

Fracture load and shear stress of prefabricated glass fiber posts

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Aim: This study evaluated the fracture load and pattern failure of different prefabricated glass fiber posts (GFPs) of the same diameter. **Methods:** Seventy-eight (n=13 for six groups) GFPs of 1.6 mm coronal diameter of different brands were evaluated— Exacto (Angelus), Power Post (BM4), White Post DC (FGM), HiRem (Overfibers), Maquira fiber post (Maquira), and Superpost (Supodont). The posts were subjected to fracture load testing (45° of inclination and 1 mm/min until fracture). Each factor (load (N) and shear stress (MPa)) was analyzed separately using one-way ANOVA followed by the Tukey test ($\alpha=0.05$). **Results:** The type of failure was evaluated on a stereomicroscope ($\times 10$). The Power Post samples presented higher values of fracture load ($p<0.001$) followed by Maquira fiber post, White Post, HiRem, Superpost, and the Exacto posts. The failure pattern observed was intralaminar mode II in-plane shear, such as a failure occur parallel to fibers. **Conclusion:** Despite the same diameter of GFPs, the fracture load and shear resistance were brand-dependent.

Keywords: Glass. Materials testing. Stress, mechanical. Flexural strength.



Introduction

After endodontic treatment on teeth (ETT) with extensive mineral tissue loss, an intraradicular post can improve the retention of the coronal restoration¹, considering the quantity and quality of the dental remaining². When the remaining is higher than 2 mm, prefabricated glass fiber posts (GFPs) can be used; otherwise, a cast post and core are preferred³.

Glass fiber posts are usually used in dentistry because they present adequate adhesion to mono- and dimethacrylates⁴, good aesthetic properties, and clinically higher survival rates⁵⁻⁷. The GFPs are composed of unidirectional fibers, lying parallel to each other (carbon, quartz, or glass), and a polymer matrix. The polymer matrix is a highly cross-linked structure composed of epoxy polymers of a high conversion degree⁸. The performance of fibers is influenced by the type, orientation, adhesion to the polymer matrix, and impregnation of the polymer matrix on the fibers⁹.

The fibers are responsible for tensile resistance, whereas the matrix supports the compression stresses¹⁰. The union between the fibers and the polymer matrix is an important factor that can influence GFP resistance⁸. During the manufacturing process, a silane layer is applied on the fibers (inorganic portion) to improve the adhesion with the resin matrix (organic portion)¹¹. Another step in the manufacture of GFPs that improves the mechanical properties is the pretension of fibers. This process occurs before matrix incorporation, enabling fiber resistance at tensile stresses when the post is exposed to bending forces¹⁰. Wandscher et al.¹² (2015) showed that the shear stress was similar among fiber posts of different diameters of the same brand when tested with a 45° loading (except for 1.4 mm). Besides, Wandscher et al.¹³ (2016) showed that an endodontically treated tooth restored with fiber post and metal-ceramic crown failure with similar characteristics (scallops, consequences by shear stress) at *in vitro* studies^{12,14,15}. So, a sequence of events can lead to the ultimate failure in anterior ETT restored with posts due to shear stresses that is present in the central region of the restorer assembly during the load application, inducing adhesive failures in the post/cement/dentine interfaces¹⁶. Thus, the question is, which fiber post is less flexible to minimize the shear stresses? GFPs from different manufacturers exhibit a wide variation because of different fabrication processes. Thus, the aim of the present study was to evaluate the fracture load and the pattern failure of different prefabricated GFPs of the same diameter commercially available in the Brazil. The null hypothesis tested was that there is no difference between brands.

Materials and methods

Seventy-eight GFPs of 1.6 mm coronal diameter were allocated to six groups ($n=13$) based on their manufacturer (Table 1). The coronal distance was set to 6 mm with a digital caliper. The posts were fixed in a parallelometer and embedded in PVC cylinders with a self-cure acrylic resin (VIPI Flash, VIPI, Pirassununga, SP, Brazil) to the reference of 6 mm.

