Original Study

EVALUATION OF MICROLEAKAGE AND FATIGUE BEHAVIOUR OF SEVERAL FIBER APPLICATION TECHNIQUES IN COMPOSITE RESTORATIONS

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ABSTRACT

This study was done to evaluate different fiber placement methods on fracture resistance and microleakage of MOD cavities on a molar teeth. The study was carried out in two parts, the fracture resistance test group (T1) and the microleakage test group (T2). 110 third molars were randomized (T1:n1/4=80, T2:n1/3=30). MOD cavities restored after being prepared as standard were as follows: group K; composite restoration (Gaenial Posterior, GC), group KFT; cavity lined with polyethylene fiber (Ribbond, Ribbond Inc. Seattle, WA, USA) + composite restoration, group KFH; polyethylene fiber circumferentially placed on the inner walls of the cavity + composite restoration. Group Control for T1 were intact teeth. The microleakage values, fracture strength, and fracture types were evaluated. Statistical analysis was performed with Kruskal Wallis H and MannWitneyU tests. It was found that fracture strength were not significantly different between the groups (p> 0.05). Groups KFT and KFH had more restorable fracture types than Group K. Group KFT and KFH microleakage values were significantly lower than Group K (p<0.05), but there was no difference between each other (p> 0.05). As a result of these findings, it is seen that the use of polyethylene fiber in the restoration of MOD cavities provides an advantage to composite restorations.

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

Introduction

The stress at the bonded interface due to a rigid bond between resin composite and the tooth structure is a crucial factor for managing the clinical failure of an extensive composite restoration [1]. This stress is performed by the volumetric shrinkage of the composite resin, which determines visco-elastic behaviour, defined as elastic modulus development and flow capacity. The relationship between shrinkage stress values and microleakage was confirmed [2]. Different failures such as marginal deterioration, recurrent caries, postoperative sensitivity, and fractures may result from this high stress and leakage [3, 4]. The unbonded surface area in composite resins plays a role in the ratio of polymerization stresses [1]. The material's flowability during curing and C-factor affect curing stresses. To solve this problem, it is suggested to use an intermediate resin that possesses a modulus of elasticity and low viscosity between the bonding agent and the composite in order to take part as an elastic buffer and stress breaker. One of the materials utilized to achieve that aim is flowable composites [5-7]. However, it has been reported that the use of flowable composites in large MOD cavities does not increase fracture resistance [8], however, it increases when the flowable composite is utilized together with polyethylene fibers, which is another material used for this purpose [9-11].

Previous studies have reported that flexural strength and flexure modulus of fiber-reinforced composites are sufficient for functioning successfully in the mouth [12, 13]. It was reported by Eskitascioglu *et al*. [14] that the elastic modulus of a polyethylene fiber when combined with adhesive resin and flowable composite was 23.6 GPa. It was noted that a lower flexural modulus and higher elastic modulus of the polyethylene fiber provide a modifying influence upon the interfacial stresses which are improved throughout the etched enamel-resin boundary [15]. In a recent study [8], increased fracture strength was found to be achieved in endodontically treated teeth involving MOD preparations, or it was possible to achieve higher micro tensile bond strength in prepared cavities possessing a high C-factor in such a way as to embedded the polyethylene fiber into the flowable resin bed before finishing restoration with composite [8]. Dentin adhesion is influenced by C-factor, however, the use of a suitable layering technique may raise the bond strength to deep cavity floors [16]. For this reason, intracoronal reinforcement of the teeth, particularly in the posterior region and those that are structurally damaged, is of vital significance in terms of protecting the structure against fracture [9, 13, 17].

There are different reinforcement techniques available for the polyethylene fiber combination of composite restoration which are introduced as a liner under the composite resin, insertion into a prepared groove in the occlusal of the finished restoration, insertion buccolingually [10, 16-19]. Deliperi *et al*. [20] developed a new method that aims to prevent microcracks. This technique involves the use of polyethylene fiber circumferentially within the axial walls to reinforce the restoration and teeth after the missing walls have been restored with composite resin.

