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Fracture Resistance of Different Complex Class II Restoration Techniques with Two Bucco-lingual Widths

Alaa M. Mohamed
Demonstrator of Operative Dentistry Department, Faculty of Dental Medicine for Girls, Al-Azhar University, Egypt., alaamousa45@yahoo.com

Wael E. Jamil
. Professor of Operative Dentistry, Faculty of Dental Medicine for Girls, Al-Azhar University, Egypt

Nevin A. Gad
Associate Professor of Operative dentistry, Faculty of Dental Medicine for Girls, Al-Azhar University, Egypt

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ORIGINAL STUDY

Fracture Resistance of Different Complex Class II Restoration Techniques with Two Bucco-lingual Widths

Alaa M. Mohamed*, Wael E. Jamil, Nevin A. Gad

Operative Dentistry Department, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt

Abstract

Purpose: This study aimed to evaluate the effect of different restoration techniques using either nano-hybrid composite alone or with an underlying fiber reinforced composite or flowable composite within two bucco-lingual cavity widths of class II mesio-occlusal distal (MOD) cavities on the fracture resistance. **Materials and methods:** A total of 48 maxillary premolars were selected and divided into three main groups according to the restoration techniques (n = 16 each) as follows A1: all nano-hybrid composite (Essentia Universal) in all the 4 mm cavity depth, A2: 2 mm fiber reinforced composite (everX posterior) covered by 2 mm nano-hybrid composite (Essentia Universal), and A3: 2 mm flowable composite (everX flow) covered by 2 mm nano-hybrid composite (Essentia Universal). Each group is subdivided into two subgroups according to class II cavity width (i.e., 8 each) B1: 2 mm and B2: 3.5 mm buccolingual width. Specimens were mounted in cold cure acrylic resin blocks then thermocycle at 5–55 °C for 2000 cycles. The fracture resistance test was done using universal testing machine. **Results:** Analysis of variance (ANOVA) test was performed. All nano-hybrid composite revealed a statistically significant lower fracture resistance mean values than both reinforced/nano-hybrid and flowable/nano-hybrid. There was no statistically significant difference between both reinforced/nano-hybrid and flowable/nano-hybrid. Also, there were no statistically significant difference between the two cavity width on tooth fracture resistance. **Conclusions:** The fracture resistance of both reinforced and flowable composite covered with nano-hybrid composite were higher than all nano-hybrid composite and the difference in cavity buccolingual width did not affect the teeth fracture resistance.

Keywords: Fiber reinforced composite, Fracture resistance, Nano-hybrid composite

1. Introduction

Fracture of the teeth is a common dental problem and the cavity preparation seems to be the major cause of most cuspal fractures. Posterior teeth, especially maxillary premolars are more likely to fracture under occlusal forces due to the unfavorable crown/root ratio and its anatomical shape and form [1]. Nowadays, resin composite restorations are the most commonly used filling materials due to their high esthetics and preservation of tooth structure. Fracture resistance of restorative dental materials is one of the most important properties that depends on the resistance of the material to crack propagation internally and/or externally [2].

The removal of the marginal ridge in class II cavity causes a 2.5-fold reduction in tooth stiffness, resulting in 46 % decrease in tooth stiffness. As a result, high fracture resistance restoration material is highly recommended in cases that are subjected to large loads, such as class II [3]. One of the most difficulties in dentistry is the restoration of large carious teeth, many studies and researches have been conducted to overcome the shortcomings of composite, resulting in development of resin composites with enhanced properties [4].

Recent materials with improved properties including fiber-reinforced resin composites, bulk-fill resin composites, and resin composites with high fillers. The bulk short fiber reinforced resin

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* Corresponding author. Al-Azhar University. Fax: 01094315260.
E-mail address: alaamousa45@yahoo.com (A.M. Mohamed).

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composite (SFRC) function is to support the surface composite layer while also acting as a crack stopper [5]. The fiber fillers reinforcing effect is based on stress transfer from matrix to the fibers. Individual fibers, on the other hand, act as crack stoppers. Only fibers with a length equal or greater than the critical fiber length can transfer stress. E-glass micro fibers have essential fiber lengths ranging from 140 μm in length and 6 μm in diameter. The position and orientation of fibers affect the mechanical properties [6,7].

