Fracture Stregnth of Endodontically Treated Teeth with Minimally Invasive Access Cavity Desgins Versus Conventional One (An In Vitro Study)

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Abstract

Aim: Assess the fracture strength of endodntically treated teeth with minimally invasive access cavity design versus conventional one.

Methods: Forty four extracted molars were assigned to 4 groups. Conservative Access Cavity, Ninja Access Cavity, Truss Access Cavity, Traditional Access Cavity (n = 11/group/type). Teeth in the Traditional group were prepared following the principles of traditional endodontic cavities. Conservative access prepared by using 2 periapical radiographs to determine canals location. Ninja access scans were plotted on cone beam computed tomographic images for localization of root canal orifices and Truss group were scanned, and merged with cone beam computed tomography, for fabrication of an endodontic guide.The 44 specimens were loaded to fracture in a universal material testing machine. The maximum load at which the teeth fractured and fracture pattern (restorable or unrestorable) were recorded.

Results: Regarding the fracture strength, results showed that there was a significant difference between Ninja, Conservative,Truss and traditional access groups with ($p < 0.001$) and no significant difference between Conservative and Truss groups. Regarding restorability, there was no statistical difference observed between the four groups with ($p < 0.001$).

Conclusion: Teeth with traditional access showed lower fracture strength than the ones prepared with Conservative, Ninja and Truss.

Keywords: *conservative access ,fracture resistance, ninja, traditional access ,truss.*

Introduction

One of the most important steps for successful endodontic treatment is access cavity preparation which may influence the quantity of the residual dental substance thus affecting its resistance to fracture under functional loads [1,2] .

In traditional endodontic cavity (TEC) preparation, the controlled removal of the tooth structure was thought to prevent complications that can occur during endodontic treatment [3]. However, the removal of tooth structure needed for access cavity preparation decreased the resistance of the tooth to fracture under functional loads [1].

Minimally invasive endodontics is a concept that is adopted recently, comprising smaller access cavities.

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Conservative endodontic cavity (CEC) preparation is a minimally invasive procedure that can preserve tooth structures, such as pericervical dentin which can improve the fracture strength of endodontically treated teeth [1,3.]

An extreme conservative approach known as ''Ninja'' tooth can be outlined on cone-beam computed tomographic (CBCT) images by plotting the trajectory toward each canal. In ultraconservative access cavity ''Ninja'' Access was proposed in order to improve the fracture strength of endodontically treated teeth in comparison to both TEC & CEC techniques [1].

Minimal access cavities have been presented as an alternative to traditional endodontic access cavity (TEC), and have been supported to preserve as much tooth structure as possible and thus, theoretically preserve the fracture resistance of root filled teeth [4] .The more conservative access design is mainly supported by the preservation of a greater amount of tooth structure on the occlusal surface, seeking to increase its fracture strength [5] .

Hence, the aim of the present study was to assess the influence of minimally invasive access cavity designs on the fracture resistance of endodontically treated teeth.

Materials and Methods

This is an in-vitro study. Conducted in a faculty of dentistry-cairo university, Egypt from September 2018 to October 2021.

Sample size calculation:

Forty four mandibular first molars were randomly assigned to four equal groups according to the required access cavity design where each group comprise 11 samples. Group I: comprise 11 samples where each undergo conservative access cavity design. Group II: comprise 11 samples where each undergo ninja access cavity design. Group III: comprise 11 samples where each undergo truss access cavity design. Group IV: comprise 11 samples where each undergo traditional access cavity design.

· Teeth were inspected, cleaned from blood and tissue debris then root surfaces were scraped with a curette to remove calculus or attached periodontal ligament fibers. Teeth were inspected with a dental operative microscope for cracks then stored in normal saline solution at room temperature till use.

· To simulate the periodontal ligament space, roots were covered with a uniformly thin 0.2-mm layer of silicone impression material.

· Using the analyzing rod of the dental surveyor, each tooth was positioned vertically in a brass ring of self-cured acrylic resin, then teeth were embedded up to 2 mm below the cementoenamel junction.

· In the CAC group, in order to determine the outlines of the access cavity and locate the pulp chamber and canals, we used 2 periapical radiographs made from buccal and mesial aspects as a guide. Then, starting from thecentral fossa, cavities were extended only as necessary to visualize and locate canal orifices while taking care to preserve pericervical dentin. Fig (1).

· In the NAC group, the access cavity was prepared by a size 856 diamond burs in a high-speed hand piece with a sufficient water coolant directed towards the central fossa perpendicularly at the deepest point of the occlusal surface till a drop was felt. Then, when the pulp chamber was reached the cavity was slightly expanded. The mesiodistal length of the cavity was set to 2 mm; meanwhile, the buccolingual length of the cavity was 3 mm Fig (1).

