC) and were mounted in a custom- made wax rim. (Fig. 2)

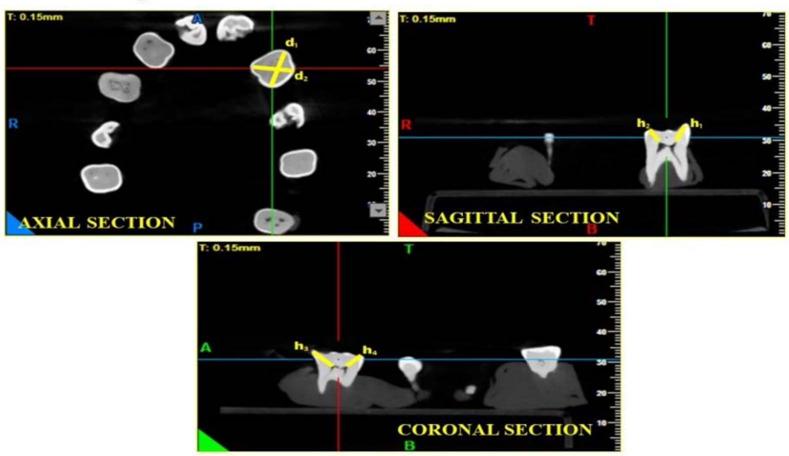
Figure 1: - RANDOMIZATION OF SAMPLES

Figure 2: CBCT MODELS

Pre operative imaging was done with the NEWTOM cone beam computer tomography (CBCT). Using Digital Imaging and Communications in Medicine data (DICOM) software the total enamel and dentin crown volume for each tooth were calculated. (Fig. 3)

- Using diagonals method, the volume of tooth crown was measured by area of crown multiplied by height of crown.
- To determine the area of crown , the length of diagonal($d_1 \times d_2$) was measured in axial section divided by 2.
- To determine the height of crown, the average height of crown was measured from cusp tip to the pulp chamber roof in sagittal section and coronal section.

Figure 3: PRE – OPERATIVE CBCT MEASUREMENT



Traditional (TEC), Truss (CEC) and Ninja (NEC) cavity accesses of all teeth were prepared by the same operator with Endo Access bur mounted on a high- speed handpiece under water cooling. The Traditional (TEC) access cavity preparation was usually triangular, with round corners extending toward, but not including, the mesiobuccal cusp tip, marginal ridge and oblique ridge. This triangular preparation permits direct access to the root canal orifices. In Truss (CEC), the slot and oval cavities were performed over the buccal and palatal canal of the tooth, respectively, guided by the computed tomographic images. The pulp chamber roof was maintained beneath the truss of the tooth structure in this group, between the buccal and palatal cavities. In Ninja (NEC), molar teeth were accessed in the same way as the teeth in the Truss (CEC) group, but the chamber roof was maintained as much as possible. The ninja access outline was derived from the oblique projection toward the central fossa of the root canal orifices on the occlusal plane. By doing this, localization of all the root canal orifices was possible even from axial, coronal and sagittal visual angulations because the endodontic access was parallel with the enamel cut at 90º or more to the occlusal table. The extension was equally balanced between the mesiobuccal, distobuccal and palatal orifices. (Fig.4)

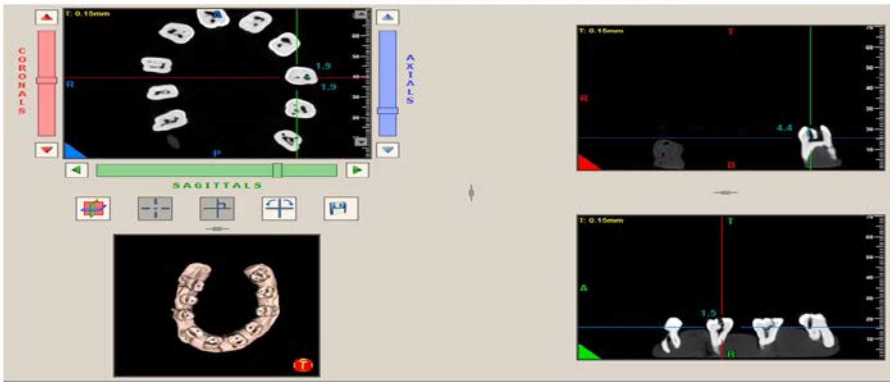
Figure 5: POST – OPERATIVE CBCT MEASUREMENT:

Once the access preparations were completed, the teeth samples in the TEC, CEC and NEC groups were subjected to post-operative CBCT imaging. (Fig. 5) The percentage of volume of coronal enamel and dentin removed by TEC, CEC and NEC access cavities were calculated using DICOM software.

