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The Effect of Fibers Insertion on Fracture Resistance of Maxillary Premolar Teeth with MOD Cavity Restored with Composite (*In Vitro* Study)

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Abstract

Aim of the study: The purpose of this in vitro investigation was to compare the impact of different fibers on the fracture resistance of maxillary first premolar teeth with MOD cavities.

Materials and methods: Sixty sound, non-carious human maxillary first premolars were selected for this study and randomly divided into four groups (n = 15). Groups A, B, and C consisted of intact teeth utilized as the control group, teeth restored with ribbond, and teeth restored with composite (Palfique LX5, Tokuyama, Japan) respectively. Group D included dental restorations using SFRC Ever X Posterior (GC, Japan). The occlusal surface of each tooth was imprinted using flowable composite material (stamp technique), and all teeth were mounted in a 2cm² square block of self-curing acrylic resin. A large class II MOD cavity preparation was performed for all groups except for Group A. The dimensions of the cavities were standardized as follows: the occlusal depth was 3 mm, the occlusal width buccolingually was 2/3 of the intercuspal distance, and the MO and DO boxes were prepared with a height of 1.5 mm at their axial walls. The teeth were tested in a universal testing apparatus with a 0.5 mm/min compressive load rate till fractures take until fractures occurred.

The analysis of variance (ANOVA) and Tukey's (HSD) tests were used to determine the statistical significance of the variation in fracture resistance among the groups under investigation, using a significance level of 0.05.

Results: The results revealed that the groups restored with fibers (Group B and Group D) exhibited greater fracture resistance than group restored with composite only (Group C).

Conclusions: In the context of the present investigation, teeth restored with Ribbond insertion demonstrated a significant increase in fracture resistance compared to the other tested groups, followed by teeth restored with Ever X posterior. In contrast, teeth restored with Tokuyama Palfique LX5 composite without fibers exhibited the least fracture resistance.

Keyword: Fracture resistance, palfique lx5, ribbond, ever X posterior.

1. Introduction

One of the most difficult dental restorations is treating teeth with large cavity. To address the drawbacks including polymerization shrinkage, microleakage, water sorption, and method sensitivity, several kinds of molecular research and improvements are underway (Cötert et al., 2001).

Composite fillings are now commonly utilized in the posterior part of the mouth due to their low cost and good aesthetic effects, which have been made possible by advancements in adhesive procedures and composite resin restorative materials. However, the long-term effectiveness of composite restorations is limited by the less suitable material qualities of composites (Peutzfeldt and Asmussen, 2000; Lange and Pfeiffer, 2009).

Contemporary direct restorations need to preserve the remaining tooth structure from fractures and restore function in addition to aesthetic concerns (Taha et al., 2011).

As more dentin is lost from posterior teeth due to trauma or cavities, it becomes increasingly challenging to strengthen the more complex established by the restoration and the remaining tooth material. The most difficult cavities to treat are MOD (mesio-occlusal-distal) cavities, which can occur in posterior teeth. This results in a significant decrease of stiffness and is caused by the disappearance of both marginal ridges (Wu et al., 2010).

A mean loss of 63% in relative cuspal stiffness is associated with upper premolars using conventional MOD cavity architecture, although the loss of one marginal ridge is only related with a mean loss of 46% (Plotino et al., 2008; El-Helali et al., 2013).

Improved handling qualities, less polymerization shrinkage, and better fracture toughness are features of new materials including polyethylene fiber, fiber-reinforced composites, and higher filler content composites. Because fiber reinforcement inside strengthens the restorations and lowers the likelihood of fractures, it has extended the possible applications of composite restorations in restorative dentistry (Dyer et al., 2005).

The most commonly used fiber-reinforced composites (FRCs) were glass FRCs and polyethylene ribbon FRCs. Research has shown that both kinds are crucial for boosting the fracture resistance of restorations on teeth that have had endodontic therapy as well as those that have not (Garlapati et al., 2017; Sáry et al., 2019). Additionally, they enhance the marginal integrity and reduce microleakage of the restorations (Ozel and Soyman, 2009). The aim of this research is to compare the impact of fibers on the fracture resistance of maxillary first premolar teeth with MOD cavities, repaired using the subsequent methods (palfique lx5 reinforced ribboned fiber composite EverX Posterior with short fiber reinforcement Tukoyama palfique lx5 composite).

