Comparative study of flexural strength and elasticity modulus in two types of direct fiber-reinforced systems

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Abstract: The objective of this study was to compare the flexural strength and elasticity modulus of two types of staple reinforcement fibers, Interlig - Ângelus®/glass (Londrina, PR, Brazil) and Connect - KerrLab®/polyethylene (MFG Co., West Collins Orange, CA, USA), which are widely used in Dentistry for chairside use, after varying the number of layers employed and submitting or not to thermocycling. This study was performed on 72 specimens, divided into 8 groups: G1 – single layer of Interlig fibers without thermocycling; G2 – double layer of Interlig fibers without thermocycling; G3 – single layer of Interlig fibers with thermocycling; and G4 – double layer of Interlig fibers with thermocycling; G5 – single layer of Connect fibers without termocycling; G6 – double layer of Connect fibers without termocycling; G7 – single layer of Connect fibers with termocycling; G8 – double layer of Connect fibers with termocycling. For each group, values for flexural strength and elasticity modulus were obtained. The polyethylene fiber employed in a double layer presented the highest flexural strength ($p < 0.05$), independently of thermocycling ($p < 0.001$), when compared to the other evaluated combinations. The polyethylene fiber, used in a single layer without thermocycling, demonstrated a significantly higher elasticity modulus, when compared to the other groups ($p < 0.05$). Within the limits of this study, it was concluded that the polyethylene fiber in a double layer appears to be more resistant, regardless of whether it was submitted to thermocycling or not.

Descriptors: Dentistry; Composite resins; Dental materials.

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Introduction

Fiber reinforcement is currently a popular approach in aesthetic dentistry, since the composite resin itself fails to maintain an adequate pontic bonding to supporting structures. Reinforcement fibers may be composed of glass, polyethylene, Kevlar, or carbon. Glass reinforcement fibers are made of silicon oxide, aluminum and magnesium. In contrast, the polyethylene reinforcement fiber has a flexible white mesh appearance and is treated with cold plasma gas in order to increase its reactivity and wetting ability, thus enabling chemical and physical interactions with composite resins.

The reinforcing capacity of fibers is dependent on their adhesion to the resin, on the orientation of the fibers, and on impregnation with the resin.[1] Other desirable physical properties of a fiber are good flexural strength and no requirement for mechanical retention on supporting teeth when compared to the conventional metallic-structured fixed prosthesis.[2]

This feature led to investigations concerning pre-impregnated and non pre-impregnated fibers used in conjunction with adhesive materials. Freilich *et al.*[3] (2000) concluded that pre-impregnated systems are well indicated for direct applications, i.e., splinting or direct adhesive bridges. In these clinical applications, mechanical and physical properties of composite materials are strongly influenced by the structure and properties of the fiber-matrix interface, and differences between the elastic properties of the matrix and the fibers may modify the force transmission through the interface. The pre-impregnated reinforcement fibers create a substructure that has been shown to support 2-3 times more load and to have a flexural modulus that is 10 times higher than that of the hand-impregnated designs.[4,5,6,7]

Despite the evolution of reinforcement fiber systems, the parameters related to reinforcement fibers on direct resin composites are not well defined. Several studies concerning the mechanical properties and clinical evaluation of these materials have been published in the literature.[1,4,5] Due to the increased interest surrounding the use of reinforcement fibers, the mechanical properties of these materials require further study, particularly flexural strength and elasticity modulus. Thus, in order to clarify these issues, the aim of this *in vitro* study was to compare the flexural strength and modulus of elasticity of two systems of reinforcement fibers: glass reinforcement fibers (Interlig – Angelus®) and polyethylene (Connect - KerrLab®) for chairside dental use. Furthermore, the effects of thermocycling and the number of layers of fiber employed on the mechanical parameters were evaluated.

Materials and Methods

Details of the materials used in this investigation are given in Table 1.

Seventy two specimens were manufactured using a split metallic mold measuring 25 x 2 x 2 mm. A microhybrid composite resin, color A3 (Filtek A3, 3M ESPE, Sumaré, SP, Brazil), was placed in the mold in 1-mm increments. According to the experimental groups, 1 or 2 layers of reinforcement fibers were placed, and then another 1-mm resin increment was applied. These specimens were polymerized for 4 minutes in a Powerlux (EDG equipments, São Paulo, SP, Brazil) equipment, using a high intensity halogen light with 1,200 mW/cm² that produces wave lengths ranging from 320 to 520 nm. Thirty-six specimens were submitted to thermocycling that consisted of 5,000 cycles in a standard machine (521-AD, Nova Ética Indústria e Serviços, Vargem Grande Paulista, SP, Brazil), with the temperature

Table 1 - Description of the materials used in the study.