· In TRAC the endodontic guide was printed by a form 3 flawless printer and using dental LT clear resin 3d printing material and a Carbide surgical bur size 2 with a diameter of 1.5 mm with a maximum working length of 13 mm from the top of the sleeve till each orifice opening of each canal in each tooth. The truss access was done by the surgical bur directed towards the access points through the metal sleeves in the endodontic guide exposing each canal orifice Fig (1).

· In the TAC group, traditional endodontic access cavities were prepared following conventional guidelines. In order to obtain straight-line access to all canal orifices, outlines of the cavity and pericervical dentin were removed or modified where necessary Fig (1).

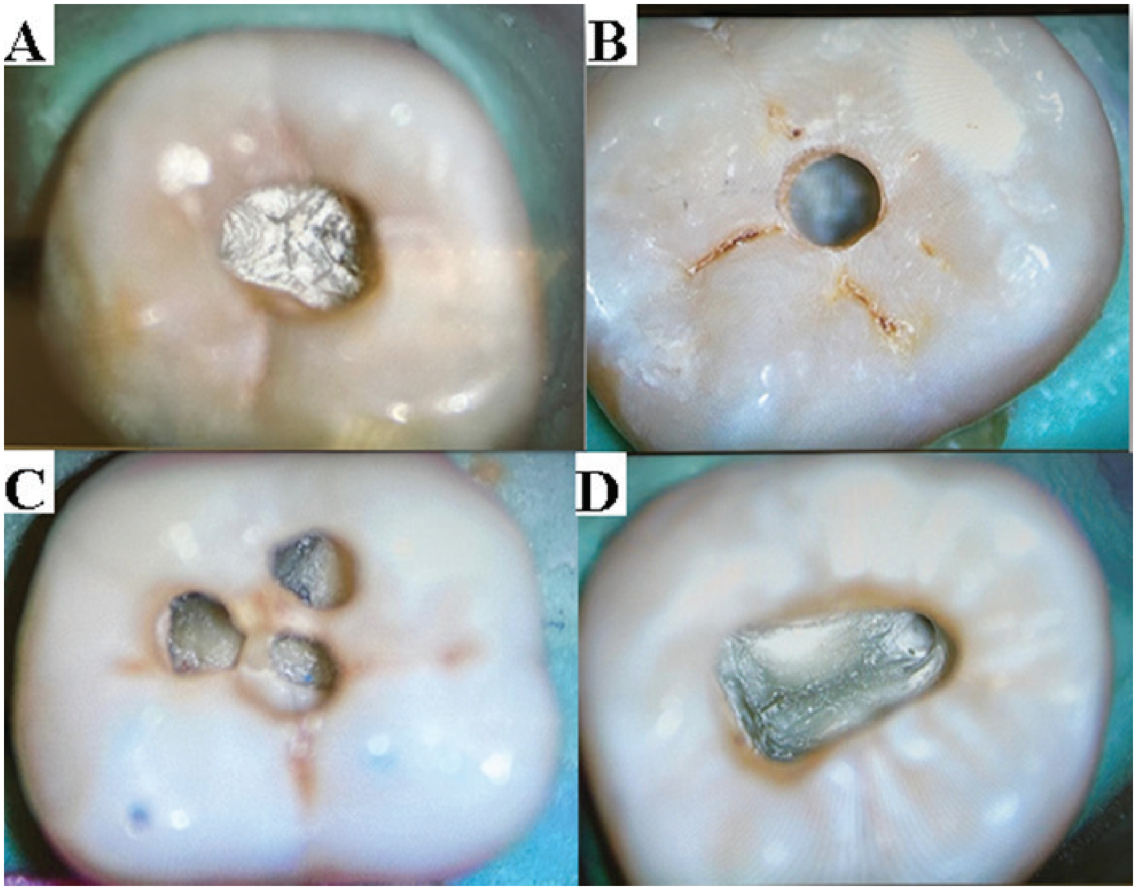

Figure 1. (A–D) photographs showing lower molars prepared with different access cavity designs. (A) Conservative access cavity, (B) Ninja access cavity, (C) Truss access cavity and (D) A traditional access cavity.

Loading of the specimens

1) All the accessed teeth in each group were subjected to the fracture resistance test using the Universal Testing Machine. The testing machine allows an error of 0.04% for a maximal load of 10,000 kg, 0.01% for a repetitive maximal load of 10,000 kg, resolution of displacement of 0.01 mm (10 mm), and an accurate speed of 0.01% of full scale.

