

# Effect of Operator Experience on the Outcome of Fiber Post Cementation With Different Resin Cements

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## Clinical Relevance

RelyX U100 (commercially available outside Brazil as RelyX Unicem) was shown not to be affected by the operator's experience and therefore seems to be more suitable for use by less experienced clinicians.

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## SUMMARY

**Objectives:** To evaluate the influence of operator experience (dentist vs student) and cementation system (Adper Scotchbond Multi-Purpose [SBMP] + RelyX ARC [1]; Adper Single Bond 2 [SB] + RelyX ARC [2] and RelyX U100 [3]) on the push-out bond strength (BS) of fiber post to radicular dentin.

**Materials and Methods:** The roots of 48 extracted human maxillary central incisors were prepared and divided into six groups (n=8), according to combination of the above factors. Glass fiber posts were cemented in accordance with the instructions of the manufacturer of each cementation system. After water storage at 37°C for one week, the roots were cross-sectioned into six 1-mm thick slices and the push-out test was performed (0.5 mm/min). Data were statistically analyzed by two-way analysis of variance and Tukey tests ( $\alpha=0.05$ ). The BS results obtained by dentist and student

for each cementation system were compared using the Student *t*-test ( $\alpha=0.05$ ).

**Results:** Higher BS means were observed for the expert operators, irrespective of the cementation system used ( $p=0.006$ ). RelyX U100 showed the highest bond strength, but it did not differ from SBMP + RelyX ARC. The Student *t*-test revealed that only RelyX U100 was not affected by the operator's experience.

**Conclusion:** Within the limitations of this *in vitro* study, it can be concluded that the self-adhesive cement RelyX U100 showed the highest bond strength to the root canal in the student's group, and its performance was not affected by the operator's experience.

## INTRODUCTION

Teeth with extensive loss of dental structure frequently require endodontic treatment, and in the majority of cases, this leads to the use of intraradicular retainers and filling cores to retain the final restoration.<sup>1</sup> Moreover, to restore these teeth, an interesting option has been to use materials with a modulus of elasticity similar to that of dentin resulting in biomimetism between the properties of dentin and the post/cement set. This favors a more uniform stress distribution in the root structure and thus reduces the risk of root fractures.<sup>2-4</sup> However, bonding posts to root walls is compromised by many factors such as timing of post space preparation and cementation,<sup>5</sup> type of post and its adaptation to the post space,<sup>6,7</sup> type of adhesive and cementation system,<sup>8,9</sup> and operative procedures.<sup>10</sup> Furthermore, it is difficult to achieve direct irradiation by light in deep regions of the root canal, and to overcome this, it is necessary to use resin cements with chemical or dual activation.<sup>11</sup>

As this procedure is technically complicated, the operator's experience may directly affect the quality of this restorative procedure. It has indeed been proved that there is a variability in the results of adhesive procedures resulting from the operator.<sup>12,13</sup> Other authors have demonstrated that failure to follow the manufacturers' recommendations also affects the bond strength results.<sup>14,15</sup> Nevertheless, there is little related information in the literature, on how the operator's experience may influence the success or failure of procedures for adhesive cementation of intraradicular posts.<sup>16</sup>

One may hypothesize that materials/techniques with fewer bonding steps may be less sensitive to technique variables. Differently from the traditional

resin cements, self-adhesive materials require no previous treatment of the dental substrate, since the stages of acid etching and adhesive system application have been eliminated.<sup>17</sup> Based on this, the aim of this study was to evaluate the influence of the operator's experience and three different cementation systems on the push-out bond strength to dentin. Two null hypotheses were tested: 1) no significant difference would be detected among the push-out bond strengths to dentin produced by different cementation systems, and 2) the operator's experience would not affect the push-out bond strength to dentin for different cementation systems.

## MATERIALS AND METHODS

Forty-eight extracted human maxillary central incisors were stored in distilled water at 4°C and used within 6 months after extraction (ISO/TS 11405).<sup>18</sup> The inclusion criteria were absence of root caries and cracks, absence of restorations and previous endodontic treatments, posts or crowns, absence of severe root curvatures, and a root length measured from the cemento-enamel junction (CEJ) of  $14 \pm 1$  mm.

