



Effect of moisture on flexural strength of fiber-reinforced composites used as splinting materials

Efeito da umidade na resistência flexural de resinas compostas reforçadas por fibras usadas como material de esplintagem

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Abstract

Objectives: Different fiber types are available for reinforcing composite restorations. Little information exists regarding flexural strength of various fiber used to reinforce direct composites. This *in vitro* study examined the flexural strength of polyethylene and glass fibers when used to reinforce composite and influence of moisture exposure on the same materials. **Materials and methods:** The two types of fiber were used to reinforce blocks of composite (RX Flow, Dental Life Sciences) prepared to test flexural properties and compared with the unreinforced controls. Mean flexural strengths values were determined in a 3-point bend test at a crosshead speed of 8 mm/min by use of a universal testing machine. **Results:** Significant increases in mean flexural strength were found for all fiber-reinforced groups in comparison to the unreinforced controls at both before and after moisture exposure. The polyethylene fiber gave the greatest reinforcing effect. After 1 month of storage in an artificial saliva substitute, a significant decline occurred in the mean flexural strength of all the groups tested. **Conclusion:** Within the limitations of this study, the choice of fiber type was shown to have a significant increase on the flexural properties of the fiber-reinforced composite. Polyethylene fibers increased the flexural strength of the composite the most.

Keywords: Composite Resin. Splinting. Polyethylene fibers. Glass fibers. Tooth stabilization. Flexural strength.

Resumo

Objetivo: Diferentes tipos de fibras estão disponíveis para reforçar restaurações em resinas compostas. Há pouca informação sobre a resistência flexural de fibras usadas para reforçar compósitos diretos. Este estudo in vitro avaliou a resistência à flexão de fibras de polietileno e de vidro, quando usadas para reforçar resina composta e a influência da exposição à umidade sobre os mesmos materiais. **Materiais e métodos:** Os dois tipos de fibras foram usados para reforçar blocos de resina composta (RX Flow, Dental Life Sciences), preparados para testar as propriedades mecânicas e comparados com os controles não reforçados. Os valores médios de flexão foram determinados em um ensaio de flexão de três pontos a uma velocidade de 8 mm/min em uma máquina de ensaio universal. **Resultados:** Um aumento significativo na resistência à flexão média foi encontrado para todos os grupos reforçados com fibras, em comparação com os controles não reforçados, tanto antes quanto depois da exposição à umidade. A fibra de polietileno forneceu o maior efeito de reforço. Após 1 mês de armazenamento em saliva artificial, houve uma diminuição significativa na força média de flexão de todos os grupos testados. **Conclusão:** Dentro das limitações do presente estudo, o tipo de fibra demonstrou exercer um aumento significativo sobre as propriedades de flexão do compósito reforçado com fibras. Fibras de polietileno aumentaram mais a resistência à flexão do compósito.

Palavras-chave: Resina composta. Esplintagem. Fibras de polietileno. Fibras de vidro. Estabilização dentária. Resistência flexural.

Introduction

Tooth mobility is one of symptoms of the periodontal disease. This mobility comes as a result of bone destruction which causes dysfunction, traumatic occlusion and in the end loss of the teeth. Stabilization is one of the treatment modality which allows retaining teeth that are periodontally compromised with loss of attachment apparatus often having increasing levels of mobility. Tooth mobility has been described as an important clinical parameter in predicting prognosis of teeth (1). For this reason and for patient comfort, splinting has been the recommended therapy to stabilize mobile teeth. Recent research supports the use of tooth stabilization and splinting to improve the prognosis (2, 3).

The reinforcing materials, like wires, pins and mesh used in the past could only mechanically lock around the resin restoration. This led to the potential of creating shear planes and stress concentrations that would lead to fracture of the composite and premature failure. The earlier materials (wires) were also not aesthetically pleasing. Thus the need to respond to the ever-increasing patient demand for aesthetics, tissue maintenance, and cost efficiency has resulted in the evolution of newer techniques and materials (4).

