Microtensile bond strength of photoactivated and autopolymerized adhesive systems to root dentin using translucent and opaque fiber-reinforced composite posts

Andre Mallmann, DDS, PhD,[a] Leticia Borges Jacques, DDS, MS, PhD,[b] Luis Felipe Valandro, DDS, MS,[c] and Antonio Muench, DDS, PhD[d]
School of Dentistry, Bahiana Foundation for Science Development, Salvador, Bahia, Brazil; School of Dentistry, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil; School of Dentistry, University of Sao Paulo, Sao Paulo, Brazil

Statement of problem. The use of fiber-reinforced composite resin posts in endodontically treated teeth has increased. However, selecting an adhesive system that provides reliable and long-lasting bonding to root canal dentin remains difficult.

Purpose. This study evaluated the microtensile bond strength of 2 adhesive systems to root dentin and 2 different fiber-reinforced composite resin posts.

Material and methods. Forty single-rooted teeth were instrumented, and root canals were prepared for translucent (Light Post [LP]) or opaque (Aestheti Post [AP]) quartz fiber-reinforced composite resin posts. Two adhesive systems were used: Scotchbond Multi-Purpose Plus (SBMP) (autopolymerized) as a control group, and Single Bond (SB) (photoactivated). Teeth were assigned to 4 groups (n=10): SBMP+LP, SBMP+AP, SB+LP, SB+AP. After post cementation, roots were perpendicularly sectioned into 1-mm-thick slices, which were trimmed to obtain dumbbell-shaped specimens. The specimens were divided into 3 regions: cervical (C), middle (M), and apical (A). To determine the bond strength, the bonding area of each specimen was calculated, and specimens were attached to a device to test microtensile strength at a crosshead speed of 1 mm/min. Data were analyzed using 3-way analysis of variance and the Tukey test (α=.05). Fractured specimens were examined under a ×25 stereomicroscope to determine the mode of fracture.

Results. There were significant differences only among root dentin regions ($P<.001$). The cervical third (9.16 ± 1.18 MPa) presented higher mean bond strength values, especially for SBMP. Middle and apical regions demonstrated lower values (7.08 ± 0.92 and 7.31 ± 0.60 MPa, respectively). Adhesive and post main factors did not demonstrate significance. Also, no interaction was significant. No cohesive fractures within resin cement, fiber-reinforced composite resin post, or root dentin were identified.

Conclusions. Both adhesive systems tested demonstrated reliable bonding when used with translucent and opaque fiber-reinforced composite posts. (J Prosthet Dent 2007;97:165-72.)

CLINICAL IMPLICATIONS

The results of this in vitro study suggest that both autopolymerized and photoactivated adhesive systems provide reliable bonding to root canal dentin when cemented with dual-polymerizing resin cement, irrespective of the use of the translucent or opaque fiber-reinforced composite resin posts tested.

Prefabricated, fiber-reinforced composite resin endodontic posts have been used since the beginning of 1990s with the introduction of carbon fiber posts, which have an elastic modulus similar to dentin.[1] Other types of fiber-reinforced posts have been recently developed with the aim of obtaining more esthetic treatment outcomes, and have resulted in the introduction of clear glass and white quartz fiber-reinforced composite resin posts. More recently, these posts were produced using translucent matrices that allow light propagation to enhance polymerization of photoactivated adhesive systems.[2]

Post cementation into a root canal is still a concern, as confirmed by clinically observed failures.[3] Some manufacturers recommend autopolymerized, photoactivated or dual-polymerized adhesive systems for cementation of prefabricated endodontic posts.[4] However, autopolymerized

---

This research was presented at the Brazilian Society for Dental Research annual meeting in Aguas de Lindoia, Sao Paulo, September, 2004.

This study was partially supported by CAPES grants.

[a] Assistant Professor, School of Dentistry, Bahiana Foundation for Science Development.

[b] Assistant Professor, Restorative Dentistry, School of Dentistry, Federal University of Santa Maria.

[c] Assistant Professor, Restorative Dentistry, School of Dentistry, Federal University of Santa Maria.

[d] Chair and Professor, Dental Materials, School of Dentistry, University of Sao Paulo.

adhesive systems are the most commonly used for this procedure.[5,6] Therefore, doubts remain as to whether bonding of photoactivated materials to root dentin is effective, especially in areas of difficult light access, such as the middle and apical thirds of root canals.[7] The chemical incompatibility between composite resin and adhesive systems with a low pH[8] and configuration factor (C-factor)[9,10] is also important in bonding adhesive materials to dentin.[11]

For composite resin restorations, the bonding strength to dentin competes with the developing shrinkage stress of the setting material. Only in restorations where flow can relieve a great part of this stress will the bond not be disrupted. Since the degree of flow is determined by material being supplied from the free, unbonded outer surfaces of the restoration, the preservation of the bond depends, among other things, on the 3-dimensional configuration of the restoration.[12]

The C-factor is an important consideration in bonding procedures and was first described by Feilzer et al[12] as the ratio of the bonded to unbonded (free) surfaces of preparations. In intracoronal restorations, the C-factor can be categorized by type (types 1 to 5). The higher the C-factor, the greater the stress from polymerization contraction. The best situation is C=1 (Class IV restorations), because this means there is only 1 bonded surface and 5 free surfaces to allow for polymerization contraction. Class I and Class V restorations, in which the C-factor is categorized as C=5, represent the worst situation, since there are 5 bonded surfaces and only 1 unbonded surface to allow flow of the resin material.

