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Retention of Root Canal Posts: Effect of Cement Film Thickness, Luting Cement, and Post Pretreatment

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Clinical Relevance

When treating oversized post spaces, posts should be adhesively bonded in the root canal. That is, the posts should be luted with resin cement and adhesion ensured not only to the dentin of the root canal but also to the post.

SUMMARY

The aim of this study was to investigate the effect of the cement film thickness of a zinc phosphate or a resin cement on retention of untreated and pretreated root canal posts. Prefabricated zirconia posts (CosmoPost: 1.4 mm) and two types of luting cements (a zinc phosphate cement [DeTrey Zinc] and a self-etch adhesive resin cement [Panavia F2.0]) were used. After removal of the crowns of 360 extracted premolars, canines, or incisors, the root canals were prepared with a parallel-sided drill system to three different final diameters. Half the posts did not receive any pretreatment. The other half received tribochemical silicate coating according to the manufacturer's instructions. Posts were then luted in the prepared root canals (n=30 per group). Following water storage at 37°C for seven days, retention of the posts was determined by the pull-out method. Irrespective of the luting cement, pretreatment with tribochemical silicate coating significantly increased retention of the posts. Increased cement film thickness resulted in decreased retention of untreated posts and of pretreated posts luted with zinc phosphate cement. Increased cement film thickness had no influence on retention of pretreated posts luted with resin cement. Thus, retention of the posts was influenced by the type of luting cement, by the cement film thickness, and by the post pretreatment.

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DOI: 10.2341/14-159-L

INTRODUCTION

Posts are often inserted into endodontically treated teeth with minimal remaining tooth substance to

provide retention and stability for a core.[1] Several studies[2-4] have investigated the clinical survival and failure of teeth restored with posts and cores. Failure modes include loss of retention of the post, fracture of the root, and fracture of the post or the core, with loss of retention of posts reported as one of the most frequent types of failure.[1-4] In their review of failure modes of teeth restored with posts luted adhesively with resin cement, Rasimick and others[4] found debonding loss to account for 37% of all reported failures. These authors[4] also calculated pooled odds of 2.3% that a restoration will fail due to debonding, compared with the 4.3% calculated for posts luted with zinc phosphate cement or glass ionomer cement.

The retention of posts is influenced by numerous factors related to the post, the luting cement, as well as the cement-post and cement-dentin interactions.[1-8] Focusing on the type of luting cement, several studies[9-14] found superior retention of posts luted with resin cement compared with posts luted with zinc phosphate cement. One explanation is the superior strength of resin cements over zinc phosphate cement,[10,15] another, the ability of resin cements to supplement micromechanical retention by adhesive bonding, thereby reinforcing the restored tooth.[13,16]

Regarding the interface between the resin cement and the post, several pretreatments of the post have been proposed to improve adhesion. These pretreatments include sandblasting with alumina particles, tribochemical silicate coating followed by application of a silane, etching with hydrofluoric acid, and coating with primers. The tribochemical silicate coating system CoJet (3M ESPE, Seefeld, Germany) has been found to significantly improve bonding of resin cement.[16-19] This system uses silicate-coated alumina particles to sandblast the post surface prior to the application of silane and resin cement. Sandblasting produces high spot heat, which, together with the blasting pressure, results in the welding of the silicate layer onto the post surface. Subsequent silanization enhances the bond strength of resin cement to the silicated surface.[19]

Retention of posts depends not only on bonding the resin cement to the post but also on bonding the resin cement to the dentin of the root canal. This latter bonding is influenced by the dentin surface area, the presence of a smear layer on the dentin surface after post space preparation,[20-22] the surface conditioning of dentin, the adhesive system, and the type of resin cement.[7,23-25]

