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Original Article

Fracture Resistance of Different Resin Composite Restorative Materials in mesio-Occluso-distal Cavities Prepared in Maxillary Premolar Teeth With and Without Ribbond Fibers Reinforcement: An In-vitro Study

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Abstract

Aim: : Our study aimed to evaluate the effect of polyethylene fibers application on the fracture resistance of different resin composite restorative materials in MOD cavities prepared in maxillary premolars with and without Ribbond fibers reinforcement.
Subjects and methods: fifty intact human upper premolars teeth extracted for periodontal or orthodontic causes were collected, The teeth were divided into five equal groups: Group 1 (control group): positive control intact teeth without cavity preparation, and 4 intervention groups where the MOD cavity was prepared and treated with different interventions as following, group 2: Filtek Z350 XT without Ribbond fibers, group 3: Filtek Z350 XT with Ribbond fibers placed on axial wall and pulpal floor, group 4: Estelite sigma quick composite without Ribbond fibers and group 5: Estelite sigma quick composite with Ribbond fibers placed on axial wall and pulpal floor. Teeth were thermocycled 500 times ranging from temperature 5^0 to 55^0 for one minute in each cycle. Loads at which the restorations fractured were recorded and statistically analysed.
Results: There was no statistically significant difference between positive control group and the Filtek Z350 XT and the Estelite sigma quick composite without Ribbond fibers. The fracture load was significantly elevated in Filtek Z350 XT with Ribbond fibers (1658±189.84) and Estelite sigma quick composite with Ribbond fibers groups (1691.2±359.12) compared to the positive control group ($p<0.001$)..
Conclusion: The higher fracture load was achieved when reinforcing Filtek Z350 XT or Estelite sigma quick composite resin with Ribbond fibers for MOD restorations.

Keywords: Fracture resistance, ribbond fibers, Filtek Z350 XT, Estelite sigma quick, MOD.

Introduction

Dental caries could be considered one of the most common oral disease all over the world. More than 2.8 billion of population are suffering from dental caries (***Albar et al., 2023***) Restoring an MOD cavity especially in premolars is considered a challenge due to the excessive amount of tooth structure lost from caries, defective old restoration, and/or root canal treatment which causes further weakening of the remaining tooth structure ***(Abdulamir et al., 2023).*** Therefore, MOD cavity preparation of these teeth represents the worst scenario. Compound Cl II cavity preparation decreases the fracture toughness of premolar teeth by about 5%, while MOD cavity preparation in premolars decreases fracture toughness by about 24% up to 44%, therefore it is recommended to restore MOD cavities with indirect restoration rather than direct resin composite restorations, that could reinforce the remaining tooth structure *(Bilgi et al., 2016)*

This raises the demand for the development of restorative materials and techniques that could restore mutilated teeth. Advancement in dental restorative materials and modern cavity designs have made esthetic restorations the best approach in modern caries management. Resin composite restorative materials have excellent esthetic and mechanical properties, with an overall good strength and fracture resistance ***(Pallesen et al., 2015)***.

In modern dentistry, resin composite restorative materials are, in general, the first option in restoration of anterior as well as posterior teeth due to many advantages which are material dependent such as excellent esthetic, conservation of tooth structure, and reinforcement of remaining tooth structure ***(Demarco et al., 2022).*** Considering wear and micro leakage, composite restorations have a failure rate of nearly 5% ***(Moraschini et al., 2015)*** .In terms of fracture resistance in restorative dentistry, resin composite may give strength to the remaining tooth structure; however, this beneficial effect is depending on the material properties and should be considered during the selection of a suitable composite material ***(Alshiddi et al., 2022***).

Possibility of restoration fracture in MOD cavities are magnified by polymerization stresses ***(Hall et al., 2022).*** Clinical success of the restoration is greatly dependent on fracture strength of the restorative material and is considered an important decisive characteristic in successful clinical results.

Nanohybrid universal resin composite is used for restoring both anterior and posterior restorations with a universal adhesive to bond the restoration to the tooth structure permanently. It has excellent polishability excellent shade matching and unique nano-filler technology with improved fluorescence ***(Chodhorry et al., 2018).***

Supra-nanofilled universal composite is a universal resin composite restorative material with higher filler loading and spherical supra-nanofiller particles of silica and zirconia with improved mechanical and physical material properties, quick curing time and increased polymerization conversion rates ***(De Souza et al., 2011)***.

Ribbond reinforcement fibers are delivered in the form of leno-woven polyethylene fibers that improve the adaptation of the restorative material to the cavity walls and floor[1]. Resin composite interlocks mechanically into different directions with the 3D structure and results in decrease the crack propagation during polymerization ***(Karbahari et al., 2017).***

This will raise a question about the possibility of restoring MOD cavities prepared in premolar teeth with direct reinforced resin composite restorative materials. Therefore, this study aimed to investigate the fracture resistance of different direct resin composite restorative materials in MOD cavities prepared in maxillary premolar teeth with and without Ribbond fibers reinforcement.

