Zirconia ceramic post systems: a literature review and a case report

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Cast metal post-core systems have a long history of successful use because of their superior physical properties. However, their high elastic modulus can cause stress concentrations within the surrounding radicular dentin, resulting in root fractures. Moreover, the increasing demand for more esthetically appealing and bio compatible restorations has led to the development of tooth-colored, translucent, metal-free post-core systems. Notably, prefabricated zirconia ceramic post systems have been introduced to satisfy this trend toward a heightened awareness of esthetics, whereby the translucency of all-ceramic crowns can be successfully maintained with the use of ceramic post-core materials. Owing to the keen interest in and widespread use of zirconia ceramic post systems, many in vitro studies on zirconia posts have been published in the last 15 years. The aim of this article was to present data about the retention, fracture resistance, microleakage, light transmission, esthetic advantages, and radiopacity of zirconia posts. Two clinical survival rate studies were also presented. Based on the results of these studies, zirconia posts have been shown to improve the esthetic quality of all-ceramic crowns and thus their usage is recommended. Apart from literature review, a case report in which a fractured fiber post was replaced with a custom-made zirconia post was also presented.

Keywords: Zirconia post, Clinical experience, In vitro studies

INTRODUCTION

Endodontically treated teeth with insufficient tooth structure are often restored with crowns. If there is insufficient dentin to support a restoration, a post-core is required to provide retention and support. Although posts are recommended to strengthen the teeth, several investigators have cautioned that posts with inadequate resistance to rotational forces on the posts can weaken the teeth. Consequently, root fractures constitute the most serious type of failure in post-restored teeth. To prevent root fractures, a post should have an elastic modulus similar to that of dentin—a property which enables a more uniform distribution of stress by distributing the occlusal load. On the other hand, while it is important to ensure that a post is firmly cemented to provide adequate retention for the restoration and adequate protection of the remaining tooth structure, it should yet be easily removed if retreatment were required.

Traditionally, titanium, carbon, polyethylene fiber, and stainless steel posts are used for the anterior region. However, when all-ceramic restorations are preferred, metal posts may negatively affect the esthetic results. Besides, corrosion reactions can cause metallic taste, oral burning, oral pain, sensitization, and other allergic reactions. With regard to both esthetic and health concerns, non-metal posts not only render esthetic superiority over metallic posts, but also preclude the possibility of corrosion and reduce the risk of toxicity. For these advantageous reasons, a wide range of esthetic posts have become commercially available, such as fiber-reinforced composite resin posts (FRC) and yttrium-stabilized zirconia-based ceramic posts.

Zirconia posts were first introduced by Meyenberg et al., who reported that the flexural strengths (900–1200 MPa) of these posts were comparable to cast gold or titanium, and that it is possible to have the same post dimensions as high gold alloys or titanium. Currently in prosthodontics, zirconia is a widely used material because of its good chemical stability, high mechanical strength, high toughness, and a Young’s modulus similar to that of stainless steel alloy. The high initial strength and fracture toughness of partially stabilized zirconia stems from a physical property known as transformation toughening. Apart from its favorable chemical and physical properties, zirconia also wields the esthetic advantage of having a color similar to that of natural teeth.

However, zirconia posts fall short of the requirement that an ideal post should be easily removed when retreatment is needed, because it is nearly impossible to remove zirconia posts from the root canal when a failure occurs. It is impossible to grind away a zirconia post, but removal of a fractured zirconia post by ultrasonic vibration has been found to cause temperature rise of the post and on the root surface. Another disadvantage stems from the rigidity of zirconia posts. It is noteworthy that wear, loss of retention, and fracture of posts under intraoral forces are more desirable than tooth fractures. However, the high elastic modulus of zirconia posts at 200 MPa causes stress to be transferred to the less rigid dentin, thereby resulting in root fractures.

Many techniques are available for post and core reconstruction. With zirconia posts, these core restoration techniques have been applied: direct composite resin curing, direct ceramic core heat-pressing, and indirect ceramic core processing. For example, IPS Empress Cosmo Ingot (Ivoclar Vivadent) is a glass-ceramic containing zirconia and used as a...
core material that is heat-pressed onto zirconia posts\textsuperscript{38}. For indirect ceramic core processing, an example is Ceracap (Komet Brasseler) —which is a prefabricated glass-ceramic core cemented onto CeraPost with resin cement\textsuperscript{39}.

To date, many research articles on zirconia posts have been published. However, there is little consensus with regard to their mechanical behavior and reliability, and the factors which would contribute to their optimal application performance. Therefore, the purpose of this paper is to give a succinct literature review on the material properties of zirconia posts, based on the results of original, full-length, scientific papers published in journals listed in PubMed.