The most used dental composites for restoration are microfilled types, they offer good esthetics but low mechanical properties. Nanocomposites, that is nano filled and nano hybrid. The resin matrix composition of nano filled and nano hybrid was similar, but the filler particle type, size, and distribution were different. Nanofilled resin composites consist of nanometer particle size and the nanohybrids combine nanometer sized particles with more conventional filler technology [8−10].

Dentin is made up of collagen fibers embedded in hydroxyl apatite matrix, while conventional resin composite is made up of filler particles embedded in resin matrix. Therefore, dentin should be rather seen as a natural fiber-reinforced resin composite. The restoration and the tooth should form a structurally and mechanically combined form that can withstand recurrent stresses for a long time, according to modern restorative dentistry concepts [11].

In restorative dentistry, fiber-reinforced resin composite has become the material of choice [12]. So, the purpose of this study was to give clinicians a comparative overview exclusively on the fracture resistance of biomimetic material packable and flowable SFRC as a posterior restorative material.

2. Material and methods

This research was performed after the approval of local ethical committee of Faculty of Dental Medicine, Al-Azhar University for Girls, in accordance with international guiding principles, Code: OPDEN 108-1-y.

2.1. Sample size calculation

According to a previous study [13], mean values were 946.67 ± 179.8, 1326.2 ± 452.3 and 1432.6 ± 503.3 using different restoration techniques. A large effect size of ~0.47 is expected [14]. A total sample size of 48 teeth (16 in each group, 8 in each subgroup of buccolingual width) will be sufficient to detect an effect size of 0.47, with a power (1-β error) of 0.8 (80 %) using a two-sided hypothesis test, with a significance level (α error) 0.05 for data.

2.2. Tooth collection and preparation

A total of 48 freshly extracted maxillary premolars that examined for the presence of cracks or any other defects using stereomicroscope. Teeth were scaled to remove the adhering soft tissue and calculus using ultrasonic scaler (Cavitron), and then teeth were stored in physiologic saline solution for maximum period of one month till use, to keep them hydrated and prevent cracking during preparation. Teeth were washed every three days and the solution was changed. Teeth were then embedded up to 2 mm apical to the cemento-enamel junction (CEJ) using teflon ring (2 cm internal diameters and 2 cm height) within chemically cured acrylic resin.

2.3. Cavity preparation

All teeth were planned to receive standardized slot mesio-occlusal distal (MOD) cavity preparation without proximal box in order to reduce the preparation variation. A line was drawn at occlusal surface by a waterproof marker (Faber Castell, Germany), to represent cavity outline then measured using a digital caliper. The dimensions of the cavity were as follow: occluso-cervical depth = 4 ± 0.2 mm at buccal wall and buccolingual width = 2 ± 0.2 mm for subgroup (B1) and = 3.5 ± 0.2 mm for subgroup (B2). A new fissure carbide bur that replaced after every five preparations (Number 012, Komet Geber, Brasseler, Legmo, Germany) with rounded end was used to prepare the cavities in a high-speed handpiece (NSK, Pana Air, Nakanishi Inc Japan) under copious amount of water [15].

2.4. Sample grouping

The tested materials used in the current study are shown in Table 1. The prepared teeth were divided into three main groups (16 each) according to the restoration techniques, where (A1): all nano-hybrid resin composite (Essentia Universal) in 4 mm cavity depth, (A2): 2 mm fiber reinforced resin composite (everX posterior) covered by 2 mm resin nanohybrid composite (Essentia Universal). And (A3): 2 mm flowable resin composite (everX flow) covered by 2 mm nano-hybrid resin composite (Essentia Universal). Each group was subdivided into two subgroups (8 each) according to the cavity width either (B1): 2 mm buccolingual width and (B2): 3.5 mm buccolingual width.

Table 1. Materials used in this study.