- In **TEC group,** volume of coronal tooth structure removed calculated using the formula $\mathbf{d_1 \times d_2 \times h}$, where d_1 and d_2 were access cavity diagonals measured in the axial section, h was the access cavity height measured in coronal section
- In **CEC group**, volume of coronal tooth structure removed calculated using the formula $\mathbf{(d_1 \times d_2 \times h) + (2d \times h)}$. In buccal cavity $d_1 \times d_2 \times h$ was calculated similar to that with the TEC group (Fig 11). In circular
- palatal access cavity **2d × h** calculated, where d was diameter of the palatal access cavity measured in sagittal section and h was height of the access cavity measured in coronal section
- In **NEC group,** volume of coronal tooth structure removed calculated using the formula $\mathbf{(2d \times h)_1 + (2d \times h)_2 + (2d \times h)_3}$ where d was diameter of access cavity measured in sagittal section and h was height of access cavity measured in coronal section. $(2d \times h)_1$ were calculated from mesiobuccal access cavity, $(2d \times h)_2$ were calculated from distobuccal access cavity and $(2d \times h)_3$ were calculated from palatal access cavity
- The **volume percentage of coronal enamel and dentin removed** in TEC, CEC, NEC

were calculated using formula:**(Reduction of tooth \ total volume of tooth) × 100**

Figure 5: POST – OPERATIVE CBCT MEASUREMENT:



The biomechanical preparation was done under copious irrigation with sodium hypochlorite, normal saline and EDTA solution. The canals were dried with paper points and obturated with single-cone gutta-percha and zinc oxide eugenol sealer. The access cavities were cleaned and etched with 37% phosphoric acid for 15 seconds and rinsed for 20 seconds with a water/air spray and gently air dried to avoid desiccation. A light-polymerizing primer bond adhesive [3M ESPE Scotchbond™ Universal Adhesive] was applied, gently air thinned and exposed to light-emitting diode polymerization for 40 seconds and restored with direct composite resin [Swiss TEC] which was added in increments and cured for 40 seconds (Fig 6

Figure 6 : CORONAL COMPOSITE RESTORATION

The roots were embedded in acrylic resin block upto the level of CEJ (Fig 7a) and mounted in the Instron Universal Testing Machine.The teeth were loaded at their central fossa at a 30° angle from the long axis of the tooth.(Fig 7b).

Figure 7 a: TOOTH EMBEDDED IN ACRYLIC RESIN BLOCK FOR FRACTURE RESISTANCE TESTING

Figure 7 b: INSTRON UNIVERSAL TESTING MACHINE

The continuous compressive force at crosshead speed of 0.5 mm\min was applied using a 5 mm diameter ball ended steel compressive head. The loads at which the teeth were fractured (Fig 8A, B, C), indicated by the software of the load testing machine, were recorded in Newtons. All the data were tabulated and analyzed statistically.

Figure 8: FRACTURE PATTERNS OF 3 GROUPS

TEC (A) – Unrestorable fracture CEC (B) – Restorable fracture NEC(C) – Restorable fracture

Results:

The inter group comparison of the mean values of fracture resistance and volume percentage of the tooth structure removed during different access cavity designs were assessed using Repeated Measures ANOVA followed by Post- Hoc Bonferroni test for pairwise comparison. Statistically significant differences were expressed by non overlapping 95% confidence intervals.

1. Repeated Measures ANOVA:

Table: 1 Fracture Resistance (Newtons)

Groups	N	Mean (Newtons)	Std Deviation
I-Traditional	20	815.35	64.34
II-Conservative	20	1099.06	57.98
III-Ninja	20	1403.08	45.066

- From Table -1 it is evident that there is a significant difference ($p < 0.005$) between the fracture resistance values measured from three different methods of access cavity preparation. Group III NEC showed significantly higher mean fracture resistance (1403.08N)when compared to the other two groups. Group II CEC showed mean fracture resistance value (1099.06N) which showed statistically significant difference with TEC and NEC groups.Group 1 TEC showed the lowest fracture resistance mean value (815.35N) when compared to the other two groups.