**METHODS**

The first and foremost criteria for search in PubMed were dental journals from 1995 to 2009. Following which, these keywords were used to narrow the search scope: post/posts, dowel/dowels with zirconia or zirconium dioxide. Where possible, attempts were made to retrieve the full text of articles; otherwise, electronically available abstracts were extracted. Papers written in foreign languages were not reviewed if no abstracts in English were available.

In summary, the inclusion criteria for articles reviewed in this paper were: (1) Related to zirconia posts; (2) Must be in English language; (3) English abstracts available for papers written in foreign languages; (4) Abstracts were used for review where the full text could not be obtained.

**RESULTS**

The total number of papers which met the inclusion criteria was 79. Of these papers, 62 were in vitro studies\textsuperscript{12,14,29,32,33,35,39-94}, three were clinical studies\textsuperscript{77,28,58}, and 14 were case reports and review articles with clinical application guidance\textsuperscript{18,24,29,96-105}.

Of the 62 in vitro studies, 29 studies investigated the fracture strength\textsuperscript{12,14,29,33,35,39-82}, 21 studies investigated the retentive strength of zirconia posts to both the tooth and cores of different materials\textsuperscript{63-83}, three studies investigated the microleakage of endodontically treated teeth restored with different post systems\textsuperscript{88-90}, and four studies investigated the stress distribution in teeth restored with zirconia posts by using finite element analysis\textsuperscript{84-87}. Other in vitro studies examined the yield strength\textsuperscript{91}, radiodensity\textsuperscript{92}, esthetic properties\textsuperscript{32}, marginal gap formation\textsuperscript{93}, stiffness and elastic limit\textsuperscript{94} of zirconia posts, as well as the use of a proof-test technology to eliminate low-quality zirconia posts with critical microscopic defects so as to help reduce clinical failures\textsuperscript{95}.

Apart from in vitro studies, three clinical studies were included for review. Two were on clinical performance and survival rate\textsuperscript{28,95}, and one study was on the light transmission of zirconia posts\textsuperscript{77}.

In vitro studies

1. Fracture strength

The fracture strength of zirconia posts was evaluated using natural teeth in 15 studies\textsuperscript{12,14,33,39,41-43,48,49,51,55,56,60-62} (Table 1) and artificial roots in three studies\textsuperscript{9,53,59}, and according to core material (composite resin core \textit{versus} ceramic core) in nine studies\textsuperscript{55,40,44-47,52,54,57} (Table 2).

Table 1 shows that the fracture strengths of teeth with zirconia posts and composite cores ranged between 300 N and 700 N. However, when ceramic cores were used, these values ranged between 800 N and 1500 N. These results concurred with studies which evaluated the fracture strength of zirconia posts according to core material\textsuperscript{35,40,44,45,54}. Taken together, these studies unanimously suggested that posts exhibited higher fracture strength when used with ceramic cores than with composite cores. On the other hand, exceptions were found in some of the studies reviewed. One study by Toksavul et al.\textsuperscript{46} reported higher fracture strength with a composite core (497.5 N) than with a ceramic core (474.6 N), although there was no statistically significant difference. Similarly, Wan et al.\textsuperscript{47} found no significant differences in the fracture strength of zirconia posts when used with ceramic and composite cores.

Table 2 further reveals that two of the studies reviewed focused on the different techniques of using ceramic cores with zirconia posts\textsuperscript{52,57}, wherein Strub et al.\textsuperscript{57} claimed that zirconia posts exhibited higher fracture strength when used with bonded prefabricated ceramic core (1494.5 N) than with bonded custom-made ceramic core (463.3 N). This lower value of heat-pressed custom-made ceramic core over zirconia post was a result of changes in the inner structure of the zirconia material during the heating process.

According to the studies reviewed, coronal extension of the tooth above the crown margin played a pivotal role in fracture resistance. Akkayan et al.\textsuperscript{48} reported that increasing the ferrule length enhanced the fracture strength and that 2-mm ferrule was a rational clinical guideline. Table 1 shows the ferrule lengths of the natural teeth tested in the reviewed studies, whereby fracture strength ranged between 320 N and 780 N with no ferrule\textsuperscript{12,48,49,58}, but between 350 N and 1500 N with 2-mm ferrule\textsuperscript{14,39,42,43,51}.

With artificial roots, lower fracture strength values were obtained because they reduced the effect of structural differences between natural teeth and the posts\textsuperscript{29,53,59}. Ottl et al. stated that the fracture strength of zirconia post (193.5 N) was lower than those of FRC, metal, and alumina posts\textsuperscript{53}. Similarly, Asmussen et al. found the fracture strengths of Biopost and CeraPost to be 237 N and 228 N respectively\textsuperscript{49}. On the effect of surface treatment, Oblak et al. found that airborne particle abrasion increased the fracture load \textit{versus} grinding with a diamond bur such that airborne particle-abraded zirconia post had a higher fracture strength (627 N) than ground zirconia post (385.9 N)\textsuperscript{59}.

