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Push-out Bond Strength of Two Fiber Posts in Composite Resin Using Different Types of Silanization

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Clinical Relevance

Silane surface treatment and type of glass fiber post influence bond strength of the post to a composite core.

SUMMARY

Objectives: The aim of this study was to evaluate the effect of different surface treatments and thermocycling (TC) on the push-out bond strength of two brands of glass fiber posts (GFPs) to composite resin. Methods: White Post DC (WP) (FGM Dental Group International, Joinville, Santa Catarina, BR) and Exacto (EC) (Angelus, Clinical Research Dental, Londrina, PR, Brazil). GFPs were cleaned with 70% alcohol and divided into five groups, according to the surface treatment (n=15): control (C), without treatment; prehydrolyzed silane (S-pre) (Prosil, FGM Dental Group International); 37% phosphoric acid + prehydrolyzed silane (AcS-pre); Scotchbond Universal Adhesive System (AdU), 3M Oral Care; two-bottle silane (S2B) (Dentsply Sirona Inc). The composite resin was inserted around the posts by using a split matrix. The samples were cut into 1-mm slices. Half of the samples were subjected to the push-out test immediately, and the other half underwent TC before the test. After failure analysis, the data were submitted to three-way analysis of variance (ANOVA) (α=0.05). Results: EC achieved higher bond strength than WP, regardless of TC (p<0.05). Regarding WP, surface treatments (p<0.001) and TC (p<0.001) influenced bonding strength. As for EC without TC, the highest bond strength (p<0.05)

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was found for C, then AcSpre, S-pre, AdU, and S2B. Application of TC resulted in a statistically higher bond strength values for the EC AcS-pre group (*p*<0.05), followed by S2B, S-pre, C, and AdU. The WP failures were predominantly cohesive, similar to the EC AdU and EC S2B groups. The other EC groups showed mostly mixed failures. Conclusions: Surface treatment and TC affected the bond strength to composite resin, depending on which post was used. It is important for dentists to understand the effects of different types of silanization on their chosen post.

INTRODUCTION

Glass fiber posts (GFPs) have been used as an alternative to metal posts when intracanal retention is needed, owing to their high esthetic potential, application technique, dentin-like elastic modulus, and cost.[1-3] The success of the final restoration of teeth treated with GFP depends on the remaining amount of dental structure, the condition of the supporting tissues, the esthetics of the restoration, and the chosen post.[1,4] Good post–composite resin interface quality is also needed for good bonding,[5] which allows post customization (by relining the posts) and the final restoration to be made suitably.[6,7]

However, it is common in clinical practice for failure to occur between the post and the composite resin. Therefore, it is fundamental to select an appropriate post and surface treatment to improve this bonding.[1,8,9]

The mechanical properties of GFP are affected by fiber arrangements inside the post.[4] A parallel fiber arrangement with the fiber orientation along the long axis of the tooth optimizes the flexural properties of the post.[10] The number and the thickness of these fibers also play a role in the strength and stiffness of the post. A higher fiber:matrix ratio leads to greater fracture resistance, whereas a higher number of fibers/mm^2 of post leads to a lower flexural modulus.[11] Exacto GFP (EC) (Angelus) and White Post DC (WP) (FGM Dental Group International) are two GFP options of double conicity—80% of their composition is parallel glass fibers, and 20% is epoxy resin. The two brands have a similar market value; however, they differ significantly in the number of fibers per post and fiber thickness. EC has a significantly greater number of fibers per post, compared to WP DC, but its fibers are thinner.[11] Furthermore, WP DC has “polymerization factors” that FGM Dental Group International failed to divulge when it was contacted; it merely informed the authors that these factors are a business secret. The EC post does not have these factors. Although these brands are macroscopically similar, it is unclear how their microscopic differences interfere in the final restoration.