### Specimen Preparation

Teeth were cross-sectioned immediately below the CEJ using a low-speed diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, USA). A crown-down technique was used for instrumentation with Gates Glidden drills No. 2 to No. 4. Apical enlargement was performed to size 40 and .06 taper. Roots were dried with paper points, filled with AH Plus (DeTrey, Dentsply, Konstanz, Germany) and tapered gutta-percha points, using the warm vertical condensation technique. The root access was temporarily filled with Vitro Fil (DFL, Rio de Janeiro, RJ, Brazil). The roots were stored for one week at 37°C in 100% humidity.

After one week, the gutta-percha was removed, leaving 4 mm of the apical seal. The post space was then prepared with a low-speed bur provided by the post manufacturer (Tenax Fiber Trans Drills, Coltène/Whaledent, Cuyahoga Falls, OH, USA) up to a fixed depth of 10 mm from the CEJ. One bur was used for only five preparations. All specimens were prepared by one experienced operator in a standardized procedure. The canals were irrigated with 10 mL of distilled water and dried with paper points. To make sure that there was no residual gutta-percha on the walls of the post space preparation, a radiographic evaluation was performed (Figure 1).

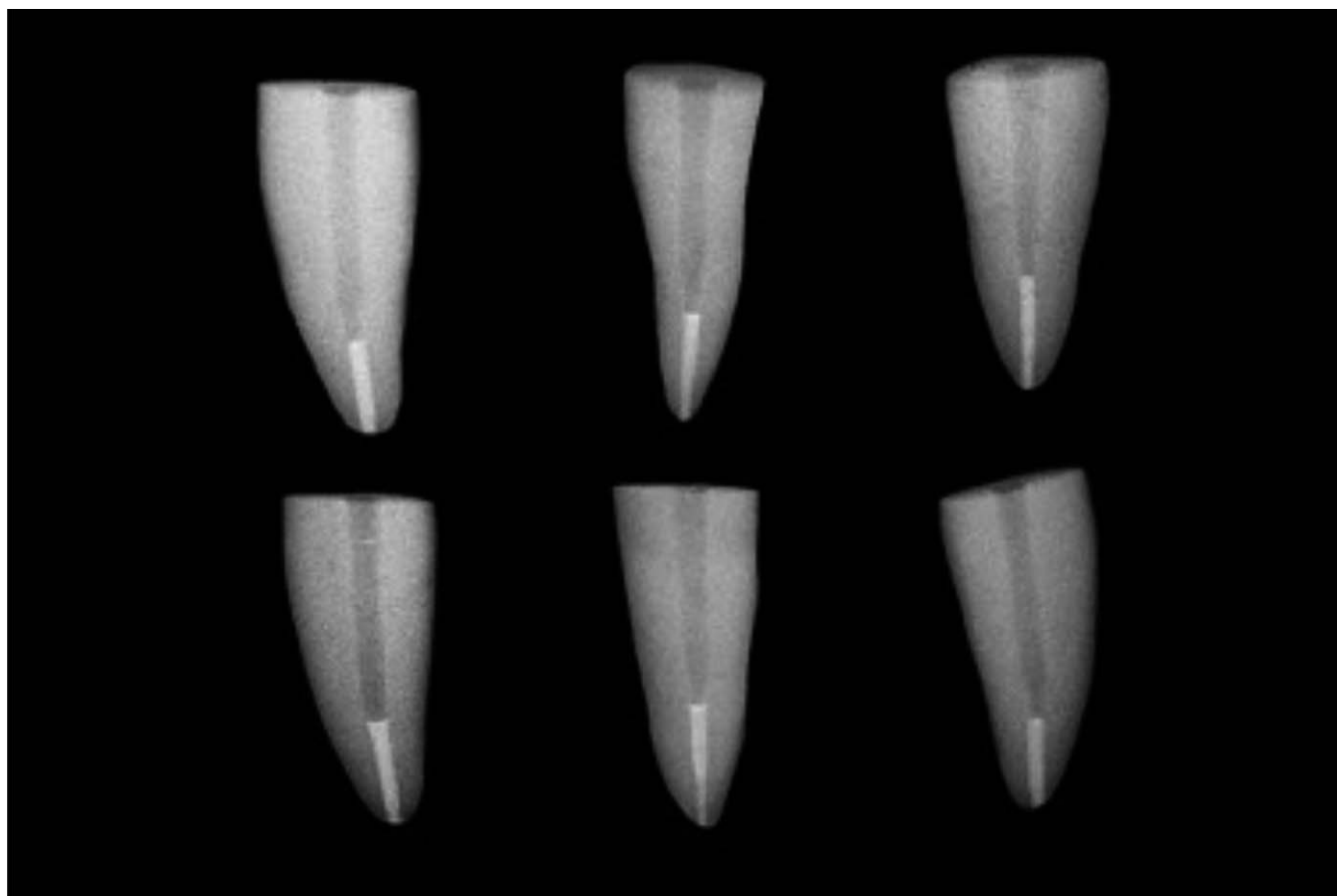


Figure 1. Radiographic evaluation of the radicular canals.

Six experimental conditions resulting from the combination of the main factors, operator experience (two levels) and cementation system (three levels), were evaluated. Expert dentists (eight dentists specialized in Restorative Dentistry) and undergraduate students (eight undergraduate students in the fourth year of the course) were selected to