The polymerization contraction may affect the dentin-adhesive interface at different levels, depending on the preparation configuration (C-factor). By means of a microtensile bond strength (MBS) test, Mallmann et al[9] demonstrated lower dentin bond strength values in preparations with a C-factor of 5 when compared to a C-factor of 1, using an adhesive system that requires phosphoric acid etching.

Another method to estimate the configuration factor is to divide the free surface area by the total bonded area, as described by Bouillaguet et al.[13] The authors reported that when endodontic posts are cemented inside root canals, the C-factor may exceed 200 (ratio of the bonded to the unbonded area). This is because there is a large area of resin cement bonded to the dental substrate and endodontic post, and there is little free area to allow for polymerization contraction. The authors also observed that the combination of a photoactivated adhesive system (Single Bond) with a dual-polymerization resin cement (Rely X ARC) in a high C-factor condition produced lower bond strength values (5.3 MPa). However, when teeth were sectioned longitudinally and endodontic posts were cemented onto open post spaces, thus reducing the cavity configuration, mean bond strength values increased considerably (23.2 MPa). Similarly, Perdigao et al[10] found lower bond strength values in the apical zone than in the cervical zone, also due to a high C-factor.

Goracci et al[14] evaluated the push-out strength among root dentin, resin cement, and the fiber post, comparing the application of a dentin adhesive system to no application of this system, and it was observed that the adhesive did not increase the bond strength. The authors believed that the polymerization stress of the resin cement inside the root canal was high due to a high C-factor, impairing bonding to root canal dentin. Even though in vivo[3,6] and in vitro[15,16] studies have reported that adhesive luting is crucial for improving the pull-out strength of a fiber post, Goracci et al[17] recently reported that the frictional effect between the fiber post–resin cement–root dentin interfaces appears to be an important factor for improving dislocation resistance of fiber posts.

The bonding effectiveness among dentin, resin luting agents, and posts can be evaluated using microscopic analysis,[4,7,18,19] by microleakage,[20] and by bond strength tests.[14,21,22] In 1994, Sano et al[23] developed the microtensile test technique, thus making it possible to perform bond strength studies in specific areas of dental structures. Some studies using MBS tests have investigated the bonding to root dentin. However, only external root surfaces were used as a bonding substrate in these studies.[24-26] Gaston et al[21] evaluated the regional MBS of 2 resin luting agents to root dentin. However, no post was inserted into root canals. There are few investigations regarding the bond strength of photoactivated adhesives associated with resin luting agents and fiber-reinforced composite resin posts in different regions of the root canal. Boschian Pest et al[27] evaluated the bond strength between a resin luting agent and dentin, and between a resin luting agent and a fiber-reinforced composite resin post, and reported good results when photoactivated adhesive systems were associated with translucent fiber-reinforced composite resin posts. Bouillaguet et al[13] investigated the MBS between fiber-reinforced composite resin posts and root dentin using photoactivated adhesive systems and demonstrated that it is possible to perform these tests even with a high C-factor, as observed in endodontic post cementation. Perdigao et al[10] commented that the high C-factor of the root canal contributed to the lower bond strength values in the apical root region when compared to the values obtained in the cervical root region. According to the authors, as the number of dentin tubules decreases, moving from the crown to the root apex, the difference in the number of tubules may explain why the strongest adhesion occurred in the most coronal sections. Adhesion is enhanced by penetration of resin into the tubules, and if there were a greater number of tubules per mm^2, a stronger bond would be expected. Also, the coronal portion of the canal is the most accessible part of the canal space,

Table I. Mode of activation, composition, and batch number of tested luting materials

Materials (manufacturer)	Mode of activation	Composition	Batch no.
Scotchbond Multi-Purpose Plus (3M ESPE, St. Paul, Minn)	Autopolymerized	Activator: ethyl alcohol, benzene sulfinic acid, sodium salt	7546
		Primer: water, HEMA, Vitrebond copolymer	3008
		Catalyst: Bis-GMA, HEMA, benzoyl peroxide	7547
Single Bond (3M ESPE)	Light-polymerized	Bis-GMA, ethyl alcohol, HEMA, UDMA, water, glycerol 1,3 dymethacrylate, copolymer of acrylic and ithaconic acids	16061
Rely X ARC (3M ESPE)	Dual-polymerized	Silane, treated silica filler, TEGDMA, Bis-GMA, dymethacrylate polymer	CMCM

HEMA, 2-hydroxyethyl methacrylate; *Bis-GMA*, bisphenol-glycidyl methacrylate; *UDMA*, urethane dimethacrylate; *TEGDMA*, triethylene glycol dimethacrylate.

making it easier to etch and more thoroughly apply the adhesive agents.

