FRACTURE RESISTANCE OF MAXILLARY PREMOLARS RESTORED WITH VARIOUS RESIN BASED RESTORATIVE SYSTEMS AND LAYERING PROTOCOLS

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ABSTRACT

Objectives: The aim of the present study was to verify the fracture resistance of premolar teeth with standardized mesioocclusodistal (MOD) preparations restored with different resin composites and layering protocols.

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 increment technique with nanohybrid resin composite (Grandio, Voco); G4: was filled in bulk with flowable composite (x-tra base, Voco); G5: bulk filled with multi hybrid composite (x-tra fil, Voco); G6: was restored by increment technique with x-tra base / x-tra fil and G7: was filled in increment with x-tra base/Grandio. After being stored 24 hours at 37°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 resin composite layering improve fracture resistance. Moreover, bulk fill flowable resin composite should be covered by methacrylate based resin composite.

Keywords: Fracture Resistance; Bulk fill; Resin Composite; Flowable Composite Lining, Layering Protocols.
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 different protocols were compared.

MATERIALS & METHODS

In this in vitro study, seventy recently extracted sound human 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°C until cavity preparations were done. 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. The composition and characteristics of the restorative materials used (VOCO, Germany) are listed and described in Table 1.

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 3 ± 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.

Adhesive application

Following cavity preparation the prepared surfaces were prepared for bonding with an etch and rinse adhesive system (Solobond M, VOCO, Germany) according to manufacturer instructions. Firstly, the MOD cavity was air dried for 30 seconds prior to the application of 37% phosphoric acid etching gel (Scotch bond etchant, 3MESPE, St Paul, MN, USA) for 30 seconds then rinsed for 10 seconds with water. Following 3 seconds light air drying, two consecutive coats of the adhesive was applied with a sponge applicator, left for 10 seconds to flow 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.

Resin composite layering protocols

The resin composites used for filling the MOD cavities were nanohybrid composite (Grandio, VOCO, Germany), a multi hybrid bulk fill composite (x-tra fil, VOCO, Germany) and Flowable bulk fill resin composite (x-tra base, VOCO, Germany) (Table 1). For simulation of the clinical conditions, “Tofflemier” metal matrix bands and the matrix holder were used. According to the layering 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): Universal nano-hybrid restorative material (Grandio) 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 (x-tra base) 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 (x-tra fil) 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 (x-tra base) in 2mm thickness and light cured for 20 seconds followed by one incremental layer of regular bulk fill resin composite (x-tra fil) 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 (x-tra base) in 2mm thickness and light cured for 20 seconds. The remaining 2 mm was filled with Universal nano-hybrid restorative material (Grandio) 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.

**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.

**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).

**TABLE (1) Brand names, product description and chemical composition of the used materials**

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Material Category</th>
<th>Composition</th>
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<tbody>
<tr>
<td>Grandio</td>
<td>Nano hybrid</td>
<td>Resin matrix: based on dimethacrylates, contains Bis-GMA and TEGDMA. Inorganic filler particles: Nano-sized silica filler particles (87 % w/w-71.4vol%). BHT (butyle-hydroxy toluene; inhibitor), Camphorquinone (photoinitiator) and colour pigments (iron oxide)</td>
</tr>
<tr>
<td>x-tra fil</td>
<td>Multi hybrid</td>
<td>Resin matrix: Bis-GMA, UDMA and TEGDMA. Inorganic filler particles (86%w/w-70.1vol%): Bariumalumosilicate glass, fumed silica and ytterbium fluorid. Photoinitiator is camphorquinone.</td>
</tr>
<tr>
<td>x-tra base</td>
<td>Flowable bulk fill</td>
<td>The resin matrix is composed of different methacrylates: Bis-EMA and aliphatic methacrylates Inorganic filler particles(75%w/w): Bariumalumosilicate glass, fumed silica and ytterbium fluoride. Photoinitiator is camphorquinone. Amines and BHT as inhibitor.</td>
</tr>
<tr>
<td>Solobond M</td>
<td>Two step, etch and rinse adhesive system</td>
<td>It is based on acetone (solvent). It contains HEMA, Bis-GMA, phosphoricacidester (adhesive monomer), BHT (inhibitor) and camphorquinone (photo initiator)</td>
</tr>
</tbody>
</table>