A review of the in vitro studies also revealed that measurement conditions influenced the fracture
Table 1  *In vitro* studies which examined the fracture strength of zirconia posts using natural teeth

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of post</th>
<th>Type of core material</th>
<th>Compared post systems</th>
<th>Luting agent for zirconia posts</th>
<th>Ferrule length</th>
<th>Fracture strength</th>
<th>Comparison with other groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosentritt, 2000</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>Titanium, FRC, Cast gold, Ceramic</td>
<td>Variolink, Ivoclar</td>
<td>0 mm</td>
<td>338 N</td>
<td>Zirconia&gt;other groups</td>
</tr>
<tr>
<td>Heydecke, 2001</td>
<td>CeraPost</td>
<td>Zirconia (one piece)</td>
<td>Titanium, Composite</td>
<td>Panavia 21, Kuraray</td>
<td>–</td>
<td>1057 N</td>
<td>Zirconia&gt;other groups</td>
</tr>
<tr>
<td>Akkayan, 2002</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>Titanium, Quartz fiber, Glass fiber</td>
<td>Reli X ARC, 3M ESPE</td>
<td>0 mm</td>
<td>78.91 kgf*</td>
<td>Quartz&gt;Zirconia= Glass&gt;Titanium</td>
</tr>
<tr>
<td>Pontius, 2002</td>
<td>CeraPost</td>
<td>Bonded ceramic</td>
<td>Cast metal, Ceramic</td>
<td>Panavia 21, Kuraray</td>
<td>2 mm</td>
<td>1494.5 N</td>
<td>Zirconia&gt;other groups</td>
</tr>
<tr>
<td>Maccari, 2003</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>FRC</td>
<td>C&amp;B, Bisco</td>
<td>2 mm</td>
<td>36.5 kgf*</td>
<td>Zirconia&lt;FRC</td>
</tr>
<tr>
<td>Akkayan, 2004</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>FRC, Easypost</td>
<td>Reli X ARC, 3M ESPE</td>
<td>2 mm</td>
<td>95.42 kgf*</td>
<td>Zirconia&lt;other groups</td>
</tr>
<tr>
<td>Mitsui, 2004</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>Titanium, FRC, Cast metal</td>
<td>Reli X ARC, 3M ESPE</td>
<td>0 mm</td>
<td>33.46 kgf*</td>
<td>Zirconia&lt;other groups</td>
</tr>
<tr>
<td>Sahafi, 2005</td>
<td>CeraPost</td>
<td>Composite</td>
<td>Titanium, FRC</td>
<td>Panavia F, Kuraray</td>
<td>0 mm</td>
<td>435.52 N</td>
<td>Zirconia&gt;other groups</td>
</tr>
<tr>
<td>Xible, 2006</td>
<td>CosmoPost</td>
<td>Ceramic</td>
<td>Titanium, FRC</td>
<td>Cement It, Pentron</td>
<td>1.5 mm</td>
<td>886.5 N</td>
<td>Zirconia&lt;other groups</td>
</tr>
<tr>
<td>Forberger, 2008</td>
<td>CosmoPost</td>
<td>Pressed ceramic</td>
<td>FRC, Cast gold</td>
<td>Variolink, Ivoclar</td>
<td>2 mm</td>
<td>1253.7 N</td>
<td>Zirconia&gt;other groups</td>
</tr>
<tr>
<td>Kivanç, 2008</td>
<td>CosmoPost</td>
<td>Composite</td>
<td>Titanium, FRC</td>
<td>Reli X ARC, 3M ESPE</td>
<td>1 mm</td>
<td>582.89 N</td>
<td>Titanium&lt;Zirconia&lt;FRC</td>
</tr>
<tr>
<td>Nothdurft, 2008</td>
<td>CeraPost</td>
<td>Composite</td>
<td>Titanium, FRC</td>
<td>Panavia F, Kuraray</td>
<td>2 mm</td>
<td>384.13 N</td>
<td>FRC&gt;Zirconia&gt;Titanium</td>
</tr>
<tr>
<td>Nothdurft, 2008</td>
<td>CeraPost</td>
<td>Composite</td>
<td>Titanium, FRC</td>
<td>Panavia F, Kuraray</td>
<td>1 mm</td>
<td>341.63 N</td>
<td>Zirconia&lt;other groups</td>
</tr>
</tbody>
</table>

*1 kgf=9.8 N

Table 2  *In vitro* studies which examined the fracture strength of zirconia posts according to core material

