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The fit of tapered posts in root canals luted with zinc phosphate cement: A histological study

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Summary *Objectives*. Stress transmission to the root through passive fitting dental posts is partly influenced by the thickness of the cement layer between the post and the prepared root canal surface as well as the fit of the post in the root canal. The objective of this study was to compare the cement gap between the post surfaces and the root canals using five prefabricated, tapered, unthreaded titanium posts of different manufacturers, without and with cement.
Methods. Following the endodontic treatment with hand instruments of 100 intact anterior teeth, post spaces were prepared using opening drills of the corresponding size of post. Fifty posts were cemented with zinc phosphate cement into the roots for each system while another 50 posts were inserted into the canal without using the cement. After histological sectioning, the cement gap was measured at six sites for three times at the coronal, middle and apical regions between the root canal wall and the post surface under a light microscope before and after cementation.
Results. Before cementation, the highest overall cement gap was observed with the Dr Mooser post system® (46 μm) and the lowest with the Velva post system® and Cylindro-Conical system® (30 μm). Significantly less ($P<0.05$) mean cement gap was observed with respect to the Erlangen post system® (41 μm), the Dr Mooser post system® (48 μm), the MP Pirec post system® (34 μm) and Velva post system® (33 μm) when compared with the Cylindro-Conical system® (62 μm). The Cylindro-Conical system® (79, 61 μm) and MP Pirec post system® (25, 24 μm) demonstrated no significant difference ($P>0.001$) compared with Velva-Post® (38, 20 μm) at the coronal and middle part, respectively (Mann-Whitney *U*-test, Boneferroni correction). Significant differences ($P<0.001$) were observed between the cement gap at the coronal and apical part for the Cylindro-Conical system® (79, 46 μm), Dr Mooser post system® (45, 56 μm) and MP Pirec post system® (25, 52 μm). After cementation,

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the highest cement gap at the coronal part was obtained with the Cylindro-Conical system® (79±21 μm) and the lowest with the MP Pirec post system® (25±9 μm). However, at the apical end, the MP Pirec post system® (52±89 μm) and Dr Mooser post system® (56±16 μm) revealed the highest gap.
Significance. Form-congruence between the preparation drill and the post systems exhibited differences. The most consistent cement gap either at the coronal, middle or apical parts of the root canals was obtained with the Erlangen post system®.

Introduction

Restoring an endodontically treated tooth often requires a post and core. A great number of prefabricated post systems are available for endodontically treated teeth with insufficient coronal tooth structure. In principle, the post should stabilize the core and not weaken the root. In order to avoid root fracture, the use of passive tapered posts is frequently advised [1,2]. The posts should be chosen in adequate length and width in accordance with the root dimension to provide permanent anchorage in the root canal [3-5]. However, the retention ability of passive tapered posts is less in comparison to active posts or passive parallel posts. Therefore, it is necessary to improve the retention when this kind of post is chosen [6,7]. In general, the length of the post, its surface area, the surface structure of the tooth and the construction, the taper angle, the type of the cement and thickness of the cemental joint, all influence the retention of a passive fitting dental post against tensile forces [8,9]. From those factors, a homogeneous and preferably small cement joint is a prerequisite for good retention. The anchorage in several post systems varies in design, but the common requirement from all systems is maximum retentive strength [10-15].

Variations in the cement film thickness along the post may cause non-homogeneous stress transmission through the root that might effect the failure rate of the post long-term [13,14,16]. Moreover, histological sections have revealed significant differences in the width of the cement joint between various post systems and the root canals when their corresponding preparation burs are used [17-23].

The objective of this study was to evaluate the cement gap between the post surface and the root canal using five prefabricated, tapered, unthreaded titanium posts from various manufacturers at coronal, middle and apical regions before and after cementation.