Silane is commonly used in dentistry, since it is easy to use and to gain access to. It is formed by 3-trimethoxysilylpropylmethacrylate (MPS) diluted in a solution of water and ethanol, and has two functional groups of different polarities—one being alkoxy and the other, methacrylate.[12] The alkoxy group bonds chemically with the inorganic surface of the post, and the methacrylate group polymerizes with monomers of the composite resin. The reaction between the silane and the resinous monomers is induced by reactive free radicals that are created by the photoactivation of initiator components in the resin matrix.[13] It is also believed that silane can increase surface wettability, which helps form chemical bridges through covalent hydroxyl bonds with the substrates.[9,14,15] There are two conventional silane presentations: the prehydrolyzed (1-bottle) and the nonhydrolyzed (2-bottles) version; in the latter, the hydrolysis process occurs only when mixing the silane and an acid.[9,12] It is known that this last system has a longer life span and that atmospheric humidity acts against the prehydrolyzed form.[12] In addition, authors have found that this particular system can enhance the hydrolytic stability of the GFP–composite resin interface.[16] Notwithstanding this added feature, some studies have shown that both presentations act to increase the bond strength between post and resin,[12] whereas others deny this statement.[9,17] Some authors have proposed previous use of phosphoric acid to optimize its performance.[18] It is believed that this acid can increase the surface energy of the post by degreasing it, increase its wettability, and change its topography, resulting in greater contact surface between post and resin.[9] Other authors, however, did not find that bonding improved when the fiber post was treated with phosphoric acid prior to silanization.[19] The complete reaction mechanism of silane is an issue that is still not fully understood.[12]

There are also adhesives modified by silane. The Scotchbond Universal Adhesive System (3M ESPE, St Paul. MN, USA) is a self-etching adhesive system that contains silane in its composition.[20] According to its manufacturer, this adhesive can be applied using both the conventional and the self-etching techniques and is indicated for direct and indirect restorations on virtually any surface, whether enamel, dentin, zirconia, fiberglass, or ceramic. The silane component contained in this adhesive system may increase the adhesiveness of the post to composite resin.[17]

Thermocycling (TC) is normally used to simulate thermal changes that the oral cavity regularly undergoes in daily activities, like chewing food of varying temperatures, drinking fluids, and even breathing, which can interfere with the adhesive interface of the restorations.[21] TC promotes the artificial aging of the sample, thereby allowing samples that have undergone this test to be compared with others that have not. This is an important resource, because it allows researchers to assess how the given surface treatment of a post can behave inside the oral cavity in the long term.[22,23]

The purpose of this study was to evaluate the bond strength of two commercial brands of GFP, submitted to different surface treatments as well as to analysis with and without TC. The tested null hypothesis was that the bond strength between the two commercial brands of GFP to composite resin would be the same, regardless of the surface treatment and application of TC.

METHODS AND MATERIALS

Ethical Aspects

This study was exempted from submission following Research Ethics Committee assessment (protocol number 2017/0859), since it does not involve human beings.

Experimental Design

- Type of study: *In vitro* study, with a completely random factorial structure (2×5×2).
- Experimental units: GFP (N=150, n=15).
- Factors under study:
  - Commercial brand of GFP on two levels: White Post (WP) DC3 GFP (FGM, Joinville, SC, Brazil).
  - Post surface treatment, on five levels: Prosil Silane, FGM Dental Group International (S-pre); phosphoric acid (37%)+Prosil Silane, FGM Dental Group International (AcS-pre); Universal Adhesive System containing silane in its composition, Scotchbond Universal, 3M ESPE (AdU); Silano two-bottle silane (primer and activator), Dentsply Sirona Inc (S2B); control (C), without surface treatment.
  - TC, on two levels: Without (control) and with (5000 thermal cycles).
- Response variable: Push-out bond strength (MPa)—quantitative and qualitative (percentage failure mode)
- Sample size calculation: The means and standard deviations were used to calculate the effect size (f=0.219), based on a pilot study carried out with three specimens. The G*Power 3.1.9.4 software program (Heinrich-Heine Universität, Dusseldorf, Germany) retrieved 13 specimens per group to detect the difference among the groups, at a 0.05 alpha level and 80% power. The final sample size per group was established at 15 specimens to account for potential losses during the study.

Preparation of the Specimens

All the posts were immersed in 70% alcohol for 1 minute. Seventy-five GFP specimens of each commercial brand were randomly divided into five groups, according to the surface treatment (n=15). The application of each treatment is detailed in Table 1.

The posts were fixed in a vertical position using a bisectioned metallic matrix (Figure 1), containing a main central cylindrical hole 10 mm high and 5 mm in diameter, and a secondary central also cylindrical hole 2 mm high and 2 mm in diameter. Opallis DA3 nanohybrid resin (FGM, Joinville, SC, Brazil) was used to fill the matrix; and an Ultraled (Dabi Atlante, Ribeirão Preto, SP, Brazil) light curing unit was applied with a minimal irradiance of 500 mW/cm^2. Then, 2 mm layers of the resin were inserted into the posts laterally, followed by light curing for 40 seconds each, until the entire length of the matrix (10 millimeters) was filled with composite resin.

