RESEARCH PAPER

Effect of different packing protocols on Fracture Resistance of Maxillary Premolars Restored with bioactive composite

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Abstract

Objectives: The aim of the present study was to verify effect of different packing protocols on fracture resistance of maxillary premolar teeth with standardized mesioocclusodistal (MOD) preparations restored with bioactive composite.

Materials and Methods: Seventy sound maxillary premolar teeth with standardized MOD cavities were randomly allocated to seven groups (n=10): G1 (control): sound teeth; G2: unrestored MOD preparation; G3: was filled by an incremental technique with nanohybrid resin composite (Beautifil II LS, Shofu); G4: was filled in bulk with flowable composite (Beautifil Bulk Flowable, Shofu); G5: bulk filled with nanohybrid composite (Beautifil Bulk, Shofu); G6: was restored by increment technique with Beautifil Bulk Flowable / Beautifil Bulk and G7: was filled in increment with Beautiful Flowable/ Beautifil II LS. After being stored 24 hours at 37^{o}C, specimens were subjected to a 4mm diameter steel sphere in a universal testing machine at a cross-head speed of 5mm/min until fracture occurred. D'Agostino-Pearson test, Kruskal–Wallis test and Mann–Whitney U tests at a 5% significance level were used to determine the statistical differences among groups.

Results: A significant difference was resulted between tested groups on mean fracture resistance. Groups G1, G6 and G7 showed the highest mean fracture resistance followed by group G3 and G5 with an insignificant difference between each other. The lowest mean fracture resistance resulted for G2 and G4.

Conclusions: Bulk fill flowable composite lining under nanohybrid resin composite improved fracture resistance. Moreover, bulk fill flowable resin composite should be covered by nanohybrid resin composite.

Keywords: Fracture Resistance; Bulk fill; Resin Composite; Flowable Composite Lining, Layering Protocols.

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1. Introduction

Composite restorations have been widely used over the past decade with the increase in patients' demand for esthetics and more emphasis on preservation of tooth structure. It has become an essential part of every-day dental practice. Occlusal wear, secondary caries and fracture are the predominant causes of failure in composite fillings [1]. Fracture resistance is one of the most important characteristics of dental materials. It depends on material resistance to crack propagation from its internal defects. These cracks can result in microscopic fractures of the restoration margins or bulk fracture of the filling [2].

Recent researches have focused on several concerns related to weakening of the teeth after MOD preparations and the effect of restorative material and technique in strengthening the remnant tooth structure [3, 4]. It has been claimed that cavity preparation brings about a significant reduction in tooth strength, especially with MOD cavities, due to the loss of marginal ridges and fatigue of the brittle tooth structure as result of propagation of microcracks under repeated occlusal forces [5, 6]. Moreover, fracture of the cusps in teeth with wide cavities occurs as result of the occlusally applied loads that tend to force cusps apart [7, 8]. Therefore, reinforcement of such teeth is of utmost importance in providing fracture resistance.

The clinical performance of the newer dental composites has been continued to improve over the past decade to provide adequate strength, enabling expanded use in posterior restorations with good longevity. However, the relatively high brittleness and low fracture toughness of current resin composites still remain a major drawback in stress-bearing posterior restorations.

In addition, clinical strategies have been suggested to improve fracture resistance of composite such as incremental filling technique to decrease the configuration factor (C factor=bonded surface area/non bonded surface area) [9-13]. Moreover, the use of an intermediary resin with low viscosity and modulus of elasticity which serves as an elastic buffer is a proposed procedure to resolve the above mentioned problem [14-16]. One of the materials which can be used is flowable composite. The development of flowable composites provides expanded solutions for restorative dentistry.

The first generations were used as liners only due to their low modulus of elasticity. However the second generations are developed for bulk-fill flowable bases being marketed for use as liner in class I and II beneath conventional resin based restorative materials with reported depth of cure in excess of 4mm [17-22]. Research studies which have evaluated their properties are still limited especially when the material is to be applied in stress bearing areas. The aim of this study was to investigate the effect of layering techniques and the use of bulk fill flowable composite on fracture resistance of composites. The research hypothesis was that no difference in the fracture resistance of restored teeth would be observed when layering protocols were compared.

