# Influence of cement thickness and mechanical cycling on the push-out bond strength between posts and root dentin

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The aim of this study was to assess the influence of mechanical cycling and cement thickness on the bond strength between fiber posts and root dentin. Forty bovine teeth were sectioned (16 mm) and randomly assigned to four groups ($n = 10$). Specimens in Groups 1 and 2 were cemented using a thinner cement layer, while specimens in Groups 3 and 4 were cemented using a thicker cement layer. Groups 2 and 4 were submitted to mechanical cycling. Four slices per specimen were produced and submitted to push-out testing.

Bond strength values were not affected by mechanical cycling ($P = 0.2893$), although the thickness of the cement layer did affect bond strengths ($P = 0.0059$, thinner > thicker). Tukey's test showed that Group 1 (19.27 MPa) had a higher mean bond strength value than Group 3 (12.4 MPa) and Group 4 (13.6 MPa), while Group 2 (15.0 MPa) was statistically similar to all groups. These results indicate that a thicker cement layer negatively affected the push-out bond strength between a fiber post and root dentin, regardless of whether the specimens were subjected to mechanical cycling.

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The association between fiber-reinforced composite posts and endodontically treated teeth when using adhesive and cement systems has presented positive longitudinal results.[1-3] Some authors have attributed this success to the similarity between the mechanical properties of the various materials (post-cement-dentin), which results in a homogeneous system.[4-8]

Attention must be given to the selection of the luting agent. When the cement has good mechanical properties, similar to the modulus of elasticity of dentin, it can act like a shock absorber and increase the lifespan of the restoration.[9] However, if the cement has an elasticity modulus too much higher or lower than that of the other materials, the system can demonstrate an adverse behavior.[9-11]

Similar importance must be given to the cement thickness used for bonding the fiber post to the root dentin. Some studies have demonstrated that a thicker cement layer could damage the fracture resistance of the dental element and the pull-out bond strength between post and root dentin.[12,13] Perez *et al* found that a thicker cement layer surrounding a quartz fiber post did not impair the push-out bond strength of the post to the root dentin in dry conditions.[10] However, to the authors' knowledge, no study has investigated the influence of the thickness of the cement layer surrounding the fiber post cemented into a root canal after mechanical fatigue cycling testing.

The mechanical fatigue test is conducted in a humid environment and can simulate, *in vitro,* the clinical performance of materials and restorative techniques.[14,15] Failures induced by mechanical cycling test occur as a result of the propagation of microscopic cracks from areas of force concentration, similar to clinical evidence.[14,15] In addition, this test can simulate a long clinical period in only a few days, because 1 million cycles correspond to approximately five years of clinical function.[16]

The objective of this study was to evaluate the push-out bond strength between fiber posts and root dentin after mechanical cycling. Additionally, two hypotheses were assessed: First, that a thicker cement film would not significantly affect the push-out bond strength; second, that mechanical cycling would not significantly affect the push-out bond strength.

## Materials and methods

Forty single-rooted mandibular bovine incisors were cleaned with periodontal curettes and stored in distilled water at 4°C until use. The coronal and cervical portions were sectioned with a diamond disc under water cooling to standardize the size of the specimens at 16 mm. The

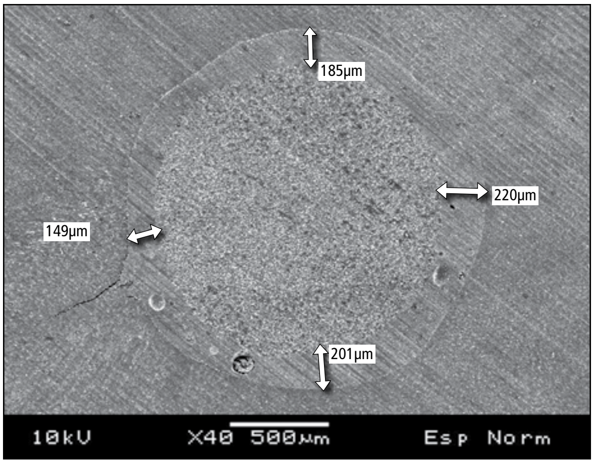


Fig. 1. Post cemented with a lower cement thickness.