Among the experimental groups, the highest fracture strength was observed in Group III – Ninja Endodontic Cavity (NEC) restored using the resin composite material. These results showed that improved fracture strength of teeth in the NEC group(1403.08N), because of dentin preservation obtained by cavity size reduction.

Table: 2 Volume Percentage (%)

GROUPS	N	MEAN (%)	STD DEVIATION
I-Traditional	20	36.85	6.28
II-Conservative	20	16.56	4.21
III-Ninja	20	7.92	1.69

- Table 2 showed that there is a significant difference in the volume percentage of the tooth structure removed among the three groups with p -value < 0.005.Group -III NEC showed the least mean volume percentage value (7.92%),from which it is evident that this cavity design resulted in minimal tooth structure removal. Whereas the mean volume percentage of Group- II CEC (16.56%) followed by Group- I TEC with highest mean volume percentage value (36.85%) showing maximum tooth structure removal among the three groups.

This results clearly explains that as the Volume of the tooth structure removed during the cavity preparation decreases, the fracture resistance of the teeth increased. Hence the NEC group showed minimal loss of volume of tooth structure (7.92%),suggesting that this can influence positively in the increase in fracture resistance of the tooth following a coronal restoration.

2. **Post-hoc Bonferroni test:**

Table 3: Pairwise Comparison – Fracture Resistance

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.[b]
	II	283.707*	22.291	.001
	III	587.730*	20.828	.001
II	I	283.707*	22.291	.001
	III	304.024*	16.200	.001
III	I	587.730*	20.828	.001
	II	304.024*	16.200	.001

- From Table 3 it is evident that on comparison with Group I TEC and II CEC, the mean fracture resistance values of Group III NEC showed statistically significant (p=0.001)mean difference values. (Group III – I = 587.730N and Group III – II = 304.024N).
- Also Group II CEC showed a statistically significant (p=0.001)mean fracture resistance value on comparison with Group I TEC (283.707N) and Group III NEC (304.024N).
- It is also evident that Group I TEC showed very significant difference in the mean fracture resistance values on comparison with NEC (587.730N) and CEC (283.707N)
- Hence it is clear that Group-III NEC showed the highest mean fracture resistance when compared to TEC and CEC groups.

Table 4: Pairwise Comparison – Volume Percentage

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.[b]
	II	20.28*	1.928	.001
	III	28.94*	1.627	.001
II	I	20.28*	1.928	.001
	III	8.65*	.923	.001
III	I	28.94*	1.627	.001
	II	8.653*	.923	.001
*. The mean difference is significant at the .05 level.				

- Table 4 shows that the mean volume percentage values of Group III NEC are statistically significant (p=0.001) on comparison with Group I TEC and II CEC.

(Group III – I = 28.94%) and Group III – II =8.653%).

- Hence it is evident that Group-III NEC showed the least mean volume percentage of tooth structure removed when compared to TEC and CEC groups.
- Mean Volume of the tooth structure removed was significantly smaller (p<0.005) for NEC followed by CEC than for TEC.

The ultraconservative NEC access improved the fracture resistance of teeth. Moreover, restored CEC and NEC did not reduce the fracture strength, but they did influence the fracture pattern of TEC.

Discussion:

The emerging concept of conservative and ultra conservative endodontic access is a shift to transform the outline of the endodontic cavity from a traditional operator-centric design to a scheme that focuses more on dentin preservation and the endodontic-restorative interface[7]. The traditional requirements of straight-line access and complete unroofing of the pulp chamber while emphasizing the importance of preserving the crucial pericervical dentin. This regional dentin is significant for the distribution of functional stress in teeth. It is thus necessary to conserve pericervical dentin as much as possible to maintain the biomechanical response of the radicular dentin. A soffit is described as the underside of an architectural feature such as ceiling, the corner of the ceiling, and the wall. The long-term strength attributes of dentin preservation and provide some degree of structural bracing, which in turn would minimize cuspal flexure during chewing[8].