Materials and methods

Twenty posts of maximum length from each of the following passive tapered post systems were used:

A. Cylindro-Conical post system® (Cendres & Métaux SA, Biel, Switzerland)
B. Erlangen post system® (Messrs. Brassier, Lemgo, Germany)
C. Dr Mooser post system® (Cendres & Métaux SA, Biel, Switzerland)
D. MP Pirec post system® (Metalor, Neuchatel, Switzerland)
E. Velva Post system® (Maillefer, Ballaigues, Switzerland)

The functional length, taper angle at the coronal and apical parts, surface roughness of each post surface and the dentin wall are presented in Table 1. From these systems, the Cylindro-Conical post system® had a vertical groove over the whole length

Table 1 The functional length (mm), taper angle at the coronal and apical parts, surface roughness (μm) of post surface and the dentin wall.

Post system	Length	Angle of convergence		Surface roughness	
		Coronal (°)	Apical (°)	Post surface	Dentin wall
A. Cylindro-Conical	15	0	3.24	1.8	1.5
B. Erlangen	15	2.1	2.1	12.9	21.0
C. Dr Mooser	13.2	3.08	3.08	1.1	1.4
D. MP Pirec	10.5	3.5	3.5	2.0	2.2
E. Velva Post	11	5.8	1.15	1.6	1.4

for the cement flow, whereas the MP Pirec post system® had one vertical and the three horizontal grooves in its coronal part and the Erlangen post system® had sandblasted surfaces. The surface roughness of the post and the root canal wall was measured for all systems with the use of a surface profile-measuring instrument machine (Perthometer S8P 4.51, Feinprüf GmbH, Göttingen, Germany). The roughness values from the canal walls were obtained by cutting a separate set of teeth into half vertically using a band saw as described previously [24].

A total of 100 newly extracted non-carious human anterior teeth were stored in physiological saline solution before use. The clinical crowns were removed perpendicular to the long axis of the root by a saw (Exact band system®, Norderstedt, Germany). Five experimental groups each consisting of 20 roots were formed for each post system. Ten posts in each group were cemented into the root canal while the other 10 posts were inserted in the canal without using cement.

The root canals were endodontically prepared using hand instruments up to one size smaller than the respective post space preparation instrument. The post spaces were prepared using the corresponding opening drills from each system. Care was taken that each post fitted well to its root canal without any movement. In the case of the Erlangen post system®, the root canals were additionally roughened with a hand-held diamond coated drill of the same size and shape as the post preparation drill, by rotating it five times (diamond instrument, ER post system®, $R_a = 52\ \mu m$) as recommended by the manufacturer. The post spaces were copiously irrigated with 1.5% sodium hypochlorite and thoroughly dried with paper points (Roeko, Langenau, Germany) of the respective sizes.

For the purpose of cementation, zinc phosphate cement (Tenet, Vivadent, Inc., Amherst, NY) was used. The cement was always mixed by the same investigator on a cooled (6 °C) glass mixing slab at a constant room temperature of 20 °C, according to the manufacturer's directions. Powder was added to the liquid in small increments and mixed thoroughly by using the majority of the mixing slab to arrive at a creamy consistency where a small portion of the mix did not drop from the spatula. The posts were lightly coated with cement and seated into the prepared post spaces. Posts were placed according to the instructions of each manufacturer. Constant finger pressure of approximately 40–50 N was maintained for 10 min until the cement had set. Standardization of the finger pressure was practiced on a scale, both before and during cementation process. All of the posts were stored in physiologic saline solution in a closed container at 37 °C for 24 h prior to histological sectioning.

In the non-cemented group, the post from the kit was tried in and seated into the prepared post space under finger pressure. No attempt was made to fix the posts by any acrylic medium in case acrylic contamination affected the coronal measurement. A plastic ring was placed at the coronal part of the post just above the cemento-enamel junction in order to avoid the infiltration of acrylic during embedding.

