EGYPTIAN
DENTAL JOURNAL

Vol. 68, 1827:1839, April, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 2021-12-25 • Accept Date : 2022-01-26 • Available online: 2022-03-30 • DOI : 10.21608/edj.2022.112910.1926

AN IN VITRO EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED USING DIFFERENT RESTORATIVE MATERIALS AND GLASS FIBER POSTS

Ahmed El-Kabbaney*, Dina S. Farahat **, Rabab Mehesen *** *and* Abdelraheem Abdelkader ****

ABSTRACT

Objectives: The aim of this study was to compare fracture resistance of endodontically treated premolars restored with fiber reinforced post and different resin composite restorative materials.

Materials and Methods: Eighty sound extracted premolar teeth were divided in to 3 groups; A (10 teeth kept sound as +ve control), B (10 teeth prepared only as –ve control), C (60 teeth divided into subgroup a as prepared and restored without post, and subgroup b as prepared and restored with prefabricated fiber-reinforced post (Glassix plus, Harald Nordin SA, Switzerland)). Each subgroup was divided into 3 divisions (n=10); 1 (coronal restoration with Tetric EvoCeram), 2 (coronal restoration with Tetric N-ceram), and 3 (coronal restoration with Tetric N-ceram Bulk-fill). All the teeth in group C were prepared for MOD cavities, root canal cleaned, shaped and obturated. All the teeth were subjected to thermo-mechanical aging and the universal testing machine by applying vertical compressive force at a crosshead speed of 0.5 mm/ min. All the data were collected to be subjected to quantitative statistical analysis.

Results: Group A showed the highest fracture resistance values, and Group B showed the lowest values. Two-way ANOVA showed a significant difference among all groups.

Conclusions: Bulk-fill resin composite restorations supported with prefabricated fiber-reinforced post improved fracture resistance of endodontically treated maxillary premolars.

KEYWORDS: fiber-reinforced post, nano-hybrid resin composites, fracture resistance, thermo-mechanical cycling, Bulk-fill resin composite.

* Department of Endodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
** Department of Dental Biomaterials, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
*** Department of Operative Dentistry, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
**** Department of Fixed Prosthodontic, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

INTRODUCTION

The loss of moisture in the dentin of endodontically treated teeth, significantly increases its brittleness making these teeth more prone to fracture. Moreover, the coronal destruction due to carious lesions, access cavity preparation, root canal instrumentation and previous fracture adds to the weakness of such teeth. [1,2] For an endodontically treated tooth, an ideal final restoration should restore function and esthetics, conserve any remaining tooth structure and inhibit microleakage to prevent ingress of bacteria into the root canal. [3] The coronal restoration and seal have greater influence on apical and periodontal health than the endodontic treatment's technical quality. Accordingly, endodontically treated teeth are considered especially at risk. As a result, it is not until the final coronal restoration has been placed, that the root canal therapy can be deemed complete. [4,5]

In prosthetic terms, the treatment modalities utilized with a root canal treated tooth include custom made or pre-shaped posts and cores and full crowns. On the other hand, amalgam, composite, or reinforced glass ionomer restorations supported by prefabricated posts are used to describe the used treatments in restorative terms. [6] Contemporary restorative concepts aim for less invasive forms of restorative treatment aided by the continuous advances in adhesive dentistry and restorative materials. Also, the use of different adhesive direct restorative techniques and materials yielded promising in vitro results especially adhesive resin composite restorations when compared to amalgam and glass ionomer. [7,8]

Different improvements in resin composites have enhanced the physical and mechanical properties and held back the problem of polymerization shrinkage. Higher filler content, an improved filler technology, chemical modifications in the organic monomers associated with different modes of polymerization, and new equipment have helped to improve their mechanical and physical properties, handling, and durability [9]. The advancements in the resin matrix formulation and filler technology have led to alterations in the motives for replacement of restorations with increased tendency to use composite restorations in stress bearing areas in posterior teeth. [10]

Recently, prefabricated fiber reinforced plastic posts have been gradually replacing cast metal posts due to their easier clinical procedure, superior tissue tolerance, ease of manipulation, lower cost, suitable mechanical properties, corrosion resistance, easier removal, and better aesthetics compared to metal posts. [11] The higher rigidity of metal posts allows them to endure high forces without deformation. However, such high elastic modulus does not allow for the uniform distribution of stresses resulting in higher concentration of stresses especially at the apex of the root thus increasing the risk for root fracture. [12,13]

A success rate of 88% - 99% was reported in clinical investigations in which fiber-reinforced posts were used to restore endodontically treated teeth, with no incidence of root fracture. [14] This can be attributed to favorable elastic modulus of fiber posts which is close to that of dentine allowing for improved stress distribution to root canal walls thus decreasing the risks of root fractures. [15]

These advancements in materials and techniques allow clinicians to approach old challenges from new perspectives that can result in innovative novel solutions. Accordingly, it is strongly recommended to adopt these advancements in the adhesives, new composite resin systems and new posts to develop a more conservative, durable, and aesthetically acceptable restoration of root canal treated teeth.

Thus, this study was designed to evaluate the fracture resistance of endodontically treated teeth restored with and without posts and different resin composite restorations. The null hypotheses were: (1) there is no difference in the fracture resistance of sound and endodontically treated teeth (2) there is no difference in the fracture resistance of endodontically treated teeth restored with or without post insertion (3) there is no difference in the fracture resistance of endodontically treated teeth restored with different resin composite materials.