Name	Composition	Company
Interlig	Glass pre-impregnated fiber system	Angelus, Londrina, PR, Brazil
Connect	Polyethylene non-impregnated fiber system	Kerr, MFG Co., West Collins Orange, CA, USA
Filtek (Colour A3)	Bis-GMA, UDMA and BIS-EMA with zircon and silica	3M ESPE, Sumaré, SP, Brazil

Bis-GMA: Bis-phenol glycidyl methacrylate; UDMA: Urethane dimethacrylate; BisEMA: Ethoxylated bisphenol A dimethacrylate.

controlled between 55°C ± 2°C and 5°C ± 2°C. These specimens were submerged for 15 seconds in each one of the compartments, with an interval of 5 seconds; following this procedure, they were stored in distilled water at 37°C for 24 hours.

The specimens were divided into 8 groups (n = 9), varying the type of reinforcement fiber and number of layers, and submitted or not to thermocycling. The complete descriptions of the groups are presented in Table 2.

All the specimens were submitted to a compressive load of 500 kgf until fracture, with a three point test at a rate of 1 mm/min, to evaluate flexural resistance using a universal testing machine (Kratos, model K- 5002, Dinamômetros Ltda., São Paulo, SP, Brazil).

The means and standard deviations of each group were compared. One-way analysis of variance (ANOVA) followed by *post-hoc* paired Tukey tests ($\alpha = 0.05$) were used for flexural strength and elasticity modulus data analysis.

Results

Comparison of flexural strength values was performed following descriptive statistical measurements (Table 3).

For each fiber type and thermocycling condition (with or without), the means were higher for the specimens with 2 layers than for those with only 1 layer. In addition, the highest values were detected when Connect fiber (polyethylene) was used in 2 layers (Graph 1).

Statistically significant differences were observed between group 6 and all the other experimental groups ($p < 0.05$), with the exception of group 8. However, no statistically significant difference was demonstrated between the mean values for groups 6 and 8.

The same descriptive statistical analysis was performed before the comparative analysis for elasticity modulus (Table 4).

The elasticity modulus mean values were lower for specimens with Connect fibers in 2 layers, and the remaining values ranged from 69.44 to 89.34 MPa. The mean values were lower when the fibers were placed in 2 layers than when only 1 layer was used, with the exception of the group that used Interlig (glass) without thermocycling (Graph 2).

The mean value for elasticity modulus in group 1 was statistically different from that of the remaining

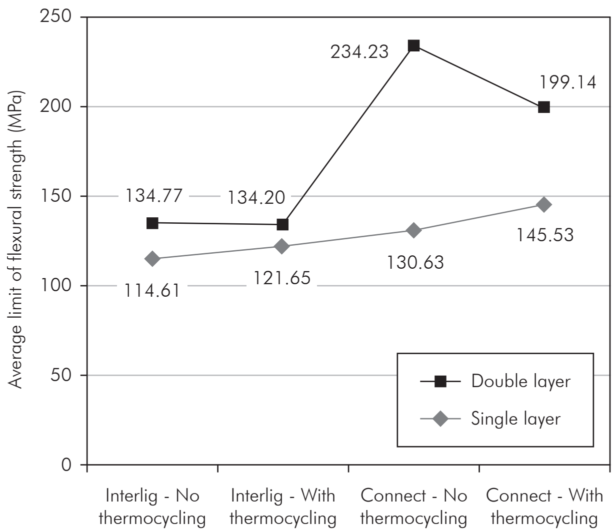
Table 2 - Details of the specimens made for the 8 experimental groups tested.

Group	Number of specimens	Fiber System	Numbers of layers	Thermocycling
01	9	Interlig	One layer	Without
02	9	Interlig	Double layer	Without
03	9	Interlig	One layer	With
04	9	Interlig	Double layer	With
05	9	Connect	One layer	Without
06	9	Connect	Double layer	Without
07	9	Connect	One layer	With
08	9	Connect	Double layer	With

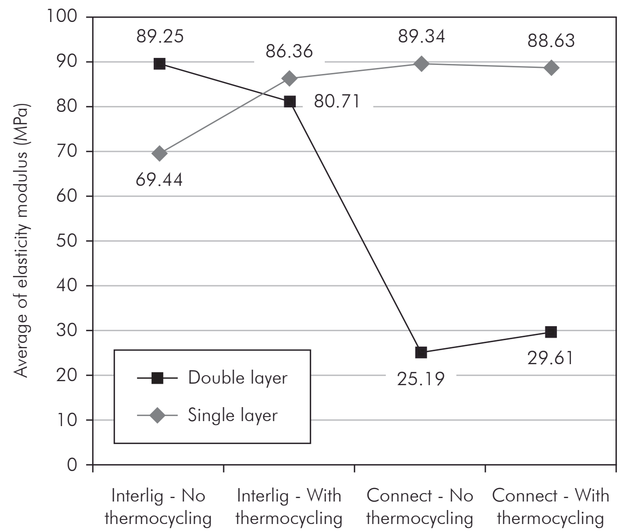
Table 3 - Descriptive statistics of the flexural strength limits for Filtek composite with 2 fiber types, submitted or not to thermocycling, using a single or double layer (MPa).

