Resin cements are commonly used to lute glass-fiber posts in endodontically treated teeth. Adhesive cementation techniques often involve the use of adhesive systems associated with conventional resin cements as well as self-adhesive resin cements. Several dentin adhesives are available commercially. These include etch-and-rinse and self-etch adhesive systems. Etch-and-rinse adhesive systems require greater clinical expertise because the phosphoric acid needs to be washed off. During the drying of dentin, the collagen fibers may collapse, which prevents the resin monomers from diffusing into the demineralized matrix. The excess moisture present is undesirable because it dissolves the solvent and monomer resin, which results in incomplete sealing of the dentin. In this respect, self-etch adhesive systems, in which the dentin is demineralized and infiltrated by the monomer simultaneously, seem more promising.

**ABSTRACT**

**Statement of problem.** The mechanical properties of the adhesive materials used in intraradicular treatments could vary according to the interaction between the restorative material and dentin substrate. An evaluation of these properties is essential to determine the success of the luting procedures performed on glass-fiber posts.

**Purpose.** The purpose of this study was to evaluate the mechanical properties of dentin adhesives, resin cements, and the dentin that underlies the bonding interface in different thirds of intraradicular dentin.

**Material and methods.** Forty extracted, single-rooted human teeth were used in this study. After the endodontic treatment of the post spaces, the teeth were divided into 5 groups (n=8): Adper Single Bond 2 + RelyX ARC, Excite DSC + RelyX ARC, Adper SE Plus + RelyX ARC, RelyX Unicem, and Set. The hardness and elastic modulus values were measured at the adhesive interface in different thirds of the radicular dentin by using an ultramicrohardness tester. The data were subjected to 2-way ANOVA and the Fisher protected least significant difference test (α=0.05).

**Results.** In the underlying dentin, the highest Martens hardness values were found in the apical region for all groups; the exceptions were the groups with the self-etching adhesive. In the adhesive layer, the highest Martens hardness values were obtained for the Adper SE Plus + RelyX ARC group; further, no statistical differences were found among the different regions for this group. RelyX ARC had the lowest Martens hardness and elastic modulus values in the apical regions when used with Adper Single Bond 2 and Adper SE Plus. No differences were found in the Martens hardness and elastic modulus values for the self-adhesive resin cement in the regions investigated.

**Conclusion.** The mechanical properties of adhesive materials and the underlying dentin are influenced by the interaction between the two as well as by the depth of the analyzed intraradicular area. (J Prosthet Dent 2015;113:54-61)
Clinical Implications

Selecting resin materials with the appropriate mechanical properties is essential for ensuring the longevity of cementation procedures performed with adhesive glass-fiber posts in intraradicular dentin.

The development of self-adhesive resin cements has made them an alternative for the cementation process, thus eliminating the pretreatment of the dentin. The cements contain acidic monomers that demineralize and infiltrate the tooth substrate, which results in micromechanical retention. A secondary reaction, a chemical reaction between the hydroxyapatite and the particles of aluminum fluoro-silicate (glass) present in the cements, similar to that which occurs with glass ionomer cements, can occur. An understanding of the properties of the materials and substrates involved in dental restorations is essential to ensuring the longevity of the bonded interface. The most common parameters used to assess materials are their hardness and elastic modulus (Eit) values, which can be determined through indentation tests. An ideal resin material would have a modulus (Eit) nearly equal to or slightly less than the modulus of dentin, to facilitate the transmission of the forces at the interface.

The purpose of this study was to evaluate the mechanical properties (hardness and Eit) of the components of the adhesive interface in different regions of intraradicular dentin (cervical, middle, and apical). Two null hypotheses were tested: that the interaction between the adhesive system and the resin cement would not cause changes in the mechanical properties (Martens hardness [MH] and Eit) of the materials and underlying dentin and that no difference would be found in the mechanical properties of the components of the adhesive interface in different thirds of intraradicular dentin.

