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Original Article

Comparative Evaluation of the Flexural Strength of Fiber-Reinforced Composite and Composite Containing Spheroidal Filler Particles: An *In Vitro* Study

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Abstract

Introduction: The mechanical properties of resin composites are largely influenced by their filler characteristics. Fillers come in various sizes and shapes which also govern their loading as well as the mechanism by which it strengthens the composite. Hence, the aim of the present study was to compare two composites with different file composition. Thus, in the present study, the flexural strength of composite containing fibrous fillers and composite containing spheroidal fillers was analyzed.

Methodology: Specimens were prepared based on ISO standardization and subjected to three point bending test to determine their flexural strength. Each group had a sample size of 20. Intergroup comparison was done using *t*-test and $P<0.05$ was considered to be statistically significant.

Results: It was observed that fiber-reinforced composite had higher flexural strength than composite containing spheroidal filler particles.

Conclusion: The filler morphology has an influence on the mechanical properties of resin composite. Fiber-reinforced composites have higher flexural strength than composites with spherical filler particles. However, both the composites meet the minimum requirement of flexural strength that is indicated for an occlusal restoration.

Key words: Fiber-reinforced composite, Flexural strength, Resin composite, Spheroidal filler

INTRODUCTION

Composite resins have gained popularity as the choice of restorative material both for anterior and posterior restorations due to their enhanced mechanical properties and demand for esthetics. Over the years, there has been significant development in the monomers used and the filler particles. The resin component forms the matrix which binds the filler particles together with the help of a coupling agent.[1] Of particular, importance is the characteristic of the filler particles which largely govern the mechanical properties of composites. The mechanical properties of composites, such as strength and elastic modulus, wear resistance and polymerization shrinkage is said to have been improved by improving its filler loading which is further influenced by filler morphology, whereas filler size influences the restoration's polish ability.[2] Composites with round filler particles have higher filler loading and thus higher strength.[2] Estelite Σ (Estelite) by Tokuyama Dental Corp is a new type of composite with fillers produced by the sol gel mechanism. The filler produced by the sol–gel method has a spherical shape and average particle size of 0.2 μm.

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Earlier, silicate glass was the most commonly used filler particle. However, since they were not strong enough, cracks could propagate either through or around the glass particles.[3] This has been overcome with the development of newer fillers such as glass fibers, branched fibers, ceramic whiskers, and nanoporous fillers.[1] Glass fibers were the most commonly used fibers in dental composites. The properties of composites reinforced with fibers depend on

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the aspect ratio (l/d), volume fraction, and the orientation of fibers.[4] Favorably, oriented fibers allow fiber bridging which is a fiber toughening mechanism. Another factor that is important is the critical length of the fiber. If the length of the fiber exceeds the critical length by 2 times, then the fibers tend to break and the bridging energy declines. Longer fibers tend to align in a plane providing anisotropic reinforcement, whereas shorter fibers will be randomly distributed providing isotropic reinforcement.[4] Randomly, oriented fibers enhance the load bearing capacity by lowering the debonding. Since shape of the fiber is one of the factors that govern the mechanical properties of composite, the present study was conducted with the aim of analyzing and comparing the flexural strength of composite containing fibrous fillers (everX posterior by GC Corp., Tokyo, Japan) and composite containing spheroidal fillers (Estelite by Tokuyama Dental Corporation).

MATERIALS AND METHODS

The study consisted of two groups with 20 specimens in each group. Group A consisted of specimens made using Estelite by Tokuyama Dental Corporation and Group B consisted of specimens made using everX posterior by GC Corp., Tokyo, Japan.

To prepare standardized specimens for analysis, custom molds of dimension 25 × 2 × 2 mm were fabricated as per ISO standardization 4049:2009 and ISO 9917-1:2007 for polymer-based materials and powder/liquid acid-based cements, respectively. The test materials were packed into the molds using a teflon-coated composite filling instrument in increments of 2 mm thickness. To prevent the material from sticking to the walls, the molds were lined by petroleum jelly. Each increment was cured for 30 s by keeping the curing light of intensity 1200 mW/cm^2 at a distance of 2 mm from the increment. The final crement was cured by placing a mylar strip on top and the excess was removed using a polishing disk. The specimens were analyzed for voids and inaccuracies in dimension. To determine the flexural strength, the samples were mounted on a 3 point bending test device and loaded in the universal testing machine at a cross head speed of 1 mm/min. The flexural strength of each sample was calculated using the following formula:

$\sigma = 3Fl/2bh^2$
F – Maximum load (Newton)
l – Distance between the supports (millimeter)
b – Width of the specimen (millimeter)
h – Height of the specimen (millimeter).