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of zirconia post</th>
<th>Type of crown</th>
<th>Luting agent for zirconia posts</th>
<th>Fracture resistance of composite core</th>
<th>Fracture resistance of ceramic core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butz, 2001</td>
<td>CeraPost</td>
<td>Cast crown</td>
<td>Panavia 21</td>
<td>202 N</td>
<td>378 N</td>
</tr>
<tr>
<td>Strub, 2001</td>
<td>CeraPost</td>
<td>All-ceramic crown</td>
<td>Panavia 21</td>
<td>Not used</td>
<td>Custom-made: 463.3 N Prefabricated: 1494 N</td>
</tr>
<tr>
<td>Heydecke, 2002</td>
<td>CeraPost</td>
<td>Cast crown</td>
<td>Panavia 21</td>
<td>503 N</td>
<td>521 N</td>
</tr>
<tr>
<td>Jeong, 2002</td>
<td>CosmoPost</td>
<td>Without crown</td>
<td>Not luted to teeth</td>
<td>Not used</td>
<td>Pressed: 22 N Bonded: 25.3 N</td>
</tr>
<tr>
<td>Toksavul, 2005</td>
<td>CosmoPost</td>
<td>All-ceramic crown</td>
<td>Variolink</td>
<td>497.5 N</td>
<td>474.6 N</td>
</tr>
<tr>
<td>Dilmener, 2006</td>
<td>CosmoPost</td>
<td>Without crown</td>
<td>ResiLute resin cement</td>
<td>450.3 N</td>
<td>710.2 N</td>
</tr>
<tr>
<td>Friedel, 2006</td>
<td>CeraPost</td>
<td>Without crown</td>
<td>Panavia 21</td>
<td>390.5 N</td>
<td>521.8 N</td>
</tr>
<tr>
<td>Nissan, 2007</td>
<td>ZircoPost</td>
<td>Cast crown</td>
<td>Resin cement</td>
<td>826.6 N</td>
<td>870.6 N</td>
</tr>
</tbody>
</table>
strength results of zirconia posts. When not bonded into teeth, Zhang et al. showed that zirconia post had a lower fracture strength (193 MPa) than FRC (199 MPa) and metal (210 MPa) posts. In another study, Cormier et al. also showed that the fracture strength of zirconia post varied according to the different stages of tooth restoration. When the post alone was bonded into tooth, fracture strength was 101.5 N; when the post was bonded into tooth with core buildup, fracture strength was 179.7 N; with post and core buildup as well as full veneer restoration, fracture strength was 238.8 N. In view of the apparent increase in fracture strength, Cormier et al. concluded that a crown restoration with post-core was more fracture-resistant than a post-core restoration alone.

2. Retentive strength of zirconia posts

The retentive strength of zirconia posts was examined using natural teeth in 11 studies (Table 3) and in artificial post spaces using different luting agents in five studies (Table 4). The bond strength of zirconia posts to different core materials was also examined in six studies (Table 5), thus making it a total of 21 studies.

On the influence of bond strength evaluation method, Table 3 shows that the bond strength of zirconia posts to natural teeth ranged between 123 N and 436 N with tensile testing. With push-out tests, lower values in the range of 1.4−7.7 MPa were obtained instead. With regard to the reduction in bond strength values when push-out testing was used, it was caused by internal stresses at the dentin-post interface. On the influence of luting agents upon retentive strength, Table 3 also shows that zirconia posts bonded to teeth with resin cements exhibited higher retentive strengths than with glass ionomer (GI) cements. Higher bond strength values were expected from resin cements because of their retentive properties to tooth structures.

On the influence of surface pretreatments, Table 4 shows that pretreatment procedures enhanced the bond strength of zirconia posts to root dentin. Significantly increased retentive strength values were obtained when surface treatments such as airborne particle abrasion, silica coating, priming, and silanization were applied to zirconia surfaces. Amongst which, the CoJet system (3M ESPE, Seefeld, Germany) (intraoral airborne particle abrasion using silicated Al₂O₃ particles) or the Rocatec system (3M ESPE) (extraoral airborne particle abrasion using silicated Al₂O₃ particles) with silanization seemed to be the most appropriate and effective treatment modality for zirconia surfaces. For example, Bitter et al. reported that CosmoPost treated with Rocatec system resulted in a higher bond strength (21.4 MPa) than with the CoJet treatment (16.6 MPa).