Finally, not only the type of luting cement but also the film thickness of the cement may influence the retention of posts. A uniform cement film thickness between 25 and 50 μm has generally been accepted for luting of fixed prosthetic restorations.[26] Optimal and uniform thickness of the cement requires precise fit of the post in the post space. Due to the irregularities of the root canal morphology or the tapered endodontic preparations, obtaining a precisely fitting post and a uniform film thickness would often require extensive post-space preparation and lead to weakening of the remaining tooth structure. To the knowledge of the present authors, no studies have investigated the effect of film thickness on retention of posts using zinc phosphate cement. However, increasing the film thickness of zinc phosphate cement has been shown to decrease the retention or the resistance to loading of inlays or crowns.[26-28] In contrast, numerous studies have investigated the effect of film thickness on the retention of posts luted with resin cements; however, the results of these studies are conflicting. Whereas some studies[29,30] report no influence of film thickness, one study[31] found retention to be lower with a thick film (oversized post space) compared with a thin film (precisely fitted post space). Another study[32] found retention to be higher with a thick cement film (oversized post space), and yet other studies[33-35] found greater film thicknesses (oversized post space) to increase retention, provided the film thickness was not too great. One reason for the contradicting conclusions could be that the quality of the adhesion of the resin cement to the post and to the dentin varied among the studies, reflecting that different posts, resin cements, and adhesive systems were used. Considering the superior mechanical strength of resin cements over zinc phosphate cement and their adhesive potential, it seems likely that the retention of posts luted with resin cement is less sensitive to variations in film thickness. However, none of the studies carried out so far have considered the role of adhesion when investigating the influence of the cement film thickness on the retention of posts. Therefore, the aim of this *in vitro* study was to test the following hypotheses: 1) When posts, untreated or pretreated, are luted with zinc phosphate cement, thus being without any adhesive bonding, retention of the posts decreases with increasing film thickness of the cement and 2) when untreated posts are luted with resin cement, thus being without adhesive bonding to the surface of the post, retention of the posts decreases with increasing film thickness of the cement, but 3) when pretreated posts are luted with resin cement, thus being

Table 1: *Post, Luting Cements, and Pretreatments Used*

Post	Luting Cements	Pretreatment Steps
Zirconia posts: CosmoPost Ivoclar Vivadent, Schaan, Liechtenstein	Zinc phosphate cement: DeTrey Zinc Dentsply DeTrey, Konstanz, Germany	No pretreatment
		Tribochemical silica coating (CoJet): CoJet-Sand (particle size=30 μm) 3M ESPE, Seefeld, Germany Silane coating: ESPE Sil 3M ESPE, Seefeld, Germany
	Self-etch adhesive resin cement: Panavia F2.0 Kuraray, Okayama, Japan	No pretreatment
		Tribochemical silica coating (CoJet): CoJet-Sand (particle size=30 μm) 3M ESPE, Seefeld, Germany Silane coating: ESPE Sil 3M ESPE, Seefeld, Germany

adhesively bonded to both the dentin and the surface of the post, retention is not affected by the film thickness of the cement.

METHODS AND MATERIALS

Retention of Prefabricated Zirconia Posts

Prefabricated zirconia posts and two types of luting cements (a zinc phosphate cement [DeTrey Zinc, Dentsply DeTrey, Konstanz, Germany] and a self-etch adhesive resin cement [Panavia F2.0, Kuraray, Okayama, Japan]) were used in the present study. Half the posts did not receive any pretreatment. The other half was pretreated by tribochemical silicate coating according to the manufacturer's instructions. This treatment system consisted of air abrasion with an intraoral sandblasting device (Dentoprep, Rønvig, Daugaard, Denmark) at 3 bar for 15 seconds using 30-μm silicate-coated particles (CoJet-Sand, 3M ESPE), followed by silane application. The investigated posts, pretreatment, and luting cements are listed in Table 1 along with their respective manufacturers.

A total of 360 extracted single-rooted human premolars, canines, or incisors were kept in an antimicrobial medium (0.5% chloramine-T) after extraction. The teeth were extracted for therapeutic reasons. The clinical crown of each tooth was removed perpendicularly to the long axis with a low-speed diamond saw, leaving at least 10 mm of root length. The roots were randomly distributed into 12 experimental groups, each consisting of 30 roots. Roots were prepared with a parallel-sided drill system (Edenta, Au, Switzerland) to three different diameters (1.40, 1.55, or 1.80 mm). For all roots, the length of the prepared root canal was 5 mm. The precise length of post-space preparation was ensured by a "stop" of resin composite luted 5 mm from the top of the drill. Following preparation, the canal was rinsed with deionized water for 60 seconds and dried with paper points (No. 45 Top Dent, Upplands Väsby, Sweden).