Fiber type	Thermocycling	Number of layers	Minimum (MPa)	Maximum (MPa)	Mean (MPa)	SD [(1)] (MPa)	V[(2)] (%)
Interlig	No	single	87.87	158.87	114.61	21.35	18.63
		double	94.54	176.52	134.77	25.76	19.12
	With	single	105.13	156.52	121.65	17.33	14.25
		double	98.07	170.64	134.20	26.99	20.12
Connect	No	single	104.74	158.87	130.63	15.75	12.06
		double	185.55	274.59	234.23	35.74	15.26
	With	single	121.60	176.13	145.53	18.51	12.72
		double	151.81	285.97	199.14	47.25	23.73

[(1)]SD = Standard deviation; [(2)]V = Variance.



Graph 1 - Mean flexural strength limits for Filtek composite with 2 fiber types, submitted or not to thermocycling, using a single or double layer (MPa).



Graph 2 - Mean elasticity modulus for Filtek composite with 2 fiber types, submitted or not to thermocycling, using a single or double layer (MPa).

Table 4 - Descriptive statistics of elasticity modulus limits for Filtek composite with 2 fiber types, submitted or not to thermocycling, using a single or double layer (MPa).

Fiber type	Thermocycling	Number of layers	Minimum (MPa)	Maximum (MPa)	Mean (MPa)	SD(1) (MPa)	V(2) (%)
Interlig	No	single	64.17	73.24	69.44	3.36	4.84
		double	78.01	117.68	89.25	12.09	13.54
	With	single	75.33	97.72	86.36	7.59	8.78
		double	65.95	89.15	80.71	7.50	9.29
Connect	No	single	72.53	99.29	89.34	8.47	9.48
		double	19.59	32.42	25.19	4.49	17.81
	With	single	78.21	94.64	88.63	5.18	5.83
		double	12.77	41.21	29.51	12.36	41.89

(1)SD = Standard deviation; (2)V = Variance.

experimental groups. Furthermore, the means for groups 6 and 8 were not statistically significantly different; however, these values were statistically different for all the other experimental groups.

Discussion

The objective of the present study was to compare the flexural strength and modulus of elasticity of two systems of reinforcement fibers. In addition, the influence of thermocycling and the number of employed layers of fibers on mechanical features were also evaluated. This study showed that the non-impregnated polyethylene fiber had better flexural strength in comparison to the pre-impregnated glass fiber.

Flexural strength and elasticity modulus are the most important mechanical properties for the evaluation of fiber reinforcement systems. Previous studies have evaluated these physical parameters[8,9] in order to compare restorative and/or reinforcement materials. Thus, the present study, which was intended to compare two reinforcement fiber systems, was also based on the evaluation of the cited variables.

Some controversy surrounds the employment of hand-impregnated fibers in restorative procedures. In the present study, hand-impregnated fibers demonstrated higher flexural strength values. This result contrasts to those reported by Goldberg, Burstone[5] (1998), who concluded that pre-impregnated systems are preferable because they have higher flexural properties due to their higher fiber content, achievable with the manufacturing process. Conversely, Ellakwa *et al.*[10] (2002) found that the use of silane for pre-treating before impregnation with the bonding agent significantly reduced the flexural strength of an ultra-high molecular weight polyethylene fiber. Thus, some pre-treatment procedures could not attain satisfactory results in terms of improving mechanical properties.

Thermocycling is a standard method to evaluate mechanical patterns of restorative and/or prosthetic materials, in order to simulate clinical characteristics. However, in the present study, some groups were not submitted to this simulation and the physical properties evaluated were not influenced by thermocycling. Thus, this issue should be considered in future studies. To the authors' knowledge, no information is available concerning the use of a double layer of reinforcement fiber systems. The reason for testing this alternative approach was to improve the mechanical features of these materials when compared to the standard use of the reinforcement fibers in a single layer.

Conclusions

The findings from the present study showed that the polyethylene fibers in a double layer had a higher flexural strength in comparison to all the other combinations tested. In contrast, the glass fibers did not demonstrate the same results, and the mechanical properties were similar both in single or double layers. Further studies are needed to clarify these questions.

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