Core build-up designs

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CHAPTER 4

The Influence of Fatigue Loading on Different Post and Core Build-up Systems in Premolars

4.1 Abstract

Objective. Clinical studies show a failure incidence after years of service of endodontically treated premolars when restored with post-core crowns, especially those with short posts or deficient ferrules. The reason for this can be a deterioration of the luting cement around the post by fatigue from functional loading. Because the anatomy of premolars may frequently be incompatible with the application of long endodontic posts the aim of this study was to evaluate the influence of fatigue loading on the quality of the cement layer between posts with restricted length and the root canal wall in single rooted premolars. The study was divided in three investigations. The first part concerned cast post and core restorations cemented with an adhesive and a non-adhesive cement (Chapter 3). In the second part (this Chapter) post and core systems with varying post and core stiffness cemented with an adhesive cement were considered and in the third part (Chapter 5) various luting agents for cementation of quartz-coated carbon fiber posts were evaluated with core build-up resin composite. This Chapter was confined to the second part.

Materials and methods. Four types of post and core systems were selected for this study; three prefabricated post systems combined with a resin composite core material and one cast post and core. The three prefabricated posts were Titanium posts (Tenax), Quartz fiber posts (Aestheti-Post) and Quartz coated Carbon fiber posts (Aestheti-Plus). The post-and- core restorations were made on single-rooted, human, premolars from which the coronal sections were removed at the level of the proximal cemento-enamel junction (CEJ). Following the endodontic treatment a cast post-and-core (post length 6 mm) was prepared for each tooth individually (direct method) and cemented into the root canal with chemically-cured resin composite cement Panavia 21 TC. The prefabricated posts were directly cemented in the root canal with the identical cement and then, after applying a dual-cured adhesive (Clearfil Photo Bond), built up with a core build-up composite (Clearfil Photo Core). For each group (n = 8) half of the specimens were exposed to fatigue loading in buccal-lingual direction (10⁶ load cycles) almost perpendicular to the axial axis (85°), while the other half was used as control. Three parallel, transverse, root sections of 1.5 mm thickness were cut from each specimen. These sections were examined by Scanning Electron Microscopy to evaluate the cement integrity, while the retention strength of the cemented post sections were determined with a push-out test.

Results. Fatigue loading did not cause separation of the build-ups from the roots or affect the push-out strength (P = 0.986). On a univariate level only SEM evaluation showed significant differences between the types of post, between fatigue loading and between the levels of root sections (P = 0.002, P = 0.001 and P < 0.001 respectively). The cement integrity with the Titanium post was significantly less than with the other three systems (P = 0.002), which did not differ among themselves. The differences could not be explained by differences in stiffness between the posts.

Conclusion. A resin composite core build-up, adhesively bonded to dentin, and supported by Quartz fiber posts or Quartz coated Carbon fiber posts, which are cemented with adhesive resin- composite cement, may be a viable alternative for the conventional cast post and core.
Chapter 4

4.2 Introduction

The ideal restoration of the tooth crown should rehabilitate function and esthetics, and preserve
the health of the remaining tooth and surrounding tissues from a mechanical as well as a
biological perspective. Some investigators suggest that endodontically treated teeth do not need
to be reinforced by means of a post because the dentinal hardness and moisture content of
pulpless teeth are similar to vital teeth [1,2]. The success rate of such restorations is rather the
result of a proper ferrule design of the crown than the presence of a post [3-5] Nevertheless,
unsupported tooth structure of endodontically treated teeth, in particular premolars, is prone to
fracture, which often leads to laborious restorative procedures that may include periodontal
surgery and/or orthodontic extrusion or even extraction of the tooth. Therefore, a proper build-up
procedure and cuspal coverage are instrumental for the long-term success of endodontically
treated teeth [6,7]. If not enough axial dentin can be preserved to obtain adequate retention of a
resin composite core build-up restoration, it may be necessary to insert a post. However, the
application of a post often contributes to further loss of tooth structure, which may involve a risk
of root fracture when functional loads reach high values [8,9]. This is in conflict with the
requirement that a post and core restoration should protect the remaining tooth structure, and
most importantly it opposes the requirement to keep preparation procedures as non-invasive as
possible [10-12].

As described in chapter 3 adhesive luting cements can increase the retention by adhesion to
both the post and root canal wall, bonding these components together [13-15]. For both
biological and mechanical requirements, the luting material plays a role of paramount
importance. However, full cementation, all the way down to the remaining root canal filling, not
only depends on the quality of the luting agent, but also to a considerable degree on the technical
skills of the operator [16]. For that reason, the incidence of failure for post and core restorations
may still be high [17].