The purpose of this study was to evaluate the regional (cervical, middle, and apical thirds) MBS of photoactivated and autopolymerized adhesive systems to root dentin when used for cementation of translucent and opaque quartz fiber-reinforced composite resin posts. The tested hypotheses were that autopolymerized and photoactivated adhesive systems promote different bond strength values in distinct root canal segments, and that photoactivated adhesive systems produce higher bond strength values in different root canal regions when used in association with translucent quartz fiber-reinforced composite resin posts rather than opaque posts.

MATERIAL AND METHODS

Forty single-rooted teeth extracted for periodontal reasons and previously stored in 0.5% chloramine solution (Formula & Acao, Sao Paulo, Brazil) were used for this study. Coronal structures were removed by transverse sections 1 mm above the cemento-enamel junction, using a low speed diamond-coated saw mounted in a cutting machine (Labcut 1010; Extec Corp, Enfield, Conn) under constant water cooling.

This study included 2 main independent factors with 2 levels (2 adhesive systems and 2 types of posts) and 1 within-tooth factor with 3 levels (cervical, middle, and apical regions of root dentin), since a single tooth specimen provided data for the 3 regions. The 40 teeth were divided into 4 groups (n=10), and each of these groups provided 3 subdivisions (cervical, middle, and apical regions), which resulted in 12 subgroups.

Root canals were manually instrumented (No. 15 to 40 K-file series; Dentsply Maillefer, Ballaigues, Switzerland) along the entire working length, and were subsequently enlarged with reamers (Nos. 2, 3, and 4 Largo drills; Dentsply Maillefer). Irrigation using distilled water was performed after each file or drill size change throughout the shaping process. Teeth presenting some obliteration along the root canal or with a working length of less than 14 mm were discarded from the sample and replaced. Root apices were externally sealed using an adhesive system (Single Bond; 3M ESPE, St. Paul, Minn) and composite resin (Filtek Z250; 3M ESPE, St. Paul, Minn) to avoid extrusion of luting materials through the apex. Root canals were prepared for No. 2 translucent (Light-Post; Bisco, Schaumburg, Ill) or opaque (Aestheti Post; Bisco) quartz fiber-reinforced composite resin posts using the rotatory instruments supplied by the manufacturer. Roots were molded with heavy-bodied addition silicone impression material (Simply Perfect; Discus Dental, Culver City, Calif) to avoid light propagation through external root surfaces during the subsequent polymerization of adhesive systems and resin cement.

The mode of activation, composition, and batch numbers of tested luting materials are summarized in Table I. Before application of resin cement systems, root canals were irrigated with 0.5% sodium hypochlorite solution (Miyako do Brasil Ind e Com Ltd, Sao Paulo, Brazil) for 1 minute, rinsed with distilled water, and dried using paper points (Dentsply Maillefer). Canals were etched using 35% phosphoric acid (3M ESPE) for 30 seconds, rinsed with distilled water, and thoroughly dried until no visible moisture could be observed. Fiber-reinforced composite resin posts were also etched using 35% phosphoric acid (3M ESPE) for 60 seconds for the purpose of cleaning, rinsed with distilled water, and thoroughly air dried, as recommended by the manufacturer. Each root was placed into its previously fabricated silicone mold.

A single coat of activator from an adhesive system (Scotchbond Multi-Purpose Plus Activator 1.5; 3M ESPE) was applied to the post space dentin using a superfine microbrush (Jeneric Pentron, Wallingford, Conn). This step was added to make the adhesive autopolymerizing. The excess of activator was removed from the walls using paper points (Dentsply Maillefer), and the adhesive was gently air dried for 5 seconds. Next, a single coat of a primer (Scotchbond Multi-Purpose Plus Primer 2; 3M ESPE) was applied, excess was removed, and the primer was gently air dried for

5 seconds. Finally, a single coat of a catalyst (Scotchbond Multi-Purpose Plus Catalyst 3.5; 3M ESPE) was applied, excess was removed, and the catalyst was air dried gently for 5 seconds. The dual-polymerized resin cement (RelyX ARC; 3M ESPE) was placed into the root canal with the aid of a spiral drill (Lentulo; Dentsply Maillefer). A single coat of an adhesive system (Single Bond; 3M ESPE) was applied into root canal dentin for 20 seconds using a superfine microbrush (Jeneric Pentron), excess was removed using paper points (Maillefer), the adhesive was gently air dried for 5 seconds, and then polymerized for 30 seconds with a light-polymerizing unit (500 mW/cm^2, QHL Curing Lite; Dentsply Caulk, Milford, Del). The dual-polymerized resin cement (RelyX ARC; 3M ESPE) was inserted into the root canal with the aid of a spiral drill (Lentulo; Dentsply Maillefer).