Table 1. Experimental groups

Groups/posts	Brands	Composition*
EX	Angelus, Londrina, PR, Brazil	Glass fiber (80%) Epoxy resin (20%)
PW	BM4, Maringá, PR, Brazil	N/A
WP	FGM, Joinville, SC, Brazil	Glass fiber (80%) Epoxy resin (20%)
HR	Overfibers, Mordano, BO, Italy	Fiber Glass (65–72%) Epoxy Resin (35–28%)
FP	Maquira, Maringá, PR, Brazil	N/A
SP	Superdont, Rio de Janeiro, RJ, Brazil	N/A

* According to the manufacturers' brochures. N/A—not available.

Fracture loading test

The specimens were positioned at 45° (in relation to the horizontal plane) in a universal testing machine (DL-1000, Emic, São José dos Pinhais, Brazil), and a cylindrical piston of planar tip (ϕ : 6 mm) applied a load at the rate of 1 mm/min on the more coronal portion of the post until fracture. The force (N) on the fracture moment was recorded, and the shear stress (MPa) was calculated according to Wandscher et al.¹² (2015):

$$t = 16F_{\max} \cos 45 / 3\pi D^2 (1)$$

Where t = shear stress, F_{\max} = maximum force to fracture (N), $p = 3.14$, D = diameter of the specimen.

Failure analysis

After the fracture loading tests, the samples were submitted to failure analysis on a stereomicroscope (Discovery V20; Carl Zeiss, Germany) on X10. Representative images were observed in scanning electron microscope (SEM) (VEGA3, Tescan).

Statistical analysis

The mean values of the force/load (N) and the shear stresses (MPa) were analyzed using one-way ANOVA and the Tukey test ($\alpha=0.05$), after to prove the normal distribution and equality of the data with Shapiro-Wilk and Levene tests, respectively.

RESULTS

The statistical analysis showed differences between groups, in terms of force values and shear stresses, wherein the PW group exhibited the highest values followed by FP, WP, HR, SP and EX groups ($p<0.0001$). The fracture load and shear stress values are listed in Table 2.

The pattern of failure is presented in Figure 1 and 2 (stereomicroscope and SEM respectively). It was possible to observe that all specimens fractured with a central longitudinal crack perpendicular to the direction of the applied force.

Table 2. Fracture load (N) and shear stress (MPa) of the glass fiber posts.

Groups	Load/Resistance \pm Standard Deviation*	
	Fracture (N)	Shear (MPa)
PW	137.1 \pm 9.5 ^a	63.7 \pm 4.4 ^a
FP	119.5 \pm 19.6 ^b	55.5 \pm 9.1 ^b
WP	112.2 \pm 15.7 ^{b,c}	52.1 \pm 7.3 ^{b,c}
HR	110.15 \pm 20.4 ^{b,c}	51.2 \pm 9.5 ^{b,c}
SPT	103.5 \pm 11.6 ^{b,c}	48.1 \pm 5.4 ^{b,c}
EX	100.1 \pm 6.5 ^{c,d}	46.5 \pm 3 ^{c,d}
p-value	<0.0001	<0.0001

*Different letters indicate statistically significant differences. One-way ANOVA was performed separately for fracture and shear stress.