Materials Brand Name	Composition	Manufacturer	Lot No.
(Essentia Universal) Nano-hybrid resin composite	Matrix: UDMA, Bis MEPP, Bis-EMA, Bis-GMA, TEGDMA Filler: prepolymerised fillers, barium glass, fumed silica		191001A
(everX Posterior) Short fiber reinforced resin composite	Matrix Bis-GMA, PMMA, TEGDMA, Filler: millimetre scale glass fiber filler, Barium glass 76 wt%, 57 vol%	GC, Toky Japan[a]	2,005,081
(everX Flow) Short fiber reinforced flowable resin composite	Matrix Bis-EMA, TEGDMA, UDMA, Filler: micrometer scale glass fiber filler, Barium glass 70 wt%, 46 vol%		2,001,241
(G-Premio BOND) Universal self etching bond	MDP, 4-MET, MEPS, methacrylate monomer, acetone, water, initiator, silica		2,010,201

[a] https://europe.gc.dental/en.

2.5. Restorative procedures

Every prepared tooth was subjected to the following procedures; washing with air water spray, tofflemire matrix application then selective etching to enamel by application of 37 % phosphoric acid etchant (Prime-Dent, U.S.A) 10–15 s followed with water rinsing for 5 s then gentle air dryness for 5 s [16,17]. Application of universal self-etch dental adhesive (G-Primo Bond) with brush and agitation for 20 s with the brush to help in entering the adhesive then left it undistributed for 10 s then followed with air thinning for 5 s [18]. Adhesive was light cured for 10 s with light curing unit (LED cordless 10 W APOZA Enterprise Co., Ltd. Taiwan). The application of all tested materials was applied according to the manufacturer's instructions.

In group (A1); Essentia Universal was placed in oblique increments to fill all the cavity in 4 mm depth, then light curing of each increment for 20 s with light curing unit. In group (A2); everX posterior was placed in bulk to fill 2 mm of the cavity then light curing for 20 s with light curing unit. Then Essentia Universal was applied in increments in 2 mm and cured for 20 s with the same light curing unit. In group (A3); everX flow bulk shade was applied in bulk in the cavity fill 2 mm of cavity then, then light curing for 20 s. Then Essentia Universal was applied in increments in 2 mm and cured for 20 s with the same light curing unit. Finally, all restorations were finished and polished using discs with aluminum oxide coating of four descending grits [19].

2.6. Thermocycling

The total number of cycles used in this study was 2000 cycles. The dwell times were 25 s with a lag time of 10 s in a water bath at 5–55 °C using thermocycling device [20].

2.7. Fracture resistance assessment

All samples were examined using universal testing machine to determine the fracture resistance of different composite restorations. Fracture test was done by compressive mode of load (measured in Newton), that applied occlusally using a metallic rod with round tip 3.6 mm diameter (Fig. 1).

2.8. Statistical analysis

Numerical data were presented as mean and standard deviation values. One-way analysis of variance (ANOVA) test was done followed by Tukey's post hoc test. Comparison of both depths was performed by independent t-test. Two ways ANOVA test was used to study the interaction of restoration and cavity depth variables.

3. Results

3.1. Effect of restoration techniques regardless of the cavity width

Comparing the mean values, results revealed that, groups A2 and A3 showed the higher mean values

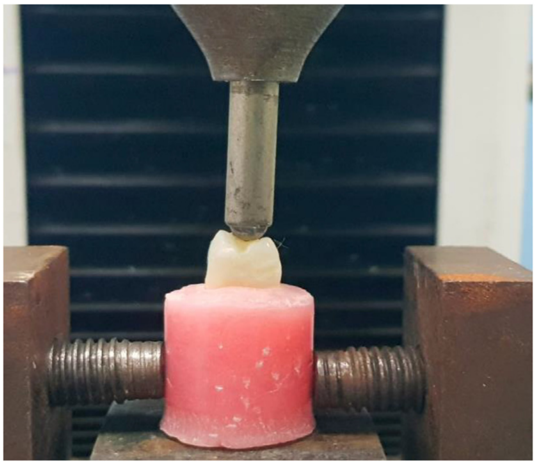

Fig. 1. Metallic rod for load application till fracture.

Table 2. Descriptive statistics and result of analysis of variance test for fracture resistances of the restoration techniques regardless of the cavity width.