perform the fiber post cementation. Students from the fourth undergraduate year were selected because they had been taught restorative dentistry one year earlier and had learned to perform fiber post cementation procedures. They were given the three cementation systems shown in Figure 2. Three glass fiber posts, one of each material, were luted by each operator. Before cementation procedures, each glass fiber post (cylindrical with tapered end [Tenax Fiber Trans Esthetic Post System, Coltène/Whaledent]) was marked at a distance of 13 mm from the apical end and was horizontally sectioned at this point, using a water-cooled diamond rotary cutting instrument. Ten millimeters of the post were cemented inside

the root canal, while the other cervical 3 mm served as a guide to standardize the distance of the light curing device from the cervical root region. The posts were tried in, cleaned with alcohol, and cemented in accordance with the instructions provided by the manufacturer of each cementation system described in Table 1, which were given to all operators, who were instructed to follow them strictly. All bonding procedures were performed on the same mannequin, with the purpose of simulating a clinical setting. The composition of the materials used for the cementation procedure is described in Table 2.

The adhesive systems (Table 1) were applied by means of microbrushes (Vigodent, Rio de Janeiro, RJ, Brazil), and the resin cements were applied with a Centrix syringe (DFL, Rio de Janeiro, RJ, Brazil). A LED light curing device (L.E.Demetron I/Kerr Corporation, Orange, CA, USA) was used for activation purposes ( $800 \text{ mW/cm}^2$ ). Specimens were then stored in water at  $37^\circ\text{C}$  for one week.