2) All the specimens were placed in a custom-made water bath and mounted in the universal testing machine.

Teeth were loaded at their central fossa with an axial angle from the long axis of the tooth. A continuous compressive force at a crosshead speed of 1 mm/min was applied using a 6 mm-diameter ball-ended steel compressive head till fracture occurs.

Primary outcome (Fracture strength): The loads, at which the teeth were fractured, indicated by the software (BlueHill Instron) of the load testing machine, were recorded in newtons.

Secondary outcome (Fracture restorability): The fractured specimens were examined under a stereomicroscope at 17 X to determine the fracture pattern according to.

Fracture patterns were classified into: Favorable: when the failures were above the level of acrylic resin level which signifies that the site of fracture was above the bone level and was restorable. Unfavorable: when the failures were extended below the level of the acrylic resin level which signifies that the site of fracture was below the bone level and was difficult to restore or totally non restorable.

Results

Comparison between the fracture resistance of the different access cavity designs

Group II showed the highest mean and standard deviation values of fracture resistance (1086.68 ± 262.43) followed by group I with a mean and standard deviation of (725.91 ± 232.22) then group III with a mean and standard deviation of (656.62 ± 445.64), and finally group IV presented the least mean and standard deviation of (242.49 ± 50.55).

Applying Kruskal Wallis test, a significant difference was observed between the four groups with ($p < 0.001$). Using Mann – Whitney U test a statistically non-significant difference was observed between group I and group III

Table (1) Mean, standard deviation values and the results of Kruskal Wallis test for the comparison of the compressive strength between the four test groups

	Group I	Group II	Group III	Group IV	P - Value
Mean	725.91b	1086.68a	656.62b	242.49c	
SD	232.22	262.43	445.64	50.55	
Median	796.82	983.42	619.69	231.41	< 0.001*
Min	364.48	858.60	262.71	171.41	
Max	988.13	1601.00	1479.69	343.41	

Comparison between the fracture patterns of the different access cavity designs:

Group II showed the highest frequency of the restorable fractures (63.6%) in comparison to the non-restorable ones (36.4%) within the same group followed by the group I with a frequency of the restorable fractures (54.5%) in comparison to non- restorable fractures (45.5%) within the same group then group III with a frequency of the restorable fractures (36.4%) which was less than the non-restorable fractures frequency (63.6%) within the same group , and finally group IV presented the least frequency of the restorable fractures (18.2%). Using chi square test, a statistically non-significant difference was observed between the four groups with ($p = 0.14$).

	Group I		Group II		Group III		Group IV		P - Value
	N	%	N	%	N	%	N	%	
Favourable	6	54.5%	7	63.6%	4	36.4%	2	18.2%	0.14
Unfavourable	5	45.5%	4	36.4%	7	63.6%	9	81.8%	

Table (2): Frequencies (N), percentages (%) and the result of chi square test for the comparison of the patterns of fracture between the four tested groups

Discussion

One of the most important causes of fractures in root-filled teeth is the loss of tooth structure during the preparation of the traditional access cavity designs. Thus, a proper and more conservative endodontic access cavity designs are suggested to improve the prognosis for an endodontically treated tooth [1,6.]

Mandibular molars were used in the present study as these teeth are more susceptible to fracture due to its wider occlusal tables subjected to high occlusal stresses. These teeth are also the most commonly endodontically treated posterior teeth and often require cuspal protection [7.]

In the present study, simulation of the periodontal ligament around the teeth was done with polyvinyl siloxane, an elastomeric material that to prevent concentration of stresses in the cervical region of the tooth, since the method of root embedment may affect the fracture resistance significantly [8.]

Cone beam computed tomography (CBCT) was used in ninja access cavity for localization of all root canal orifices. Moreover, truss access cavity was guided by CBCT to design a 3D print for fabrication of endodontic guide template to control the drill path and the needed depth of the drill to the root canal orifices [1, 9, 10,11.]

The fracture resistance was tested using a static compressive loading in a universal testing machine, guided by a sphere head with 5-6 mm diameter to allow adequate contact with cuspal inclines during testing. [7, 12.]

