Efficacy of Bulk Fill Flowable Composite Reinforced with Short Fibers in Fracture Resistance of Restored Extensive Premolars Cavities

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KEYWORDS

*MOD restorations,
Bulk fill Flowable composite, Short
fibers, Dentine,
Fracture resistance.*

ABSTRACT

Objectives: Tooth fracture is a common complication following MOD restorations. This study sought to assess the effect of bulk fill flowable composite reinforced with short fibers on fracture resistance of maxillary premolar teeth that have extensively restored MOD cavities. **Materials and Methods:** In this invitro experimental study, 60 human maxillary sound premolar teeth were chosen and stored in chloramine solution. The teeth were then mounted into acrylic blocks 1mm below the CEJ. The teeth were randomly divided into 4 groups of 15 each. Group A, Teeth were intact without any cavity (negative control). Wide MOD cavities were prepared using cylindrical bur with high-speed handpiece for the 3 other groups. Group B, the teeth with MOD cavities without any restoration (positive control); Group C, the teeth were restored with bulkfill flowable composite Tetric N flow bulk fill (Ivoclar Vivadent); and group D, the teeth were restored with short fibers reinforced bulkfill flowable composite ever X Flow(GC). The teeth were then stored in water at 37°C for 24h and their fracture resistance was assessed using (INSTRON). The load at fracture was recorded in N, fracture mode was observed. Data were analyzed using one-way ANOVA and Tukey's test with 95% CI. **Results:** The mean fracture strength was 1216 ± 352 N in group A, 330 ± 201 N in group B, 1013 ± 389 N in group C and 1019 ± 164 N in group D. **Conclusion:** Extensive MOD cavities restored with bulk fill flowable composite having short fiber reinforcement, increased the fracture strength of teeth against compressive forces, with no difference than did the other bulk fill flowable composite.

INTRODUCTION

Removal of tooth structure during cavity preparation, especially marginal ridges decreases fracture resistance. Adhesive materials are capable of reinforcing the weakened teeth, resulting in partial or total recovery of fracture resistance. This, in addition to sufficient esthetics and mechanical performance of composite restorations, has led to their routine use in daily practice. ⁽¹⁾

Large direct restorations present several challenges especially in the posterior dentition. Mastering of shape, contours, occlusal anatomy and function requires particular skills. One must be aware of the

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potential risk factors and characteristic types of failure in the posterior region. Two main causes of posterior restoration failure have been identified: bulk fracture and secondary caries. Early failure was more closely related to fractures, while caries was more likely to be the background of long-term failure. In long-term studies (with more than 10 years of follow up) that failure was more frequently the result of fracture than of caries. This finding suggests that bulk fracture is a considerable risk to posterior restorations, regardless of the lifespan or the age of these restorations. ⁽²⁾

Layering protocols have been explained by a number of studies showing that layering does not necessarily decrease shrinkage stresses but might even make them worse compared to bulk filling. Hence, In the recent years, manufacturers have shifted their attention toward simplification using new materials for bulk filling, with encouraging results (stress reduction & strength) in both flowable and packable form. ⁽³⁾

Throughout its well-documented history in industry, the application of fiber-reinforced composite (FRC) technology is constantly evolving as a result of innovative treatment solutions to increase the fracture resistance. Utilizing different types of fibers with various orientations and lengths is quite an old idea in engineering and in architectural applications to construct devices with high strength and fracture resistance. The use of FRC in dental applications has been discussed in the literature since the early 1960s. Today, fiber reinforcement has become an effective material of choice within restorative dentistry. ^(4,5)

In 2013, short fiber-reinforced composite (SFRC) was introduced to the market with the goal to mimic the stress absorbing properties of dentine. The SFRC material is intended to be used as bulk base in high stress-bearing areas for restoring vital and non vital teeth. ⁽⁶⁾ It presents a higher fracture resistance and flexural modulus within the family of bulk-fill materials but can be used easily in 4-mm

deep increments and can potentially match the fracture resistance of dentin. ^(7,8)

It consists of a combination of a resin matrix, randomly-orientated E-glass fibers, and inorganic particulate fillers. The resin matrix contains semi-interpenetrating polymer network (semi- IPN), which provides enhanced bonding properties for repairs and improves the fracture resistance of the polymer matrix. ⁽⁹⁾