The development of synthetic fibers like the glass and polyethylene has allowed the incorporation of

fiber-reinforced materials to replace metal splints. The development of fiber-reinforced composite technology has opened new avenues for splinting that are esthetic and simple in design and execution and have the potential for excellent durability. This is because of their chemical ingredients, bonding ability, conservative preparation, preservation of tooth structure and esthetics.

When fiber-reinforced composites are exposed to moisture, water can destroy the fiber-polymer matrix bond and cause an irreversible reduction of the strength. Also, a reversible reduction in the mechanical properties of the fiber reinforced composite is caused by plasticization of the polymer matrix (5).

Pollack et al. (6) described 25 years of successful treatment of mobile, periodontally involved teeth with stabilization techniques using adhesive composite resins. The chief problem was that repairs were frequently needed because of fractured composite between the teeth.

The problem was attended to with the introduction of colourless ribbon that has high strength, is bondable, is biocompatible, is aesthetic, can be easily manipulated and can be embedded into a resin structure (7).

Different fiber types have been added to composite materials to improve their physical and mechanical properties (8, 9, 10). Fibers made of materials such as carbon, polyethylene, and glass

is available. In spite of the fact that carbon fibers raise the flexural strength of polymers, their unsightly black color restricts their use (11). Out of the list of fibers available glass and polyethylene fibers have the most aesthetic appearance.

Many investigators have confirmed the reinforcing effect of fibers on different polymer types (12, 13). The explanation for this increase was the transfer of stress from the weak polymer matrix to fibers that have a high tensile strength (10). Samadzadeh (8) and Vallittu (9) reported significantly higher fracture strength of polyethylene fibers. But Kolbeck (12) stated that the reinforcing effect of glass fibers is more effective than that of polyethylene fibers. This has been attributed to adhesion problems between ultra-high modulus polyethylene fibers and the resin matrix (11, 8).

Thus the aim of our present study was to compare the flexural strengths of the commercially available glass and polyethylene fiber reinforced composite before and after exposure to moisture.

Materials and methods

Thirty composite blocks (RX Flow composite; Dental Life Sciences) of 10 × 3 × 2 mm were prepared, using a mould made of die stone. Blocks were divided into three groups of 10 each comprising of:

- 1) *Unreinforced Composite blocks.*
- 2) *Composite blocks reinforced with polyethylene fibers.*
- 3) *Composite blocks reinforced with glass fibers.*

The mould was placed on a glass slab and a Mylar matrix was placed under the mould to obtain flat surface. Composite resins were applied in the mold in 2 mm layers to fill the mould. For the group 2 and 3 respective fibers were placed half way in the mould and the resin was cured subsequently. For the last layer a Mylar matrix was placed over the layer. Light curing was done for 40 seconds per layer. In order to have maximum curing, each specimen was post-cured 10 minutes after preparation for 60 seconds at all directions.

Artificial Oral Environment

Hanck's Balanced Salt Solution (HBSS; Hi-Media Laboratories), an artificial salivary substitute, was

prepared as moisture medium. The blocks of each group were further subdivided into two groups: pre-aging group and post-aging group.

Pre-aging group was not subjected to moisture exposure. Blocks of the post aging group were immersed in HBSS and were kept in an incubator at 37°C for 4 weeks. Then all the composite blocks were subjected to flexural tests on a Universal Testing Machine. The tests were carried out at a cross head speed of 8mm/min. with a span length of 6 mm and the load at breaking point was calculated.

Flexural Strength was then calculated by using the formula:

$$\text{Flexural Strength} = (3 \times P \times L) / (2 \times b \times d^2)$$

Where: P = Breaking Load, L= Span Length, b = Width of Block, d = Depth of Block

Statistical analysis

The intergroup analysis was carried out using two way analysis of variance, while the intragroup analysis was done using independent 't' test.

Results

Significant increases in mean flexural strength were found for all fiber-reinforced groups in comparison to the unreinforced controls at both before and after moisture exposure. The polyethylene fiber gave the greatest reinforcing effect. After 1 month of storage in an artificial saliva substitute, a significant decline occurred in the mean flexural strength of all the groups tested.