2. Materials & methods:

2.1 Teeth collection and mounting:

In this in vitro study, seventy recently extracted sound maxillary premolar teeth free from caries, hypoplastic defects, fracture or cracks were collected. The maximum bucco-palatal width of each premolar was measured with digital micrometer gauge (ESSENTRA, Ontario, Canada) with a tolerance of 10µm and the teeth were distributed into seven groups (n=10) such that variance of the mean bucco-palatal width between groups was less than 5% [23-26]. Teeth were stored in saline solution containing 0.1 % thymol at 4^{o}C until cavity preparation. To simulate periodontium, root surfaces were dipped into melted wax to a depth of 2mm below the cement enamel junction (C.E.J) to produce a 0.2 – 0.3 layer. Then the teeth were fixed crown uppermost and long axis vertical using a chemically activated acrylic resin (Acrostone, Egypt) into a cubic cupper mould. The acrylic resin extended to within 2mm of the C.E.J. Specimens were then divided at random into seven groups that are summarized as follows: Group 1: sound unprepared teeth; in Groups 2 through 7 standardized Class II MOD cavities were prepared. Group 2 specimens were left unrestored to be tested without restorations.

2.2 Cavity preparation:

Standard MOD cavities were prepared using straight fissure carbide bur no. 57 size 010 (Brassler, Savannah, Georgia, USA) rotating at high speed with air/water cooled hand-piece in specimens of group 2 through 7. The cavity dimensions were 4 ± 0.2 mm for the pulpal depth from the tip of the palatal cusp and 4 ± 0.2mm for the buccopalatal width. The proximal walls were parallel and the occlusal isthmus width was one-third of the intercuspal distance. A single periodontal probe was used as a guide for all the cavities and no bevel was performed in the margins of the cavities.

2.3 Adhesive application:

Following cavity preparation, the prepared surfaces were prepared for bonding with an selective enamel etching protocol using universal adhesive (BeautiBond Extreme, Shofu, Japan) according to manufacturer instructions. Firstly, the MOD cavity was gently air dried for 10 seconds prior to the application of 37% phosphoric acid etching gel (Scotch bond etchant, 3MESPE, St Paul, MN, USA) for 15 seconds on enamel margin then rinsed for 15 seconds with water. Following 5 seconds light air drying, one coat of the adhesive was actively applied with a microbrush for 20 seconds and then light cured for 20 seconds using a LED light curing unit (Elipar S10, 3MESPE, St Paul , MN ,USA) operating in standard mode at light intensity 1200 mW/cm².

G3: was filled by an incremental technique with nanohybrid resin composite (Beautifil II LS, Shofu); G4: was filled in bulk with flowable composite (Beautifil Bulk Flowable, Shofu); G5: bulk filled with nanohybrid composite (Beautifil Bulk, Shofu); G6: was restored by increment technique with Beautifil Bulk Flowable / Beautifil Bulk and G7: was filled in increment with Beautiful Flowable/ Beautifil II LS.

2.4 Resin composite layering protocols:

The bioactive resin composites used for filling the MOD cavities were nanohybrid composite (Beautifil II LS, Shofu), a bulk fill composite (Beautifil Bulk, Shofu), Flowable bulk fill resin composite (Beautifil Bulk Flowable, Shofu) and Flowable resin composite (Beautifil Flowable, Shofu). For simulation of the clinical conditions, “Tofflemier” metal matrix bands and the matrix holder were used. According to the packing protocol, the cavities to be restored (Group 3 through group 7) were randomly assigned and filled with resin composites by one of the following protocols:

Group 3 (incremental filling): nano-hybrid restorative material (Beautifil II LS) was placed in two horizontal incremental layers with increment thickness 2mm and it was light cured at a right angle from the occlusal surface. Each increment was light cured for 20 seconds.

Group 4 (bulk filling): Flowable bulk fill resin composite (Beautifil Bulk Flowable) was injected to fill the whole cavity (4 mm depth) and then light cured from the occlusal surface for 40 seconds.

Group 5 (bulk filling): Regular bulk fill resin composite (Beautifil Bulk) was packed in one increment (4mm thick) and then light cured for 40 seconds from the occlusal surface.

Group 6 (incremental filling with flowable liner): The first layer was flowable bulk fill resin composite (Beautifil Bulk Flowable) in 2mm thickness and light cured for 20 seconds followed by one incremental layer of regular bulk fill resin composite (Beautifil Bulk) in 2 mm thickness and light cured for 20 seconds.

Group 7 (incremental filling with flowable liner): The first layer was flowable bulk fill resin composite (Beautifil Flowable)) in 2mm thickness and light cured for 20 seconds. The remaining 2 mm was filled with nano-hybrid restorative material (Beautifil II LS) and light cured for 20 seconds.

