Influence of Fatigue Loading on the Performance of Adhesive and Nonadhesive Luting Cements for Cast Post-and-Core Buildups in Maxillary Premolars

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Purpose: This study evaluated the influence of fatigue loading on the performance of an adhesive and a nonadhesive cement for cast post-and-core restorations in maxillary premolars. ***Materials and Methods:*** The adhesive cement used was Panavia 21, a resin-based composite cement, and the nonadhesive cement was PhosphaCem/C, a zinc-oxy-phosphate cement. The coronal sections of single-rooted human maxillary premolars were removed at the level of the proximal CEJ. After endodontic treatment, a cast post and core was prepared for each tooth and cemented into the root canal with either Panavia 21 (n = 8) or PhosphaCem/C (n = 8). Half of the specimens from each cement group were exposed to fatigue loading almost perpendicular to the axial axis; the other half were used as controls. Three parallel transverse root sections were cut from each specimen and used for evaluation of the influence of fatigue loading. For each section, cement integrity was studied by SEM, and retention strength of the cemented post section was determined with a push-out test. ***Results:*** For SEM evaluation and the push-out test, Panavia 21 proved significantly better than PhosphaCem/C. However, fatigue loading did not show any effect. ***Conclusion:*** Under the conditions of this study, fatiguing of cemented cast post-and-core restorations was not decisive as a single test to evaluate the quality of the cement. *Int J Prosthodont 2004;17:571–576.*

Conventional use of nonadhesive luting cements such as zinc-oxy-phosphates has relied on frictional forces for the retention of posts. The degree of friction depends on the accuracy of fit of the post and on the surface roughness of both the post and root canal. These nonadhesive luting cements were intended primarily to fill the space between post and tooth tissue. This concept had to be revised with the introduction of adhesive resin-based composite luting cements, as adhesion contributes substantially to retention.[1–3]

Clinical studies have shown that many post-and-core restorations fail over a period of years.[4–6] Apart from traumatic injuries that can occur at any moment, cyclic mechanical loading during physiologic function is considered an important factor for failures over the long term.[7,8] Cyclic loads during mastication can lead to fatigue of the cements, resulting in disintegration of the cements and/or failure of the cement-substrate interface. If leakage occurs at the same time, dissolution of the cement may further degrade the mechanical properties of the cement layer,[9] finally resulting in loosening of the post-and-core buildup. In this respect, adhesive resin-based composite cements may perform better over the long term than nonadhesive zinc-oxy-phosphate cements for post-and-core restorations on endodontically treated premolars, especially when the post length is limited[10] and/or an adequate ferrule is absent.[11–13] Also, the endodontic seal of an adhesive cement may be better than that of a nonadhesive cement.

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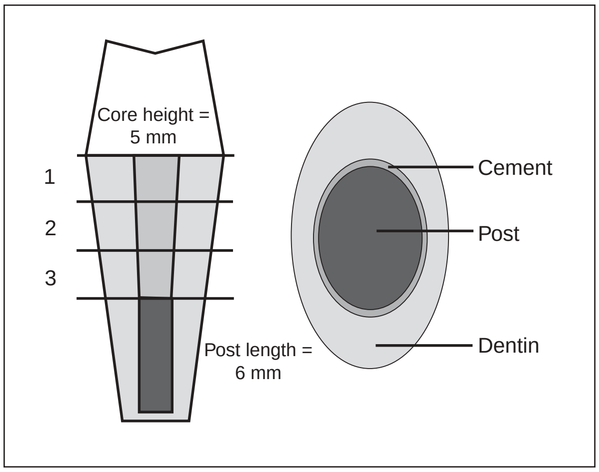

Fig 1 *Left:* Premolar root with post-and-core buildup and levels *(horizontal lines)* where root is cut to obtain 1.5-mm-thick coronal *(1),* medial *(2),* and apical *(3)* cross-sections. *Right:* Cross-sectional view.

The aim of this study was to evaluate the influence of fatigue loading on the quality of the cement layer around the post and along the root canal wall of an adhesive and a nonadhesive cement by means of scanning electron microscopic (SEM) observation and the push-out test. It was hypothesized that cast posts placed with adhesive cements would resist fatigue loading better than cast posts placed with nonadhesive cements.