Posts were positioned into root canals immediately after insertion of the resin cement, and photoactivation was performed through the cervical portion of the root for 40 seconds. Before testing, specimens were kept in a 100% relative moisture environment for 24 hours and then stored in distilled water for an additional 24 hours, always at 37°C.

Specimens were fixed with sticky wax (Horus; Dentsply, Petropolis, Brazil) into a device adapted to the cutting machine (Labcut 1010; Extec Corp) and perpendicularly sectioned into approximately 1-mm-thick sections using a low-speed diamond-coated saw under constant water cooling (Fig. 1). This procedure resulted in 12 serial slices per root, identified as cervical 1, 2, 3, 4; middle 1, 2, 3, 4; and apical 1, 2, 3, 4. With the aid of a ×4 magnifying glass, slices were held with finger pressure and trimmed using a tapered diamond rotary cutting instrument (No. 3195; KG Sorensen, Sao Paulo, Brazil) starting from the mesial surface until it touched the post. The same procedure was performed from the distal surface, so that dumbbell-shaped specimens were obtained, as demonstrated in Figure 2. All slices were examined under a stereomicroscope (StereoZoom4; Bausch & Lomb, Bern, Switzerland) with ×25 magnification to ensure that the diamond rotary cutting instrument touched the post during trimming procedures (Fig. 3).

A digital caliper (Model 227; Starrett, Sao Paulo, Brazil) with 0.01-mm precision was used to measure the thickness (t) of each slice. The surface area of resin cement bonded to root canal dentin on one side of the dumbbell-shaped specimen (Fig. 3) was obtained by applying the following equation, according to Mallmann et al[28]: $A = (PC \div 2) - DIWD \times t$, where PC is post circumference, DIWD is the diamond rotatory cutting instrument working diameter (0.6 mm), and t is the section thickness. The post diameter was 1.8 mm in the cervical and middle thirds, and 1.2 mm in the apical third. The working diameter was 0.6 mm. The PC was calculated using this formula: $PC=2\pi r$, where π value is 3.14, and r is post radius. Hence, the following PC values were obtained for the cervical and middle thirds: $PC_{CM} = 2 \times 3.14 \times 0.9 = 5.6$ mm, and $PC_A = 2 \times 3.14 \times 0.6 = 3.8$ mm for the apical third. Therefore, the length of resin cement bonded to dentin (L) in the cervical and middle thirds was: $L_{CM} = (5.6 \div 2) - 0.6 = 2.2$ mm, and $L_A = (3.8 \div 2) - 0.6 = 1.3$ mm in the apical third. The length of the bonded dentin multiplied by the thickness yielded the total bonded area. Dumbbell-shaped sections were attached to a special device designed for the MBS test using cyanoacrylate glue (Super Bonder Gel; Loctite, Sao Paulo, Brazil). Each slice was submitted to an MBS test in a universal testing machine (Kratos Model K–2000 MP; Equipamentos Industriais Ltda, Sao Paulo, Brazil) at a crosshead speed of 1 mm/min until fracture. After each test, fractured slices were examined under a ×25 stereomicroscope (StereoZoom4; Bausch & Lomb) to determine the mode of fracture. Failure modes were classified as adhesive between resin cement and post (RC−P), adhesive between resin cement and root dentin (RC−RD), mixed failure if the fracture was partially at the resin cement-post interface and partially at the resin cement-root dentin interface, or cohesive within the resin cement, post, or root dentin.

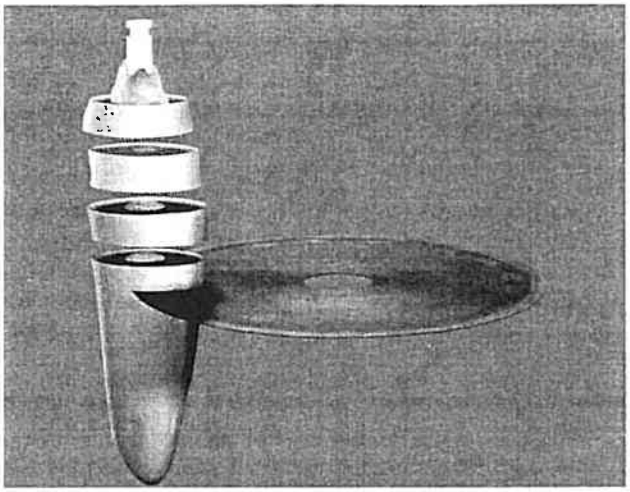

Fig. 1. Perpendicular sectioning of root-post sets into approximately 1-mm-thick sections.

The load at failure (N) divided by the total bonded area (mm^2) was used to calculate the bond strength in MPa for each slice. Mean bond strength values in the cervical, middle, and apical thirds of each root were calculated, for a total of 120 values, which were submitted to 3-way analysis of variance (ANOVA) using the complex split-plot model, where the main factors, adhesive systems and posts, both with 2 levels, are independent factors, and the region, with 3 levels, provides a within-tooth effect.[29] Post hoc comparisons were made using the Tukey test at a significance level of α=.05.