There are a limited number of studies investigating the effects of polyethylene fiber reinforced restorations with different inserts on the fracture strength and microleakage in high C-factor cavities that are large MOD cavities in molars, especially without endodontic access [9, 21, 22].

Therefore, the study aimed to make a comparison between different fiber reinforcement techniques regarding composite restoration under loading in MOD cavities' restorations of molar teeth in terms of fracture resistance and fracture behaviour, and to assess the influence of these restoration techniques upon microleakage.

The null hypothesis of the current study was that fiber reinforcement in the course of composite restoration of an MOD cavity would have no impact on fracture strength and microleakage.

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: 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, 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) in accordance with 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 in accordance with 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 bonding, 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. 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 were 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.

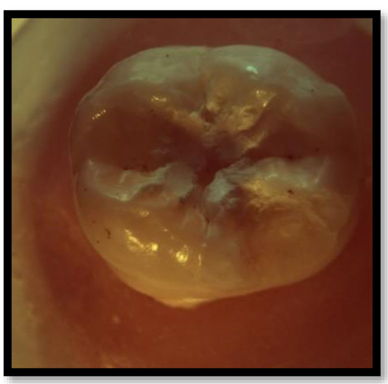
All the teeth, the restoration of which was completed, were stored in distilled water at 37°C for 24 hours. Following that, it was exposed to a thermal cycle 600 times in 5 °-55 ° C bath waters. Each cycle was completed by keeping at 5 ° C for 15 seconds, outside, and at 55 ° C for 15 seconds.

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 behaviour 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 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 was non-restorable.



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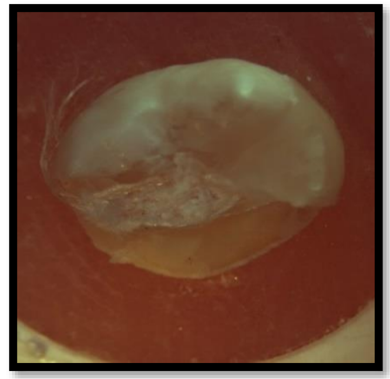

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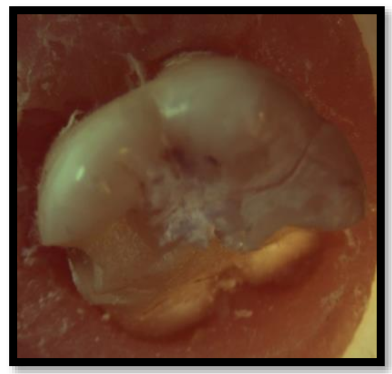

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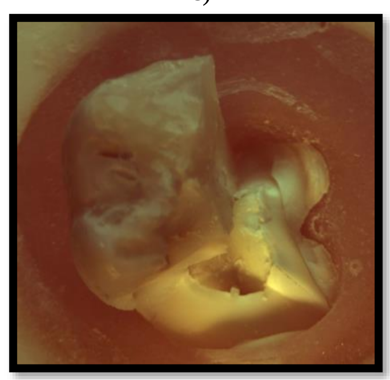

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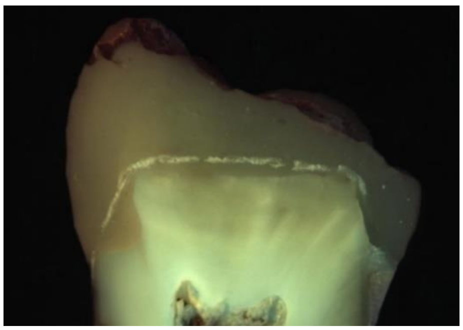
Figure 1. Representative of fracture modes. a) Tip I (restorable fracture), b) Tip II (restorable fracture), c) Tip III (unrestorable fracture), d) Tip IV (unrestorable fracture)

Microleakage test

Groups for microleakage assessment were Group K, KFT, and KFH ((n1/3=30).) Cavity preparation, restoration steps, and thermal cycling procedures are as 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 mesio-distal 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**.



