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Evaluation of Bond Strength of Aesthetic Type of Posts at Different Regions of Root Canal after Application of Adhesive Resin Cement

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Abstract

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Keywords: Bond strength; Fiber post; Zirconia post; Push-out bond testing and root regions

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AIM: This study aimed to evaluate the bond strength between esthetic posts and dentin at different regions of the root canal in passive mode or push-out active mode.

METHODS: Twenty extracted human bicuspid single canal teeth were used in this study. Teeth were sectioned below the cement-enamel junction. The roots of teeth were endodontically treated. Glass fibre posts (Glassix plus, Harald Nordin SA, Switzerland) and zirconia posts (Zirix, Harald Nordin) were then adhesively luted with total-etch (Variolink N, Ivoclar Vivadent, Schaan, Liechtenstein) and self-adhesive (Multilink Speed, Ivoclar Vivadent) resin cement. The roots were divided into two main groups of 10 samples each, according to the type of post used. Each group subdivided into 2 subgroups of 5 samples each, according to the type of cement used. The specimens were transversally sectioned into three slices of 2 mm thickness to perform the push-out test. The push-out tests were performed at crosshead-speed, 0.5 mm/min). Failure modes were evaluated using a scanning electron microscope at magnification (x 150).

RESULTS: The results revealed that push-out bond strengths were significantly affected by the type of luting agent and the type of post ($P \leq 0.05$). The mean push-out bond strength values for fibre post were significantly higher than those for zirconia post independent of the luting strategy used. The score values of total-etch adhesive resin cement were higher than those for self-adhesive resin cement irrespective of other variables. Regarding the effect of the root segment on push-out bond strength, results revealed that bond strength decreased from the coronal to the apical section. The cement-dentin interface found to be the weakest part of the root-cement-post unit.

CONCLUSION: Glass fibre posts revealed better results in all root third when they adhesively luted with total-etch or self-etch adhesive resin cement and provided significantly increased bond strength compared to the zirconia posts.

Introduction

It is known that teeth that have been undergone endodontic treatment are weak, the structure is less tolerable to the external stresses, mechanical shocks and less withstand the masticatory forces. This become clearer if the remaining walls of those teeth are not enough to provide the resistant form against fracture and breakage. Therefore, the proper reconstruction of such teeth is essential before

the placement of the final restorative materials or crowns. The use of post and core is one of a successful application that leads to the supporting and strengthening of endodontically treated teeth, but the choice of the most suitable type of each case needs proper diagnosis and the ability of the dentist to perform these procedures in a high skilled manner [1]. Several in-vitro studies have been conducted to assess the different aspects of post and core. These studies have indicated the importance of using a complex combination of materials (dentin, metal

posts, cement, and core materials) with varying degrees of rigidity and stiffness. With the increasing demands for aesthetic procedures, aesthetic posts have become more used by dentists than ever before, specifically, the usage of metal-free post-and-core systems, e.g. zirconia and fibre posts [2]. Selection of a suitable adhesive and luting procedures for bonding posts to root dentin is a challenge. The actual bond strength at the post cement-root interface is affected by many factors including the degree of dehydration of the root canal dentin, the type of conditioning agent, type of cement used; the unfavorable cavity configuration of the root canal; the use of eugenol-containing sealers and the anatomic differences in density and orientation of the dentinal tubules at different levels of the root canal areas.

Furthermore, the difficulty of moisture control and the lack of direct vision into the root canal adversely affect the bonding procedures [3], [4], [5]. The push-out tests have been used to measure post retention in different regions of post space. This method was shown to have fewer premature specimen failures and a lower data distribution variability compared to conventional shear test. This may be due to the nature of fracture occurred in the push-out test that takes place parallel to the dentin bonding interface, which may make it a true shear test [6], [7].

Material and Methods

Twenty single-rooted human mandibular first premolar teeth were collected from middle-aged male patients (35-45 years old). Teeth selected to be used in this study were of an average similarity in size, shape and root morphology. The roots were inspected under proper lighting with a magnifying lens to ensure the absence of caries, cracks or fracture. The teeth were cleaned from loose debris, hard and soft attachments using scalar (Martin, Germany). The selected teeth were then placed in a 0.9% standardized saline solution and stored at room temperature until use.