After the matrix was completely filled, the specimens were removed (Figure 2), stored in 100% humidity, put aside for 1 week, and then sectioned transversely by using a cutting machine with a diamond cutting disc for 1/2” shafts, diameter 4”×0.012” thick in six 1 mm high samples.

Thermocycling

The samples were aged using the following process: 1 week after the samples were cut, three random sections were subjected to TC in an Elquip machine (model MSCT-3e, Salvador, Bahia, Brazil) from the Oral Biochemistry Laboratory of the Institute of Health Sciences, Federal University of Bahia, Brazil. A total of 5000 cycles were performed, with baths at temperatures of 5°C and 55°C, and with a dwell time of 30 seconds in each bath.

Push-out Test

The samples that did not undergo artificial aging were submitted to the push-out test 1 week after sectioning, and those that did were submitted to the test after TC. Each sample was submitted to the micro-push-out test (Figure 3), by using a Universal Testing Machine (model EMIC-DL 2000; EMIC - Instron, Salvador, Bahia, Brazil), and extrusion of the posts was evaluated with the microshear bonding test, showing the results in Newtons (N). The bond strength was calculated in megapascals (MPa) by dividing the maximum force

Table 1: *Materials Used and Method of Application*

Material/ Manufacturer	Composition	Application Mode[a]
White Post DC (WP) GPF - number 3 (FGM, Joinville, SC, Brazil)	Glass fibers (80±5%), epoxy resin (20±5%), inorganic filler, and promoters of polymerization	—
Exacto 3 (EC) GFP - number 3 (Angelus, Londrina PR, Brazil)	Glass fibers (80%) and epoxy resin (20%)	—
Opallis composite resin - shade DA3 (FGM, Joinville, SC, Brazil)	Monomeric matrix: Bis-GMA, Bis-EMA, UDMA, and TEGDMA. Fillers: barium aluminum, silanized silicate, nanoparticles of silicone dioxide camphorquinone as a photoinitiator, accelerators, stabilizers, and pigments. Composite particles range from 40 nm to 3.0 microns (average particle size: 0.5 microns). Inorganic filler loading is about 78.5% to 79.8% by weight and 57% to 58% by volume. Opallis is a nanohybrid resin.	—
Condac 37 phosphoric acid (FGM, Joinville, SC, Brazil)	37% phosphoric acid, thickener, dye, and deionized water	Apply for 30 seconds, wash for 30 seconds, and dry by air jet for 60 seconds
Prosil Silane (FGM, Joinville, SC, Brazil)	MDP, ethanol, and water	Apply a thin layer, wait for 60 seconds and dry with a light air jet for 30 seconds
Silano coupling agent (Dentsply Sirona Inc., Pirassununga, SP, Brazil)	Silane primer: 95% ethyl alcohol and Silane A 174. Activating silane: 95% ethyl alcohol and glacial acetic acid	Apply a thin layer of a 1:1 mixture of each silane after a 5 minute wait, and then dry by light air jet for 30 seconds
Scotchbond Universal Adhesive System (3M ESPE, St Paul, MN, EUA)	MDP phosphate monomer, dimethacrylate resins, Vitrebond copolymer, filler, ethanol, water, initiators, and silane	Apply a thin layer, wait for 60 seconds and dry by light air jet for 30 seconds

Abbreviations: Bis-GMA, bisphenol A-glycidyl methacrylate; Bis-EMA, bisphenol A ethoxylated dimethacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate.
[a] *According to manufacturer's instructions*

values in Newtons (N) by the area of the bonding interface. The following formula was used:

$$\frac{F\,(\mathrm{N})}{2\pi r h}$$

where F is the force obtained in Newtons, "π" is the constant value of 3.14, "r" is the radius of the post, and "h" is the height of each sample, obtained with a digital caliper.

Fracture Mode Analysis

After undergoing the push-out test, the specimens from each group were assessed with an optical microscope at 30× magnification to establish the failure types. The failures were classified as: 1) adhesive failure between resin cement and fiber post, 2) composite resin cohesive failure, 3) post cohesive failure, and 4) mixed failure when a combination of two or more of the failure types were found in the same sample (Figure 4).