In the past decade, in addition to the new adhesive luting cements, a wide range of new posts
and build-up materials have been introduced. The development of new post and core materials
and adhesive luting cements requires a renewed investigation regarding the most effective way
of restoring endodontically treated teeth. From a mechanical point of view, it is believed that a
highly rigid post contributes to the stability of the post and core restoration. However root
fractures observed with these posts may occur because of the extreme difference in flexibility of
post and root [9,18], which concentrates stresses during loading mainly in the root. With the
introduction of non-metal posts with mechanical properties more similar to those of the tooth
structure, such stress concentrations in the surrounding tooth structure can be diminished [19-
Fatigue loading on different post and core systems

21]. On the other hand, the more flexible posts may lead to stress concentration at the adhesive interfaces between the cement and the post or intra-radicular dentin, which may result in loss of adhesion between the two [22,23].

As explained in Chapter 3 for premolars shorter posts should be preferred for morphological reasons. However, it has been reported that short rigid posts show unfavorable stress distribution in the surrounding dentin [24] and may induce root fractures. Therefore, posts with a flexibility closer to that of tooth structure may be preferred. In this way the stresses on the core will more or less be dissipated along the post in the direction of the apical part of the root.

The aim of this study was to evaluate the influence of fatigue loading on the quality of the cement layer between posts with restricted length and root canal wall, for four different post and core systems.

4.3 Materials and methods

Preparation of tooth

For this study thirty-two freshly extracted, caries free, human, single-rooted premolars were prepared as described in Chapter 3. These teeth were divided in four groups each with 8 teeth. During all experimental procedures throughout the investigation, the teeth were kept moist or stored in distilled water at 37 °C.

Post and core procedure

Following the endodontic procedure, the cast post and cores were constructed by means of the direct method and seated into the root canal with Panavia 21 TC. The prefabricated posts were directly cemented into the root canal with the identical cement and then built up with the resin composite core material. Table 4.1 shows the types of posts that were used in this study and Figure 4.1 shows their configuration.

In each group (n = 8) 6 mm of the gutta-percha in the root canal, measured from the shoulder, was removed with a low-speed Gates Glidden drill # 3 (Dentsply/Maillefer), in most cases leaving 4-6 mm gutta-percha filling in the apical part of the root. The exact post space was made to the same depth with a low-speed calibrated drill, provided by the manufacturer of the selected post system. For each tooth the root canal and dentin shoulder were cleaned with pumice and rinsed with water. After removing the water in the root canal with absorbent paper points the tooth was air-dried but not dehydrated.
Table 4.1 The four types of posts used in this study.

<table>
<thead>
<tr>
<th>Group</th>
<th>Post</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Titanium Tenax, code yellow</td>
<td>Coltène Whaledent</td>
</tr>
<tr>
<td></td>
<td>TE-EP 13 (diameter = 1.3 mm)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Quartz fiber Aestheti-Post</td>
<td>RTD</td>
</tr>
<tr>
<td></td>
<td>(diameter = 1.2 mm apical and medial, 1.8 mm coronal)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Quartz coated Carbon fiber Aestheti-Plus</td>
<td>RTD</td>
</tr>
<tr>
<td></td>
<td>(diameter = 1.2 mm apical and medial, 1.8 mm coronal)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cast Post and Core: Tenax burn-out post code yellow,</td>
<td>Coltène Whaledent</td>
</tr>
<tr>
<td></td>
<td>TE-EP 13 (diameter = 1.3 mm) and Phantom metal alloy</td>
<td>Degussa AG</td>
</tr>
</tbody>
</table>

In Group 1 the calibrated drill (Coltène Whaledent) provided an accurate fit for the corresponding Titanium post. Only in the more spacious coronal part of the root canal, where the diameter of the calibrated drill was not always sufficient, the fit was less accurate. The post was cleaned with ethanol and dried. The dentin shoulder was etched for 30 seconds with 32% phosphoric acid (Bisco) and thoroughly rinsed with water. After removing the water in the root canal with absorbent paper points the tooth was air-dried, but not dehydrated. Self-etching ED Primer (Kuraray) was applied to the root canal dentin with a micro brush (Demedis). The dentin was conditioned for 60 seconds, the excess primer was blown away and the primer in the root canal was removed with absorbent paper points.