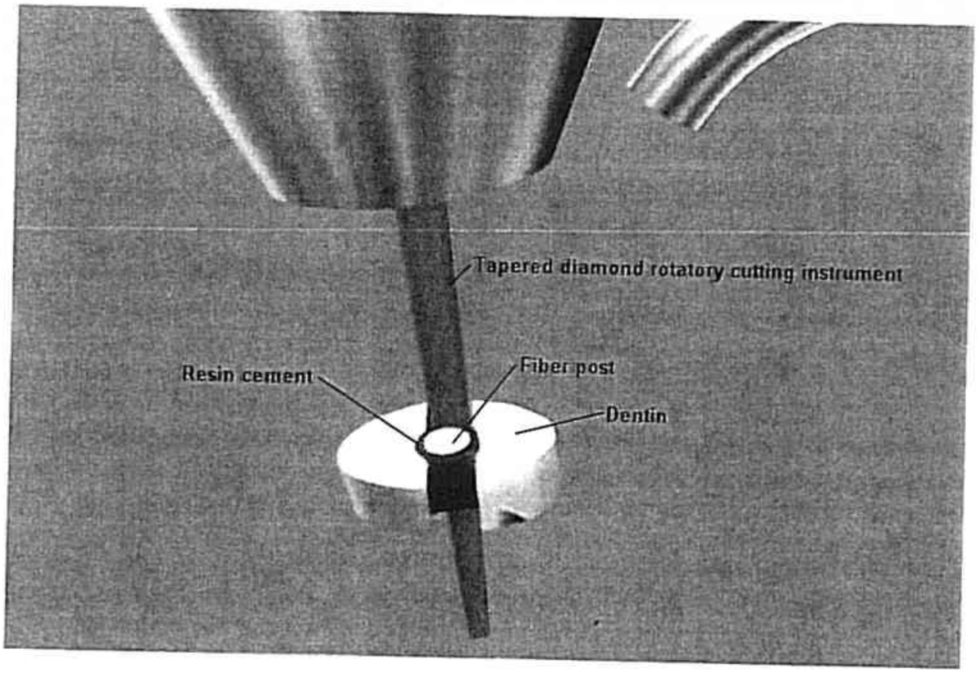

Fig. 2. Interproximal slice trimming using tapered diamond rotatory cutting instrument.

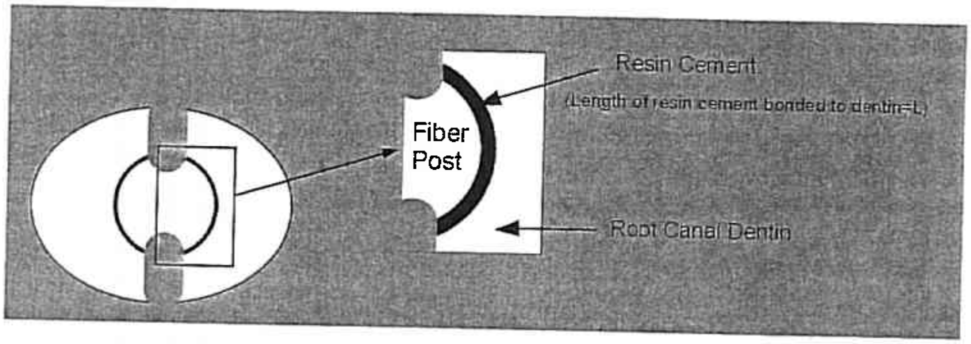

Fig. 3. Dumbbell-shaped specimen. Magnified view showing length of resin cement bonded to root dentin *(L)*.

RESULTS

Three-way ANOVA (Table II) showed no significant differences between the adhesive systems and fiber-reinforced composite resin posts. Otherwise, significant differences were observed among root dentin regions ($P<.001$). Table III shows the mean bond strength values (MPa) obtained for the 12 tested experimental conditions. It was found that the highest bond strength values were measured in the cervical region. When Scotchbond Multi-Purpose Plus (SBMP) was used with the Light Post (LP), the cervical segment demonstrated significantly higher values than the middle and apical thirds. However, no significant difference was found between middle and apical root canal regions, irrespective of the adhesive system and fiber-reinforced composite resin post association. Also, no interaction was significant. The total number of slices, the number of slices lost during preparation, and mode of fracture

Table II. ANOVA of microtensile bond strength (split-plot model)

Source	*df*	Mean square	F	*P*
Adhesive (A)	1	38.62	2.23	.014
Post (P)	1	5.06	0.29	.597
A × P	1	0.00	0.00	.988
Error I	36	17.28	–	–
Main-plot	39	–	–	–
Region (R)	2	54.14	19.75	<.007
A × R	2	6.27	2.29	.106
P × R	2	2.27	0.83	.550
A × P × R	2	7.51	2.74	.694
Error II	72	2.74	–	–
Subplot	80	–	–	–
Total	119	–	–	–

Table III. Mean microtensile bond strength (SD) of 12 subgroups, and mean values (MPa) of effect of main factor region

