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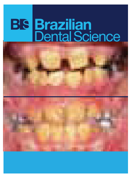

ORIGINAL ARTICLE

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Effect of root perforations on the bond strength of fiberglass post using different adhesive systems and resin cement

Efeito das perfurações radiculares na resistência de união de pinos de fibra de vidro utilizando diferentes sistemas adesivos e cimento resino

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ABSTRACT

Objective: This study evaluated the effect of root perforations on the bond strength of fiberglass posts cemented to the root canal with two adhesive systems and resin cement. **Material and Methods:** Forty single-rooted human teeth received endodontic treatment and were prepared for the cementation of fiberglass posts (Exacto Mini, Angelus). The teeth were divided into four experimental groups (n = 10) according to the root condition (with or without perforation) and the adhesive system used: G1: without perforation + Adper Single Bond 2 (3M ESPE), G2: without perforation + Clearfil SE Bond (Kuraray), G3: with perforation + Adper Single Bond 2, G4: with perforation + Clearfil SE Bond. The perforation was executed on the root surface with a diamond bur and sealed with white mineral trioxide aggregate (MTA). The specimens were sectioned and a push-out test was carried out (1 mm/min speed and 50 kgf). The data were statistically analyzed by ANOVA and Tukey Test (5%). **Results:** Adper Single Bond 2 promoted the greatest values of bond strength to the roots without root perforation. The presence of root perforation led to the reduction in bond strength values regardless of the bonding system used ($p < 0.05$). **Conclusion:** The root perforations caused a direct effect on the bond strength of the fiberglass posts cemented by reducing the bond strength values to the root dentin regardless of the adhesive system used.

KEYWORDS

Adhesion; Cementation; Dental adhesives; Dental cements; Fiberglass pins.

RESUMO

Objetivo: O objetivo deste estudo foi avaliar o efeito das perfurações radiculares na resistência de união de pinos de fibra de vidro cimentados com dois sistemas adesivos e um cimento resinoso. **Material e Métodos:** Quarenta dentes humanos unirradiculares receberam tratamento endodôntico e foram preparados para cimentação de pinos de fibra de vidro (Exacto Mini, Angelus). Os dentes foram divididos em quatro grupos experimentais (n = 10) de acordo com a condição radicular (com ou sem perfuração) e o sistema adesivo utilizado: G1: sem perfuração + Adper™ Single Bond 2; G2: sem perfuração + Clearfil SE Bond; G3: com perfuração + Adper™ Single Bond 2; G4: com perfuração + Clearfil SE Bond. A perfuração foi realizada na superfície radicular com uma ponta diamantada e selada com agregado de trióxido mineral branco (MTA). Os espécimes foram seccionados para realização do teste de extrusão por cisalhamento (Push-out) com velocidade de 1 mm/min e célula de carga de 50 Kgf. Os dados obtidos foram submetidos à Análise de Variância (ANOVA) e Teste de Tukey a 5%. **Resultados:** O sistema adesivo Adper Single Bond 2 promoveu os maiores valores de resistência de união nas raízes sem perfuração radicular. A presença de perfuração promoveu redução nos valores de resistência de união, independentemente do sistema adesivo utilizado ($p < 0,05$). **Conclusão:** As perfurações radiculares causaram efeito direto sobre a resistência de união dos pinos de fibra de vidro, promovendo redução nos valores da resistência de união independentemente do tipo de sistema adesivo utilizado.

PALAVRAS-CHAVE

Adesão; Cimentação; Adesivos dentinários; Cimentos dentários; Pinos de fibra de vidro.

INTRODUCTION

Root perforations are operative accidents that may occur during either endodontic treatment and retreatment or intraradicular prosthetic preparation leading to the communication between root canal and periodontal ligament. The most conservative treatment for these cases has been the perforation sealing with proper materials. Many materials can be employed to seal root perforations; among them, mineral trioxide aggregate (MTA) has been a very promising one [1,2].

When the dental structure loss is very significant after the root perforation sealing and endodontic treatment, the use of intraradicular posts is mandatory. Prefabricated intraradicular fiberglass posts have a modulus of elasticity similar to that of dentin, allowing the absorption and a more uniform distribution of the tensions over the root remnant. Moreover, their use results in a more conservative adhesive restorative procedure, decreases the risk of root fracture and increases the retention of the filler material [3]. Thus, the adhesive cementation of fiberglass posts has been indicated.