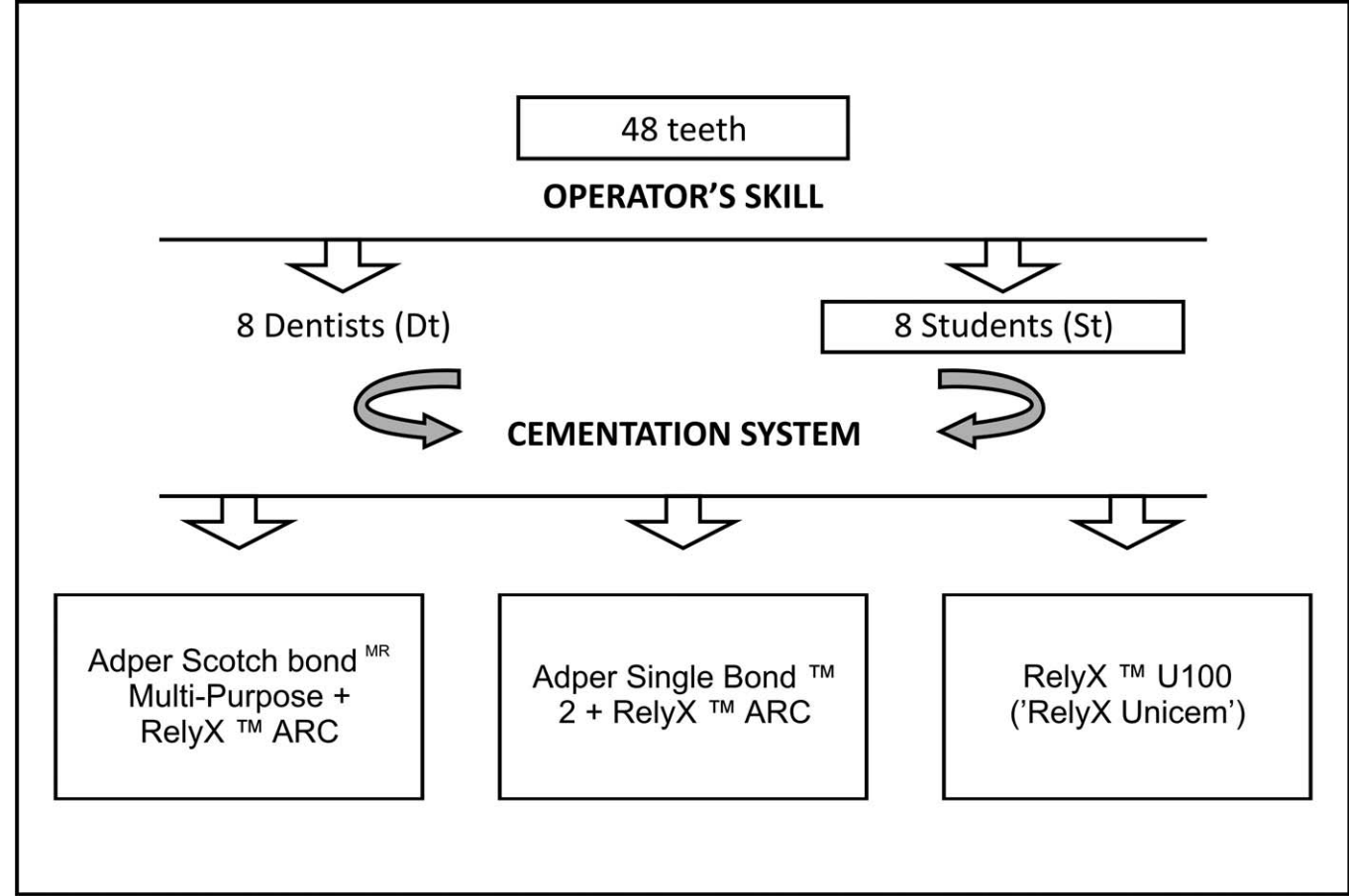


Figure 2. Experimental flowchart.

**Preparation of Sections for Push-Out Bond Strength Test**

After this, the roots were embedded in polyvinyl chloride tubes using acrylic resin, and the portion of each root was sectioned perpendicular to the long axis into six 1-mm serial slices. Subsequently, all specimens were observed with a light stereomicroscope at 10× magnification to discard slices with artifact defects.

The coronal side of each slice was identified and its thickness measured with a digital caliper (Mitutoyo, Tokyo, Japan). Images from both sides of the slides were recorded with an optical microscope (Olympus, model BX 51, Olympus, Tokyo, Japan) at 40× magnification to measure the coronal and apical post diameters and allow the bond area to be calculated using UTHSCSA ImageTool 3.0 software (Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, TX, USA).

Each slice was subjected to a push-out test using a universal loading device (AG-I, Shimadzu Autograph, Tokyo, Japan) at 0.5 mm/min with the load applied in the apical-coronal direction until the post was dislodged. The maximum failure load was recorded in Newton (N) and converted into MPa by dividing the applied load by the bonded area ( $S_L$ ). The latter, being the lateral surface of a truncated cone, was calculated by the formula:  $S_L = \pi(R + r)[(h^2 + (R - r)^2)^{0.5}]$ , where  $\pi = 3.14$ ,  $R$  = coronal post radius,  $r$  = apical post radius, and  $h$  = root slice thickness.