In all groups, buccal and lingual post-curing was done for 40 seconds after removing the matrix band. Ten minutes after the restorative procedure, restorations were finished with finishing bur and polished with rubber points in a low- speed handpiece (NSK, Japan).

The specimens were stored in 37°C distilled water for 24 hours.

2.5 Measurement of fracture resistance:

Fracture resistance test was conducted using universal testing machine (Model LRX-plus; Lloyd

Instruments Ltd., Fareham, UK). A 4 mm diameter steel sphere was applied on the inclined planes of the buccal and lingual cusps of the tested teeth at a cross-head speed of 5 mm/min until the fracture occurred. The force was recorded in Newton as the fracture resistance.

2.6 Statistical analysis

Data were presented as mean, standard deviation (SD), minimum and maximum values. Data were explored for normality using D'Agostino-Pearson test for Normal distribution. Fracture resistance showed an abnormal distribution so Kruskal–Wallis test used followed by paired group comparisons using Mann–Whitney U tests at a 5% significance level were used to analyses the effect of packing protocol on fracture resistance. Statistical analysis was performed with IBM® SPSS® Version 22 for Windows (SPSS Inc., IBM Corporation, NY, USA).

3. Results

The mean loads (N) necessary to induce fracture in the groups are displayed in Table 2 and presented in Figures 1. According to this table, a significant difference was resulted between tested groups on mean fracture resistance at p≤0.001. Groups G1 (992.84±117.17 N), G6 (1025.55±93.14 N) and G7 (1010±109.72 N) showed the highest mean fracture resistance with an insignificant difference between each other. Followed by group G3 (827.07±60.91 N) and G5 (855.99±59.32 N) with an insignificant difference between each other. The lowest mean fracture resistance resulted for G2 (459.52±90.66 N) and G4 (479.24±67.33 N) with an insignificant difference between each other.

Table 1: Mean, standard deviation (SD), minimum and maximum of fracture resistance and results of Kruskal–Wallis test for the effect of packing protocol.

		Group							p-value
		G1	G2	G3	G4	G5	G6	G7	
Fracture resistance (N)	Mean	990.84[a]	447.52[c]	833.07[b]	466.24[c]	874.99[b]	1031.55[a]	1019.00[a]	≤0.001*
	SD	117.17	90.66	60.91	67.33	59.32	93.14	109.72	
	Minimum	886.90	292.40	738.20	378.80	731.40	921.60	893.70	
	Maximum	1217.30	589.20	913.90	589.70	930.50	1209.60	1219.70	

SD: standard deviation. Means with the same letter within each row are not significantly different at p=0.05.
**=Significant*

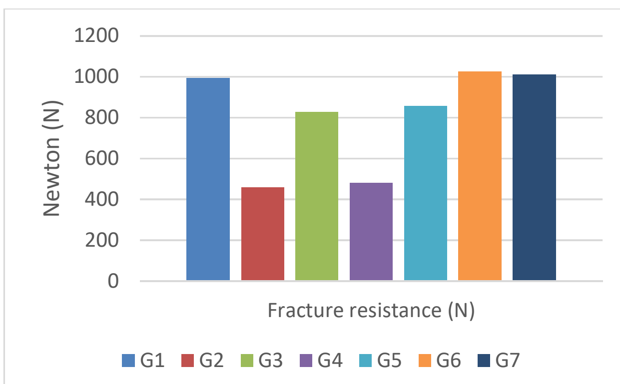

Figure 1: Histogram showing the mean Fracture resistance of different tested groups.

4. Discussion

Direct resin-based restorative materials play an essential role in contemporary dentistry. However, several adverse effects associated with resin-based composite materials have been attributed to polymerization shrinkage [18]. Furthermore, technique sensitivity remains a major concern for clinicians and may influence the predictability and long-term success of restorative procedures. Although bulk-fill resin-based composites have been introduced to simplify the restorative procedure by allowing placement in thicker increments, relatively few clinical and laboratory studies have evaluated their performance. Such investigations are particularly important when these materials are intended for use in stress-bearing areas. Therefore, the present study evaluated the fracture resistance of bulk-fill resin composites that, according to their manufacturers, can be placed in bulk increments. In addition, different layering protocols were compared to determine their influence on the fracture resistance of restored teeth.

