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SHORT COMMUNICATION

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Flexural strength of composites: influences of polyethylene fiber reinforcement and type of composite

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Abstract *Main problem:* The microfill veneering of hybrid composite restorations has been indicated to improve esthetics. Also, polyethylene fiber reinforcement has been proposed for use in composite restorations in high-stress clinical situations. However, minimal information in the literature addresses the influence of such combinations on the resistance to fracture. The purpose of this study was to investigate the flexural strength of two composites, a microfill and a hybrid, the effect of their combination, and the influence of polyethylene fiber reinforcement. *Materials and methods:* Twenty-eight specimens were prepared using a standard metallic mold (20×2×2 mm) and divided into groups of seven each: Filtek Z-250 (3M ESPE, St. Paul, Minn., USA) (group I), Filtek A-110 (3M ESPE) (group II), Filtek Z-250 combined with Filtek A-110 (group III), and Filtek Z-250 combined with polyethylene fiber (Ribbond, Seattle, Wash., USA) (group IV). The specimens were stress-loaded to fracture in a three-point bending device according to International Standardization Organization (ISO) 4049. *Results:* Data were analyzed using analysis of variance and Tukey's test at a 0.05 level of significance. No statistically significant differences were observed between groups I and IV. Group II, however, exhibited statistically lower resistance to fracture than the other groups. Group III presented intermediate results, showing statistically higher fracture resistance than group II but lower than group I. *Conclusions:* With the methodology employed, microfill composite presented the lowest flexural strength, but its association with hybrid composite increased the resistance to fracture. The combination of polyethylene fiber and hybrid composite did not present higher flexural strength than hybrid composite alone.

Keywords Fiber reinforcement · Flexural strength · Mechanical properties · Resin composites · Ribbond

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Introduction

The use of light-cured composite resins in posterior and anterior teeth has increased significantly in the last years. Besides the remarkable improvements achieved concerning their mechanical and esthetic qualities, their ability to bond to hard dental tissues allows more conservative cavity design, reducing the loss of healthy dental substance [28, 32]. These characteristics have allowed the application of composite materials in a range of clinical situations, not only for intracoronal restorations but also for situations of greater stress such as inlay, onlay, overlay, and adhesively bonded prostheses [17, 27].

Modern hybrid composites are densely filled materials that combine the fracture resistance of conventional composites with acceptable esthetic appearance. Although these composites show enhanced polishability, microfilled materials are still unique in producing an enamel-like surface. However, microfilled composites exhibit worse mechanical properties than hybrid composites, limiting their application to areas subjected to lower stress [2, 31]. Microfill veneering of hybrid composite restorations has been proposed as an alternative to improve both esthetics and resistance to fracture [26].

The replacement of a single lost tooth could be performed with an oral implant or a conventional ceramic or fixed porcelain-fused-to-metal (PFM) prosthesis [11]. However, economic factors, occlusal disturbances, and excessive removal of sound dental structure (with PFM) are variables that could limit treatment options. Directly bonded composite prosthesis appears as an extremely conservative treatment option, offering satisfactory esthetics, resistance, and minimal tooth loss [23, 27].

Table 1 Materials, manufacturers and batch numbers

Product	Manufacturer	Batch #
Filtek Z-250	3M ESPE St.Paul, Minn.	OBP and 9 AM
Filtek A-110	3M ESPE St.Paul, Minn.	EXI-127
Scotchbond Multipurpose	3M ESPE St.Paul, Minn.	8JY
Ribbond	Ribbond, Inc., Seattle, Wash.	9518

Despite the evolution of modern composite materials, their application has been questioned in clinical situations of greater stress such as resin-bonded composite bridges. Fiber reinforcement has been an option for increasing the resistance to fracture of materials applied in medicine [25]. Reinforcement of composite restorations with polyethylene fibers was also proposed [13]. Composite resins with polyethylene fiber reinforcement have been used as a potential alternative to adhesive fixed partial dentures with metal frameworks or conventional three-element fixed partial dentures in cases of single tooth loss [4, 8]. This option can be more cost-effective than other treatments and more conservative than conventional fixed partial dentures. Nevertheless, few reports in the literature have investigated its mechanical properties.