The adhesive cementation procedure is generally based on either the use of the acid etching of the tooth structure followed by the bonding agent application [4-9] or the utilization of self-etching adhesive systems [4,8,10,11]. These latter imply in a smaller technique sensibility and greater usage easiness because of the elimination of the acid etching step thus not compromising the adhesion inside the root canal because of either the incomplete removal of the acid or inefficient drying [12] prior to the application of the resin cement.

Because of the large variety of adhesive systems available with different properties and compositions that may interfere in the adhesion of the intraradicular post to root canal, a comparative study on the bond strength to tooth structure is necessary. Therefore, the aim of this present study was to evaluate the bond strength of intraradicular fiberglass posts to root dentin by varying the type of the adhesive system and the presence or absence of the root perforation sealed by mineral trioxide aggregate. The null hypotheses tested were that the retentive strength of glass fiber posts challenged by push-out bond strength test is irrespective of 1) the type of adhesive, 2) either the presence or absence of the root perforation, 3) and the interaction of the factor “adhesive system” and “root perforation (present or absent)”.

MATERIAL & METHODS

Preparation of the specimens

Forty single-rooted human teeth, extracted due to orthodontic or periodontal reasons were used after the approval of the Ethical Committee in Research of the School of Dentistry of São José dos Campos – UNESP (Process 061/2008). All teeth were stored into water at 4 °C until further processing.

The tooth crown was removed with the aid of a diamond disc (Microdont, São Paulo, SP, Brazil) at low speed under constant cooling and the length of roots was standardized at 16 mm. The teeth were randomly divided into four experimental group (n = 10) according to the root condition (with or without root perforation) and the adhesive system employed (Chart 1).

Chart 1 - Division of the groups

Groups	Adhesive systems	Root Condition
G1	Adper™ Single Bond 2 (3M ESPE, Sumaré, São Paulo, Brazil)	With root perforation
G2	Clearfil SE Bond (Kuraray Medical Inc, Okayama, Japan)	
G3	Adper™ Single Bond 2	Without root perforation
G4	Clearfil SE Bond	

All root canals were manually instrumented at the working length of 15 mm (1 mm short of the actual tooth length), by using Kerr files (Dentsply/Maillefer instruments, Ballaigues, Switzerland) through serial technique. The apical stop was obtained at size 50 memory file through step back technique (at every 1 mm) up to size 80 file. Irrigation was performed with 1% sodium hypochlorite at every file changing. Prior to obturation, the canals were treated by 17% EDTA for 3 min, washed with 5 ml of saline solution and dried with absorbent paper points. Obturation was carried out with gutta-percha points and AH Plus cement (Dentsply DeTrey, Konstanz, Germany,) sealed with Citodur (Dorident, Wien, Austria). The teeth were stored into an incubator at 37 °C and relative humidity for 7 days.

Perforation of root surface

After obturation, a perforation was executed on the specimens of G3 and G4 (vestibular surface) at 6.5 mm short of the cervical margin up to the filling material with the aid of a number 1011 diamond drill (KG Sorensen Ind. e Com. Ltda, Barueri, São Paulo, Brazil), perpendicular to the root surface, at high speed, under water and air refrigeration. Aiming to standardize, the perforation was performed through using a high speed handpiece coupled to a microscope base [13]. The diamond drill was replaced after every five perforations and the perforations was irrigated with 5 ml of saline solution, dried with absorbent paper points and sealed with white mineral trioxide aggregate (MTA, Angelus, Londrina, PR, Brazil). The excesses of the material were removed with cotton pellet moistened in saline solution, and the roots were maintained in an incubator at 37 °C and relative humidity for 24 h.

Perforation of root surface

All root canal fillings were removed at 12 mm short of the cervical margin, leaving 3 mm of filling material at the root apex. The dowel space was drilled in each root using a calibrated drill corresponding to the conical Exacto Mini glass Fiber Post size #2 (Exacto Mini, Angelus, Londrina, PR, Brazil) to a length of 12 mm. A new drill was replaced after every 5 preparations. The specimens were embedded into colorless acrylic resin (Jet, Artigos Odontológicos Clássico, São Paulo, SP, Brazil) at the 3 mm left in the apical area with the aid of a laboratorial silicone mold (Silibor; São Bernardo do Campo, SP, Brazil) with 1 cm^2, supported onto a platinum base of a delineator [14] (Bio Art; São Carlos, SP, Brazil).