2. Materials and Methods

2.1. Sample Selection and storage

Before any samples were collected, the present research was authorized by the Ethics Committee of Mustansririyah University (Reference number: REC 130 01/May/2023). Sixty sound, non-carious human maxillary first premolars with patient's age range from 17 to 22 years, were used in this study collected from the department of oral and maxillofacial surgery was removed to address orthodontic concerns.

The teeth were examined under an electron microscope (magnification 10x) to exclude any cracks. Using an air scaler, all the specimens had the adhering soft tissue and calculus removed. Then the teeth were polished using rubber cups and pumice devoid of fluoride and rinsed with water.

All teeth exhibited regular occlusal anatomy. The maximum BP, MD dimensions and ICD were measured by a digital caliper. The teeth selected had the MD widths ranging from 6.9 to 7.6 mm, while the BP widths ranged from 8.9 to 9.7 mm (Taha et al., 2009).

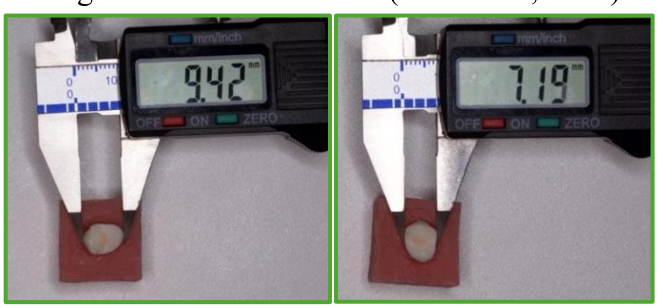

Figure 1: Measuring BP and MD dimensions by a digital caliper.

Before the experiment, all the chosen teeth were kept at room temperature to avoid becoming dehydrated, use deionized water and to inhibit the growth of bacteria and fungi. They were submerged in a 0.1% thymol solution for 48 hours (Ali and Kassim, 2021).

2.2 Teeth mounting

To simulate the periodontal ligament of the teeth, a wax layer was applied on the exterior root surface. Using an indelible marker, each tooth was initially marked 1.5 mm apical to the CEJ.

Then, a primer width of the roots was recorded. The root width was measured with a digital caliper at cervical third. Using a dipping wax machine, melted wax was applied to the root surfaces at 70°C for five seconds, reaching a depth of 2.0 mm apical to the CEJ.

All teeth were imbedded in a (20 × 20 × 25 mm) square a self-curing acrylic resin block. After melting the wax on the root surfaces with hot water, the tooth's long axis was positioned perpendicular to the base of the block. In order to replicate the support that alveolar bone provides in a natural tooth, acrylic coating was applied to the roots up to approximately 1.5 mm from the CEJ (Taha et al., 2011).

Polyvinyl siloxane impression material was used to cover the resulting gap in a manner reminiscent of periodontal ligament.

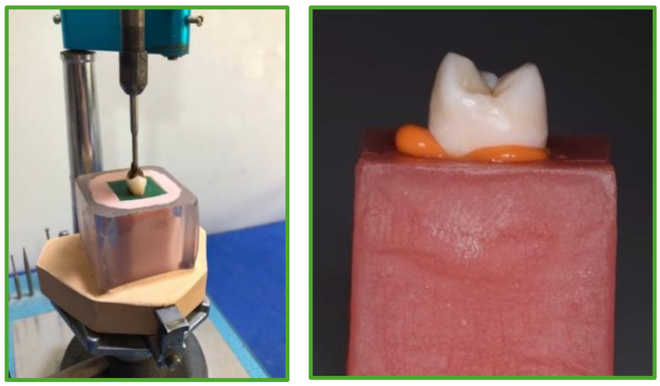

Figure 2: A-Embedding of tooth into the acrylic block. B-Insertion of the tooth into the light body.

2.3 Stamp technique

Using flowable composite material and the stamp technique, an imprint of the occlusal surface was created prior to cavity preparation. Using this technique, the teeth were restored to their natural occlusal architecture with a minimum amount of finishing and polishing using composite restoration.