![Fig 4.1 Schematic representation of a premolar root with a cast post and core build-up (left) and with a titanium and fiber post with a resin composite core build-up (middle and right). The horizontal lines indicate the levels where the root was cut to obtain 1.5 mm thick coronal, medial and apical cross-sections.](image-url)
Fatigue loading on different post and core systems

Then the entrance of the root canal and the post were coated with a surplus of mixed Panavia 21 TC (Kuraray) and the post was seated into the root canal. Excess cement was removed with a brush and the post was kept under occlusal finger pressure for 3 minutes. The cement in the entrance of the root canal, the part of the post exterior to the root canal, and the dentin shoulder were covered with a thin layer of dual-cured resin bonding agent Clearfil Photo Bond (Kuraray) and light-cured for 20 seconds (Astralis 5). Then, a standard matrix was placed around the premolar and filled with a light-cured resin composite Clearfil Photo Core (Kuraray) using a Centric syringe (Hawe Neos). To ensure complete polymerization the composite was light-cured for 60 seconds. After setting, the core build-up was prepared with high-speed, coarse diamond burs (type FG 142 G. 014, Horico) under profuse water spray. The height of the core was adjusted to $5.0 \pm 0.2$ mm and the axial surfaces were trimmed in conformity with the shape of the tooth.

In group 2 and 3 the calibrated drill (RTD) provided an accurate fit for the corresponding two-stage parallel-sided (a diameter of 1.2 mm apical and medial and 1.8 mm coronal) Quartz fiber and Quartz coated Carbon fiber posts, including the more spacious coronal part of the root canal where the diameter (1.8 mm) was sufficient. The post was sandblasted like a composite inlay, with $50\mu m$ aluminum oxide particles (Danville Engineering) for 1-2 seconds [25]; the nozzle of the sandblaster was held at a distance of approximately 50 mm in a position perpendicular the post surface. Then it was cleaned with ethanol, dried, and silanized for 30 seconds with Ceramic primer (3M-ESPE) and dried again [25]. The steps of cementation and building-up the cores were identical to group 1.

In group 4 the cast post and cores were constructed by means of the direct method as described in Chapter 3. Then the luting cement was mixed and the post and core were coated with a surplus and seated into the root canal; the steps of cementation with Panavia 21 TC were as those applied for the previous groups.

Fatigue loading procedure, SEM, Push-out test

The procedures for fatigue loading and quality evaluation of the cement layer by SEM and push-out strength were identical to those described in Chapter 3. For all groups half of the specimens ($n = 4$) was exposed to a fatigue loading and the other half ($n = 4$) was used as control (non-fatigue). SEM photographs of the four post types, typical for non-fatigued medial sections are shown in Figure 4.2.
Figure 4.2 SEM micrographs of non-fatigued medial cross-sections of a Titanium post (upper left), Quartz coated carbon fiber post (upper right), Quartz fiber post (lower left), and Cast post (lower right), cemented with Panavia.

**Statistical Analysis**

The data were statistically analyzed by a multiple analysis of variance (MANOVA), with the aid of the GLM subprogram of the SPSS package (Windows version 11.00). Effects with a P-value not exceeding .05 were considered significant. Whenever a main effect was significant on a multivariate level it was univariately examined next. Whenever called for, effects were further explored by means of simple effects comparison and pairwise comparisons. In this analysis SEM scores and push-out results were the dependent variables. Type of post (Titanium, Quartz fiber, Quartz coated Carbon fiber and Cast) and test condition (fatigue or control) were treated as between subjects factor, while section location (apical, medial or coronal) was entered as a within subjects factor.

**4.4 Results**

During fatigue loading no spontaneous failures occurred. Data for SEM evaluation and push-out strength are presented in tables 4.2, 4.3 and 4.4. The main effects, type of post, test condition and section location were multivariately significant ($F = 3.790, P = 0.004$; $F = 6.719, P = 0.005$; and
Fatigue loading on different post and core systems

F = 6.508, P = 0.001 respectively). On a univariate level all main effects, type of post, test condition and section location were significant for SEM only (F = 6.370, P = 0.002; F = 13.462, P = 0.001; and F = 12.155, P < 0.001 respectively). Pairwise comparisons between the posts showed that the SEM-scores for Titanium posts were significantly higher than for the Quartz fiber posts (P = 0.007), the Quartz coated Carbon fiber posts (P = 0.000) and the cast posts (P = 0.005), while the latter three did not significantly differ among themselves. Polynomial contrasts tests showed that the SEM-score declined linearly from apical to coronal (F = 25.266, P < 0.000). This indicates that the integrity of the cement layer improved significantly from the apical to coronal level.