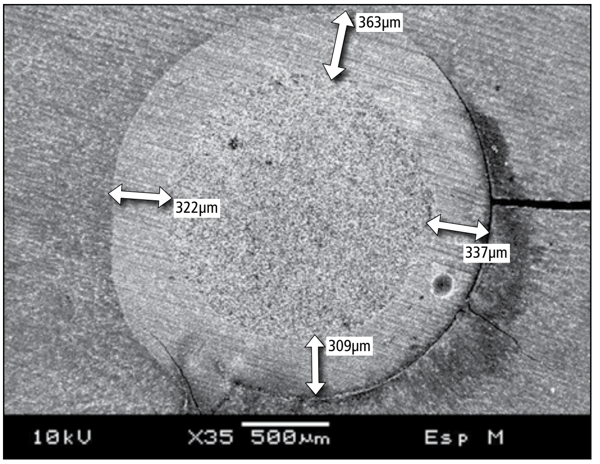


Fig. 2. Post cemented with a higher cement thickness.

coronal diameters of the canals were measured with a Starrett 727 digital caliper (L.S. Starrett Company), and specimens with diameters larger than 1.6 mm were discarded and replaced with other specimens that met this requirement.

The root canals were instrumented and irrigated with Dakin solution (10 mL). The root apices were sealed with a composite resin to avoid overflowing of the adhesive system and resin cements during the experimental procedures. The specimens were randomized into four groups ($n$ = 10). To obtain different cement thicknesses, the specimens were prepared using custom drills of different diameters. Root canals in Groups 1 and 2 were prepared to 12 mm with the No. 1 post system drill (White Post DC, FGM) (Fig. 1), while root canals in Groups 3 and 4 were prepared to 12 mm with the No. 4 post system drill (White Post DC) (Fig. 2).

After root canal preparation, the specimens were embedded into a PVC cylinder filled with a chemically cured acrylic resin (Dencrilay, Dencril Produtos Odontologicos). First, the preparation bur of the post system was placed inside the prepared root canal. Next, the bur (with the root) was attached to an adapted surveyor so that the long axes of the bur, specimen, and cylinder were parallel to each other and perpendicular to the ground. Finally, the acrylic resin was prepared and poured inside the cylinder up to 3 mm of the most coronal portion of the specimen.

### *Post cementation*

For post cementation, the fiber post surfaces (White Post DC No. 1) were cleaned with 70% alcohol and silanized with Prosil (FGM). The root and coronal dentin surfaces were treated with a multiple-bottle, total-etch adhesive system (ScotchBond MultiPurpose, 3M ESPE). The dentin was conditioned with 37% phosphoric acid (Condac 37%, FGM) for 30 seconds, then rinsed and dried with paper points (No. 80). The activator, primer, and catalyst from the adhesive system were applied separately to the root dentin as recommended by the manufacturer, using a microbrush (Cavibrush, FGM).

The dual-cured resin cement (AllCem, FGM) was manipulated and placed into the root canal by means of lentulo drills, and the fiber post was positioned into the root canal. The cement was photocured for 40 seconds (Radii Cal, SDI North America).

### *Mechanical cycling*

Specimens from Groups 2 and 4 were submitted to mechanical cycling using the following parameters: 1 million cycles, a load of 88 N, a frequency of 4 Hz, immersion in water at ±37°C, and an angle of 45 degrees.

Specimens from Groups 1 and 3 were not cycled but were kept in water (±37°C) for three days, corresponding to the same time period for the specimens that received mechanical cycling.

### *Production of disk-specimens and push-out test*

Each specimen was fixed on a metallic base of a sectioning machine (LabCut 1010, Extec Corp.). The first cervical slice (approximately 1 mm) was discarded because of excess cement in that region that

Table 1. Tukey's HSD all-pairwise comparison test of MPa for cycling*thickness.

| Group | Cement thickness | Mechanical cycling | Mean ± SD |
|---|---|---|---|
| 1 | low | no | 19.3 ± 2.3[a] |
| 2 | low | yes | 15.0 ± 7.8[ab] |
| 3 | high | no | 12.4 ± 2.4[b] |
| 4 | high | yes | 13.6 ± 2.8[b] |

Note: Similar superscript letters indicate statistical similarity at $P < 0.05$.

could influence adhesive resistance.[17] Four other sections per specimen (thickness: 2.0 ± 0.3 mm) were obtained (40 per group).

