

Effect of Two Different Polyethylene Fiber Positions on Fracture Resistance of Endodontic Treated Premolars: *In vitro* Comparative Study

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Abstract

Aim of the study: This study evaluated the effect of different polyethylene fibers positions on fracture resistance of endodontic treated premolars.

Material and method: 40 maxillary upper first premolars had been randomly divided in to 4 groups; (n=10). Except for control group, MOD cavity preparation with no steps were done within groups. After endodontic treatment and adhesive step and band application teeth restored with different techniques as follows: B-incremental with G- aenial posterior micro hybrid composite, C-circumferential Ribbond application (wallpapering) with incremental layering, D- bulkfill technique with ribbond reinforcement . Fracture test was measured using LARYEE device (a computer controlled universal testing machine, China). Statistical analysis was done by One way ANOVA then LSD test to evaluate significance among groups.

Results: The highest mean of fracture resistance in restored groups was recorded with group C (885 N) (wallpapering technique); while group D showed the lowest fracture resistance mean (678 N).

Conclusion: positioning of polyethylene fibers circumferentially can enhance the fracture strength of endodontic treated teeth.

Keywords: Fracture resistance , Endodontic treated teeth , Fiber reinforced materials, Poly ethylene fibers, incremental layering , Wallpapering technique.

Introduction

Post endodontic restoration integrity and durability are regarded as critical aspects in the success and longevity of endodontically treated teeth; Due to variations in strength and modulus of elasticity, these teeth have been shown to be more brittle, or susceptible to shatter under an occlusal force than vital teeth (Eapen et al., 2017). Novel materials with improved physical qualities, as well as novel procedures, have been explored to increase the fracture resistance of endodontic teeth (Mortazavi, 2012). Composition and filling methods of composite resins are among the most important means of preventing volumetric contraction and

shrinkage stresses from developing (J.L. Ferracane et al., 2011). The progress made in adhesive restorations has made a noteworthy contribution towards enhancing the fracture resistance(FR) of teeth. The selection of an appropriate restorative modality is crucial for the success of post-endodontic restorations, as it helps to compensate for the loss of coronal tooth structure (Sengun et al., 2008). Internal fractures of the body (bulk) and restoration margins, as well as secondary caries, that were cited as significant causes on the topic of the failure of posterior composites. (van Dijken et al 2015). The material properties associated with fractures,



including fracture resistance, deformation under occlusal load, and marginal degradation of materials, are typically determined by flexural strength and fracture toughness (Lassila et al 2019). Fracture toughness is a fundamental mechanical property that characterises the ability of brittle materials to withstand the propagation of defects in the presence of an external load, thereby preventing catastrophic failure; consequently, It measures fatigue resistance and describes damage tolerance; The fracture toughness values are dependent on the physical characteristics and chemical composition of individual segments of the restorative material; From a biomimetic perspective, missing tooth tissue should be replaced with biomaterials that have similar physical qualities, Particularly with regards to flexural strength, modulus, and thermal expansion coefficient (Magne et al 2002). Recent advances in the properties of resin-bonded composites have inspired clinicians to conduct adhesive restorations on endodontically treated teeth (ETT). Ribbond (Ribbond, Seattle, WA, USA) is an ultrahigh elastic modulus polyethylene fibre. Recent research has shown that LWUHMWPE fibres (Ribbond Inc) can be successfully employed for the immediate restoration in the structurally impaired teeth following endodontic treatment (Deleperi et al.,2009), The objective of this investigation was to determine the effect of two positional application of ribbond fibers on the fracture resistance of endodontic treated premolars.

Materials and Methods:

40 sound upper first premolars were used in this study after approval of ethical committee of Mustansiriyah University/ College of Dentistry (MUO pr14). The teeth were

disinfected by immersion in 0.1 % thymol for 48 hours, the teeth were preserved in distilled water and replaced daily until used (Abdo et al 2011). 0.2-0.3 mm wax on the root surface. Teeth were encased in self-curing acrylic resin. Hot water melted the wax on the root surfaces, and polyvinyl siloxane impression material resembled periodontal ligament in the gap. The roots were coated with acrylic up to about 2 mm from the CEJ to simulate the support provided by alveolar bone in a natural tooth (Taha et al., 2011).

