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Original Article

Impact of Fiber Reinforcement on Microleakage and Fatigue Resistance in Composite Restorations

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Abstract

This study aimed to investigate the effects of different fiber implantation techniques on the microleakage of MOD cavities and fracture resistance in molar teeth. The study was conducted in two phases: the microleakage test group (T2) and the fracture resistance test group (T1). There was a randomization of 110 third molars (T1:n1/4 = 80, T2:n1/3 = 30). Group K was the composite restoration (Gaenial Posterior, GC); group KFT was the cavity lined with polyethylene fiber (Ribbond, Ribbond Inc., Seattle, WA, USA) + composite restoration; group KFH was the polyethylene fiber placed circumferentially on the cavity's inner walls + composite restoration; and group KFT was the MOD cavities restored following standard preparation. Teeth in the T1 control group were not damaged. Types of fracture, fracture strengths, and microleakage values were evaluated. The Kruskal Wallis H and Mann-Witney U tests were used for statistical analysis. It was found that there was no significant difference in fracture strength between the groups ($P > 0.05$). Compared with the K group, there were more restorable fracture types in the KFT and KFH groups. The microleakage values in the KFT and KFH groups were significantly lower than those in the K group ($P < 0.05$), but they were not different from each other ($P > 0.05$). These results indicate that the use of polyethylene fibers in MOD cavity restoration offers an advantage for composite restorations.

Key words: Composite resins, Polyethylene fiber, Fracture strength, Reinforcement

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Introduction

A key element in controlling the clinical failure of a large-scale composite restoration is the stress at the bonded interface brought on by a strong bond between the resin composite and the tooth structure [1]. Visco-elastic behavior, which is

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characterized by the growth of the elastic modulus and flow capacity, is determined by the volumetric shrinkage of the composite resin, which performs this stress. Microleakage and shrinkage stress values were found to be related [2]. This high stress and leakage may lead to various failures, including fractures, postoperative sensitivity, recurrent caries, and marginal degeneration [3, 4]. One factor influencing the ratio of polymerization stresses in composite resins is the unbonded surface area [1]. Curing strains are influenced by the C-factor and the material's flowability during curing. It is recommended that an intermediate resin with a modulus of elasticity and low viscosity be used between the bonding agent and the composite to act as a stress-breaker and elastic buffer to address this issue. Flowable composites are one of the materials used to accomplish that goal [5-7]. Nevertheless, it has been noted that flowable composites do not improve fracture resistance in large MOD cavities [8], but that they do when combined with polyethylene fibers, another substance employed for this purpose [9-11].
According to earlier research, fiber-reinforced composites' flexural strength and flexure modulus are enough for their successful oral function [12, 13]. Eskitascioglu *et al*. [14] showed that a polyethylene fiber's elastic modulus was 23.6 GPa when it was mixed with flowable composite and adhesive glue. The polyethylene fiber's higher elastic modulus and lower flexural modulus were found to change the interfacial tensions, improving them over the etched enamel-resin border [15]. A recent study [8] found that endodontically treated teeth with MOD preparations had higher fracture strength, or that cavities with a high C-factor could have higher micro tensile bond strength if the polyethylene fiber was embedded in the flowable resin bed before the composite restoration was completed [8]. Although the C-factor affects dentin adherence, using an appropriate layering strategy can strengthen the attachment to deep cavity floors [16]. Because of this, giving teeth intracoronal strengthening is crucial for preventing fractures, especially in the posterior region and in teeth that are structurally compromised [9, 13, 17].
There are different reinforcement techniques available for the polyethylene fiber combination of composite restoration which is introduced as a liner under the composite resin, insertion into a prepared groove in the occlusal of the finished restoration, and insertion buccolingually [10, 16-19]. Deliperi *et al*. [20] developed a new method that aims to prevent microcracks. After the missing walls have been repaired with composite resin, this procedure uses polyethylene fiber positioned circumferentially within the axial walls to support the restoration and teeth. The effects of polyethylene fiber reinforced restorations with various inserts on microleakage and fracture strength in large MOD cavities in molars with high C-factors, particularly those without endodontic access, have been the subject of very few investigations [9, 21, 22].
Thus, the study sought to compare the fracture resistance and fracture behavior of various fiber reinforcement techniques concerning composite restorations under loading in MOD cavities for molar tooth restorations, as well as to evaluate the impact of these restoration techniques on microleakage.
The current study's null hypothesis was that microleakage and fracture strength would not be impacted by fiber reinforcement during the composite restoration of a MOD cavity.