MATERIAL AND METHODS

The materials used in this study are listed in Table 1. The study was approved by the research and ethics committee of the Araçatuba School of Dentistry, Sao Paulo State University (Protocol 01809/09). Forty single-rooted human premolars from different individuals, extracted for orthodontic or periodontal reasons, were used in this study. All teeth that exhibited clinical signs of caries, root resorption, cracks, or fractures were excluded. The anatomic crowns of all teeth were removed 1.0 mm above the cementum-enamel junction through a transversal section, under water cooling, by using a low-speed diamond saw (Isomet 2000; Buehler). The specimens then were endodontically treated. A no. 10 K-file (Maillefer Instruments) was introduced into the root canal until it was visible at the apical foramen. The working length was determined to be 1.0 mm less than this length. The root canals were instrumented with K-files with sizes of up to no. 45 by using the crown-down and step-back techniques after the preparation process had been completed. This process was performed with Hedstrom files of up to no. 60 scaled to be natural and progressive, and used as an instrument of memory a K-file 2 number lower than the larger caliber used in the apical preparation. Throughout the preparation process, the root canals were irrigated with 2.5% sodium hypochlorite. The instrumented root canals were dried with sterile paper points and immediately obturated by the lateral condensation of gutta percha cones (Dentsply-Maillefer) and calcium hydroxide cement (Seal-apex; Kerr Corp). Coronal access was sealed with zinc oxide–zinc sulfamate cement (Coltosol; Vigodent). The endodontically treated teeth were stored at 37°C and 100% relative humidity for 7 days.

The glass-fiber post system used in this study was Reforpost no. 2 (Angelus Industry Dental Products S/A). The post spaces in all the specimens were prepared with a no. 2 low-speed drill (Dentsply-Maillefer). The gutta percha cones were removed to a depth of ±9 mm with reference to the working length of the tooth. After the completion of the preparation process, the adaptation of the fiber posts was verified to be complete by placing them in the post space. If the posts penetrated to the 9-mm depth, then they were considered to have adapted. Before the start of the adhesive procedure, the surfaces of the glass-fiber posts were treated with 35% phosphoric acid (3M ESPE) for 60 seconds. They were then washed and air-dried. The post surfaces were silanized for 60 seconds (Angelus Industry Dental Products S/A) and gently dried with an air jet. Finally, on the basis of the treatment to be performed in the intraradicular dentin, the adhesive system used on the dentin surface also was applied on the post surface if required. Thereafter, to prevent contamination, the post was not further manipulated.

The post spaces were irrigated with 2.0 mL distilled water to remove any gutta percha debris and to maintain the humidity of the environment. The post space was dried with air and sterile paper points before the bonding procedures. The specimens were divided by drawing lots into the following 5 groups (n=8) on the basis of the luting procedure.

SB2 Group: Adper Single Bond 2 + RelyX ARC
Post spaces were etched with 35% phosphoric acid (3M ESPE) for 15 seconds, washed, and dried with sterile paper points without drying the dentin. Adper Single
Bond 2 bonding system (3M ESPE) was applied in 2 consecutive layers by gently shaking a brush saturated with the material onto the surface of the dentin for 15 seconds. The teeth were gently dried in air to evaporate the solvent and were light polymerized with a light-emitting diode (Dabi Atlante) for 20 seconds. The RelyX ARC conventional resin cement (3M ESPE) was mixed for 10 seconds and placed in the post space with an endodontic file. The resin cement was applied to the post surface and brought into position within the post space; any excess cement was removed. Resin cement was light polymerized for 40 seconds.

**EXC Group: Excite DSC + RelyX ARC**

Post spaces were etched with 35% phosphoric acid (3M ESPE) for 15 seconds, washed, and dried with sterile paper points, without drying the dentin. The Excite DSC dual bonding system (Ivoclar Vivadent) was activated and applied for 10 seconds with a microbrush in the canal. Any excess material was removed with paper points and by gently blowing air for 3 seconds. The system was light polymerized with an ultra light-emitting diode for 10 seconds. The RelyX ARC conventional resin cement was mixed and inserted into the post space in the same way as described for the SB2 group. Cement was applied to the post space, the post was placed in position, and any excess material was removed. Resin cement was light polymerized for 40 seconds.

