Flexural properties at various span-to-thickness ratio

R & D Team

SFC, LLC
172 North Plains Industrial Road,
Wallingford, CT 06492, USA

Abstract

3-point flexural tests were conducted on two different (uni-axial and braided) designs of fiber splint products at 3 different support spans. For the similar cross-sectional dimensions, both flexural strengths and moduli increased with the increased support spans.

Introduction

Fiber reinforced composites (FRCs) have been successfully used in many dental applications, such as frameworks for crowns, anterior or posterior fixed prostheses and periodontal splints [1-2]. Among many high strength fibers, those made from glass, quartz and polyethylene are the most popular. In many cases, FRCs are used to replace metal which is suspected to release harmful ions and discoloration to the teeth. Fiber reinforced composites on the other hand have adequate mechanical properties and pleasant esthetics. FRCs also eliminate the concern of metallic ions. Fibers are used in different forms such as milled short fibers, woven or braided tape and continuous fibers. Each form has its advantages and disadvantages. The continuous fibers provide the maximum potential for mechanical properties. However, the composites made of continuous fibers are considered to be anisotropic which means its properties are dependent on the fiber direction. Furthermore, in flexure mode, the modulus of elasticity of FRC is dependent on the span-to-thickness (L/D) ratio, which is very important factor to consider for application such as substructure for multi-unit dental bridge. Such dependence of modulus on L/D ratio of uni-axial FRC is well known. In fact, as per ASTM D790, the L/D ratio for uni-axial FRCs is recommended to be 60. However, the dimensions of test specimens as per ASTM D790 are larger and may not accurately represent the situation in actual dental applications. In dental industry, the commonly used cross-sectional dimension for flexural test, as described in ISO 10477, is 2 mm x 2 mm. In an earlier study [3], the optimal L/D ratio for uni-axial dental FRC was determined to be much less than 60. In this study, the flexural properties of FRCs with two different design structures (uni-axial versus braided) were compared at various span-to-thickness ratio.

Materials and Methods

Two different FRC products, 1) Splint-S 3MM (uni-axial) and 2) Splint-S 2MM (braided), both from SFC, LLC, Wallingford, CT, USA, were used for this study. Teflon mold with 2mm x 2mm x 60mm cavity size was used to make the test specimens. Multiple strips of each product were packed into the cavity, covered with glass slide, and light cured for 2 minutes, using a UV light source (Figure 1), having a peak at about 350 nm. During curing, the light tip was moved back and forth to cover the entire length of the specimen. The specimens were cut to appropriate length to have span length of 20, 35 and 50 mm. The span length corresponds to the distance between two supports (Figure 2). The overall length of each test specimen was 10 mm longer than the span length. 3-point flexural test was conducted at crosshead speed of .5mm/min. Flexural strength and modulus were calculated using the equations given in ISO 10477. The results were subjected to one-way ANOVA (95% CI) using statistical software (Minitab 19).

Results and Discussions

Flexural strength and modulus of each product, tested at 3 different spans, are listed in tables 1 and 2. Each value is an average of 3 test results. For both products, the average flexural strengths and moduli at 20 mm span were lower than those at test spans of 35 and 50 mm. As can be seen, the difference between the values at test spans of 35 and 50 mm are very low. For uni-axial design, the average modulus at 20 mm span was significantly ($p<=.001$) lower than both at 35 and 50 mm. The difference between average modulus at spans of 35 and 50 mm was not significant. For braided design, the modulus at 20 mm span was significantly ($p<= .035$) lower than that at 50 mm.

The average strength and modulus versus span-to-thickness (L/D) ratio for both products are depicted in Figures 3 and 4. As can be observed in Figure 4, both strength and modulus curves for the braided (2MM) design tends to level off at span of 35 mm. On the other hand, for uni-axial (3MM) design the values are still upward, indicating that the effect of L/D ratio in uni-axial design is more pronounced than in the braided design.

References:

1. Freilich M, Meiers J, Duncan J and Goldberg J: Fiber-reinforced composites in clinical dentistry; Quintessence Publishing Co., 2000.
2. Freilich M, Karmaker A, Charles B and Goldberg J: Development and clinical applications of a light-polymerized fiber-reinforced composite; The Journal of Prosthetic Dentistry, Sept. 1998
3. Karmaker, A and Prasad, P: Effect of design parameters on the flexural properties of fiber-reinforced composites; Journal of Materials Sci. Letts., 19(2000), 663-665.

Table 1: Flexural Properties of Splint-S 3MM (uni-axial)

Width (mm)	**Thickness (mm)**	**Span (mm)**	**Span to Thickness (L/D)**	**Span/Thickness (L/D)**	**Strength (MPa)**	**Modulus (GPa)**
2.02	2.12	20	9.4	9.4	609.2 (68.2)	21.81 (.87)
2.03	2.06	35	17.0	17.0	823.9 (38.5)	31.23 (.99)
2.03	1.93	50	25.9	25.9	908.6 (93.5)	34.36 (3.41)

Table 2: Flexural Properties of Splint-S 2MM (braided)

Width (mm)	Thickness (mm)	Span (mm)	Span to Thickness (L/D)	Span/Thickness (L/D)	Strength (MPa)	Modulus (GPa)
2.28	2.10	20	9.5	9.5	394.8 (42.3)	17.64 (1.49)
2.03	1.97	35	17.8	17.8	503.1 (75.1)	25.71 (3.50)
2.03	1.97	50	25.4	25.4	508.0 (129.6)	25.94 (4.22)