**Failure Mode Analysis**

The failure modes of all specimens were evaluated under a stereomicroscope (40× magnification), and approximately 30% of the specimens from each group were randomly selected and processed for scanning electron microscopy (SEM) evaluation. Slices were rinsed in a 95% alcohol solution for one minute, air-dried, mounted on a metal stub and

Table 1: Bonding Procedures

Cementation System/ Manufacturer/ Abbreviation	Mode of Application (Batch Number)
Adper Scotchbond Multi-Purpose/3M ESPE + RelyX ARC/3M ESPE (SBMP + ARC)	1) Apply 35% phosphoric acid (lot: 7KU) for 15 s; 2) rinse with water for 15 s followed by air drying (2 s); 3) remove excess moisture with a paper point; 4) apply activator (lot: 7KY) of the adhesive system in canal and remove excess with air drying (5 s); 5) apply primer (lot: 7BJ) of the adhesive system in canal and remove excess with air drying (5 s); 6) apply catalyst (lot: 7BA) of the adhesive system in canal; 7) dispense cement (lot: GN8JA) onto a mixing pad and mix for 10 s; 8) apply cement in and around canal; 9) place a thin layer of mixed cement on post and seat the post; 10) remove excess cement while holding post in place; and 11) light-polymerize for 40 s from an occlusal direction.
Adper Single Bond 2/3M ESPE + RelyX ARC/3M ESPE (SB + ARC)	1) Apply 35% phosphoric acid (lot: 7KU) for 15 s; 2) rinse with water for 15 s followed by air drying (2 s); 3) remove excess moisture with a paper point; 4) apply two consecutive coats of the adhesive (9WH) in canal and remove excess with air drying (5 s); 5) remove excess (if any) with a dry paper point; 6) light-polymerize for 10 s; 7) dispense cement (lot: GN8JA) onto a mixing pad and mix for 10 s; 8) apply cement in and around canal; 9) place a thin layer of mixed cement on post and seat the post; 10) remove excess cement while holding post in place; and 11) light-polymerize for 40 s from an occlusal direction.
RelyX U100 (RelyX Unicem)/3M ESPE (U100)	1) Irrigate the canals with NaOCl 2.5% and with distilled water; 2) remove excess moisture with a paper point; 3) dispense cement (338618) onto a mixing pad and mix for 20 s; 4) apply cement in and around canal; 5) place a thin layer of mixed cement on post and seat the post; 6) remove excess cement while holding post in place; and 7) light-polymerize for 20 s from an occlusal direction.

sputter-coated with gold-palladium (Polaron SC7620, Quorum Technologies Ltd, East Sussex, UK) for five minutes at 10 mA. Each specimen was examined by SEM (JSM 6360LV, Jeol Ltd, Tokyo,

Japan) at a 15-kV accelerating voltage at different magnifications (40× to 200×) and photographs were taken. Two independent operators evaluated the failure modes according to the following criteria: 1)

Table 2: Composition of the Materials

Material	Composition
Adper Scotchbond Multi-Purpose (SBMP)	Activator: ethanol-based solution of a sulfinic acid salt and a photoinitiator component.
	Primer: aqueous solution of HEMA (hydroxyethyl methacrylate) and polyalkenoic acid copolymer.
	Catalyst: HEMA and Bis-GMA (bisphenol-A-glycidyl methacrylate).
Adper Single Bond 2 (SB)	Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator system, and a methacrylate functional copolymer of polyacrylic and polyitaconic acids.
RelyX ARC (ARC)	Paste A: Bis-GMA, triethyleneglycol dimethacrylate, zircon/silica filler, photoinitiators, amine, pigments.
	Paste B: Bis-GMA, triethyleneglycol dimethacrylate, benzoic peroxide, zircon/silica filler.
RelyX U100 (U100)	Paste base: glass fiber, methacrylated phosphoric acid esters, dimethacrylates, silanated silica, sodium persulfate.
	Paste catalyst: glass fiber, dimethacrylates, silanated silica, p-toluene sodium sulfate, calcium hydroxide.



Table 3: Means and Standard Deviations (MPa) of Push-Out Bond Strength Values for the Experimental Groups			
Cementation System	Operator		Student <i>t</i> -Test*
	Dentist (A)	Student (B)	
SBMP + ARC (a,b)	13.2 ± 8.2	10.3 ± 6.6	≠
SB + ARC (b)	11.3 ± 6.7	8.3 ± 7.0	≠
U100 (a)	14.4 ± 7.9	13.3 ± 6.7	=
* Similar lowercase letters indicate statistically similar means within each row. Similar capital letters indicate statistically similar means within column. Symbol ≠ indicates different means for each cement; symbol = indicates similar means.			

adhesive failure between dentin and luting cement, 2) adhesive failure between luting cement and post, 3) cohesive failure within luting cement, 4) cohesive failure within the post, 5) cohesive failure within dentin, and 6) mixed failure.