MATERIALS AND METHODS

1. Selection of teeth

A total number of eighty caries free freshly extracted human mature maxillary premolar teeth were collected and selected for this study. The teeth were obtained according to the protocol reviewed and approved by the Ethical Committee, Faculty of Dentistry, Mansoura University. They were extracted in the dental clinic of Oral Surgery Department, Faculty of Dentistry, Mansoura University for orthodontic purposes after the patients approved and signed a consent form. The storage protocols followed international and institutional infection control guidelines. After removing all the external debris with an ultrasonic scaler, distilled water was used as a storage medium. They were stored at 37°C in an incubator (BTC, Model: BT1020, Cairo, Egypt), and the storage medium was replaced every 2 days. Then, the samples were cleaned with ultrasonic scaler again to remove all soft tissues and calculus deposits, washed under running water, and examined under stereomicroscope (Leica, Hanau, Germany) at 24 X to exclude teeth with caries, defects, or cracks. After examination, they were stored in 0.2% anti-bacterial thymol solution at 4°C until used for this study in a period not more than 3 months.

2. Grouping of samples

The selected teeth were divided into three main groups; group (A) in which 10 teeth (n=10) were left sound (+ ve control), group (B) in which 10 teeth (n=10) had undergone access cavity, root canal preparation only (- ve control), and group (C) in which 60 teeth (n=60) had undergone access cavity, root canal preparation, obturation only. Then, group (C) was divided into two subgroups (n=30); subgroup (a) in which teeth had undergone access cavity, root canal preparation, obturation, and restored coronally without post insertion, subgroup (b) in which teeth had undergone access cavity, root canal preparation, obturation, and restored coronally with insertion of prefabricated glass fiber-reinforced post (Glassix plus, Harald Nordin SA, Switzerland). After that, each subgroup was divided into three divisions (n=10) according to the coronal restorative material. Division 1 was restored with nano-hybrid resin composite (Tetric EvoCeram, Ivoclar Vivadent, Liechtenstein), division 2 was restored with nano-hybrid resin composite (Tetric N-ceram, Ivoclar Vivadent, Liechtenstein), and division 3 was restored with bulk-fill resin composite (Tetric N-ceram Bulk-fill, Ivoclar Vivadent, Liechtenstein) (Figure 1) (Table 1).

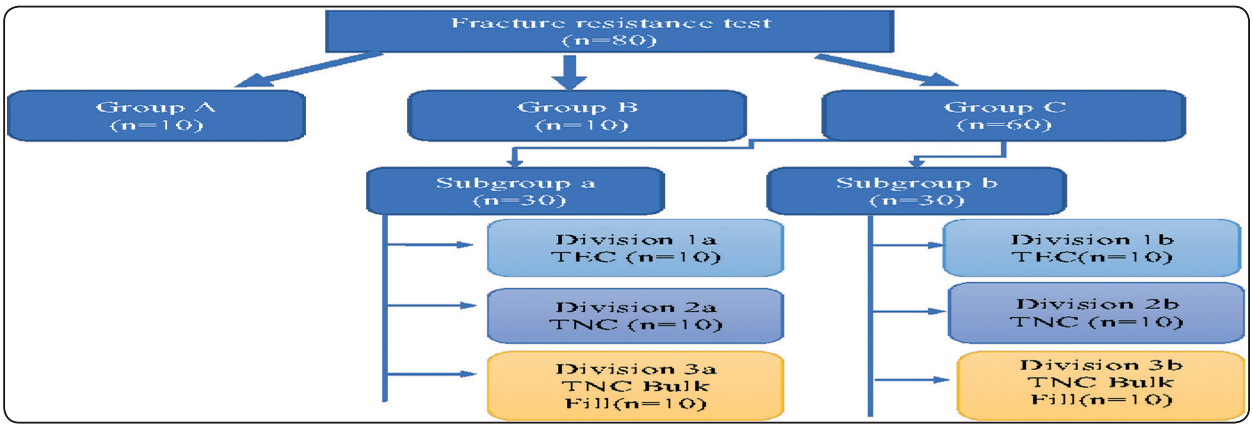

Fig. (1) The study design of all the tested restorative materials.

TABLE (1) Different resin composite materials.

Product	Composition	Manufacturer
Tetric-N-Bond	Bisacrylamide, water, Bismethacrylamide Dihydrogen phosphate, amino acid acrylamide, hydroxy alkyl methacrylamide, silicon dioxide, fillers, stabilizers	Ivoclar,Vivadent, Schaan, Liechtenstein
Tetric EvoCeram	• Dimethacrylates: Bis-GMA, UDMA, Ethoxylated Bis-EMA (16.8 wt%) • barium glass, ytterbium fluoride, mixed oxides (48.5 wt%) • Prepolymers (34 wt%) • Additives, catalysts and stabilizers and pigments	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric N-Ceram	• Dimethacrylates: Bis-GMA, UDMA, Bis-EMA (18.6 wt%) • barium glass, ytterbium trifluoride, mixed oxides, silicon dioxide (63.5 wt%) • Prepolymerized fillers (17 wt%) • Additives, stabilizers, catalysts, pigments	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric N-Ceram Bulk-fill	• Dimethacrylates: Bis-GMA, Bis-EMA, UDMA, EBPADMA • prepolymer filler, barium glass filler, ytterbium trifluoride (average size 40-100 nm)	Ivoclar Vivadent, Schaan, Liechtenstein

Bis-GMA: Bis phenol A-glycidyl methacrylate, UDMA: urethane dimethacrylate,

Bis EMA: bisphenol-A ethoxylated methacrylate, TEGDMA: Tri-ethylene glycol dimethacrylate, EBPADMA: ethoxylated bisphenol A dimethacrylate.