Fiberglass post cementation

Previously to the cementation, size 2 fiberglass posts (length: 17 mm, cervical diameter: 1.4 mm and apical diameter: 0.9 mm) (Exacto Mini, Angelus; Londrina, PR, Brazil) were cleaned in 96% ethanol, coupled with silane (Angelus; Londrina, PR, Brazil) for 5 min and gently air dried for 5 s.

The fiber post cementation technique was performed according to the manufacturers' recommendations in each experimental group, as follows:

Groups 1 and 3

1. Root canal irrigation with 5 ml of 1% sodium hypochlorite (NaOCl);

2. Root canal drying with absorbent paper points;

3. Root canal etching with 37% phosphoric acid (Scothbond Etchant, 3M ESPE, St. Paul, MN, EUA) for 15 s;

4. Washing with 10 ml of distilled water and drying with absorbent paper points;

5. Application of two layers of Adper™ Single Bond 2 (3M ESPE) with the aid of a ultra-fine microbrush (FGM Ltda., Joinvile, SC, Brazil) onto root dentin;

6. Drying with air jet for 10 s;

7. Light-curing (Optilight Plus, Gnatus,

Ribeirão Preto, São Paulo, Brazil) with intensity of 450 mW/cm2, for 30 s;

8. Mixing of the resin cement (Rely X™ ARC, 3M ESPE) for 10 seconds and insertion of the cement with size 40 lentulo fillers (Dentsply/Malleifer) within root canals;

9. Placement of the post within root canal and light-curing for 40 s (Optilight Plus, Gnatus, Ribeirão Preto, São Paulo, Brazil) with intensity of 450 mW/cm^2, onto vestibular and lingual surfaces.

Groups 2 and 4

1. Root canal irrigation with 5 ml of 1% sodium hypochlorite (NaOCl);

2. Root canal drying with absorbent paper points;

3. Application of the primer agent of Clearfil SE Bond, by rubbing an ultra-fine microbrush (FGM Ltda., Joinvile, SC, Brazil) for 20 s;

4. Application of the bonding agent of Clearfil SE Bond, by rubbing an ultra-fine (FGM Ltda., Joinvile, SC, Brazil) for 30 s;

5. Drying with air jet for 10 s;

6. Light-curing (Optilight Plus – Gnatus, Ribeirão Preto, São Paulo) with intensity of 450 mW/cm^2, for 10 s;

7. Mixing of the resin cement (Rely X™ ARC, 3M ESPE) for 10 s and insertion of the cement with size 40 lentulo fillers (Dentsply/Malleifer) within root canals;

8. Placement of the post within root canal and light-curing for 40 s (Optilight Plus, Gnatus, Ribeirão Preto, São Paulo) with intensity of 450 mW/cm^2, onto the vestibular and lingual surfaces.

Push-out Bond Strength Test

Bonded roots were sectioned into 2-mm-thick slices under water cooling (EXTEC-ERIOS, São Paulo, SP, Brazil), after 7 days of storage into incubator at 37°C in relative humidity. For each specimen, three 2-mm-thick slices were obtained and divided into cervical (A), medium (B) and apical (C) segments of the cervical and medium thirds of the roots (Figure 1).

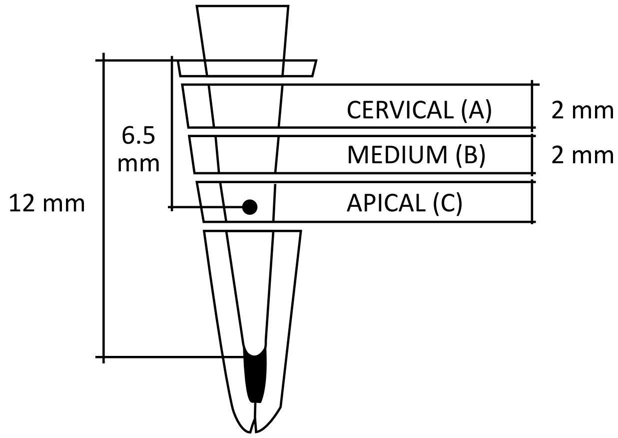

Figure 1 - Schematic representation of specimen preparation for the push-out test. Specimen sectioning into three 2 mm thick post-dentin sections (cervical, medium and apical); Location of root perforation sealed with MTA; Extension of the dowel space inside the root canal.