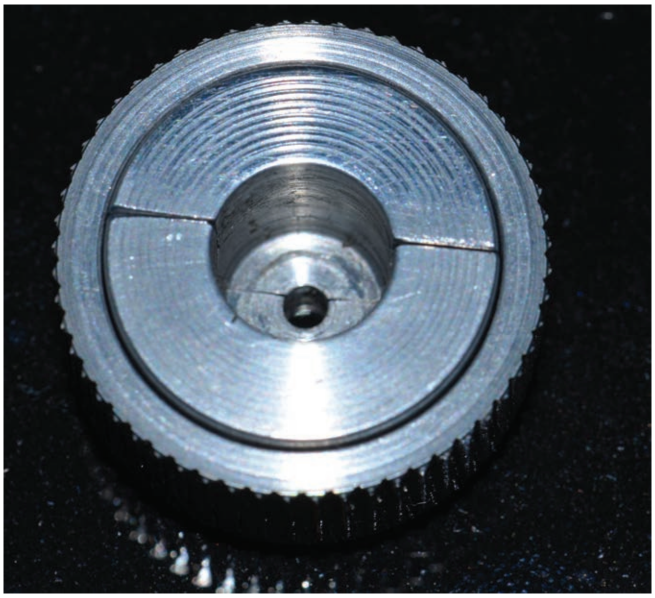

Figure 1. *Bisectioned metallic matrix.*

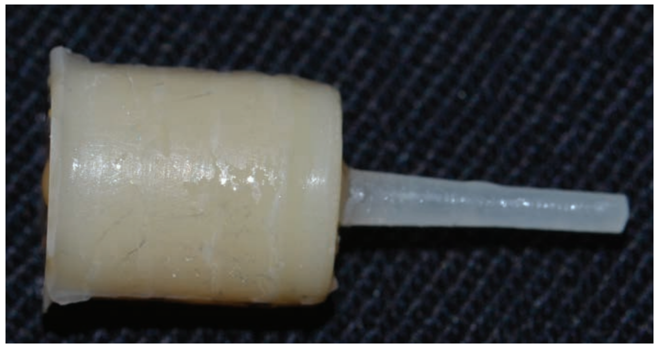

Figure 2. *Post bonded to composite resin before being sectioned transversally.*

Statistical Analysis

The normality and homogeneity of variance were analyzed using the Shapiro–Wilk and the Levene tests, respectively.

Application of the three-way analysis of variance (ANOVA) test investigated the effects of the GFP brand, the surface treatment, and the TC, as well as the triple and double interactions among these three factors. Two-way ANOVA and Tukey tests were used to assess the separate parts of the interactions. The failure modes observed after the bond strength test were presented as relative frequency.

The statistical calculations were performed using the IBM SPSS Statistics version 23 program (SPSS Inc., Chicago, IL, USA), adopting a significance level of 5%.

RESULTS

Three-way ANOVA revealed that the triple interaction between post versus surface treatment versus TC was significant (p=0.042). Two-way ANOVA and Tukey tests were used to evaluate the separate parts of the interaction; the findings are described below.

In regard to WP GFP, application of acid followed by silane and two-step silane were found to provide bond strength values significantly lower than those found for the control group, regardless of whether or not TC was performed (ANOVA: p=0.001). In regard to the universal adhesive system and the prehydrolyzed silane, intermediate values of bond strength were found and did not differ from those of any other treatment. In regard to TC, the bond strength values were significantly lower (ANOVA: p<0.001; Table 2), whether or not the