Materials and Methods

Tooth Preparation

Sixteen freshly extracted, caries-free human maxillary single-rooted premolars were used for this study. During all experimental procedures throughout the investigation, the teeth were kept moist or stored in distilled water at 37°C. The coronal section of each premolar was cut from the root at the proximal cementoenamel junction (CEJ) using a low-speed water-cooled saw (grit 230 to 270, Buehler). Root canals of the sectioned teeth were instrumented with endodontic files to 1 mm from the apex while regularly irrigating with 2% sodium hypochlorite, then dried with paper points and filled with gutta-percha points (Demedis) and AH 26 root canal sealer (Dentsply/Maillefer) using the lateral condensation technique. A periodontal ligament was simulated by coating the root surface with a thin layer (approximately 0.3 mm) of silicone (TSE 3991, General Electric). Finally, the teeth were embedded in acrylic resin inside a standard copper tube, leaving 2 mm of the root above the acrylic resin.

Cast Post and Core

Gutta percha was removed from the root canal with a low-speed Gates Glidden drill (No. 3) to a depth of 6 mm as measured from the shoulder, in most cases leaving 4 to 6 mm of gutta percha filling in the apical part. A post space was made to the same depth with a low-speed calibrated drill (code yellow, 1.3 mm) provided by the manufacturer of the Tenax endodontic post system (Coltène Whaledent). The corresponding burnout post (code yellow, TE-EP 13) displayed an adequate fit in the apical part of the root canal. In the more spacious medial and coronal part of the root canal, where the diameter of the calibrated drill was not always sufficient, the post was adjusted with Duralay resin (Reliance Dental).

A standard matrix was placed around the premolar and filled with Duralay to form a core buildup pattern. After setting, the core buildup was prepared with high-speed, coarse diamond burs under profuse water spray (type FG 142 G. 014, Horico). The height of the core was adjusted to 5.0 ± 0.2 mm, and the axial surfaces were in conformity with the shape of the tooth. When completed, the post-and-core pattern was removed and used to cast a permanent post and core in nonprecious Phantom metal (Degussa).

Cementation

The 16 prepared specimens and their corresponding cast posts and cores were randomly assigned to one of two groups. In the first group, Panavia 21 (Kuraray) was used as the luting cement; in the second group, PhosphaCem/C (Ivoclar Vivadent) was used. All posts and cores were cleaned with ethanol and dried. The root canal and shoulder were rinsed with water spray and dried with absorbent paper points and, gently, with air.

Mixed PhosphaCem/C was applied to the shoulder and injected into the root canal with a Lentulo Paste Carrier (Maillefer) before seating the posts.[14] For Panavia 21, the root canal and shoulder were first conditioned for 60 seconds with ED Primer (Kuraray) applied with a microbrush and paper point. Excess was blown away and in the apical part removed with absorbent paper points. Then, the entrance of the root canal and post and core were coated with a surplus of mixed Panavia 21 and the post was seated into the root canal. Excess cement was removed with a brush, and the cement margin was covered with Oxyguard II (Kuraray). The Lentulo Paste Carrier was not used for Panavia 21, as this method involved the risk of accelerated setting of the cement because of the contact with the primer and the anaerobic conditions in the apical part of the root canal. Premature setting of the cement would make it difficult to get the post in place.