Every group underwent this process, except for the control group.

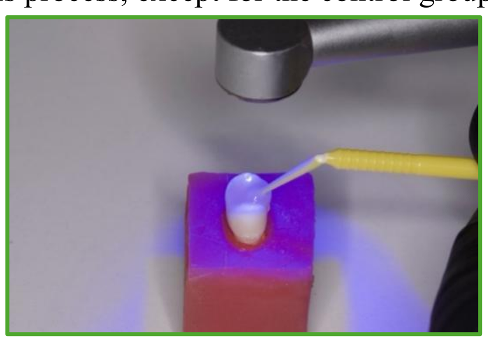

Figure 3: Stamp technique

2.4 Sample grouping

Group A: Intact teeth used as (control group) (n =15).
Group B: Teeth restored with insertion of polyethylene fiber (Ribbond) (n =15).
Group C: Teeth restored with composite (palfique lx5) (n =15).
Group D: Teeth restored with SFRC (Ever X posterior) (n =15).

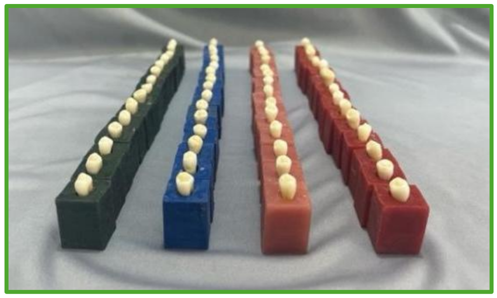

Figure 4: Groups are coded according to four colors. A-Control. B-Ribbond. C-Palfique lx5 composite. D-EverX posterior.

2.5 Cavity preparation

Before cavity preparation, the outline of the cavity was drawn with a super color marker. A large Class II MOD cavity was created using a parallel-side, flat-end diamond fissure bur with a 1.2 mm diameter. A super color marker was used to make a line on the bur at 3 mm from its tip, to serve as a reference to determine the depth of the occlusal cavity. The bur was first placed at the area that was the deepest in the center of the tooth. The cavities' measurements were standardized to be as follows: the occlusal box 3 mm depth in respect to the bottom of the central groove, buccopalatally was 2/3 of the intercuspal distance to produce an extensive cavity preparation. Two reference points were marked with a waterproof color marker on the tips of the buccal and palatal cusps), the MO and DO boxes were prepared with a height of 1.5 mm at their axial walls (Georges et al., 2003).

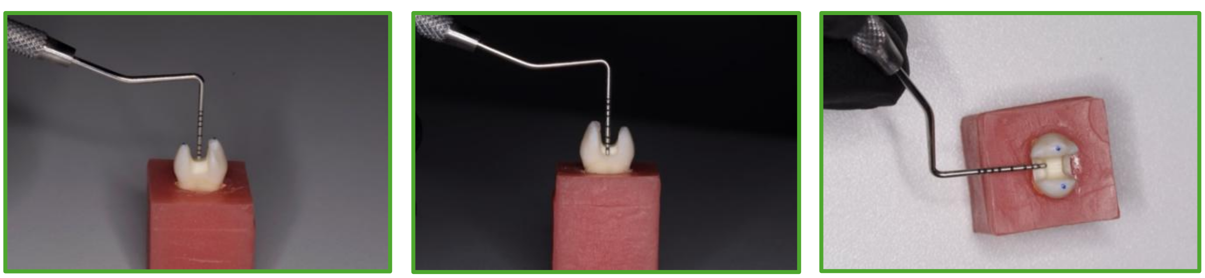

Figure 5: A-Measuring the depth of cavity by periodontal probe. B-Measuring the height of cavity box. C- Measuring the width of cavity box.

To standardize the cavity preparation, the preparation will carry out by the same operator with the use of dental surveyor. The plate of the surveyor was fixed in a horizontal plane, and the teeth were placed on the surveyor’s plate.

2.6 Placement of the matrix system

SuperMat Matrix system from kerr was used to restore the proximal walls of the cavity.