		Root dentin regions		
Adhesive*	**Post****	**Cervical**	**Middle**	**Apical**
SBMP	LP	10.84 (2.60)^{a}	7.87 (1.57)^{bc}	7.20 (1.36)^{bc}
SBMP	AP	9.16 (2.93)^{ab}	7.89 (3.29)^{bc}	7.64 (1.87)^{bc}
SB	LP	8.34 (3.73)^{bc}	6.21 (3.49)^{c}	7.88 (3.09)^{bc}
SB	AP	8.32 (2.64)^{bc}	6.37 (3.07)^{c}	6.51 (2.23)^{c}
Mean values		9.16 (1.18)^{A}	7.08 (0.92)^{B}	7.31 (0.60)^{B}

Mean values with different superscript letters are statistically different ($P<.05$). Lowercase letters compare 12 subgroups, and capital letters compare mean values of main factor, region.

*SBMP, Scotchbond Multi-Purpose Plus; SB, Single Bond.

***LP,* Light Post; *AP,* Aestheti Post.

Table IV. Total number of slices, number and % of slices lost during preparation, and mode of fracture distribution (%) for each experimental condition

				Mode of fracture		
Adhesives* + Post**	**Root dentin regions**	**Total number of slices**	**Lost slices (%)**	**Adhesive RC–P**	**Adhesive RC–RD**	**Mixed**
SBMP + LP	Cervical	38	–	34 (89.5)	1 (2.6)	3 (7.9)
	Middle	39	–	36 (92.3)	3 (7.7)	–
	Apical	40	1 (2.5)	37 (92.5)	2 (5.0)	–
SB + LP	Cervical	37	3 (8.1)	14 (37.8)	9 (24.3)	11 (29.7)
	Middle	35	2 (5.7)	14 (40.0)	8 (22.9)	11 (31.4)
	Apical	39	8 (20.5)	18 (46.2)	5 (12.8)	8 (20.5)
SBMP + AP	Cervical	37	1 (3.7)	36 (97.3)	–	–
	Middle	39	–	37 (94.9)	2 (5.1)	–
	Apical	38	–	36 (94.7)	2 (5.3)	–
SB + AP	Cervical	38	2 (5.3)	27 (71.1)	8 (21.1)	1 (2.6)
	Middle	36	4 (11.1)	23 (63.9)	5 (13.9)	4 (11.1)
	Apical	38	4 (10.5)	24 (63.2)	8 (21.1)	2 (5.3)

RC-P, Resin cement–post; *RC–RD,* resin cement–root dentin.

**SBMP,* Scotchbond Multi-Purpose Plus; *SB,* Single Bond.

***LP,* Light Post; *AP,* Aestheti Post.

distribution for each experimental condition are described in Table IV. No cohesive fractures within resin cement, fiber-reinforced composite resin post, or root dentin were identified. By analyzing the mode of fracture, it was observed that the distribution of failures for SBMP was more homogeneous, and failures were predominantly at the interface between the resin cement and fiber-reinforced composite resin post. However, there was heterogeneity for Single Bond (SB) with an inconsistent distribution of fractures.

DISCUSSION

The bond strength values obtained in the present study revealed no significant differences between photoactivated and autopolymerized adhesive systems for both middle and apical thirds. Therefore, the first hypothesis of this study, that autopolymerized and photoactivated adhesive systems promote different bond strength values in distinct root canal segments, was partially rejected. One of the critical aspects of bonding to root canal dentin is the use of adhesive systems that rely on photoactivation. This subject has been investigated by several authors,[4,7,19] who demonstrated the presence of an interdiffusion resin-dentin zone in the root canal dentin by scanning electron microscopy (SEM). The results found in the present study disagree with SEM observations reported by Vichi et al,[7] who described a more effective micromechanical bonding mechanism in the apical third of the root with autopolymerized rather than photoactivated systems. Among the variables tested in this study, "region" was the only factor that demonstrated significant differences. These findings regarding bond strength values to different thirds of root canals are in agreement with SEM observations reported by Ferrari and Mannocci,[19] which showed higher resin tag density in the cervical than in middle and apical thirds. However, the results demonstrated by Gaston et al[21] were different from the results of the current study, because the authors showed higher mean bond strength values in the apical third of root dentin when compared to middle and cervical regions.

The root dentin bond strength values observed in the current study (6.21 to 10.84 MPa) are much lower than the coronal dentin bond strength values found by Inoue et al,[11] which may exceed 40 MPa. Also, the findings of the present study are lower than the root dentin bond strength values reported by Gaston et al,[21] which exceeded 20 MPa.