Histological specimens were then prepared in the longitudinal direction along the root with the sawing and grinding technique described by Donath and Breuner [25] using a band saw to investigate the post cement interface. In order to prevent artefacts caused by post or cement dislodgement, the specimens were infiltrated with photo-polymerizing methacrylate resin (Technovit 7200 VLC, Kulzer & Co GmbH., Friedrichsdorf, Germany) using a dehydration and infiltration system (Shanton PSI Gewebeeinbett-Automat, PSI Medizintechnik, Gruenewald GmbH., Laudenbach, Germany). This method was developed to obtain thin sections for histological examination of undecalcified specimens that cannot be processed in paraffin or cut by conventional techniques, including teeth containing metal restorations. In order to prevent loosening of the posts, one histological specimen was produced from each root at the maximum diameter in the vertical direction.

The cement gap was measured at six reference points for three times under a light microscope (Videoplan®, Zeiss, Jena, Germany) before and after cementation. The measurements were made at the coronal, middle and apical parts at both mesial and distal sides between the root canal wall and the post, at a magnification of ×920 with the aid of a view analyzing system (Axiophot Pol®, Zeiss, Jena, Germany). Fig. 1 displays the five post systems used in this study and the measurement locations of the cement gap.

The data were analyzed statistically using the Mann–Whitney *U*-test and corrected with the Boneferroni test due to the significance levels ($P < 0.05$) (SPSS-Version 7.0. StatView 5.0, SAS Institute, Inc., Cary, NC).

Results

The cement gap varied in accordance with the post system and the location in the root canal (Fig. 2a and b) before and after cementation. Tables 2 and 3 display the significant differences associated with the post systems and locations.

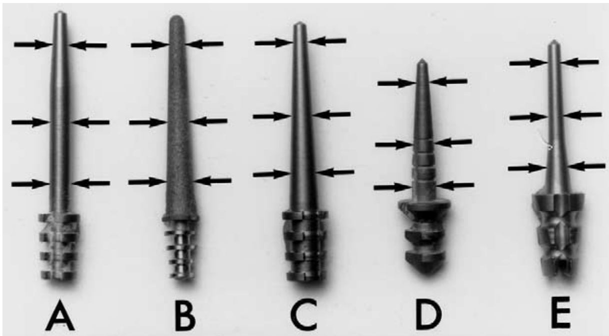

Figure 1 Five post systems used in this study and the measurement locations of the cement film thickness: (A) Cylindro-Conical post system®; (B) Erlangen post system®; (C) Dr Mooser post system®; (D) MP Pirec post system®; (E) Velva post system®.

Significantly less ($P<0.05$) mean cement gap was observed with respect to the Erlangen post system® (41 ± 6 μm), the Dr Mooser post system® (48 ± 13 μm), the MP Pirec post system® (34 ± 16 μm) and the Velva Post® system (33 ± 14 μm) when compared with Cylindro-Conical system® (62 ± 23 μm). The mean cement gap of Dr Mooser post system® was significantly different from those of MP Pirec and the Velva post system® ($P<0.05$).

Significant differences ($P<0.05$) were observed between the gap at the coronal and apical part for the Cylindro-Conical system® (79 ± 21), 46 ± 16 μm), the Dr Mooser post system® (45 ± 11, 56 ± 16 μm) and the MP Pirec post system® (25 ± 9, 52 ± 8 μm). The most consistent cement gap with the lowest standard deviations either at the coronal (45 (11) μm), middle (38 (5) μm) or apical (44 ± 7 μm) parts of the canals was obtained with the Erlangen post system®.

The highest cement gap at the coronal part was obtained with the Cylindro-Conical system® (79 ± 21 μm) and the lowest with the MP Pirec post system® (25 ± 9 μm) after cementation. However, at the apical end, the MP Pirec post system® (52 ± 89 μm) and Dr Mooser post system® (56 ± 16 μm) revealed the highest gap. Before cementation, the highest overall cement gap was observed with the Dr Mooser post system® (46 μm) and the lowest with the Velva Post® system and the Cylindro-Conical system® (30 μm) (Fig. 2c). The effect of cementation was the greatest for the Cylindro-Conical system®.

