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The effects of composition, diameter and post-curing methods on the flexural properties of fiber posts.

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Abstract: Objective: This study evaluated the influence of fiber composition, diameter and post-curing treatments performed at relining on flexural strength and modulus of fiber-posts. Materials and methods: Sixty posts of Reforpost® Glass Fiber [GF]) and Reforpost® Carbon Fiber [CF] (Angelus, Londrina, PR, Brazil) with diameters of 1.0mm and 1.4mm were used. Each group was further subdivided into three subgroups (n=5) according to treatment received: dry-stored control group (C), oven-cured (Ov) or autoclaved (Ac). A universal testing machine measured flexural strength and modulus of all specimens. Results: Post composition and post-curing treatments had no significant effects on flexural properties of specimens while post diameter had significant effects ($p<0.05$). The highest flexural strength and modulus (MPa) (1331±95.8 and 21532±1550, respectively) were obtained with Ov/GF/1.1, while lowest values (890±79.4 and 10675±952, respectively) were for Ac/GF/1.5. Conclusions: 1.1mm diameter posts had better mechanical properties than 1.5mm thick posts. Neither post composition nor post-curing procedures affected the mechanical properties of relined posts.

Keywords: *Postes de fibra, Composición, Diámetro, Post-curado.*
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INTRODUCTION.

Fiber-reinforced composite (FRC) posts have been used for decades as alternatives to the more conventional ones, including prefabricated titanium posts or cast metal posts, as fiber posts offer the advantages of generally having favorable biomechanical and optical properties, eliminating the need for the laboratory intervention, in addition to being easier to remove[1]. FRC posts contain high volume percentages of continuous reinforcing fibers embedded in polymer matrixes that help keeping the fibers together[2].

As previously reported by *in vivo* and *in vitro* studies, the longevity of root-post-core-crown systems is affected by many factors, including those related to post design as length, diameter, shape and passive retention of the posts into the canals, the quantity of remaining tooth substance, including ferrule effect and thickness of root dentin, and cementation related factors as endodontic irrigants/medicaments/sealers, smear layer thickness, luting cements and bonding agents[3].

As opposed to metal or cast posts which fail mostly due to root fracture, the most common cause of reported *in vivo* failure of fiber posts was the pullout of the cement-post-restoration assembly, through debonding between fiber post-resin and/or resin-root canal dentin interfaces as a result of inadequate bond strength or shrinkage stresses generated along canal walls during the polymerization of resin cements[3,4].

Uzunoğlu *et al.*[4] showed that resin cement film thickness influences the bonding of fiber posts. Unless considerable amount of root canal tissue is sacrificed to improve the fitting of the posts with the root canal walls, the resin cement layer would be excessively thick, and bubbles are likely to form predisposing to debonding. Therefore, relining of the fiber posts with composite resins was previously proposed to overcome such a problem[5,6]. Through this technique, the fiber post is covered with composite resin and inserted into the canal, ini-

tially light-cured for 20s, then removed and light-cured for additional 20s. Relining is considered quick and easy as it can be done in one visit[6]. Furthermore, relining increases the adaptation of the post to the canal walls through sliding friction and the pressure during cementation, thus reducing the resin cement thickness, the possibility of void formation and consequently, reducing the possibilities for future cohesive failures[7].

Adequate polymerization of composites is an important factor to ensure good clinical performance[8]. However, the 20s curing time recommended by the anatomic post technique (bulk fill technique) can be insufficient to achieve optimal polymerization of the composite resin used for relining fiber post[9]. Using post-curing methods has been found to further improve the mechanical properties of resin composites used for indirect or semi-direct restorations, with lower final treatment costs[8,10-12].

There are only a few studies that evaluated the effects of post-curing treatments of the relining resin on the mechanical properties of relined fiber posts. Therefore, the aim of this study was to evaluate the influence of post-curing treatments on flexural strength and flexural modulus of fiber posts with different compositions and diameters.

MATERIALS AND METHODS.

Sixty posts, of two compositions (30 each): glass fiber (GF) (Reforpost® Glass Fiber, Angelus, PR, Brazil) and carbon fiber (CF) (Reforpost® Carbon Fiber, Angelus, PR, Brazil) were used in this study. Those were parallel-sided with 2 different sizes (n=15) of 1mm and 1.4mm.

Each group was further subdivided into three subgroups (n=5)[2] according to the treatment received as follows: dry stored, which was used as a control group [C], post-polymerized in an oven at 170º for 10 minutes [Ov], or post-polymerized in an autoclave at 100ºC for 15 minutes [Ac].

A three-point bending test, following the ISO 10477 standard, with a span of 10.0mm, crosshead speed of 1.0mm/min, cross-sectional diameter of loading tip of 2mm, was used to obtain the flexural strength and modulus of all post specimens.