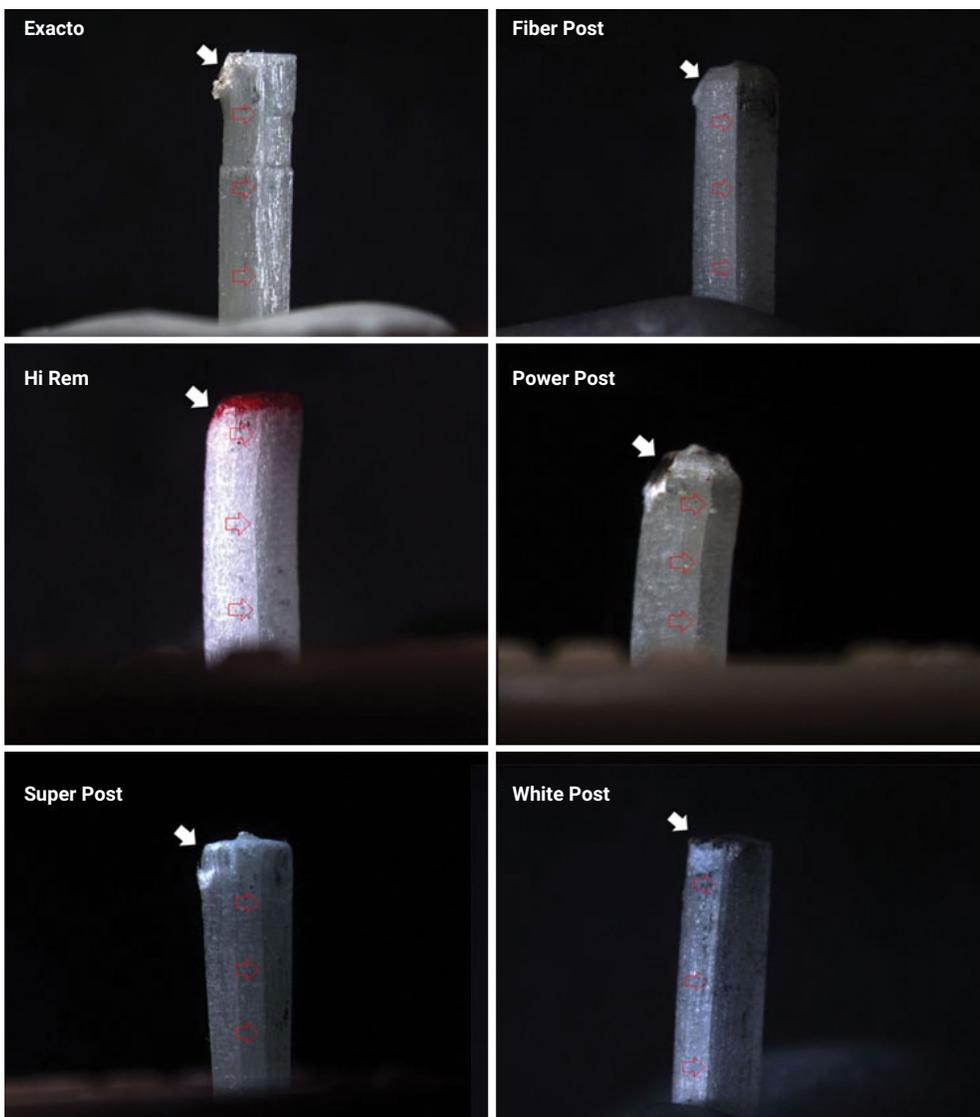


Figure 1. Representative images of the failure pattern. We can observe that the cracks occurs in the center of the specimen (red arrows), which is a characteristic of failure by shear stresses. The white arrow indicates the load application sense.

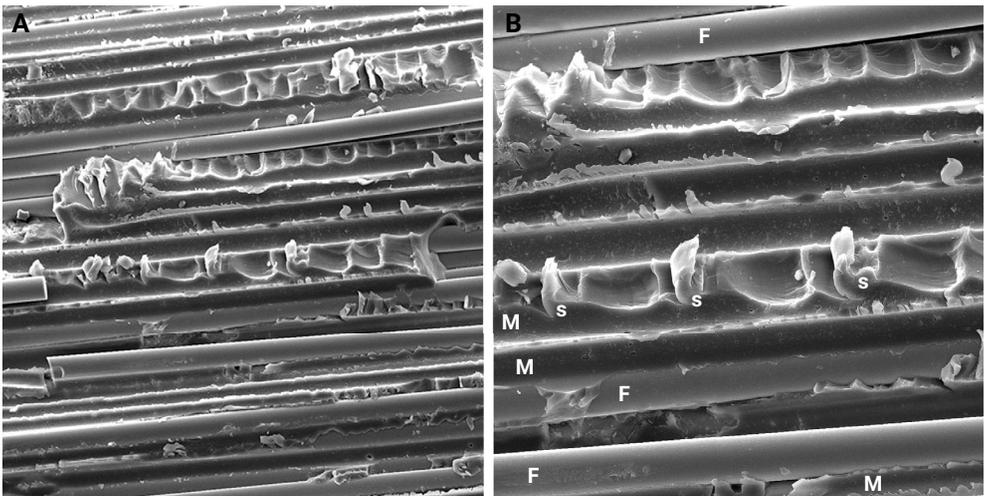


Figure 2. SEM images of the shear failures in the GFPs. A. Representative SEM of the WP group x500. B. SEM (x1000) of the WP group presenting the F: glass fiber, M: epoxy matrix and S: scallops (undulations on the epoxy matrix consequences of the shear stresses).