Several factors may have contributed to the discrepancies in bond strength values, such as morphological differences between substrates (coronal dentin and root canal dentin) and root canal irrigation solutions, as well as further methodological variations. Nevertheless, it is believed that polymerization contraction of the resin cement might have been the factor that most influenced bond strength values, as noted by Bouillaguet et al.[13]

Regarding fiber-reinforced composite resin posts, there was no significant difference between translucent and opaque posts, thus suggesting that if halogen light passed through the translucent fiber-reinforced composite resin post, such light propagation had no influence on bond strength values of luting materials. Therefore, the second hypothesis of this study, that photoactivated adhesive systems produce higher bond strength values in different root canal regions when used in association with translucent quartz fiber-reinforced composite resin posts rather than opaque posts, was not supported by the data. Boschian Pest et al[27] investigated the association of resin cements with endodontic fiber-reinforced composite resin posts and observed by means of push-out tests that the combination of translucent posts and photoactivated resin cements resulted in the highest bond strength values. However, the authors reported that such good results should not be attributed to post translucency, but to the presence of a small amount of bubbles within the photoactivated resin cement when compared to autopolymerization and dual-polymerization resin cements, because these cements require hand mixing, which increases the amount of bubbles within the resin cement.

When 2 substrates are bonded by means of a bonding agent, it is important that they be compatible with the luting materials. To prevent early bonding failures between teeth and restorative materials, there must be chemical affinity between the adhesive systems used to seal the dentin and the resin cements. Especially in bond strength tests, the least adherent substrate or the one with less affinity breaks down first, thus resulting in failure of the restoration. Some investigators assert that there must be some incompatibility between photoactivated adhesives and autopolymerized resin materials.[8] Moreover, it is important that dual-polymerization materials polymerize even in the absence of a light source. Theoretically, as these materials have a dual mode of activation, polymerization should be effective either with or without the aid of a light source. However, Witzel et al[22] verified that the association of SB adhesive system with Rely X ARC resin cement, which was also tested in this study, produced a decrease in bond strength values when the resin cement was not photoactivated, in comparison to the group that was photoactivated. Regarding bond strength values, it could be assumed that both photoactivated and autopolymerized adhesive systems tested in the present study showed good affinity with Rely X ARC dual-polymerization resin cement. This assumption is based on the result that both adhesive systems achieved good bonding to root dentin and fiber-reinforced composite resin posts, and there was no significant difference with respect to each other, although higher bond strength values were found with the association of translucent fiber-reinforced composite resin posts and an autopolymerized adhesive system.

When the mode of fracture was analyzed for the autopolymerized system (SMBP), most failures occurred between the resin cement and fiber-reinforced composite resin post. Initially, this was not a concern because it was believed that the adhesion between adhesive system and the fiber-reinforced composite resin post would exceed the bond between the adhesive and root dentin. However, for the photoactivated system (SB), a considerable number of failures occurred between the resin cement and root dentin, causing concern regarding the adhesion both to root canal dentin and the fiber-reinforced composite resin post. These failures may be responsible for the lower bond strength values obtained for the photoactivated system.

This study verified that it is possible to perform MBS testing to evaluate the bond between root dentin and nonrigid, prefabricated endodontic posts. This was also observed by Bouillaguet et al,[13] who used composite resin prefabricated posts (Z100) luted with different resin cement systems. However, it should be observed that there may be limitations to the direct application of the results of the present study to clinical situations. One limitation is the absence of thermal cycling or dynamic loading, which may provide additional information about the durability of the bond. Despite advances in bonding to dental structures, concerns regarding the cementation of endodontic posts using resin cements remain. Therefore, further investigation is needed to minimize polymerization contraction of resin cements, as well as to improve bonding of autopolymerized systems to fiber-reinforced composite resin posts. Finally, problems related to the bonding of photoactivated adhesives to both root dentin and fiber-reinforced composite resin post must be addressed in future studies.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The photoactivated adhesive system presented similar bond strength values to the autopolymerized system, although the association of the autopolymerized adhesive with the translucent fiber-reinforced composite resin post showed the highest bond strength values.
2. The bonding mechanism to root canal dentin was not influenced by the type of fiber-reinforced composite resin post (translucent or opaque).
3. The cervical region of root dentin showed significantly higher mean bond strength values than the middle and apical thirds.
4. No cohesive fractures within resin cement, fiber-reinforced composite resin post, or root dentin were identified. The distribution of failures for SBMP was more homogeneous, and failures were predominantly at the interface between resin cement and fiber-reinforced composite resin post. However, the failures for SB were heterogeneous, with an inconsistent distribution of fractures.

The authors thank Bisco, 3M ESPE, Dentsply-Maillefer, Discus Dental, and KG Sorensen for supplying the materials used in this experiment, Mr Paulo Santos and Mr Antonio Lascala for the illustrations, and Ms Eliane Placido for language support.