Specimen preparation

The crown of each tooth was sectioned horizontally 2 mm coronal to the cement-enamel junction, on a plane perpendicular to the long axis of the tooth. A fissure carbide bur (Komet-Brasseler GmbH, Lemgo, Germany) mounted on a high-speed handpiece was used with copious air-water spray, to obtain a root length of 15 ± 1 mm. The cut surfaces were smoothed using a fine diamond disc (Komet-Brasseler) The coronal access opening was sealed with eugenol-free temporary filling Coltosol F (colténe

AG, Altstätten, Switzerland) and the teeth stored in normal saline solution at room temperature till endodontic treatment. The Canal patency was determined by a file size 15 K-file. The roots were endodontically instrumented at a working length of 1mm from the apex using a 35-master apical file. All root canals were instrumented by the same operator, and the step-back technique was used for cleaning and shaping of root canals, which were enlarged to size 50 H-file. Irrigation was performed with 5.25% sodium hypochlorite solution (NaOCl) using a plastic syringe after each change in the size of file throughout the shaping process. Then, the root canals were rinsed with distilled water, dried with paper points (Dentsply-Maillefer) size 35, being ready for obturation.

The master cone was tried to fit the prepared canal and to reach the full working length with a tug-back action. The prepared canals were filled with calcium hydroxide sealer (Apex plus, Ivoclar Vivadent) with the aid of intra-canal tips, Guttapercha points (Dentsply-Maillefer) were coated with the sealer and placed in the root canal. A finger spreader was inserted into the root canals to a level approximately 1 mm short of the working length; then it was removed by rotating it back and withdrawn. Accessory points were selected and applied. The process was repeated until the canal was filled. Excess gutta-percha was removed, and the coronal mass was compacted with a plugger. Finally, the canal openings were filled with Coltosol F temporary filling material. The roots were embedded in auto-polymerising acrylic resin (Acrostone Dental Factory, England) surrounded by a custom-made hollow plastic cylinder having the 25 mm external diameter and 30 mm height. To ensure an accurate vertical and centralised position of each root and its canal in the acrylic resin cylinder, a specially designed centralising device was constructed for this purpose.

Post luting procedures

The length of the samples was determined to be 15 ± 1 mm. By leaving 4 mm of gutta-percha in the canal space as an apical seal, the post space length was determined to be 11 mm. The gutta-percha was removed up to the appropriate depth using pilot reamer (Harald Nordin), a rubber stopper was inserted in its shaft and adjusted to the desired post length. The root canal of each specimen was then enlarged with a low-speed drill provided by the manufacturer of the post system, using the corresponding drill of the selected post. The canals were flushed using sterile water then dried with paper points. The prepared roots were randomly divided into 2 main groups of 10 samples each, according to the type of post used (Glass fibre and Zirconia) posts, 5 samples each, according to the type of cement used (total-etch and self-adhesive) resin cement.

Post cementation with total-etch resin cement

The canal was etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent). The etching gel was introduced into the canal with a needle, and after 15 seconds, the post space was rinsed with distilled water using a plastic syringe and dried with paper points. Using micro-brush, the (Excite F DSC, Ivoclar Vivadent) dual-cure single component adhesive system was applied, excess adhesive solution was absorbed with paper points, gently air-dried and exposed to light for 10 seconds from a coronal direction. An equal amount of Vriolink N (Ivoclar Vivadent) base and catalyst of low viscosity was mixed on the mixing bad for 10 seconds using cement spatula and applied into the canal with a lentulo spiral (Dentsply-Maillefer) using a low-speed handpiece, in addition, the external surface of each post was coated with cement prior to placement into the prepared canal, the post firmly and carefully placed into the canal within 1-1.5 minutes from initial mixing, finger pressure was maintained and excess cement was removed with a micro-brush. Samples were then light-cured (LED curing light, Guangzhou, China) through the cervical portion of the root for 40 seconds to accelerate the curing process.