DISCUSSION

The results of the current study showed statistical difference between the tested groups; thus, the hypothesis that there is no difference between brands was rejected. The PW group exhibited higher values, and the EX group exhibited smaller values. As the samples were of same diameter and, basically, of the same composition (of glass fiber and epoxy matrix), the difference between groups should be explained by factors such as fiber/matrix proportion, the diameter and pretensioning of the fibers, and fiber/matrix union. In addition, possible errors in the manufacturing process such as bubble incorporation and empty spaces can jeopardize the mechanical properties of GFPs. It may be concluded that the shear stress and diameter are not correlated because the shear values did not change for the different diameters¹².

However, one factor makes the discussion of the results difficult: the exact composition of the GFP. The difficulty arises especially because some manufacturers do not present this information explicitly. The brochures present only the basic composition (glass fiber and epoxy resin). Data such as fiber diameters, type of glass fibers, pretension of the fibers, and application of a coupling agent (silane) on the fiber are not disclosed. A higher fiber/matrix ratio is reported to generate a higher loading fracture^{8,17}. However, if the link between fibers and the matrix is not adequate, no improvement occurs⁸. This fact can explain the small value of the loading found for the EX group, although posts from this group contain 80% of fibers. Bubbles and empty spaces left during the fabrication process may cause inadequate fiber/matrix union, consequently leading to the formation of structural defects propagating failure¹⁸.

On the other hand, during the fabrication process, fiber treatment can improve the mechanical properties of GFP. Pretension of fibers is one way to achieve it. In this process, the fibers are pretensioned, incorporated into the matrix, and liberated only

after the complete cure of the epoxy resin. Thus, the fibers are compressed and are able to absorb tensile stresses, when an oblique force is applied¹⁰. Another possibility is the application of a couple agent on fibers before the matrix incorporation, promoting a better chemical union between the fibers (inorganic portion) and the matrix (organic portion)¹⁹.

Despite the diameter of the posts being the same, the diameter of the fiber might have influenced our results. Larger diameters may improve the mechanical properties of GFPs²⁰, since the distribution of these fibers in the matrix are homogeneous²¹.

With respect to failure pattern, most of the specimens presented a longitudinal crack in the center of the coronal portion (Figure 1) because of shear stresses. These failures, classified as intralaminar mode II in-plane shear, are consequences of two important factors: fiber arrangement (parallel, 0°) and shear stress. An important feature are the scallops in the epoxy matrix (figure 2) consequences of the shear stresses in the GFPs. These scallops were founded too in other studies^{12,13,15}.

The fracture loading test at 45° evaluated the resistance of fiber-reinforced polymers by simulating the load application in an anterior tooth¹⁷. An oblique force (45°) applied on the post generated tensile stresses on the outer surface and compression stresses on the interior surface causing a dislodgement of the fiber/matrix interface in the center of the specimen and consequently failure by shear stresses^{12,15}. Besides, using finite element analysis, Wandscher et al.¹² (2015) showed that shear stress on fiber-reinforced polymers is the highest in the center of the specimens and null on the extremities, justifying the failure pattern obtained in the current study. Furthermore, Marchionatti et al.¹⁴ (2014) evaluated the fracture resistance of teeth restored with fiber posts and composite cores and showed that this type of failure also occurs when teeth are restored with fiber posts. Another factor that could influence this type of failure (fiber/matrix interface) is the different elastic moduli between glass fibers and the matrix, because when a load is applied, the stresses converge to this interface⁸.

An important limitation of the current study is that the test evaluated only the mechanical properties of the posts, thus, the clinical significance is to better know the mechanical properties of GFPs. In addition, the posts were submitted only to static loads and this does not occur clinically. Fatigue tests simulate the clinical situation better, because cyclic loads are applied simulating the chewing^{22,23}. Until now, studies are not available that show how much load support an endodontically treated tooth restored clinically with fiber post. In vitro studies as well as clinical studies evaluating the fracture and fatigue of endodontically treated teeth restored with posts are recommended.

In conclusion, despite the diameter of the glass fiber posts being the same, fracture resistance is brand-dependent.

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