The posts were luted "upside down" to ensure that the entire luted part of these parallel-conical posts was parallel-sided. In the case of luting with Panavia F2.0, the walls of the root canals were treated with the corresponding primer (ED Primer II, Kuraray) according to the manufacturer's directions. Both luting cements were mixed according to the manufacturer's recommended procedure and applied inside the root canal with the aid of needle tubes (AccuDose NeedleTubes, Centrix, Shelton, CT, USA). Following luting of the posts with Panavia F2.0, the resin cement was light-cured for 20 seconds (Bluephase LED light-curing unit, Ivoclar Vivadent, Schaan, Liechtenstein) using the high-power program (>1200 mW/cm^2).

All specimens were allowed to set for 15 minutes and then were stored in water at 37°C for seven days. The retention of the prefabricated zirconia posts was tested by the pull-out method. The specimens were placed in a jig that fixed the root and the nonluted part of the post in a universal testing machine (model 5566, Instron Ltd, High Wycombe, UK). The posts were then extracted from the roots at a crosshead speed of 1 mm/min. The direction of the tensile loading was parallel to the long axis of the luted post. All luting and testing procedures were carried out by the same operator.

Determination of Film Thickness

The diameter of three randomly selected posts was measured by a digital micrometer (model ID-U1025, Mitutoyo, Kawasaki, Japan). Three measurements

Table 2: *Retention (N) of Untreated or Pretreated Posts Luted With Zinc Phosphate Cement (DeTrey Zinc) or Resin Cement (Panavia F2.0) of Three Different Film Thicknesses*

Luting Cement	Cement Film Thickness	Untreated			Pretreated		
		65 μm	124 μm	259 μm	65 μm	124 μm	259 μm
DeTrey Zinc	Mean	116.1	89.1	72.3	150.6	110.3	105.5
	SD	40.6	33.2	30.5	45.8	40.0	52.5
	Median	114.4	89.0	74.0	144.1	101.8	84.0
	Maximum	222.6	162.1	141.0	234.2	197.8	220.1
	Minimum	45.8	26.1	21.8	67.5	48.7	37.7
Panavia F2.0	Mean	151.7	123.9	112.8	240.8	255.6	225.0
	SD	41.2	40.6	36.7	54.9	66.4	67.8
	Median	155.2	128.5	113.3	237.8	252.4	215.1
	Maximum	230.4	200.7	179.8	367.1	397.5	365.7
	Minimum	78.5	45.8	26.3	133.1	132.0	105.0

per post were made, and a final mean diameter of 1.370 mm (±0.007 mm) was calculated. In 15 additional roots, the canals were prepared with the burs intended for posts with diameters of 1.40, 1.55, and 1.80 mm, respectively. The diameter of each prepared root canal was measured under a light microscope (model M420, Leica, Heerbrugg, Switzerland) at 32× magnification. Per bur size, five canals were prepared and six measurements were made per canal. The following mean values and standard deviations of the root canal diameter were calculated from the preparations performed with the bur for a 1.4-mm post: 1.500 ± 0.047 mm; bur for a 1.55-mm post: 1.618 ± 0.029 mm; and bur for a 1.8-mm post: 1.888 ± 0.051 mm. Film thickness was then calculated as follows:

$$\text{Film thickness} = (\text{diameter of root canal} - \text{diameter of post})/2$$

The calculations resulted in the following three film thicknesses: 65, 124, and 259 μm.