Table 4.2 Means and standard deviations (in brackets) for SEM scores and Push-out strength per type of post, per level (apical medial and coronal) and per condition (non-fatigue and fatigue). If no irregularities were found a SEM evaluation score of zero was assigned. A score of one was assigned when irregularities occupied 1/12th or less (8.3% or less) of the cement circumference. The highest score level of 12 indicates irregularities occupying 91.7 to 100% of the cement circumference.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Type of post</th>
<th>Apical section</th>
<th>Medial section</th>
<th>Coronal section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non Fatigue</td>
<td>Fatigue</td>
<td>Non Fatigue</td>
<td>Fatigue</td>
</tr>
<tr>
<td>SEM score (Ranking 0-12)</td>
<td>Titanium</td>
<td>4.0 (1.4)</td>
<td>7.5 (1.3)</td>
<td>3.8 (3.1)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>4.0 (0.8)</td>
<td>6.5 (2.4)</td>
<td>4.8 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>3.5 (0.6)</td>
<td>5.5 (2.9)</td>
<td>1.8 (1.5)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>4.5 (1.3)</td>
<td>6.0 (1.2)</td>
<td>3.0 (1.8)</td>
</tr>
<tr>
<td>Push-out strength (MPa)</td>
<td>Titanium</td>
<td>5.0 (4.3)</td>
<td>5.3 (2.2)</td>
<td>3.9 (1.5)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>3.8 (1.9)</td>
<td>3.5 (2.9)</td>
<td>5.3 (2.6)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>5.5 (2.3)</td>
<td>4.9 (0.8)</td>
<td>6.1 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>5.5 (3.1)</td>
<td>6.2 (3.6)</td>
<td>6.1 (1.9)</td>
</tr>
</tbody>
</table>

For the push-out strength, on a univariate level, none of the main effects, type of post, test condition or section location was significant (F = 2.785, P = 0.063; F = 0.000, P = 0.986; and F = 2.491, P = 0.095 respectively), although post type and section location were close to significance. This lack of significance was not due to a “lack of difference” so much, but rather to the large standard deviations found for this variable. Close inspection of the raw data revealed a (nearly) bimodal distribution of this variable in some cells. Values were either extremely low or extremely high with values in between mostly missing. Polynomial contrasts tests showed that the push-out strength declined linearly from coronal to apical (F = 4.294, P = 0.049).
Table 4.3 Means and standard deviations (in brackets) for SEM scores and Push-out strength per type of post and per level (apical, medial and coronal) with the conditions (non-fatigue and fatigue) pooled. Differences between pooled data within the sections are significant for SEM scores ($P < 0.001$) and not for Push-out strength ($P = 0.095$), but the trend for the latter is significant ($P = 0.049$).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Type of post</th>
<th>Apical section</th>
<th>Medial section</th>
<th>Coronal section</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM score (Ranking 0-12)</td>
<td>Titanium</td>
<td>5.8 (2.3)</td>
<td>5.4 (2.7)</td>
<td>5.5 (2.5)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>5.3 (2.1)</td>
<td>4.5 (1.7)</td>
<td>1.9 (1.3)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>4.5 (2.2)</td>
<td>3.1 (2.2)</td>
<td>2.0 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>5.3 (1.4)</td>
<td>3.1 (2.1)</td>
<td>3.0 (1.7)</td>
</tr>
<tr>
<td></td>
<td>Posts pooled</td>
<td>5.2 (2.0)</td>
<td>4.0 (2.3)</td>
<td>3.1 (2.2)</td>
</tr>
<tr>
<td>Push-out strength (Mpa)</td>
<td>Titanium</td>
<td>5.1 (3.2)</td>
<td>3.8 (1.8)</td>
<td>5.5 (1.0)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>3.7 (2.3)</td>
<td>5.0 (2.0)</td>
<td>4.8 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>5.2 (1.6)</td>
<td>5.8 (1.3)</td>
<td>6.4 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>5.8 (3.1)</td>
<td>6.1 (2.0)</td>
<td>6.0 (1.1)</td>
</tr>
<tr>
<td></td>
<td>Posts pooled</td>
<td>5.0 (2.6)</td>
<td>5.2 (1.9)</td>
<td>5.6 (1.7)</td>
</tr>
</tbody>
</table>

