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Comparison and evaluation of fracture resistance of endodontically treated teeth with different access cavity designs: An in-vitro study

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Abstract

Aim: Aim of the study was to compare and evaluate the fracture resistance of endodontically treated teeth with different kinds of access cavity preparation designs.

Methodology: Eighty freshly extracted, human mandibular molars were selected. Different access cavities were prepared ,they were divided into following groups : (n=20)

GROUP 1 Control group

GROUP 2 Traditional endodontic access cavity preparation

GROUP 3 Ninja endodontic access cavity preparation

GROUP 4 Truss access cavity preparations

Working lengths were recorded and canals were prepared till size F2 for mesial and F3 for distal canals (Pro Taper Dentsply Maillefer, Ballaigues, Switzerland). The canals were dried and filled using

gutta-percha (F2 for mesial canals and F3 for distal canals) and a resin-based sealer (AH Plus; Dentsply De Trey, Konstanz, Germany) and was restored with Glass Ionomer cement (GIC) (GC Inc.). Fracture resistance was evaluated for the teeth using a Universal Testing Machine (UTM). One-way ANOVA and one-way Tukey HSD test were utilized for the comparative analysis of the groups and significance level was set at 0.01.

Results: Group 3 Ninja endodontic access cavity preparation displayed significantly greater values of fracture resistance as compared to other groups.

Conclusion: Increased fracture resistance of endodontically treated mandibular molars was demonstrated by Ultra-conservative "NINJA" endodontic access cavity design.

Keywords: Access cavity preparation; Fracture resistance; Mandibular molar; Ninja endodontic access; Truss endodontic access.

Introduction

Access cavity preparation is a vital part of successful endodontic treatment. Only minor modifications in the traditional endodontic cavity (TEC) design have been made over the past several decades[1]. However, the removal of the tooth structure required for access preparation may undermine the resistance of the tooth to fracture under functional load. Endodontically treated teeth often fracture thus, requiring extraction, which is not pleasant for the patient as well for the clinician[2]. Recently, a great deal of effort has been laid on preservation of some of the chamber roof and the peri-cervical dentine so as to minimize tooth structure removal as much as possible and this concept is termed as conservative endodontic cavity (CEC) preparation[3]. Apart from these, one more conservative approach that has come up, is the Truss access, wherein both the mesial and distal canal orifices are exposed through individual direct accesses from the occlusal surface and the intervening dentin is left intact[4]. Furthermore, an extremely conservative approach has been recently reported i.e "NINJA". This technique has shown improvement in the fracture resistance of teeth that have been endodontically treated. Hence, the motive of this study was to comparatively evaluate the fracture resistance of endodontically treated teeth using TEC, Ninja, or Truss access cavity design.

Methodology

The extracted teeth for this study were collected from the Department of Oral Surgery of Inderprastha Dental College and Hospital, Sahibabad. This study included 80 non-carious human permanent mandibular molars with completely formed apices. The teeth that showed the presence of caries, any prior restoration and any visible cracks/fracture lines, resorption, radix and extra canals were excluded. The teeth were stored in normal saline.

Division into Groups and distribution of samples: (Table 1)

The samples were then divided into 4 groups (n=20),

Table 1:Distribution of Samples

GROUPS	DISTRIBUTION OF SAMPLE	n
GROUP 1	Control group	20
GROUP 2	Traditional endodontic access cavity preparation	20
GROUP 3	Ninja endodontic access cavity preparation	20
GROUP 4	Truss access cavity preparation	20

Access Cavity Preparation

Cavity was prepared by ENDO access bur (Mani Inc.) mounted on high speed air rotor.

In Group 1, "Control group", No access cavity preparation was done.

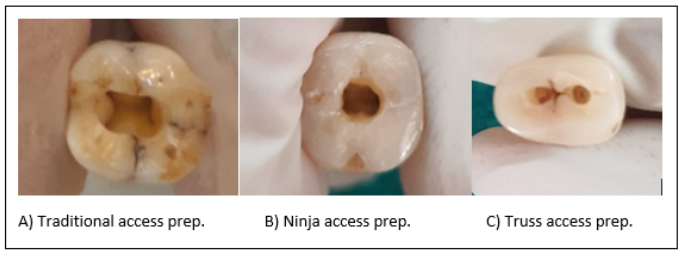
In Group 2, "Traditional endodontic access (TEC) group", molars were accessed, the initial penetration was done from the centre of the pulp chamber where the roof

and floor of the pulp chamber were the widest in order to have a straight-line access till the canal orifices (Fig 1).