**SEP Group: Adper SE Plus + RelyX ARC**

The post spaces were dried and etched with Adper SE Plus self-etching adhesive (3M ESPE). Primer (Liquid A) was applied throughout the intraradicular dentin with a microbrush, without drying the dentin. Adhesive (Liquid B) then was applied by gently shaking a microbrush saturated with the material for 20 seconds, and the adhesive was dried for 10 seconds. A second layer of the adhesive was applied, spread by gently blowing air, and light polymerized for 10 seconds. The cementation step for the glass-fiber posts with treated surfaces was performed in the same way as described for the other groups treated with RelyX ARC resin cement.

**UNI Group: RelyX Unicem**

The post spaces were dried and RelyX Unicem self-adhesive resin cement (3M ESPE) was manipulated and inserted in the post space with an endodontic file. The cement was applied to the post surface, the post was placed in position, and any excess cement was removed. Finally, the resin cement was light polymerized for 40 seconds.

**SET Group: Set**

The post spaces were dried, and Set self-adhesive resin cement (SDI) was manipulated and inserted into the post space with an endodontic file. Next, the cement was applied to the post surface, the post was placed in position, and any excess cement was removed. Finally, the resin cement was light polymerized for 40 seconds.

All the teeth were stored for 7 days. The teeth were sectioned perpendicular to the long axis with a low-speed diamond saw under water cooling with an Isomet 2000 (Buehler) to obtain slices approximately 1.3 mm in thickness. These were analyzed from each third (cervical, middle, and apical). The slices were embedded in acrylic resin (Classico); manually finished with no. 320-, 600-,
and polished with diamond pastes (6, 3, and 1 μm) for a period of 4 minutes each. The specimens were cleaned in an ultrasonic unit (model 2210; Branson Ultrasonic Corp) with deionized water for 2 minutes between the steps and at the end of the process.

The MH and Eit values were measured with an ultramicrohardness tester (DUH-211; Shimadzu) under a load of 3 mN at a speed of 0.2926 mN/s; the holding time was 5 seconds. The regions analyzed were those that corresponded to the components of the adhesive interface: resin cement, adhesive system, and dentin that underlies the bonded interface. A Vickers tip was used, and 3 indentations were made in each region (Fig. 1). The MH and Eit values were calculated automatically by the software program installed with the tester. Statistical analyses were performed with 2-way ANOVA, when considering the experimental groups (the luting procedures) and the different regions of intraradicular dentin (cervical, middle, and apical) as the factors. Subsequently, the Fisher protected least significant difference test (α=.05) also was performed.

RESULTS

The results of ANOVA of the HM values indicated statistically significant differences among the groups (P<.001) and the different thirds of intraradicular dentin (P<.001). There was no interaction among these factors (P=.356). Similarly, for the Eit values, no significant differences were found among the groups (P<.001) or intraradicular thirds of dentin (P=.048). There was no interaction between these factors (P=.271).

The HM and Eit values for the different thirds of the intraradicular dentin are given in Table 2. The apical third exhibited the highest HM values for all groups. No statistically significant differences were found among the values of the middle third for the SB2 group, the cervical for the EXC group, and the cervical and the middle for the SEP group. The groups with self-adhesive resin cement (UNI and SET) had the highest HM values for dentin for all the regions studied (P<.05). The SEP group had a mean that was statistically similar to those of the UNI and SET groups; the exception was the apical third, for which the dentin in the SET group had higher values than the dentin in the SEP group (P=.005).

