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IMPACT OF CONSERVATIVE ACCESS CAVITY DESIGNS AND REMAINING TOOTH STRUCTURE ON FRACTURE RESISTANCE OF MAXILLARY FIRST PREMOLARS

Marian Safwat Shafik*, Abeer Hashem Mahran** *and* Mohamed Fakhr***

ABSTRACT

Objective: To evaluate the impact of various access cavity designs and the amount of remaining tooth structure (traditional access, truss access &conservative access) on the fracture strength of upper first premolar teeth.

Materials and methods: forty-two intact maxillary premolars with two roots were anatomically distributed among four main groups: Control group: 6 intact sound premolars. Traditional access cavity group (TAC): 12 premolars prepared with the traditional access. Truss group (TREC):12 premolars prepared with the truss access. Conservative access group (CEC):12 premolars prepared with the conservative access. The three access cavity test groups were further subdivided into 2 subgroups 6 teeth each according to the number of remaining residual walls either 3 or 2 residual walls as follows: TAC (3 walls group), TAC (2 walls group), CEC (3 walls group), CEC (2 walls group), TREC (3 walls group) and TREC (2 walls group). During access cavity preparation, Cone Beam Computed Topography (CBCT) was utilized as a guide tool to detect canal orifices while maintaining the integrity of the peri cervical dentin. The teeth were embedded in self-curing acrylic resin 2 mm below the cementoenamel junction after access cavity preparation. After that, the specimens were loaded in a universal loading machine (Instron model 3345) until they fractured, and the fracture values were recorded in newtons. Tukey post hoc analysis was used for multiple comparisons ($P < .05$) and 2-way analysis of variance was used to analyze the data. R statistical analysis software, version 4.3.1 for Windows, was used to conduct the statistical analysis.

Results: Only the remaining tooth structure had a significant effect on the teeth's fracture resistance, and the loss of the mesial and distal marginal ridges significantly reduced the teeth's strength. That truss access cavity did not significantly improve the fracture resistance in the 3 remaining wall groups however when the tooth structure was already compromised in the 2 remaining wall groups the truss access cavity had a significant effect on the fracture resistance.

KEY WORDS: Conservative access cavity, truss access cavity, fracture strength, remaining tooth structure, residual walls.

* MSc Student, Endodontics, Miu

** Professor, Professor of Endodontics, Endodontic Department Faculty of Oral and Dental Medicine, Ain Shams University, Cairo, Egypt

*** Associate Professor, Endodontics, Endodontic Department, Faculty of Oral and Dental Medicine, Misr International University, Cairo, Egypt

INTRODUCTION

Because of the loss of tooth structure and vitality, teeth that were treated with endodontic treatment are considered to be more prone to fracture. One of the most undesirable phenomena that might lead to tooth extraction is teeth fracture, which can be caused by compromised structural integrity of teeth that have had endodontic treatment. According to Moosavi et al., teeth with endodontic treatment may be weaker and more brittle than healthy teeth, and they may break more readily when subjected to biting forces. [(2)] The design of the endodontic access cavity affects the amount of loss of the tooth structure. I. The access cavity is the key step that should be adequately prepared in order to allow further instrumentation without procedural errors, proper canal shaping and then obturation. [(3)] The Traditional access cavity may result in weakening of the remaining tooth structure which was previously destructed by carious lesions or fractures. The designs of traditional endodontic cavities are the same over the past decades due to limitations in imaging techniques.[(4)]With the introduction of recent modalities, materials, instruments and techniques, restorative dentistry has shifted towards minimal invasive dentistry. Since there is no material that is similar to the biomechanical structure of the missing dentine, new modalities focus on preservation of sound dentine to reinforce affected teeth.[(4)]

With the evolution that occurred in the dental field generally and in the endodontic field specifically, as advances in the imaging techniques (with the introduction of cone beam computed tomography), advances in instruments as the introduction of new flexible alloys and with the use of the dental microscope improving the precision of endodontic procedures.[(5)]

Minimal invasive dentistry offers new access designs alternative to the traditional access to preserve the tooth structure. These designs include the conservative or contracted access, truss access and ninja (ultraconservative) access cavities. The design of the contracted or conservative access cavity is incomplete deroofing and preservation of part of the coronal pulp chamber roof known as dentin soffit.[(6)]