In Group 3, ‘‘Ninja’’ an oblique projection towards the central fossa of the root canal orifices on the occlusal plane was gained. A balanced extension was made between the buccal and lingual orifices (Fig 1).

In Group 4, “Truss access group”, the mesial and distal canals were exposed and intervening dentin was left intact (Fig 1).

Figure 1: Types of cavity preparartion



Endodontic treatment

Root canals were negotiated with size 10 K-type files (Mani Inc.) up till the minor apical foramina. The working length was taken, and root canals were prepared using the ProTaper Universal Rotary File System (Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer’s recommendation till size F2 for the mesial canals and size F3 for the distal canals. During instrumentation, sodium hypochlorite 5.25% (PRIME DENTAL) was used for irrigation and it was intermittently deposited using ProRinse side-vented 30-G needles (Dentsply Tulsa Dental Specialties, Tulsa, OK), and after instrumentation, the root canals were irrigated with 17% EDTA **(**Dental Avenue Avue Prep EDTA) solution. Root canals were then dried using paper points and obturated with gutta-percha (F2 and F3) and a resin-based sealer (AH Plus; Dentsply De Trey, Konstanz, Germany) and was restored using Glass ionomer cement (GIC) (GC Inc.). Afterwards, the teeth were subjected to postoperative radiographs. Then the teeth from all groups were placed on lower plate of universal testing machine (ASAIN testing equipments), Upper plate included a steel spherical tip with a diameter of 5mm.Force was applied at 1mm/min until fracture occurred; force was recorded in Newton(N). Data were analysed using Kruskal –Wallis test (one way Anova test) for the groups.

Results

The specimens were subjected to a compressive load until they fractured individually in a universal testing machine. Peak load to fracture (N) was measured for each specimen. All collected data was entered in to MS excel and analysed. The statistical software SPSS 16.0 for windows (SPSS Inc, Chicago, IL, USA, 2001) was used for analysis of data. The normality of data was tested by Shapiro wilks test and found data was normally distributed, so parametric test of significance was used to test the significant difference. The mean difference in fracture resistances among four groups were calculated by using one-way ANOVA test. Tukey HSD TEST was used to calculate multiple comparisons of the mean differences of fracture resistance between groups. The Level of significance was set at p-value < 0.01. The distribution of Mean ± Std. Deviation of Fracture resistance of group 1, Group2, Group3 and Group 4 was 1668.60 ±20.096, 916.10 ±8.472, 1517.20 ±7.958 and 1381.70 ±9.825 (table 2) respectively. By one way ANOVA there was a highly significant difference in means of fracture resistance in all four groups, $p<0.01$.Therefore the mean of fracture resistance of Group 1 is significantly higher than all three groups. It was found that on multiple comparisons by Tukey’s HSD test (table 3), the mean difference of fracture resistance between Group 1 vs Group 2(752.500), Group 1 vs Group 3 (151.400), Group 1 vs Group 4 (286.900), So, mean of fracture resistance of Group 1 is significantly higher than all three groups, $p<0.01$. The

mean difference of fracture resistance between Group 2 vs Group 3 (-601.100), Group 2 vs Group 4 (-465.400), so, the mean of fracture resistance of Group 2 is significant lower than Group 3 and Group 4, p<0.01. The mean difference of fracture resistance between Group 3 vs Group 4 (135.500), Group 2 vs Group 4 (-465.400), so, the mean of fracture resistance of Group 3 is significantly higher than Group 4, p<0.01. (Fig 2)

Figure 2: Inter Group Comparison of Mean difference of Fracture resistance

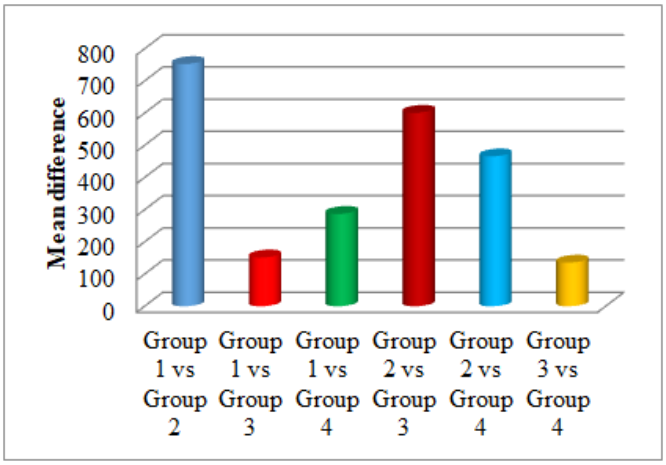


Table 2: Comparison of Mean of Fracture resistance of four groups by one way ANOVA