2.7 Adhesive procedure

3M Bond Universal Adhesive with a selective etch technique was used for standardization in groups, except for the control group. After thorough cavity preparation and band application, the cavity was dried with a gentle air blast and cleaned with deionized distilled water using a triple syringe from a dental unit.

In order to guarantee that the etching substance was completely removed, after applying a 37% phosphoric acid gel to the cavity for 15 seconds, thoroughly cleaning it with water for 30 seconds and then subjected to a gentle stream of air that lingered for almost five seconds and was roughly one centimeter distant.

Next, the dentin and all other components of the cavity were coated with a drop of universal adhesive bonding enamel, using a disposable bond brush. This was rubbed in for 20 seconds, and then there was a 5-second gentle air thinning period. In compliance with the manufacturer's instructions, after that, the glue was light-cured for 15 seconds using an LED light-curing apparatus with a 2100 mW/cm² power intensity.

2.8 Restorative techniques

Group A: Sound teeth (Control group).

Group B: Insertion of ribbond

palfique lx5 composite resin was employed to fill up the lost proximal tooth structure in millimeter increments. After that, select fibers with the right width and length to fit the cavities (Ribbond, Seattle, WA, USA).

First, an unfilled resin (Ribbond Wetting resin, Ribbons Inc.) was used to wet a ribboned fiber piece that measured 3 mm in width and length in the tooth.

Ribbond Securing Composite (Ribbond Inc.), a tacky flowable composite, was applied very thinly over the fibers after the extra resin was removed.

The gingival seats and pulpal floor were covered with ribboned fiber, which was applied horizontally and dried for 20 seconds. Palfique LX5 composite resin was then added to the cavity in wedge-shaped increments.

After the stamp was applied and let to cure, the final layer was completed.

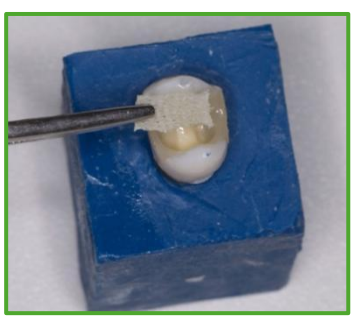

Figure 6: Application of Ribbond fibers.

Group C: Teeth restored with TOKUYAMA Palfique LX5 composite

After restoring the proximal missing walls as mentioned before for group B and return the cavity to class I, Palfique LX5 the composite was applied incrementally, curing for 10 seconds after each application.
The final layer was cured for 20 sec after placing the imprint by using stamp technique.

Figure 7: Restore missing mesial & distal walls.

Group D: Bulkfill with SFRC Ever X Postarior (GC corporation)
First, the same technique was used as mentioned in group B to restore the missing proximal walls, the following that, cavities were repaired using a short fiber reinforced EverX posterior per the guidelines provided by the manufacturer.
Following the manufacturer's recommendations, the EverX restorative material was inserted up to 4 mm into the cavity and light cured employing an LED curing device (SDI) with a 2100mW/cm² power light intensity for 20 seconds. The bulk-fill base was poured into the cavity, and when it was light-cured, the remaining portion of the cavity which measured between 0.5 and 1 mm in thickness was replaced to finish the restoration.
The final layer, however, has been cured for 20 seconds following the application of the stamp and the removal of extra material.

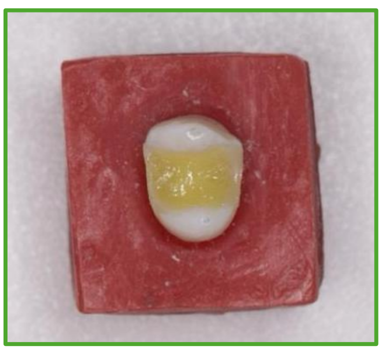

Figure 8: Application of Ever X fibers.

2.9 Thermocycling

In an attempt to replicate the temperature variations that occur in the mouth, which may result in variations in the micro gap between the restoration and the tooth, all the samples underwent thermal change cycles. The teeth are moved back and forth between two specially designed water baths during the operation. Water bath for standardization in which one is maintained one for fifteen seconds at 55°+_5°C and the other at 5°+_5°C. It was reported that there were 500 cycles in this water bath (Loguercio el al., 2019) Upon activation, the device's screen offers customization options to restrict the quantity many cycles and how long it takes for hot and cold water to fill the sample reservoir and leave it. There were 500 predefined cycles.