Materials and Methods

The protocol of the present study was approved by the local ethics committee of the Dentistry School (2018/09).
110 third molars extracted due to periodontal or orthodontic problems were used for the present study. In the study, 80 of these teeth were randomized for the first part (T1: fracture resistance test) of the in vitro tests and 30 for the second part (T2: microleakage test). The soft tissue residues on the teeth were removed with a hand scaler. Teeth with no damaged crown during extraction, no cracks, no caries, and no hypoplasia were included in the study. Teeth were kept in sterilized saline solution at room temperature until the time of the experimental procedure. The anatomical crowns of the selected teeth had similar morphology. For this purpose, mesiodistal and buccolingual widths of teeth were measured with the help of digital calipers (Mitutoyo Corp, Tokyo, Japan). In this respect, the teeth with a mesiodistal width of 12.0 ± 0.7 mm at the cementoenamel junction level and a buccolingual width of 10 ± 0.7 mm were utilized in the study. The teeth in all groups were vertically placed in cylindrical plexiglass molds in an autopolymerizing acrylic resin. The teeth were placed 2 mm below the enamel-cement junction with their occlusal surfaces parallel to the ground.

Cavity preparation and restorative procedures

A trained operator left one group intact to use as a control group (n:20) for T1 and prepared the rest of the teeth as standard in the MOD cavity which has a wall thickness of 2.5 mm and a depth of 5 mm. The preparation was carried out with a diamond bur with round and parallel tips. The thickness of the opposing walls in the cavity floor was designed to have a specified single thickness of 2.5 mm using a digital caliper. Preparation of cavity walls was performed parallel to the tooth axis. The depth of the cavity was assessed by measuring with a periodontal probe directed from the top of the cusps.

The groups are as follows;

Group control

An intact tooth without preparation.

Group K

All prepared cavities were rinsed and dried with an air/water syringe. A matrix system (Tofflemire, Italy) was utilized, and then selective acid etching of the enamel with 37% phosphoric acid was performed, which lasted for 15 seconds, followed by water rinsing and air drying procedures. The adhesive procedure was achieved (Clearfil SE Primer-Bond Kuraray Inc., Tokyo, Japan) following recommendations by manufacturers. The cavity restoration was then performed with a composite resin (Gaenial Posterior, GC, Tokyo, Japan) through the incremental technique. The curing time on each layer lasted 20 seconds. Aluminum oxide discs were used to perform the polishing process of the restoration.

Group KFT

After applying the bonding procedures described in group K, the cavity was lined with a 0.5-1 mm thick flowable resin. A 2 mm wide piece of polyethylene fiber (Ribbond THM; Ribbond Inc., Seattle WA, USA) was cut to the specified length (approximately 9 ± 1 mm) measured using aluminum foil, and then impregnated with adhesive resin (Clearfil SE Bond) during two minutes. Removal of excess resin from the fiber surface was carried out with the help of a hand tool parallel to the direction of the fiber, which was followed by embedding the resin to the flowable resin bed following the protocol described by Belli *et al*. [5, 8]. The combination of fiber and flowable resin was cured for 20 seconds and afterward, restoration of the cavity was completed through the use of the incremental technique. During the restoration, each layer was cured for 20 seconds after the application.

Group KFH

Following the process of bonding, the creation of the missing mesial and distal walls of the cavity was achieved with the help of composite resin material and they were cured for 20 seconds. The lining of the inner surfaces of the cavity converted into a Class I cavity was performed with flowable resin and pre-wetted polyethylene fiber with a 2 mm width and a length of approximately 18 ± 1 mm was embedded into the flowable resin bed in a circumferential way, which was carried out by following a protocol described by Deliperi *et al*. [20] previously. Upon curing for 20 seconds, restoration of the cavity was conducted with composite resin.