3. Preparation and restoration of teeth

A. Endodontic treatment

All teeth were then endodontically treated by the same endodontist (AK). Access cavities were prepared using carbide bur in a high-speed handpiece with air water coolant, then size twenty barbed broaches were used to remove the necrotic pulp tissue. To calculate the working length, a K file #10 (Mani Inc., Japan) was inserted into the canal and moved past the apical foramen till its tip was barely visible. The file was then retracted from the canal and its length was measured and used to determine the working length by subtraction of 0.5 mm from the measured length. ProTaper NEXT rotary files (Dentsply Maillefer, Ballaigues, Switzerland) were used for root canals preparation in a brushing motion with a rotational speed of 300 rpm and torque of 2.0-5.2 (using X-Smart Plus electric motor), till X4 file (40/6). 3ml of 5.25% Sodium hypochlorite (NaOCl) were used to irrigate the prepared root canals between files. Then, 1 ml of 17% Ethylenediamine Tetraacetic Acid (EDTA) (MD-cleanser, Meta Biomed) was used to eliminate the smear layer and lastly 5 ml of distilled water were used for final irrigation. The prepared root canals were dried using paper points. Single cone technique was applied in root canal obturation using Protaper Next matching single gutta percha cones corresponding to files (X4) and Adseal sealer (Meta Biomed Co, Cheongju, Korea). Finally, EQ-V Pack Tip (Meta Biomed Co, Cheongju, Korea) was used to remove excess gutta-percha and then a hand plugger was used to condense the gutta-percha.

B. Mounting of teeth

The roots of each tooth were inserted into molten wax to a level just 2 mm below the buccal cemento-enamel junction (CEJ) producing a layer about 0.2-0.3 mm that mimics the thickness of the periodontal ligament, in an effort to simulate the periodontium. Each tooth was mounted in a polyvinyl chloride ring (PVC) with 1.8 cm height and 1.4 cm internal diameter filled with acrylic resin. Standardization of the angulation and position of each tooth was achieved using a specially designed jig. At the end of the dough stage, each tooth was retrieved from the resin then, the wax spacer was scrapped from the acrylic resin alveoli and the root surfaces. Soft polyether impression material (Impregum, 3M ESPE Dental products, MN, USA) was mixed and dispensed into the acrylic resin alveolus, then each tooth was repositioned into its corresponding PVC cylinder, and the polyether material was allowed to set. A scalpel was used to remove any excess polyether material and to provide a flat surface 2 mm below the buccal CEJ for each tooth.

C. Coronal cavity reparation

Standardized MOD slot cavities were prepared by the same operator (RM) in the teeth down to CEJ so that the thickness of the wall at the buccal occlusal surface was 2.5 mm, at the buccal CEJ was 3 mm, at the lingual occlusal surface was 2 mm, and at the lingual CEJ was 2 mm and occluso-gingival depth was 5-7 mm. The preparations were carried out using no. 59 fissure bur (Komet, Brasseler, Lemgo, Germany) in a high-speed handpiece under copious air-water cooling. For standardization, the handpiece was fixed in a specially designed jig and fixer that was designed at Production Engineering and Mechanical Design Department, Faculty of Engineering, Mansoura University. A new fissure bur was employed for each 5 preparations, to ensure high cutting efficiency.

D. Post space preparation and insertion

For those teeth that would receive posts; palatal canals were selected for post insertion. The study was designed to standardize the post to 11mm length; 8mm to be inserted in the root canal, leaving 4 mm of gutta-percha in the apical canal space as an apical seal, and the remaining 3 mm of the post intruding into the coronal cavity. Post space preparation was accomplished by using pilot reamer (Harald Nordin, Switzerland) and a rubber stopper was added to its shaft and adjusted to the desired post length. A low- speed drill corresponding to the selected post size, provided by the manufacturer of prefabricated glass fiber-reinforced post system (Glassix plus, Harald Nordin SA, Switzerland), was used to enlarge the root canal of each specimen. The canals were flushed using sterile saline then dried with paper points.

Cementation of the posts was carried out following the manufacturer's instructions for all divisions using self-adhesive dual-cure resin cement (G-CEM LinkAce™, GC Corporation, Tokyo, Japan). A brush was used to apply cement on the post surface and a paste carrier tip was used to apply it inside the post space. Finger pressure slowly fixed all the posts, removing any excess cement by a brush. Immediately on cementing the post, a LED curing unit (BlueLEX LD-105, Monitex, Taiwan) was used to direct curing light from the top of the post using an output of 800 mW/cm^2 for 60 seconds. A radiometer was used to periodically check the light curing output (Demetron, Kerr, CT-100, Danbury, USA).