The push-out load was applied using cylindrical plungers attached to a universal testing machine (EMIC model DI-1000, Curitiba, Brazil) at crosshead speed of 1 mm/min and load cell of 50 Kgf. The apical surface of the slices was positioned facing the punch tip to apply the loading force in the apical-coronal direction until fiber post dislodgment from the root slice. The punch diameter (0.85 mm) was selected up to the luted fiber post cross-section diameter for each slice, without stressing the surrounding root canal walls. Post diameters were measured on each surface of the post-dentin sections using a digital caliper (Starrett; Itu, São Paulo, Brazil), and the total bonding area for each post segment was calculated using the formula of a conical frustum: $A = \pi(R1+R2)(h2 + [R1-R2]2)1/2$ (Figure 2) [6,11]. Push-out strength data were converted to MPa by dividing the maximum failure load value (in Newton) by the bonded surface area in mm^2. Data were analyzed statistically by ANOVA (two-way) and Tukey test at the level of significance of 5%.

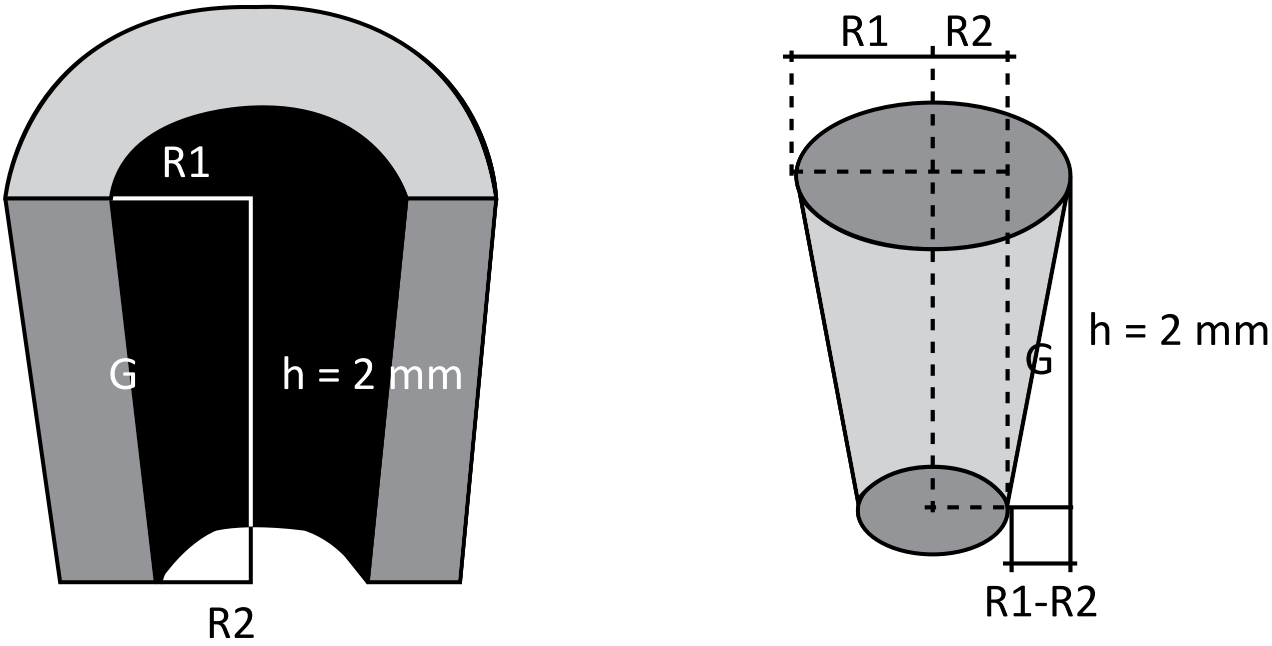

Figure 2 - Schematic drawing corresponding to the internal section of the specimen (root walls) - geometric figure of a straight circular cone frustum of parallel bases, where h is the specimen height, R1 is the radius of the smaller base and R2 is the radius of the greater, and G is the geratrix of the cone frustum.

