Fracture resistance of posterior teeth restored with high-viscosity bulk-fill resin composites in comparison to the incremental placement technique

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Abstract

Aim: Comparative evaluation of the fracture resistance of maxillary premolar teeth restored with two high-viscosity bulk-fill composites and incrementally placed composite.

Materials and Methods: Seventy-five freshly extracted maxillary premolar teeth were selected. Fifteen specimens served as positive control (Group 1). Mesio-occluso-distal cavity preparation was prepared on the rest of the specimens. These specimens were further divided into four groups: unrestored teeth (Group 2), teeth restored with incrementally placed nanocomposite (Group 3), teeth restored with high-viscosity bulk-fill giomer (Group 4), and teeth restored with high-viscosity bulk-fill nanocomposite (Group 5). The specimens were then subjected to compressive axial load using Instron universal testing machine. Data were analyzed using Statistical package for social sciences software (SPSS v 20.0, IBM Corp.).

Results: The positive control group exhibited highest fracture resistance (1104.70 ± 122.2 N). There was no statistically significant difference seen in between the incrementally placed nanocomposite and high-viscosity nanocomposite (P > 0.05). The fracture resistance values displayed by the high-viscosity bulk-fill giomer were found to be statistically lower than the other two groups.

Conclusion: High-viscosity bulk-fill nanocomposite may substitute incrementally placed nanocomposite with respect to fracture resistance.

Keywords: Bulk fill; fracture resistance; giomer; nanocomposite

INTRODUCTION

Resin-based composites are today one of the most widely used restorative materials. However, its most debilitating problem is volumetric shrinkage due to polymerization which may result in contraction stress and subsequent microleakage and adhesion failure.[1] The impetus of tooth fracture arises from the weakening effect of dental caries and its treatment, alongside occlusal wear and secondary caries.[2] Transfer of stresses occurs differently in restored tooth versus an intact tooth.[3] The fracture resistance of restored teeth is related to several factors, such as cavity design, magnitude and type of stress, composite composition (filler content and matrix composition), and the filling technique.[4,5]

Vale experiment has proved that fracture resistance of a tooth reduces considerably when marginal ridges are involved and intercuspal distance is increased.[6] Mesio-occluso-distal (MOD) cavity preparation brings about a significant reduction in tooth strength due to the loss of both the marginal ridges and microfractures caused by applied occlusal forces.[7]

The advent of adhesive dentistry has significantly contributed to the fracture resistance of teeth because it

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can reinforce the dental structure as a result of bonding to the tooth and may act as an internal splint to further stabilize the teeth. Strategies such as incremental layering, soft-start polymerization, and application of resilient intermediate liners have been suggested to minimize polymerization-related shrinkage.

Incremental layering technique has been the most widely adopted placement technique, in a way to combat polymerization shrinkage. However, it has certain drawbacks such as incorporation of voids, increased operational time, difficulty in placement of increments in small cavities, interlayer contamination, and difficulty in maintaining isolation.

A novel restorative approach involves the use of high-viscosity bulk-fill composites. Based on the rationale that bulk fill composites would reduce the time and effort needed for layering when placing posterior composites. It eliminates the possibility of voids between the layers enabling up to 4 mm increments to be cured in one step, without negatively affecting polymerization shrinkage kinetics and macromechanical properties.

The aim of this in vitro study is to analyze the fracture resistance of teeth with MOD preparations restored using two different types of high-viscosity bulk-fill composites and an incrementally placed composite when subjected to occlusal load.

**MATERIALS AND METHODS**

Freshly extracted intact human maxillary premolars (for orthodontic purpose) without caries were selected. The teeth were examined with a stereomicroscope under ×10 magnification to detect craze lines or cracks which were excluded from the study. Performing the above procedure resulted in 75 specimens. To simulate periodontium, root surfaces were dipped into melted wax to a depth of 2 mm below the cementoenamel junction to produce a thin layer and then vertically embedded in polyvinyl cylinders with self-cure acrylic (to simulate the alveolar bone). The wax spacer was later substituted with light-body addition silicone (to simulate the periodontal ligament).

Teeth were then randomly divided into five groups (n = 15):
- Group 1: Positive control (no tooth preparation was done)
- Group 2: Negative control (unrestored teeth)
- Group 3: Incrementally placed nanocomposite (Filtek Z350 XT Universal Restorative - 3M ESPE)
- Group 4: High-viscosity bulk-fill giomer (Beautifil-Bulk Fill restorative - SHOFU)
- Group 5: High-viscosity bulk-fill nanocomposite (Filtek Bulk Fill posterior restorative - 3M ESPE).