2.10 Mechanical Testing

Using a universal testing apparatus, we determined the teeth resistance to breakage was determined. A 6 mm round stainless-steel ball was used to apply compressive loading to each specimen at a strain rate of 2 mm/min. In order to replicate the tendency of the masticatory forces to deflect the cusps under stress, the ball should contact the inclined planes of the palatal and facial cusps outside the restoration's boundaries. The fracture force was measured in Newtons (N), and the collected data were collated and statistically analyzed using the industry-standard IBM SPSS Statistics program.

2.11 Statistical Analysis

The following statistical methods were used to analysis the collected data:

1. Descriptive statistics:

Including mean, standard deviation (SD), minimum (Min.), and maximum (Max).

2. Inferential statistics:

The one-way analysis of variance test (ANOVA) was used to determine if there are statistically significant differences between groups.

Tukey’s (HSD) test to find any statistically significant difference between groups.

p-value of less than 0.05 indicates a statistically significant

3. Results

The Newton's measurements of the fracture resistance incorporate the numbers for the mean, maximum, minimum, and standard deviation (SD) for group recorded in this investigation. Among the tested groups, in this study, teeth restored with Tokuyama Lx5 composite showed the lowest mean value of fracture resistance, whereas sound teeth free of cavities (Group A) displayed the highest mean value (1158.4±0.35 N) (766.4±0.36 N).

3.1 Testing the normality of distribution

Using the Shapiro-Wilk test, we assessed whether the recorded data distribution was normal. The test's outcome showed the distribution of the data distribution was normal ($p>0.05$). Consequently, we conducted parametric testing to evaluate group differences.

Table 1: Discreptive statistics: - Mean, SD, Min., Max.

Groups	N	Mean	±SD	Minimum	Maximum	Shapiro-Wilk
Control	15	1158.400	70.339	1046.000	1300.000	0.082
Ribbond	15	904.733	51.135	819.000	1022.000	0.281
Tokuyama	15	766.400	62.519	652.000	860.000	0.666
EverX Posterior	15	780.067	80.036	638.000	894.000	0.608

3.2 Inferential statistics

The One-way ANOVA test was applied to statistically analyze fracture resistance in this investigation. This test revealed that the groups that were involved in the experiment. The significance of these differences was measured and compared using Tukey's significant distribution (HSD) at a significance level of (0.05).

Table 3: One Way ANOVA.

	Sum of Squares	df	Mean Square	F	P value
Between Groups	1485043.333	3	495014.444	110.761	0.000
Within Groups	250275.067	56	4469.198		
Total	1735318.400	59			

Table 4: Tukey HSD.

(I) Groups	(J) Groups	Mean Difference (I-J)	p value
Control	Ribbond	253.667	0.000
	Tokuyama	392.000	0.000
	EverX Posterior	378.333	0.000
Ribbond	Tokuyama	138.333	0.000
	EverX Posterior	124.667	0.000
Tokuyama	EverX Posterior	-13.667	0.943

4. Discussion

Direct restorations are often recommended due to their ability to be completed in a single visit and their reasonable cost. Additionally, the continuous development of new materials provides a wide range of options (Lukarcanin et al., 2022). However, the quality and longevity of these restorations must be carefully considered, as they significantly impact the outcome of treated teeth. A successful rehabilitation of posterior teeth should aim to restore both anatomy and function while protecting against unfavorable fractures and enhancing mechanical resistance (Scotti N et al., 2016).

4.1 Discussion of methodology

Due to their inadequate crown-root ratio, crown volume, and anatomical structure, maxillary first premolars are more likely to cusp fractures. Therefore, these teeth were utilized in this experiment (Al-Ibraheemi et al., 2021).

Throughout mastication, premolars are exposed to a harmful combination of lateral stresses, particularly compressive and shear forces, which increases the risk of future cuspid fractures (Frater et al., 2021; Robbins et al., 2002). Additionally, the teeth located before the molars are the most frequently extracted healthy teeth for orthodontic treatment, as they are uniform in size, shape, and form (McHugh et al., 2017).

