Fibre post adaptation and bond strength in oval canals.

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Abstract

Aim
To evaluate *ex vivo* the bond strength and adaptation of fibre posts with oval and circular cross sections luted in oval canals with post spaces prepared using dedicated drills or ultrasonic tips.
Methodology
Forty extracted premolars with oval canals were root filled, then randomly divided into four groups according to the post space preparation device and the shape of the luted fibre post: dedicated drill + round post, dedicated drill + oval post, ultrasonic tip + round post and ultrasonic tip + oval post. Posts were cemented with a self-adhesive cement (RelyX Unicem 2; 3M ESPE). Samples were sectioned in 1-mm-thick slices and observed under a microscope, and the area occupied by the post within the post space area was calculated. Bond strength was then measured using a push-out test, and the failure modes were evaluated with a stereomicroscope at 40× magnification. Fibre post adaptation and push-out test results were evaluated by analysis of variance ($P < 0.05$).
Results
Fibre posts, both round and oval, were better adapted to the apical region of the post space ($P = 0.001$). In oval canals, the bond strength was significantly higher in coronal regions, when the post space was prepared with a dedicated drill and an oval post was luted ($P < 0.0001$). Adhesive failures between cement and post were the most frequent type of failure in all groups.
Conclusions
Circular and oval posts achieved similar adaptation to oval canals, but the use of ultrasonic tips and round posts resulted in reduced bond strength values.

Introduction

Root filled teeth must be restored effectively to prevent clinical failure due to bacterial reinfection of the root canal system by secondary caries (Touré *et al*. **2011**) or to coronal and root fractures (Zadik*et al*. **2008**). Post-endodontic restorations must assure tooth form and function, create anchorage for restorative materials to prevent displacement and provide adequate force distribution (Dietschi*et al*. **2008**). Fibre post–retained restorations are used commonly in this type of treatment. The post functions as an intraradicular retainer, providing support for a subsequently placed restoration (Schwartz & Robbins **2004**).
Oval canals are prevalent in the human dentition, and bonding procedures are difficult to perform in such canals (Schwartz & Robbins **2004**, Tay *et al*. **2005**, Cleghorn *et al*. **2007**, Dietschi *et al*. **2008**). Circular posts are commonly employed, and resin cement is used to compensate for their lack of adaptation to the canal walls. However, cement thickness may be a critical factor affecting the clinical performance of fibre posts (Grandini *et al*. **2005**); it is correlated with the fit of the post within the post space, with greater adaption to the canal walls resulting in reduced cement thickness. Ideal adaptation is difficult to obtain when using a round fibre post in a canal with an irregular

anatomic configuration. Recently, posts with oval cross sections have been introduced in an effort to achieve better adaptation to the post space in oval canals.

Drills are usually employed for post space preparation in oval canals, but this procedure alters canal anatomy and sacrifices dentine (Coniglio *et al*. **2008**). The primary goal is to achieve the best possible adaption of the fibre post to the canal walls, thereby minimizing the thickness of the cement layer (Coniglio *et al*. **2009**). To reduce anatomic alteration during post space preparation, a more conservative ultrasonic oval tip designed for use in oval canals has been introduced (Ellipson tip; RTD/Satelec, Merignac, France). To date, no study has evaluated the correlations between fibre post bond strength, post shape and post adaptation.

The aim of this laboratory study was to evaluate bond strength and the adaptation of posts with oval and circular cross sections luted in oval canals with post spaces prepared using two different drilling techniques. The null hypothesis was that neither post shape nor post space preparation technique would affect push-out bond strength or fibre post adaptation to canal walls.

Materials and methods

Extracted, intact human mandibular premolars with single root canals were selected. After debriding the root surfaces, specimens were stored in 0.5% chloramine at 4 °C for <1 month. Each tooth was sectioned at the cemento–enamel junction perpendicular to the long axis of the tooth to visualize canal morphology. Mesiodistal and buccolingual radiographs of each tooth were taken. Teeth with long : short canal diameter ratios ≥2 at 5 mm from the apex were considered to have oval canals (Wu*et al*. **2000**). The mean length of roots in the study sample was 13 mm.