The CBCT Guidelines for conservative and Ninja endodontic cavities are:

1. The goal of the three-dimensional image assessment is to preclude clinically exploring the anatomy by removing dentin structure while focusing on the actual anatomy and practicing a precise approach for dentin conservation.
2. Three-dimensional imaging is used to provide a detailed assessment of the root canal and root anatomy via a high-definition localized CBCT scan

It is used to determine the number of roots, canals, sizes, curvatures and characteristics in order to establish a customized strategy with which to approach the canal anatomy in the most conservative way[9].

Burns stated the maxillary first molar to be “the frequently treated, minimally apprehended, posterior teeth” (**Gaba et al 2019**)[10]. The use of mature, intact maxillary molars was a priority to avoid the effects of varying degree of tooth structure loss (**moore 2016**)[11]. In this regard, this study sought to evaluate and compare the fracture resistance of endodontically treated teeth in traditional, truss and ninja approaches of access cavity preparation. Because the available data on fracture resistance of maxillary molars are lacking (**sabeti et al 2018**)[12] and most of the documented fracture resistance studies were done on premolars or mandibular molars. Maxillary molars were selected for the study as these are the second most common teeth affected by caries and are the main teeth responsible for chewing action (**aposa et al 2017**)[13]. This study assessed the influence of different access cavity design with CBCT and measured the effect of coronal tooth loss on fracture resistance in maxillary molars.

Access cavities were restored with bonded resin composite to stimulate clinical procedures and facilitate loading test (**moore**

et al 2016)[14]. A 30° inclination angle was used because teeth are most vulnerable to fracture when eccentric forces are applied, reaching the failure point at lower loads when compared with the axial fracture loads (**platino et al**)[15]. The continuous compressive force at a crosshead speed of 0.5mm\min was applied using a 5mm diameter ball-ended steel compressive head and were loaded at their central fossa from the long axis of the tooth. The load at which the teeth were fractured, indicated by the software of the load testing machine, were recorded in newtons.

Fracture pattern were classified as 'restorable' when the failures were above the level of bone simulation (site of fracture above the acrylic resin) and 'unrestorable' when the failures were extending below the level of bone simulation (site of fracture below acrylic resin) (**platino et al**)[15]. In this study TEC shows unrestorable fractures, CEC and NEC shows restorable fractures. The restorable fractures were significantly higher than the unrestorable fractures in CEC & NEC, whereas the unrestorable fractures was higher than the restorable ones in TEC. No difference was observed for the CEC and NEC groups.

A proper and reduced endodontic access design could improve the prognosis of an endodontically treated teeth. However, **David Clark and Khademi (2010)**[16] have modified traditional access cavities and these designs are been advocated to minimize the tooth structure removal. Conservative endodontic cavity and ninja endodontic cavity were proposed to reduce the fracture risk in endodontically treated teeth. Indeed, clinically these approaches can mainly be performed on intact teeth that are going to be treated endodontically.

Truss and Ninja access approaches mainly emphasize on the preservation of the healthy tooth structure with the minimally invasive approach. Complete justification with this concept can be done only if the root canal treatment is attempted after CBCT evaluation. In our study the volume percentage of the tooth structure removed in TEC group (36.85%) were significantly higher than CEC group (16.56%) and NEC group (7.92%). Indeed, the analysis of cone beam computed tomography images revealed that the volume of dentin removed was significantly smaller in the teeth with ninja access cavity preparation. This pattern of dentin conservation was in accordance with the suggestion that pericervical dentin should be preferentially conserved to buttress the teeth.

Restoration of endodontic access cavity may restore the fracture strength of teeth up to 72% of that of intact teeth (**platino et al**)[15]. In recent years, minimally invasive dentistry is a paradigm shift towards an unwavering, systematic respect for original tissue and considerable technical competence. The main objective is 'Restriction with conviction" and recognizes that caries is not cured by restorations and that cavities weaken the tooth. Because no restorative material or technique can overcome lost dentin biomaterial, especially in key areas of tooth, treatment steps directed towards dentin conservation are essential as the primary means to buttress the root-filled teeth. The results of present study showed higher fracture resistance in NEC (1408.08 N) followed by CEC (1099.06 N) and significantly lower in TEC (815.35 N).

Conclusion:

Within the limitations of this study it can be concluded that the **Ultra-conservative "NINJA" endodontic access cavity design** showed increased fracture resistance of endodontically treated maxillary molars with the least volume percentage of tooth structure removed when compared to conservative-

Truss endodontic access cavity design and traditional endodontic access cavity design.

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