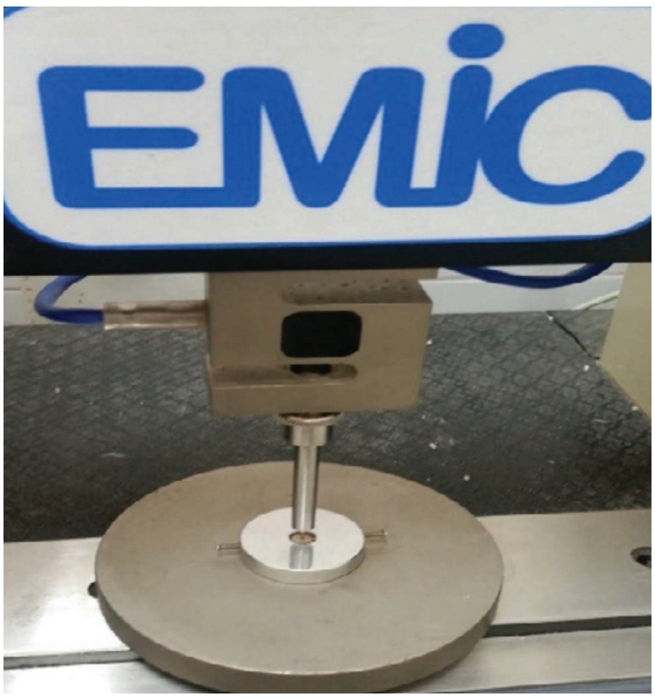

Figure 3. *Push-out test.*

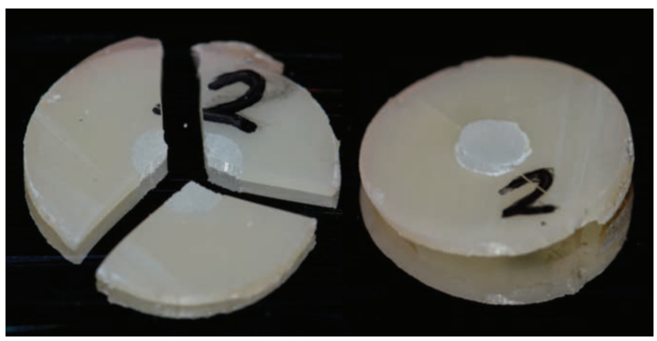

Figure 4. *Representation of the predominant failure types after push-out test. (A) Cohesive failure of post and composite resin; (B) mixed failure, adhesive+cohesive of composite resin.*

Table 2: *Average Values and Standard Deviations of White Post (WP) DC Bond Strength (MPa), According to Surface Treatment and Thermocycling (TC), and Triple Post versus Treatment versus TC Interaction*[a]

Main Factor	Comparison Between Groups				
Treatment	C 4.66 A (1.09)	S-pre 4.22 AB (0.73)	AcS-pre 4.19 B (0.73)	AdU 4.21 AB (0.48)	S2B 3.94 B (0.56)
Thermocycling (TC)	Without 4.62 a (0.79)	With 3.86 b (0.56)	—	—	—

Abbreviations: "—", no data; C, control; S-pre, Prosil silane; AcS-pre, phosphoric acid (37%)+Prosil silane; AdU, Scotchbond Universal; S2B, Silano two-bottle silane.

[a]Different uppercase letters indicate statistical difference between treatments, regardless of TC. Different lowercase letters indicate statistical difference between the means of the specimens tested immediately and those submitted to TC, regardless of the surface treatment.

different surface treatments were applied. The data for WP (Table 2) were grouped together (treatment regardless of TC and then TC regardless of treatment), because these factors did indeed produce an effect, even though there was no interaction between them. Comparatively, the data for EC (Table 3) indicates that there was an interaction between these factors.

Unlike WP GFP, EC GFP showed an interaction between the effects of surface treatment and TC (p=0.019). Analyzing these combined effects, primarily in the case without TC, the Tukey test revealed that the bond strength in the group whose post remained untreated was significantly greater than that achieved with the application of all other surface treatments, except for that in the group treated with phosphoric acid followed by silane. In contrast, this last group presented higher values only in comparison with the group that received the two-step silane, whose values did not differ significantly from those found for the EC GFP specimens treated with the universal adhesive system (Table 3).

Table 3: *Average Values and Standard Deviations of Exacto Post Bond Strength (MPa), According to Surface Treatment and Thermocycling (TC), Considering Triple Post versus Treatment versus Thermocycling (TC) Interaction Separately*[a]

Treatment	Thermocycling (TC)	
	Without	With
C	6.49 (0.96) Aa	5.84 (0.80) Cb
S-pre	6.15 (1.20) Ba	5.86 (1.02) Cb
AcS-pre	6.31 (0.83) ABa	6.54 (0.54) Aa
AdU	5.92 (0.81) BCa	5.02 (0.75) Db
S2B	5.82 (0.75) Cb	6.24 (0.94) Ba

Abbreviations: C, control; S-pre, Prosil silane; AcS-pre, phosphoric acid (37%)+Prosil silane; AdU, Scotchbond Universal; S2B, Silano two-bottle silane.