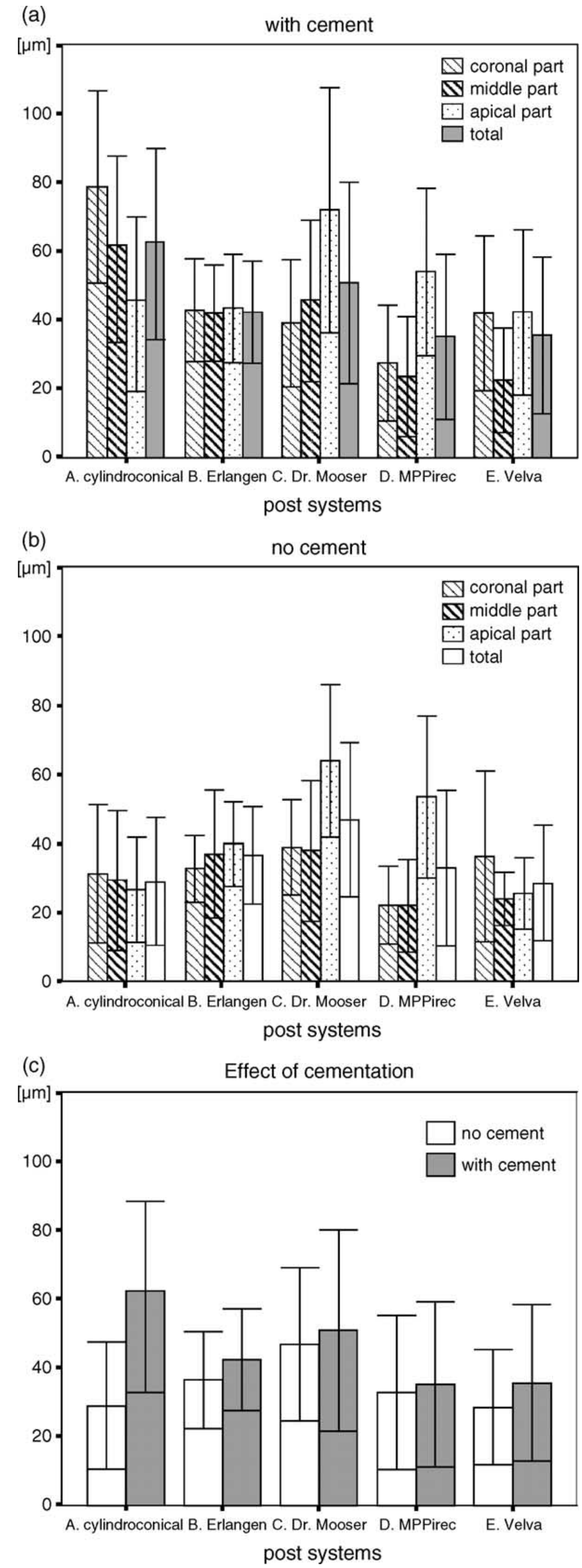

Figure 2 (a) Mean cement gap obtained, together with the standard deviations for each post system at coronal, middle, apical parts together with total mean gap before cementation. (b) Mean cement gap obtained, together with the standard deviations for each post system at coronal, middle, apical parts together with total mean gap after cementation. (c) Overall mean cement gap obtained, together with the standard deviations for each post system before and after cementation.

Table 2 Significant differences (*$P<0.05$) associated with the post systems (n.s., not significant).

Post system	A	B	C	D	E
A. Cylindro-Conical	-	*	*	*	*
B. Erlangen	*	-	n.s.	n.s.	n.s.
C. Dr Mooser	*	n.s.	-	*	*
D. MP Pirec	*	n.s.	*	-	n.s.
E. Velva Post	*	n.s.	*	n.s.	-

Table 3 Significant differences (*$P<0.05$) associated with the post systems (n.s., not significant) associated with the post systems at coronal, middle and apical parts. (n.s., not significant).