During the analysis of the Eit values, the highest values were exhibited by the SEP group (Adper SE Plus), the UNI group (RelyX Unicem resin cement), and the SET group (Set resin cement). No statistically significant differences were found among the thirds analyzed; the exception was the SET group, which had statistically lower values in the cervical and middle thirds compared with the apical third. Further, the SB2 group, unlike the other groups, exhibited higher Eit values for the cervical third, there being statistically significant differences for
Table 2. Mean (standard deviation) (GPa) values of Martens hardness (HM) and elastic modulus (Eit) of dentin categorized according to cementing procedure and root third

<table>
<thead>
<tr>
<th>Mechanical Property and Region</th>
<th>SB2 Group</th>
<th>EXC Group</th>
<th>SEP Group</th>
<th>UNI Group</th>
<th>SET Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical HM</td>
<td>0.24 ±0.09Aa</td>
<td>0.30 ±0.17Ab</td>
<td>0.46 ±0.10Aa</td>
<td>0.47 ±0.06Ba</td>
<td>0.47 ±0.13Ba</td>
</tr>
<tr>
<td>Middle HM</td>
<td>0.33 ±0.16Abc</td>
<td>0.26 ±0.08Bc</td>
<td>0.43 ±0.10Ab</td>
<td>0.48 ±0.10Ba</td>
<td>0.50 ±0.10Ba</td>
</tr>
<tr>
<td>Apical HM</td>
<td>0.42 ±0.15Ac</td>
<td>0.43 ±0.14Ac</td>
<td>0.48 ±0.17Ac</td>
<td>0.59 ±0.09Ab</td>
<td>0.70 ±0.16Ac</td>
</tr>
<tr>
<td>Cervical Eit</td>
<td>28.58 ±16.65As</td>
<td>15.00 ±5.82Aa</td>
<td>36.75 ±14.06Aa</td>
<td>35.63 ±12.09Aa</td>
<td>27.23 ±7.63Aab</td>
</tr>
<tr>
<td>Middle Eit</td>
<td>15.44 ±8.02Ab</td>
<td>15.82 ±8.83Ab</td>
<td>36.96 ±17.06Aa</td>
<td>31.52 ±6.62Aa</td>
<td>28.44 ±7.53Aa</td>
</tr>
<tr>
<td>Apical Eit</td>
<td>17.19 ±6.76Ab</td>
<td>23.21 ±12.87Aa</td>
<td>38.17 ±17.13Aa</td>
<td>38.23 ±11.99Aa</td>
<td>36.10 ±6.53Aa</td>
</tr>
</tbody>
</table>

SB2, Adper Single Bond 2 + RelyX ARC; EXC, Excite DSC + RelyX ARC; SEP, Adper SE Plus + RelyX ARC; UNI, RelyX Universal; SET, Set.
Different superscript uppercase letters in columns and lowercase letters in rows indicate statistically significant differences (P<.05).

Table 3. Mean (standard deviation) (GPa) values of Martens hardness (HM) and elastic modulus (Eit) of adhesive systems in different root thirds

<table>
<thead>
<tr>
<th>Mechanical Property and Region</th>
<th>SB2 Group</th>
<th>EXC Group</th>
<th>SEP Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical HM</td>
<td>0.13 ±0.06Ab</td>
<td>0.12 ±0.06Bb</td>
<td>0.24 ±0.04Ac</td>
</tr>
<tr>
<td>Middle HM</td>
<td>0.06 ±0.04Ab</td>
<td>0.16 ±0.06Ab</td>
<td>0.23 ±0.10Ab</td>
</tr>
<tr>
<td>Apical HM</td>
<td>0.07 ±0.05Ac</td>
<td>0.24 ±0.12Ab</td>
<td>0.19 ±0.10Ac</td>
</tr>
<tr>
<td>Cervical Eit</td>
<td>10.54 ±5.90Aa</td>
<td>9.62 ±5.80Aa</td>
<td>8.93 ±2.35Ab</td>
</tr>
<tr>
<td>Middle Eit</td>
<td>3.03 ±2.27Ab</td>
<td>8.74 ±0.83Ab</td>
<td>9.04 ±4.21Ab</td>
</tr>
<tr>
<td>Apical Eit</td>
<td>3.96 ±4.46Ab</td>
<td>9.24 ±3.61Ab</td>
<td>9.23 ±5.42Ab</td>
</tr>
</tbody>
</table>

SB2, Adper Single Bond 2 + RelyX ARC; EXC, Excite DSC + RelyX ARC; SEP, Adper SE Plus + RelyX ARC.
Different superscript uppercase letters in columns and lowercase letters in rows indicate statistically significant differences (P<.05).