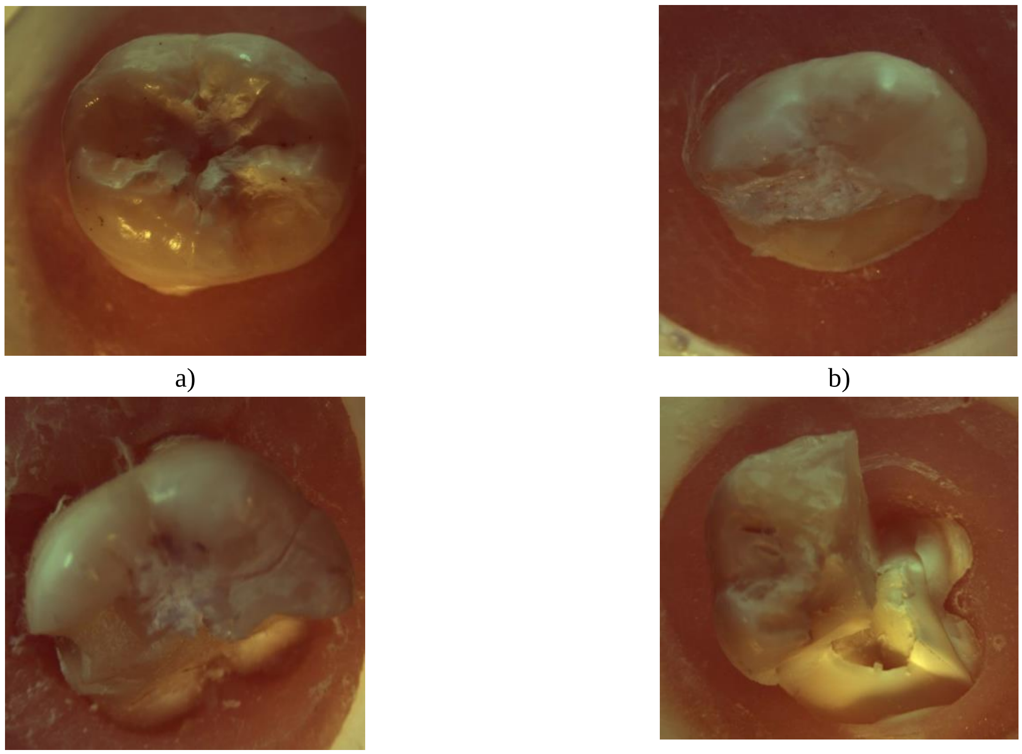
All the teeth, the restoration of which was completed, were stored in distilled water at 37 °C for 24 hours. Following that, it was exposed to a thermal cycle 600 times in 5-55 °C bath waters. Each cycle was completed by keeping at 5 °C for 15 seconds, outside, and at 55 °C for 15 seconds.

Fracture resistance test

All teeth (n1/4: 80), the thermocycles of which were completed, were kept at room temperature and in distilled water until the application of the fracture resistance test. A stainless steel bar with a diameter of 5 mm was prepared to correspond to the central fossa of the teeth which would be used in the test. A fracture resistance test was conducted by the Instron universal test device. To achieve the test, a force was applied to the center of the occlusal surface at a speed of 1 mm per minute with a steel bar. The applied force was paid great attention in terms of being parallel to the long axis of the tooth. Measurements were carried out at room temperature. Force was applied until the tooth or filling material broke. The minimum and maximum forces at the moment of breaking were recorded in the computer environment as values in Newton (N). The fracture behavior of each sample was categorized in **Table 1** and images were taken under the microscope **(Figures 1a-1d)**.

Table 1. Fracture pattern classification.