The tested materials and their components are listed in Table 1. For specimens from Groups 2 to 5, MOD cavities were prepared by a single operator. The occlusal isthmus width was kept 1/3rd of the intercuspal width with a pulpal depth of 2 ± 0.2 mm. The proximal boxes were prepared with a gingival width equal to 1.5 ± 0.2 mm and with an axial height of 2 ± 0.2 mm in an occlusal-gingival direction. A single periodontal probe was used as a guide for better harmony among cavities. Teeth were prepared using a straight fissure diamond point. An adult universal Tofflemire matrix band and retainer was applied before each restorative procedure.

Group 3: Incremental placement technique: Cavities were etched using 37% phosphoric acid for 15 s and rinsed. Single Bond Universal Adhesive (3M ESPE) was applied and light cured using light-emitting diode unit (Bluephase Polywave LED, Ivoclar Vivadent). The proximal boxes were filled first using one horizontal and two oblique increments, each 2 mm thick. The occlusal component was filled using two oblique increments. Photoactivation was done for 20 s from the occlusal aspect.

Groups 4 and 5: Bulk-fill technique: Etching and bonding procedure was similar to that of Group 3. The cavities were filled with a single increment to restore the final contour and light cured using light-emitting diode unit (Bluephase Polywave LED, Ivoclar Vivadent). The proximal boxes were filled first using one horizontal and two oblique increments, each 2 mm thick. The occlusal component was filled using two oblique increments. Photoactivation was done for 20 s from the occlusal aspect.

All composites were photo-activated again for 40 s from the buccal and lingual aspect of the preparations after removing the matrix bands. Finishing and polishing procedures (using CompoMaster – Shofu Dental Corporation) were initiated 10 min after final curing. These specimens were stored in distilled water at 25°C for 1 week.

**Mechanical testing**

All the specimens were subjected to compressive axial loading with a crosshead speed of 3 mm/min in an Instron universal testing machine (Zwick, Germany) using a steel bar (4.5 mm in diameter), which was placed central to the occlusal surface, and applied parallel to the long axis of the teeth. Load was applied until failure and the force, at
which the tooth fractured, was recorded in Newton as the fracture resistance. Failure mode of each of the specimens was evaluated under a stereomicroscope ×10.

Statistical analysis
Mean (± standard deviation) was calculated for each group. Data analysis was carried out using the one-way analysis of variance and Tukey’s post hoc honestly significant difference test at a 95% significance level.

RESULTS
The mean fracture resistance and the standard deviation for each of the five experimental groups are presented in Table 2.

Positive (1104.70 ± 122.2 N) and negative control groups (304.25 ± 125.95 N) showed the highest and lowest values of fracture resistance, respectively. No significant difference in fracture resistance was observed between Groups 3 (824.67 ± 264.5 N) and 5 (781.09 ± 216.3 N) (P = 0.96 ≥ 0.05). Furthermore, the fracture resistance values for Group 4 were statistically lower than both the above-mentioned groups. This has been graphically represented in Figure 1.

DISCUSSION
Incremental layering technique has been the standard of care for placement of dental composites. It aids reduction in polymerization shrinkage and associated stress as well as overcomes the inability to light-cure composite beyond a certain depth.[10] Bulk-filling technique of composite placement was not accepted until recently, with the advent of new group of bulk-filling posterior composites. These claim to allow up to 4 mm increments to be placed and cured in a single increment. This may be due to the improvements in monomer chemistry (matrix and initiator) and filler characteristics of these materials.[13-15]

In the present study, high fracture resistance values were displayed by both the incrementally placed and high-viscosity bulk-fill nanocomposites. No statistically significant difference (P > 0.05) was observed between the two groups. This can be attributed to the presence of nanomer and nanocluster filler particles in both nanocomposites. Nanomers are discrete nanoagglomerated particles (zirconia/silica) 20 nm–75 nm in size, and nanoclusters are loosely bound agglomerates of nano-sized particles (zirconia/silica). This combination reduces the interstitial spacing of the filler particles, thus increasing filler loading.[16] This is reflected in their higher fracture toughness. The high-viscosity bulk-fill nanocomposite; in addition to having the above-mentioned properties of a nanocomposite, is said to contain two novel methacrylate monomers. These in combination act to lower polymerization stress and ensure depth of cure of up to 4 mm. Aromatic urethane dimethacrylate is a high molecular weight monomer, which reduces the volumetric shrinkage by reducing the density of crosslinking and addition–fragmentation monomer, can fragment in response to shrinkage stresses and rebond in a more relaxed position.[13]

As early as 1996, Versluis et al.[17] conducted a finite element analysis to question the credibility of incremental placement technique in reducing polymerization shrinkage stress. The study pointed out that incremental placement led to more amount of composite to be condensed in the cavity as opposed to bulk filling, thus increasing the overall stresses at the tooth-composite interface. Hence, they discredited incrementalization for posterior restorations. Since then, many authors have reported the minimal difference in overall outcome of composites placed using both the techniques.[18,19]