The rationale behind the usage of fiber reinforcement is partly to internally strengthen the structurally compromised tooth and partly to prevent the occurrence of fractures. The efficacy of fiber reinforcement is dependent on several factors; including the resins used, the length of the fibers, the orientation of fibers, the position of the fibers, the adhesion of the fibers to the polymer matrix and the impregnation of the fibers into the resin. ⁽⁴⁾

The reinforcing effect of the fiber fillers is based on stress transfer from the polymer matrix to the fibers. However, the individual fibers also act as crack stoppers. Stress transfer from the polymer matrix to the fibers is essential. This is only possible if the fibers have a length equal or greater than the critical fiber length. The critical fiber lengths to diameter ratio of E- glass micro fibers vary between [140 μm length and 6 μm in diameter]. Also, the position and orientation of the reinforcement within a structure is known to influence its mechanical properties. ⁽¹⁰⁾

The question arises whether this new flowable SFRC material is able to reinforce the dental structure that lead to improve fracture resistance and more favorable fracture patterns when applied according to biomimetic principles. ⁽¹¹⁾ Thus, the sole purpose of the present study was to give clinicians a comparative overview exclusively on the fracture resistance of biomimetic material flowable SFRC and bulk fill flow posterior restorative material.

MATERIALS AND METHODS

Teeth selection:

Following approval of the study protocol by the local ethics committee, 60 intact maxillary premolars extracted for orthodontic reasons were selected. The teeth were selected to be approximately similar in buccolingual (BL) and mesiodistal (MD) dimensions (9.2 ± 0.5 and 7 ± 0.5 mm, respectively). Teeth with defects and fracture lines were excluded. After cleaning, the teeth were stored in 0.5% chloramine solution and then distilled water.

The roots of all the teeth were covered with a thin layer (0.2-0.3 mm) of wax and embedded in a cylinder of self-curing acrylic resin up to 1 mm apical to the cemento-enamel junction (CEJ). After resin setting, the teeth were removed from the resin cylinder, and then the covering wax was melted by immersing them in boiling water. This space was filled with polyether impression material, and the teeth were reinserted into the cylinders. The resulting layer mimicked the periodontal ligament. The long axis of the tooth was perpendicular to the base of the cylinder.

Cavities preparation:

Standardized wide mesio-occluso-distal (MOD) cavities were prepared on 45 randomly selected

premolars, with the gingival margin placed 1 mm coronal to the CEJ, using cylindrical diamond burs. The cavity dimensions were: occlusal width=1/2 of inter-cuspal width; pulpal depth = 2.5 mm; proximal box width=1/2 of buccolingual dimensions; and axial depth=1.5 mm. The facial and palatal walls of the cavities were parallel to the long axis of the teeth. The cavosurface margins were prepared at 90° with rounded internal line angles.

One experienced operator made all preparations. Measurements were made with a caliper with 0.2-mm sensitivity for proper and accurate standardization of cavity dimensions.

Grouping:

The randomly non prepared 15 premolars were labeled as **Group A**, teeth were intact without any cavity to serve as (negative control). After wide MOD cavities were prepared for the 45 premolars, they are randomly divided into 3 groups of 15 each. **Group B**, the teeth with MOD cavities without any restoration (positive control); **Group C**, the teeth will be restored with bulkfill flowable composite Tetric N flow bulk fill (Ivoclar Vivadent); and **group D**, the teeth will be restored with short fibers reinforced bulkfill flowable composite ever X Flow (GC).

Table (1) *The materials used.*

Material	Type	Composition	Manufacturer	LOT number
everX Flow	Short fiber reinforced flowable composite for dentin replacement (Bulk shade)	ever X Flow is based on a combination of organic resin matrix and inorganic glass fibers and filler particles. The resin matrix contains Bis-MEPP 15-25%, TEGDMA 1-10% and UDMA 1-10%. The fillers are a mix of short E-glass fibers and particle fillers, mostly barium glass Average length of fibers 140µm diameter 6 µm. The total filler rate of ever X Flow is 70% in weight. % of fibers (w/w) 25%	GC corporation Tokyo, Japan	1910162
Tetric N-flow	Bulk fill flowable light cured composite	Urethane dimethacrylate, Bis-GMA 27.8% Triethyleneglycol dimethacrylate - 7.3 Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide 63.8% Additives, stabilizers, catalysts, pigments 1.1%	Ivoclar Vivadent AG Schan Liechtenstein	Y39762