Although pretreatment of zirconia posts plays an

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Table 3  *In vitro* studies which examined the bond strength of zirconia posts to tooth structure

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of zirconia</th>
<th>Luting agents</th>
<th>Bond strength to zirconia</th>
<th>Bond strength test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohen, 2000</td>
<td>CeraPost</td>
<td>RelyX Unicem</td>
<td>23.4 lb</td>
<td>Not provided</td>
</tr>
<tr>
<td>Al-Harbi, 2003</td>
<td>CosmoPost/CeraPost</td>
<td>C&amp;B, Bisco</td>
<td>200 N/123N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Hedlund, 2003</td>
<td>CosmoPost</td>
<td>Variolink</td>
<td>89 N</td>
<td>Applying pressure on the apical end of the posts</td>
</tr>
<tr>
<td>Perdiago, 2004</td>
<td>CosmoPost</td>
<td>Variolink</td>
<td>1.43 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td>Sahafi, 2004</td>
<td>CeraPost (with CoJet treatment¶)</td>
<td>ParaPost Cement/ Panavia F</td>
<td>184 N/169 N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Germhardt, 2005</td>
<td>CeraPost (non-blasted)</td>
<td>Resin cement/GI cement</td>
<td>303.5 N/242.9 N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Marchan, 2005</td>
<td>CosmoPost</td>
<td>Resin cement/GI cement</td>
<td>228.1 N/121.8 N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Bottino, 2007</td>
<td>CosmoPost</td>
<td>Duolink</td>
<td>7.7±1.3 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td>Polat, 2007</td>
<td>CosmoPost</td>
<td>Panavia/RelyX ARC</td>
<td>1.836 N/0.926 N</td>
<td>Pull-out test</td>
</tr>
<tr>
<td>Galhano, 2008</td>
<td>CosmoPost</td>
<td>Duolink</td>
<td>7.7±1.3 MPa</td>
<td>Push-out test</td>
</tr>
</tbody>
</table>

CoJet (3M ESPE): Intraoral silicate ceramic surface treatment system
Table 4  
**In vitro** studies which examined the bond strength of zirconia posts using artificial post spaces with different luting agents

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of zirconia</th>
<th>Luting agents</th>
<th>Bond strength to zirconia</th>
<th>Bond strength test</th>
</tr>
</thead>
<tbody>
<tr>
<td>O’Keefe, 2000</td>
<td>CosmoPost (with acid-etched)</td>
<td>Panavia 21/C&amp;B/Bis-Core</td>
<td>31.6/12.8/7.6 MPa</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td></td>
<td>CeraPost (with acid-etched)</td>
<td>Panavia 21/C&amp;B/Bis-Core</td>
<td>21.7/7.4/8.2 MPa</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Sahafi, 2003</td>
<td>CeraPost (with CoJet treatment)</td>
<td>Panavia F/ParaPost Cement</td>
<td>27.9 MPa/32.3 MPa</td>
<td>Shear bond strength test</td>
</tr>
<tr>
<td>Sahafi, 2004</td>
<td>CeraPost (with CoJet treatment)</td>
<td>Panavia F/ParaPost Cement</td>
<td>43.7 MPa/39.3 MPa</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Sahmali, 2004</td>
<td>CeraPost</td>
<td>Panavia F/GI cement</td>
<td>23.786 MPa/10.503 MPa</td>
<td>Shear bond strength test</td>
</tr>
<tr>
<td></td>
<td>CosmoPost</td>
<td>Panavia F/GI cement</td>
<td>25.346 MPa/9.681 MPa</td>
<td>Shear bond strength test</td>
</tr>
<tr>
<td>Bitter, 2006</td>
<td>CosmoPost (with CoJet treatment)</td>
<td>Panavia F</td>
<td>16.6±3.1 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td></td>
<td>CosmoPost (with Rocatec treatment)</td>
<td>Panavia F</td>
<td>21.4±3.2 MPa</td>
<td>Push-out test</td>
</tr>
</tbody>
</table>

Rocatec (3M ESPE): extraoral silicate ceramic surface treatment system

Table 5  
**In vitro** studies which examined the bond strength of zirconia posts to different core materials