[a]Different uppercase letters indicate statistical difference between treatments, considering testing with or without TC separately (comparisons in the same column). Different lowercase letters indicate statistical difference between the specimens tested immediately and those submitted to TC, considering each surface treatment separately (comparisons in the same row).

In the case in which TC was performed, the bond strength value of the EC posts treated with phosphoric acid followed by silane exceeded the values found for all the other groups. The treatment that provided the second highest bond strength value for EC posts with TC was two-step silane. Significantly lower values were observed for the silanized (Prosil) and control groups, which did not differ from each other, but were higher than the values of the group that received the universal adhesive system for treatment of the EC post (Table 3).

TC caused a statistically significant reduction in the bond strength of the EC posts of the control group and those treated with silane (Prosil) or with the universal adhesive system. When the treatment consisted of phosphoric acid followed by silane, there was no statistically significant difference between the values obtained with or without TC. In the group that received two-step silane, the bond strength values were significantly higher in the case in which there was TC (Table 3).

Whether the samples were submitted to TC or not, the bond strength values achieved using EC GFP, overall, were significantly higher than those obtained with the WP GFP.

The normality of the data was based on the Shapiro–Wilk tests, which indicated a value of p>0.05 for the variables of the EC post (*p*=0.788), AcS-pre-surface treatment (*p*=0.055), S-pre (*p*=0.096), and control (*p*=0.269), whereas $p<0.05$ was observed for the other variables and for the Levene test. The decision to use parametric statistical analysis allowed the authors to maintain the structure of the triple factorial design of the present study, and based it on a histogram-type graph and a Q-Q plot-type graph, which indicated normal data distribution.

As for the failure mode, as shown in Figure 5, WP had predominantly cohesive post and composite resin failures in all the groups, ranging from 80% to 96% of the failures, with the exception of the AdU and S2B groups with TC, in which case there were 100% cohesive failures. As for the EC post, the AdU and S2B groups followed the same pattern, and obtained predominantly cohesive failures (96% with TC and 98% without TC), but the other groups obtained mostly mixed failures, ranging from 51% to 67%.

DISCUSSION

The results of the present study showed a statistical difference among the groups, thus leading to rejection of the null hypothesis. Comparison of the two different posts tested shows that EC GFP resulted in significantly higher bond strength values than WP GFP. In addition, the posts behaved differently in regard to the surface treatments. Another difference and possible explanation for the results, other than the "polymerization factors" present in WP GFP and absent in EC, can be found in the number of fibers per post. EC has a significantly greater number of fibers (7951 fibers/post) compared with WP (2924 fibers/post).[11] The fibers of EC are thinner; therefore, the resin matrix space between them is smaller. Although the bond strength values were significantly higher for EC, it had more adhesive failures than WP, which had more cohesive failures. The resin matrix space in the GFP is where there is less flexural strength. The fact that this space is larger in WP may lead to cohesive failure of the post when subjected to the push-out test. Nonetheless, when comparing the different groups, this probably does not mean that the GFP is inferior. Because the GFP has thicker fibers, the flexural strength of this post, as a whole, is similar to that of the EC post when evaluated on its longitudinal axis, and its flexural modulus is significantly greater.[11] Both posts, however, have a parallel fiber arrangement. Wandscher and others[4] found that the parallel fiber arrangement in anterior teeth has less fracture resistance when supporting oblique occlusal loads. They also found that fracture occurred in cases associated with other factors, such as the absence of remaining coronal tooth structure and/or lack of occlusal stability, which reiterates the importance of these factors.

As for WP, it was observed in the research herein that the control group (only immersed in 70% alcohol) obtained the highest bond strength value, which was significantly higher than the groups treated with AcS-pre and S2B. No statistically significant difference was