Table 4.4 Means and standard deviations (in brackets) for SEM scores and Push-out strength per type of post and per condition (non-fatigue and fatigue) with the three levels (apical, medial and coronal) pooled. Differences between pooled data within the conditions are significant for SEM scores ($P < 0.001$) and not for Push-out strength ($P = 0.986$). In the last column the conditions (non-fatigue and fatigue) are pooled and only the value for the SEM score for the Titanium post is significantly higher than for the other posts, which are not different among them.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Type of post</th>
<th>Non fatigue</th>
<th>Fatigue</th>
<th>Conditions pooled</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM score (Ranking 0-12)</td>
<td>Titanium</td>
<td>4.3 (2.4)</td>
<td>6.8 (1.5)</td>
<td>5.5 (2.4)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>3.3 (2.1)</td>
<td>4.5 (2.3)</td>
<td>3.9 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>2.3 (1.3)</td>
<td>4.2 (2.3)</td>
<td>3.2 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>3.8 (1.8)</td>
<td>3.8 (2.3)</td>
<td>3.8 (2.0)</td>
</tr>
<tr>
<td></td>
<td>Posts pooled</td>
<td>3.4 (2.0)</td>
<td>4.8 (2.4)</td>
<td>4.1 (2.3)</td>
</tr>
<tr>
<td>Push-out strength (Mpa)</td>
<td>Titanium</td>
<td>4.8 (2.6)</td>
<td>4.8 (1.9)</td>
<td>4.8 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Quartz fiber</td>
<td>4.8 (2.4)</td>
<td>4.2 (1.9)</td>
<td>4.5 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Carbon fiber</td>
<td>6.0 (1.8)</td>
<td>5.6 (1.6)</td>
<td>5.8 (1.7)</td>
</tr>
<tr>
<td></td>
<td>Cast post</td>
<td>5.7 (2.0)</td>
<td>6.3 (2.4)</td>
<td>6.0 (2.1)</td>
</tr>
<tr>
<td></td>
<td>Posts pooled</td>
<td>5.4 (2.3)</td>
<td>5.4 (2.4)</td>
<td>5.3 (2.1)</td>
</tr>
</tbody>
</table>

4.5 Discussion

As explained in the previous Chapter even a thorough approach to mimic clinical conditions it is hardly possible to simulate the complex of clinical conditions all at the same time in one *in vitro* test. Therefore, extrapolation of *in vitro* results to the clinical situation should be done with care. Yet, several results of this study obtained with the present set-up may be of clinical relevance, such as the significant effect fatiguing had on the SEM scores. The increase found in all sections was mainly due to crack formation in the cement layer or loss of adaptation of the cement to post
or dentin. The cast post and cores were an exception, as they did not show defects from fatiguing (Tables 4.2, 4.3 and 4.4). Crack formation and loss of adaptation during loading can be ascribed to axial pulling forces in conjunction with bending forces, which are in tension at the buccal side and in compression at the lingual side. Prefabricated posts with composite build-ups may flex substantially, and with the relatively small diameter of the posts (Titanium posts 1.3 mm, and Fiber posts 1.8 mm coronal and 1.2 mm medial and apical), which may not fit accurately in all areas of the canals, this could result in unfavorable localized stresses reaching values that may exceed the strength of the luting agent [26]. For the cast post and core, the situation is different. The higher stiffness of the cast post and core system allowed less flexion and the cast posts had an exact fit and were supported by a relatively large surface. Exactness of fit and support of forces by a large surface may contribute to a more homogeneous stress distribution in the cement layer.

For all samples tested, the adhesive interface between core and root survived one million load cycles, despite the fact that the load direction was most unfavorable, nearly perpendicular to the axial axis. However, the presence of cracks and the loss of adaptation of the cement to post or dentin, observed after loading, indicates that the posts had to carry a significant part of the forces as well. Without the support of a post, one may expect that the core would separate from the root during fatigue in this experiment. The stability of the four post and core systems showed that adhesive cements and dentin adhesives of the kind investigated in this study can offer sufficient retention for build-ups with short post lengths [27]. Although stability will even be better with build-ups supported by a crown with a ferrule preparation, it should be remembered that just because of the absence of the ferrule preparation, the core build-up was supported by a larger amount of dentin.

