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FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS WITH DIFFERENT ACCESS PREPARATIONS AND CORONAL CAVITY DESIGNS – AN IN VITRO STUDY

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ABSTRACT

The aim of this study was to compare the effect of three different access cavity designs on fracture resistance of endodontically treated upper first premolars restored with two different coronal cavity designs.

Materials and Methods: Seventy two upper first premolars were selected and divided into three equal groups: Group I, traditional endodontic access cavity (TEC); Group II, conservative endodontic access cavity (CEC); Group III, Truss endodontic access cavity (TUS). Each group was further subdivided into two equal subgroups according to the coronal cavity design either with or without cusp tipping preparations (CTP) or (CCP) respectively (n = 12/subgroup). According to the assigned subgroup, teeth were endodontically treated and restored with nanohybrid resin composite with etch and rinse adhesive system. Samples were mounted in a universal testing machine, loaded to failure and fracture strength was measured in Newton (N). Data were statistically analyzed by two-way ANOVA and Tukey's post hoc significance difference test were used to analyze the data.

Results: Two-way ANOVA showed that different designs of endodontic access cavities and different types of coronal cavity preparations used in the study had a significant effect on fracture resistance.

Conclusions: TUS access cavity preparation had a positive influence on fracture resistance of root canal treated maxillary premolars. Direct cusp coverage improved the fracture resistance of root canal treated maxillary premolars compared to direct intra coronal restorations. Combining the use of cusp coverage coronal cavity design in restoring root canal treated maxillary premolars with TEC or CEC access cavities may be beneficial.

KEYWORDS: Fracture resistance, Endodontically treated premolars, Coronal cavity design.

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INTRODUCTION

Teeth are subjected to a variety of forces during function. Clinically, the occlusal load at the bicuspid area is estimated to be 222-445 N (average 322.5 N), that may reach up to 520-800 N in case of parafunctional habits(1). These forces are not only delivered in a favorable direction as compressive forces but mostly as lateral and oblique destructive forces. In posterior teeth, transverse and oblique ridges play a major role in strengthening and stabilizing not only the cusps but also the whole tooth(2).

The main objective of restorative and conservative dentistry is to minimize, even preventing, further loss of dental structure to restore function, health and esthetics of teeth. It is well known that successful root canal treatment is neither reached by debriding necrotic pulpal tissue nor establishing a tight apical seal but also by the re-participation of the affected tooth in the function that it was created to perform. Such performance is totally dependent on the final restoration of the coronal part of the tooth(3,4).

According to literature, the main causes of mechanical failure of root canal treated teeth are the overextended non conservative coronal design, access cavity and/or intra-radicular preparations(4). The ideal protocol for restoring root canal treated teeth remain a controversial issue till the moment. As there is a wide variation in biomechanical properties between healthy and endodontically treated teeth(5). Such variation in the biomechanical properties and structural integrity of the teeth are most-likely attributed to dehydration, changes in the crosslinking of collagen in the dentinal structure, dentin toughness, structural loss, initial caries, cracking, coronal cavity design in addition to the access cavity preparation prior to endodontic therapy(6-8). That is why several endodontic access cavity designs, various coronal cavity preparation strategies and multiple restorative materials have been proposed in literature for restoring endodontically treated mutilated teeth(9).

Minimal invasive approaches, which gained a wide popularity in dentistry through the past years, depends on preserving and conserving biological structures, enhancing fracture strength and longevity of the offended tooth, and preventing or at least minimizing catastrophic failures(10-12).

The extension of access cavity preparation has a major impact on the fracture resistance of affected teeth. Several modifications of traditional endodontic access cavity preparation were developed to prevent excessive removal of tooth structure, that was done to create wider passage for proper biomechanical preparation of the root canal, such modifications are: conservative endodontic access cavity, orifice–directed dentin conservation access cavity (Truss), ultra conservative access cavity (Ninja), caries driven, restorative driven, Cala lilly enamel preparation, image guided endodontic access, dynamically guided endodontic access and micro guided endodontic access(6). Reducing tooth structure removal, protecting the pericervical dentin and a part of the chamber floor, favoring survival and function of endodontically treated teeth(13).