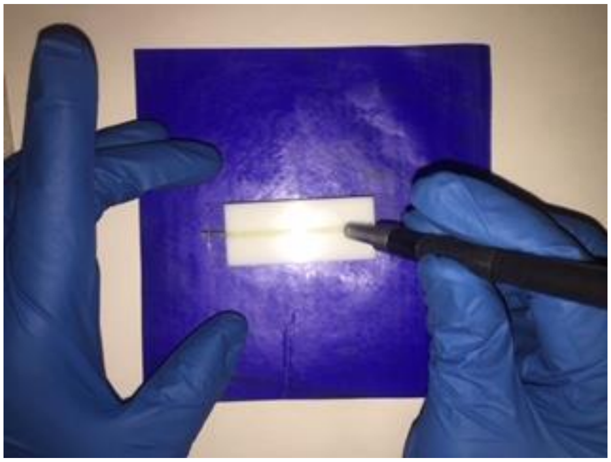

Figure 1: Light cure of Splint-S test specimen in a Teflon mold.

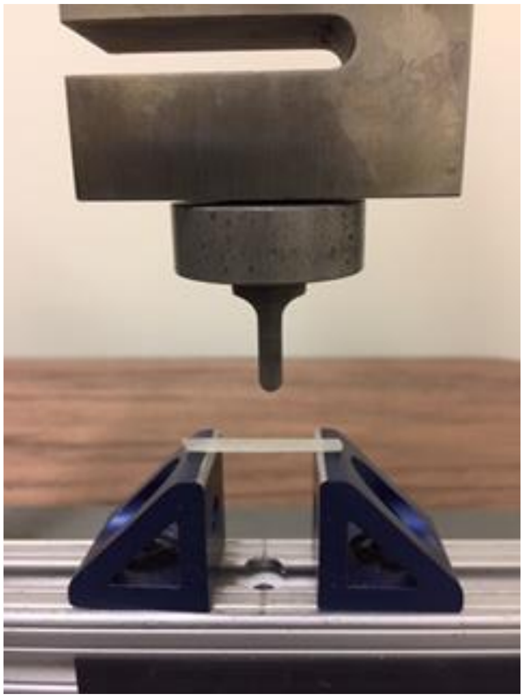

Figure 2: Setup for 3-pt Flexural Test (showing 20 mm Support Span)

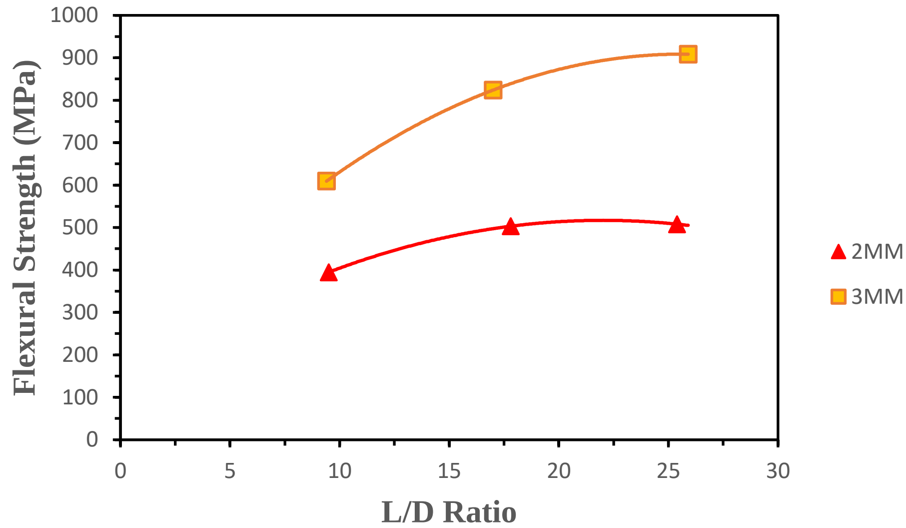

Figure 3: Flexural Strength versus L/D Ratio

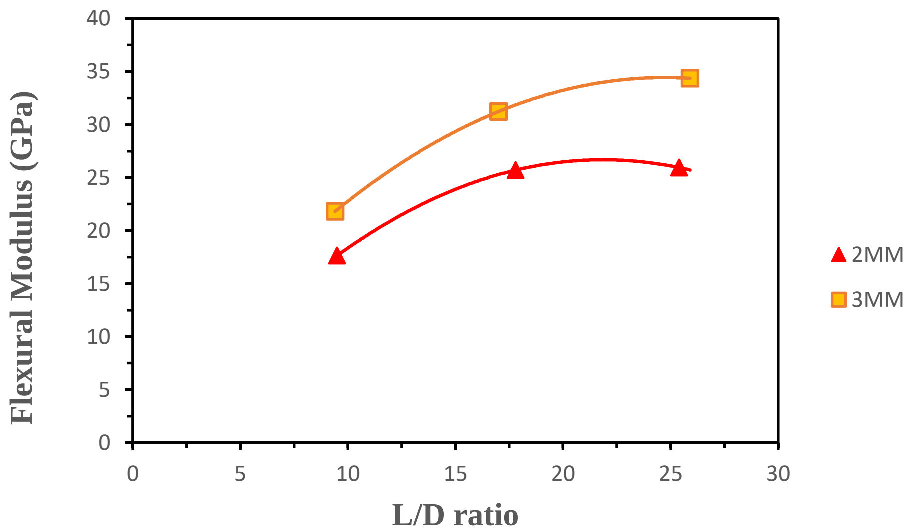

Figure 4: Flexural Modulus versus L/D Ratio