Further inspection of the results showed that the fatigue test did not increase the SEM scores for one system significantly more than for another and did not affect the push-out strength for any of these systems. This may suggest that as long as core and root remain adhesively united, no distinction can be made between stiff and more flexible posts. However, if the adhesive interface between core and root would fail in a later stage, posts with a high stiffness may become a serious threat to root integrity. Root fracture will occur sooner with posts with high elastic modulus [19-21,28,29], as they are less able to elastically yield to lateral forces on the root canal wall.

The finding that the push-out strength was not affected after fatiguing, while the SEM scores increased significantly in all sections, needs an explanation. One can argue that the push-out strength is strongly determined by the many irregularities like insufficient adaptation, air bubbles
or voids present in the cement already from the start. Also remnants of gutta-percha and AH26 sealer, which are not included in the SEM scores, can be incorporated (Figure 4.3).

![Fig 4.3 SEM micrograph of the apical cross-section of a quartz coated, carbon-fiber post. Remnants of gutta-percha (A) interfere with good adaptation of the luting cement (B) between post (C) and intra-radicular dentin (D).](image)

The irregularities, gutta-percha and AH26 remnants can be present inside the cement layer throughout the complete thickness of a section, while the defects from fatiguing are more isolated and for this reason may play a minor role in the strength. This reasoning is supported by the analysis of contrasts for the post systems between the apical, medial and coronal sections. The SEM scores showed an upward trend \( P < 0.000 \) going from coronal to apical, while the push-out strength showed a downward trend \( P = 0.049 \) in this direction. In other words, the more irregularities, the lower the push-out strength. If a better integrity between post, cement and root canal wall could be obtained by reducing the mentioned irregularities, higher strength values might be expected.

The presence of voids in the cement layer and the occurrence of imperfect adaptation between the cement and root canal wall and post, in particular in the deepest part of the canal, are the result of the handling techniques to insert posts into the root canals, which still remains a difficult task. The insertion technique for Panavia 21 did not make an exception. The difficulties faced with the insertion technique for this material have been described in Chapter 3.

The Titanium post showed significantly higher SEM scores than the other posts (Table 4.4), which tended to be greater in the coronal section than for other posts (Table 4.3). This is probably caused by a greater difference in perimeters in the coronal area between the Titanium post (diameter = 1.3 mm) and the Carbon and Glass fiber posts (diameter = 1.8 mm). When inserting a post into the canal, the voids in the cement paste that find their way to the entrance of the canal will not be fully squeezed out if the fit at the entrance is not accurate, as in the case for the Titanium post. Better results may be obtained when the cement is injected into the root canal.
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space with a needle syringe first [30]. In view of the results of this study the application technique should be improved to further diminish incorporation of voids and to ease and speed-up handling.

As noted before traces of gutta-percha and AH26 sealer in the medial or apical part of the root canal that remain after preparation for 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. Moreover, the 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 causes mentioned, that 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. Therefore special attention should be paid to remove these traces of gutta-percha after preparation of the post space, with endodontic instruments and if available under enhanced visibility with the aid of dental microscopes.

The post and core build-up system may be a decisive factor when it is used as a foundation restoration for full crown restorations. However, for the general practitioner it is of major importance to keep in mind that an adequate ferrule and the preservation of tooth structure are the key factors in promoting resistance to failure. Towards this last requirement core build-up systems with prefabricated posts and direct core materials are in favor. Moreover, the procedures for these core build-up systems can be carried out in a single session, which has the additional advantage that contamination of the root canal during the period of the temporary restoration can be prevented [31].

4.6 Conclusions

Within the borders of the test set-up used in this study, it can be concluded that:

- To survive fatigue loading the adhesive luting cement Panavia 21 TC provided sufficient strength for a cast post and core, as well as for a prefabricated post and composite core, the latter being bonded with a dentin adhesive.
- In the root canal, the adhesive integrity was significantly affected by fatigue, as revealed by SEM, which showed crack formation in the cement layer or loss of adaptation of the cement to post or dentin, but this did not result in a significant decrease of the push-out strength.
- Like other common techniques, the insertion technique of Panavia 21 TC showed more voids in the apical section than in the coronal section. The total amount of voids seen with cast, carbon or glass fiber posts is significantly lower than with titanium posts, probably due to the smaller diameter of titanium posts.
The overall SEM and push-out strength evaluations showed that a core build-up of composite resin adhesively bonded to the dentin and supported by a carbon or glass fiber post, cemented with an adhesive cement, has a performance comparable with a conventional cast post and core.

4.7 References


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