Load-Bearing Capacity of Posterior CAD/CAM Implant-Supported Fixed Partial Dentures Fabricated with Different Esthetic Materials

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Purpose: To compare the load-bearing capacity after long-term use (5-year simulation) of posterior three-unit implant-supported fixed partial dentures (FPDs) fabricated with different esthetic materials. Materials and Methods: A total of 20 specimens fabricated from one design file using CAD/CAM were divided into four groups: polyetherketoneketone (PEKK) veneered with composite resin (CR); PEKK veneered with lithium disilicate (LD); zirconia veneered with fluorapatite (FA); and monolithic zirconia. Samples were placed into a chewing simulator with simultaneous thermocycling. The fracture load after aging was measured using the universal testing machine with load on the central fossa of the pontic. Results: FPDs fabricated with PEKK + LD had significantly higher fracture load (1,526.56 [SD 95.54] N) compared to PEKK + CR (1,069.54 [SD 67.94] N) (P < .05). FPDs fabricated with zirconia materials had significantly higher fracture load compared to PEKK materials (P < .05). There was no significant difference between monolithic zirconia and zirconia + FA (P > .05). Conclusion: FPDs fabricated with PEKK + LD were superior to PEKK + CR. These materials can be promising alternatives for use as implant-supported FPD materials in the high-stress-bearing posterior region. Zirconia + FA can be an alternative to monolithic zirconia in cases that require more esthetics. Int J Prosthodont 2019;32:201–204. doi: 10.11607/ijp.6128

High esthetic demands and advancements in computer-aided design/computer-assisted manufacturing (CAD/CAM) technologies have increased the popularity of esthetic materials to be used for implant-supported fixed partial dentures (FPDs) that can withstand high stress.1 A recently available material, polyetherketoneketone (PEKK; manufactured by Cendres+Métaux), has been reported to show 80% higher compressive strength than its predecessor, polyetheretherketone (PEEK). The use of PEKK as an FPD framework was reported to show reduction of stresses in the framework while increasing stress in the veneering materials. However, the literature is limited in showing PEKK performance, especially after long-term use (5-year simulation). Currently, no literature is available regarding in vitro testing of the load-bearing capacity of three-unit implant-supported FPDs fabricated from PEKK and veneered with lithium disilicate (LD). The aim of the present study was to compare the load-bearing capacity after long-term use in posterior CAD/CAM implant-supported FPDs fabricated with different esthetic materials.

MATERIALS AND METHODS

Substructure Reference Model Fabrication
A substructure reference model consisting of two implant abutments (TS Transfer Abutment with Hex, Osstem Implant) was scanned with a digital scanner (Identica Hybrid, Medit) and used for designing the superstructure three-unit FPDs for all
groups. The substructure specimens were duplicated (Figs 1a and 1b).

**FPD Superstructure Fabrication**

Superstructures were designed using exocad DentalCAD. All of the veneered FPDs and monolithic FPDs were made with the same shape and dimension. The data were then transferred to the milling machine to fabricate: monolithic zirconia FPDs (Katana zirconia ML, Kuraray Noritake Dental) (Fig 2a); zirconia frameworks (Katana zirconia ML) (Fig 2b); PEKK (Pekkton Ivory, Cendres+Métaux) frameworks (Fig 2c); and wax veneer (Mazic Wax, Vericom) (Fig 2d). The veneering materials fluorapatite ceramic (FA) (IPS e.max Ceram, Ivoclar Vivadent); lithium disilicate (LD) (IPS e.max press, Ivoclar Vivadent); and composite resin (CR) (Sinfony Indirect lab composite, 3M ESPE) were fabricated to fit into the frameworks.

A total of 20 FPD units were fabricated and split into four groups (Fig 3): PEKK veneered with composite resin (CR); PEKK veneered with LD; zirconia veneered with FA; and monolithic zirconia. A chewing simulation was performed, and fracture load was measured using the universal testing machine. A priori sample size calculation using power analysis was not conducted, and the same sample size of a previous study by Tinschert et al (n = 5) was decided to use in this study. Using computer-aided design/computer-assisted manufacturing (CAD/CAM) for fabrication of the frameworks and the veneers, the sample size of five was expected to have a sufficient power to ensure a robust statistical analysis because a smaller standard deviation was expected compared to the previous study. Nonparametric Friedman analysis was used to analyze the overall differences in fracture load between different esthetic materials. Wilcoxon analysis was used to analyze differences between two groups. The significance level was established at $P < .05$. 

**Fig 1** (a) Implant analog positioning jig fabricated in the reference model. (b) Duplicated substructure specimens consisting of implant abutments and analogs embedded in clear acrylic resin.

**Fig 2** The materials (a) monolithic zirconia, (b) zirconia framework, (c) PEKK framework, and (d) wax veneer were milled using CAD/CAM milling machines.

**Fig 3** Overview of research methods. Reference models were scanned and duplicated, followed by the CAD/CAM process to fabricate FPDs from four groups. FPDs were cemented to the substructure model, then put in the chewing simulator to simulate 5-year aging. Fracture load after aging was measured. FW = framework; FA = fluorapatite; LD = lithium disilicate.
RESULTS

There were significant differences ($P < .05$) in the load-bearing capacity of FPDs fabricated with different esthetic materials after long-term use (Tables 1 and 2 and Fig 4).

