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Effect of the interfacial area measurement parameters on the push-out strength between fiber post and dentin

César Dalmolin Bergoli [a], Julia Magalhães da Costa Lima [a], Renata Marques de Melo [a], Marco Antonio Bottino [b], Luiz Felipe Valandro [c,*]

[a] Sao Jose dos Campos Dental School, Sao Paulo State University (UNESP), Street Francisco José Longo, No. 777, Jardim São Dimas, São José dos Campos, CEP 12245-000, São Paulo, Brazil

[b] Department of Dental Materials and Prosthodontics, Sao Jose dos Campos Dental School, Sao Paulo State University (UNESP), Street Francisco José Longo, No. 777, Jardim São Dimas, São José dos Campos, CEP 12245-000, São Paulo, Brazil

[c] Prosthodontics Unit, Faculty of Odontology, Federal University of Santa Maria, Brazil Street Floriano Peixoto, 1184, 97015-372 Santa Maria, Rio Grande do Sul, Brazil

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ABSTRACT

Purpose: To verify the influence of different instruments and operators on the bonding interfacial area and on the push-out bond strength values.

Material and methods: Fifteen anterior human teeth ($n=15$) were selected, cleaned and standardized to 15 mm length. Root canals were prepared in 12 mm and the fiber posts were cemented using the RelyX U-100 cement. Three slices were obtained per tooth ($N=45$) and submitted to the push-out bond strength test. The bonding interfacial area (mm^2) of each specimen was calculated based on the disc slice dimensions: coronal and apical diameter and height. The bonding area of each specimen was used to calculate the bond strength (Mpa). The dimensions were analyzed by different operators, using two instruments: G1 – Operator A with a digital caliper; G2 – Operator A with a stereomicroscope; G3 – Operator B with a digital caliper; G4 – Operator B with a digital stereomicroscope; G5 – Operator C with a digital caliper; G6 – Operator C with a stereomicroscope. The mean area was submitted to inter-operator and intra-operator analyses, while the mean area and mean of bond strength were submitted to the 2-way ANOVA with repeated measures and the Tukey test ($\alpha=0.05$).

Results: The inter-operator kappa was 0.83 to the digital caliper and 0.91 to the stereomicroscope, while the intra-operator kappa was 0.76. The operator and the measurement instrument influenced the interfacial bonding area ($p=0.000$ and $p=0.001$) and the push-out bond strength values ($p=0.000$ and $p=0.000$, respectively) of the disc slices.

Conclusion: The final push-out bond strength values are influenced by the measuring instrument and by the measurer operator.

1. Introduction

The development of adhesive systems has changed conservative dental treatments worldwide and has promoted the emergence of new restoration techniques [1,2]. Among these new techniques, coronal reconstruction and root reinforcement, performed with the help of fiber posts, allow the preservation of large amounts of tooth structure and decrease the risk of root fractures because of the good mechanical properties of the fiber posts [3–7]. However, clinical studies have shown that the main type of failure of these restoration techniques is post debonding [8–10].

Randomized clinical studies provide the highest level of scientific evidence for evaluating the materials used to cement fiber posts. However, performing such clinical studies is difficult because of the high costs and long follow-up periods involved [11]. Therefore, performing laboratory tests is important for bond strength evaluation as well as for qualitative comparisons of different materials used for cementation under the same test conditions [11].

According to Goracci et al. [12] the push-out test, which evaluates the bond strength between fiber posts and root dentin, is more reliable than the microtensile test. The push-out test shows less variability, can record low levels of bond strength, and is easy to perform [12].

* Corresponding author. Tel.: +55 55 3220 9276; fax: +55 55 3220 9272.
E-mail address: lfvalandro@hotmail.com (L.F. Valandro).

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To determine the value of bond strength (MPa) between the fiber post and the root dentin, the rupture force (N) of the bond between cement and root dentin is divided by the adhesive interfacial area of the specimen (mm^2). The rupture force (N) is usually analyzed using the load cell of the testing machine. For determining the adhesive area, the height (h) of the disc slice and the diameter of the post space (d) need to be measured; measuring these dimensions is an important step in the experiment because these dimensions influence bond strength calculations.

Previous studies have used either calipers or stereomicroscopes to measure the height and diameter of the specimens [13–17]. However, no consensus has been reached about a standardized tool for the verification of these important dimensions, and no literature is available on possible interoperator variability with regard to the measurement of these values. Clarifying and resolving these standardization and variability issues can bring important information regarding whether comparisons between such studies are valid.

Therefore, we aimed to evaluate the influence of different operators and instruments on the values of bonding area of the specimens and, consequently, the values of bond strength. The hypotheses were the following: (1) the adhesive area of the specimens and (2) the bond strength values would not be influenced by the different operators or by the type of measuring instrument.