Subjects and Methods

Sample size calculation:

The sample size calculation was done to detect the power of the study to determine 30% improvement in the fracture load after adding polyethylene fibers according to a previous study by ***Taher et al., 2019***. The sample size was based on the following considerations: power of 90%, 95%significance, the minimum required sample size was found to be 42 teeth, other eight teeth were added to overcome dropout, thus a total of 50 teeth were involved in the study, 10 teeth in each group.

Study design:

In our present study, a total number of fifty human intact premolar teeth were used which were extracted for orthodontic purpose after signing an informed consent from patients. Teeth should be intact with no cavitation, cracks, fractures, pathological wear, or previous restorations after examination using a magnifying lens. This study followed the ethical committee of our institute.

Teeth were first cleaned immediately after extraction to remove any remnants of periodontal tissues or calculus using a hand scaler then teeth were disinfected using a 08% sodium hypochlorite solution immersed in it for 20 min, after that teeth were stored in distilled water at room temperature until use.

At time of using, root of each tooth was covered with 0.5mm light body vinyl – polysiloxane impression material to simulate periodontal ligaments and then embedded perpendicularly in auto polymerized acrylic resin. Then an impression with flowable composite for the occlusal surface of each tooth was taken to make an occlusal stamp to facilitate restoring the original anatomy.

Teeth were mounted and fixed to blocks made from acrylic resin 1.5 mm apical to the cemento-enamel junction.

Cavity design:

Mesio-occluso-distal Class II cavity was prepared with standardized dimensions using a high-speed hand piece under water coolant by the same operator and repeated on all teeth. A round bur was placed in the middle of the occlusal surface of each tooth to gain access. The buccal and lingual walls were prepared parallel to the long axis of the tooth using a fissure bur. The thickness of the buccal and lingual walls was measured throughout the preparation using a caliper. The occlusal cavity had a 2.5 mm pulpal depth, one third intercuspal distance width, axial step was prepared with 1.5 mm depth using a straight fissure bur and the measurements were verified using a periodontal probe for all teeth.

Grouping of teeth and restorative procedure:

Teeth were divided into five equal groups:

Group 1 (Control group): positive control intact teeth without cavity preparation.

Group 2: universal Nano-filled composite (Filtek Z350 XT) without Ribbond fibers. Cavities were cleaned, dried, and etched with 35% phosphoric acid for 15 seconds. Then each tooth was rinsed for another 15 seconds and dried for 2 seconds. After that, 3 consecutive coats of a total etch adhesive (3M-ESPEAdper single bond 2,3M, USA) were applied to etched enamel and dentin for 10 seconds gently using a fully saturated micro-brush and light cured for 10 seconds using LED curing unit 3M Elipar Deep Cure-S LED Curing Light, 3M, USA) at 600 mW/cm2. Light intensity output was verified every 10 samples using a digital read out light meter. Tofflemire retainer and a circumferential matrix band were adapted and applied around the tooth and the cavity was restored with Filtek Z350 XT by an oblique incremental packing technique with 1.5 mm thickness for each increment and cured for 40 seconds according to the manufacturer's instruction.

Group 3: Filtek Z350 XT with Ribbond polyethylene fibers (Ribbond Inc., Seattle, WA, USA). This group resemble group 2 with addition of the fibers that were placed into the middle of the first increment of composite before curing. The fibers were packed on axial wall and pulpal floor away from the gingival seat of the proximal box. After curing for 20 seconds, the cavity was restored with Filtek Z350 XT as in group 2. Group 4: universal composite with Radical Amplified Photopolimerization (Estelite sigma quick, Tokoyama) without Ribbond fibers. Resin composite material was incrementally packed and cured for 20 seconds for each increment.

Group 5: Estelite sigma quick composite with Ribbond polyethylene fibers. The group resembled group 4 with Ribbond polyethylene fibers that were placed on axial wall and pulpal floor like in group 3. The materials and product details were presented in table 1.

Table1: Materials and product details

Material	Composition
Filter Z350 XT, 3M ESPE	BIS-GMA (Bisphenol A dislvcidy] ether dimethacrylate), UDMA (ure-thane dimethacrylate), and Bis-EMA (bisphenol A polyethylene glycol diether dimethacrylate)
ribbond polyethylene fibers	polyethylene Woven fibers. It has a high coefficient of elasticity, high resistance to elongation and deformation and high tensile strength (3 GPa)
Estelite posterior composite	Bis-GM, Bis-MPEPP, UDMA, and TEGDMA. Filler load: 82% by weight: Spherically shaped (mean particle size 200 nm) silica–zirconia filler
Adper single bond 2, 3M	Bis-GMA, HEMA, dimethacrylates, 5nm silica nanofiller, initiators, bisphenol-A methacrylate.