The loss of tooth structure is directly proportional with reduction in fracture resistance, which may lead to increased possibility of failure of teeth under occlusal challenges. Now a days, introduction of biomimetic principles which are based on adhesion had increased the role of bonded restorations allowing for partial coverage of the coronal structure, rendering the restorative system more resistant to the occlusal load through more favorable distribution of forces on wider areas(14).

Although indirect restorations (i.e. crown, onlay, etc.) are widely used as a final treatment for root canal treated teeth, yet direct resin composite restorations were introduced as a non-costly material with an acceptable physical and mechanical properties. Such properties, in addition to adhesion to tooth structure, would allow for improving their response to incident forces and transmitting them favorably to the underlying restorative system which lead to minimizing cusp deflection and wedging. Moreover, the adhesive concepts allow more conservative cavity designs and improve resistance of tooth structure to catastrophic fracture(15).

Based on the aforementioned data, this study was designed to compare the effect of three different access cavity designs (traditional, conservative and truss access cavity) on fracture resistance of endodontically treated upper first premolar restored with two different coronal cavity designs. The null hypothesis tested was; that there would be no effect of different access cavity designs on fracture resistance of endodontically treated upper first premolars, restored with or without cusp tipping and cusp coverage.

MATERIALS AND METHODS

Sample selection and preparation:

Seventy two upper first premolars extracted due to periodontal reasons were selected for this study. Sample size calculation was done by power analysis used fracture resistance in Newton (N) as a primary outcome. The effect size f = (4.673911) was calculated based upon the results of Mincik et al. 2016(16) and assuming that the standard deviation within each group = 70.535, using alpha level of 5% and beta level of 95% i.e. power = 95%. The minimum estimated sample size was a total of 72 samples (12 samples per subgroup). Sample size calculation was done using G*Power version 3.1.9.2.

The selected teeth fulfilled the inclusion criteria which were; fresh extraction with fully developed apices, no anomaly, two root canals and no evidence of root resorption. While the exclusion criteria included teeth with caries, restorations and apparent fracture lines or fissures(17). All teeth were radiographically examined to assure matching the inclusion criteria. Teeth were stored in containers with individual numbers containing 0.1% thymol solution at 4°C to prevent dehydration.

The selected teeth were divided into three equal groups according to the type of access cavity; Group I: Traditional endodontic access cavity (TEC); Group II: Conservative endodontic access cavity (CEC); Group III: Truss endodontic access cavity (TUS). Each group was further subdivided into two equal subgroups (n= 12/subgroup) according to the coronal cavity design received either with cusp tipping preparation (CTP) or without cusp tipping (CCP). In order to reduce the impact of tooth size and shape differences, a homogeneous subgroups were constructed.

Simulation of periodontal ligament:

The thickness of periodontal ligaments was simulated by surrounding the root of the teeth with 0.3-mm thickness of light body silicon impression material (elite HD+, Zhermack dental, Italy). This silicon layer was supposed to allow for a minimal movement of the teeth in its epoxy resin socket, in an attempt to simulate the action of the periodontal membrane(18).

Mounting in epoxy resin molds:

Selected teeth were embedded in epoxy resin cylinders with their occlusal surface facing upwards and parallel to the horizontal plan. The cemento-enamel junction was located slightly above the epoxy resin surface by 2mm (Figure 1). This was accomplished by using a cylindrical Teflon mold.