Restorative steps:

Every prepared tooth was subjected to the following; washing with air water spray, Tofflemire matrix application then application of N etch 37% phosphoric acid (Ivoclar Vivadent AG Schan Liechtenstein) 30s for enamel and 15s for dentine followed with thorough water washing for 20 s then gentle air dryness for 5s only. application of futurabond M+ universal dental adhesive (VOCO Cuxhaven Germany) for 10 seconds with brush rubbing followed with air thinning for 2s. adhesive was light cured for 10 s with light curing unit (LED cordless 10 W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/cm² light intensity

Group C:

Immediately after curing of dental adhesive, Tetric N flow bulk fill (Ivoclar Vivadent) was applied into the cavity as one layer to fill both proximal boxes and occlusal cavity leaving only 1mm from occlusal cavo-surface angle, then light curing for 10 s with light curing unit (LED cordless 10 W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/cm² light intensity. Superficial 1 mm of universal resin composite essential (GC corporation Tokyo, Japan) was applied and cured for 10s with the same light curing unit.

Group D

everX Flow (GC corporation Tokyo, Japan) was applied into the cavity as one layer to fill both proximal boxes and occlusal cavity leaving only 1mm from occlusal cavo-surface angle, then light curing for 10 s with light curing unit (LED cordless 10 W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/cm² light intensity. superficial 1 mm of universal resin composite essential (GC corporation Tokyo, Japan) was applied and cured for 10s with the same light curing unit.

All materials are applied according to the respective manufacturers' instructions. After finishing the restorations with Sof-Lex discs (3M ESPE), they were stored in distilled water for 24 hours at 37°C.

Fracture resistance assessment:

After one day of water storage, the specimens of four groups were subjected to fracture strength measuring; a continuous compressive axial loading at a 1-mm/min crosshead speed using a universal testing machine (Zwick Roell, Ulm, Germany). The force was applied by a smooth cylindrical head measuring 5 mm in diameter, parallel to the long axis of the teeth in contact with the occlusal slopes of the buccal and lingual cusps. Peak load to fracture for each tooth was recorded in Newtons as a fracture strength value. Data were analyzed with one-way ANOVA at a significance level of $\alpha = 0.05$, using SPSS 11.5 (SPSS Inc., Chicago, IL).

Failure pattern assessment:

The fractured teeth were then evaluated by two independent operators to determine the mode of fractures, as:

Type I fracture; fracture of enamel only.

Type II fracture; fracture of enamel and dentin with no root involvement.

Type III fracture; fracture of enamel and dentin with root involvement.

Both type I and II considered as restorable fracture because they ending above the CEJ. Type III considered as non-restorable fracture because they ending more than 1 mm below the CEJ).

RESULTS

I- Results of fracture resistance assessment:

The highest mean fracture load value was recorded in group A 1216.6 ± 352.2 followed with 1019.7 ± 164.8 for group D then 1013.3 ± 389.6 for group C while the lowest mean fracture load value 330.6 ± 201.5 was recorded in group B. One-way ANOVA test revealed that the difference between groups was statistically significant ($p=0.00$). Tukey' s post hoc test revealed significant difference between group B with all other groups at the 0.05 level.

Fig. (1) *Steps of samples preparations; a*-premolars dimensions determination, *b*-wide MOD cavity prepared, *c*-Tofflemire matrix and adhesive applications, *d*-sample with Tetric N flow composite (group C), *e*-sample with everX flow composite (group D), *f*-superfacial layer of universal composite application, *g*-universal testing machine, *h*-cylindrical head on buccal and palatal slopes of premolar to measure fracture resistance, *i*-different materials used.

Fig. (2) Fracture resistance results.

II- Results of Failure pattern assessment:

The negative control (group A) predominantly fractured with restorable patterns 80% with the highest type I fracture. While the positive control (group B) predominantly fractured in non-restorable patterns 80% with the highest type III fracture. Fracture pattern for group C was 80% restorable fracture and for group D was 66.67 % restorable fracture.

Table (2) Failure patterns and percentages of restorable and non-restorable failure in each group.