The utilization of fracture resistance to static stress in experiments to quantify the effects of cavity preparation and/or repair on tooth strength. Although a fracture load is often significantly bigger than functional occlusal loads, it is a valuable technique to evaluate restorative materials and various cavity designs (Frater 2020, Taha et al., 2011). There could be a major biomechanical problem as a result of the MOD cavity design. When teeth with MOD cavity preparations are chipped, they act as a cantilever beam in accordance with Hood's idea length and thickness of the beam influence how much it deflects under stress. (Frater et al., 2020), This indicates that the cusp's bending is supported by the prepared cavity floor, and that the cantilever's length increases with cavity depth (Lee et al., 2007).

Compared to metal, plastic, and even animal teeth, extracted human teeth exhibited microstructures, bonding qualities, and strength that were more like those found in a clinical setting. This made them the preferred material for this in vitro comparative investigation (Chitmongkolsuk et al., 2002).

Purred cold-cured acrylic resin was applied between the root and a 0.2–0.3 mm thick layer of light body addition silicone to replicate the careful movement of the periodontal ligament during the fracture resistance test (Zhang et al., 2021).

Because they were the easiest to obtain from orthodontic patients and had the least amount of morphological variation from other teeth, maxillary first premolars were chosen for this investigation (Monga et al., 2009; Bassir et al., 2013). All the chosen teeth were similar in size and shape to lessen the variance in the outcomes.

All teeth were prepared using a modified dental surveyor in order to ensure uniformity and a distinct tapering degree.

The study's measurements were carried out after the thermocycling procedure. Thermocycling is widely recognized in the literature as a common and approved technique for evaluating the longevity of restorations (Deng et al., 2014; Gönülol et al., 2015). Adhesive repair stability and longevity may be jeopardized by rapid temperature fluctuations caused by a patient's eating, drinking, and breathing habits (Deng et al., 2014). The study utilized a median of 500 thermal cycles, with a dwell period of 30 seconds, and temperatures ranging from 5 °C (± 2 °C) to 55 °C (± 2 °C), in accordance with International Standards Organization TR 11405 (Gale and Darvell, 1999).

A cylindrical rod with 6 mm diameter was suggested for the mechanical test in order to simulate the clinical setting and evaluate the premolars' resistance to fracture. This setup would allow contact with that imitate the clinical situation, both functional and non-functional situations (Burke, 1999).

4.2 Discussion of Results

Ribbond fiber is preferable over Ever X Posterior for reinforcing large cavities because it has the highest mean fracture resistance (904.73N) (780.07N), and tokuyama palfique LX5 composite (766.40N). Thus, our null hypothesis has been disproved.

A fracture refers to a complete or partial break in a material caused by excessive force. The prevention of crack propagation is closely correlated with its fracture resistance. Cusps are prone to deflection from masticatory forces; however, the presence of fibers reduces this tendency (Schultrich, 2011).

A 2019 study compared maxillary premolars with Class II (MOD) cavities replaced with Ever X posterior and Estelite Sigma Fast composite (the previous generation of Palfique LX5). The study found that the latter had the highest mean fracture resistance and this disagree with our results. However, there was no significant difference between Ever X and Estelite sigma quick composite, and this agree with our study; this may attributed to the Colten Swiss Tec micro hybrid composite was used to construct the walls of the MOD cavities (Hada et al., 2019).

Another study conducted in 2021 investigated to investigate the fracture resistance of different composite resins in conventional posterior composite, and fiber-reinforced composites (EverX Posterior), the result show that EverX Posterior displayed the highest values of fracture resistance, which might be explained by the use of different adhesive bonding agents between the groups, as well as the remaining occlusal part of Ever X group was restored using G Aenial Posterior composite (neslihan et al., 2021).

The changes in the filler size, distribution, filler amount, and matrix chemical makeup may account for some of the strength variation observed among the various composites. Therefore, the relationship between an increase in surface hardness and compressive strength and a decrease in filler size and volume is straightforward (Belli et al., 2007; El-Mowafy et al., 2007; Ozel and Soyman 2009).