Post cementation with self-adhesive resin cement

The auto-mixing syringe of the Multilink Speed (Ivoclar Vivadent) resin cement was prepared for use. This was done by examining the level of cement base and catalyst in the two orifices of the syringe to ensure even flow of both base and catalyst. The mixing tip with intra-oral tip was then attached to the syringe. The cement was gently dispensed with the help of intra-oral tip inserted into the canal. The post was then placed into the canal, finger pressure was maintained, and the excess cement was removed with a micro-brush. Samples were then light-cured through the cervical portion of the root for 20 seconds to accelerate the curing process. All posts were cemented by a single operator adhering strictly to each manufacturer's instructions. To standardise the load application during cementation procedure, each post was maintained under a load of 1 kg for 2 minutes; the cement was then light-cured. A specially designed loading device was fabricated for this purpose. After cementation, all samples underwent 1500 thermal cycles in a thermo-cycling device (MPM Instruments, Bernareggio MI, Italy) between 5°C and 55°C, with a 30 seconds dwell time in each bath and 10 seconds transfer between temperature baths [43]. The temperatures were checked every 15 minutes using a thermometer in each bath and time checked by using a stopwatch. The samples were then stored in a distilled water at room temperature for one week.

Preparation of the samples for testing

The prepared roots of the tested teeth were sectioned horizontally, and perpendicular to the long axis of the root into 2 mm sections using a diamond saw underwater irrigation for the push-out test. The apical section was cut 4 mm away from the root apex to avoid cutting through obturating materials. The first coronal 2 mm together with the most apical 4 mm of the root was discarded. Three sections of the 2 mm thickness (cervical, middle, and apical) were obtained (Figure 1). Each section was marked on its coronal side with an indelible marker, and the thickness of each section was measured with a digital calliper.

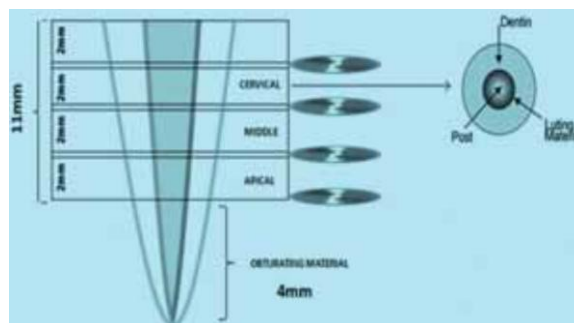


Figure 1: Schematic view of specimen preparation for the push-out test

Push-out bond strength test

Each section was subjected to compressive loading via a computer-controlled material testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) with a load cell of 5kN. Data were recorded using computer software (Nexygen-MT; Lloyd Instruments). Each sample loaded by 3 plungers of different diameters (1, 0.75 & 0.5 mm). The plunger centred on the post segment provided that, contact with the surrounding dentin surface was avoided. Loads were applied in an apical-to-cervical direction (Figure 2).

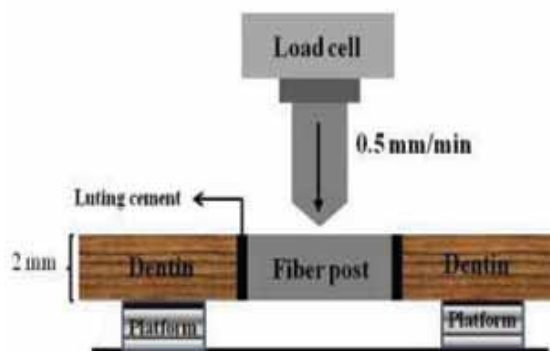


Figure 2: Schematic representation of the push-out test procedure. Consequently, shear bond strength MPa

The force in Newton (N) required to debond the post was recorded for all posts. To express the bond strength in MPa, the load at failure recorded in

Newtons was divided by the computed surface area as calculated by the following formula:

$$\text{Bond} = F/A \quad A = \pi h (r_1 + r_2)$$

where: A; area of the post/dentin interface, π ; is the constant 3.14, r_1 ; coronal radius, r_2 ; apical radius and h; is the thickness of the slice in mm, standardised at 2 mm.