Cavity preparation:

Except for the control group, all of the teeth had MOD cavity preparation utilizing a modified dental surveyor that does not include any proximal steps (Bogra et al 2012). The occlusal isthmus bucco-lingual width was equivalent to half of the intercuspal dimension, the cavity floor was prepared (1 mm) coronal to the CEJ, and the overall cavity depth was 6 mm measured from the palatal cusp. The cavo-surface margins were constructed with rounded internal line angles (Taha et al., 2011).

Root canals were instrumented by rotary Ni-Ti instruments (pro taper gold system) using a crown-down technique, canals were prepared by ProTaper GOLD to size F2 (25/08) at 300 (RPM) and torque (2.5 Ncm). Subsequently, gutta-percha points of corresponding size were inserted into all canals and sealed using (AH Plus, Dentsply, Maillefer, Germany) which is resin-based sealer.

Sample grouping:



40 teeth were arranged in a random manner into 4 groups: - (figure 1)

Group A:- control group (n =10) Intact sound upper first premolars were used as a control group to compare with other techniques.

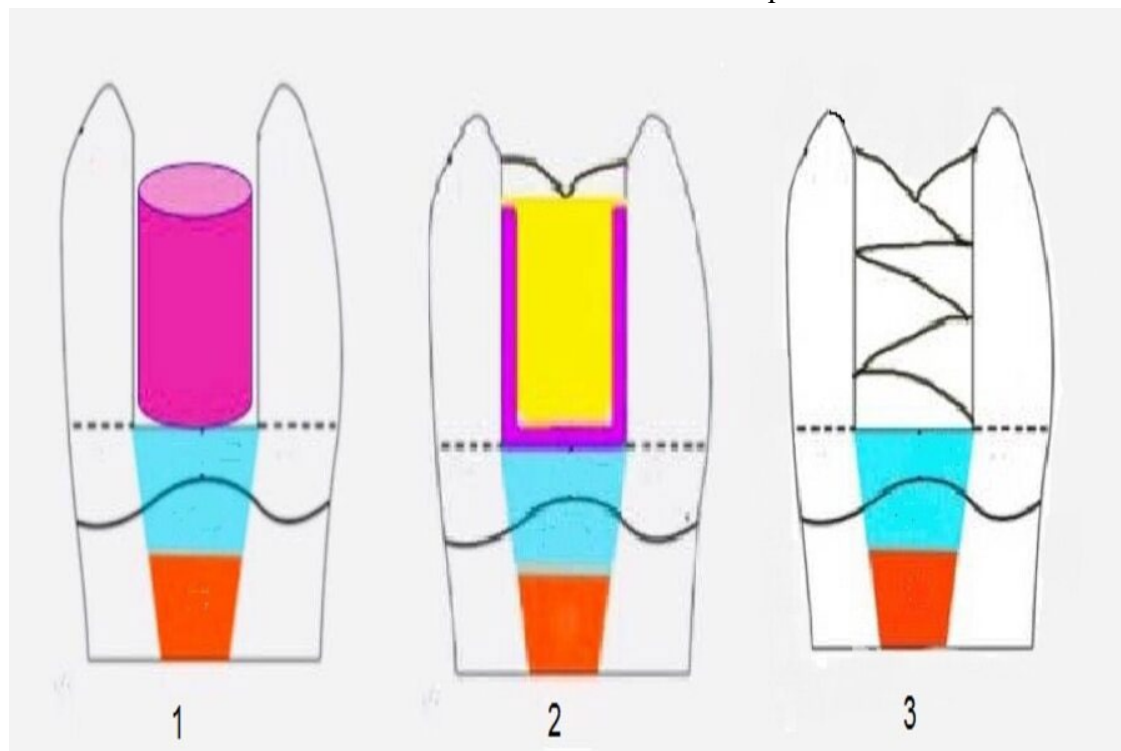


Figure1:- Restorative techniques:- 1-wallpapering with ribbon; 2-Bulkfill technique with ribbon reinforcement; 3- Incremental layering.

GROUP B: Incremental technique (n=10)

The restoration of cavities was carried out using composite resin (G-aenial posterior, GC Corporation) and an incremental technique was employed. Wedge-shaped increments of 2 mm of resin were placed during each turn.