Type 1: Cusp or composite resin fracture above the CEJ was considered to be restorable.
Type 2: A vertical fracture at one or two cusps that did not extend into the root and was considered to be restorable.
Type 3: A vertical fracture at one or two cusps below the CEJ extending into the root and was considered to be non-restorable.
Type 4: Vertical longitudinal fractures involving the crown that extended into the root or bifurcation and were non-restorable.



a) b) c) d)

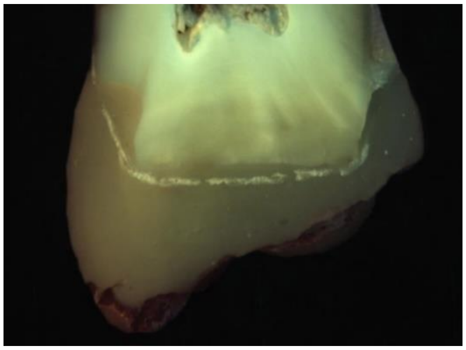
Figure 1. Representative of fracture modes; a) Tip I (restorable fracture), b) Tip II (restorable fracture), c) Tip III (unrestorable fracture), and d) Tip IV (unrestorable fracture)

Microleakage test

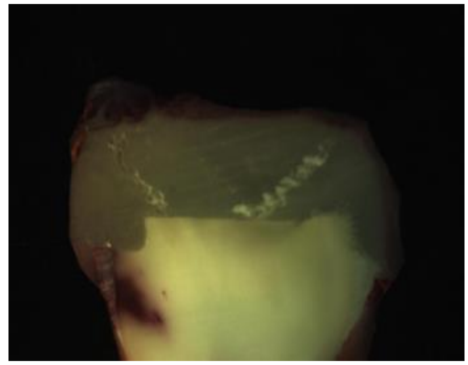
Groups for microleakage assessment were group K, KFT, and KFH (n1/3 = 30). Cavity preparation, restoration steps, and thermal cycling procedures are described in the previous section. To prepare the retrograde cavity of the specimens, 2 mm were removed from the apical region of the tooth root and coated with resin-modified glass ionomer cement (GC Fuji II LC, GC Corp, Tokyo, Japan). Following that, all surfaces were covered with two layers of nail polish (Flormar, Turkey) at a distance of 1 mm from the cavity boundaries. The prepared samples were kept in a 0.5% basic fuchsin solution (Sigma Aldrich, Sigma Chemical Comp., St. Louis, USA) for 24 hours in a non-light environment. At the end of this period, all the samples were washed under water and excess paint on the tooth surface was removed.

Afterward, sections were taken from all samples with the help of a diamond disk (Medcon, Turkey) through the use of the IsoMET device at low speed and with continuous irrigation of water. Two sections were taken from each tooth, which formed a total of 60 sections. These sections were made in the mesiodistal direction of the tooth from the center of the restoration and the closest part of the restoration to the tooth.

Then, all of the samples in which the microleakage test was performed were examined under a stereo microscope (20X magnification) and their images were recorded **(Figures 2a-2e)**. While evaluating the scores, the value with the highest score value from two sections taken from each tooth was taken into consideration. Microleakage scores are described in **Figure 2**.



a)



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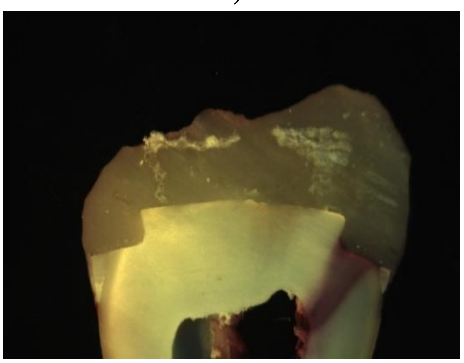

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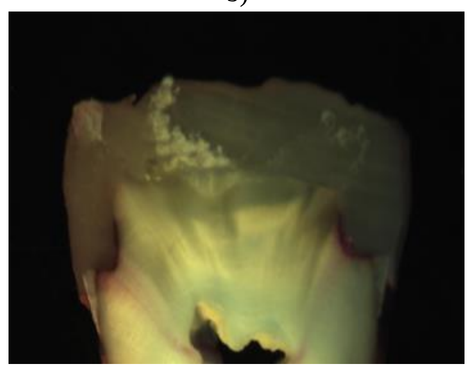