Statistical Analysis

The mean bond strength (BS) (MPa) of all slices originating from the same tooth was first averaged in order to provide one mean for each tooth. These values were then evaluated by a two-way analysis of variance (ANOVA) and Tukey test ( $\alpha=0.05$ ) for pairwise comparisons.

A second statistical analysis with a more powerful statistical test was performed to evaluate the effect of the operator’s experience on the BS data of each cementation system, which was compared using the Student *t*-test ( $\alpha=0.05$ ). Thirdly, the pairwise comparison of the fracture patterns was analyzed by Fisher exact test ( $\alpha=0.05$ ).

RESULTS

None of the specimens observed presented artifacts caused by the sectioning procedure; therefore, all slices were tested. The mean cross-sectional areas ranged from 3.0 to 6.0 mm<sup>2</sup>, and no difference was detected among groups ( $p>0.05$ ).

The main factors operator experience and cementation system ( $p=0.006$  and  $p=0.0006$ , respectively) were significant. Higher push-out BS means (MPa) were observed for expert operators (12.9 ± 7.6) in comparison with the undergraduate students (10.6 ± 6.7) (Table 3) irrespective of the cementation system used ( $p=0.006$ ). With regard to the cement,

Table 4: Distribution of the Fracture Pattern (%) Among the Different Experimental Groups				
Cementation System	Operator			
	Expert Dentist		Student	
	Adhesive Dentin-Cement	Mixed	Adhesive Dentin-Cement	Mixed
SBMP + ARC	73	27	23	77
SB + ARC	60	40	47	53
U100	13	87	23	77
<sup>a</sup> No cohesive failure in dentin and post or adhesive failure between cement and the post were observed. Significantly more mixed failures occurred for U100 in the expert dentist group ( $p<0.02$ , Fisher exact test).				

higher BS means were observed for U100 (13.9 ± 7.3) irrespective of the operator’s experience. The lowest means were observed for SB + ARC (9.8 ± 6.8) ( $p<0.05$ ). SBMP + ARC (11.8 ± 7.4) had an intermediate performance and it was similar to the other groups ( $p>0.05$ ). The Student *t*-test revealed that the push-out means of U100 were not affected by the operator’s experience ( $p>0.05$ ).

No significant difference in the fracture pattern was observed among materials in the undergraduate student group (Table 4). With regard to the expert operators, U100 showed more mixed failures than the other two materials. Most of the mixed failures (70%) occurred between resin cement and dentin with cohesive failure of the cement. A representative image of the most prevalent fracture mode can be seen in Figure 3.

DISCUSSION

In this study, it was observed that the use of a simplified etch-and-rinse (ER) adhesive SB together with ARC produced lower bond strength in comparison with U100, which led to rejection of the first null hypothesis. An adverse chemical interaction has been reported between unpolymerized acidic resin monomers in the oxygen inhibition layer of simplified ER adhesives and the tertiary amine present in auto/dual-cured composites, which may be responsible for incompatibility among these systems.<sup>19-21</sup> Although the materials evaluated in this study (SB and ARC system) were not tested in the cited studies,<sup>19-21</sup> one cannot rule out the possibility that this may be a plausible explanation, especially in the apical region of the root canal where the conversion of the dual