The results showed a statistically significant difference between the four groups accessed with different cavity designs. The fracture strength of the traditional access cavity (control group) was significantly lower than that of the conservative access cavity (CAC), ninja access cavity (NAC) and truss access cavity (TRAC) groups. This could be explained by the fact that access cavity preparation by itself reduces the fracture resistance of the tooth as a result of removal of strategic internal architecture at the center of the tooth during complete deerofing of the pulp chamber [7, 13]

The results of this study were in agreement with Panitvisai et al. 1995, Clark et al. 2010, Krishan et al. 2014, Reddy et al. 2020, who found that the fracture resistance of (CAC) is higher than (TAC). Similar findings were observed in a study conducted by Plotino et al. 2017 who found that the fracture resistance of TAC was lower than CAC. However, these results were in contrast to those found by Moore et al. 2016, Rover et al. 2017, Sabeti et al. 2018 who found that there was no statistical difference between TAC and CAC in maxillary molars. A possible explanation for these differences could be due to the difference in study design as the use of a different type of teeth or due to canal instrumentation. Moreover, Moore et al. 2016 and Rover et al. 2017 restored the cavities with composite bonded restorations.

In the current study, all tested minimally invasive cavity designs (CAC), (NAC), (TRAC) resisted a fracture load significantly higher than (TAC). This could be attributed to the dentin preservation that occurred due to cavity size reduction which improved the fracture resistance of these teeth [14, 15, 17]. Also, in CAC preparation, there was an emphasis on preserving the pericervical dentin by maintaining the soffit dentin which plays an important role in providing a ferrule effect thus increasing the fracture resistance of the tooth [19, 20.] In the same time, it was reported that the removal of cervical dentin, as in TAC, could increase the cuspal deflection and enhance the potential for fracture [14,15.]

Teeth in the NAC group showed significantly higher fracture resistance values than those observed in the control TAC, CAC and TRAC groups, this could be attributed to the minimally invasive access cavity designs of NAC [1] .This was confirmed by Reddy et al. 2020 who calculated the volume percentage of coronal enamel and dentin lost by TAC, CAC, and NAC access cavities and subtracted it from the total enamel and dentin crown volume for each tooth type using CBCT and declared that NAC group contained the least amount of hard tissue removal which resulted in significantly higher fracture resistance for the tested teeth. Moreover, Plotino et al.2017, Schroeder et al. 2002 and Saygili et al. 2018 found that the fracture strength values of teeth prepared with NAC was higher than that of teeth prepared with CAC and TAC.

In the present study a significant difference was found in the fracture resistance between NAC and CAC groups which is in contrast to Reddy et al. 2020 and Plotino et al. 2017 who found that there was a non-significant difference in fracture resistance between NAC and CAC groups. This might be attributed to the difference in tooth type as Plotino et al. 2017 used a maxillary molars while Reddy et al. 2020 used an unerupted impacted lower third molar with sectioned apex to simulate immature teeth, the second difference was in the test used as Reddy et al. 2020 used Insert On Demand 3D™ software which calculated the volume percentage of coronal enamel and dentin lost by TAC, CAC and NAC access cavities by subtracting the new enamel and dentin crown volume from the total enamel and dentin crown volume for each tooth type. However, no significant difference between the fracture resistance of the CAC and TRAC cavity groups was detected which was in agreement with Plotino et al. 2017 and Corestino et al. 2018. This result might be explained by the fact, that both are minimally invasive access cavity designs with minimal hard tissue removal.

A higher number of restorable fracture patterns in NAC and CAC, TRAC teeth than those in the ones prepared with TAC was presented in this study. This might be due to the preservation of the pulpal chamber roof and precervical dentin [3] . Furthermore, the majority of the teeth prepared with TAC showed unrestorable fracture patterns with no significant difference among the different access cavity designs which may be attributed to the positive correlation between the remaining coronal dentin surface area and the fracture strength; as TRAC access cavity involves separate individual cavities in multirooted teeth which maximizes the dentine preservation between the cavities than in the TAC group which scarifies a much coronal dentin [2,19] . In addition, Plotino et al. 2017 observed that the mean volume of pericervical dentin lost was greater in TEC (14.8%) group, followed by CEC (8.3%) group and then NEC (6.8%) group which was in agreement with Platino et al. 2017, Özyürek et al. 2018, Abou-Elnaga et al. 2019 and Barbosa et al. 2020. Hence, conservative variation from traditional access cavity design might preserve more sound teeth structure increasing the fracture resistance of endodontically treated teeth.

Conclusion

Within the limitations of this study, it could be concluded that: Minimally invasive access cavity designs improved the fracture strength of endodontically treated teeth. Ninja access cavity design presented the highest fracture resistance when compared to other conservative access cavity designs. Fracture patterns doesn't lean toward any of the conservative access cavity designs nor to the traditional one.

Ethical Clearance: Approved by the ethical committee of faculty of dentistry, Cairo University.

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