E. Restorative procedures

All the restorative systems used in this study were applied according to their manufacturer's instructions using shade A3 for all the restored teeth. Light polymerization of resin composite restorative systems was accomplished with a light LED curing unit (BlueLEX LD-105, Monitex, Taiwan) for 20 seconds. The light curing output was checked for an average irradiance of 800mW/cm^2 by the same radiometer.

1. Tetric EvoCeram nano-hybrid resin composite

For cavities in division 1 in both sub-groups were restored with Tetric EvoCeram nano-hybrid resin composite. All the cavity walls were etched using total etch strategy with 37% phosphoric acid etchant gel (Eco-Etch, Ivoclar Vivadent, Schaan, Liechtenstein) which was applied to enamel and dentin for 30 seconds then rinsed with water stream for 10 seconds and dried thoroughly. The bonding agent (Tetric-N-Bond, Ivoclar Vivadent, Schaan, Liechtenstein) was applied to all the cavity surfaces using fully saturated brush tip for 2 consecutive coats, then dried gently for 2-5 seconds and light cured for 20 seconds for each coat using LED curing light.

Tofflemire metal retainer and metal band were used to restore the teeth and reestablish the proximal contours. To prevent resin composite overhanging at the proximal gingival margin, an ivory No.1 retainer with one heavy rubber piece at each prong of the retainer was tightened over the mid-mesial and mid-distal cervical areas of metal band to ensure full adaptation to gingival wall (Figure 2). The resin composite was inserted in increments, so that each does not exceed 2 mm in thickness and was photo cured using LED curing unit for 20 seconds. After completion of the restoration, the matrix band was removed, and additional curing of the restoration was carried out from each side for 20 seconds. Finishing carbide bur FG 8379 (SS White, New Jersey, USA) was used to remove excess resin composite at occlusal and proximal margins under water coolant. After that, each restoration was polished using Enhance polishing discs (Dentsply Sirona, USA) under water coolant.

Fig (2): The Matrix system fixed and ivory retainer no. 1.

2. Tetric N-Ceram nano-hybrid resin composite.

Teeth in division 2 in both sub-groups were restored with Tetric N-Ceram nano-hybrid resin composite in the same technique as before.

3. Tetric N-Ceram Bulk-fill resin composite.

Teeth in division 3 in both sub-groups were restored with Tetric N-Ceram bulk-fill resin composite in the same technique as before except the insertion of resin composite was done using a 4-mm layer and light cured for 20 seconds.

4. Thermo cycling:

All the restored teeth were stored in an incubator at 37 °C in 100% humidity for 48 h, and all specimens were thermo-cycled for 500 cycles between 5°C±2 and 55 °C±2 using a dwell time of 30 s.

5. Cyclic loading:

The PVC rings with the teeth were then mounted on the cyclic loading machine, and the buccal walls of the teeth were 500,000 cycles using a load with a peak of 100 N applied with specimens' long axis with a frequency of 75 cycles/min.

6. Fracture resistance test:

The specimens were fixed in a Universal Testing Machine (Instron, MA, USA) to assess their fracture resistance. A stainless-steel bar with a diameter of 5-mm was attached to the upper stage of the machine and aligned parallel to the long axis of the tooth. The bar was fixed so that it was centered above the teeth and barely contacted the buccal and lingual cusps of the tooth and the occlusal surface of the restoration. Then, a vertical compressive force was applied at a crosshead speed of 0.5 mm/ min till fracture. The load needed to fracture each tooth was recorded in Newtons.

Statistical analysis

The fracture resistance test data were normally distributed and presented as mean ± standard deviation for descriptive statistics. Two-way ANOVA was used to compare fracture resistance test data between groups and restorative materials followed by Tukey's multiple comparisons if significant differences detected. $p < .05$ was considered statistically significant.

RESULTS

All specimens were subjected to (TC/ ML) and survived 500,000 cycles of dynamic loading. No fracture has been recorded. Descriptive statistics for fracture resistance values in newton (N) of all the groups with thermal and mechanical loading showed that sound teeth group (+ve control) presented the highest mean of fracture resistance values (1515 N), while prepared un-restored group (-ve control) showed the lowest mean values (203.9 N). Analysis of variance indicated significant differences among all the groups, with the sound teeth (Group A) (+ve control) presenting higher fracture resistance values than the other groups (Group B and Group C), while the prepared unrestored (Group B) showed the lowest values compared to the other groups, Table (2).

The fracture resistance results of restored groups arranged from the lowest to the highest as follows: Group C division 1a showed the lowest mean fracture resistance value (608.1N) followed by Group C division 2a that showed mean fracture resistance of (662.6N), followed by Group C division 3a that showed mean fracture resistance value of (674.5N), followed by Group C division 1b that showed mean fracture resistance of (846.7N), followed by Group C division 2b that showed mean fracture resistance of (854.4 N), and the highest value was in Group C division 3b that showed mean fracture resistance of (897.7 N), as presented in Figure (3).

TABLE (2): Comparison of fracture resistance values in (N) of all groups.

Groups	No	Mean	±S.D	Min.	Max.
Group A	10	1515	111	1442	1610
Group B	10	203.9	17.3	174.1	225.2
Group C Division 1a	10	608.1	30.2	561.7	617.4
Group C Division 2a	10	662.6	49.1	600.2	760.1
Group C Division 3a	10	674.5	39.6	622.1	730.3
Group C Division 1b	10	846.7	48.2	737.1	893.8
Group C Division 2b	10	854.4	51.16	761.6	926.3
Group C Division 3b	10	897.7	44.5	850.6	959.1

No = Number of specimens, ±S.D = Standard deviation.