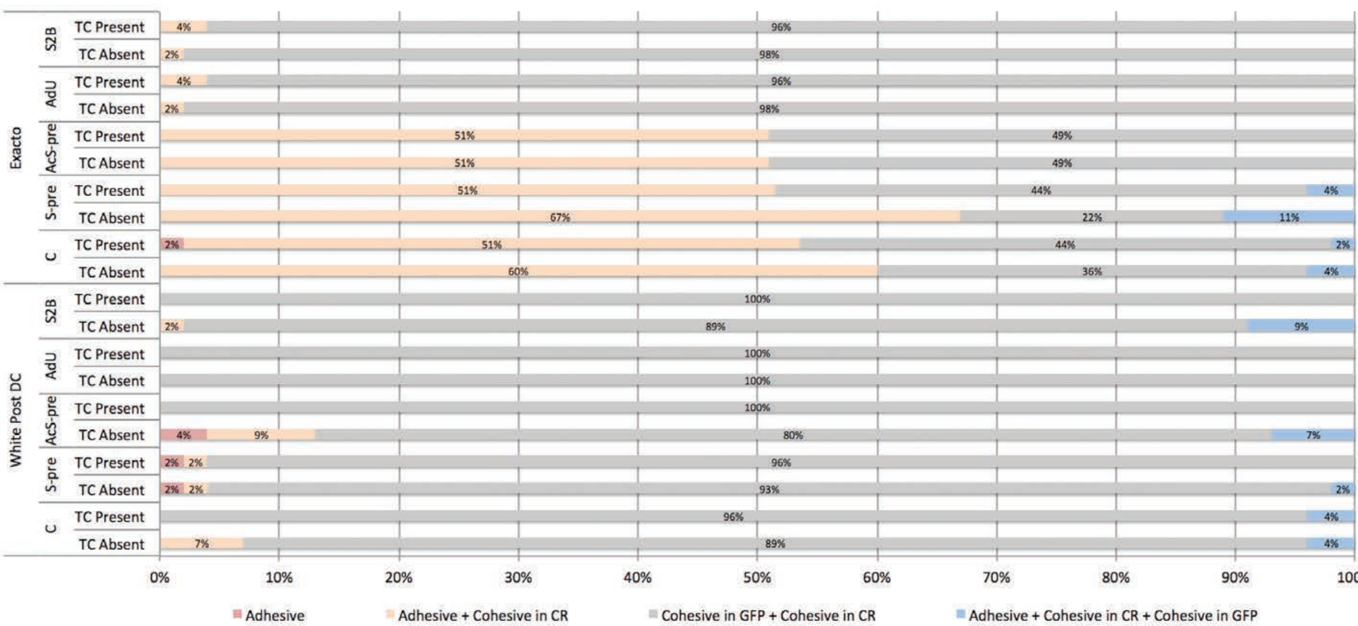

Figure 5. *Relative frequency (%) of failure modes after push-out bond strength testing of GFPs White Post and Exacto, subjected to different surface treatments, according to thermocycling.*

observed between these last two groups or between them and the other groups, with or without TC. When Belwalkar and others[14] tested different surface treatments to determine the bond strength of GFP, they observed that silanization alone did not increase the bond strength of prefabricated posts, compared with the nonsilanized group. They attributed this to the property of silane that increases the wettability of the surface of the post and consequently forms chemical bridges with the monomers of resin cements or composite resin. However, the authors added that the glass fibers in the post they used were protected superficially by epoxy resin (40% of the post), which interfered with this bridge formation. This also may have occurred with the posts in the present study. Furthermore, immersion of GFP in 70% alcohol for 1 minute performed herein was applied in all the groups, including the control group. The alcohol may have increased the surface energy of the GFP, thus increasing its wettability in relation to the composite resin. Since these posts are coated with a layer of epoxy resin, this increase may have been enough to enhance their adhesion. Faria and others[3] observed that using 70% alcohol prior to silane and adhesive promoted significantly higher bond strength results than using just silane and adhesive.

After TC, the bond strength values of the EC post control group decreased significantly, whereas those of the AcS-pre were maintained, and S2B increased significantly. In a systematic review and meta-analysis, Moraes and others[18] found that silanization improves the retention of the GFP only when the post surface is pretreated appropriately before application of silane. This explains why the AcS-pre group behaved the best. Corroborating these results, Li and others[15] found the best results after TC (5000 cycles) in the groups of posts treated with S2B and S-pre. The authors attributed this to the formation of covalent bonds (–Si–O–Si–) between post and resin. Similarly, Daneshkazemi and others[19] evaluated the effect of phosphoric acid, hydrogen peroxide, and silane on the adhesion of GFP to composite resin and found the best results for the group that was treated with phosphoric acid followed by silanization. AcS-pre was the best group for the EC post with or without TC (along with the control group without TC). The significant increase in bond strength values in the EC S2B group after TC may be attributed to induction of late polymerization of the composite resin. Ghavami-Lahiji and others[21] found that the degree of conversion of the tested composite resin after 4000 thermal cycling events increased significantly. The temperature increase provided by TC can promote a diffuse reaction where small molecules can enter the resinous polymer matrix and stimulate free radicals trapped during the resin vitrification phase, to induce late polymerization.[21] The reaction between silane and resinous monomers is induced by these reactive free radicals.[13] A study by Kim and others[16] found that two-step silanization produces a more stable hydrolytic bond between post and composite resin, compared with pre-hydrolyzed silane. This may explain why this study found a significant increase in the EC S2B group and not in the other groups. This more stable bond may have allowed new chemical bridges to be formed after stimulation of free radicals by TC. The same did not occur in the WP S2B group, possibly due to the “polymerization factors.” These factors may have caused a higher conversion rate prior to TC, which led to decreased availability of free radicals. Acidic pH in universal adhesives induces a self-condensation reaction in the silanol groups over time, forming siloxane oligomers, which reduces the effectiveness of universal adhesives.[20] This is in line with the results for the EC post where the universal adhesive behaved worse regardless of TC.