Groups	Failure pattern			Percentage of restorable fracture	Percentage of non-restorable fracture
	Enamel fracture	Enamel and dentine fracture	Enamel and dentine fracture with root fracture		
Group A	7	5	3	80%	20%
Group B	0	3	12	20%	80%
Group C	5	7	3	80%	20%
Group D	2	8	5	66.67	33.33

Fig. (3) The results of fracture mode.

Fig. (4) The different modes of fractures (two examples of every type).

DISCUSSION

The aims of this study were to evaluate the fracture resistance of premolar teeth by using a standardized MOD preparation restored with SFRC and to compare it with bulk fill flow composite materials. The most critical factor associated with crown fractures is the weakening of tooth structures by caries and large unsupported intra coronal restorations. In this study we tested teeth with large MOD cavities that are more prone to fracture due to construction in the cervical zone and cuspal inclination with high tensions on cusps. This is supported by studies demonstrating that any cavity preparation significantly reduces dental fracture resistance. ^(12,13)

Another factor that responsible for weakening the tooth is the polymerization shrinkage of a resin composite that can create contraction forces which may disrupt the bond to cavity walls or cause deformation on the surrounded tooth structure lead to tooth fracture. ⁽¹⁴⁾

In the present study we selected the bulk fill flow composite. Because the correlation between the polymerization shrinkage and weakening for the restoration, explained with some studies showed that bulk fill flow composites could reduce polymerization shrinkage in posterior teeth. Due to their low elastic modulus which act as a flexible layer and might relieve stresses of the cavity during polymerization. This probably explains why the bulk fill flow composite helped in increase the fracture resistance of teeth with MOD cavity preparations. ⁽¹⁵⁾

In this study, we used an alternative bi-layered technique or biomimetic composite structure which is a restoration that includes both fibers reinforced composite (FRC) and particulate filler composite (PFC). Due to several studies have shown that the FRC substructure supported the composite restoration and served as a crack-prevention layer. SFRC was introduced as a dentine-replacing material (bulk base) to support the remaining tooth structure and improve the durability of the final biomimetic composite restoration. ⁽¹⁶⁾

SFRC materials exhibits unique fiber and polymer variety in their composition, and consequently, a variety of enhanced mechanical and physical properties. The biomimetic restorative technique, using SFRC as a substructure with conventional composite overlying it, is a recommended direct restoration alternative, and can be used reliably for the coronal restorations of teeth with large cavities in high stress- bearing areas. It also distributes the stress caused by polymerization shrinkage and load testing more evenly due to the gradient concentration of its nanofillers. ⁽¹⁷⁾

According to our results, flowable SFRC has a non significantly higher fracture resistance compared to bulk fill flow composite resin. This might be attributed to lower polymerization shrinkage strain due to fiber content. These fibers could provide an isotropic reinforcing effect because each fiber behaves as a crack stopper and stress transfer from the polymer matrix to stronger fibers. Furthermore, SFRC can absorb stresses and dissipate energy similar to dentin, improving mechanical performance by preventing brittle failure and preserving structural integrity. ⁽⁵⁾

Confirming the previously mentioned laboratory data, many authors have demonstrated in their clinical reports that using SFRC as a bulk base or core under direct composite restorations for posterior teeth can be considered an economical and practical measure that could obviate the use of extensive prosthetic treatment. ^(18,19) In contrast to the previously mentioned studies, some investigators reported that the incorporation of SFRC inside the

cavity of posterior destroyed teeth restored with thick PFC resin overlays is not useful to increase their fracture resistance. They explained that the discrepancy between their studies and previous studies resulted from a difference in the thickness of overlay PFC composites, loading set-up and the adhesive system used. ⁽²⁰⁻²²⁾

Some authors determined the fracture resistance of SFRC in comparison to different commercial composite resins, and stated that SFRC differed significantly in its physical properties and has superior fracture resistance compared to other tested bulk- fill or conventional composite materials ⁽²³⁾, with the difference that in our study we used both tested materials in a flowable bulk fill form .