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Type of zirconia post</th>
<th>Core material</th>
<th>Bond strength to zirconia</th>
<th>Bond strength test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edelhoff, 2002</td>
<td>CosmoPost</td>
<td>Direct heat-pressed ceramic core</td>
<td>765.48 N</td>
<td>Push-out test</td>
</tr>
<tr>
<td></td>
<td>CosmoPost</td>
<td>Cemented ceramic core</td>
<td>194.48 N</td>
<td>Push-out test</td>
</tr>
<tr>
<td>Al-Harbi, 2003</td>
<td>CosmoPost/CeraPost</td>
<td>Bis-Core (Bisco) resin core</td>
<td>194 N/175 N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td>Xible, 2006</td>
<td>CosmoPost (with Rocatec treatment)</td>
<td>Tetric Ceram (Ivoclar) resin core</td>
<td>28.1±2.3 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td></td>
<td>CosmoPost (with no treatment)</td>
<td>Tetric Ceram (Ivoclar) resin core</td>
<td>8.9±3.97 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td>Akgüngör, 2008</td>
<td>CosmoPost (with CoJet treatment)</td>
<td>Build-it FR (Pentron) resin core</td>
<td>11.8±1.2 MPa</td>
<td>Push-out test</td>
</tr>
<tr>
<td>Sahafi, 2009</td>
<td>CosmoPost (with CoJet treatment)</td>
<td>Opaque PCR (Centrix) resin core</td>
<td>193 N</td>
<td>Tensile bond strength test</td>
</tr>
<tr>
<td></td>
<td>CosmoPost (with no treatment)</td>
<td>Opaque PCR (Centrix) resin core</td>
<td>130 N</td>
<td>Tensile bond strength test</td>
</tr>
</tbody>
</table>
important role in maintaining a strong adhesion to resin cements, the choice of a suitable type of luting agent is also a decisive factor. In Table 4, the bond strengths of luting agents to zirconia posts were measured without bonding to any tooth structure, and it was shown that a dual-cured resin cement, Panavia (Kuraray, Osaka), produced better results than other cement types. In a study by Bitter et al., it was also found that bond strengths to posts were significantly affected by the type of luting agent. In that study, it was found that GI cement (Ketac Cem, 3M ESPE) produced the lowest bond strength value, whereas a three-step etch-and-rinse resin cement (PermaFlo DC, Ultradent) produced the highest bond strength value. Similarly in another study by Sahmali et al., the resin cement produced a higher bond strength than GI cement, thereby confirming the experimental results of Bitter et al. These differences in bond strength values were attributed to the better tensile and shear strengths of resin cements. In addition, it was noted that lower bond strength values (16–21 MPa) were obtained when push-out tests were used, probably due to the same reason as described above.

In Table 5, the retentive strength of zirconia posts was evaluated according to different core materials. With ceramic core being the common denominator, a study by Edelhoff and Sorensen highlighted the influence of bonding procedures upon retentive strength in that CosmoPost with direct heat-pressed ceramic core exhibited a significantly higher bond strength (765.48 N) than with adhesively bonded ceramic core (194.48 N). In a study by Xible et al. using composite cores, they highlighted the effect of tribochemical treatment on bond strength in that zirconia posts treated with the Rocatec system exhibited significantly improved composite core retention. This finding by Xible et al. was consistent with that by Sahafi and Peutzfeldt in that surface treatment by the CoJet system improved the retention of zirconia posts to the composite core.

On the effect of root region on retentive strength, Kurtz et al. reported that the bond strengths of posts in the crown section were significantly higher than in any other root regions. On other factors that may affect the retentive strength of zirconia posts, it was reported that mechanical cycling impaired the bonding of zirconia posts to root dentin, such that the bond strength was reduced from 7.7 MPa to 3.3 MPa.

3. Microleakage

Microleakage, which occurs through a break in the coronal seal, has an adverse impact on clinical success. Higher endodontic failure rates have been reported as a result of coronal leakage when endodontically treated teeth were not adequately restored. Therefore, in addition to retention, an endodontic post should contribute to a hermetic coronal seal and help to prevent microleakage.

Usumez et al. reported that FRC posts exhibited less microleakage compared to stainless steel and zirconia posts. Jung et al. stated that cast metal posts showed a higher level of microleakage (6.21%) compared to prefabricated metal (3.38%), FRC (3%) and zirconia posts (2.36%). Similarly, Reid et al. claimed that titanium posts showed significantly greater microleakage than FRC and zirconia posts. Taken together, the reviewed studies unanimously suggested that FRC and zirconia posts might be the preferred clinical choice for preventing coronal microleakage.

4. Stress distribution

Four studies examined the stress distribution of teeth restored with zirconia posts by using finite element analysis. On one hand, Eraslan et al. and Spazzini et al. reported that the stress values observed with zirconia posts were higher than with FRC posts, and they attributed this result to the high elastic modulus of zirconia. On the other hand, Toksavul et al. and Asmussen et al. suggested that zirconia posts created slightly less stress concentration in dentin than FRC and titanium posts.

5. Mechanical and physical properties

On yield strength, 0.2% yield strength (R0.2) measurements by Pfeiffer et al. indicated that zirconia post had a significantly higher yield strength (58±4 N) than FRC (27±1 N) and titanium (54±3 N) posts.

On stiffness and elastic limit, Asmussen et al. conducted a study to determine these two mechanical properties of two zirconia posts, namely Biopost and CeraPost. In their study, it was found that the elastic limits of Biopost and CeraPost were 237 N and 228 N respectively, and the stiffness values for Biopost and CeraPost were 136 N/0.05 mm and 137 N/0.05 mm respectively. These results showed that zirconia posts were very stiff and strong, but had no plastic behavior.