There is no study compare the fracture resistance between teeth restored with tokuyama palfique LX5, SFRC (Ever X posterior) with Palfique LX5 and Ribbond fibers with Palfique LX5.

Most commonly, restorations of teeth with structural weakness are strengthened using fiber-reinforced composites (Garoushi et al., 2009, Mangoush et al., 2017). The degree to which fibers can be reinforced depends critically on several factors, including their type, orientation, resin impregnation, and adherence (Vallittu, 1997).

The fracture strength of a tooth is primarily determined by the structure that remains after a cavity is prepared (Hannig et al., 2005). To strengthen the tooth structure that is still present, restorative materials have been used various procedures have been employed to enhance the properties of standard materials. Choosing the right material is crucial to effectively replace missing retain the residual tissue and retain the tooth structure (Sengun et al., 2008).

Because of the way that different types of FRCs strengthen teeth, they are some of the most significant instances of modified composites (Fráter et al., 2014). Belli's study revealed that restorations supported by fiber-reinforced composites (FRCs) had higher fracture strength values than restorations that were not (Belli et al., 2006).

The addition of fibers to a composite material, its mechanical properties are significantly improved. The presence of fibers aids in preventing the spread of cracks when stress is transferred from the matrix to the fibers (Vallittu, 2001). Every X posterior with 1-2 mm long E-glass fibers impregnated within the nanohybrid composite could be applied in increments of 4 mm.

While certain research discovered discrepancies between glass and polyethylene in terms of fracture strength values fiber reinforced composites, other studies found that both materials boosted the restorations' fracture strength in a comparable manner. As per Kemaloglu et al. and further sources (Kemaloglu et al., 2015, Hiremath et al., 2017, Tekçe et al., 2017, Shah et al., 2020), Comparing the two FRC groups were identical to one another although the groups reinforced with FRC restorations had a much better fracture strength than the class II cavities that are not repaired or that are treated with composite restorations without fiber reinforcement. As seen by the manner in which the interfacial stresses were modified by the short glass fibers in SFRC that are multidirectional, or by the polyethylene fibers that are interwoven and multidirectional yarns lock, which created numerous routes of load (Garoushi et al., 2013, Belli et al., 2006). This lessens the degree of the tension and stops the cracks from growing quickly by aiding in the twisting and redistribution of the occlusal forces. Furthermore, compared to restorations using fiber reinforced composites, composites without fiber reinforcement have much less fracture toughness and less crack-arresting capabilities, which makes cracks easier to propagate. The irreversible failures of the FRC restorations and the disastrous failure of the straightforward composite restorations that caused these research could be explained by this increasing the strains at the crack-filler interface (Kemaloglu et al., 2015 , Shah et al., 2020).

Study by Sáry examined the fracture resistance of two varieties of glass fiber reinforced composites (FRCs) used with different restoration techniques: everX Posterior and everX Stick NET procedures and restorations were reinforced with polyethylene (Ribbond) (Sáry et al., 2019). The findings demonstrated that when everX Posterior was used circumferentially within the cavity or as an occlusal splint, alone or in conjunction with everX Stick NET, the restorations that Rib bond endorsed and the other restorations did not differ statistically significantly. The results indicate that the bidirectional glass fiber net is significantly influenced by its placement. The scientists postulated that instead of merely exhibiting an isotropic reinforcing effect in a few specific orientations, the fibers that were randomly orientated displayed an influence in several directions when everX in dentine, posterior is used substitute in dentine (Garoushi et al., 2007). This is largely because the SFRC substructure acts as a crack-prevention layer and may support the composite restoration that is overlaid (Garoushi et al., 2005; Garoushi et al., 2007).

5. Conclusions

1. Deep MOD cavities in vital teeth can be reinforced using either polyethyene or glass fibers in direct restorative procedures.
2. Polyethylene fibers can reinforce the MOD cavities Teeth restored with Polyethylene fibers (Ribbond) provided higher fracture resistance compared to glass fibers.
3. Short fiber-reinforced composite (EverX) does not significantly increase the fracture resistance of teeth compared to stander composite.
4. Type of the composite restoration used to restore missing walls in MOD cavities affect the fracture resistance significantly.

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Conflicts of interest:
The authors declare that they have no conflicts of interest.

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