Data obtained were compiled on a Microsoft Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States) and were subjected to statistical analysis using the Statistical package for the social sciences (SPSS v 26.0, IBM). The Mean and SD were obtained for numerical data. Normality of numerical data was checked using Shapiro–Wilk test and it was found that the data followed a normal curve; hence, parametric tests were used for comparisons. Inter group comparison (two groups) was done using t-test. For all the statistical tests, $P < 0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

RESULTS

It was observed that the mean flexural strength of fibrous filled composite everX posterior (104.8655 MPa) was significantly higher than Estelite which contained spheroidal filler particles (87.3565 MPa) [Table 1]. *P*-value of *t*-test was <0.00 which signifies a highly significant difference.

DISCUSSION

Flexural strength of a material is defined as the maximum stress in a material just before it yields in a bending test. In a three point bending test, the inner and outer edges of a material are called its extreme fibers. At the inside, the material experiences maximum compressive stress, while at the opposite side, the stresses will be at the maximum tensile value. Most materials fail due to tensile stress. Composite resins are more susceptible to tensile stresses than compressive stresses.[5] Hence, higher the values of flexural strength, stronger is the material.

Based on the ISO classification 4049, polymer-based restorative material is classified as type I which is used for occlusal surface restoration and type II which include all other polymer-based restorative material.[6] The three-point bending test is based on the ISO specification number 4049/2000 for polymer-based restorative materials.[7] The minimum flexural strength requirement for Type I is 80 MPa and 50 MPa for Type II.[6] It was observed in the study that both the composites had flexural strength that met the minimum requirement to be used as a restorative material on an occlusal surface. However, everX posterior had higher flexural strength compared to Estelite which had spheroidal filler particles.

In a previous study, Estelite has shown comparable mechanical properties to nanocomposites and micro hybrid composites.[8] It has also been observed that Estelite maintains high gloss during wear due to its spherical sub-micron filler particles that help in keeping the surface smoother than irregular particles on exposure.[9] These fillers have been produced by sol–gel method. The

Table 1: The table depicts the standard deviation and mean values of flexural strength observed in each group

Variable / outcome	Group	*n*	Mean (MPa)	Std. Deviation	Std. Error Mean	*P*-value of t test
Flexural strength	Estelite (Group A)	20	87.3565	2.80875	0.62806	0.000**
	everX posterior (Group B)	20	104.8655	2.06015	0.46066	

***P*-value of *t*-test<o.oo is indicative of a highly significant difference

average particle size is 0.2 μm, with a narrow range from 0.1 to 0.3 μm; thus, the material is called a submicron composite.[8] Spherical fillers have smaller surface area and hence need less resin matrix to wet them. This allows a high filler loading in Estelite contributing to its mechanical properties.[8] An increase in fracture toughness is observed with increase in the filler loading. There are several mechanisms responsible for this. The crack bowing effect increases the line energy at the crack front and is a result of pinning by the filler particles. Another mechanism is crack branching which increases the crack surface area and resultant fracture energy.[2]

The reasons for the higher strength of fiber-reinforced composite in the present study is due to the action of fibers in resisting opening and crack propagation, their ability to stretch, to bridge, deflect crack, and the transfer of stress from matrix to fibers.[4,10] Mere insertion of fiber into composite is not enough to enhance the mechanical properties of the material. Of critical importance is the length and diameter of the fiber.[11] The length of the fiber must exceed the critical length which is calculated as the ultimate tensile strength of the fiber (*f*) multiplied by the fiber diameter (*d*), and divided by twice the shear strength of the matrix interface.[11] The minimum length at which the center of the fiber reaches its ultimate tensile strength when the matrix reaches its maximum shear strength is defined as the critical fiber length. In a study, the measured critical length of everX posterior was between 0.85 and 1.09 mm.[4] An optimum fiber length is required to maintain the bridging phenomenon which is 1.2 times the critical fiber length. It has been observed under scanning electron microscope that fractured parts of fiber-reinforced composite show fibers traversing the crack line and between fractured parts. This shows the ability of the material to resist displacement which will help in preventing food impaction and cavitation as well as imparting better potential for repair.[12] The results of the present study are in accordance with the previous studies which have also reported improved mechanical properties of short fiber-reinforced composites.[13,14] However, it must be noted that this study was performed under a controlled laboratory setting. Further, comparative studies are required which test the materials under clinical scenarios.

CONCLUSION

Within the limitations of the present study, it can be concluded that filler morphology has an influence on the mechanical properties of resin composite. Fiber-reinforced composites have higher flexural strength than composites with spherical filler particles. However, both the composites meet the minimum requirement of flexural strength that is indicated for an occlusal restoration.

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