Post system	*n*	1. Coronal part	2. Middle part	3. Apical part of the post
		1 and 2	2 and 3	1 and 3
Cylindro-Conical	10	n.s.	*	*
Erlangen	10	-	-	-
Dr Mooser	10	-	*	*
MP Pirec	10	n.s.	*	*
Velva post	10	*	*	n.s.

Fig. 3a–e shows the histological sections from each post system after cementation. In all post systems, it was found that the cement penetrated completely into all irregularities on both the root canal walls and the post surface. In none of the histological sections, air lacunes were observed in the cement layer.

Discussion

Some previous studies implied that the retentive strength of posts increased by parallel post use [2,6]. However, a cylindrical post without convergence, weakens the apical area of the root that could lead to root fracture [2]. Research

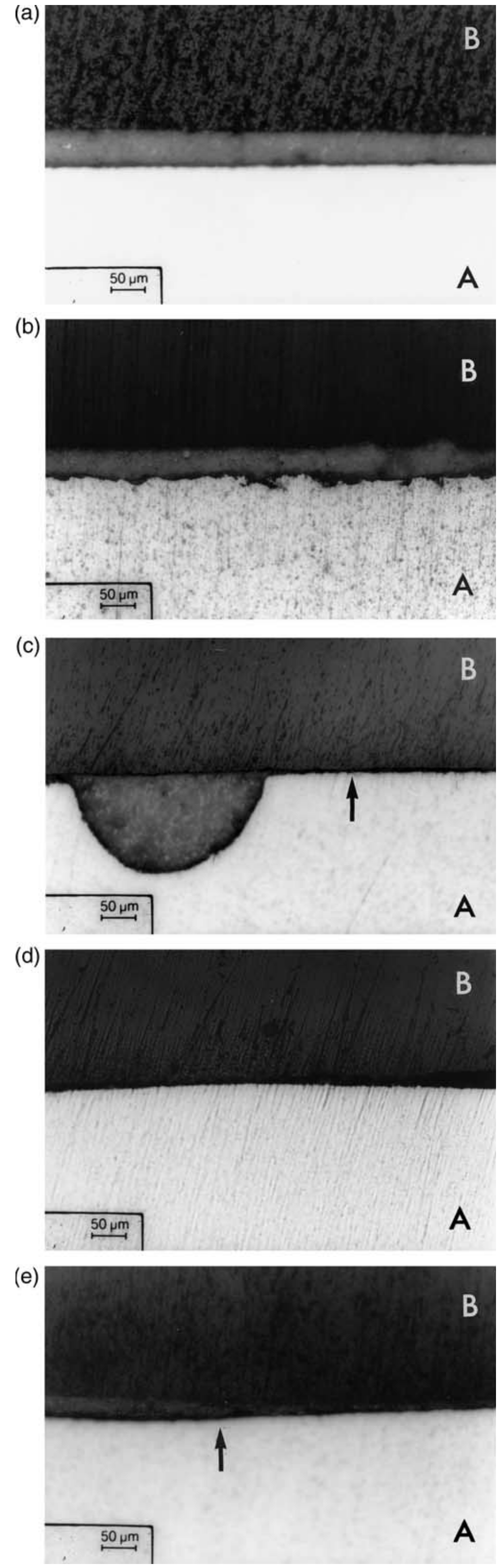

Figure 3 (a) The cement gap (62 μm) between the Cylindro-Conical post system® and the dentin wall of the post space at ×920 magnification (A, post; B, dentin wall). (b) The cement joint (41 μm) between the Erlangen post system® and the dentin wall of the post space at ×920 magnification (A, post; B, dentin wall). (c) The cement gap (25 μm) between the Dr Mooser post system® and the dentin wall of the post space at ×920 magnification (A, post; B, dentin wall). Note that the spiral-shaped groove in the middle of the post was filled with cement. The post partially contacted the dentin in that region without any cement. (d) The cement gap (34 μm) between the MP Pirec post system® and the dentin wall of the post space at ×920 magnification (A, post; B, dentin wall). (e) The cemental gap (33 μm) between the Velva Post system® and the dentin wall of the post space at ×920 magnification (A, post; B, dentin wall).