Fracture resistance testing:

Teeth were thermocycled 500 times ranging from temperature 50 to 550 for one minute in each cycle. Fracture resistance was measured with a steel ball of 5mm diameter with a cross head speed of 1mm/min using a Universal Testing Machine. The occlusal surface was subjected to vertical load until fracture of the restoration. The load that causes fracture of the restoration was recorded for statistical analysis.

Results

Statistical analysis:

Data was sent to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Shapiro-Wilk test was used to verify the normality of distribution. Data revealed as means and standard deviations for groups and multiple comparisons were performed by One Way Analysis of Variance (One Way ANOVA) followed by Tukey`s post hoc test.

Fracture load was significantly differed between groups (p<0.001). There was no significant difference between the positive control intact teeth without cavity preparation group (952.2 ±119.85) and Filtek Z350 XT without Ribbond fibers (816 ±136.44) and the Estelite sigma quick composite without Ribbond fibers (945.2±127.72) (P1=0.834 and P3=1, respectively). The fracture load was significantly elevated in Filtek Z350 XT with Ribbond fibers (1658±189.84) and Estelite sigma quick composite with Ribbond fibers groups (1691.2±359.12) compared to the positive control group (p<0.001).

The one-way ANOVA test showed that Restoration of prepared teeth with resin composite significantly increase the fracture. Fracture resistance of the prepared maxillary premolar teeth greatly improved by resin composite restorations reinforced with Ribbond fibers (p=0.0001). Comparing means of fracture resistance of all the tested groups with different systems, the one-way ANOVA test showed that there were statistically significant differences between all the restored groups (p=0.0001). (Table 2, Figure 1)

Table 2: Comparison of Fracture load

Groups (n=10)	Fracture load (Mean ± SD)	P value Post Hoc
positive control group	952.2 ±119.85	P<.001*
Filtek Z350 XTwithout Ribbond fibers	816 ±136.44	
Filtek Z350 XT with Ribbond fibers	1658±189.84	
Estelite sigma quick composite without Ribbond fibers	945.2±127.72	
Estelite sigma quick composite with Ribbond fibers	1691.2±359.12	

Data are presented as Mean ± SD, * P value < 0.05 is considered statistically significant. There was statistically significant difference at P<.001 observed in group 3 with the control group which represents Filtek Z350 XT with Ribbond fibers at fracture load of (1658±189.84) and group 5 which represents Estelite sigma quick composite with Ribbond fibers at fracture load of (1691.2±359.12). Most of significant difference was seen in group 2 which represents Filtek Z350 XTwithout Ribbond fibers (p= 0.834) and group 4 for Estelite sigma quick composite without Ribbond fibers (p= 1).

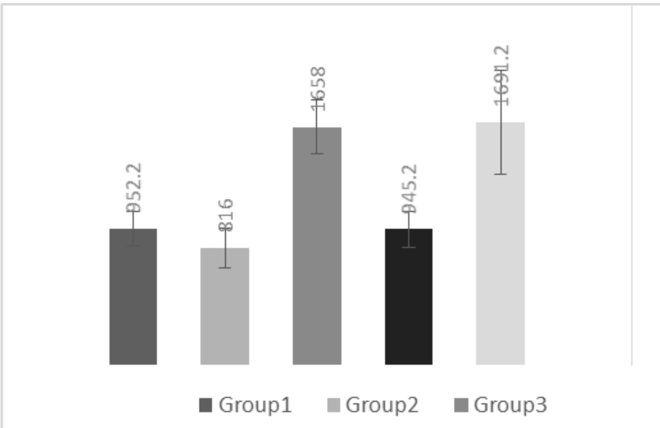

Figure 1: fracture load among the studied groups

Discussion

Over the last years, the improvements of the restorative materials and techniques in adhesive dentistry result in reinforcement of weakened dental hard tooth structure. MOD cavity preparation reduces the tooth resistance to fracture as a result of the loss of marginal ridges. Occlusally applied loads may cause cuspal fracture and in teeth with wide Class II cavities, fracture of the cusps occurs as a result of fatigue of the brittle tooth structure by propagation of microcracks under repeated loading.

In the current in-vitro study, we compared the fracture resistance of maxillary premolar teeth restored with different resin composite systems with and without Ribbond fibers reinforcement. The null hypothesis which stated that there is no significant difference in fracture resistance of maxillary premolar teeth with MOD cavities restored with reinforced resin composite systems was partially accepted since there are 2 reinforced resin composite groups showing higher fracture resistance value than non-reinforced groups.