Each slice was positioned on a metallic device with a central opening (Ø = 3.0 mm) larger than the canal diameter. The most coronal portion of the specimen was placed downward. For push-out testing, a metallic cylinder ($Ø_{extremity}$ = 0.8 mm) induced a load in an apical to coronal direction on the post without applying any pressure to the cement and/or dentin. Considering that the specimens were embedded in the epoxy resin parallel to the root axis and that the specimens were sectioned perpendicular to that axis, the post was submitted to parallel pressure to the greatest extent in relation to the root axis.

The push-out test was performed in a universal testing machine (EMIC Ltd.) at a speed of 1 mm/minute. The bond strength (σ) in MPa was obtained using the formula $\sigma = F/A$, where F is the load for specimen rupture (N) and A corresponds to the bonded area ($mm^2$). To determine the bonded interfacial area, the formula to calculate the lateral area of a circular straight cone with parallel bases was used. This formula is defined as $A = 2\pi g (R1 + R2)$, where $\pi = 3.14$, g = slant height, R1 = smaller base radius, and R2 = larger base radius. To determine the slant height, the following calculation was used: $g^2 = (h^2 + [R2 - R1]^2)$, where h = section height. R1 and R2 were obtained by measuring the internal diameters of the smaller and larger bases, respectively, which corresponded to the internal diameter between the root canal walls.[8,18] These diameters and the section height were measured using a Starrett 727 digital caliper. Disk-specimens with cohesive fracture of the fiber post or dentin were excluded from the study because they would not reflect the true push-out bond strength; they also were excluded to avoid misinterpretation of the results.

After push-out testing, the averages of the bond strength values for each specimen were calculated. Considering that each group was composed of 10 specimens, 10 mean bond strength values from each group were used for statistical analysis (two-way ANOVA and post-hoc Tukey's test, alpha = 0.05).

### *Analyzing pushed-out samples*

All tested specimens were analyzed under a light microscope (BX60M, Olympus America) up to 200x magnification to observe the area of failure. Failures were classified as either A1 (adhesive between dentin and cement system) or A2 (adhesive between post and cement system); C1 (cohesive of cement system), C2 (cohesive of post), or C3 (cohesive of dentin); or M1 (mixed failure; adhesive between dentin and cement associated with adhesive between cement and post) or M2 (mixed failure; adhesive failure associated with cohesive failure). Representative specimens from the four groups were selected for analysis in a scanning electron microscope. The selected specimens were mounted on a metallic stub, sputter-coated with gold (DESK II, Denton Vacuum, LLC), and observed under a scanning electron microscope (JSM-6360, JEOL USA, Inc.) at different magnifications.

## Results

During specimen sectioning, one disk specimen from each group was lost; however, the number of disk specimens obtained was sufficient to conduct a test with statistically significant differences.[19] After testing, some post cohesive failures and dentin fractures were observed. These samples were excluded from the results. In Group 2, only nine mean bond strength values were used for statistical analysis because one specimen showed cohesive post and dentin fractures.

The two-way ANOVA showed that the push-out bond strength results were significantly affected by the cement thickness factor ($P = 0.0063$; thinner > thicker), while mechanical cycling did not affect the results ($P = 0.2877$).

The groups with a higher cement thickness (Groups 3 and 4) demonstrated lower bond strengths than the groups with a lower cement thickness (Groups 1 and 2); however, the only significant difference occurred between Groups 3 and 4 with Group 1 (Table 1). In this case, the first hypothesis was rejected. Because there was no significant difference between the groups submitted and not submitted to mechanical cycling, independent of the cement thickness, the second hypothesis was confirmed. Results regarding modes of failures are illustrated in Table 2.