With the aid of stereomicroscopic magnifying glass (Stemi 2000 – C, Karl Zeiss), at x50 magnification, the fracture patterns of the specimens were analyzed after the mechanic test: (1) cohesive fracture within dentin; (2) cohesive fracture within cement; (3) cohesive fracture within the post; (4) adhesive fracture at the dentin-cement interface, post enveloped by resin cement; (5) fracture at the cement-post interface; (6) mixed fracture (adhesive and cohesive).

RESULTS

Table 1 displays that Adper Single Bond 2 promoted bond strength values significantly higher than those of a Clearfill SE Bond without root perforation ($p < 0.05$). The presence of root perforation resulted in the reduction of the bond strength vales regardless of the adhesive system used.

Table 1 displays that Adper Single Bond 2 promoted bond strength values significantly higher than those of a Clearfill SE Bond without root perforation ($p < 0.05$). The presence of root perforation resulted in the reduction of the bond strength vales regardless of the adhesive system used.

Table 1 - Mean ± standard deviation for the bond strength values (MPa) according to the adhesive systems and radicular condition (with or without perforation)

Root condition	Adper Single Bond 2	Clearfill SE Bond
With root perforation	4.52^{a*} ± 2.86	2.81^{b} ± 1.90
Without root perforation	2.90^{b} ± 1.92	2.30^{b} ± 1.24

In Table 2, it was verified that both the adhesive system and the root perforation (present or absent) exhibited statistically significant differences ($p < 0.05$). However, there were no statistical significant differences in relation to the interaction of the factors ($p > 0.05$).

Table 2 - ANOVA for the experimental groups

Experimental groups	Sum of Squares	Degrees of Freedom	Mean square	F	p*
Adhesive systems (1)	40.47	1	40.47	9.51	0.003*
Root perforation (2)	34.20	1	34.20	8.03	0.005*
Interaction (1) and (2)	9.20	1	9.20	2.16	0.144
Residue	493.79	116	4.26		

Table 3 - Mean ± standard deviation of the bond strength values (MPa) in relation to the interaction factor (Groups and Segments)

Root Segment	Experimental groups			
	1	2	3	4
A	3.79 ± 2.12 ^{a}	2.24 ± 1.58 ^{a}	3.19 ± 2.60 ^{a}	1.89 ± 1.03 ^{a}
B	4.99 ± 3.39 ^{a}	3.16 ± 2.08 ^{a}	2.43 ± 1.48 ^{a}	2.48 ± 1.29 ^{a}
C	4.79 ± 3.08 ^{a}	3.04 ± 2.06 ^{a}	3.09 ± 1.60 ^{a}	2.52 ± 1.40 ^{a}

Evaluation of the fracture types

The data obtained after the stereomicroscopic observation showed that most of the fractures were of adhesive type at the cement-dentin interface (97.5%), while 2.5% were of mixed types. The following fracture types were not observed: cohesive within either dentin, resin cement or intraradicular post. In Group 1 (Adper Single Bond 2 without root perforation), 97% of the fractures were adhesive at the cement-dentin interface, while 3% were mixed fractures (adhesive and cohesive). In Groups 2 and 3, all fractures were adhesive at the cement-dentin interface, while in Group 4 (Clearfill SE Bond with root perforation) 93% of the fractures were adhesive at the cement-dentin interface and 7% of mixed type (adhesive and cohesive).

DISCUSSION

The results of this study require the rejection of the null hypotheses because 1) the type of adhesive system and 2) root perforation (presence or absence) had no effect on the retentive strength of fiberglass posts challenged by the push-out bond strength test. Conversely, as no difference was found in bond strength between the interaction of the adhesive systems and the root condition (with or without perforation), the third null hypothesis was accepted.

Tooth perforations have been defined as artificial and involuntary lesions consequently communicating the pulp cavity with the periodontal ligament with prognosis depending on the location, size, shape, presence or absence of infection, and the tooth involved (anterior or posterior) so that the bacterial infection is either prevented or treated after sealing [15]. Lee et al. [16] described for the very first time the use of mineral trioxide aggregate (MTA) in the sealing of root perforations. Since then, other authors [1,2] have demonstrated the viability of this material to seal the communications between the pulp cavity and the external surface of the teeth, both in the crown and root.