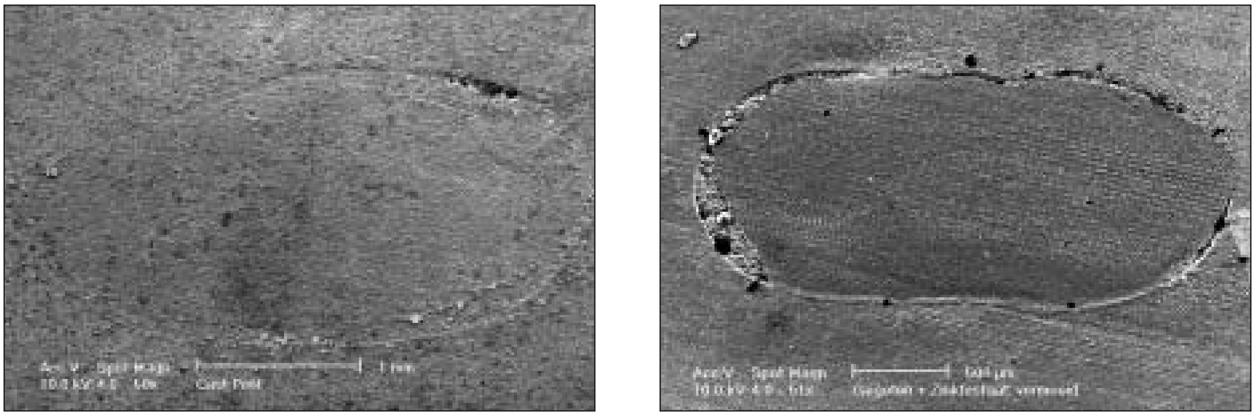

Fig 2 SEM views of medial cross-sections of cast posts. Specimen cemented with Panavia 21 *(left)* shows fewer air bubbles and better adaptation to the post and intraradicular dentin than does specimen cemented with PhosphaCem/C *(right).*

During setting of the materials, the post and core was kept under occlusal finger pressure for 5 minutes. This was always done by the same operator to standardize the pressure as much as possible. Excess luting agent was removed with a probe.

Fatigue Loading

In each cement group, half of the specimens (n = 4) were fixed in acrylic resin blocks and placed in distilled water at 37°C in the ACTA fatigue machine (ACTA). They were loaded in a buccolingual direction for 1,000,000 cycles[7] (277 hours) on the axioocclusal corner of the core at an 85-degree angle to the axis of the post. With each cycle, the load alternated between 8 N (0.8 s) and 40 N (0.2 s). (More details can be found at www.dentalmaterials.nl.) This load is within the range of reported physiologic masticatory forces.[9,15–17] The remaining half of the specimens served as controls to gauge the effect of the fatiguing procedure.

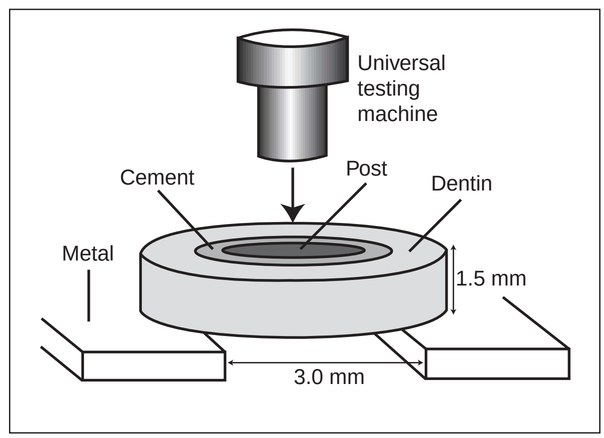

Fig 3 Push-out test. Each disk (1.5 mm) is positioned with the coronal plane downward. Pushing steel rod is only in contact with the central post segment (cross-head speed 0.5 mm/min).

SEM Evaluation

Starting just apical from the level of the proximal CEJ, three consecutive, parallel, transverse 1.5-mm sections were cut from all 16 specimens (Fig 1) using the low-speed, water-cooled saw previously described. Impressions of the coronal surfaces of the three sections (coronal, medial, and apical) were made with a polyether impression material (Impregum F, 3M/ESPE). The boxed impressions were poured in epoxy resin (Araldite D, Vantico) and kept under vacuum to remove air bubbles. After setting, the epoxy replicas were mounted on 10-mm aluminum stubs (Balzers) and gold sputter coated (Edwards S150BE). The epoxy replicas were then examined in a Philips XL 20 SEM (Philips) for irregularities like cracks and air bubbles in the cement layer and insufficient adaptation of the cement to the post or dentin (Fig 2) and photographed at a magnification of approximately 50×. If no irregularities were found, a score of 0 was assigned. A score of 1 was assigned when irregularities occupied $^{1}/_{12}$ (8.3%) or less of the cement circumference. The highest score of 12 indicated irregularities occupying 91.7% to 100% of the cement circumference.