Statistical Analysis

The retention data were statistically analyzed with a nonparametric aligned rank transformation (ART) analysis of variance (ANOVA)[36] followed by a Bonferroni-Holm correction for multiple testing. The ART ANOVA was followed by exact Wilcoxon rank sum tests without correction for multiple testing. Consequently, the *p*-values of the latter tests must be interpreted in an explorative context. To measure the correlation between film thickness and retention, Spearman rank correlation coefficients were calculated. All statistical analyses were performed with R version 2.12.1 using the extension package exactRankTests (The R Foundation for Statistical Computing, Vienna, Austria; http://www.r-project.org). A global level of significance of $\alpha=0.05$ was applied.

RESULTS

The retention of the prefabricated zirconia posts, untreated or pretreated, are described in Table 2 and visualized in Figure 1.

The ANOVA showed a significant effect of luting cement ($p<0.0001$), pretreatment ($p<0.0001$), and film thickness ($p<0.0001$). In addition, a significant interaction between luting cement and pretreatment ($p<0.0001$) was observed.

Irrespective of the luting cement, the pretreatment with tribochemical silicate coating significantly increased the retention of prefabricated zirconia posts (DeTrey Zinc: $p=0.0001$; Panavia F2.0: $p<0.0001$). Moreover, luting with Panavia F2.0 resulted in higher retention of the zirconia posts than did luting with DeTrey Zinc, irrespective of the surface treatment (untreated posts: $p<0.0001$; pretreated posts: $p<0.0001$).

When untreated posts were luted with DeTrey Zinc, the film thickness of 65 μm resulted in significantly higher retention than did the film thicknesses of 124 μm ($p=0.007$) or 259 μm ($p<0.0001$). Furthermore, the film thickness of 124 μm resulted in significantly higher retention than the film thickness of 259 μm ($p=0.03$). When posts luted with DeTrey Zinc were pretreated by tribochemical silicate coating, the film thickness of 65 μm still resulted in higher retention than did the film thicknesses of 124 μm ($p=0.004$) or 259 μm ($p=0.001$). Here, though, no significant difference

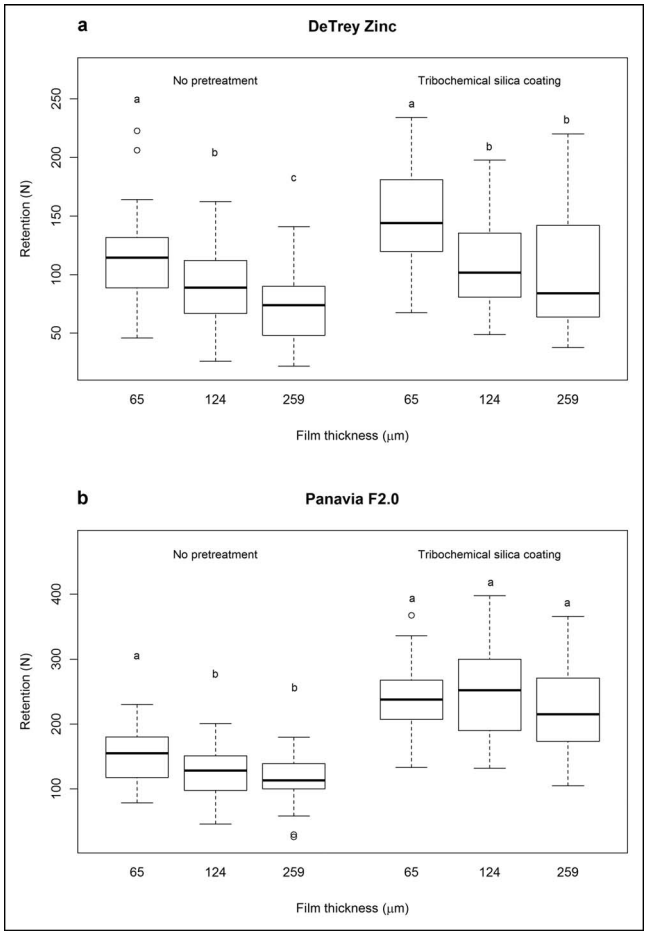

Figure 1. *Retention of untreated or pretreated posts luted with (a): zinc phosphate cement (DeTrey Zinc) or (b): resin cement (Panavia F2.0) of three different film thicknesses. Within each of the four groups of comparison (DeTrey Zinc, no pretreatment; DeTrey Zinc, tribochemical silica coating; Panavia F2.0, no pretreatment; Panavia F2.0, tribochemical silica coating), identical letters indicate no statistically significant difference (*p*>0.05).*

in the retention of posts was present between the film thicknesses of 124 μm and 259 μm (p=0.4232).