concerning stress transmission by posts revealed that stress peaks along the dentin wall of the post space could be avoided if the post has a passive fit [9,13,19]. This demand as well as high retention is offered, only if the post has a congruent-form to the prepared space and anatomical form of the root. In this manner, the forces are led to a maximal surface contact while the stress peaks are avoided. As the post transmits the occlusal forces through the root, greater resistance to dislodgement by the occlusal forces in the long-term could be obtained and also root fractures could be prevented [9,26]. However, the retention decreases rapidly with the increasing conicity [17]. For these reasons, five prefabricated post types with convergence at varying degrees at their coronal, middle and apical parts were involved in this investigation.

When a passive fitting post is used, the retention relies highly on the close adaptation of the post to the root canal and the cement layer. Currently, a great number of preparation drills accompanying the prefabricated posts are available to provide adequate fit of the post and sufficient cement space. Thin and homogeneous cement with small film thickness is of great importance for a passive fit, providing a remarkable increase in retentive strength. Under clinical conditions, a cement joint value between 24 and 31 μm for the cast post and 30 and 50 μm for the prefabricated post is required in order to minimize the failure rate of the posts [17]. The mean cement gap observed in four post systems tested in our study, ranging between 33 and 48 μm, did not exceed the recommended values except the Cylindro-Conical post system® for which the mean gap was 62 μm.

With the exception of the Erlangen post system®, all the other systems investigated showed significant differences at various measuring points. Although the angle of convergence was the highest for the Velva-Post system® at the coronal part, the cement gap was not the highest. On the contrary, the angle of convergence was the least for the Cylindro-Conical post system®, but the gap at the coronal region was the highest for this system. One other finding was the imperfect form-congruence between the preparation drill and the post that was noted for the Dr Mooser post system® and the MP Pirec post system®. The cement at the coronal part of a post can be more prone to solubility when compared with the middle or the apical parts and therefore, a perfect fit particularly at this region, is of clinical importance. In this respect, the preparation drills play a significant role in adaptation. The Cylindro-Conical post system® has a vertical groove to make it easier for the cement to flow out of the canal and to achieve a thin cement layer, but the post systems without this groove also exhibited good cement contact microscopically. This indicated that the width of the cement joint was evidently not influenced by the vertical groove.

Cementation influenced the fit of the Cylindro-Conical post system® the greatest, most probably due to its low convergence angle. Not only the vertical groove for the cement flow but also the properties of the cement, are important in post retention. A homogeneous and preferably small cement joint is a prerequisite for good retention and equal transmission of forces [27]. In this study, zinc phosphate was used for cementation purposes due to its clear advantages and long track record. The histological sections proved that the microscopic irregularities were filled with cement without any air bubbles inside the cement layer. Denticulation of the cement in both the post surface and dentin walls in the roots was achieved in all experimental groups. In fact, the consistencies of the cements slightly differ and this may contribute to differences in film thickness. However, meticulous mixing procedures and proper handling when using the powder–liquid cement from the post systems resulted in no voids within the set cement film.

When the luting cement surrounding the canal walls and the post surface is not homogeneous, during force transmission in the oral cavity, these areas are only to be separated by shattering the cement [28]. Among all the post systems compared in this study, the most consistent, cement joint was obtained with the Erlangen post system® at all measurement locations. More information about the clinical performance of these post systems is needed.

Conclusions

1. The cement gap of the luting cement varied in accordance with the post system and the location of the measurements with the highest effect for Cylindro-Conical post system®.
2. The most consistent cement gap either at the coronal, middle or apical parts of the root canals was obtained with the Erlangen post system®.
3. Form-congruence between the preparation drill and the prefabricated post systems in this study exhibited differences.

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