The failure mode analysis of the present study showed almost all cohesive failures of the post and composite resin for all WP groups tested, as well as for the EC, AdU, and EC S2B groups. This corroborates the findings of França e Silva and others,[17] who found predominantly cohesive failures in almost all of their tested groups, including the group treated with the universal adhesive (Scotchbond Universal), which obtained 100% cohesive post and composite resin failures, similar to the equivalent group in the present study. However, the EC C, EC S-pre, and EC AcS-pre groups had more mixed failures (Adhesive+Cohesive of the composite resin). This is partially in line with the results of França e Silva and others,[17] who found mostly adhesive flaws in their control group, whereas the composite resin group remained intact. The present study used Opallis resin, whereas França e Silva and others[17] used Filtek Z250. The latter resin has significantly higher flexural strength values, compared with Opallis resin,[24] thus explaining the cohesive failure of the resin occurring herein and not therein. Since there were mostly cohesive failures of composite resin and post, it is understandable that the weak link of the samples was not the adhesive interface. Therefore, the values in MPa found by using the push-out test in this study were not representative of that area but must be viewed as the least of what can be expected.

The push-out test is appropriate to assess adhesive forces between GFPs and resinous materials, because it simulates clinical conditions better than the other tests.[25-28] However, the test has the disadvantage of having nonuniform stress distribution.[28,29] This negative feature can be offset by cutting the slices in a thickness no greater than 1 mm,[28-30] as was done in the present study. This promotes less variability in the mechanical tests and a more homogeneous distribution of forces.[28,29] This gives the test great clinical relevance,[28,29] which is why it was chosen as the method of evaluation in this study. Moreover, thicker slices may cause the bond strength to be overestimated.[28] However, push-out force is reported to decrease linearly with reduced thickness of the samples.[28] This may be because thin slices may cause a collapse in areas other than the adhesive interface, possibly explaining the high occurrence of cohesive failures seen in this and other like studies.

Normal occlusal forces during chewing range between 20 and 120 N.[31] Shear stress is a tangential force exerted on a contact surface. Considering that the whole post is at least 10× longer than the tested sections (at least 10-mm long), and that ideal conditions of fixation are in place, it can be concluded that under normal conditions shear stress would support at least 10 times the value of the pressure exerted for the rupture of a segment. Thus, analyzing the average values found in N for each of the tested groups (with and without TC), all tested adhesive systems are within the range of normal occlusal forces during chewing. It is worth mentioning that the density and stiffness of dentin is greater compared with composite resin evaluated in the present study, and so dentin is able to support and distribute greater occlusal forces than composites. Consequently, it is possible that under clinical conditions, the final treatment with a GFP, which has an intraradicular portion associated with the filling core, behaves better than that observed in the present study.

CONCLUSION

It can be concluded that immersion of the GFP in 70% alcohol before the insertion of the composite resin in the GFP increases its bond strength. Furthermore, the influence that the different types of surface treatments have on GFPs depends on the type of post used. For WP, no surface treatment other than the immersion in 70% alcohol had the highest bond strength results, while the group treated with 37% phosphoric acid prior to prehydrolyzed silane showed greater and more stable bond strength values for EC. TC influenced the results depending on the post and the surface treatment.

Regulatory Statement

Author represents that the study was performed in compliance with author's institution's appropriate policies. The approval code issued for this study is 2017/0859.

Conflict of Interest

The authors of the present study certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in the present article.

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