When untreated posts were luted with Panavia F2.0, a film thickness of 65 μm also resulted in significantly higher retention than the film thicknesses of 124 μm (p=0.02) or 259 μm (p=0.0006). No significant difference was observed on the retention of posts for film thicknesses of 124 μm and 259 μm (p=0.2524). When posts luted with Panavia F2.0 were pretreated by tribochemical silicate coating, no significant difference in their retention was present for the three investigated cement film thicknesses (65 vs 124 μm: p=0.37; 65 vs 259 μm: p=0.20; 124 vs 259 μm: p=0.08).

Moderate negative correlations between the film thickness and retention existed among the three groups of untreated posts luted with DeTrey Zinc (Cor(Spearman)=–0.4475). The same correlation was observed for pretreated posts luted with DeTrey Zinc (Cor(Spearman)=–0.3410), and among the untreated posts luted with Panavia F2.0 (Cor(Spearman)=–0.3596). Conversely, a very weak correlation was observed for pretreated posts luted with Panavia F2.0 (Cor(Spearman)=–0.1242).

DISCUSSION

The present study evaluated the effect of cement film thickness, luting cement, and post surface pretreatment on the retention of endodontic posts luted in root canals of extracted human premolars, canines, and incisors. This retention is a complex expression of a multitude of factors including the type of luting cement, the bonding of the luting cement to the post and to the dentin, the mechanical properties of the luting cement and of the post, as well as the surface structure and shape of the post. In addition, studies[20,37,38] have demonstrated that surface design (eg, grooved, roughened, serrated, or threaded) influences the retention of posts. In order to eliminate any such influence, the present study was conducted on a smooth post.

When posts were luted with zinc phosphate cement, increased cement film thickness resulted in decreased retention of the posts irrespective of whether the posts had been pretreated. This finding leads to acceptance of the first hypothesis and is in agreement with previous studies,[26-28] although these studies dealt with retention of inlays and crowns and not with root posts. One explanation may be sought in the mechanical properties of zinc phosphate cement. Traditionally, mechanical retention, such as that ensured by zinc phosphate cement, has been thought to depend on three factors: the roughness of the retentive surfaces, the strength of the luting cement, and the compressibility of the cement.[39] Furthermore, the thicker the cement film, the more compressible it will be and the lower the expected retention of the luted restoration.[39] The fact that the tensile and compressive strengths of zinc phosphate cement are inferior to the strength of resin cements[28,40-45] suggests that zinc phosphate cement is much less capable of resisting the forces transmitted to the luting cement during the retention test, thus resulting in premature crack formation of the luting cement and in dislodgement of the posts at a lower loading force. Another explanation may be sought in the resistance of zinc phosphate cement to crack formation and crack propagation. As explained by Wiskott and others,[28] all materials contain defects

randomly located within their microstructure. Under load, each defect is likely to initiate crack growth. The thicker the material, the more numerous the defects, the higher the probability of crack initiation, and hence the reduced resistance of thicker cement layers.[28]

When untreated posts were luted with Panavia F2.0, increased cement film thickness resulted in decreased retention of the posts. This finding is in agreement with previous studies[31,28] and leads to acceptance of the second hypothesis. The fact that film thickness had a significant effect on retention despite the use of a resin cement may be explained by the just mentioned negative influence of increased cement film thickness on the resistance of the cement to crack formation.[28] An additional explanation is inadequate adhesion between the resin cement and the untreated zirconia posts.[7,8,16,18] Although the resin cement may have adhered well to the dentin, poor adhesion to the post resulted in a situation similar to the one found when zinc phosphate cement was used (eg, where retention was obtained by micromechanical interlocking and not by adhesive bonding). It should be noted that for these untreated posts, the resin cement resulted in higher retention than did the zinc phosphate cement, due to the superior strength of the resin cement.