ANOVA					
Fracture resistance					
	Sum of Squares	df	Mean Square	F	P value
Between Groups	6339773.200	3	2113257.733	$1.330*10^4$	.000**
Within Groups	12074.000	76	158.868		
Total	6351847.200	79			

** Highly significant p<0.01

Table 3: Multiple Comparisons of fracture resistance among four groups by Tukey HSD test

(I) Group vs (J) Group	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
				Lower Bound	Upper Bound
Group 1 vs Group 2	752.500	3.986	.000**	742.03	762.97
Group 1 vs Group 3	151.400	3.986	.000**	140.93	161.87
Group 1 vs Group 4	286.900	3.986	.000**	276.43	297.37
Group 2 vs Group 3	-601.100	3.986	.000**	-611.57	-590.63
Group 2 vs Group 4	-465.600	3.986	.000**	-476.07	-455.13
Group 3 vs Group 4	135.500	3.986	.000**	125.03	145.97

** Highly significant p<0.01

Discussion

For the success of the endodontic treatment, all the organic substrates from the complex root canal system have to be eliminated. A well-shaped canal is the utmost requirement for promoting the long – term health of the supporting structures. The access preparation can be regarded as the first and the foremost step in endodontic treatment procedure. Proper access preparation is critical for the effective preparation and appropriate delivery of irrigating solutions into the root canals. Moreover, it helps in safeguarding from iatrogenic complications while performing endodontic procedures[5].

Maximum prevention of the intact coronal, cervical as well as radicular tooth structure while performing the endodontic therapy lays the foundation for Minimally invasive endodontic (MIE) treatment[6]. It involves the very minimal removal of dentin while performing all the three crucial steps of the endodontic procedure, i.e., the coronal access preparation, the radicular apical preparation and finally the flaring of the canal to connect the coronal and the apical preparations.

Enamel is a crystalline structure and it has 100% natural support from the underlying dentin. While on the other hand, dentine is a multilevel composite material that can stand alone and also behaves ideally just like a semi-rigid pipe. For a strong cavity to be able to resist fractural forces; Noy stated some criteria[7], 1) enamel must be surrounded by sound dentine, 2) enamel rod which form the cavosurface angle must have their inner end resting on sound dentine and 3) angular cavosurface angles should be trimmed. Failure of the Root canal treated teeth while functioning is chiefly identified by two etiologies: (1) Quantity of stress which is experienced by the tooth while it is under load and (2) The Biomechanical properties present inherently in the tooth structure that remains, which is responsible for resisting fracture.

Among technical elements of root canal therapy, access preparation and post space preparation are most relevant

in causing the tooth more susceptible to significant destabilisation and thereby determining future biological success (i.e., non-existence of any Periradicular disease) and the tooth's survivability[6].

There are three essential aspects of clinical endodontics[6]: 1) The canal microbes in the apical 3-4mm of the canal should be removed for biological success, 2) The survivability of the tooth in the long run is greatly improved by the minimal removal of the original tissue present in the coronal two-thirds of the canal and 3) Access to both the coronal and apical parts of the canal is critical.

Traditional endodontic cavity (TEC) has geometrically predesigned shapes. The extension-for-prevention kind of access cavity often requires sacrificing the healthy dentin obstructing the straight-line path to the apex or, to the primary root canal curvature, in some cases. The remaining dentin, then acts as a crucial factor and a foundation for the ensuing post-endodontic restorative procedures. Hence, to preserve the functional and mechanical integrity of endodontically treated teeth, it is often desirable to conserve the coronal/radicular dentin and also maintaining the root canal geometry[8].

The loss of toot much tooth structure is one of the most important and very common causative factor for fracture in root-filled teeth. Also, it has been reported that following TEC principle is the second largest cause of loss of tooth structure [9]. Hence, the prognosis of a Root canal treated tooth may be improved by incorporating a proper and reduced endodontic access preparation design[10].

To minimize the removal of tooth structure, conservative-Truss and ultra-conservative- Ninja endodontic cavities are alternatives to traditional endodontic cavities that help in maintaining the mechanical and physical strength and stability of the tooth, thereby improving greatly the long-term survivability and functioning of the root canal treated teeth[11].