A total of 40 specimens were selected and root canals prepared to working length using Pathfiles (1–2–3) and ProTaper files (S1–S2–F1–F2–F3; Dentsply Maillefer, Ballaigues, Switzerland). The working length was established using a microscope at 10× magnification (Pro Magis, Carl Zeiss, Germany), when the tip of the file became visible at the apical foramen. Using a 2-mL syringe and a 22-gauge endodontic needle, specimens were irrigated with 10 mL 5% NaOCl (Niclor 5; Ogna, Muggiò, Italy) alternated with 2 mL 10% EDTA (Tubuliclean; Ogna). The canals were dried with paper points (Mynol; Curaden Healthcare, Saronno, Milan, Italy). In accord with the continuous wave technique, specimens were filled with endodontic cement (Pulp Canal Sealer EWT; Kerr, Sybron, Romulus, MI, USA) and medium-sized gutta-percha points with DownPak (Hu-Friedy, Chicago, IL, USA) and Obtura III (Analytic Technologies, Redmond, WA, USA). After 24 h, the samples were divided randomly into two groups ($n = 20$ each) according to the post space preparation device used. A dedicated drill (3M ESPE, St. Paul, MN, USA) was used in group A, and a fine-grit (46-μm) diamond-coated ultrasonic tip with an oval cross section (Ellipson tip; RTD/Satelec) mounted on a Suprasson handpiece (Satelec) operated at medium power in group B. A 8-mm post space was prepared in each sample, leaving 5 mm of apical root filling. Teeth were then randomly assigned to two subgroups ($n = 10$ each) within each group according to the morphology of the luted fibre post. Round glass–fibre posts (RelyX Fibre Post, 3M ESPE) were used in subgroup 1, and oval glass–fibre posts (Ellipson post; RTD/Satelec) were used in subgroup 2.

Before cementing, the correct length of each post was verified. The posts were cleaned with a microbrush immersed in 70% alcohol, and a silane agent (Ceramic Primer; 3M ESPE) was applied after drying. The external surfaces of all roots were covered with wax to avoid lateral polymerization. The internal root dentine was washed with water and dried with paper points. The luting agent (RelyX Unicem 2; 3M ESPE) was manipulated according to the manufacturer's instructions and inserted into the canal. Three minutes after post insertion, photoactivation was performed with a LED curing light (VALO, Ultradent, Salt Lake City, UT, USA) for 40 s each (total, 120 s) on the cervical face of the root in the direction of the long axis, and then obliquely to the buccal and palatal surfaces. After polymerization, the samples were stored in distilled water at 37 °C for 24 h.

Six slices, each of 1 mm thick, were prepared from each sample. As previously reported (Zhang *et al*. **2008**, Salas *et al*. **2011**), the data of the coronal three slices were considered to represent the coronal region, those of the apical three slices were considered to represent the apical region of the post space. Each sample was sectioned perpendicular to the post axis using a low-speed diamond saw (Micromet; Remet, Bologna, Italy) under abundant water. The coronal side of each disc was marked with an indelible marker and observed under a stereomicroscope. A 40× magnification image of all sides of all discs were recorded with a stereomicroscope (Stemi 2000-C, 40× objective, Carl Zeiss Jena, Jena, Germany) using a graph paper as background. Every image was edited using Photoshop CS5(Microsoft Co., Redmond, WA, USA) in order to increase the contrast, the area occupied by the post was in red, the area the cement was highlighted in green, and on the, two 1-mm spaced blue points were drawn. These colours were chosen to ensure the identification of the three parts from the dedicated software that used RGB colour system. The was able to calculate the distance between the two blue points in order to obtain a linear ratio mm/pixel and as a consequence an area ratio/pixel; besides, it counted the number of red and green pixels and allowed the result to be expressed mm^2. The proportion of canal space occupied by the post (post area/canal area × 100) and the area of the cement layer were calculated on these images (Fig. 1).