The truss endodontic cavity is “an orifice-directed access, in which separate independent cavities are prepared to negotiate the different roots of the molars avoiding removal of the central part of the roof of the pulp chamber leaving a dentine truss between the 2 cavities.[(7)]

The objective of the ninja access or ultraconservative access is to perform a small central hole just locating the orifices, with preservation of all the dentine overlying the pulp horns, the occlusal enamel, and up with convergent walls [(7)]

It has been proposed that maintaining tooth structure when preparing an access cavity will increase the fracture resistance and improve the survival of endodontically treated teeth.[(8)]

Loss of axial walls, marginal ridges, and the internal tooth portion during access cavity preparation, associated with cusp deflection during mastication especially in maxillary premolars may result in tooth fracture. These fractures may propagate to the root resulting in catastrophic failure which may lead to tooth extraction.[(9)]Thus it is important to evaluate the influence of different access cavity designs and the remaining tooth structure on fracture strength of endodontically treated teeth.

Hence, the objective of the present study was to assess the effect of the loss of the mesial or the mesial and distal walls in combination with TEC, CEC, and TREC preparation on the fracture resistance of endodontically treated teeth.

MATERIALS AND METHODS

Teeth preparation and grouping

After ethical approval number MIU-IRB-2122-129, 46 extracted intact human first maxillary premolars with completely formed apices were collected from Misr international university teeth bank. The exclusion criteria for the tested teeth were the presence of caries, previous restorations, or visible fracture lines or cracks. Extracted teeth were cleansed of visible blood and gross debris, the teeth were examined for caries, cracks, restorations, and fractures using a microscope with a 10 x magnification. Using a gauge at the cementoenamel junction, the buccolingual and mesiodistal dimensions were determined. To make sure that teeth of comparable dimensions were included in each of the study groups, the length of each tooth was also measured. Reducing specimen variation made it possible to compare several groups in a meaningful way.

The 36 intact maxillary first premolars with two roots were anatomically distributed among the three selected groups (n=12) according to the access cavity design:

Group I (CEC): 12 premolars were prepared with the conservative access cavity.

Group II (TREC): 12 premolars were prepared with the truss access cavity.

Group III (TAC): 12 premolars were prepared with the traditional access cavity.

The three test groups were further subdivided into two subgroups six teeth each according to the number of remaining residual walls whether three (subgroup A) or two residual walls (subgroup B).

For the CEC a CBCT was performed to determine the orifices location and the access cavity preparation started in the middle of the occlusal surface at the central groove perpendicular to the long axis of the tooth to expose the canals without complete deroofing, with convergent walls and without the need for divergent walls or extension for prevention thus preserving the pericervical dentine keeping the access cavity as small as possible. Each time a new diamond stone was used to avoid crack induction from old burs loaded in a contra high speed with coolant. In the TREC, after CBCT scan the dicom files were used to determine the location of the canals and measured from the external surface of the tooth to the canal orifice using the planmeca romexis software then this relation was transferred to the teeth using a periodontal probe to locate the orifices by measuring it from the external surface of the tooth, the location was marked using molten wax marking two points over the buccal canal and the palatal canal. Starting from the marked points a direct access was made from the occlusal surface to expose the canal orifices and leaving the intervening dentin intact so that the two round cavities were prepared above the buccal and palatal canals leaving a truss of dentin between the two holes. The TEC was performed by removing the entire pulp chamber roof ending up with divergent walls and a straight line path to the canals.

Fracture resistance test

Acrylic blocks were manufactured from performed templates. For mounting of teeth on the acrylic resin blocks, petroleum jelly was applied on the custom-made plastic blocks so that the resin blocks could be removed easily from the plastic blocks. Self-cure acrylic resin (Acrostone) was mixed with the desired powder and liquid ratio and the mix was placed inside the template. Teeth were positioned at the center of the acrylic template so that the long axes of the teeth were perpendicular to the floor. The teeth were submerged in water for five minutes during resin polymerization to prevent overheating. The acrylic block of each specimen was fixed to the lower fixed head of the universal testing machine Instron model 3345. Each crown was subjected to a continuous static load using a stainless steel ball of 6 mm diameter attached to the upper movable head of the testing machine.

As indicated in (figure 1), an axial compressive mode of force was applied at a crosshead of 1.0 mm/min until the specimen failed, which was verified by an abrupt drop in the testing machine's measurement. The force required for failure (Newton) was recorded by the machine software (BlueHill Instron England). The results were recorded, tabulated and statically analyzed.