Group C: Wallpapering Technique(n=10)

A circular matrix was placed around the tooth, then one-millimeter increments of a composite were used to build up the missing proximal tooth structure, with micro-hybrid composite resin (G-aenial, tokyo, japan). The wallpapering was prepared by Ribbon fiber piece (4 mm wide) applied circumferentially

against the cavity walls and the cavity was finished with wedge-shaped increments of micro-hybrid layer (Sáry et al 2019, Deliperi 2017).

Group D: Bulkfill technique with ribbon reinforcement (n=10)

The poly ethelene fiber was inserted in a buccolingual direction with flowable composite. The cavity was rebuilt using SDR bulk-fill flowable composite (Dentsply) with 4mm thickness and cured for 40 seconds (Tekçe et al 2017). The top layer then had been restored with 1-mm-thick G-Aenial micro-hybrid composite.

Mechanical testing

Each specimen undergone compressive axial force until failure. In the context of computerized universal testing equipment. The crosshead's diameter was 6mm and its speed was 0.5 mm/min. A steel bar will be inserted in the middle of the occlusal surface, position has been altered so that the bar is applied parallel to the tooth's long axis and cusps (instead of the restoration) (Kikuti et al 2012) . A computer linked to the loading machine recorded the highest breaking loads in Newton.

Results

Highest fracture resistance mean in this study was revealed by intact teeth (control group) with a mean (1237)N. A one-way ANOVA

test revealed a highly significant difference ($P=0.01$) between all groups. The wallpapering group (group C) showed the highest mean among restored groups (885 N) followed by group B (789 N) the lowest mean recorded with group D with a mean (678 N) as seen in table 1.

The statistical analysis was done by One way ANOVA test then the significance among groups were obtained by LSD test that showed the control group had a significant effect with all restored groups; while group B has no significance with groups C & D. Group C also showed a significant difference with group D As seen in table (2,3).

Table 1 : mean values of fracture resistance of groups experimented in this study.

Groups	Mean	Std. D	Minimum	Maximum
A	1237	142.18142	1037	1469
B	789	93.59012	645	953
C	885	75.13543	712	970
D	678	76.25462	497	780
Total	897.2	232.99400	497	1469

Table 2: one-way anova test.

One -way ANOVA					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1753249.075	3	584416.358	57.813	<0.001
Within Groups	363912.900	36	10108.692		

Total	2117161.975	39		
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Table 3: post hoc LSD test.

(I) group	(J) group	Mean Difference (I-J)	Sig.
A	B	448.00000	<0.001
	C	352.00000	<0.001
	D	558.90000	<0.001
B	C	-96.00000	0.040
	D	110.90000	0.019
C	D	206.90000	<0.001

*. The mean difference is significant at the 0.05 level.

Discussion:

The efficacy of root canal therapy is significantly influenced by the quality and durability of restorations in endodontically treated teeth, which must be regarded as a critical final stage to accomplish success (Akman et al 2011). Access cavity and endodontic preparation weakens the dental crown when cavities or fractures compromise it, the tooth's fracture strength is determined by how much structure remains following cavity preparation (Kemaloglu et al 2015). Despite the fact that indirect restorations are thought to be reliable alternatives for endodontically treated teeth (Chrepa et al., 2014). Advances in direct resin composites with enhanced mechanical qualities have made it possible for them to be used even in load-bearing applications (Kemaloglu et al 2015). Fibers used in conjunction with resin composite in restoring endodontic teeth that are structurally impaired is seen as a viable solution for addressing the limitations of

resin based composites. while restorations with fiber reinforced Composite would alter the stress dynamics at the restoration-tooth interface; The addition of fibers to resin composites improves their fracture toughness and flexural strength. The architecture of fibers creates a network that inhibits crack growth (Valizadeh et al 2020). According to the result of this study; wallpapering technique with incremental layering showed the highest mean of fracture resistance following the control group with statistically no significance with the incremental layering group alone (group B). This result is compatible with many studies that affirm the effect of poly ethylene fiber incorporation within the composite direct restoration can enhance the fracture resistance of restored tooth (Belli et al 2006, Shafiei et al 2021, Abdulmir et al 2023). When choosing a direct restorative material, the type of cavity preparation is very important. The magnitude of the cantilever effect is greater in deep