The middle and apical thirds (P<.001). The 2-way ANOVA for HM found a statistically significant difference among the groups (P<.001); however, no statistically significant difference was found among the different thirds of the intraradicular dentin (P=.134). In addition, there was no interaction between these factors (P=.165). In contrast, the Eit values of the groups had a significant difference (P=.002), and there were significant interactions among the factors (P=.007). Finally, no difference was found in the different thirds analyzed (P=.997).

The HM and Eit values of the different adhesive systems used in the SB2 group (light polymerized), the EXC group (dual polymerized), and the SEP group (self-etched) are given in Table 3. The SEP group exhibited the highest HM values. In this group, there was no statistical difference among the thirds analyzed (P>.05). In contrast, the SB2 group had the lowest HM values. HM values decreased significantly in the cervico-apical direction (P<.05). With regard to the Eit values, the EXC and SEP groups exhibited statistically similar values, which were independent of the regions. In these groups, there was no difference among the thirds. The lowest values were exhibited by the SEP group in the middle and apical thirds (P<.05). The results of ANOVA of the HM values indicated a statistically significant difference among the groups (P<.001) and among the different thirds of the intraradicular dentin (P<.047); however, the interactions between these factors were not statistically significant (P=.070). For Eit values, the ANOVA results indicated a significant difference among the groups (P<.001) and the regions analyzed (P=.002). Significant interactions also were found among these factors (P=.022).

The HM and Eit values of the resin cements in the different thirds of the intraradicular dentin are presented in Table 4. After analyzing each group separately, no statistically significant difference was found among the thirds for the EXC, UNI, and SET groups for both parameters studied (P>.05). In groups SB2 and SEP, the highest HM values were found in the cervical third. Regardless of the third analyzed, the groups represented by the self-adhesive resin cements (UNI and SET) had higher HM values than did RelyX ARC resin cement associated with the different adhesive systems. With respect to the Eit values, groups EXC, UNI, and SET exhibited no variations in the values when the different thirds were compared. In the case of Adper Single Bond 2 (the SB2 group), RelyX ARC had higher values for the cervical third, there being a statistically significant decrease in the remaining thirds (P=.001).

**DISCUSSION**

The hardness and Eit of a material are mechanical properties that can be used to indirectly evaluate the degree of conversion of the material and, consequently, its extent of polymerization. In the present study, the HM values were determined based on both elastic and plastic deformations and the local Eit values (cervical, middle, and apical) of the following materials: resin cements, adhesive systems, and the dentin that underlies the bonding interface. In general, the results found that the mechanical properties of the adhesive-interface components depend on the interaction between the restoration material and the substrate, and, therefore, the first null hypothesis of the study was
January 2015

Table 4. Mean (standard deviation) (GPa) values of Martens hardness (HM) and elastic modulus (Eit) of resin cements in different root thirds

<table>
<thead>
<tr>
<th>Mechanical Property and Region</th>
<th>SB2 Group</th>
<th>EXC Group</th>
<th>SEP Group</th>
<th>UNI Group</th>
<th>SET Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>0.25 ±0.10&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>0.25 ±0.11&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>0.36 ±0.05&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>0.43 ±0.18&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.40 ±0.14&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td>Middle</td>
<td>0.07 ±0.07&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>0.33 ±0.16&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>0.26 ±0.10&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>0.56 ±0.39&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>0.37 ±0.18&lt;sup&gt;Ac&lt;/sup&gt;</td>
</tr>
<tr>
<td>Apical</td>
<td>0.08 ±0.05&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>0.31 ±0.04&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>0.14 ±0.09&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>0.36 ±0.10&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.38 ±0.23&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td>Eit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cervical</td>
<td>15.03 ±7.17&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>12.99 ±7.52&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>11.87 ±2.33&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>19.56 ±7.73&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>13.37 ±3.08&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td>Middle</td>
<td>4.20 ±5.29&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>17.70 ±8.79&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>9.40 ±3.46&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>16.65 ±10.91&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>10.04 ±3.71&lt;sup&gt;Bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Apical</td>
<td>4.27 ±6.94&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>15.55 ±6.86&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>5.25 ±3.04&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>12.51 ±3.54&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>11.54 ±4.88&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

SB2, Adper Single Bond 2 + RelyX ARC; EXC, Excite DSC + RelyX ARC; SEP, Adper SE Plus + RelyX ARC; UNI, RelyX Unicem; SET, Set.