Occlusal silicon index fabrication:

Before endodontic access preparation, impressions were taken for teeth using putty silicone impression material (elite HD+, Zhermack dental, Italy). After setting of the impression material, it was sectioned bucco-palatally by a scalpel into two halves to serve as an occlusal index, guiding in restoring the crowns to their original form (Figure 2)

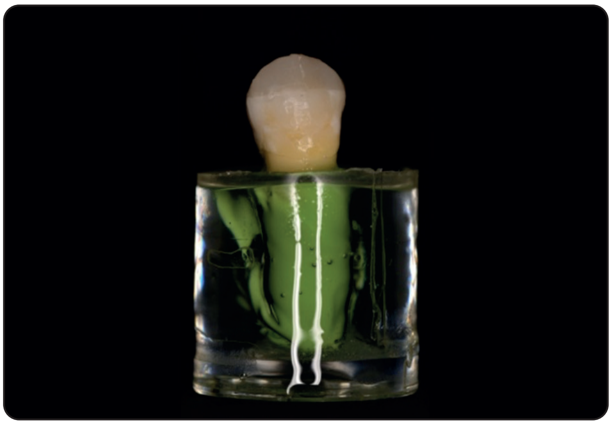

Fig. (1) A tooth mounted in epoxy resin mold with periodontal ligament simulation.

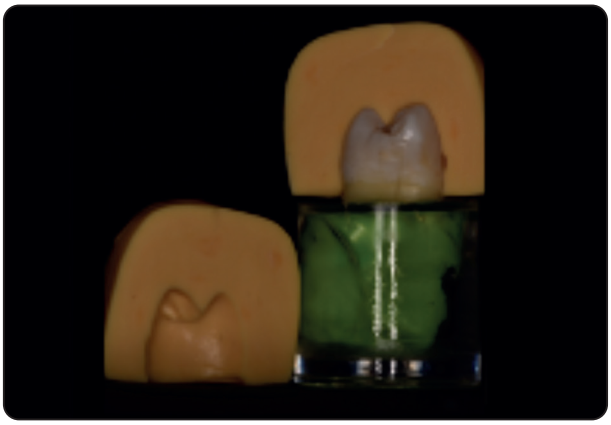

Fig. (2) Impressions were taken and sectioned bucco-palatally by a scalpel into two halves to serve as an occlusal index

Preparation of TEC, CEC and TUS endodontic access cavity designs:

Group I (TEC): Traditional endodontic access cavity was done using round carbide bur (Mani Inc. bur size no #3), mounted in a high-speed hand piece under copious water coolant, with complete removal of the roof of the pulp chamber allowing straight line access to the canal orifices and flaring of walls was done using tapered stone with rounded end (Mani, Utsunomiya, Japan) (Figure 3a).

Group II (CEC): Conservative endodontic access cavity was done to be centered between the roots and existing root canals and extended only as necessary to access canal orifices while preserving peri-cervical dentin and part of the chamber roof with a small round carbide bur (Mani Inc. bur size no #2) mounted in a high-speed hand piece under copious water coolant (Figure 3b).

Group III (TUS): Truss endodontic access cavity was gained from the occlusal surface to the roof of the pulp chamber by orienting the bur parallel to the long axis of the tooth in oval shape buccolingually with a small round bur (Mani Inc. bur size no #2) using a high-speed hand piece under copious water coolant. The buccal pulp horn was confirmed using a DG-16 probe. Then, the bur was placed over the palatal pulp horn and access to

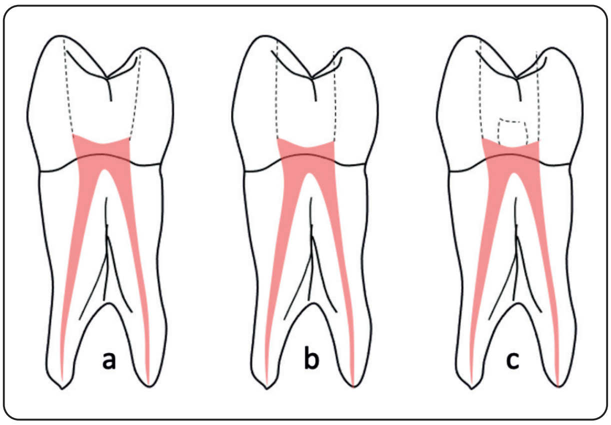

Fig. (3) Schematic diagram for the three endodontic access cavity designs [(a)TEC, (b)CEC, (c)TUS]

the pulp chamber was gained keeping the dentinal bridge (roof) in place between buccal and palatal canal orifices[19]. (Figure 3c)