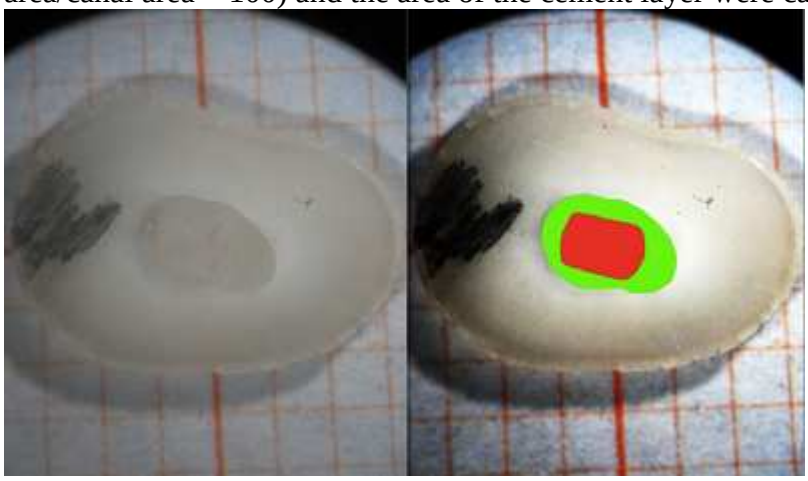

Figure 1.
Images of the post space with fibre post areas marked for the calculation of fibre post adaptation. Magnification: 40×.

Push-out test

The push-out test was performed by applying an axial load to the post at a crosshead speed of 0.5 mm min^{-1} using an Instrom Machine I (model 10/D; Sintech, MTS, Canton, MA, USA). The most coronal region was always faced downward (load direction, apical to coronal). The maximum failure load was recorded in newtons (N) and converted into megapascals (MPa) by dividing it by the interfacial area of the post fragment, which corresponded to the bonded area (in mm^2). The bonded area was calculated differently for each post shape, as described by Coniglio *et al*. (**2011**). Debonded specimens were examined using stereomicroscope at 40× magnification (Stemi 2000-C, 40× objective, Carl Zeiss Jena), and the failure mode was classified according to the following criteria: adhesive failure between dentine and cement (AD), adhesive failure between the cement and the post (AP), cohesive failure within the cement (CC), cohesive failure within the post (CP), mixed failure (M). The percentage of each type of failure mode within each group was then calculated.

Statistical analysis

To evaluate the effects of post space region (P), post space preparation technique (T), fibre post shape (F) and the interaction between T and F on fibre post adaptation and bond strength, analysis of variance (ANOVA) was performed. Interactions involving the P effect were not taken into account in theANOVA because they are not relevant for the aim of this study. The failure mode data were analysed using the chi-square test. In all tests, differences were considered statistically significant when$P < 0.05$. Statistical analyses were performed using the SW MINITAB software (ver. 15; Minitab Inc., State College, PA, USA).

Results

The mean proportion of space occupied by the post and mean bond strength values are summarized in Table 1. The proportion of space occupied by posts differed significantly only in relation to the post space region ($P = 0.001$; Table 2).

Table 1. Mean proportion of post space occupied by the post [± standard deviations (SD)], mean bond strength (±SD) and failure modes in the four test groups

Group	Proportion of post space occupied by post (%)		Bond strength ± SD (MPa)		Failure mode (%)				
	Coronal	Apical	Coronal	Apical	AD	AP	CC	CP	M
A1	32.53 ± 14.15	54.81 ± 18.33	14.448 ± 5.135	10.545 ± 3.197	57.3	14.9	6.7	0	21.1
A2	47.04 ± 11.75	47.97 ± 10.21	17.776 ± 5.337	12.081 ± 5.270	52.9	16.3	8.5	0	22.3
B1	36.67 ± 8.28	44.21 ± 18.17	8.612 ± 3.862	6.748 ± 4.131	54.1	18.9	4.3	0	22.7

Group	Proportion of post space occupied by post (%)		Bond strength ± SD (MPa)		Failure mode (%)				
	Coronal	Apical	Coronal	Apical	AD	AP	CC	CP	M
B2	39.72 ± 9.44	38.34 ± 11.64	10.789 ± 4.243	8.861 ± 3.612	56.2	15.1	5.2	0	23.5

Table 2. Analysis of variance results for fibre post adaptation

Source	Degrees of freedom	Sum of squares	Mean square	*F*-test statistics	*P*-value
Point	1	1391.7	1391.7	13.41	0.001
Tool	1	397.5	397.5	3.83	0.055
Post	1	21.7	21.7	0.21	0.649
Tool × Post	1	54.1	54.1	0.52	0.473
Error	59	6123.5	103.8		
Total	63	7988.6			

Push-out test results indicated that all factors tested in this study influenced the bond strength of fibre posts ($P < 0.0001$), whereas the interaction between T and F did not affect bond strength or the space occupied by the post (Table 3).