Scanning electron microscope

Representative samples for sectioned roots were gold-sputtered and used to evaluate the distribution of the luting material in the canal and to assess the resin dentin inter-diffusion zone, the hybrid zone, at magnification (X1000).

Results

Data were presented as mean and standard deviation (SD) values. Regression analysis using repeated measures Analysis of Variance (ANOVA) was used for studying the effect of post type, cement type, root segment and their interactions on mean push-out bond strength. Tukey's post-hoc test was used for pair-wise comparison between the mean values when the ANOVA test is significant. Detailed comparisons between the two post types as well as between the two cement types were performed using Student's t-test. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

Push-out test

The push-out bond strengths were significantly affected by the type of luting agent and the type of post ($P \leq 0.05$). The mean push-out bond strength values for fibre post (10.1 MPa) were significantly higher than those for zirconia post (6.5 MPa) at $P \leq 0.05$ independent of the luting strategy used. The total-etch adhesive resin cement (13.8 MPa) score values higher than those for self-adhesive resin cement (2.8 MPa) at $P \leq 0.05$ irrespective of other variables.

Results also revealed that the coronal segment showed statistically significant highest mean push-out bond strength (10.9 MPa), followed by middle segment (7.9 MPa), while the apical segment showed the statistically significant lowest mean push-out bond strength (6.1 MPa) at $P \leq 0.05$, regardless of other variables. The effects of different variables interactions on push-out bond strength are presented in Table 1.

Table 1: The mean, standard deviation (SD) values and results of the comparison between the different interactions

Post type x Cement x Root segment	Mean	SD	P-value
Fiber x Variolink x Coronal	20.7 a	1.1	
Fiber x Variolink x Middle	16.3 b	1.6	
Fiber x Variolink x Apical	13.3 c	0.6	
Fiber x Multilink x Coronal	6 f	0.3	
Fiber x Multilink x Middle	2.7 h	0.3	
Fiber x Multilink x Apical	1.8 i	0.2	< 0.001*
Zirconia x Variolink x Coronal	13.4 c	0.2	
Zirconia x Variolink x Middle	10.7 d	0.5	
Zirconia x Variolink x Apical	8.4 e	0.8	
Zirconia x Multilink x Coronal	3.6 g	0.3	
Zirconia x Multilink x Middle	1.7 i	0.2	
Zirconia x Multilink x Apical	1 j	0.1	

*: Significant at $P \leq 0.05$, Different letters are statistically significantly different

Microscopic observation

The hybrid zone between radicular dentin and total-etch (Variolink N) resin cement at the **cervical** section revealed that: The hybrid layer is well defined with abundant resin tag formation, and tight interfacial seal, the extension of resin tags into the dentin surface can be observed. They appear to belong, thin and arranged in a relatively parallel pattern (Figure 3).

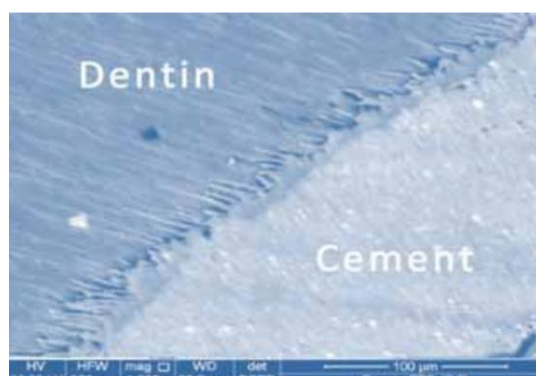


Figure 3: SEM photomicrograph of the hybrid zone for the segment of a Variolink N resin cement sample cervical at (X1000)

In comparison, the hybrid zone between radicular dentin and self-adhesive (Multilink speed) resin cement at the cervical section revealed that: The hybrid layer is ill-defined. The resin tags appear to be irregular and intermingling with the dentin in some areas. The interfacial gap can be seen along the whole length of the specimen (Figure 4).