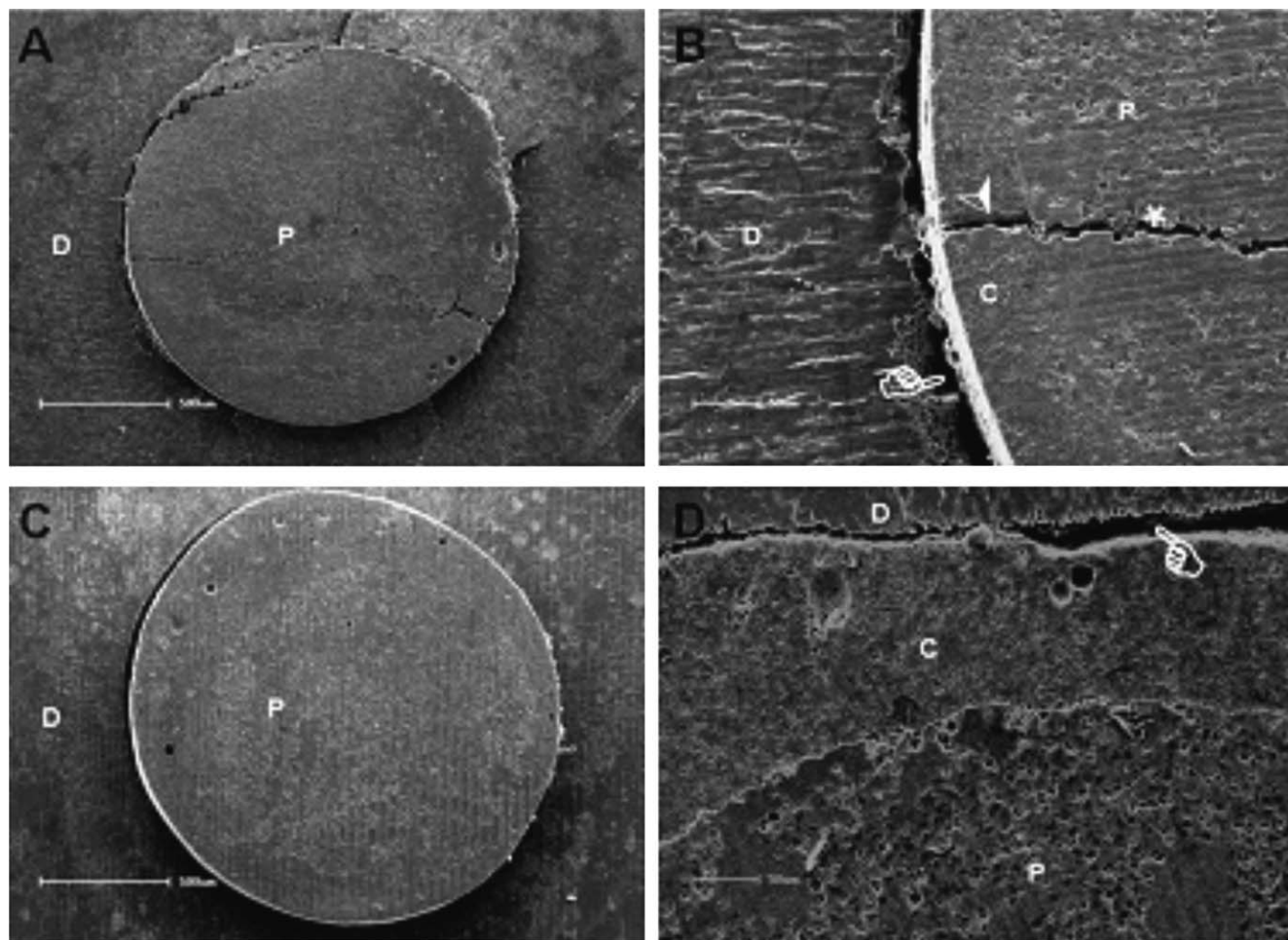


Figure 3. Scanning electron micrographs of representative fracture patterns. A mixed failure mode can be seen in low (A) and high (B) magnification. In (B) one can observe the adhesive failure between the cement and the dentin interface (pointer) along with a cohesive failure within cement (arrow head) and a fissure in the post (asterisk). An adhesive failure mode can be seen in low (C) and high magnification (D). In (D) one can observe that the failure occurred between the cement and dentin (pointer). Abbreviations: C, cement; D, dentin; P, post.

resin cement practically relies on chemical activation, as light does not reach this area properly.<sup>22,23</sup> Moreover, simplified ER systems have been shown to function as permeable membranes,<sup>21-24</sup> allowing water movement across their structure even after polymerization,<sup>25,26</sup> which may adversely affect the coupling of auto/dual-cured resin cements to the dentin surface.<sup>24,25</sup>