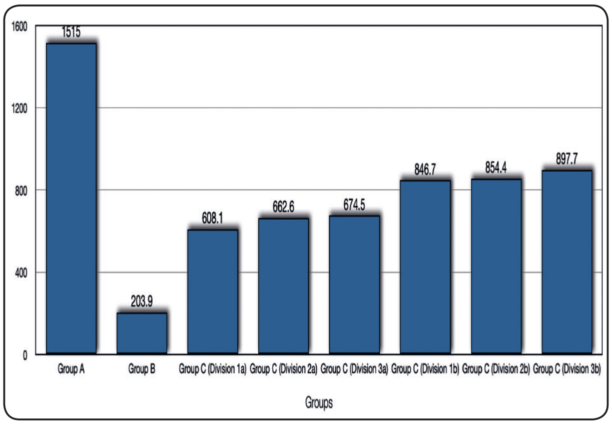

Fig (3): Fracture resistance values in (N) of all groups.

Two-way ANOVA test was used for comparison among all groups and showed that there was a significant difference (*P*<.05) with respect to resistance to fracture. Groups B and C revealed a significant decrease in fracture resistance values in comparison to Group A. While Group B revealed significant decrease in the fracture resistance values when compared to Group C with each restorative system used. Student t-test showed significant increase in the fracture resistance of group C division 1b compared to group C division 1a (P=.0001). Also, there was a significant increase in the fracture resistance of group C division 2b group restored compared to group C division 2a (P=.0001). Also, there was a significant increase in the fracture resistance of group C division 3b compared to group C division 3a (P=.0001) as presented in Table 3.

TABLE (3): Comparison among the mean values of fracture resistance in (N) for all groups.

Groups	No	Mean	±S.D	T	p	F
Group A	10	1515	111	37	.0001	452.2
Group B	10	203.9	17.3			
Group C Division 1a	10	608.1	30.2	40.2	.0001	
Group C Division 1b	10	846.7	48.2			
Group C Division 2a	10	662.6	49.1	50.2	.0001	
Group C Division 2b	10	854.4	51.16			
Group C Division 3a	10	674.5	39.6	37.2	.0001	
Group C Division 3b	10	897.7	44.5			

Regarding the restorative resin composite systems without post in Group C, One way ANOVA test was used and showed that there was a significant difference (P = .0007). Group C division 3a showed the highest fracture resistance mean value, followed by division 2a, and the lowest value was for division 1a as presented in Table 4, and Figure 4. Regarding the restorative system with prefabricated glass fiber-reinforced post, One way ANOVA test was used and showed that there was a significant difference (P = .0007). Group C division 3b showed the highest fracture resistance mean value, followed by division 2b, and the lowest value was for division 1b as presented in Table (5) and Figure (5).

TABLE (4): Comparison among the mean values of fracture resistance in (N) of different resin composite groups without post.

Groups	No	Mean	±S.D	F	P
Group C Division 1a	10	608.1	30.2	9.66	.0007
Group C Division 2a	10	662.6	49.1		
Group C Division 3a	10	674.5	39.6		

TABLE (5): Comparison among the mean values of fracture resistance in (N) of different resin composite groups and fiber post.

Groups	No	Mean	±S.D	F	P
Group C Division 1b	10	846.7	48.2	9.66	.0007
Group C Division 2b	10	854.4	51.16		
Group C Division 3b	10	897.7	44.5		

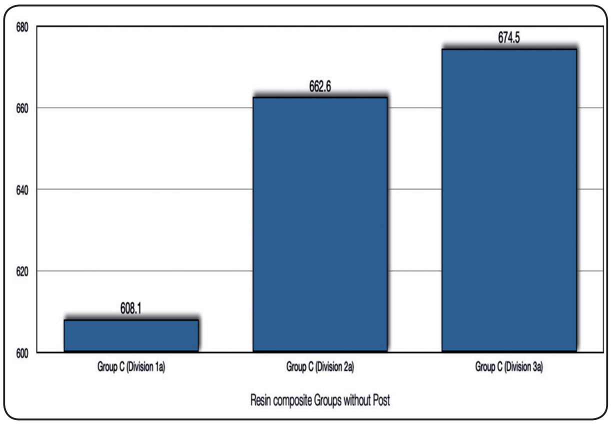

Fig (4): Fracture resistance values in (N) of resin composite groups without post.

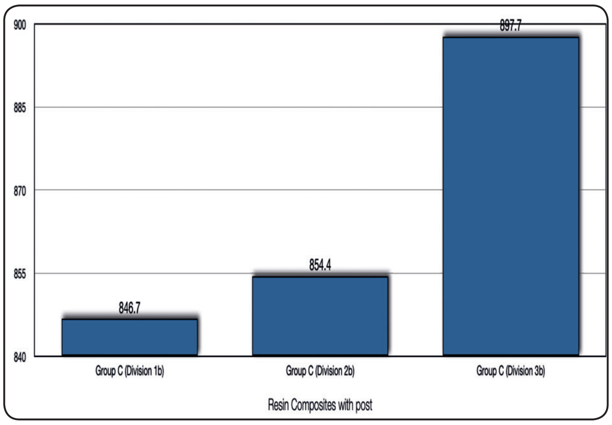

Fig (5): Fracture resistance values in (N) of resin composite groups and fiber post.