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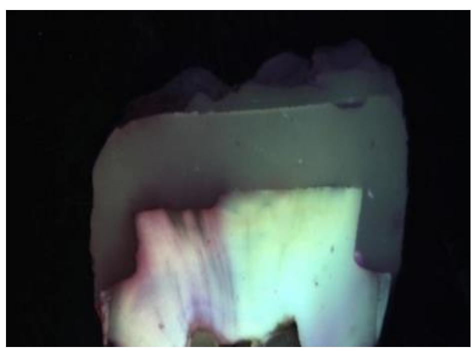

e)

Figure 2. Definition of dye penetration scores; a) 0-No dye penetration, b) 1-dye penetration is half of the marginal edge, c) 2-dye penetration along the marginal edge, d) 3-dye penetration along the half of the axial wall, and e) 4-dye penetration along the axial wall

Statistical analysis

All statistical evaluations in the study were carried out using the SPSS 21 package program. Descriptive statistics were used in the study, Kolmogrow Smirnov analysis for normality, comparisons of more than two independent groups were performed with Kruskal Wallis H test, and comparison of two independent groups was performed with Mann Whitney U test.

Results and Discussion

Table 2 displays the average fracture resistance values and standard deviation (SD) information. The groups with the highest fracture strength values were group KFH, group Control, group KFT, and group K. The statistical comparison of the materials' fracture resistance in our study took mean values into account. Statistical analysis of the fracture strength test results showed that there were no significant differences between the groups (P > 0.05).

Table 2. Fracture test values in groups undergoing fracture strength test.

Groups	Min.	Max.	Mean ± S.S.	P*
Control	1516.11	3994.87	2710.43 ± 171.25	0.068
K	1465.21	3181.16	2312.50 ± 112.00	
KFT	1932.08	3890.14	2602.15 ± 126.22	
KFH	2079.95	4089.49	2805.79 ± 125.97	

*P < 0.05

Table 3 displays the fracture behavior of materials conducting a fracture resistance test. Group KFT 65% and group KFH 60% of the teeth in the control group had a restorable fracture type, compared to 75% of the teeth in the control group. With a 40% recoverable fracture type, group K has the worst fracture behavior prognosis. More restorative fracture types were seen in composite resin restorations reinforced with polyethylene fiber (group KFT-KFH) compared to composite resin restorations constructed without polyethylene fiber (group K).

Table 3. Results of modes of failure and distribution of the samples according to the fracture patterns.

Fracture mode	Group control	Group K	Group KFT	Group KFH
Tip I (R)	10	6	11	7
Tip II (R)	5	2	2	5
Tip III (UR)	4	7	5	3
Tip IV (UR)	1	5	2	5

(R: Restorable fracture, UR: Unrestorable fracture)

The groups' microleakage scores are displayed in **Table 4**. According to the microleakage values, there is a significant difference between the groups (P < 0.05). When groups were compared in pairs, the difference was substantial (P < 0.05). In contrast, group KFT and group KFH did not differ statistically significantly in their microleakage scores due to the varied ways that polyethylene fiber was inserted into the cavity (P > 0.05) **(Table 5)**.

Table 4. Microleakage scores of the groups.

Score	0	1	2	3	4
Group K	1	0	0	1	8
Group KFT	5	0	0	2	3
Group KFH	3	1	1	3	2

Table 5. Evaluation of the mean microleakage scores.

Groups	N	Mean ± S.S.	P*	P*
K	10	3.50 ± 0.40	0.046	0.027*
KFT	10	1.80 ± 0.57		0.030**
KFH	10	1.90 ± 0.58		0.937***

Kruskal Wallis H /Mann Whitney U test; P*: K & KFT, P**: K & KFH, P***: KFT & KFH; *P <0.05