Results of the current study it was found that there was no significant difference between the positive control group and Filtek Z350 XT without Ribbond fibers and the Estelite sigma quick composite without Ribbond fibers groups. The fracture load was significantly elevated in Filtek Z350 XT with Ribbond fibers and Estelite sigma quick composite with Ribbond fibers groups compared to the positive control group.

Evaluation of the remaining amount of tooth structure after cavity preparation is considered an important decisive factor for determining the fracture resistance of both tooth and restoration. The extensive loss of tooth structure will lead to tooth weakening and subsequent fracture that may lead to complete or partial splitting of cusps which may extend to involve the roots of premolar teeth specially the maxillary one ***(Chowdhury et al., 2018).***

When comparing MOD cavity preparations to unprepared teeth, it was found that there is about 54% reduction in fracture resistance ***(Hannig et al., 2005).*** In order to overcome this problems, fiber-reinforced composite restorative materials have been introduced to provide strength and improve fracture resistance of the remaining tooth structure.

In accordance with our results, Vitale et al. found placement of Ribbond fibers could stratify composite materials that allow for a good restoration of the tooth integrity. It was also reported that restoration of a complex crown fracture by Ribbond fibers reinforced composite to create a central support core could be a beneficial approach in restoring mutilated premolar teeth ***(Vitale 2004).***

Unlike other reinforced fibers such as Kevlar and carbon fibers, polyethylene fibers are almost not visible in resinous materials, in addition to improve the flexural strength, impact strength and modulus of elasticity of composite materials, these fiber-reinforced composite restorative materials seem to be the most appropriate and esthetic solution for restoration of MOD cavities specially in maxillary premolars ***(Vitale 2004).***

Moreover, Chowdhury et al. concluded that under compressive stress, Filtek Z350 XT restorative materials significantly improve strength after restoring Class II cavity preparations.

As a major feature in Estelite sigma quick is the catalyst technology known as RAP technology, the initiator reduce the high polymerization needed to cure resin with short exposure time and this technology significantly reduces residual monomers compared to conventional C-Q amine photopolymerization resulting in increased polymerization. Also Estelite sigma quick embodied supra-nano monodispersing spherical filler particles (silica and zirconia) of diameter 0.2 um which give better balance between mechanical properties and esthetics ***(Abdelaziz et al., 2023).***

Additionally, Chhabra et al, found that MOD cavities restored with fiber reinforced resin composites reported the significantly highest mean values of the maximum load to produce fracture ***(Chihabra et al., 2022).***

In contrast to the results obtained by ***Albar et al., 2023*** who found that when placing Ribbond fibers within everX posterior resin composite material, the fracture resistance was reduced. This was explained that there was a poor fiber–matrix interlocking as observed by scanning electron microscope. The poor adhesion of the resin composite to polyethylene fibers may be due to the difficult impregnation of the polyethylene fibers, which leads to poor physical and mechanical properties of the final restoration[18]. In other words, heterogeneous combination of two different materials may negatively affect their strength because of the weak interlocking between Ribbond and resin composite ***(Foek et al., 2009).***

Ribbond fibers have a lock-stitch pattern that transfers the forces through the fibrous weave and stop its propagation during polymerization. In addition, fibers applied on two opposing walls may act as a splint, acting as a stress breaker to absorb stresses and preventing crack initiation and propagation to improve the mechanical properties of the material ***(Mangoush et al., 2021)***.

In-vitro investigations under static loading conditions have certain limitations that differ from clinical studies. The limited but important early data from such trials guides subsequent clinical studies to assess the materials' clinical performance. In addition, comparing data from laboratory studies is not fair due to a lot of variables such as the study protocols, cavity designs whether class II or MOD, restoration application and the influence of different techniques to reinforce the restored tooth, the difficulty of accurate measurement of the fracture load due to the complicated anatomy of the tooth.

Future researches are required to compare such factors and their effects on the result. Further researches should examine material bonding and failure patterns (adhesive, cohesive, or mixed). Future research might examine cracked specimens using SEM.

Conclusion:

The best fracture resistance can be obtained with Filtek Z350 XT or Estelite sigma quick reinforced composite resin MOD restorations with Ribbond fibers compared to the same materials without ribbond fibers.

Under the limitations of our study, it could be concluded that restoring weakened premolar teeth with new available direct reinforced resin composite restorative materials had improving the fracture resistance of mutilated premolars and improved strength of the restored tooth.

Conflict of Interest:

The authors declare no conflict of interest.

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Ethics:

Ethical approval was obtained from Research Ethics Committee, Faculty of Dentistry, Cairo University. Research approval number (421023).

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