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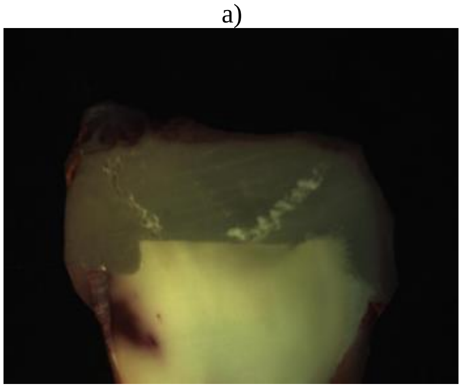

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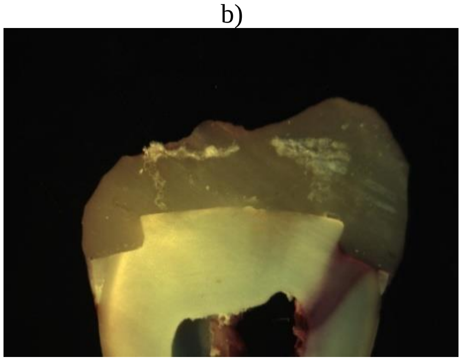

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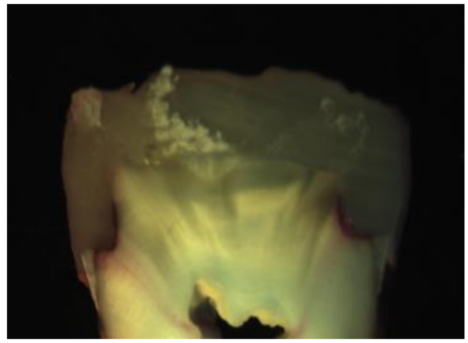

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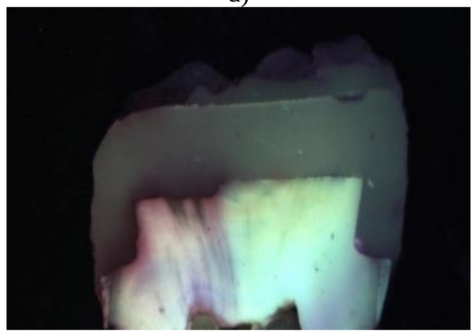

e)

Figure 2. Definition of Dye Penetration Scores. a) 0- No dye penetration. b) 1- Dye penetration half of the marginal edge. c) 2- Dye penetration along the marginal edge. d) 3- Dye penetration along the half of the axial wall. 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 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

Mean values of fracture resistance and standard deviation (SD) data are presented in **Table 2**. Maximum values of fracture strength were observed as Group KFH> Group Control> Group KFT> Group K. In our study, mean values were taken into consideration in the statistical comparison of the fracture resistance of the materials. When the fracture strength test findings were evaluated statistically, it was determined that the differences between the groups were not significant (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

The fracture behaviour of samples undergoing fracture resistance test is shown in **Table 3**. While the teeth in the control group had a 75% restorable fracture type, Group KFT 65% and Group KFH 60% had a restorable fracture type. Group K has the worst prognosis in terms of fracture behaviour with a 40% recoverable fracture type. It was observed that composite resin restorations reinforced polyethylene fiber (Group KFT-KFH) have more restorative fracture types than composite resin restorations made without using 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)

Table 4 shows the microleakage scores of the groups. It was determined that there is a significant difference between the groups in terms of microleakage values (p<0.05). In paired comparisons between groups, the difference was found to be significant (p<0.05). However, there was no statistically significant difference in terms of microleakage scores between Group KFT and Group KFH which was made by placing polyethylene fiber in the cavity in different ways (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