The hypotheses were that the association of microfilled and hybrid composites would produce higher flexural strength than microfilled composite alone and that polyethylene fiber reinforcement of hybrid composite would produce higher flexural strength than unreinforced hybrid composite. Thus, the purpose of the present study was to investigate the flexural resistance of hybrid, microfill, microfill/hybrid, and fiber-reinforced hybrid composite laminate.

Materials and methods

The specimens were prepared by placing the composite into a standard metallic mold (20×2×2 mm) in one or two increments, depending on the study group. Materials used, manufacturers, and batch numbers are described in Table 1. Twenty-eight specimens were made, with seven in each group:

- Group I: Filtek Z-250 resin composite (3M ESPE, St. Paul, Minn., USA) placed in one increment and photopolymerized for 40 s in each third of each side
- Group II: Filtek A-110 resin composite (3M ESPE), placed and photopolymerized as in group I
- Group III: Filtek Z-250 was placed in a 1-mm increment and then photopolymerized for 20 s in each third of the mold. The mold's height was completed with Filtek A-110 in one increment (1 mm) which was cured in the same way as the first increment. Polymerization was then performed on the other side of the mold for 40 s in each third
- Group IV: Filtek Z-250 resin composite combined with 2-mm woven polyethylene fiber (Ribbond, Seattle, Wash., USA). A 1-mm increment of composite was placed, and Ribbond tape previously moistened with Scotchbond Multipurpose adhesive (3M ESPE) was then condensed over the unpolymerized composite. After adaptation of the fiber, another increment was placed and photopolymerized as in group I. An XL 3000 light curing unit (3M ESPE) with energy level greater than 450 mW/cm^{2}was used during the experiment (Table 1).

In accordance with International Standardization Organization (ISO) 4049 [10], specimens were prepared with the mold positioned on one glass slide. Excess material was removed and a second glass slide placed on top of the mold with gentle pressure. Between each glass slide and the mold, we positioned polyester matrix strips through which the polymerization was performed. Total photocuring time was 240 s, 120 s for each side. After removal from the mold, the specimens were stored in physiologic saline solution for 7 days at room temperature.

Following storage, all specimens were subjected to transverse loading to determine the maximum load required for fracture. These measurements were performed using a K2000 MP universal testing machine (Kratos, Taboão da Serra, SP, Brazil) at a cross-head speed of 0.5 mm/min. The specimens were placed on a three-point bending device with 16 mm between the supports, ensuring an equally distributed load. Group III specimens were placed with the hybrid composite layer opposite to the loading piston. In group IV, the loading piston incidence was perpendicular to the fiber's width. Flexural strengths were expressed as maximum flexural load per cross-sectional area of the specimen in MPa according to ISO 4049. The fractured specimens were observed under magnification with a Tecnival stereomicroscope (Biosystems, Curitiba, PR, Brazil) to evaluate the failure patterns. Statistical analysis of the data was done using analysis of variance (ANOVA) and Tukey's test.

Results

Since the sample distribution of the data was normal and homogeneous, parametric tests were performed. The ANOVA demonstrated statistically significant differences between groups ($P<0.01$). An additional Tukey's post hoc test was used at the 0.05 level of significance to determine differences in flexural strength. Mean flexural strengths for the different groups and Tukey's intervals are shown in Table 2. Groups I and IV exhibited similar behavior, while group II presented the statistically lowest strength. Group III showed intermediate results – statistically

Table 2 Flexural strength means (MPa) and Tukey interval

Group	Fracture load mean (SD)	Tukey (p=0.05)
I	76.3 (±8.82) a*	9,9
II	42.4 (±3.13)	
III	65 (±13.41) b*	
IV	67.6 (±9.50) ab*	

* Same letters indicate statistically equal means

higher than group II and similar to group IV but lower than group I (Table 2).

After being subjected to transverse loading, group III specimens presented a pattern of fracture in which the two layers of composite broke in different places, following the union line and forming a step. Specimens of group IV presented a different pattern of fracture: the composite layers broke in two but stayed connected by the polyethylene fiber. Groups I and II exhibited similar, homogeneous fracture patterns.

Discussion

Fracture resistance is an important property of composites, especially in unfavorable clinical conditions [6]. The flexural strength test deserves special attention since it measures compression and tension acting together, simulating clinical conditions. The three-point bending test has been largely used to investigate flexural strength [3, 7, 16], being recommended by ISO guidelines [10].