On radiodensity, Soares et al. stated that the

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Number of posts</th>
<th>Cement</th>
<th>Follow-up period</th>
<th>Failures</th>
<th>Reason of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul, 2004</td>
<td>79 (with direct composite core)</td>
<td>Resin cement</td>
<td>57.7 months</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>34 (with glass-ceramic core)</td>
<td>Resin cement</td>
<td>46.3 months</td>
<td>3</td>
<td>Loss of retention</td>
</tr>
<tr>
<td>Nothdurft, 2006</td>
<td>30</td>
<td>GI cement</td>
<td>29 months</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
radiopacity of posts was dependent on their composition, whereby zirconia posts showed the highest radiodensity level, followed by metallic posts, carbon fiber posts, glass fiber posts, and carbon fiber post covered with quartz fiber.

In another study by Vichi et al., they investigated the effects of thickness of all-ceramic crown restoration and film thickness of luting cements on masking the opaque posts (zirconia, carbon fiber, and resin composite). It was found that a ceramic thickness of 2.0 mm was needed to ensure an acceptable esthetic outcome with the opaque posts, whereas luting cement thickness was found to have slight influence on the final esthetic results.

The physical properties of endodontic posts are closely related to their marginal adaptation. In a study by Dietschi et al., which investigated the marginal adaptation of different post types to root dentin after mechanical cyclic loading, it was reported that the carbon fiber post presented the lowest marginal gap proportion (7.11%) compared to other post types which presented higher degrees of marginal gap formation: titanium post at 11%, zirconia post at 16.5%, and stainless steel post at 17.4%.

Clinical studies
1. Survival rate
As shown in Table 6, two clinical studies on the survival rate of zirconia posts were reviewed. In the first study, 79 zirconia posts with direct composite cores and 34 zirconia posts with indirect glass-ceramic cores (IPS Empress Cosmo) were evaluated after a mean clinical service of 57.7 months and 46.3 months respectively. For zirconia posts with indirect glass-ceramic cores, three failures were observed because of loss of retention; on the other hand, no failures were observed for the 79 zirconia posts with direct composite cores. In the other clinical study, 25 anterior and five posterior zirconia posts (CosmoPost and CeraPost with heat-pressed ceramic cores) cemented with GI cement were evaluated. After an observation period of 29 months, there were no reports on loss of retention, fracture, or dislodgement.

2. Light transmission
For the third and last clinical study reviewed in this paper, Michalakis et al. evaluated the light transmission properties of a cast metal post, a ceramic post (Celay), a polyester post reinforced with 65% zirconium fibers (Snowlight) with composite core, and a zirconia post (CosmoPost) with heat-pressed ceramic core. They reported that the cast metal post did not allow light transmission in the apical and central portions of the crown. In comparison, Celay permitted better light transmission than the cast metal post, and Snowlight permitted better light transmission than Celay. On the overall, CosmoPost exhibited superior light transmission properties compared to the Celay post and cast metal post.

A CASE REPORT
Dental examination and treatment plan
A 41-year-old female patient was referred for treatment at the Department of Prosthodontics, Faculty of Dentistry, Yeditepe University, with an all-ceramic crown and a FRC post fracture which occurred after 18 months of usage (Fig. 1). Intraoral examination revealed that the upper left central incisor had fractured (Fig. 2). Probing depths around the tooth were in physiological range and there was no pathological mobility. According to radiographic evaluation, 3 mm of gutta-percha was observed in the apical region (Fig. 3).

Based on these findings, the treatment plan indicated removing the fractured FRC post and applying a custom-made zirconia post-core with zirconia crown, chiefly due to the higher fracture strength of zirconia ceramic.

Zirconia post-and-core fabrication
First step of the treatment plan was to remove the fractured FRC post with a round tungsten carbide bur under ×2.5 magnification. Then, the post space was re-shaped with Peeso reamers (Fig. 4). It was decided to

Fig. 1 Fractured FRC post and zirconia crown.

Fig. 2 Intraoral view of fractured tooth
remove only the coronal part of the FRC post such that there was enough space for the zirconia post, because complete removal of the fractured FRC post fragment in the root canal might lead to excessive heat formation and strip perforation of the root (Fig. 5). Consequently, owing to the compromised vertical post space, a custom-made zirconia post-core was constructed in order to improve adaptation and retention. However, the upside was that the milled ceramic post-core would be stronger due to its one-piece construction.

An impression was taken with a metal strip and silicone-based materials (Zetaplus and Oranwash L, Zhermack, Italy) (Fig. 6). In the laboratory, a stone die was generated from the impression. By means of a dental MAD/MAM (Manual Aided Design/Manual Aided Manufacturing) system (Zirkonzahn, Italy), the zirconia post-core was fabricated using zirconia ceramic (Fig. 7). During the trial appointment, post adaptation was verified in the mouth and a control radiograph was taken (Fig. 8).

**Post-core buildup with crown restoration**

Post surface was air-abraded with 50-µm Al₂O₃ particles prior to cementation. The cementation procedure was then performed using a dual-cured resin cement (Variolink II, Ivoclar Vivadent) according to manufacturer’s instructions.