The newly introduced concept of conservative as well as the ultra-conservative endodontic access cavity is an attempt at transforming the shape of the access from the original operator-oriented shape and design to one that emphasizes much more on the conservation of dentin as well as the endodontic-restorative interface[12].

These endodontic access designs often tend to prioritize removal of restorative material before tooth structure, enamel before dentin and occlusal tooth structure before cervical dentin.

The traditionally employed straight-line access design usually leads to the complete deroofing of the entire pulp chamber. However, the conservative designs focus more on soffit preservation which provides some degree of structural bracing and minimizes cuspal flexure during mastication. Soffit can be understood as the underside of any architectural structure like a ceiling, or the corner joining the ceiling, and the wall[13].

More recently, ninja endodontic cavity (NEC) has been introduced in order to prevent the fracture in root canal treated teeth. However, clinically, these approaches can mainly be performed on intact teeth that are going to be treated endodontically. However, studies state that this clinical scenario does not seem to occur frequently, representing only 8% of the cases treated by the authors in the last 5 years[14].

In Root canal treated teeth, the prime reason for the failure after long term may be due to cracks, diminishing dentine hardness and endodontic access cavity width effects which can be attributed to improvements in magnifying visualizations and tool development [15].

Various authors have tried to study and analyze the endodontic access cavity designs with varying

inferences. Some studies demonstrated no difference between the conservative endodontic access cavity[16] and traditional one pertaining to the fracture resistance but still the reverse of this conclusion can also be found in the literature[14]. It isn't completely understood with conviction whether decreasing the dimensions of the endodontic access cavity preparation can reduce the fracture resistance or not. Thus, there arises a need to perform more studies and do more research in this regard.

In this study, it was found out that the traditional endodontic access (TEC) group removed much more tooth hard tissue than the NEC group. But, we have tried preparing the narrowest pathway by using a #10 K-file which could easily reach till the apex, and it was observed that there were differences in terms of the hard tissue that was removed. Quantity of the hard tissue removed is crucial as the fracture strength of root canal treated teeth decreases significantly even if a millimetre of remaining dentin is sacrificed[17].

However, conservative accesses may lead to difficulty in operating due to the small operating space, insufficient visible light, missed canals, pulp remnant left, insufficient irrigation and may also lead to the apical transportation, ledge formation and sometimes instrument fracture[18].

The truss access was prepared according to a study done by Neelakattan et al[19]. As per Plotino et al.[14] , teeth with TEC showed lesser values of fracture resistance compare to the ones that were prepared using CEC or NEC which supports our study.

Corsentino et al.[16] studied and inferred that TRECs do not increase the fracture strength of endodontically treated teeth as compared to TECs. Furthermore, loss of the mesial as well as the distal marginal ridges leads to a significant reduction in the fracture resistance of teeth. Their result is in contrast to our study and this might be due to different angulations of the photographs taken.

A universal testing machine (UTM) was employed for evaluation of fracture resistance for the samples. A 30˚ inclined angle was used as the teeth are most prone to being fracture when eccentric forces are acting on them and fatigued tests might not reveal complete root fracture patterns for the complicated masticatory procedure. The access cavities were restored using Glass Ionomer Cement in order to simulate the clinically done procedures and also to aid in the loading tests. Endodontic access cavities, when restored may in turn, restore the fracture resistance of the teeth by up to 72% of the same tooth when intact [14].

The same expert operator performed all specimen preparation procedures in order to avoid different results caused by different operator skills to reduce the bias.

Of late, minimally invasive endodontics has proven to provide a paradigm shift in the direction of an unwavering, systematic appropriate respect for original tissue and considerable technical competence. The main objective is 'Restriction with conviction"[20] and believes in the concept that caries is not cured by restorations only and cavities weaken the tooth. Because no restorative material or technique can overcome lost dentin biomaterial, especially in key areas of tooth, treatment steps aimed at dentin preservation are pivotal as the best way to prolong the life of the endodontically treated teeth [21].

However, there are some inherent drawbacks of this in-vitro study conducted, like loading to fracture methodology used for such analyses does not ideally mimic conditions present intraorally in which failures occur mainly due to fatigue. Likewise, the axial cyclic fatigue tests might not completely demonstrate the

patterns of root strain for the complex masticatory process.

Conclusion

Hence, keeping in mind the limitations of this in vitro study, it can be inferred that the "NINJA" (Ultra-conservative) endodontic access cavity demonstrated increased fracture resistance values of endodontically treated mandibular molar teeth as compared to the other two groups, i.e., the traditional endodontic access and truss endodontic access.

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