**Abbreviations:** BisGMA = Bis-phenol-A-glycidyl methacrylate, UDMA = Urethane dimethacrylate, Bis-EMA = ethoxylated bisphenol A glycol dimethacrylate, TEGDMA = triethylglycol dimethacrylate, HEMA=2-hydroxyethyl methacrylate, BHT=Butylated hydroxytoluene
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 \( p \leq 0.001 \). Groups G1 (992.84\( \pm \)117.17 N), G6 (1025.55\( \pm \)93.14 N) and G7 (1010\( \pm \)109.72 N) showed the highest mean fracture resistance with an insignificant difference between each other. Followed by group G3 (827.07\( \pm \)60.91 N) and G5 (855.99\( \pm \)59.32 N) with an insignificant difference between each other. The lowest mean fracture resistance resulted for G2 (459.52\( \pm \)90.66 N) and G4 (479.24\( \pm \)67.33 N) with an insignificant difference between each other.

DISCUSSION

Direct resin based restorative materials play an essential role in dentistry. Several negative effects in resin based composite materials are related to polymerization shrinkage [18]. In addition, the technique sensitivity remains a main concern for dentists for achieving successful results. Although a new category of bulk fill resin based composites have been introduced, there are few clinical and laboratory studies investigating the success of these materials. In fact, these studies are of paramount importance when the material is to be used in stress bearing areas. So this study investigated the fracture resistance of bulk fill composites that, according to their manufacturers, are capable of being placed in bulk. In addition, different layering protocols were compared.

In the current study, MOD cavity design was prepared in premolar teeth as it would weaken the remaining tooth structure and favor cuspal fracture. The bucco-palatal width was standardized in all teeth to be within differences of a maximum 5% between the teeth to ensure comparisons in each group and between groups. It would be expected
that, irrespective of layering protocol used, all of the restored teeth should present higher fracture resistance values when compared to the prepared unrestored teeth because the modulus of elasticity of resin composite would restore the fracture resistance as well as guide the fracture mode \([27]\). These findings are consistence with the present study that observed lowest fracture resistance values in unrestored group.

The present results confirmed that various layering protocols of resin composite had essential role for improving the fracture resistance. In this study the fracture resistance of the groups restored with bulk fill flowable composite as a base showed nearest value to the unprepared teeth and was significantly higher than that without a flowable liner, which corroborates the findings of previous studies [28]. It has a cushion effect and reduces polymerization shrinkage stresses from the overlying composite restorative due to its low modulus of elasticity and great ability to deform \([29-31]\).

In the study, no statistically significant difference was observed between the fracture resistance of bulk fill with x-tra fil and incremental filling with Grandio. This could be attributed to the higher percent of volumetric filler content in Grandio (71.4%) and in x-tra fil (70.1%) as the compressive strength was dependent on the percent of filler content, and a high fracture resistance was obtained at the 50% filler content \([20,32,33]\). Previous studies noted that variables such as shape, size, content per volume/weight and distribution of filler particles influence the mechanical strength, elastic modulus and hardness of resin composites \([34,35]\).

Interestingly, when the bulk fill flowable composite was used to restore the MOD cavities to within 4mm in a single increment the mean fracture resistances recorded were significantly decreased. This finding is in agreement with groundbreaking paper of Versluis et al. [36], which reported the widely accepted concept that an incremental filling technique reduced polymerization stress generation. Additionally, the placement of large increment constrains both cusps simultaneously during light irradiation that further limits the overall means cuspal deflection \([19,37,38]\). However within the restrictive term bulk fill, the bulk fill flowable resin composite are essentially base layers that should be essentially covered by surface layer of 2mm of methacrylate-based resin based composite.

This study was conducted in premolar teeth only, and fracture resistance was evaluated shortly after the restoration. However, there are some variables in the oral cavity which may affect the induced fracture such as thermal, chemical, physical factors, fatigue stresses and aging. In addition, stresses in the oral cavity are cyclic with variations in speed, magnitude and directions. So further investigations are necessary to evaluate in vivo behavior of these materials and layering techniques with dynamic loading.

**CONCLUSIONS**

Within the limits of this study, the following conclusions can be derived:

- Bulk fill flowable resin composite as bases significantly improve fracture resistance.
- Bulk fill flowable resin composite should be covered by methacrylate based resin composite.

**ACKNOWLEDGEMENT**

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