Root canal preparation:

Apical patency was established with K-file size #10 (Mani, Utsunomiya, Japan) using watch winding motion until it reached the apex. The working length was determined by subtracting 1mm from the length of #10 K-file in a periapical radiograph. The root canals were shaped using M-Pro NiTi rotary files reaching a final continuous 0.06 taper up to size 25 using crown-down technique. Then apical preparation was completed using flexible manual RT files (Mani, Utsunomiya, Japan) till master apical file size # 35. Instruments with any sign of deformation after root canal preparation were discarded and replaced. Irrigation was performed between each file using 30-gauge endodontic needle (NavyTip, Ultradent, USA) that was inserted 1 mm short from the working length during and after instrumentation. Each root canal was irrigated with 4 ml of 2.5% sodium hypochlorite.

Root canal obturation:

The canals were dried with absorbent paper points (Absorbent paper points, Meta Biomed, Chungcheongbuk,-do, Korea) similar to the master apical file. Resin based sealer (ADSEAL, Meta Biomed, Chungcheongbuk,-do, Korea) was used according to the manufacturer instructions. Master gutta-percha cone size 35 taper 2% (Gutta Perch Points, Meta Biomed, Chungcheongbuk,-do, Korea) was selected and tugback was checked. Spreader size 30 was inserted to within 2 mm of working length to laterally pack the gutta-percha. Accessory cones size 25 were coated with sealer and inserted into the canal until it was completely filled. Excess obturation material was removed using flame heated condenser. Final periapical radiographs were taken for the obturated teeth. **(Figure 4)**

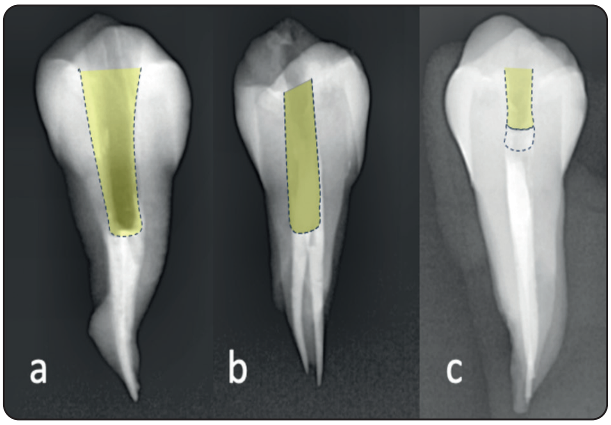

Fig. (4) Radiographic evaluation for three obturated premolars with the three endodontic access cavity designs (highlighted) [(a)TEC, (b)CEC, (c)TUS]

Preparation of coronal cavity designs:

Standardized class II occluso-mesial cavities were prepared with a coarse cylindrical diamond bur (80 µm APS, Intensiv SA, Grancia, Switzerland) as follow: occlusal cavity depth of 2.5 mm, occlusal cavity width was prepared half of intercuspal distance at isthmus. Mesial box cavity was prepared with the following criteria; axial wall height 1.5 mm, gingival floor depth 1.0 mm, and gingival floor width was prepared half intercuspal distance. The cavity margins were not beveled and all inner angles were slightly rounded[20]. Schematic diagram showing the occluso-mesial cavity parameters is presented in Figure (5).