In accordance with the present study, Rauber et al.[20] observed that there was no difference with reference to fatigue resistance when the bulk-fill resin placed in a

Table 1: Materials used in the study

| Fillers                              | Group 1            | Group 2            | Group 3            | Group 4            | Group 5            |
|--------------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Organic matrix                       | Bis-GMA            | Bis-GMA            | Bis-GMA            | Bis-GMA            | Bis-GMA            |
| Fillers (%)                          | 72.5/55.6          | 72.5/55.6          | 72.5/55.6          | 72.5/55.6          | 72.5/55.6          |
| Fillers (wt%, vol%)                  |                    |                    |                    |                    |                    |
| Fillers (organics matrix)            |                    |                    |                    |                    |                    |
| Fillers (nanofillers, nanocluster)   |                    |                    |                    |                    |                    |
| Fillers (F-B-Al-Si-glass)            |                    |                    |                    |                    |                    |
| Fillers (Ytterbium trifluoride)      |                    |                    |                    |                    |                    |

Table 2: Mean and standard deviation

| Groups | n  | Mean±SD  |
|--------|----|----------|
| Group 1| 15 | 1104.70±122.19924 |
| Group 2| 15 | 304.25±125.95268 |
| Group 3| 15 | 824.67±264.56723 |
| Group 4| 15 | 781.09±216.35815 |
| Group 5| 15 | 76.5/58.4 |

UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, PEGDMA: Polyethylene glycol dimethacrylate, Bis-GMA: Bisphenol A diglycidyl dimethacrylate, AUDMA: Aromatic urethane dimethacrylate, AFM: Addition-fragmentation monomer, Bis-MPEPP: 2,2-bis[(4-methacryloxy polyethoxy) phenyl] propane, Bis-EM: Bisphenol A ethoxyl methacrylate, S-PRG: Surface treated pre-reacted glass-ionomer.
single increment was compared to restorations placed incrementally. Furthermore, the results of this study are consistent with the study by Rosatto et al.\textsuperscript{[21]} that concluded that the bulk-fill technique has been shown to provide lower cuspal strain, shrinkage stress, and higher fracture resistance. Furthermore, that fractures seen with bulk-filled teeth were less catastrophic as compared to the ones with incrementally placed composites.\textsuperscript{[21]}

Giomer is a material category that is an amalgamation of glass ionomer and polymers.\textsuperscript{[22]} They maintain the clinical advantages of glass ionomers while addressing its poor esthetics and potential dehydration issues by the development of a surface prereacted glass-ionomer filler that could be incorporated into resin-based materials.\textsuperscript{[23]} Giomers have also been recently implemented in the high-viscosity bulk-fill composites. In the present study, the fracture resistance values demonstrated by the high-viscosity giomer are statistically lower than both the nanocomposites, high-viscosity bulk-fill nanocomposite as well as the incrementally placed nanocomposite. The giomer has the highest filler loading between the tested experimental groups. Therefore, the high filler loading may impede adequate light penetration and hence reduce degree of conversion, leading to incomplete polymerization.\textsuperscript{[24]} These results are inconsistent with those by Ilie and Fleming\textsuperscript{[21]} which stated that high-viscosity bulk-fill giomer showed increased micromechanical properties compared to the conventional composite materials.

Premolars were selected for this study as they are more susceptible to cusp fractures due to their unfavorable anatomical shape, crown-root ratio, and crown volume.\textsuperscript{[7]} Positive control (intact teeth) showed the maximum mean fracture resistance values among all the groups. The lowest mean fracture resistance was displayed by negative control (unrestored teeth). This was in congruence with the previously cited studies.\textsuperscript{[21,22]} The reason postulated was, application of a load on unrestored teeth produces a wedge effect between buccal and palatal cusps, leading to reduced fracture resistance and a more catastrophic fracture of the teeth.

No significant difference in the mode of fracture among groups was observed. Most of fractures were mixed, denoting that composite restorations have a viable effect on reinforcement of remaining tooth structure and hence are in congruence with previous studies that tested the effect of adhesive materials on tooth structure.\textsuperscript{[8,9]}

High-viscosity bulk-fill composites may be able to substitute the time-consuming incremental placement technique. However, various variables such as thermochemical factors and variations of magnitude, speed, and directions of forces that are peculiar to individuals’ oral environment and occlusion affect in vivo fracture resistance of restored teeth. Hence, further long-term clinical studies are required for bulk-filled composites to replace the gold standard incremental placement technique.

**CONCLUSION**

Within the limitation of this in vitro study, it can be concluded that high-viscosity bulk-fill nanocomposite displayed fracture resistance values similar to incrementally placed nanocomposite. However, fracture resistance of high-viscosity bulk-fill giomer was observed to be subordinate to the other two.

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**Conflicts of interest**

There are no conflicts of interest.

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