cavities, and correspondingly, the dimensions of the restoration are also increased, thereby highlighting the limitations of conventional composite materials (Forster et al 2019). The incorporation of polyethylene fibre ribbons into the flowable composite substrate increases the modulus of elasticity and reduces fracture during composite restoration. owing to their morphological characteristics, Endodontically treated teeth may benefit more from fiber-reinforced composites than hybrid composites (Selvaraj et al 2023). Using a stress-reduced technique, performing of direct restorations on vital and devitalized teeth with structural damage, eliminating the need to conceal remaining weak walls with cusps, Direct restorations may be taken to new heights with the help of the intrinsic property of the fiber network and the proper insertion of fibres into the cavity walls (Deliperi et al 2017). The dentino-enamel complex's crack shielding mechanism can be replicated and strengthened by contouring poly ethylene ribbons as closely as feasible to the remnant tooth substrate's internal contours (Deliperi et al 2017). The polymerization shrinkage stresses and cuspal deflection were decreased by using the incremental method. By increasing the degree of cure and decreasing the quantity of cavity bonding at each level, the incremental layering technique outperforms the bulk technique in terms of shrinkage (Shafiei et al 2021). According to Shafiei et al; (despite the use of other composite brands); fiber's insertion effect on fracture resistance relies on the composite type used (Shafiei et al 2021). It was believed that the fiber network could absorb and alter

the stress at the interface (restorative/adhesive), thereby decreasing the risk of fracture (Sáry et al 2019). Also, fibers will replace more of the composite resin increase and make the total volumetric shrinkage of the composite resin less (Ozsevik et al 2016). For this reason, the SDR group showed the lowest values of fracture resistance, this was in contrary with a recent study (Battancs et al 2022), which may be due to different procedure used. This result is compatible with sary et al. (2019) which found the buccolingual placement of ribbon was the group of the least strength. This could be because, even though the two walls are joined, the fibers are not stretched and are not under any tension at all (Sáry et al 2019). In order to keep the fabric's structure, polyethylene fibers have a high density of permanent nodal crossings. Because the load paths from one place to another are clear, pressures in the bulk of the material can be transferred more effectively (Akman et al., 2011). Polyethylene fibers exhibit a low elastic modulus and possess a high degree of adhesion to restorative materials (Ruprai et al 2022). The incorporation of these fibers into composite resin results in an enhancement of its flexural properties. Additionally, these type of fibers exhibit an elastic modulus that is comparable to that of dentin, while also affording superior levels of fatigue resistance. Furthermore, their presence enables the effective transmission of force (Eskitascioglu et al., 2002). Moreover, Ribbond exhibits a behavior that facilitates the dispersion of stresses and the absorption of energy. The phenomenon of stress concentration reduction is achieved by the dispersion of forces across a wider surface

area, thereby impeding the initiation and progression of cracks. Furthermore, it assimilates the energy resulting from recurrent occlusal impacts (Hshad et al 2018). The potential fusion of cusps may have resulted in enhanced fracture resistance, which can be attributed to the bonding capacity of the polyethylene fiber, in conjunction with the bonding agent and flowable composite (Agrawal et al 2014). Polyethylene fibers, when combined with composite resin, act as a stress absorber due to their low elastic modulus, which allowed them to be more flexible and less brittle in order to distribute stress (Ruprai et al 2022). The biomimetic methodology advocates for the utilisation of polyethylene fibers to reestablish the damaged tooth structure and mitigate the impact of loading forces. The incorporation of an internal mesh composed of these fibers serves as a basis for the placement of extensive restorations. The micro-shifting of woven polyethylene fibers enables the composite resin, which serves as a superficial restorative material, to move in various directions (Belli et al 2007). Furthermore, through the incorporation of polyethylene fibres within a flowable composite substrate, the tooth's elastic modulus is reduced, thereby mitigating residual stress and averting the risk of tooth fracture (Ruprai et al 2022, Garlapati et al 2017).

This *in vitro* study was done under static load, further investigations should be done to compare these techniques under dynamic load to mimic the oral cavity conditions and stresses.

Conclusion:

Using of poly-ethylene fibers can enhance the strength of teeth restored with direct composite restorations in teeth that have been treated endodontically. In addition, the type of composite layering used with ribbond can significantly change the resistance to fracture.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Data Availability Statement

Data are available from the authors upon reasonable request.

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