All posts were tested with a universal testing machine (Kratos Ind. Equip; SP, Brazil) at room temperature 25±1ºC. Values of fracture load of the specimens were recorded to calculate flexural strength ($S_f=8F_{max}l/\pi d^3$) and flexural modulus ($E_f=S4l^3/(3\pi d^4)$) where: Fmax is the applied load (N) at the highest point of load-deflection curve, l is the span length (10.0mm), d is the diameter of the specimens (1.1 and 1.5mm), S=F/D; the stiffness (N/m) and D is the deflection corresponding to load F at a point in the straight-line portion of the trace[2].

Three-way ANOVA followed by Tukey's post-hoc tests (SPSS, SPSS Inc., Ill, USA) were used to find significant differences between the groups in order to evaluate the effect of post-curing treatment, posts composition and diameter of the specimens.

RESULTS.

Values of flexural strength and flexural modulus of the tested specimens are shown in Tables 1 and 2, respectively. The ANOVA analyses revealed that post composition and post-curing treatments had no statistically significant effects on the flexural strength and flexural modulus of the specimens (p>0.05).

Table 1. Mean flexural strength values (MPa±SD) of tested specimens.

Experimental Groups	Treatment		
	Control	Oven	Autoclave
GF/1.1^{Aa}	1289±115.8	1331±95.8	1285±100.5
GF/1.5^{Ab}	1055±87.2	1074±100.4	890±79.4
CF/1.1^{Aa}	1279±146.6	1312±115.5	1192±155.6
CF/1.5^{Ab}	1045±93.2	1188±147.4	1048±44.3

Distinct upper case letters represents significant differences between materials. Distinct lower case letters represent differences among diameters within materials. Different symbols represent statistical differences among treatments for the same group (p<0.05).

Table 2. Mean flexural modulus values (MPa±SD) of tested specimens.

Experimental Groups	Treatment		
	Control	Oven	Autoclave
GF/1.1^{Aa}	20866±1874	21532±1550	20792±1626
GF/1.5^{Ab}	12644±1045	12872±1204	10675±952
CF/1.1^{Aa}	20700±2372	21236±1869	19294±2517
CF/1.5^{Ab}	12527±1118	14245±1767 *	12564±531

Distinct upper case letters represent statistically significant differences between materials. Distinct lower case letters represent differences among diameters within materials. Different symbols represent statistical differences among treatments for the same group (p<0.05).

However, post diameter had significant effects on both flexural strength and flexural modulus (p<0.05). GF/1.1 in the (Ov) group obtained the highest mean flexural strength (1331±95.8 MPa) and flexural modulus (21532±1550 MPa) while GF/1.5 in the (Ac) group had the lowest flexural strength (890.3±79.4 MPa) and flexural modulus (10675±951.9 MPa) values.

DISCUSSION.

This study investigated the effects of fiber post composition and diameter as well as the post-curing treatment indicated for the relining composite resin on the flexural strength and flexural modulus of posts. The results showed that while posts of diameter of 1.1mm had significantly higher flexural strength and modulus than those of 1.5mm, post composition (glass versus carbon fiber) did not significantly affect the flexural properties of the posts. Furthermore, this study showed that post-curing procedures for the relining resin, whether using an oven or an autoclave, did not significantly affect the flexural strength and modulus of the relined posts.

Previous clinical and *in vitro* studies showed that the incidence of post debonding, could be reduced with good post fitting, which is a key factor for the clinical success of restorations[13,14]. Therefore, the routine use of anatomic fiber posts was recommended when the prepared root canal is too wide or not perfectly round. The present study showed that post diameter had a significant influence on the mechanical properties evaluated. According to Lassila *et al.*[2], this might be the result of the test setup itself, as when a three-point bending test is used to evaluate the flexural properties of fiber posts, the results are related to the ratio of span length to the diameter of the test setup. Consequently, having the length of the post constant, thinner posts should have superior flexural properties compared to thicker ones[2]. Therefore, the results of our current study suggests using 1.1mm thick anatomic posts than thicker ones (1.5mm), which can be advantageous clinically, since more conservative preparation is needed for thinner posts, ultimately preserving the remaining vital tooth structure. However, only two post diameters were included in this study and future studies should concentrate on evaluating a wider range of post thicknesses before a definite conclusion regarding post diameter can be withdrawn.

On the other hand, the results of this study showed that the type of fibers used, whether glass or carbon fibers, is not a significant factor affecting the flexural properties of fiber-reinforced posts, which is in agreement with Pereira *et al.*[15] This gives the option for the clinicians to select the type of fiber posts according to their personal preferences, or depending on factors as the availability or the costs of the posts, regardless of the type of fibers used.

Some concerns were previously raised regarding the use of the same bending setup, as specified by the International Organization for Standardization, for polymer-based materials composed of more than one phase of materials[2]. However, as concluded by Novais *et al.*[16], the fibers and the matrix in fiber-reinforced materials respond as one homogeneous material. Therefore, the test is considered appropriate on fiber-posts. On the other hand, the variations in coefficient of thermal expansion existing between reinforcing fibers and the matrix polymer used in fiber posts (polymer matrix: 40-80x10^{-6} °C, quartz: 0.2x10^{-6} °C, carbon fiber: 0.4x10^{-6} °C) have to be considered when evaluating the effect of thermal stress

on fiber posts.