All Nano-hybrid A1	Fiber reinforced/Nano-hybrid A2	Flowable/Nano-hybrid A3	P-value
Mean ± SD	Mean ± SD	Mean ± SD	
606.8b ± 234.2	903.5a±268.0	896.7a±200.4	0.0009[a]

[a] Significant at P less than or equal to 0.05, different superscripts were statistically significantly different.

(903.5 ± 268.0) and (896.7 ± 200.4) with no statistically significant difference, but with a statistically significant difference with group A1 which revealed the lowest mean value (606.8 ± 234.2), as shown in Table 2.

3.2. Effect of the cavity width regardless of the restoration techniques

Comparing the mean values, the results revealed that there was no statistically significant difference between group B1 at 2 mm cavity width (821.7 ± 269.4) and group B2 at 3.5 mm cavity width (783.0 ± 269.8), as shown in Table 3.

3.3. The effect of different interactions on fracture resistance

Regarding the different restoration techniques, results revealed that groups A2B1 and A3B1 showed the higher mean values (922.85 ± 295.31) and (914.98 ± 154.82) with no statistically significant difference, but with a statistically significant difference with group A1B1, which revealed the lowest mean value (627.34 ± 250.14). Also, A2B2 and A3B2 showed the higher mean values (884.33 ± 256.77) and (878.48 ± 247.67) with no statistically significant difference, but with a statistically significant difference with group A1B2, which revealed the lowest mean value (586.40 ± 232.60). Regarding the different cavity width, there was no statistically significant difference between both cavity widths using any of the different restoration techniques as shown in Table 4.

4. Discussion

The present study was performed to evaluate the fracture resistance of maxillary premolars using a standardized MOD cavity preparation, which was restored with SFRC covered with nano-hybrid composite, also to compare it with flowable covered with nano-hybrid resin composite or restored by nano-hybrid resin composite only. The most common restorative materials are resin composites because of their good aesthetic and their ability to bond to enamel and dentin [21].

Early composite materials were used only for anterior restorations because of their weak mechanical properties. Polymerization shrinkage is the main problem associated with posterior composite restorations, that cause marginal gaps and lack of strength, therefore fracture resistance is one of the most important properties needs in posterior restoration to overcome crack propagation which cause marginal or bulk fractures of the restoration [21].

Reinforcing composite with short fibers has been used to control the crack propagation from its internal defects. The introduction of short fiber reinforced composite (SFRC), has gained attention recently as a restorative material in high stress-bearing areas [22]. Its fillers composed of a combination of barium glass and E-glass fibers, which randomly oriented to provide reinforcement in multiple directions instead of single or double directions [22]. So, this study used the recently introduced short fiber reinforced packable composite (SFRC) (everX Posterior). In this study, a bi-layered technique was used which is a restoration that include both fiber reinforced composite as a base that act as dentin replacement and covered by conventional nano-hybrid resin composite for esthetics and served as a crack-prevention layer. It supports the remaining tooth structure and increase the longevity of the final resin composite restoration [22,23]. Short fiber reinforced composite materials have a unique fiber and polymer composition, resulting in a wide range of improved mechanical and physical properties [24].

Maxillary premolars were used because their anatomical structure produces a tendency for cusp fracture during mastication, and they are same in size, shape, and commonly extracted for the orthodontic reasons [25]. The weakening of tooth structures caused by caries and large unsupported intra coronal restorations is the most important factor

Table 3. Descriptive statistics and result of analysis of variance test for fracture resistances of the cavity width regardless of the restoration techniques.

2 mm width B1	3.5 mm width B2	P-value
Mean ± SD	Mean ± SD	
821.7 ± 269.4	783.0 ± 269.8	0.569 ns

ns, nonsignificant at P greater than 0.05.

Table 4. Descriptive statistics and result of two-way analysis of variance test for fracture resistances of the different interactions.

Cavity width	All Nano-hybrid A1	Fiber reinforced/Nano-hybrid A2	Flowable/Nano-hybrid A3	P-value (between different restoration techniques)
	Mean ± SD	Mean ± SD	Mean ± SD	
2 mm (B1)	627.34b ± 250.14	922.85a±295.31	914.98a±154.82	0.036[a]
3.5 mm (B2)	586.40b ± 232.60	884.33a±256.77	878.48a±247.67	0.038[a]
P value (between cavity width)	0.740 ns	0.780 ns	0.730 ns	

[a] Significant at P less than or equal to 0.05, different superscripts were statistically significantly different, ns; nonsignificant.

related with crown fractures. In this study, the MOD cavity was prepared to stimulate the worst clinical condition [2,26].