Fracture Pattern After Loading

Monolithic zirconia showed relatively straight fracture lines with small angles between the occlusal surface and fracture line. Meanwhile, there was an extensive loss of the veneering material and an irregular fracture line in the zirconia + FA group. The fracture pattern in the PEKK + CR group was similar to the monolithic zirconia group, but showed a more irregular line and larger angle. The PEKK + LD group showed fragmentation and delamination of veneering material (Fig 5).

DISCUSSION

In this experiment, all FPDs survived artificial aging of 5 years without fracture, chipping, or deformation. A previous study reported that fracture load of zirconia FPDs without long-term artificial aging exceeded 2,000 N.$^2$ A similar result was reported for fracture load after aging in this study. There was no effect of long-term artificial aging on the fracture load of zirconia ceramic.

Rosentritt et al.$^3$ reported that the fracture resistance of veneered zirconia framework (Cercon ceram, Dentsply) FPDs after thermal cycling and mechanical loading (TCML) was significantly reduced from 1,058 N to 320–533 N. In contrast, the zirconia + FA in this study still exhibited a high fracture resistance of 2,489 N after TCML. This difference in value may result from the different size and design of the FPDs, as well as the use of different zirconia frameworks and pressable FA-based ceramic veneer in the current study. Unlike other FA porcelains, which also contain leucite particles, FA ceramic in this study only consisted of FA crystals in a feldspathic glassy matrix, which results in higher flexural strength and chemical durability.$^4$

During the fracture test, loading the central fossa of the pontic showed plastic deformation in the FPD made from PEKK material moments prior to fracture. In contrast, there was no deformation in the zirconia groups because zirconia has a higher Young modulus, which indicates its rigidity.$^5$

FPDs fabricated from PEKK + LD had a higher fracture load than PEKK + CR, but lower strength than zirconia-based FPDs. PEKK + LD showed more areas of delamination. This may be because this is the only group that used cement material between the framework and veneering material,

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Fracture Load (N) of Three-Unit Implant-Supported Fixed Partial Dentures Fabricated with Different Esthetic Materials After Long-Term Use</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Monolithic zirconia$^a$</td>
<td>2,468.82 (186.29)</td>
</tr>
<tr>
<td>Zirconia + FA</td>
<td>2,489.16 (281.63)</td>
</tr>
<tr>
<td>PEKK + LD</td>
<td>1,526.56 (95.54)</td>
</tr>
<tr>
<td>PEKK + CR</td>
<td>1,069.54 (67.94)</td>
</tr>
</tbody>
</table>

SD = standard deviation; FA = fluorapatite; PEKK = polyetherketoneketone; LD = lithium disilicate; CR = composite resin.
Friedman test.
$^a$Not normal distribution.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Post Hoc Analysis of Differences Between Two Groups</th>
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<tr>
<td></td>
<td>$P$ value</td>
</tr>
<tr>
<td>PEKK + CR vs PEKK + LD</td>
<td>&lt; .05*</td>
</tr>
<tr>
<td>PEKK + CR vs Zirconia</td>
<td>&lt; .05*</td>
</tr>
<tr>
<td>PEKK + LD vs Zirconia</td>
<td>&lt; .05*</td>
</tr>
<tr>
<td>PEKK + CR vs Zirconia + FA</td>
<td>&lt; .05*</td>
</tr>
<tr>
<td>PEKK + LD vs Zirconia + FA</td>
<td>&lt; .05*</td>
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<tr>
<td>Zirconia vs Zirconia + FA</td>
<td>&gt; .05</td>
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</tbody>
</table>

PEKK = polyetherketoneketone; CR = composite resin; LD = lithium disilicate; FA = fluorapatite.
Pairwise comparison using Wilcoxon test.
*Significant difference.
increasing the possibility of adhesive failure because of the thickness and presence of cementation materials. In comparison, the PEKK + CR group did not use cement materials, but the PEKK framework was surface treated by silicatization, followed by the application of silane or universal primer and PEKK primer. The CR was injected into the mold, then light cured.

Further studies are needed to analyze the differences between the use of PEKK framework compared to zirconia, such as the stress distribution in the FPD materials and the supporting structures (eg, implant, bone). In this study, fracture load was calculated only from one FPD design and one point of loading. Further studies using different anatomical tooth designs, dimensions, and loading conditions may also be needed.

CONCLUSIONS
Within the limitations of this study, it can be stated that FPDs fabricated with PEKK + LD have superior load-bearing capacity compared to PEKK + CR ($P < .05$). PEKK may be a promising alternative for implant-supported FPD materials in the high stress–bearing posterior region through the combination of polymers and high-strength glass ceramic. However, the zirconia-based implant-supported FPDs had superior load-bearing capacity ($P < .05$) compared to PEKK-based implant-supported FPDs. There was no significant difference between the load-bearing capacity of monolithic zirconia and zirconia + FA FPDs. Zirconia + FA can be used in cases that require more esthetics, such as anterior FPDs.

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REFERENCES