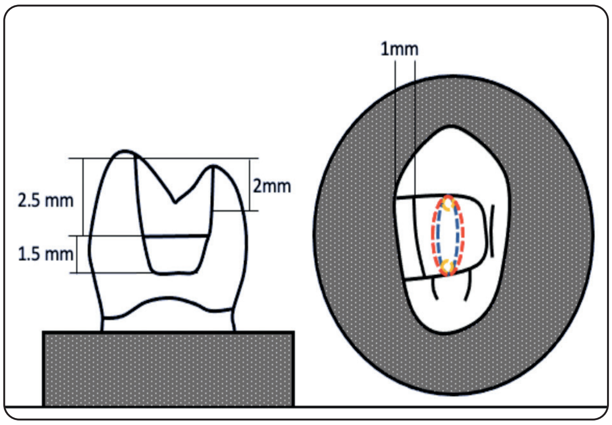

Fig. (5) Schematic diagram showing the occluso-mesial cavity parameters

In cusp tipping groups (CTP), after finishing the above mentioned cavity preparation, a few reference grooves were created with 2 mm depth on the cusps using a fissure bur. Using these reference grooves, buccal and palatal cusp were reduced. One half of the previously made occlusal silicon index was placed on the respective tooth, 2 mm occlusal reduction was checked using a periodontal probe. All cavities were prepared by one operator[21].

Restoration of Teeth:

The prepared cavities were etched with 37% phosphoric acid gel (FineEtch 37, Spident, Korea) for 30 seconds for enamel and 15 seconds for dentin.

Prepared teeth were rinsed for 30 seconds and dried, followed by the application of adhesive agent (adper, single bond 2, 3M ESPE, USA). Gentle air blast for 5 seconds was done to evaporate the adhesive solvent followed by 20 seconds of light curing by a LED curing unit (Blue phase N, Ivoclar Vivadent, Schaan, Liechtenstein, Germany). The cavities were restored with nanohybrid resin composite (filtek Z250XT, 3M, USA). Resin composite was applied in oblique increments with a maximum thickness of 2 mm followed by 20 seconds of light curing. The anatomy was restored guided by the silicon index, and a final curing was done for 40 seconds for every side of the restoration. Final coronal restorations is illustrated in Figure (6).

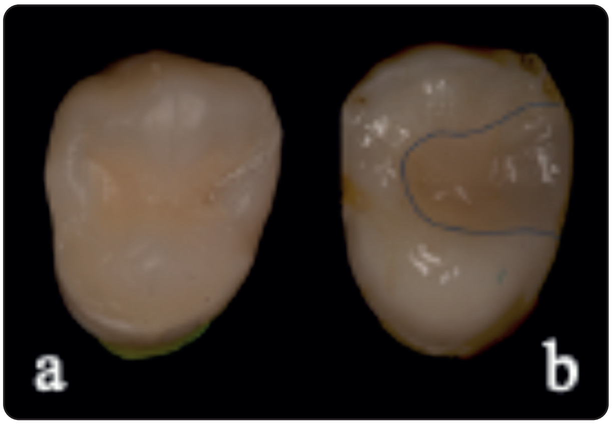

Fig. (6) Two premolars restored according to the used cavity designs [(a) CTP & (b) CCP]

Fracture resistance testing:

All teeth were subjected to fracture resistance test using universal testing machine (Instron, model 3345, England). Tightening screws were used to fix the samples on the lower compartment of the testing machine. The movable upper compartment of the machine contained a 6-mm diameter steel sphere applying a static axial load perpendicular to the long axis of the teeth and touching two points; buccal and palatal cusp ridges, with crosshead speed of 1 mm/min. Each tooth was loaded to fracture. Maximum force needed for fracture was recorded in Newton (N) using machine software (BlueHill universal, Instron, England). Schematic diagram for load application illustrated in Figure (7).

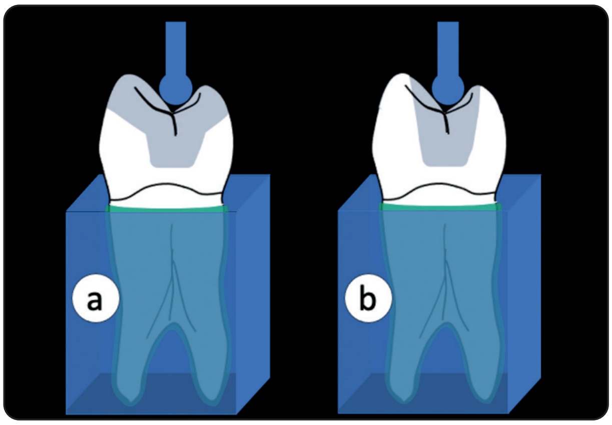

Fig. (7) Schematic diagram for load application [(a) CTP & (b) CCP].