T

able 3. Analysis of variance results for bond strength

Source	Degrees of freedom	Sum of squares	Mean square	*F*-test statistics	*P*-value
Point	1	307.11	307.11	25.37	0.0001
Tool	1	808.63	808.63	66.80	0.0001
Post	1	203.15	203.15	16.78	0.0001
Tool × Post	1	0.08	0.08	0.01	0.934
Error	123	1488.85	12.10		
Total	127	2807.83			

The chi-square test revealed no significant differences in the failure mode within the groups. No cohesive failures were observed. Adhesive failure between cement and dentine was the most frequent type of failure mode in all groups (Table 1).

Discussion

Many root canals are not circular (Peters **2004**). The difficulties of completely eliminating gutta-percha remnants, endodontic sealer and the smear layer from post space walls are enhanced in oval canals (Coniglio *et al*. **2008**), affecting the adaptation and bond strength of fibre posts. The results of this laboratory study led to the partial rejection of the null hypothesis, as only bond strength was related significantly to both fibre post shape and post space preparation technique.
Several different mechanical testing methods have been used to measure the bond strength between fibre posts and intraradicular dentine, including microtensile bond strength (Monticelli *et al*. **2006**), pull-out tests (Valandro *et al*. **2005**) and push-out tests (Dimitrouli *et al*. **2012**). In this study, fibre post bond strength was tested through the push-out test. This method is considered to be the most appropriate for measuring the retention of posts (Goracci *et al*. **2004**), even if the dislodging forces cannot be directly compared with functional stresses that the post needs to withstand during clinical service. Moreover, the interfacial areas were calculated according to the different posts shapes as previously reported (Coniglio *et al*. **2011**).

In the present study, fibre post adaptation and bond strength were significantly related to the post space region. Bond strength values decreased from the coronal to the apical region of the post space, in agreement with the results of several previous studies (D'Arcangelo *et al*. **2007a**, Zorba*et al*. **2010**) testing round-shaped fibre posts. This finding could be due to several factors, such as reduced visibility in deeper areas of the post space, which reduces the predictability of post space cleaning and results in the presence of greater amounts of debris and occluded dentine tubules that are not available for adhesion (Serafino *et al*. **2004**). As previously mentioned, this problem is enhanced in root canals with irregular morphology, where the use of a dedicated drill or ultrasonic tip is not significantly effective in dentinal wall debridement. In oval canals, it has been showed (Coniglio *et al*. **2008**) that round-shaped instruments are not able to perform effective post space debridement, leaving debris on dentinal walls particularly in buccal and lingual extensions or recesses.

Other clinical factors may be related to this result, such as the distance from the curing light (Goracci*et al*. **2008**), the less dense dentinal tubule configuration in the apical region of the root canal system (Shemesh *et al*. **2006**), apical sclerosis (Paque *et al*. **2006**), the cavity configuration factor (Tay *et al*. **2005**), and/or restrictions in the flow of cement to this part of the root canal (de Durâo Mauricio *et al*. **2007**). The variation in bond strength along the oval post space, regardless of the fibre post shape and the post space preparation technique, may also be related to the significant difference in fibre post adaptation. In fact, cement thickness may be directly related to the bond strength of fibre posts. Some studies have reported that the highest bond strength values are not obtained when a thinner cement layer surrounds the post or when an oversized post space is prepared (D'Arcangelo *et al*. **2007b**). The results of the present study revealed a reduced cement thickness, and thus better adaptation, towards the apical region of the oval post space, as described by other authors (Coniglio *et al*. **2009**, Muñoz *et al*. **2011**).

The post space preparation devices tested in this study resulted in similar fibre post adaptations. Endodontic rotary instruments usually produce a preparation with a round outline. Oval root canals are the simplest deviation from a round outline and can be found in all tooth types. In such cases, complete mechanical debridement is impossible to achieve, and uninstrumented areas remain (Wu*et al*. **2000**, Weiger *et al*. **2002**). The use of rotary instruments to prepare the post space in an oval canal yields similar results to that obtained with canal shaping files: large regions of uninstrumented post space may remain covered with filling materials and debris, thus affecting fibre post adhesion. For this reason, post space preparation in the present study focused on the instrumentation of the entire canal area, with an effort to leave no area uninstrumented. The operator moved the ultrasonic tip or dedicated drill in a buccal–palatal direction in an attempt to achieve contact with all dentinal walls and to remove debris from even the narrowest post space regions. On the contrary, a previous study (Coniglio *et al*. **2008**) reported that, within the post space preparation, an oval ultrasonic drill, which is similar to the tip tested in the present study, effectively removed the smear layer, probably because its shape enabled direct instrumentation of oval-shaped canals surfaces. Thus, the shapes of post spaces prepared by the drill and ultrasonic tip were similar, resulting in similar fibre post adaptations, although the ultrasonic tips created more conservative post spaces in the apical region.