Restorative materials are intended to strengthen the tooth, restore its structural integrity, and provide an efficient bond between the restoration and the tooth. According to recent studies comparing fracture resistance in large MOD cavities with endodontic access, the use of composite resin and polyethylene fiber greatly enhanced fracture resistance [16, 17, 23]. Comparing the fiber and non-fiber groups in the current investigation revealed no discernible differences. The null hypothesis was accepted when the fracture strength was assessed. Unlike earlier research, our study used teeth without endodontic treatment, thus variables including root canal preparation, canal irrigation filling techniques, the impact of irrigation and medications, and the effect of moisture reduction were not included. Additionally, the pulp chamber is included in cavity preparations for endodontic treatment, which results in greater material loss and less dentin remaining. As previously said, one of the most crucial elements in enhancing the fracture strength of teeth is the amount of dentin that remains. We believe that these factors contributed to the lack of variation in fracture resistance between the fiber-using and non-using groups in our investigation.

Comparing the fracture resistance of using polyethylene fiber in class II composite resin restorations, Akman *et al*. [18], Hürmüzlü *et al*. [24], Torabzadeh *et al*. [25], and Sengun *et al*. [26] found no significant difference, although the fracture resistance values of the groups using polyethylene were higher. This study is similar to ours.

The efficacy of the repair may be impacted by where the polyethylene fiber is located within the cavity. A small number of studies have suggested that adding polyethylene fiber in various locations (such as beneath the composite resin, in a groove that has been prepared on the occlusal surface of the completed restoration, or inserted buccolingually or circumferentially) strengthens the composite restoration against compressive forces. However, no statistically significant difference between these locations was discovered [16-19]. Comparably, our investigation found no discernible differences between the groups that had polyethylene fiber lined under the composite resin and around the axial walls that had been rebuilt with composite resin.

Both the teeth's fracture resistance and the perception of their fracture behavior depend on it [18]. In contrast to restorations without polyethylene fiber, polyethylene fiber reinforcement has been shown to preserve the remaining tooth structure when it breaks in a restorable fracture, and this investigation supports this finding [8, 18, 19, 25-27]. Based on the findings of our investigation, the composite-polyethylene fiber combination has a modifying influence on stress. In MOD cavities, fiber-reinforced composite restorations appear to be a more dependable restorative method than traditional composite restorations.

Our study's findings are supported by research showing that using composite resin and polyethylene fiber greatly lowers gingival edge microleakage in MOD restorations of class II cavities [5, 9, 21, 28]. The null hypothesis was disproved upon evaluation of the microleakage test results. According to earlier research, microleakage is not considerably impacted when fiber is used in conjunction with composite resin restoration [29, 30]. It is believed that the reason for the discrepancy in our study is that flowable composite, which can improve the adaptability to the cavity walls with fiber, was not utilized in these investigations.

It has been noted that polyethylene fiber is typically positioned as the cavity lining beneath composite resin, and there are a few studies in the literature assessing the microleakage in various fiber localisations with composite restorations [9, 28]. Microleakage was found to be decreased in both groups in our study, which were positioned circumferentially in contact with the cavity walls and parallel to the cavity floor under composite resin. However, it was found that there was no difference between the groups with different polyethylene fiber localisations.

All of these results lead us to believe that the fiber plays a significant role in microleakage because of its ability to modify stress along the restoration-dentin interface, improve marginal adaptation because of its strong bonding ability with resin, and reduce shrinkage stress in composites because of its low elasticity modulus. The study's findings are significant even if they were obtained in vitro since a lengthy follow-up is necessary to confirm the results and the parameters being investigated are difficult to measure in vivo. Nevertheless, additional clinical research is required to validate these findings, assess their clinical implications, and determine their significance for treatment results.

Conclusion

Composite resin restorations with polyethylene fiber reinforcement exhibited greater restorable behavior under loading, but their fracture resistance was unaffected. When compared to traditional composite resin restorations, polyethylene fiber-reinforced composite restorations dramatically decreased microleakage, regardless of the impact of various localisations.
The success and longevity of polyethylene fiber-reinforced composite restorations in MOD cavities of molar teeth will be improved following our findings.

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Conflict of interest: None

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Ethics statement: The protocol of this study was approved by the local ethics committee of the Dentistry School (2018/09). This article does not contain any studies with human participants or animals performed by any of the authors.

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