Comparative Study of the Flexural Strength of Three Fiber-Reinforced Composites

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ABSTRACT

Statement of Problem: After 30 years of intermittent reports in the literature, the use of fiber-reinforcement is just now experiencing rapid expansion in dentistry. However, there are some controversy reports in the amounts of flexural strength of fiber reinforced composites to use them as bridges.

Purpose: The purpose of this study was to evaluate the flexural strength of three commercially available fiber-reinforced composites including Belle Glass, GC Gradia, and Signum.

Materials and Method: Thirty uniform bars of 25×2×2 mm (10 for each group) were fabricated as their manufacturers recommended. Then all specimens were loaded to failure using a three-point bending test and flexural strength was determined.

Results: The mean flexural strength of Belle Glass (386.65 MPa) was significantly ($p < 0.0001$) higher than that of GC Gradia (219.25 MPa) and Signum (172.89 MPa). There was no significant difference between GC Gradia and Signum in flexural strength.

Conclusion: On the basis of these findings, Belle Glass can be used in clinical practice with greater confidence compared to GC Gradia and Signum.

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Introduction

Recently, the demand for nonmetallic, highly biocompatible dental restorative materials has increased markedly [1]. Dental resin composites are composed of fillers in an acrylic monomer matrix that is subsequently polymerized to form a solid. The composite materials have historically exhibited less than adequate occlusal wear resistance and color stability over time [2]. The microstructural improvements in fillers, resin compositions and cure conditions have resulted in significant enhancement in the wear resistance of composites [3-5].

Fiber-reinforcement is currently a popular approach in aesthetic dentistry to improve mechanical properties of dental materials [6-9]. As the composites improved in wear resistance through the incorporation of fibers, they also became more brittle materials. Flexural strength is a meaningful mechanical property for brittle materials, so in-vitro three-point bending flexural test is recommended by ISO 4049/2000 specification for polymer-based materials and is widely used for comparative purposes [10].

Fiber-reinforced composites (FRC) have good flexural strength and other desirable physical characteristics as a fixed prosthesis substructure material [9]. In addition, the FRC substructure is translucent and requires no opaque masking, which allows for a relatively thin layer of particular covering composite and excellent esthetics.

Cohen et al. compared the flexural strength of six reinforced restorative materials and noted that the reinforced composites (Ti-core, Ti-core natural, Flexi-Flow and Flexi-Flow natural) were significantly harder than glass ionomers (Ketac-silver and Miracle mix). There were no significant difference in mean flexural strength among the reinforced composites, but each reinforced composite group had significantly higher flexural strength compared to its control group without fiber-reinforcement [11]. Xu et al. showed that fiber-reinforcement of dental composite materials significantly increased the flexural strength, toughness and elastic modulus of composites. In Xu et al. Study, a hybrid composite had a flexural strength of 313 MPa, significantly higher than 120 MPa of the hybrid composite without fibers [12]. Many studies were performed to evaluate the flexural strength of Belle Glass, GC Gradia and Signum with different results [13-15]. The results of Wigren et al study showed that Belle Glass had significantly higher flexural strength compared to GC Gradia and signum [14]. But results of Kolbeck et al and Behr et al studies showed no significant differences among these three reinforced composites [13, 15].

So this study was performed to evaluate the flexural strength of these three commercially available dental fiber-reinforced composites to find out the best one for clinical use.

Materials and Method

In this study, the flexural strength of 3 commercial brands of fiber-reinforced composites included Belle Glass (Herculite XRV, Kerr, Germany) -a microhybrid composite polymerized by heat and pressure, GC Gradia (GC, USA) -a microhybrid composite and Signum (Heraeus Kulzer Gmbh Co, kG, Hanau, Germany) -a mixture of ceramic and composite were tested.

Aluminium molds with dimensions specified by the ISO 4049/2000 specification were used to fabricate 30 uniform bars of 25×2×2 mm (10 for each group). In Belle Glass group, at first 1 mm layer of composite was cured by Teklite (SDS-kerr, Orange, CA, USA) 650mW/cm^2 for 20 seconds, then a 25 mm fiber (glass) with thickness of 0.3 mm, was cut and impregnated in resin (A-174 silane, Union Carbide Corp. New York, N.Y.) for 15 minutes and applied on the first layer and cured for 20 seconds, then the last layer of Belle Glass was applied and cured for 20 seconds, then samples transferred to press stone (Econotek, Orange, CA, USA) at 140˚C with nitrogen pressure of 61 psi for 10 minutes to complete their polymerization. All the procedures were accomplished according to manufacturer recommendations [13-15].

In GC Gradia group, at first 1 mm layer of composite was applied in the mold and cured for 10 seconds by GC Steplight (model 1451A, USA), then a 25 mm fiber (fluoro-alumino-silicate glass) with thickness of 0.3 mm, was impregnated in resin (A-174 silane, Union Carbide Corp. New York, N.Y.) For 15 minutes and applied on the first layer, then the last composite layer was applied and cured for 10 seconds. Finally samples were transferred into furnace (labolight III) (Heraeus Kulzer Gmbh co KG,Hanau, Germany) for 10 minutes.