The failure patterns observed in the current study showed 66.7% restorable fracture in SFRC group that is significantly higher than cavitated non filled group as SFRC is able to sustain compressive static load. This results were in accordance with authors that evaluated the mechanical properties of SFRC in comparison to other composite resin materials and declared that the toughening capability of SFRC over their competition is attributed to two main factors: the millimeter-scale short fiber and semi-inter penetrating network (IPN) structure. Therefore, they recommended SFRC in high stress-bearing areas for its enhanced toughness. ^(24,25)

Restorable fracture was 80% for teeth restored with bulk fill flowable composite that is comparable to negative control group (sound non cavitated teeth), this is attributed to the evolution that made the bulk fill flow composites more flexural strength, more flow and less shrinkage with less cuspal strains as stated by authors about bulk fill flow composite ^(26,27)

The increase in non restorable fracture in teeth restored with SFRC (everX flow) compared to teeth filled with bulk fill flow (Tetric N flow) restorations could be due to the thicker consistency of SFRC due to the added short fibers, impairing bonding resistance and favoring breakdown of the adhesive interface. ⁽¹²⁾

CONCLUSION

Within the limitations of this study, it was possible to conclude that both bulk fill flowable composite and short fiber reinforced flowable composite can increase the fracture resistance of extensively prepared mesio-occluso-distal cavities of maxillary premolars to the limit near the sound non prepared premolars, with no significant difference between the two tested materials.

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كفاءة مركب الحشو الكتلي القابل للتدفق والمقوى بالألياف القصيرة في مقاومة الكسر للأسنان الضواك ذات التجاويف الواسعة

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الملخص :

الهدف: سعت هذه الدراسة إلى تقييم تأثير الحشو الكتلي القابل للتدفق والمقوى بالألياف القصيرة على مقاومة الكسر للأسنان الضواك ذات التجاويف الواسعة.

المواد والاساليب: في هذه الدراسة العملية تم اختيار 60 سنة من الأسنان الضواك العلوية وتخزينها في محلول الكلورامين. ثم تم تركيب الأسنان في كتل الاكرليك. تم تقسيم الأسنان بشكل عشوائي إلى 4 مجموعات 15 سنة لكل منها : المجموعة الأولى (أ) كانت الأسنان سليمة دون أي جوف (مجموعة حاكمة سلبية)؛ تم إعداد جواف واسعة باستخدام مثقاب أسطواني مع اليد عالية السرعة في باقي المجموعات. المجموعة الثانية (ب) تم عمل التجاويف الواسعة دون أي حشوات (مجموعة حاكمة إيجابية)؛ المجموعة الثالثة (ج) تم حشو الأسنان بمركب راتنجي قابل للتدفق؛ أما المجموعة الرابعة (د) فقد تم حشو الأسنان بمركب قابل للتدفق معزز بألياف قصيرة تم تخزين الأسنان بعد ذلك في الماء وعند درجة حرارة 37 درجة مئوية لمدة 24 ساعة ثم تم تعيين قوة مقاومة الكسر باستخدام جهاز الإنسترون وتسجيل القوة القصوى للكسر بالنيوتن لكل الأسنان وتم ملاحظة نوع الكسر بالجهر. بعد ذلك تم تحليل النتائج إحصائياً

النتائج : نسبة حدوث الحق الجاف كانت 20% في المجموعة (ب) بينما كانت 0% في المجموعة (أ). شدة الألم الناتج عن الجراحة أقل في المجموعة (أ) عن المجموعة (ب) في يوم الجراحة و اليوم الثاني والرابع ما بعد الجراحة وثبت وجود فرق ذو دلالة إحصائية. أما اليوم السابع والرابع عشر فلا يوجد فرق ذو دلالة إحصائية بين المجموعتين. حمض الترانكساميك ليس له أي تأثير على مقدار فتح الفم ومقدار التورم بعد جراحة ضرس العقل السفلي.

الخلاصة: إن مقاومة الأسنان الضواك العلوية ذات التجاويف الواسعة للكسر قد تأثرت إيجابياً بشكل واضح عند حشوها بالحشو الكتلي القابل للتدفق والمقوى بالألياف القصيرة ولكن هذا التأثير الإيجابي كان مماثلاً للأسنان المحشوة بالحشو الكتلي القابل للتدفق والغير مقوى بالألياف القصيرة

الكلمات المفتاحية: الحشو الكتلي القابل للتدفق، الألياف القصيرة، مقاومة الكسر، الضواك ذات التجاويف الواسعة، قوى الضغط.