Table 2. Failure modes of specimens submitted to the push-out test.

| | Failure mode | | | | | | |
|---|---|---|---|---|---|---|---|
| Group | A1 | A2 | C1 | C2 | C3 | M1 | M2 |
| 1 (*n* = 39) | 12 | 5 | - | 12 | - | 10 | - |
| 2 (*n* = 39) | 30 | 6 | - | 2 | - | 1 | - |
| 3 (*n* = 39) | 12 | - | - | 1 | 8 | 11 | 7 |
| 4 (*n* = 39) | 15 | 2 | - | 5 | 5 | 10 | 2 |
| Total (*n* = 156) | 69 (44%) | 13 (8%) | 0 | 20 (13%) | 13 (8%) | 32 (21%) | 9 (6%) |

## Discussion

Previous *in vitro* studies used bovine teeth as substitutes for human teeth due to the similarity between these teeth.[20-26] The push-out test was performed because it provides smaller adhesive areas and therefore more uniform stress distribution on the adhesive interface, few lost specimens during experimentation, low standard deviation values, and ease of execution.[27,28] On the other hand, when adhesive areas with high resistance are presented as disk-specimens, the push-out test can induce a failure of another system's structure, such as cohesive post failures and dentin fractures (Table 2).

The results of the current study indicate that push-out testing produced similar bond strength values between the groups with the same cement thickness, without any significant influence from mechanical cycling. This result is in accordance with Valandro *et al* and should be associated with the adequate mechanical properties of the glass fiber posts.[8,11,29-32] According to Spazzin *et al,* these properties provide better absorption of the chewing loads and produce lower overloads to the surrounding structures, creating less stress on the interface areas.[11]

Even though there was no significant influence of the mechanical cycling on the bond strength values, fracture analysis indicated more adhesive failures between dentin and cement in the groups submitted to mechanical cycling than in the noncycled groups (Table 2). These findings indicate that stress on the interface between cement and dentin could be strong enough to cause adhesive failures but not affect bond strength values.[11] The number of cycles in the current study might have been insufficient to simulate a condition able to cause damage to the interface and affect bond strength values. The properties of the glass fiber posts also contributed to these findings.

The highest stress values typically are concentrated at the cement/dentin adhesive interface.[3,30,33,34] Moreover, the adhesive technique is more complicated at this interface, given the potential of low hybridization.[35,36] These points make this region the most critical one in the biomechanical system.[37] Supporting this information, clinical trials have demonstrated that restoration/post debonding is the most common cause of failure for this system.[1,3,38]

When analyzing the influence of different cement thicknesses on the push-out bond strength values, it was observed that the cement thickness affected the results (Table 1). These findings agree with those of D'Arcangelo *et al* but not with those of Perez *et al.*[10,13] The difference between the results of the present study and the one by Perez *et al* can be explained in part by the design of the posts.[10] The current study used double-tapered fiber posts, while the other study used cylindrical fiber posts. This last post design promotes more retention by friction in comparison with double-tapered posts.[39,40] According to Bouillaguet *et al,* bond strength values are inversely proportional to cement shrinkage; therefore, greater cement volume causes more polymerization stress, affecting the adhesion at the interfaces.[41] A thicker cement layer induces the formation of bubbles and voids, weakening areas of the cement agent.[42] Spazzin *et al* used finite element analysis and observed that a thick cement layer had higher stress concentrations at the cement/dentin interface.[11] This could contribute to lower bond strength values in the groups with thicker cement layers.

The current results suggest that a thicker cement layer has a negative effect on the bond strength between cement and dentin. However, independent of cement thickness, mechanical cycling is not able to significantly alter bond strength values. These findings cannot be clinically extrapolated, but they appear to indicate that the cement thickness surrounding fiber posts luted into root canals should be reduced. Clinically based data from randomized controlled clinical trials will be able to define the clinical relevance of this factor on the longevity of this restorative approach.

## Conclusion

A higher cement thickness reduced the push-out bond strength between a fiber post and root dentin and could affect the retention of fiber posts regardless of mechanical cycling. When specimens were submitted to mechanical cycling, bond strength values were similar, regardless of cement thickness.

## Author information

Drs. da Rosa and Bergoli are postgraduate students in Oral Science, School of Dentistry, Federal University of Santa Maria, Rio Grande do Sul, Brazil, where Drs. Kaizer and Valandro are associate professors.

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## Manufacturers

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