In the present study, MOD cavities were prepared in premolar teeth because this cavity configuration substantially compromises the remaining tooth structure and consequently increases the susceptibility of the cusps to fracture. To minimize anatomical variations and ensure reliable comparisons within and among the experimental groups, the buccopalatal width of the selected teeth was standardized, with a maximum difference of 5% among specimens. It was anticipated that, regardless of the restorative layering protocol employed, restored teeth would demonstrate higher fracture resistance than prepared but unrestored teeth. This may be attributed to the ability of resin composite to partially restore the mechanical integrity of the weakened tooth structure through its elastic modulus and to influence the pattern and propagation of fracture [27]. This assumption is consistent with the findings of the present study, in which the unrestored group demonstrated the lowest fracture resistance values.

The present findings demonstrated that the restorative layering protocol plays an important role in enhancing the fracture resistance of resin composite restorations. In particular, specimens restored using a bulk-fill flowable composite as a base demonstrated fracture resistance values closest to those of the unprepared teeth. Furthermore, their fracture resistance was significantly higher than that of specimens restored without a flowable liner, which is in agreement with the findings of previous studies [28]. The improved performance may be explained by the stress-absorbing or "cushion" effect of the flowable composite. Its relatively low elastic modulus and greater capacity for deformation may help accommodate polymerization contraction and reduce the transmission of shrinkage stresses from the overlying restorative composite to the surrounding tooth structure [29–31].

In the present study, no statistically significant difference was observed between the fracture resistance of teeth restored with bulk-fill x-tra fil and those restored using the incremental technique with Grandio. This finding may be related, at least in part, to the relatively high volumetric filler content of both materials, reported to be approximately 71.4% for Grandio and 70.1% for x-tra fil. The mechanical properties of resin composites, including compressive strength and fracture resistance, are strongly influenced by filler loading, with previous studies reporting improved mechanical performance at relatively high filler concentrations [20,32,33]. Moreover, previous investigations have demonstrated that several characteristics of filler particles—including their shape, size, concentration by volume or weight, and distribution within the resin matrix—can significantly affect the mechanical strength, elastic modulus, and surface hardness of resin composites [34,35]. These factors may therefore contribute to the comparable fracture resistance observed between the two restorative approaches.

Interestingly, when the bulk-fill flowable composite was used to restore the MOD cavities to a depth of 4 mm in a single increment, a significant reduction in mean fracture resistance was observed. This finding is consistent with the influential work of Versluis et al. [36], which challenged the conventional assumption that incremental placement is merely a procedural preference and demonstrated the important relationship between restorative placement technique and polymerization stress development. Incremental placement can reduce the effective volume of composite polymerized at one time and may consequently reduce the accumulation and transmission of polymerization shrinkage stresses. Conversely, placement of a large bulk increment may impose greater constraints on the remaining cuspal structure during polymerization and light irradiation, potentially increasing cuspal deformation and associated stresses [19,37,38].

Nevertheless, within the context of the term "bulk-fill," it is important to distinguish between bulk-fill flowable composites and highly filled, sculptable bulk-fill materials. Bulk-fill flowable composites are generally intended to function primarily as base or liner materials and should typically be covered by an approximately 2-mm surface layer of a conventional methacrylate-based or appropriate restorative resin composite. Accordingly, the use of a flowable bulk-fill composite as the sole restorative material throughout a deep MOD cavity may not provide the same mechanical performance as a layered approach incorporating a more highly filled occlusal restorative composite.

The present study has certain limitations that should be considered when interpreting its findings. The investigation was conducted exclusively on premolar teeth, and fracture resistance was assessed shortly after restoration. Therefore, the experimental conditions did not reproduce the complex and dynamic environment of the oral cavity. Clinically, restored teeth are continuously exposed to thermal, chemical, and physical challenges, as well as fatigue stresses and aging processes, all of which may influence the mechanical behavior and fracture resistance of restorative materials and the tooth-restoration complex. Furthermore, occlusal stresses in the oral environment are cyclic and vary in magnitude, direction, and loading rate. Consequently, additional investigations incorporating thermocycling, long-term aging, cyclic fatigue, and dynamic loading are required to provide a more comprehensive assessment of the long-term clinical performance of different bulk-fill materials and layering protocols. In vivo studies are also warranted to determine whether the differences observed under laboratory conditions translate into clinically relevant differences in restorative longevity and fracture behavior.

5. Conclusions

Within the limitations of the present study, the following conclusions can be drawn:

- The use of a bulk-fill flowable resin composite as a base significantly enhances the fracture resistance of restored maxillary premolars with MOD cavities.
- Bulk-fill flowable resin composite cannot be used alone as final restorations and should be covered with a nanohybrid resin composite to achieve optimal restorative performance.
- Nanohybrid composite with flowable liner is still the simplest protocol for the MOD cavity restoration.

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