Push-out Test

Each cross-section was positioned with the coronal plane downward and the central post segment centered over a hole in a steel support aligned in a universal testing device (Instron) (Fig 3). A steel rod, only in contact

Table 1 Mean (Standard Deviation) of Cement Push-out Strengths and SEM Evaluation of Irregularities

Measurement	Apical section		Medial section		Coronal section	
	Control sample	Fatigue sample	Control sample	Fatigue sample	Control sample	Fatigue sample
Push-out strength (MPa)						
Panavia 21	5.5 (3.1)	6.2 (3.6)	6.0 (1.9)	6.2 (2.5)	5.6 (0.7)	6.4 (1.4)
PhosphaCem/C	4.1 (0.3)	3.0 (1.7)	2.7 (0.9)	4.4 (2.3)	3.2 (1.1)	4.1 (1.7)
SEM evaluation (score 0–12)						
Panavia 21	4.5 (1.3)	6.0 (1.2)	3.0 (1.8)	3.3 (2.6)	3.8 (2.2)	2.3 (0.5)
PhosphaCem/C	11.0 (1.4)	10.8 (1.9)	9.0 (2.2)	9.8 (3.9)	9.3 (2.8)	9.5 (1.7)

with the central post segment, was pressed downward with a cross-head speed of 0.5 mm/min. The load (N) required to push out the segment was divided by the area of the cylindric root surface enclosing the post and cement to calculate the bond strength (MPa):

$$\frac{\text{Push-out force (N)}}{\text{Perimeter (mm)} \times \text{Specimen thickness (mm)}}$$

The perimeter was measured with a map-measuring device (ANWB) on the SEM photographs. The thickness was 1.5 mm. No distinction was made between loss of retention between post and cement layer or between intraradicular dentin and cement layer.

Statistical Analysis

The data obtained were statistically analyzed by a multiple analysis of variance (MANOVA), with the aid of the GLM subprogram of the SPSS package for Windows, version 11.00 (SPSS). Effects with a P value $< .050$ were considered significant. When an interaction or main effect was significant on a multivariate level, it was univariately examined next. When called for, effects were further explored by means of simple effects and pairwise comparisons. In this analysis, the SEM results and push-out test results were the dependent variables. Test condition (fatigue loading or control) and type of cement (PhosphaCem/C or Panavia 21) were treated as between-subjects factors, whereas section location (apical, medial, or coronal) was entered as a within-subjects factor.

Results

Fatigue loading did not cause separation of the buildups from the roots in any of the specimens. The main effects—condition (fatigue or nonfatigue) and location (apical, medial, and coronal)—were not significant ($F = 0.450$, $P = .649$ and $F = 2.247$, $P = .144$, respectively). The cement main effect was the only one to be multivariately significant ($P < .001$). Univariately, it was significant for the push-out strength ($F = 15.729$, $P = .002$) as well as SEM score ($F = 88.571$, $P < .001$) (Table 1).

Discussion

As with many in vitro studies, it is difficult to extrapolate the results directly to the clinical situation, as it is hardly possible to simulate the complex of clinical conditions all at the same time in one in vitro test. The present study simulated, where possible, the clinical situation for cast post-and-core restorations by the application of a "periodontal ligament" and the action of mastication by fatigue loading[7] in water at 37°C. However, the height and direction of the load were constant, which is not the case with chewing forces in the clinical situation, where extremely high forces can occur by impact with hard substances in food as well as parafunctional loads.[9,15–17] The inclusion of a crown with a ferrule in the experimental setup was deliberately omitted to exclude any external strengthening influence on the post and core. The configuration used was believed to be worse than any other with regard to the resistance of the restored tooth and appeared suitable for specifically evaluating the fatigue behavior of the post in the root canal.[11–13] Standardization of the test specimens is another aspect that needs careful attention. Only single-rooted maxillary premolars were selected, but differences in the anatomic perimeter of the teeth could not be avoided.

With the present in vitro model, we were not able to demonstrate that fatigue loading would play a role in clinical failures of cast post-and-core restorations, and the hypothesis was rejected. Both cements resisted fatigue loading after 1,000,000 load cycles. Push-out strengths were not different between cyclically loaded and unloaded sections, and SEM inspection did not show an increase in irregularities like cracks in the cement layer or loss of adaptation of the cement to post or dentin. These results were somewhat unexpected, as the buildups were loaded with a relatively high force of 40 N under a most unfavorable direction, nearly perpendicular to the axis of the post. Moreover, the load was applied directly on the buildup, without the support of a crown with a ferrule preparation.[11–13] In addition, the post-to-core length ratio for the cast posts cemented with zinc phosphate was at the limit required for nonadhesive cements to offer acceptable retention.[10] Under these circumstances, an effect of fatiguing might be expected in the coronal sections, which were right below the interface between root and buildup. However, because of the exact fit of the cast post, supported by the relatively large surface of the wide oval shape of the perimeter in this part of the root, the stresses were homogeneously distributed and may have stayed well below the mechanical limits of the cements. With prefabricated metal posts, the situation will be different, as their smaller radii can result in higher local stresses that may exceed the mechanical limits of the phosphate cement.[18]