2. Materials and methods

2.1. Specimen selection

This study used 15 anterior human teeth (central and lateral incisors). After selection, the teeth were disinfected and stored in distilled water at 4 °C until use.

2.2. Endodontic procedures and root preparation

The coronal portions of all the teeth were removed by cutting with a cylindrical diamond bur at high speed under copious water cooling; the length of the remaining root was standardized to 15 mm. The diameter of the coronal portion of the root canals was measured in the buccolingual and mesiodistal directions, and teeth with coronal diameters greater than the coronal diameter of the White Post DC #4 (FGM, Joinvile, SC, Brazil), a cylindrical–conical post with coronal diameter of 2.2 mm and apical diameter of 1.45 mm, were discarded and replaced with other teeth that met this requirement. The root canals of all the specimens were manually instrumented with endodontic files #40 (Dentsply-Maillefer, Petropolis, Rio de Janeiro, Brazil) under constant irrigation with Dakin′s solution to remove intraradicular pulp. Subsequently, a 12-mm-long portion of the root canal was prepared using the low-speed post drills of the post system. The apices of all the specimens were sealed using an adhesive system (Single Bond 2; 3M ESPE, St. Paul, MN, USA) and a composite resin (Opallis; FGM, Joinville, Brazil) to avoid resin cement overflow. After the canal preparation the apical portions of the specimens were embedded with acrylic resin (Dencrilay; Dencril, Caieras, SP, Brazil). For that a drill was fixed inside the root canal and the assembly was adapted to a surveyor, maintaining the specimen parallel to the vertical axis and perpendicular to the horizontal axis (ground). Thus, the apical portion of the specimen was inserted into a plastic matrix and the acrylic resin poured into [13].

2.3. Post cementation

The surfaces of the fiber posts were cleaned with 96% alcohol. Silane agent (Prosil; FGM, Joinville, Brazil) was applied with a microbrush (Cavibrush; FGM, Joinville, Brazil) and was left undisturbed for 2 min. For cementation, equal amounts of the base and catalyst of a self-adhesive resin cement, RelyX U100 (3M ESPE, St. Paul, MN, USA), were mixed, inserted inside the canal and applied on the fiber-post surface using a syringe (Centrix; DFL, Rio de Janeiro, RJ, Brazil) with AccuDose™ tips. The post was cemented inside the canal, the excess resin cement was removed, and photopolymerization was carried out through the coronal portion of the fiber post for 40 s (Radii-Cal, SDI, Australia).

To standardize these procedures, all the cementation procedures were performed by a single operator, who had been previously trained.

2.4. Specimen preparation

At 24 h after cementation, the specimens were fixed to a metal base coupled to a cutting machine (LabCut 1010; Extec Corp., Enfield, CT, USA), with the root axis perpendicular to the diamond disc sectioning, and three disc slices of 2.0 mm thickness were obtained per specimen ($N=45$).

2.5. Push-out strength test

Immediately after sectioning, each specimen was positioned on a metallic device with a central opening ($\varnothing=3$ mm) that was larger than the diameter of the radicular canal. The cervical face of the specimen was positioned downwards, and a metallic cylinder ($\varnothing=0.85$ mm) coupled to a load cell, with a capacity of 50 kgf, was attached to a universal testing machine (EMIC DL-1000, Emic, São Jose dos Pinhais, Brazil) that induced load at a speed of 1 mm/min on the central portion of the fiber post.

The same operator performed both the sectioning and the push-out test.

2.6. Failure analysis

Failure analysis was performed using a stereomicroscope (Mitutoyo MF, Japan) with a magnitude of 50 ×. The failures were classified as follows: adhesive failure between resin cement and dentin, adhesive failure between fiber post and resin cement, cohesive failure of dentin, cohesive failure of fiber post, and cohesive failure of resin cement. Samples with fiber post or dentin cohesive fractures were excluded and new specimens were cemented to replace them.

2.7. Adhesive area calculation

To calculate the adhesive area, the formula for calculating the lateral area of a right circular cone with parallel bases was used: $A=\pi g(R_1+R_2)$, where A is interfacial area, $\pi=3.14$, g is frustum of the cone, R_1 is radius of the smaller base, and R_2 is radius of the larger base. To calculate the cone frustum, we used the formula $g^2=h^2+[R_1-R_2]^2$, where h is thickness of the specimen.

2.8. Evaluation of the specimens′ dimensions

The larger diameter, smaller diameter, and height of the specimens were measured using two different instruments: a measuring microscope (Mitutoyo MF, Japan) with a magnitude of 30 × and a digital caliper (Starrett® 727; Starrett, Itu, SP, Brazil). All the specimens were measured by three operators who used only these two instruments for measuring the dimensions.

Thus, considering the factor "operator" at three levels and the factor "measuring instrument" at two levels, the study had six experimental groups (Table 1). The study was not disclosed to the operators to avoid influencing the factors and outcomes.