DISCUSSION

At the tomb of the unknown endodontist, there is a plaque that reads "Root canal treatment is not complete until the tooth has been restored." Endodontically treated teeth are considered highly prone to fracture due to loss of tooth structure as a result of caries, trauma, removal of old restoration, endodontic procedures and finally the dehydration of dentin following the root canal treatment procedures which can lead to alterations in the actual composition of the remaining tooth structure. An increased fracture susceptibility is a common clinical finding that results from these insults combined and represents a great challenge for dentists to restore endodontically treated teeth. (16)

The anatomic configuration of posterior teeth, especially maxillary premolars, can render them more liable to cusp fracture under occlusal forces. Generally, the pulp chambers are smaller, and they have less tooth substance when compared to molar teeth. This can adversely affect the premolars' ability to maintain the core build up after endodontic treatment. Thus, endodontically treated premolars usually require post-retained restoration. Furthermore, post space preparation in premolars should be as conservative and meticulous as possible since their roots are often curved, tapered, and thin in the mesio-distal direction and contain proximal invaginations. Accordingly, premolars exhibit delicate root morphologies and show increased brittleness when subjected to lateral forces during mastication. (17)

The risk of cusp fracture increases after access preparations due to the expected increase in the cuspal deflection during function. Consequently, the strength of the dental structure is minimally affected by an access cavity preparation when the marginal ridges are intact. (18) The fracture resistance of endodontically treated teeth under load is also influenced by the amount and quality of the remaining structure. Therefore, the cuspal deflection was found to be higher in premolars subjected to occlusal forces especially those with MOD cavity preparation. (19) Low fracture resistance values in addition to high deflection values were reported for MOD cavity preparations. (20)

Defining the ideal technique for restoring endodontically treated teeth has been the focus of several investigations. It was reported that when resin composites were used to restore MOD cavities, the tooth fracture resistance increased significantly. (11) This could be attributed to the better transmission and distribution of functional stresses by adhesive restorations through the restorative material–tooth interface, with the resultant reinforcement to the remaining fragile tooth structure. [21]

Nanofilled resin composites are considered a modification of their original microhybrid predecessors; they contain different monomers as TEGDMA, and bis-EMA, in addition to bis-GMA, UDMA. A portion of TEGDMA was replaced by PEGDMA in some nanofilled materials in an effort to reduce the effect of polymerization shrinkage. The fillers are a mixture of non-agglomerated/non-aggregated 4-11 nm zirconia particles, 20 nm silica particles: and aggregated zirconia/silica clusters (0.6 - 1μm). This advanced technology improved mechanical characteristics. [22]

One of the newest developments in resin composite technology is the composite bulk-fills which were introduced in an effort to simplify the application technique and reduce polymerization shrinkage stresses. [23] The formulation of Bulk-Fills are enhanced by the addition of the following components: polymerization modulators that are chemically embedded in the polymerizable backbone of resin, pre-polymer shrinkage stress relievers, a base monomer with a high molecular weight that optimizes the network structure and flexibility and finally innovative photo-initiator systems that are highly reactive to light. [24]

The superior behavior of posts, with a modulus of elasticity similar to that of dentin, during service could be attributed to the enhanced distribution of stresses to the remaining tooth structure. [25,26] Although, the post in this study did not reinforce the endodontically treated premolars as sound ones, but they resulted in fracture resistance that could make them more amenable to treatment.

The results of this study showed that the fracture resistance of the maxillary premolars significantly decreased due to loss of tooth structure caused by endodontic treatment and MOD cavity preparation and hence the first hypothesis was rejected. Also, the results showed that the fracture resistance of teeth weakened by wide cavity preparations could be partially restored by using different adhesive intra-coronal restorations, while sound teeth recorded the highest fracture resistance values. These findings are in agreement with the previous studies which also investigated post placement in premolars with MOD cavities. [19,27]

The result of this study also showed that teeth restored with different types of composites after post insertion showed significantly higher fracture resistance values when compared to teeth restored with different types of resin composites without any post insertion and hence the second hypothesis had to be rejected. This could be attributed to the strengthening influence of the post since the bond strength is enhanced at the post area present at the level of the ferrule margin and consequently the bond strength between tooth and core is expected to increase. [28]

These results agree with the results of *Ferrari et al*. who concluded that restoration of endodontically treated premolar with a prefabricated or customized fiber post significantly increased the survival rate after an observation period of 6 years. [29] Also, *Shafiei* et al. concluded that placement of fiber posts significantly increases the fracture strength of endodontically treated premolar when compared to equivalent teeth restored without posts. [30]

Moreover, recently, a systematic review and meta- analysis was published which assessed the effect of post placement on the restoration of endodontically treated premolars teeth. They concluded that post placement had a significant influence on increasing fracture resistance of endodontically treated maxillary premolar teeth. [31] Furthermore, the existence of fiber posts allows for favorable/restorable fracture patterns, improving the survival of endodontically-treated teeth. [32]