Although the samples were loaded for 1,000,000 cycles, the period for which the fatigue experiment ran was only 11 days. Disintegration of cements by the effect of leakage is a long-term process and could not be revealed by this test. Apparently, this fatigue test is not decisive for evaluating the quality of cemented cast posts for clinical service. Many of the failures observed after years of service[4–6] may well be the result of disintegrated cement from the combination of loading and long-term leakage.[19] Follow-up studies with a test setup in which the samples are immersed in a dye solution could provide information about the leakage pattern, where leakage starts, and how it progresses inside the root canal after load cycling.[20]

Besides the significant difference between the push-out strength of PhosphaCem/C and Panavia 21, these cements also differed in the SEM evaluation of the number of irregularities like air bubbles in the cement layer between post and intraradicular dentin and insufficient adaptation of the cement to post or dentin. Although the application method of Panavia 21 increased the risk of air entrapment at the apical site, the SEM results showed this not to be the case. A typical example of a medial cross-section is shown in Fig 2.

Traces of gutta percha, which may remain in the medial and apical parts of the root canal after preparation with the round calibrated burs of the post system, can also affect the final result. This is most likely to occur in root canals of premolars, which have an oval shape or are partially connected to a second root canal.[21] Moreover, modern endodontic preparation techniques may leave more of the original oval root canal shape intact, which increases the risk of inclusion of gutta-percha remnants.

All the factors mentioned, which lead to voids and imperfect adaptation of cements to the post and root canal wall, should be minimized, as these open spaces are potential pathways for leakage to the apex.

Conclusion

The hypothesis that cast posts placed with adhesive cements would resist fatigue loading better than cast posts placed with nonadhesive cements was rejected. However, it should be kept in mind that the experiment was an accelerated test to simulate long-term effects of cyclic mechanical loading during physiologic function; the duration of the test was too short to include long-term leakage effects on cement stability. In view of the higher push-out strength and lower scores for irregularities in the cement layer, resin composite luting cements such as Panavia 21 are favorable for the cementation of cast posts and cores. Yet, the application technique should be improved to diminish incorporation of voids and ease handling. This may be facilitated when the cement is injected into the root canal with a needle syringe.[22] Besides the importance of cement type, strict compliance to the recommended procedures,[23] an adequate ferrule, and the preservation of tooth structure are the key factors in promoting resistance to failure.[23–28]

Acknowledgments

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Literature Abstract

Evaluation of the accuracy of three transfer techniques for implant-supported prostheses with multiple abutments

The accurate and passive fit of an implant prosthesis is considered an important element for its clinical success. Various techniques have been used to transfer the accurate position of implants from a patient to the working cast. This study compared the accuracy of three different transfer techniques (direct splinted, direct non-splinted, and indirect) used for an implant-supported prosthesis with multiple implants. Five impressions were made with polyether material for each technique: group1 = square transfer copings splinted with carbon steel pins and autopolymerizing acrylic resin; group 2 = square transfer copings; and group 3 = tapered transfer copings. Sixteen strain gauges were attached at four surfaces to the metal framework to measure the strain of the framework for the prediction of the accuracy of fit. The 15 samples were measured twice with the use of new prosthetic-retaining screws each time. The data were analyzed with analysis of variance and Tukey test at 95% and 99% confidence levels. Group 1 samples showed statistically less deformation than group 2 and 3 samples. There was no statistically significant difference between group 2 and 3 samples. The authors suggested that the direct-splinted technique is the most accurate transfer method for multiple abutments compared to direct non-splinted and indirect techniques.

Naconecy M, et al. *Int J Oral Maxillofac Implants* 2004;19:192–198. **References:** 33. **Reprints:** Dr Marcos M. Naconecy, Rua Fernandes Vieira 570, apto 306, 90035-090 Porto Alegre RS, Brazil. e-mail: naconecy@via-rs.net—*Eunghwan Kim, Lincoln, NE*