Statistical analysis:

Normality of data distribution was evaluated by Kolmogorov-Smirnov test. Data were found to be normally distributed and statistically analyzed by two-way analysis of variance (ANOVA) and Tukey's post hoc significance difference tests were used to analyze the data, and the significance level was set at $p \leq 0.05$.

RESULTS

Two way ANOVA was used to test the effect of the two tested variables of the study on fracture resistance. The first variable which is the type of endodontic access cavity, and it had three levels (either TEC, CEC, or TUS). While the second variable was the type of coronal cavity design, it had two levels either with or without cusp tipping preparations (CTP) or (CCP) respectively. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

Two way ANOVA showed that different designs of endodontic access cavity had a statistically significant effect on the fracture resistance of upper premolars at an F value of 61.1962 and a p-value=

TABLE (1) Two way ANOVA statistical evaluation for the effect of coronal cavity preparation and the access cavity on fracture resistance of upper premolars.

Source	Type III sum of squares	Df	Mean square	F	Sig.
Coronal cavity	1454461.172	1	1454461.172	61.1962	0.001
Access cavity	1242220.109	2	621110.0544	26.1331	0.001
Coronal cavity * Access cavity	182191.4361	2	91095.718	3.8328	0.027

TABLE (2) Means, standard deviation, and significance in Newton for the tested groups.

	TEC		CEC		TUS	
	Mean	SD	Mean	SD	Mean	SD
TCP	992.62[b]	±162.46	1097.71[ab]	±209.55	1256.83[a]	±136.29
CCP	744.82[c]	±152.52	681.81[c]	±130.15	1072.38[ab]	±116.29

Different superscript show statistical significance p≤0.05

0.001, also statistical significant effect was noticed for the impact of the type coronal cavity preparation on fracture resistance (F value=26.1331 and p-value = 0.001). Yet, there was an interaction between the two tested variables at F value =3.8328 and p-value = 0.027. **(Table 1)**

The results of different tested fracture resistance groups of upper premolars are shown in **Table (2) and Figure (8)**. The highest values in N of all the tested groups was 1256.83±136.29 for TUS/TCP designs, while the least values of 681.81±130.15 N was for CEC/CCP.

Although, TUS/TCP showed the highest values for fracture resistance (1256.83±136.29 N), yet no statistical significant difference was detected between this subgroups, and both TUS/CCP 1072.38±116.29 N and CEC/TCP 1097.71±209.55N. The least values of 681.81±130.15 MPa was scored for CEC/CCP, which had no statistical difference from the subgroup TEC/CCP. 744.82±152.52 N

All the subgroups that received TCP, showed a higher fracture resistance, such increase in fracture resistance was statistically significant except for TUS/TCP, and TUS/CCP subgroups, the increase didn't show any statistical evidence.

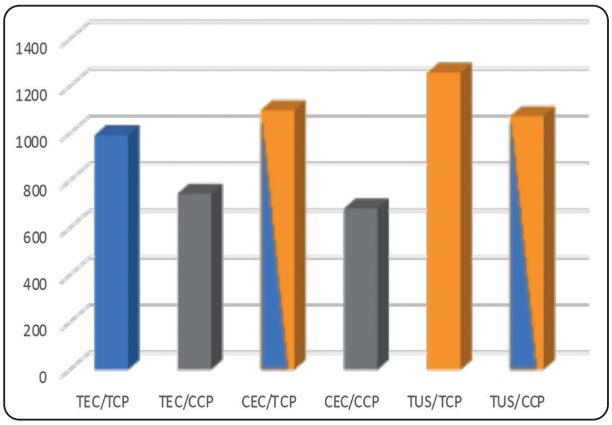

Fig. (8) Mean fracture resistance of all the tested groups in Newton

DISCUSSION

An ideal access cavity is characterized by paving the path to full debridement of pupal tissue, proper inter-radicular preparation and obturation. But unfortunately, an over extended access cavity preparation could participate in lowering the resistance of the remaining tooth structure under destructive functional forces. On the other hand, under extended access interfere with the whole endodontic procedures[22].