The purpose of restorative material is to restore the structural integrity of the tooth, provide an effective bond between the restoration and the tooth, and strengthen the tooth. In recent reports comparing fracture resistance in large MOD cavities with endodontic access, it was reported that the combination of polyethylene fiber and composite resin significantly increased fracture resistance [16, 17, 23]. In the current study, the findings reported no significant difference when comparing the fiber and non-fiber groups. When the fracture strength was evaluated, the null hypothesis was accepted. In contrast to previous studies, in our study, factors such as root canal preparation, canal irrigation filling procedures and the effect of irrigation and drugs, and the effect of moisture reduction were eliminated due to the use of teeth without endodontic treatment. In addition, in endodontic treatment, cavity preparations also include the pulp chamber, which causes more material loss and reduces the remaining dentin amount. As mentioned before, the amount of dentin remaining is a very important factor in increasing the fracture strength of teeth. We think that the fact that there was no difference in fracture resistance between the groups in which fiber was used and not used in our study was due to these reasons.

Similar to our study, Hurmuzlu *et al*. [24], Akman *et al*. [18], Torabzadeh *et al*. [25], and Sengun *et al*. [26] compared the fracture resistance of using polyethylene fiber in class II composite resin restorations and reported that there was no significant difference, but the fracture resistance values of the groups using polyethylene was higher.

The localization of polyethylene fiber in the cavity can affect the performance of the restoration. A limited number of reports have reported that the placement of polyethylene fiber in different localizations (lining under the composite resin, placement in a prepared groove on the occlusal surface of the finished composite resin restoration; inserted Bucco lingually, circumferentially) increases the strength against compressive forces on the composite restoration, no statistically significant difference was found between them [16-19]. Similarly, in our study, no significant difference was determined between the groups in which the polyethylene fiber was lined under the composite resin and circumferentially within the axial walls restored with composite resin.

It is important in terms of the interpretation of the fracture behaviour as well as the fracture resistance of the teeth [18]. Polyethylene fiber reinforcement has been reported to save the remaining tooth structure when it fails in a restorable fracture in comparison to restorations without polyethylene fiber and the present study confirms this [8, 18, 19, 25-27]. According to the results of our study, findings confirm that modifying effect on the stress provided by the composite-polyethylene fiber combination. Fiber reinforced composite restorations seem to be a more reliable restorative technique than conventional composite restorations in MOD cavities.

Studies reporting that the use of composite resin combined with polyethylene fiber significantly reduces microleakage in the gingival margin in MOD restorations of class II cavities confirm our study findings [5, 9, 21, 28]. When the microleakage test results were evaluated, the null hypothesis was rejected. Previous studies are reporting that the use of fiber in combination with composite resin restoration does not significantly affect microleakage [29, 30]. The difference in our study is thought to be due to the fact that in these studies, flowable composite, which can increase the adaptation to the cavity walls with fiber, was not used.

There are a few studies in the literature evaluating the microleakage in different localizations of the fiber with composite restorations, and it has been observed that the polyethylene fiber is generally placed lining of the cavity under composite resin [9, 28]. In our study, it was observed that microleakage was reduced in both groups, which were placed parallel to the cavity floor under composite resin and circumferentially in contact with the inner walls of the cavity, but it was determined that there was no difference between the groups with different localizations of polyethylene fiber.

As a result of all these findings, we think that the fiber has an important place in microleakage due to the stress-modifying effect of the polyethylene fiber along the restoration-dentin interface, the improved marginal adaptation due to the good bonding ability of the fiber in combination with resin, and low shrinkage stress of composite due to the low elasticity modulus of the polyethylene fiber. The results of the study, although in vitro, are important, given that the tested factors cannot be easily measured in vivo and a very long follow-up is required to confirm the results. However, more clinical studies are needed to confirm these results and evaluate their clinical effects and their relevance to treatment outcomes.

Conclusion

Polyethylene fiber reinforcement did not affect the fracture resistance of composite resin restorations, but polyethylene fiber reinforced restorations had better restorable behaviour under loading. Regardless of the effect of different localizations, polyethylene fiber reinforced composite restorations significantly reduced microleakage compared to conventional composite resin restorations. In line with these results, polyethylene fiber reinforced composite restorations in MOD cavities of molar teeth will provide an advantage in terms of the success and survival of the restoration.

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Conflict of interest: None

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Ethics statement: The protocol of this study was approved by 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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