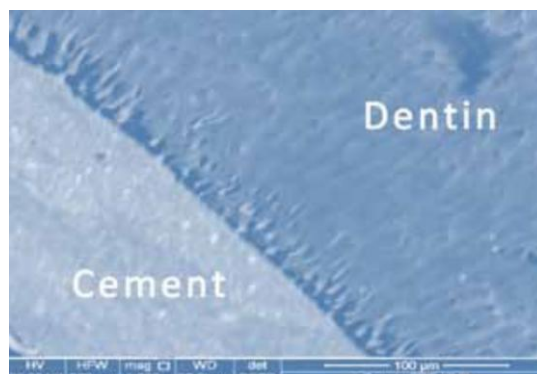


Figure 4: SEM photomicrograph of the hybrid zone for the cervical segment of a Multilink speed resin cement sample at (X 1000)

Discussion

In the present study, the push-out bond strengths of two different post types with two different luting cement at three different root regions were measured. The statistical significant difference in bond strength results between glass fiber and zirconia posts suggested that the elastic modulus of is approximately similar to that of both the fiber post and dentin, so the resultant homogeneous biomechanical unit allows a more uniform stress distribution, which better preserves the weakened tooth structure and reduces microleakage at the dentin-cement interface, secondary caries and consequently increase the bond strength [8]. Also The fibre posts are capable to bond chemically with the adhesive resin cement, indicating a good bond between the resin matrix of the fibre post and resin luting agent [9], [10]. On the other hand, establishing a reliable bond to zirconia-based materials has proven to be difficult, which is the major limitation against fabricating adhesive zirconia restorations. Its surface stability resulted in the problem of establishing a durable chemical or a mechanical bond which has proven to be a difficult task [11]. In spite of the creation of micro retention on zirconia posts, the adhesion between the post and resin luting agent was not uniform, thus indicating that the nature of post material was responsible for the bonding of the post to the tooth structure [12]. Unfortunately, H₃PO₄ and HF cannot be used effectively on non-silica-based ceramics, like ZrO₂, making it difficult to roughen the surface for micromechanical retention. The lack of silica also removes the chemical bonding between silica – silane necessary for silanization [13]. Also, the ceramic posts present modulus of elasticity higher than those of dentin and resin cement. This difference in stiffness resulting in stress concentration on the tooth during masticatory function, thus, when a load is applied, it is transmitted to the softest material, the resin cement, in this case, to compromise the bond [14].

Further, the total-etch resin cement showed a significantly higher mean bond strength than self-adhesive resin cement, irrespective of the type of post used. This could be attributed to the separate phosphoric acid etch step which removes the thick surface smear layer on root canal dentin and the smear plugs in dentinal tubules formed during post space preparation, to allow more effective micromechanical retention of resin-based cement [15], [16], [17]. On the other hand, the methacrylate phosphoric esters in the self-adhesive resin cement cannot penetrate adequately through the retained partly dissolved smear layer on the root bond strengths [17], [18]. These findings were confirmed by the SEM evaluation in figures (Figure 3 and 4). Higher bond strength in the coronal section of the root canal is most commonly explained by the higher density of dentinal tubules and the longer resin tags formed in this area [4], [19], [20]. Accordingly, there would be an

unequal response to mechanical testing of each portion and subsequent variation in retention properties. Another point that may shed light on the lower bond strength values recorded for the apical region is the limited ability of the light to diffuse across the entire length of the resin cement thus compromising the polymerisation of the cement in the most apical regions. Moreover, it is increasingly more difficult to control moisture and adhesive application towards the apical region of the canal [21].

In conclusion: 1. post type has a significant effect on push-out shear bond strength, which was superior for fiber post compared to zirconia post; 2. total-etch adhesive resin cement provided higher push-out shear bond strength compared to self-etch adhesive resin cement; 3. the coronal root canal region was significantly more retentive than the apical root canal region; and 4. the cement-dentin interface is the weakest part of the root-cement-post unit.

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