Different superscript uppercase letters in columns and lowercase letters in rows indicate statistically significant differences (P<.05).

rejected. Furthermore, the mechanical properties varied during canal preparation. The differences among the root thirds were analyzed, which led to a rejection of the second null hypothesis.

In the dentin that underlies the bonded interface, the highest HM values were obtained for the groups in which the self-adhesive resin cements RelyX Unicem and Set were applied (Table 2). These materials do not require that the dentin substrate be treated or an adhesive system be applied before use. The bonding process occurs through the chelation of calcium ions by the acidic groups, which results in chemical adhesion with the residual hydroxyapatite of the hard tooth tissue. Moreover, these phosphoric acid methacrylates react in the bonded interfaces of RelyX Unicem and Set resin cements as well as that beneath Adper SE Plus self-etching adhesive system (Table 2). This type of adhesive system also eliminates the need for prior etching with phosphoric acid, thereby simplifying the bonding technique. These products contain phosphate methacrylates, which partially condition the dentin and creates patterns of micromechanical retention for the penetration of the adhesive polymerized into the tooth. Moreover, these phosphoric acid methacrylates react with the residual hydroxyapatite of the hard tooth tissue. As for the Eit values, especially those measured in the middle and apical thirds, the dentin that underlies the bonded interfaces of RelyX Unicem and Set resin cements as well as that beneath Adper SE Plus self-etching adhesive, had higher values than did dentin treated with phosphoric acid (Table 2). According to Goracci et al,1 the methacrylate phosphate present in self-etching or self-adhesive materials has a lower demineralization capacity than that of phosphoric acid.

The initial acidity of self-adhesive resin cements results in fast action and a rapid increase in the pH. Therefore, the interaction that occurs with superficial dentin is not sufficient to allow for the formation of resinous tags. According to Pavan et al,28 the acidity of such cements is not sufficient to cause dentinal demineralization and the exposure of dentinal tubules, which could explain the higher HM and Eit values observed in this study. The lowest HM and Eit values for dentin were noticed for the groups that used the total-etch adhesive systems, Adper Single Bond 2 and Excite DSC. This can be explained by the fact that the treatment of intraradicular dentin with 37% phosphoric acid results in the removal of the smear layer. It also opens the dentinal tubules and exposes the collagen fibers, which thus enables the penetration of the hydrophilic monomers of the adhesive system into the collagen network. This establishes a mechanism of micromechanical retention. However, these highly concentrated acid solutions often demineralize the dentin to levels at which the adhesive cannot completely fill the dentin tubules and results in the formation of a fragile zone, which exposes the collagen peptide chains to degradation. From a clinical aspect, the probability is high that the gel remains on the intraradicular dentin for longer periods, thus increasing the potential for excessive demineralization of the dentin and resulting in only partial infiltration of the adhesive.

When comparing the different thirds of intraradicular dentin, we found a tendency for the apical third to exhibit the highest HM values; the exception was the dentin hybridized with the self-etching adhesive Adper SE Plus (Table 2). The higher values for the apical third could be attributed to several factors, including apical sclerosis, cavity configuration, difficulty in visualization, level of access to the apical portion, or restricted cement penetration into the deeper portions of the post space. In this respect, the application of phosphoric acid with the adhesive and resin cements would be more difficult. A few areas of the apical intraradicular dentin were probably not conditioned and/or hybridized correctly. Cervical and middle thirds would be more susceptible to conditioning by phosphoric acid or self-etching materials and would most likely undergo demineralization to greater degrees. The HM and Eit values were calculated in the adhesive layer for the first 3 groups, for which the conventional resin cement RelyX ARC was used. Adper Single Bond 2 and Excite DSC are conventional adhesives that require that the dentin be etched with acid, with the
first system being photoactivated and the second being dual activated. The third group used Adper SE Plus, a photoactivated, self-etching adhesive system that does not require prior etching.