In Signum group, the method was similar to GC Gradia except the absence of steplight stage. In this group, the mold was filled by composite and fiber (glass) and transferred into labolight III for 20 minutes. So as to minimize air inclusions, a roller was applied over the materials after placement in the mold. The molds were then sandwiched and clamped between the glass slabs. Standard size of all samples were controlled by a sand paper and a digital calliper (Osaka, JAPAN).

After 24 hours, ten bars of each material were tested by a three-point flexure test and a universal testing machine (4411, Barueri, sp, Brazil) with a cross-head speed of 1 mm/min. The maximum loads were provided and the strength (δ) was determined in megapascals (MPa) by the formula of $\delta=3FL/(2BH^2)$ where F is the maximum load (in newtons); L is the distance between the supports (in millimeters); B is the width of the specimen (in millimeters) and H is the height of specimens (also in millimeters). The data were analysed using SPSS software (version 11.5, Chicago, IL, USA) by one way ANOVA and Kruskal-Wallis tests. A $p<0.05$ was considered as significant.

Results

The mean flexural strength of Belle Glass, GC Gradia, and Signum groups were shown in Table 1. The results showed that, Belle Glass had significantly the highest flexural strength (386.65MPa) compared to GC Gradia (219.25MPa) ($p<0.0001$) and Signum (172.89MPa) ($p<0.0001$). There was no significant difference in flexural strength of GC Gradia and Signum ($p>0.05$)

Table 1 The mean flexural strength (MPa) of three composite groups (BG=Belle Glass; GCG=GC Gradia; S=Signum)

	BG	GCG	S
Mean±SD(MPa)	386.65±110.57	219.25±42.47	172.89±23.59

Discussion

Dental composites are consisted of fillers in the matrix and the size and percent volume of fillers, resin, filler-matrix bonding and the polymerization status have significant effects on composite properties [16-17].

Composite fillers are composed of glass silicate particles and the size and percent volume of fillers can affect the strength, modulus and wear resistance of composites. There are reports of strengthening of composites by short and network fibers such as silica modified ceramic whiskers [18], but such composites, would still be fragile and just applicable for small restorations [19]. Strengthening of composites with fibers would result in a more toughness [20]. So in present study, three fiber-reinforced composites were compared in their flexural strength.

Flexural strength had been widely used to determine the mechanical properties of restorative materials [20-22]. Palin reported that bi-axial flexure strength testing of composites would provide a more reliable testing method than the three-point flexure. The increase in the reliability was in terms of the associated Weibull moduli following bi-axial flexure testing as a result of the elimination of the additional induced variability introduced during the curing process of three-point flexure specimens [23]. But Chung et al. demonstrated that although the bi-axial test has the advantage of utilizing small specimens, the low reproducibility of this test does not support the proposition that it is a more reliable test method in comparison of ISO three-point bending test [24].

The three-point bending test is based on the ISO specification no. 4049/2000 [10] for polymer-based restoratives and is widely employed in dental research [24-26]. The bending test, categorized as opening mode test is usually suggested since the specimen fabrication and the load application are quite simple [8]. Although some studies recommended the alternative flexural test designs [24, 26], the three-point bending test is still the choice for evaluation of the composites flexural strength due to the lower standard deviation, the lower coefficient of variation and the less complex stress distribution produced when compared to other test designs, such as the bi-axial test [24].

The results of Xu et al. study showed that the flexural strength of a prosthetic composite was 123 MPa [12] comparing, glass ionomer cements and resin-modified glass ionomers which generally had flexural strength values of 10-30 MPa and 40-60 MPa respectively. Moreoever, an experimental composite reinforced with networked fibers had a flexural strength of nearly 140 MPa Where Silica-fused whisker composites had nearly 200MPa [12]. The flexural strength values achieved in the present study were two to three times higher than the best values achieved previously. Our results showed that Belle Glass had significantly the highest flexural strength compared to the other two groups and was in line with the results of Chaabane et al. study [27]. In the present study, the volume percent of fiber was 15% which was similar to several other studies with parallel results [28-29]. The volume percent in Xu et al. study was reported 50% and the flexural strength was 313 MPa for the fiber-reinforced composite which is identical to Belle Glass results (386.25 MPa). This study showed that increase in fiber amount would not result in an increase in flexural strength.

Our results revealed that fiber-reinforcement in Belle Glass group had a significant effect on its flexural strength, but in Signum composite, reinforcement with fiber did not lead to an increased flexural strength in comparison to the other two hybrid composites. Flexural strength for GC Gradia was between the amounts reported for the other two groups. Wigren et al. also showed a significant difference in flexural strength between Belle Glass and the other two composites [14]. The results of Kolbeck et al and Behr et al studies showed no significant differences in flexural strength among Belle Glass, GC gradia and signum [13, 15] that was not consistent with our findings. On the other hand the result of Costa et al. recent study revealed that use of glass fibers did not improve the flexural strength of composite resin [30]. In Xu et al. Study, a hybride composite had a flexural strength of 313 MPa, a significantly higher score than 120 MPa which was recorded for the hybrid composite without fibers [12]. This result is similar to our findings for Belle Glass group (386.5 MPa) but it is not consistent with Costa et al. study.

Conclusion

1. Clinical use of Belle Glass is preferred to GC Gradia and Signum.
2. Due to the low flexural strength of GC Gradia and Signum, their use may be recommended in restoration of anterior teeth with less occlusal force.

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