The temporary restoration was removed, and dentin was cleaned and conditioned with 37°C
phosphoric acid for 15 seconds (Fig. 9a). After etching with phosphoric acid, a primer (Syntac Primer, Ivoclar Vivadent) was applied for 15 seconds and then dried. This was followed by applying a dentinal adhesive (Syntac Adhesive, Ivoclar Vivadent) for 10 seconds and then dried. After applying a thin layer of luting agent (Heliobond, Ivoclar Vivadent) on the dentin and post for 10 seconds (Fig. 9b), both the base and catalyst of the resin cement were mixed and applied on the post surface. After inserting the post into the canal (Fig. 9c), excess cement was removed, and polymerization was initiated using a polymerization lamp for 40 seconds.

After final preparation of the tooth (Fig. 10), an impression was taken using the same silicone-based impression materials. After the final zirconia crown

![Fig. 6 Impression of the post space to produce zirconia post.](image)

![Fig. 7 Milled and sintered zirconia post.](image)

![Fig. 8 Control radiograph of zirconia post.](image)

![Fig. 9 Cementation procedure of the zirconia post. (a) Etching root canal dentin with 37°C phosphoric acid; (b) Applying Heliobond after Syntac Primer and Adhesive; (c) Cementing post after mixing the base and catalyst of Variolink II.](image)
was seated over the tooth, marginal fit was examined using a dental explorer. The cementation procedure for the crown was performed using the adhesive technique similar to that for the zirconia post.

CONCLUSIONS

This paper reviewed the available literature on zirconia post systems. Conclusions in the following aspects have thus been gleaned from the reviewed studies.

1. Advantages of zirconia as a post material

With the zirconia material, its main advantages lie in its translucency and tooth-colored shade, thereby rendering the material usable with all-ceramic crowns in the anterior region. In particular, a patient who has a high lip line and thin gingival tissue would require the use of a zirconia post with an all-ceramic crown to optimize the esthetic effect at the root, while maintaining an adequate level of strength.

In addition, zirconia is indicated for teeth with severe coronal destruction, because composite materials lack the strength to resist deformation when used to support crowns.

2. Disadvantages of zirconia as a post material

The higher rigidity of zirconia posts, as compared to FRC posts, can be a predisposing factor for vertical root fractures. Therefore, zirconia is not indicated for patients with bruxism. Besides, it is almost impossible to retreat teeth restored with zirconia posts because it is too difficult to grind away the zirconia post and remove it from the root canal.

3. Post space preparation

Post space preparation principles for zirconia posts are similar to other post systems. The clinician must have the fundamental knowledge of root canal configuration to avoid excessive shaping. Drills should be used in low speed to reduce the risk of perforation. Length of the post should be two-third of the root canal length, and post space preparation should not disrupt the integrity of the remaining root canal filling. If a small-diameter post had to be used, a more rigid post system such as zirconia would be advantageous.

4. Post retention and microleakage

A reliable choice of luting cement for post cementation contributes toward preventing coronal leakage. With zirconia posts, it is recommended to use resin cements because they have been shown to produce higher bonding to both the zirconia surface and dentin when compared to conventional cements. Notably, most studies revealed that Panavia—a phosphate methacrylate-based dual-cured resin cement—seemed to exhibit higher bond strength values to zirconia posts than other cement types (such as glass ionomer cement).

To further improve the retentive strength of zirconia posts to root dentin, reviewed studies revealed that surface pretreatment prior to cementation was a major contributing factor. In particular, surface roughening by the CoJet system or Rocatec system with silanization seemed to be the most appropriate and effective treatment modality for zirconia. Before cementation, the post should be cleaned with alcohol, dried, and silanized. A dual-cured resin cement should then be placed on both the post surface and root canal dentin which has been etched and treated with primer and adhesive. It is also noteworthy that since most adhesives require a moist dentin surface before bonding, complete desiccation of the dentin should be avoided during the rinsing process.

5. Influence of core construction techniques

A review of two clinical studies revealed that core construction technique was also a decisive factor in the survival rate of zirconia posts. In vitro studies indicated that constructing posts with ceramic cores instead of composite cores enhanced the fracture resistance. Therefore, direct heat-pressed ceramic cores seemed to be more advantageous for zirconia posts because of a twofold improvement: increase in fracture resistance as well as retentive strength to post.

6. Recommendation

Although many in vitro studies on zirconia posts have
been published to date, clinical long-term evaluation is crucial and mandatory to a more thorough understanding of the mechanical behavior and reliability of zirconia posts. The authors believe that before zirconia posts are used widely and prevalently in clinical practice, prospective controlled five-year follow-up studies should be conducted. This is because only two clinical studies ranging between 2 to 5 years have been conducted. A long-term follow-up study of at least 5 years would provide the much-needed data pertaining to the efficacy of zirconia material for endodontic posts.

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