The fracture resistance values of teeth restored with nano-hybrid conventional resin composites either with or without post insertion, were significantly higher in group C division 2 than group C division 1. This could be accredited to the difference in the concentrations of the types of fillers used in both of the materials. In group C division 1, the nano-hybrid composite comprised 48.5 wt% inorganic fillers and 34 wt% prepolymerized fillers. On the other hand, the nano-hybrid composite used to restore teeth in group C division 2 contained a higher amount of inorganic fillers of 63.5 wt% and a lower amount of pre-polymerized fillers reaching 17 wt%. Pre-polymerized fillers are formed by embedding fillers in resin matrix, polymerization and milling of the resultant structure to particles with the intended shape and size. [33] The use of pre-polymerized fillers was found to be associated with the reduction in strength and other mechanical properties due to the lower inorganic filler content. [34] Furthermore, the mechanical stability of the material containing a higher percentage of pre-polymerized fillers is considerably influenced by the aging process since the bond between the resin matrix and the pre-polymerized particles are considered a point of weakness. [35]

With further analysis of the results of the restorative resin composites, a significant increase in fracture resistance of teeth restored with bulk-fill resin composites was found and hence the third hypothesis was rejected. These results are in agreement with the study of *Oz* et al. [19] Bulk-fill composites are associated with lower stress levels, higher filler content, and increased elastic modulus of bulk-fill than conventional resin composites. Also, these materials were optimized to exhibit packing consistency and higher strength with the preservation of adhesive features. [36] Thus, bulk-fill composite restorations that reduce stress concentrations in the remaining tooth structure are recommended. [37]

CONCLUSIONS

Within the limitations of the present study the following conclusions were drawn:

1. No existing restoration could restore the fracture resistance of endodontically treated maxillary premolars to that of sound teeth.
2. Adhesive restorations can improve the fracture resistance of endodontically treated teeth
3. The use of fiber post can significantly enhance the fracture resistance of endodontically treated teeth restored with adhesive restoration
4. Fracture resistance of endodontically treated maxillary premolars could be significantly improved when low shrink bulk-fill resin composite is used as a restorative core material.

Recommendations

Clinical implication of fiber posts and/or bulk-fill resin composites during restoration of endodontically treated teeth may be strongly recommended as it greatly improves fracture resistance.

Conflict of Interest

The authors deny any conflict of interest. They have no financial interest in the companies whose materials are included in this article.

Author Contribution

All authors have contributed significantly. All authors are in agreement with the manuscript.

REFERENCES

1. Omur DD, Celik E, Tulga A, Sariyilmaz E, Cakici F, Kahveci C, et al. Fracture strength of endodontically treated teeth restored with novel CAD/CAM ceramic post systems. Ann Med Res 2021:28: 267-274.
2. Alaki B, Aqeeli O, Laghabi O, Sultana F. Knowledge and Awareness of Prosthetic Restoration of Endodontically Treated Teeth among the Dental Doctors of Jazan, Saudi Arabia. Saudi J Oral Dent Res 2021; 6: 39-43.
3. Ozarslan M, Buyukkaplan US, Ozarslan MM. Comparison of the fracture strength of endodontically treated teeth restored with polyether ether ketone, zirconia and glass-fiber post-core systems. Int J Clin Pract 2021; 7: 14440.
4. Morimoto S. Lia WKC. Gonçalves F. Nagase DY. Gimenez T. Raggio DP.et al. Risk Factors Associated with Cusp Fractures in Posterior Permanent Teeth: A Cross-Sectional Study. Appl Sci 2021: 11: 9299-9301.

5. Bani M, Seeshoot CM, Alaçam F. Multiple Crown Fractures of Permanent Molars: An Uncommon Case of Indirect Trauma. Clin Dent Res 2017; 41: 49-55.

6. Abdullah A, Tsitrou E, Pollington S. Comparative in vitro evaluation of CAD/CAM vs conventional provisional crowns. J Appl Oral Sci 2016:24: 258-263.

7. Taha D, Spintzyk S, Sabet A, Wahsh M, Salah T. Assessment of marginal adaptation and fracture resistance of endocrown restorations utilizing different machinable blocks subjected to thermo-mechanical aging. J Esthet Restor Dent 2018; 30: 319-328.

8. Ghajghouj O. Evaluation of fracture resistance and microleakage of endocrowns with different intracoronal depths and restorative materials luted with various. Materials 2019; 12: 25-28.

9. Lakshmi S, Krishna V G, Sivagami. Prosthodontic considerations of endodontically managed teeth. J Conserv Dent 2006; 9: 104-109

10. Schneider BJ, Freitag-Wolf S, Kern M. Tactile sensitivity of vital and endodontically treated teeth. J Dent 2014; 42: 1422-1427.

11. Sarkis-Onofre R, Pinheiro HA, Poletto-Neto V, Bergoli CD, Cenci MS, Pereira-Cenci T. Randomized controlled trial comparing glass fiber posts and cast metal posts. J Dent 2020 1; 96:103334

12. Fráter M, Sáry T, Néma V, Braunitzer G, Vallittu P, Lassila L, Garoushi S. Fatigue failure load of immature anterior teeth: influence of different fiber post-core systems. Odontology 2021; 109: 222-230.

13. Alkhatri R, Saleh ARM, Kheder W. Evaluating Fracture Resistance and Failure Modes of Root Filled Teeth Restored with CAD/CAM-Fabricated Post and Core. Clin Cosmet Investig Dent 2019; 11:349-355.