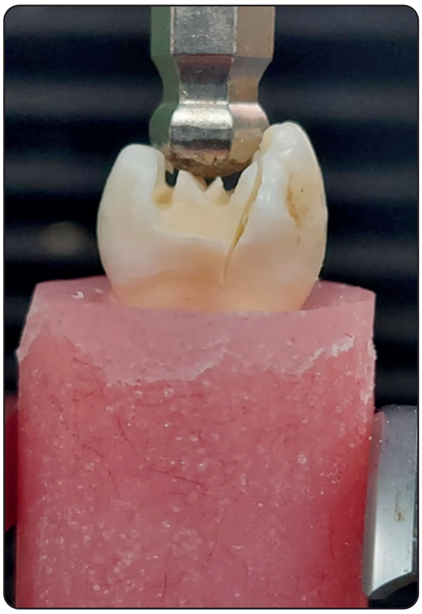

Fig. (1) Showing crack propagation in the premolar prepared with the truss access cavity.

RESULTS

1-Effect of access cavity design:

Intergroup comparisons, mean and standard deviation (SD) values of fracture resistance (N) for different access cavity designs were calculated.

There was no significant difference between different groups (p=0.062). The highest value was found in the truss access (167.04±57.51) (N), followed by the conservative access (164.80±44.04) (N), while the lowest value was found in the traditional access (129.94±59.14) (N).

2- Effect of remaining walls:

Intergroup comparisons, mean and standard deviation (SD) values of fracture resistance (N) for different remaining walls were calculated. Samples with 3 remaining walls (194.97±34.89) (N) had a significantly higher fracture resistance value compared to the other samples with 2 remaining walls (112.88±36.07) (N) (p<0.001).

3- Effect of different variables and their interaction

The results showed that the cavity design regardless of remaining walls had no statistically significant effect on mean fracture resistance. Regardless of cavity design, the remaining walls had a statistically significant impact on mean fracture resistance. Mean fracture resistance was also statistically significantly impacted by the variables' interactions. The variables are reliant on one another since there is a statistically significant interaction between them.

Only the number of remaining walls had a significant effect on the fracture resistance (p<0.001).

TABLE (1) Showing the effect of different variables and their interactions on the fracture resistance (N)

Variable	Sum of Squares	df	Mean Square	f-value	p-value
Access cavity design	6923.65	2	3461.82	3.27	**0.062ns**
Remaining walls	40434.41	1	40434.41	38.16	**<0.001***
Access design * remaining walls	1707.87	2	853.93	0.81	**0.462ns**

df =degree of freedom*; significant (p <0.05) ns; non-significant (p>0.05)

DISCUSSION

Access cavity design is an important step for the success of subsequent procedures in the endodontic treatment. There is a decrease in fracture resistance of teeth when extended access cavity design are prepared, as removal of hard tissue like enamel and dentine leaves the cusps unsupported and thus more vulnerable to fracture under occlusal and directional forces.[1,2] Consequently, more conservative access cavity designs had been suggested as a method of strengthening and maintenance of endodontically treated teeth compared to traditional access cavities.

This study aimed to evaluate and compare the effects of various access cavity designs with the remaining tooth structure in relation to endodontically treated teeth's resistance to fracture. The current study focused on upper premolars because to their unique anatomical structure, which increases the risk of cusp separation and fracture during function. This presents a serious problem for a tooth located in the aesthetic zone. It was shown that teeth with mesiodistal dimensions that are narrower than buccolingual dimensions such as maxillary premolars, mandibular premolars, and the mesial roots of mandibular molars are more likely to fracture. [9]

Studies performed by Stelle et al and Rabie et al, were in agreement with the results of the current study regarding the effect of endodontic procedures on the strength of the teeth where the control group had the greatest resistance to fracture compared to all other groups regardless of the access cavity design and the remaining tooth structure.[9,10]However, some studies showed that the fracture resistance of the control group was similar to endodontically treated teeth accessed with ninja endodontic access cavity (NEC) and CEC.[11,12]These conflicting results may be due to differences in methodologies used in these studies as Plotino et al [11] used different teeth as mandibular premolars and molars while in the present study maxillary first premolars were used. While Salameh et al [12] used different restorative procedures as composite and fiber posts.