The results after the statistical analysis between pre-aging and post-aging of each group showed a difference of 4.74 with composite, 5.2 with the glass fibers while that of the polyethylene fibers was 7.4.

The p-values for each difference detected were $p < 0.001$, thus indicating that the differences between pre-aging and post-aging group were statistically significant. The results (Table 1) showed that polyethylene fiber-reinforced group had the highest flexural strength values in both pre and post-aging

Table 1 - Mean and standard deviation (sd) of flexural strength (mpa) for composite, glass fiber and polyethylene fiber group

Group	Composite		Glass Fiber		Polyethylene Fiber	
	mean	SD	mean	SD	mean	SD
Pre-aging	853.32 ^S	4.5	1101.64 ^S	18.07	1600 ^S	63.2
Post-aging	458.34 ^S	20.41	665.02 ^S	56.05	978.34 ^S	35.14

Source: Data Research.

Note: Superscript S denotes statistical significance between the pre-aging and post-aging groups.

compared to glass fiber-reinforced and unreinforced composite group.

Discussion

The aim of this *in vitro* study was to determine and compare the flexural strengths of different commercially available fiber-reinforced composites. Fiber-reinforced composites are well established in dentistry and consist of a polymer matrix in which reinforcing fibers are embedded. Stress is transferred from the polymer matrix to the fibers which present a high tensile strength. Hence, the mechanical properties of polymers are improved (14). Aesthetics should be one of the central properties of dental materials. For that reason only commercially available polyethylene and glass fiber products were chosen for the study.

The flexural strength test is able to compare the load-bearing capacity of different materials under flexure. According to Pereira et al. (15), the flexural strength test deserves particular attention, because it measures tension and compression acting together, simulating oral clinical conditions. Thus flexural strength was the mechanical property chosen for comparison.

The results for the pre-aging group, of the study confirmed that there were significant increases in mean flexural strengths for both fiber reinforced groups in comparison to the unreinforced controls. The results are in accordance with those of Galan et al. (16). Also the intergroup comparison shows significant increase in the flexural strength of polyethylene group compared to the glass fiber group. Thus the polyethylene fibers, according to the present experiment, proved to have better flexural strength.

The results of the post-aging group of the study showed that after 4 weeks of storage in HBSS, a significant decline occurred in the mean flexural

strength of all the groups. The findings have been previously confirmed by Braem et al. (17), who stated that the flexural fatigue limit decreases after water sorption. In the present study, the intergroup comparison shows that flexural strength of polyethylene fiber group was better compared to the glass fiber group after moisture exposure.

HBSS was chosen as the aging media in the present study since Ellakwa et al. (5) reported that there was a significant decline in the mean flexural strength of the glass fiber-reinforced specimens when stored in water and Al-Turki et al. (18) showed that the decrease in flexure strength from flexure loading was mainly affected by the aging media.

Thus to simulate the oral environment HBSS was selected as a moisture medium. Also according to the ASTM standards the composite block dimensions recommended is $10 \times 2 \times 2$ mm while that used in the present study is $10 \times 3 \times 2$. This increase in size was to accommodate the width of the commercial fiber being used.

Bae et al. (19) stated that the strength of fiber reinforced composite is often reported with values at the ultimate flexural strength of the final fracture, which is somewhat questionable for clinical use. And thus a more important parameter could be the initial failure point showing the onset of failure, as sometimes only a crack in the splint may be evident but the splint is still effective. In the follow-up period, the patient should be recalled frequently to check the splint, periodontal status and oral hygiene of the patient.

Conclusion

Resin impregnated fibers increased significantly the flexural strength of the composite. Of the fibers evaluated, polyethylene fibers provided greater flexural strength than glass fibers should be preferred

for splinting. On exposure to moisture there was a decrease in the flexural strength of the fiber-reinforced composites and subsequent reduction in the flexural strength of the fiber reinforced composite. The mobility of the splinted teeth should be evaluated at every recall and teeth re-splinted if needed.

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