To attain proper polymerization in such situations, a chemically activated component of a dual-catalyst system was shown to be effective.<sup>27</sup> This was partially confirmed in this study since the use of three-step ER with the self-cure bottle of the SBMP system allowed intermediate push-out BS values to be obtained, a finding previously demonstrated in others studies.<sup>8-28</sup> The additional chemical polymerization of the three-step ER self-cure adhesive system may also compensate for the light attenua-

tion that occurs during the light polymerization step in a root canal.<sup>29,30</sup>

Despite the tendency of SBMP to obtain high BS values, the foregoing reasons do not explain why this system was similar to SB. The use of chemical coinitiators in the SBMP completely eliminates the adverse chemical interaction reported for simplified ER adhesives (such as SB) and self/dual-cured composites, but the inherent permeability of the polymerized adhesive still precludes optimal coupling to bonded hydrated dentin.<sup>31</sup> Furthermore, these two adhesives rely on the same bonding strategy, the ER approach, which requires the dentin substrate to be kept moist after acid conditioning.<sup>32</sup> Due to limited access, it is difficult to control moisture within the root canal, and this makes the procedure more critical. Furthermore, the ideal degree of moisture varies widely among the

manufacturers' instructions and also depends on the solvent used in each system.<sup>33</sup>

The foregoing discussion makes the two ER adhesives sensitive to the operator's experience, as observed in the present investigation, leading to rejection of the second null hypothesis, since expert operators achieved higher BS results than undergraduate students. This finding has been observed in the literature when bonding to coronal dentin.<sup>12,13</sup> However, contrary to the results of the present study, Simonetti and others<sup>16</sup> did not observe any influence of the operator's experience on the push-out BS of a dual-cured resin cement associated with Prime&Bond NT (Dentsply). It is speculated that the low number of operators (only one in each experimental condition) and specimens used by the authors reduced the power of the study to an extent that prevented the authors from observing a significant effect of the operator's experience on the BS. As data from push-out BS present high standard deviations, usually exceeding 50% of the means,<sup>1,5,6,16,28,34</sup> the sample size should be high enough to detect subtle differences between groups.

The self-adhesive cement U100 does not require rinsing, solving the problem of substrate moisture control and thus simplifying the clinical procedure. The high BS values observed for U100 in this study and in others<sup>1,7-9,28,35-37</sup> can be attributed to the chemical interaction between monomer acidic phosphate groups and dentin/enamel hydroxyapatite<sup>17</sup> and to low shrinkage of the material,<sup>38,39</sup> leading to closer contact of the resin cement with the root canal walls and higher frictional resistance.<sup>40,41</sup> Unfortunately, there is no consensus in the literature with regard to the superiority of this material when compared with conventional bonding strategies.<sup>5,6,37,41,42</sup> The reason for this controversy should be further investigated.

With regard to the influence of the operator's expertise on the success or failure of self-adhesive cements used for post cementation, little information is available in the literature. The reduced number of clinical steps and no need to keep the dentin substrate moist before application of the material might explain why U100 was not sensitive to the operator's experience in the present investigation. It may be said that for different operators, reducing the number of steps in the bonding procedure is an important factor in obtaining a more reliable and stronger bond between the resin and dentin. It is worth pointing out that the fact that U100 was not affected by the operator's experience in an *in vitro* setting, does not necessarily mean that this will be

the case in a clinical scenario. Further clinical studies should be conducted to evaluate this aspect.

The high number of operators in the present study was a favorable condition for the greater reliability of the data. However, this study also has some limitations. The test specimen crowns were not completely restored and no thermal cycling or mechanical stressing was applied. These factors may limit the direct application of the study results to clinical conditions.

## CONCLUSIONS

Within the limitations of this *in vitro* study, it may be concluded that:

- Higher BS means were observed for expert operators in comparison with the undergraduate students, irrespective of the cementation system used.
- RelyX U100 showed the highest bond strength, but it did not differ from that of SBMP + RelyX ARC.
- The self-adhesive cement used (RelyX U100) was not sensitive to the operator's experience.

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## Conflict of Interest

The authors of this article 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 this article.

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