Fiber post used in the present study showed superior mechanical properties than fiber posts with similar diameters tested in some previous studies[17-19]. According to Abdulmajeed *et al.*[17], increasing fiber volume fraction enhances the mechanical properties of fiber posts. This might explain the higher values of flexural strength recorded in this study as compared to previous ones as fiber posts used in the present study had 80% and 79% (by volume) of glass fibers and carbon fibers, respectively, which were 10-30% higher than posts used in the previous studies[2,4,19].

The use of post-curin g methods (autoclave, oven or microwave) has been previously found effective in enhancing the mechanical properties of resin composites used for indirect or semi-direct restorations with lower final treatment costs[10]. Autoclave and microwave curing can be considered as clinically-feasible chairside post-curing procedures. Although microwave curing was initially proposed for this study, the fiber posts used had a metallic filament in their core to facilitate their radiographic identification; therefore microwave curing was not used. The results of this current study showed that post-curing treatments did not significantly affect the flexural properties of the relined posts. Those results might indicate that intra-radicular photocuring for 20s followed by further post-curing treatment is recommended to achieve a proper degree of polymerization for the relined posts, without deleterious effect on post flexural properties. Although the results showed no deterioration on the flexural properties of the relined fiber-posts after the application of post-curing treatments, the benefits of using such treatments for the relined posts can be considered questionable, especially taking into account the added time.

Although not statistically significant, fiber posts treated by autoclave, (Ac) groups, showed the lowest values of flexural strength and flexural modulus in this study. A previous study has shown that longer periods of direct water exposure can result in inferior mechanical properties of resins caused by the plasticization of the polymer matrix by water[2]. Although in the present study, autoclave treatment of the fiber posts was only used for 15min, direct water contact at high pressure and temperature had a slightly deleterious effect on their mechanical properties. On the other hand, studies showed that when pre-photoactivated composite resin blocks were treated in an autoclave at high temperature/high pressure (180ºC/250MPa) for 60min there was a significant enhancement in their mechanical properties[20], suggesting that this new approach can provide dental resin composite blocks with superior mechanical properties and is suitable for CAD/CAM processing. Future studies should be directed towards investigating the applicability of this approach for the production of intra-radicular posts and cores in composite resins processed by CAD/CAM and thus, dispensing the use of fiber posts.

Although adhesion to the root canal is the weakest point of the restoration, failures can also occur at the fiber post/resin composite level due to the absence of chemical interaction between the methacrylate-based resin composite and epoxy resin matrix of the fiber posts[20]. Chemical and micromechanical treatment of post surface has been proposed to improve the resin cement/post adhesion mechanism with promising results[21]. In the same manner, the chemical interaction between silane and the inorganic surface of the fiber post can be optimized by heating[20]. Therefore, although the results of this study did not find a significant positive effect for using post-curing methods for relining fiber-posts, further studies should be conducted to evaluate the effect of post-curing treatments on bond strength at relining composite resin/fiber post interface and at the relining composite resin/resin cement interface before their use is justified clinically.

CONCLUSION.

Within the limitations of this study, the following conclusions can be withdrawn: post-curing treatment techniques and post composition did not affect the flexural strength and flexural modulus of fiber posts. These techniques can be used to improve the degree of conversion of relining composite resin without affecting flexural properties of fiber posts. The 1.1mm thick posts had superior flexural strength and modulus than 1.5mm thick posts.

Efecto de la composición, diámetro y método de post-curado en las propiedades flexurales de postes de fibra.
Resumen: Objetivo: Este estudio evaluó la influencia de la composición, diámetro y métodos de post-curado usados para reembasado en la resistencia y modulo flexural de postes de fibra de vidrio. Materiales y Métodos: Sesenta postes de fibra de vidrio [GF]) y de carbono [CF] (Reforpost®, Angelus, PR, Brazil) con diámetros entre 1 y 1,4mm fueron utilizados. Cada grupo fue subdividido en 3 subgrupos (n=5) según el tratamiento recibido: grupo control almacenado en seco (C), post-curado en horno (Ov) o autoclavados (Ac). Las pruebas de medición de resistencia y modulo flexural fueron ejecutados en una maquina de pruebas universal. Resultados: La composición y los métodos de post-curado no tuvieron influencia significante en las propiedades testadas. Por otro lado, el factor diámetro tuvo influencia significante (p< 0,05). Los mayores valores de resistencia flexural y modulo flexural (MPa) (1331±95,8 y 21532±1550,0 respectivamente) fueron obtenidos con Ov/GF/1,1, mientras que los valores mas bajos (890±79,4 y 10675±952, respectivamente) fueron para Ac/GF/1,5. Conclusiones: Los postes de 1,1mm de diámetro presentan mejores propiedades mecánicas que los de mayor diámetro. La composición de los postes y el método de post-curado no afectaron las propiedades testeadas.

Palabras clave: *Postes de fibra, Composición, Diámetro, Post-curado.*

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