In contrast, post space preparation technique significantly influenced bond strength. In this study, RelyX Unicem 2 was employed as the luting agent; the manufacturer claims that its action is based on micromechanical retention and chemical adhesion. However, the use of this agent has been shown to produce no evidence of dentine demineralization and/or hybridization at the micrometre level (Yang*et al*. **2006**, Al-Assaf *et al*. **2007**), indicating a limited capacity to effectively diffuse and decalcify the underlying dentin (De Munck *et al*. **2004**, Al-Assaf *et al*. **2007**). Furthermore, the ability of an acidic primer to etch through the smear layer might depend directly upon smear layer density (Sattabanasuk *et al*. **2007**). Thus, it can be assumed that the dedicated drill and ultrasonic tip produced different smear layers. Post space cleaning procedures are designed with the expectation that a drill will be used to remove filling materials and a cleaning regimen to eliminate the smear

layer. The drills used for post space preparation produce sealer and gutta-percha remnants that are plasticized by burr friction and heat and inorganic components (Serafino *et al*. **2004**). Cutting blade design affects the amounts of debris and remnants created in the canal (Jeon *et al*. **2003**). Thus, ultrasonic tips should produce greater friction on dentinal walls in comparison with drills. Ultrasonic tips may contribute to the packing of debris into dentinal tubules, making removal more difficult and reducing bond strength. Recent studies have reported that self-adhesive cement interacts superficially with dentine, leading to partial demineralization of the smear layer and to the formation of short resin tags (Monticelli *et al*. **2008**). Moreover, a previous study (Gerth *et al*. **2006**) revealed a good chemical interaction of RelyX Unicem with calcium from hydroxyapatite, which may explain the reduced bond strength values when a 'packed' smear layer, such as that created when a ultrasonic tip is employed for post space preparation, is present on dentinal walls.
Finally, the results of a recent study (Muñoz *et al*. **2011**) indicated that oval posts do not adapt better than circular posts to oval canal morphology, regardless of the post space preparation device employed. Coniglio *et al*. (**2009**) found no significant difference in adaptation to the canal between circular fibre posts and medium-grained oval tips. However, recent studies comparing the performance of oval and circular posts in oval canals have emphasized that the hypothetically better fit of oval posts did not translate to significantly higher push-out strengths than those achieved with circular posts (Coniglio *et al*. **2011**). A significant difference in bond strength related to post shape, with oval posts performing better than round posts, was found in the present study. This finding is probably correlated with fibre post adaptation and thus with cement layer thickness. In the present study, the degrees of oval- and round post adaptation were statistically equivalent, although the cement layer associated with round posts was slightly thicker. These findings and those of previous studies thus suggest that the increased thickness of the cement layer reduces bond strength because of an oversized post space (D'Arcangelo *et al*. **2007a**, Schmage *et al*. **2009**), above all in the apical region.
The analysis of failure modes after push-out test revealed a majority of adhesive between dentine and cement, implying that the weak link was the bond between the resin cement and the root dentine probably because of root canal walls debris that might have remained and interfered with effective bonding. Moreover, this finding suggested that the RelyX Unicem 2 offers optimal chemical compatibility and strong micromechanical retention with both fibre posts employed in this study, as previously reported (Radovic *et al*. **2008**).

Conclusions

Within the limitations of this laboratory study, fibre posts were better adapted to the coronal rather to the apical region of the post space. Post space preparation device nor fibre post shape influenced post adaptation to oval-shaped canals. However, fibre post adaptation was not directly correlated to bond strength. In fact, both the post space preparation with an ultrasonic tip and the use of a round-shaped fibre post reduced bond strength in oval canals when a self-adhesive cement was employed. Finally, failures were mostly adhesive, implying that the weak link was the bond between the resin cement and the root dentine.

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