This study compared the flexural strengths of a hybrid composite and a microfilled composite, their combination, and the combination of polyethylene fiber with a hybrid composite. Microfilled composites exhibited statistically lower resistance than hybrid composites. Cobb et al. [7], comparing the flexural strength of packable, hybrid, and microfilled composites, showed similar findings and verified that microfilled composites have lower strength. These results are related to the lower filler content of these materials. The mechanical properties of resin composite are closely linked to the material's composition – factors such as filler size, filler content, polymer matrix, and the coupling between filler and matrix are responsible for the physical and mechanical behavior [1, 15].

The combination of microfilled and hybrid composites increased flexural strength over microfilled composite alone. Given that many dental practitioners use microfilled composites to veneer hybrid composite in areas with high esthetic requirements, these findings may support clinical procedures that aim for better polishing and good color adaptation by the use of microfilled resins. However, even though a microfill/hybrid combination can provide more esthetic results than hybrid composite in clinical situations, it did not show equally desirable results in flexural strength.

The fiber-composite laminate evaluated in this study did not present enhanced flexural strength when compared to hybrid composite alone. This is in agreement with the results of other authors who tested fiber reinforcement of composite [20, 24] and polymethyl methacrylate [22, 29] in several circumstances and found no increased fracture strength in the reinforced groups. Since its introduction, fiber reinforcement has gained popularity mainly based on the supposition that it would improve mechanical properties [4, 21]. Fiber-reinforced composites are used for a number of alternative treatments: periodontal splinting, restoration reinforcement, intracoronal pins and cores, denture repair, and resin-bonded metal-free prosthesis [5, 9, 12]. Ribbond is the first-generation fiber reinforcement system and remains popular, but new fiber reinforcement systems have shown superior mechanical properties [8]. Since no improvement in fracture resistance was found and since fiber-reinforced restorations are more dependent on the technique used, time-consuming, and expensive, their use should be carefully considered.

It is important to point out that some limitations of the test employed in this study may have impaired the results of Ribbond-reinforced specimens. The small specimen size allowed the placement of only one small strip of the fiber. For the clinical application of resin-bonded prosthesis, a larger strip is indicated and, when possible, more than one strip should be placed to enhance fracture resistance [19]. Perhaps if the specimens were larger, results would be different.

Despite the differences in flexural strength, the specimens made with only one material (groups I and II), presented similar fracture patterns – homogeneous and parallel to the line of incidence of the loading piston. This observation may be related to better cohesion in the material mass. In group III, however, the two layers of composite – hybrid and microfilled – broke in different places and followed the union line of the materials, suggesting low adhesion. The specimens of group IV broke into two parts and stayed connected by the polyethylene fiber, which was not damaged, demonstrating its strength.

Specimens were stored in saline solution for 7 days before the test to simulate clinical conditions in which the materials are exposed to saliva after the restoration or prosthesis is completed. Studies have shown that water storage can change the mechanical properties of fiber-reinforced structures. Those studies, however, tested longer storage times than were performed in the present study [14, 30]. The Scotchbond multipurpose adhesive used to impregnate the fiber is composed of 60–70% bisphenol A-glycidyl methacrylate (bis-GMA) and 30–40% hydroxyethyl methacrylate, a hydrophilic monomer that can be altered by long water exposure [30]. Exposure of the fiber to the oral environment could increase the degradation of the fiber-reinforced structure and result in a surface difficult to polish. When fiber is exposed, the manufacturer of Ribbond recommends removal of the exposed portion and repairing it with composite.

Despite the importance of in vitro studies, clinical evaluations represent the final investigation of the performance and longevity of materials. Thus, longitudinal study results should provide the basis for selection of materials and restorative techniques [18].

One hypothesis tested in this study was confirmed, since the combination of microfilled and hybrid composites exhibited higher flexural strength than microfilled composite alone. The other hypothesis was rejected, because fiber-composite laminate presented flexural strength no better than that of unreinforced hybrid composite.

Conclusions

Polyethylene fiber did not increase the flexural strength of the hybrid composite with the methodology used. Microfilled composite alone presented the lowest flexural strength, but its use with hybrid composite increased this property.

References

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