REFERENCES

1. Sidoli GE, King PA, Setchell DJ. An in vitro evaluation of a carbon fiber-based post and core system. J Prosthet Dent 1997;78:5-9.
2. Ferrari M, Vichi A, Grandini S, Goracci C. Efficacy of a self-curing adhesive-resin cement system on luting glass-fiber posts into root canals: an SEM investigation. Int J Prosthodont 2001;14:543-9.
3. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000;13:9B-13B.
4. Ferrari M, Vichi A, Grandini S. Efficacy of different adhesive techniques on bonding to root canal walls: an SEM investigation. Dent Mater 2001;17:422-9.
5. Mannocci F, Innocenti M, Ferrari M, Watson TF. Confocal and scanning electron microscopic study of teeth restored with fiber posts, metal posts, and composite resins. J Endod 1999;25:789-94.
6. Malferrari S, Monaco C, Scotti R. Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. Int J Prosthodont 2003;16:39-44.
7. Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. Dent Mater 2002;18:495-502.
8. Sanares AM, Itthagarun A, King NM, Tay FR, Pashley DH. Adverse surface interactions between one-bottle light-cured adhesives and chemical-cured composites. Dent Mater 2001;17:542-56.
9. Mallmann A, Zovico F, Soares M, Placido E, Ferrari M, Cardoso PE. Microtensile dentin bond strength of self-etching and single-bottle adhesive systems in different cavity configurations. J Adhes Dent 2003;5:121-7.
10. Perdigao J, Geraldeli S, Lee IK. Push-out bond strength of tooth-colored posts bonded with different adhesive systems. Am J Dent 2004;17:422-6.
11. Inoue S, Vargas MA, Abe Y, Yoshida Y, Lambrechts P, Vanherle G, et al. Microtensile bond strength of eleven contemporary adhesives to dentin. J Adhes Dent 2001;3:237-45.
12. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 1987;66:1636-9.
13. Bouillaguet S, Troesch S, Wataha JC, Krejci I, Meyer JM, Pashley DH. Microtensile bond strength between adhesive cements and root canal dentin. Dent Mater 2003;19:199-205.
14. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci 2004;112:353-61.
15. Utter JD, Wong BH, Miller BH. The effect of cementing procedures on retention of prefabricated metal posts. J Am Dent Assoc 1997;128:1123-7.
16. Schmage P, Sohn J, Nergiz I, Ozcan M. Various conditioning methods for root canals influencing the tensile strength of titanium posts. J Oral Rehabil 2004;31:890-4.
17. Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M. The contribution of friction to the dislocation resistance of bonded fiber posts. J Endod 2005;31:608-12.
18. Ferrari M, Mannocci F, Vichi A, Cagidiaco MC, Mjor I. Bonding to root canal: structural characteristics of the substrate. Am J Dent 2000;13:255-60.
19. Ferrari M, Mannocci F. A 'one-bottle' adhesive system for bonding a fibre post into a root canal: an SEM evaluation of the post-resin interface. Int Endod J 2000;33:397-400.
20. Mannocci F, Ferrari M, Watson TF. Microleakage of endodontically treated teeth restored with fiber posts and composite cores after cyclic loading: a confocal microscopic study. J Prosthet Dent 2001;85:284-91.
21. Gaston BA, West LA, Liewehr FR, Fernandes C, Pashley DH. Evaluation of regional bond strength of resin cement to endodontic surfaces. J Endod 2001;27:321-4.
22. Witzel MF, Braga RR, Singer Jde M, Azevedo CM. Bond strength between polymer resin-based cement and porcelain-dentin surface: influence of polymerization mode and early cyclic loading. Int J Prosthodont 2003;16:145-9.
23. Sano H, Shono T, Sonoda H, Takatsu T, Ciucchi B, Carvalho R, et al. Relationship between surface area for adhesion and tensile bond strength—evaluation of a micro-tensile bond test. Dent Mater 1994;10:236-40.
24. Yoshiyama M, Carvalho RM, Sano H, Horner JA, Brewer PD, Pashley DH. Regional bond strengths of resins to human root dentine. J Dent 1996;24:435-42.
25. Yoshiyama M, Sano H, Ebisu S, Tagami J, Ciucchi B, Carvalho RM, et al. Regional strengths of bonding agents to cervical sclerotic root dentin. J Dent Res 1996;75:1404-13.
26. Yoshiyama M, Matsuo T, Ebisu S, Pashley D. Regional bond strengths of self-etching/self-priming adhesive systems. J Dent 1998;26:609-16.
27. Boschian Pest L, Cavalli G, Bertani P, Gagliani M. Adhesive post-endodontic restorations with fiber posts: push-out tests and SEM observations. Dent Mater 2002;18:596-602.
28. Mallmann A, Jacques LB, Valandro LF, Mathias P, Muench A. Microtensile bond strength of light- and self-cured adhesive systems to intraradicular dentin using a translucent fiber post. Oper Dent 2005;30:500-6.
29. Johnson NL, Leone FC. Statistics and experimental design in engineering and the physical sciences. 2nd ed. New York: John Wiley; 1977. p. 847-65.

Reprint requests to:
Dr Leticia Borges Jacques
Rua Venancio Aires, 1795, Room 71, Centro
Santa Maria, RS
BRAZIL, 97010-003
Fax: 55-55-3223-7832
E-mail: leticiajacques@uol.com.br

0022-3913/$32.00

doi:10.1016/j.prosdent.2007.01.008