Pretreatment with tribochemical silicate coating resulted in increased retention of the posts regardless of the type of luting cement. This finding is in accordance with previous studies.[8,18,46] The tribochemical silicate coating uses silicate-coated alumina particles to sandblast the surface prior to application of silane.[19] Sandblasting resulted in increased roughness and surface area, and the high spot heat produced, together with the blasting pressure, resulted in the welding of the silicate layer onto the surface of the post. The subsequent silanization has been found to enhance the bond strength of resin cement to the treated surface.[47] The positive effect of tribochemical silicate coating on posts luted with zinc phosphate cement may be ascribed to the increased roughness of the post surface and thus to increased mechanical interlocking of zinc phosphate cement with the surface of the post.[46]

Whereas increased cement film thickness reduced the retention of untreated posts, film thickness did not influence the retention of pretreated posts luted with resin cement. This leads to the acceptance of the third hypothesis. The tribochemical silicate coating system designed for adhesive bonding of resin cement to restorations has been found to promote effective bonding between resin cements and various types of prefabricated posts.[6-8,16-18,48,49] The positive effect that pretreatment of the posts had on the retention of the posts when these were luted in oversized post spaces (ie, with cement film thickness of 124 μm or 259 μm) may be assumed to derive from efficient adhesion of Panavia F2.0 to the posts.[16-18,48,49] Precise and uniform fit of the post in the prepared space may very often be impossible to obtain clinically if extensive, root-weakening preparation of the root canal is to be avoided. Consequently, the use of prefabricated posts inevitably results in variations in the post space and thus in the thickness of the cement film. To optimize retention in these cases and in cases of evidently oversized post spaces, the present results suggest that posts should be luted adhesively (ie, with a resin cement that effectively bonds to the post as well as to the dentin).

Numerous studies[50-55] have reported posts of relatively low elastic modulus, such as fiber-reinforced resin composite posts, luted adhesively with resin cements to show good performance and high retention, and posts with "dentinlike" elastic modulus have been favored over posts of high elastic modulus, such as titanium or ceramic posts. However, as reported by Theodosopoulou and Chochlidakis[56] in their systematic review, few studies included a control group[57] or they varied several factors at once, for example, the type of post and the luting cement (fiber-reinforced post luted with resin cement vs metal post luted with zinc phosphate cement)[53,58] or the retention principle (a smooth fiber-reinforced post vs a metal screw).[55] It is noteworthy that the one study[57] that did include a control group found no difference in the two-year clinical performance of a titanium post and a glass fiber-reinforced composite post using a self-etch adhesive resin cement. Given that the present study found the type of luting cement and adhesive bonding to influence the retention of the posts, it may be that the previously reported favorable results obtained with low-modulus posts over high-modulus posts were caused by adhesive bonding of the luting cement to the root canal dentin as well as to the post, rather than by the lower elastic modulus of the post *per se*. Further studies are warranted to clarify the correlation between elastic modulus of posts and adhesion.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

- Increased cement film thickness resulted in decreased retention of the untreated posts luted with either zinc phosphate cement or resin cement.
- Increased film thickness of resin cement did not influence the retention of posts pretreated with tribochemical silicate coating.
- Pretreatment with tribochemical silicate coating generally improved the retention of posts regardless of the type of luting cement.

Acknowledgments

The authors would like to thank Ivoclar Vivadent AG, Liechtenstein, Kuraray Europe, Germany, and 3M ESPE, Germany for providing the materials used for this investigation. Furthermore, we thank L. Martig and Prof. Dr. J. Hüsler, from Institute of Mathematical Statistics and Actuarial Science, University of Bern for the statistical analyses.

Human Subjects Statement

This research complied with the Act on Research Ethics Review of Health Research Projects (from June 14, 2011), the National Committee on Health Research Ethics of Denmark.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 15 December 2014)

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