All the specimens were subjected to thermocycling between 5_55 °C in water bath for 2000 cycles with 25 s dwell time to mimic clinical situation as the dental restorations affected by the temperature of oral environment [27]. The number of cycles shows the durability of the composites. It has been reported that, oral environment provides constant challenges to any restorative materials due to the presence of ions, and temperature fluctuation over time these challenges may affect the mechanical properties of restorative materials [28]. Thermocycling is commonly used to age dental composites, however the results vary greatly from one study to another [20].

It was found that, fracture resistance of the studied restorative materials was different. The highest fracture resistance was recorded with fiber reinforced resin composite (everX posterior) and flowable resin composite (everX flow), with no statistically significant difference, but the all nanohybrid composite (Essentia Universal), revealed a statistically significant lower fracture resistance values. This could be explained as follows; short fiber-reinforced composites using e-glass fibers improve modulus by transferring stress from matrix to fibers that acting as stress barrier [29].

Other possible explanation that, fiber acts as crack stopper by supporting the surface composite layer. The FRC has a semi-IPN resin matrix, which results in a plasticized matrix with short glass fibers oriented in different directions, making it difficult to shrink [30,31], hence resulting in reduce of the volumetric contraction of composite and blunt the crack. Short fiber reinforced composite function is a promising to support the conventional composite on the surface and acts as a crack arrest barrier [15]. The higher mean fracture resistance values of everX posterior than everX flow may due to its higher content of barium glass (76 wt%, 57 vol%) than of everX Flow (70 wt%, 46 vol%) (Table 1).

These results were in accordance with other study, that compared fracture resistance of microhybrid fiber reinforced (everX posterior) to nanohybrid resin composites used in restoring Class II MOD preparation of maxillary premolars. The result was that, fiber reinforced resin composite had higher fracture resistance compared with microhybrid and nanohybrid resin composites [8]. Another study came in agreement with the outcomes of this study, that evaluated fracture resistance of MOD cavities in maxillary premolars restored with bulk fill resin composite and SFRC (everX Posterior), the results showed a higher fracture resistance of fiber reinforced composite than other groups [31]. In a previous study [15], evaluated fracture resistance of different short fiber-reinforced resin composite SFRC (everX Posterior) thickness as an intermediate layer of class II composite restoration compared with nanohybid resin composite. The results of that study, showed that fiber reinforced composite had the highest fracture resistance.

However, these results were not full agreement with a previous study [13], that evaluated and compared the fracture resistance of maxillary premolars with class II MOD cavities restored with fiber reinforced resin composite (everX posterior), bulk fill resin composite and Estelite sigma quick resin composite systems. The results showed that, Estelite sigma quick resin composite had the highest mean fracture resistance followed with everX posterior. These difference in result may be attributed to the difference in cavity design, cavity dimensions, and numbers of the thermocycling cycles between the two studies.

The results also showed that, there was no statistically significant difference between the two cavity widths on tooth fracture resistance, this can be explained by that; removal of dental structure has a direct relation in decreasing the fracture resistance, especially in teeth with large MOD cavities, due to loss of the reinforcing structures such as the marginal ridge that become more susceptible to fracture. When these preparations are restored with adhesive materials, there is full or partial recovery of fracture resistance [32]. The success of resin composite materials in large cavities due to the continuous improvement in their mechanical

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properties therefore, fiber reinforcement enhanced their physical and mechanical properties and increasing their resistance to fracture [31].

4.1. Conclusions

Under the limitation of this in vitro study, it was concluded that both fiber reinforced resin composite and flowable resin composite covered with nano-hybrid resin composite can increase fracture resistance of MOD cavities of maxillary premolars than all nano-hybrid resin composite with no difference between the two cavity buccolingual width.

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Conflicts of interest

There are no conflicts of interest.

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