The specimens that corresponded to Adper Single Bond 2 had the highest values of HM and Eit in the cervical thirds. These were statistically different than the values of the other thirds (Table 3). This adhesive requires a light source for the conversion process. Because the polymerization of the adhesive system was occlusal, in other words, on the more coronal portion of the post space, more of the irradiating light could reach the adhesive system in the cervical third. Therefore, a decrease in the amount of light energy delivered could decrease the degree of conversion of the adhesive homogeneously and degrade its mechanical properties. Although Adper SE Plus also is activated by light, the values that correspond to this material found no statistically significant differences with respect to the analyzed thirds. This self-etching adhesive only promotes a modification in the smear layer during the hybridization process, which results in a less sensitive technique in relation to a moist environment. This should lead to more homogeneous results.

In the group for which the dual-polymerizing adhesive Excite DSC was used, no statistically significant difference was found in the Eit values. In addition to initially requiring light for polymerization, this adhesive also undergoes chemical polymerization, which can compensate for the absence of light in places it cannot reach, for example, the apical third. Furthermore, benzoyl peroxide and tertiary amines generate free radicals through a redox reaction. Hence, the polymerization reaction occurs even in the absence of light.

During the analysis of the mechanical properties of resin cements for the groups SB2 and SEP, in which the cement RelyX ARC was used with photoactivated adhesives, the materials exhibited higher MH and Eit values in the cervical third, with statistically significant difference for the values of the middle and apical thirds (Table 4). As described previously, a photoactivated adhesive is not completely polymerized in the deepest regions of the preparation. Thus, polymerization does not occur homogeneously, especially in the most apical regions. If the adhesive is not polymerized properly, then the residual acidic monomers present in the adhesive layer react with the tertiary amines of the resin cement, which has an alkaline pH. Thus, the amines are neutralized and cannot reduce the benzoyl peroxide present in the cement during the redox reaction responsible for the polymerization of the composite resin. However, this factor is not as critical in the case of the cervical third because most of the monomers present in the cement are converted to polymers during the photoactivation process. In the cervical third, where light reaches the adhesive and resin cement effectively, the issue of incomplete polymerization is not relevant.

Some limiting factors should be taken into consideration, such as the difficulty of standardizing the preparation in areas of difficult access; difficulties in drying the canal to ensure a properly conditioned dentin, especially for materials that require acid etching; and the nonhomogeneity of the substrate, because each region has its own peculiarities. Thus, future studies should investigate the intracanal cementation process by evaluating the bonding interface over time and the interaction of the MH and Eit with other properties such as the degree of conversion and nanoleakage. The search for improvements in the adhesive process, if linked to a more conservative intraradicular preparation, could lead to more predictable and clinically stable rehabilitative treatments.

**CONCLUSION**

On the basis of the results of this study, it can be concluded that the MH and Eit of adhesive materials, and the underlying dentin substrate are influenced by the interactions of the resins materials used with the dentin as well as by the intraradicular depth. In the case of resin materials, the apical third tended to exhibit lower values for the parameters analyzed. This should lead to more conservative post spaces.

**REFERENCES**

Noteworthy Abstracts of the Current Literature

Making sense of complication reporting associated with fixed dental prostheses

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The current reporting of complications associated with FDPs is inadequate and misleading. Complications, which incur significant monetary costs, will particularly impact the perceived value (worth or importance) that patients derive from their prostheses. Effective documentation of complications should include type (biologic and technical), incidence, and severity. The fiscal burden of treatment should be quantified. Comparisons of different restorative materials, techniques, and procedures should be meaningful. Data collated prospectively or retrospectively and pooled over time should allow for comparisons within and between different practice settings. The proposed classification, based on the fiscal consequences of complications, achieves these objectives. Effective documentation of complications in conjunction with actual or projected survival data and personal clinical experience will enable clinicians to provide realistic information of the expected clinical service of dental prostheses.

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