Loss of tooth walls especially marginal ridges was proven to significantly impact the fracture resistance of endodontically treated teeth this was found in the present study as well as previous studies. The results of Salameh et al were in accordance with the current study where the values of fracture resistance of the tested molars were highly dependent on the number of remaining coronal walls.[12]

Nissan et al. concluded that the main aspect influencing fracture resistance was the residual coronal structure, since more residual tooth structure provided more protection against fracture under occlusal loads. These results are also in agreement with the current study.[13] Caplan et al studied the relationship between the number of proximal contacts and survival of root canal treated teeth, they found that teeth with 2 intact proximal contact showed higher survival rate than teeth with lost proximal contacts which are weaker three times than teeth with 2 proximal contacts and that presence of intact proximal contacts is an important factor in the determination of the prognosis of these teeth.[14] These previous findings were also supported by Belli et al who found that MOD cavity preparation reduced the fracture strength of root canal treated teeth.[15]

In the present study, the cavity design regardless of remaining walls had no statistically significant impact on the mean fracture strength. However, the remaining walls regardless of cavity design had a statistically significant impact on the teeth mean fracture strength. In all cavity designs (TREC, CEC and TEC) the 3 remaining walls groups had a higher fracture resistance compared to the 2 walls groups.

No statistically significant difference between the fracture resistance of different cavity designs in the 3 remaining walls groups was found, however in the 2 remaining walls groups there was significant difference between the cavity deigns where the traditional access cavity had a significantly lower fracture resistance value compared to the other two groups. Although non-significant but the truss access had a higher fracture resistance value compared to the conservative access cavity in both the 3 and 2 remaining walls groups.

These results were supported by Corsentino et al who studied the impact of preparation of different access cavity designs and remaining tooth structure on the fracture strength of endodontically treated teeth. In that study CEC ,TREC and TEC were prepared and the teeth were divided into groups based on access cavity designs and remaining residual walls whether 2 or 3 residual walls .All samples were loaded till fracture and the study showed no significant difference between different designs however the remaining tooth structure had significant effect on the fracture resistance of these teeth (3 residual walls showed higher fracture resistance than 2 residual walls) .Thus the access cavity designs tested did not improve the fracture strength of treated teeth that was compromised by the loss of 1 and 2 marginal walls.[16]

Rover et al assessed the impact of contracted access cavity design on canal detection, efficacy of instrumentation and fracture strength in maxillary molars compared to traditional access cavity design. Maxillary molars were imaged with micro CT then divided into 2 groups either prepared with CEC or TEC. There was no significant difference between these groups which was in agreement with the present study. Their results did not show edge associated with CECs and they resulted in less root canal detection and did not improve fracture strength.[17]Sabeti et al, Augosto et al ,Silva et al, Moore et al and Ozyrek et al also conducted studies in order to compare the fracture strength of endodontically treated maxillary and mandibular molars with the traditional access versus the conservative access. These studies revealed that the fracture strength of the control groups exceed that of the experimental groups, however there was no significant difference between TEC and CEC.[19,20,21,22,23] Ivanoff et al also reached the same results in mandibular premolars .[23]

On the other side, some contradicting results were found by Rajesh et al who assessed the impacts of CEC on fracture resistance of teeth. They concluded that CEC may have the benefit of increased fracture resistance in mandibular molars. These conflicting results may be due to the difference in the methodology as they used mandibular premolars, molars and in functional loading unlike the present study which used static loading.[24]

Thus in the current study the remaining tooth structure was found to be one of the most important contributing factors for the fracture resistance of endodontically treated teeth and that the remaining walls regardless of the access cavity is the crucial factor to consider when performing endodontic access cavities.

CONCLUSIONS

Within the limitations of the present study the following points could be concluded:

1. The remaining tooth structure is a significant factor for the survival of endodontically treated teeth which are already compromised, where the preservation of marginal ridges had a significant effect on the maintenance of the strength of these teeth.
2. Remaining walls regardless of the access cavity design had a significant impact on the fracture resistance. Groups with 3 remaining walls showed significantly higher fracture resistance compared to the groups with 2 remaining walls.
3. The different access cavity designs had no effect on the fracture strength of the teeth, thus an access cavity design that would promote successful canal shaping and obturation without any errors should be employed.

Conflict of interest:

The authors deny any conflict of interest.

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