The pretreatment of the fiberglass post was accomplished by applying the silane agent without either acid etching or immersion into hydrogen peroxide [17], probably improving the bond strength of the post to the resin cement, therefore avoiding the adhesive fracture within this interface, as observed in a previous study

[18]. Unlikely, other authors have verified fractures at the cement-post interface [17].

The bond strength values (MPa) (Tables 1 and 3) were similar to those reported in the literature with push-out tests [10,14], although higher bond strength values have been also verified [7,17,19]. However, the geometry of the specimen and load application mode affected bond strength between fiber post and root dentin, stress distribution, and failure mode [7]. The compression load applied near the bonded interface in the push-out test resulted in lower bond strength than in the pull-out test [7].

The initiator radicals of polymerization within self- and dual-curing cements, as those within Relyx ARC, are strongly affected by the acid monomers inside the self-etch adhesive systems as those within Clearfill SE Bond [20]. Ozturk and Özer [21] verified that Clearfil SE Bond and Prompt L-Pop showed better results than those of adhesive systems where the acid etching was performed. Notwithstanding, Topcu et al. [9] did not observe difference between Clearfil and XP Bond. In this present study, the specimens of Group 1 exhibited bond strength values statistically higher ($p < 0.05$) than those of Groups 2, 3 and 4, in which the self-etch adhesive system (Clearfill SE Bond) was employed (Table 1). According to Özturk and Özer [21] and Bitter et al. [22], the self-etch adhesive systems are composed of weaker acids within the primer agent compared with phosphoric acid and therefore less efficient in dissolving the thick smear layer observed after the preparation with drills. The minerals within the dentinal smear layer are capable of neutralizing the acidity of the self-etch primer agents, by forming a thinner hybrid layer [23], which possibly justifies the smallest bond strength values observed in Groups 2 and 4 (Table 1).

The luting of fiberglass posts was carried out 24 h after MTA insertion. Yesilyurt et al. [24] reported that there were no differences in the bond strength of glass ionomer cements to hard set MTA for either 45 min or 72 h. Tunç et al. [25] observed that the bond strength of adhesive restorative materials to white MTA (hard set for 48 h) was better than that with total-etch one-bottle adhesive system (Single Bond). Interferences in the bond strength may occur because of the greatest difficulty in accessing and visualizing as well as achieving a perfect instrumentation, irrigation, and treatment of the root canal walls, at the apical region of the preparation [12]. In this present study, the root perforation sealed with mineral trioxide aggregate was located at the most apical area of the Groups 3 and 4 (segment C). Both the reduction of the available dentinal substrate area and the intrinsic characteristics of the substrate of this area [12], even sealed with mineral trioxide aggregate, did not avoid the decreasing ($p < 0.05$) of the bond strength values of Groups 3 and 4 in relation to the groups without perforations (Groups 1 and 2) (Table 1). Moreover, either the patient's age or even the pulp condition can alter the dentinal substrate due to the dentinal sclerosis, which reduces the dentinal permeability [26] and the quality of the substrate available for adhesion.

Bitter et al. [4] investigated the depth of nanoleakage of four luting agents for bonding fiber posts and verified that none of the investigated luting systems would be able to hermetically seal the root canal if leakage occurred around the margins of the coronal restoration. However, the perforation sealing with MTA can be improved when an adhesive system (One Up) is applied onto o MTA [27]. Moreover, two-step cementation procedure of fiberglass posts can be an alternative to reduce the polymerization contraction stress formation during the polymerization of the resin cement by reducing the C factor, increasing the bond strength of the posts to the canal walls and decreasing the marginal microleakage [28].

Many factors should be considered to restore the aesthetics and function of the teeth when adhesive procedures are required because of the clinical condition and variability of the materials available for restoration. For this purpose, new materials and further studies are necessary to assess the bond strength of the materials both to mixed substrates and teeth with perforations sealed with different materials, considering the variability of techniques and restorative materials available.

CONCLUSION

The root perforations had a direct effect on the bond strength of the fiberglass posts cemented by promoting a reduction in the bond strength values to root dentin regardless of the adhesive system used.

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