14. Wang X, Shu X, Zhang Y, Yang B, Jian Y, Zhao K. Evaluation of Fiber Posts vs Metal Posts for Restoring Severely Damaged Endodontically Treated Teeth: A systematic review and meta-analysis. Quintessence Inter 2019; 50: 8-20.

15. Godas AGL, Suzuki TYU, Oliveira-Reis B, Briso ALF, Assunção WG, Dos Santos PH. Effect of Glass Fiber Post Customization on The Mechanical Properties of Resin Cement and Underlying Dentin. Gen Dent 2020; 68: 72-77.

16. Tuloglu N, Bayrak S,Tunc ES. Different Clinical Applications of Bondable Reinforcement. Ribbond in Pediatric Dentistry. Eur J Dent 2009; 3: 329–34.

17. Xie KX, Wang XY, Gao XJ, Yuan CY, Li JX, Chu CH. Fracture resistance of root filled premolar teeth restored with direct composite resin with or without cusp coverage. Int. Endod. J.2012; 45: 524-9.

18. Silva AA, Belladonna FG, Rover G, Lopes RT, Moreira EJ, De-Deus G, Silva EJ. Does ultraconservative access affect the efficacy of root canal treatment and the fracture resistance of two-rooted maxillary premolars?. Int Endod J 2020; 53: 265-75.

19. Oz F, Attar NU, Sungur D. The influence of restorative material and glass fiber posts on fracture strength of endodontically treated premolars after extensive structure loss. Niger J Clin Pract 2019; 22: 782-89.

20. Shafiei F, Dehghanian P, Ghaderi N, Doozandeh M. Fracture Resistance of Endodontically Treated Premolars Restored with Bulk-Fill Composite Resins: The Effect of Fiber Reinforcement. Dent Res J (Isfahan) 2021; 18:60-68.

21. Soares PV, Santos Filho PC, Martins LR, Soares CJ. Influence of Restorative Technique on the Biomechanical Behavior of Endodontically Treated Maxillary Premolars. Part I: Fracture Resistance and Fracture Mode. J Prosthet Dent 2008; 99:30-7.

22. Meenakumari C, Bhat KM, Bansal R, Singh N. Evaluation of Mechanical Properties of Newer Nano-posterior Restorative Resin Composites: An In vitro Study. Contemp Clin Dent 2018; 9: 142-146.

23. Mantri SP, Mantri SS. Management of shrinkage stresses in direct restorative light-cured composites: a review. J Esthet Restor Dent 2013; 25:305-313.

24. Ilie N, Stark K. Curing behavior of high-viscosity bulk-fill composites. J Dent 2014; 42: 977-985.

25. Özyürek T, Topkara C, Koçak İ, Yılmaz K, Gündoğar M, Uslu G. Fracture strength of endodontically treated teeth restored with different fiber post and core systems. Odontology 2020; 16: 1-8.

26. Silva CF, Martins VM, de Paula Melo A, Martins LC, Santos-Filho PC. The Use of Bulk-Fill Flow in the Customization of Glass Fiber Post. Eur. J Dent 2021; 15: 139-44.

27. Ferri MK, Luisi SB, Burnett Junior LH, Melara R, Melo TA. Effect of Horizontal Position of Fiber Post Placement on Fracture Resistance and Location in Endodontically Treated Premolars with a MOD Preparation. Giornale italiano di endodonzia 2021; 35, 32-37.

28. Mamoun J. Post and Core Build-ups in Crown and Bridge Abutments: Bio-mechanical Advantages and Disadvantages. J Adv Prosthodont 2017; 9: 232-7.

29. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A Randomized Controlled Trial of Endodontically Treated and Restored Premolars. J Dent Res 2012; 91: 72-8.

30. Shafiei F, Dehghanian P, Ghaderi N, Doozandeh M. Fracture resistance of endodontically treated premolars restored with bulk-fill composite resins: The effect of fiber reinforcement. Dent Res J. 2021;18:60

31. Iaculli F, Rengo C, Lodato V, Patini R, Spagnuolo G, Rengo S. Fracture resistance of endodontically-treated maxillary premolars restored with different type of posts and direct composite reconstructions: A systematic review and meta-analysis of in vitro studies. Dent Mater 2021; 37: 455-484.

32. Costa S, Silva-Sousa Y, Curylofo F, Steier L, Sousa-Neto M, Souza-Gabriel A. Fracture resistance of mechanically compromised premolars restored with polyethylene fiber and adhesive materials. Int J Adhes Adhes .2014; 50: 211-5.

33. Marovic D, Panduric V, Tarle Z, Ristic M, Sariri K, Demoli N, Klaric E, Jankovic B, Prskalo K. Degree of conversion and microhardness of dental composite resin materials. J. Mol. Struct. 2013;1044:299-302.

34. Blackham JT, Vandewalle KS, Lien W. Properties of hybrid resin composite systems containing prepolymerized filler particles. Oper Dent 2009;34:697-702.

35. Ilie N, Hickel R. Macro-, micro-and nano-mechanical investigations on silorane and methacrylate-based composites. Dent Mater 2009;25:810-9

36. Rosatto CM, Bicalho AA, Veríssimo C, Bragança GF, Rodrigues MP, Tantbirojn D, et al. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. J Dent 2015; 43: 1519-1528.

37. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endod Top 2006; 13: 57–83.