Since the introduction of minimal invasive principal in endodontics, there is a conflict in literature about the ability of conservative access preparations to preserve remaining tooth structure compared to traditional one. Moreover, the more conservative access cavity preparation, the more need for skilled operator equipped with suitable armamentarium[23].

Many authors have argued that traditional access cavity damages a large amount of dentin, which weakens the structure of tooth and reduces fracture resistance. Silva et al. in their systematic review, mentioned studies according to which, extraction of endodontic treated teeth is mainly caused by faulty restorative design[24]. Therefore, to improve the prognosis of endodontically treated teeth, it is essential that remaining tooth structure be preserved and restored by the suitable restorative design[25].

Direct resin composite was the material of choice in our study as, in addition to being repairable, resin composite is claimed to have the advantage of reducing the number of interfaces in the restoration minimizing the accumulation of stresses at such interfaces between different materials with different modulus of elasticity which may affect fracture risk[26]. Such condition is inevitable in case of other indirect restorations.

The survival of restored endodontic treated teeth depend mainly on the remaining conserved tooth structure[14]. Limiting the extension during operative procedures is responsible not only of prevention the destruction of the remaining supported structure of teeth but also secures a sound structure capable of providing a restorative system able to withstand complex occlusal load, as it reduces lateral destructive forces and put dental structures into a more favorable condition of compression[27].

In the current study, truss endodontic access cavity preparation had a positive effect on increasing the fracture resistance of endodontic treated premolars, either with or without cusp coverage. This is in agreement with other studies that found that modern minimally invasive designs of access cavity play a role in preserving dentin, which is the major structural component of the tooth, providing a design able to favorably shift the fulcrum point for cuspal fracture[28,29]. And others who found that remaining tooth structure and wall thickness is an effective clinical parameter in selecting an appropriate adhesive restoration technique for endodontically treated premolars[30,31]. Such superior strength may be due to the preservation of teeth structure whether axial walls or even partial conservation of the roof of the pulp chamber, which may play a major role in binding the walls of the cavity, making them more resistance to unfavorable deformation during function[13].On the other hand, the findings of our study was in contradiction with Forster et al. who found that wall thickness didn't affect fracture strength in teeth restored with a direct resin composite[32].

Cuspal coverage with direct composite restoration is found to be a conservative and one-appointment complementary treatment option in large cavities. In previous studies, it was reported that cuspal coverage increases the fracture resistance of weakened endodontically treated teeth when compared to teeth restored without cusp coverage[16,33]. This may be due to reduction in the effective cusp length significantly reduced the deflection, this was evident in case of traditional and conservative access cavity groups as cuspal coverage significantly increased the fracture resistance compared to the other group that received no cusp coverage[34,35].

Although the importance of preserving tooth structure appears self-evident, it can be concluded from the literature that complete transition to minimal invasive endodontic access cavities has yet to be validated. Therefore, the application of minimal invasive endodontic access in clinical practice require critical consideration by weighing the risks and benefits of both traditional and minimal invasive endodontic access. Furthermore, the currently available evidence is insufficient to support the use of minimal invasive endodontic access indiscriminately in routine endodontic practice.

CONCLUSION

1. TUS access cavity preparation, had a positive influence on fracture resistance of root canal treated maxillary premolars.
2. Direct cusp coverage improved the fracture resistance of root canal treated maxillary premolars, compared to direct intra coronal restorations.
3. Combining the use of cusp coverage coronal cavity design in restoring root canal treated maxillary premolars with TEC or CEC access cavities, may be beneficial.

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