Mechanical Fatigue Analysis of PEEK as Alternative to Zirconia for Definitive Hybrid Abutments Supporting All-Ceramic Crowns

Sales Antônio Barbosa-Júnior, DDS, MSc, PhD1/Gabriel Kalil Rocha Pereira, DDS, MSc, PhD2/Kiara Serafini Dapieve, DDS, MSc2/Pablo Soares Machado, DDS, MSc, PhD2/Luiz Felipe Valandro, DDS, MSc, PhD2/Christian Schuh, DDS, MSc3/Rafael Leonardo Xediek Consani, DDS, MSc, PhD1/Atais Bacchi, DDS, MSc, PhD4

Purpose: The aim of this study was to inspect the mechanical fatigue behavior of an implant-supported restorative system using polyether ether ketone (PEEK) and yttria partially stabilized zirconia polycrystals (YZ) as materials for customized definitive implant-supported hybrid abutments, supporting two types of all-ceramic restorations: translucent zirconia (TZ) and lithium disilicate (LD) monolithic crowns. Materials and Methods: Forty Morse taper implants were included in epoxy resin. Titanium intermediary abutments were placed, and the specimens were randomly allocated into four groups (n = 10) according to the customized hybrid abutment material (PEEK or YZ) and the monolithic crowns (TZ or LD) representing a maxillary central incisor crown. The specimens were subjected to a mechanical fatigue test (step-stress analysis) by means of an initial 200-N load for 5,000 cycles and subsequent increase of 50 N (step-size) at each 10,000 cycles, until failure occurred. The load at failure and number of cycles until failure were recorded; survival probabilities and specimen displacement were calculated for each step. The failure pattern was evaluated, and the Weibull modulus was obtained for each condition. Results: Fatigue of both types of crowns was not influenced by the abutment material (LD-PEEK = LD-YZ; TZ-PEEK = TZ-YZ). In the PEEK abutment, the values obtained in the LD and TZ crowns showed no statistical difference; however, in the YZ abutment, the TZ crown presented a load at failure value that was statistically higher than that for LD. Failure pattern analysis revealed a higher prevalence of crown fracture for LD groups, while screw/implant platform fractures were shown for TZ groups. Conclusion: YZ and PEEK hybrid abutments promoted similar fatigue levels regardless of the crown materials, TZ crowns promoted a higher fatigue level than LD ones when associated with YZ abutments, and LD crowns promoted a similar fatigue level to TZ ones when associated with PEEK custom abutments. Higher prevalence of crown fractures was shown for LD and screw/implant platform fractures for TZ groups. Int J Oral Maxillofac Implants 2020;35:1209–1217. doi: 10.11607/jomi.8262

Keywords: dental implants, lithium disilicate, mechanical cycling, single crowns, yttria-stabilized tetragonal zirconia, zirconium oxide

Single dental implants in the esthetic area constitute a challenge for the daily practice. Traditionally, metal-ceramic crowns and metal abutments have been used for years as restorative materials in prosthetic rehabilitations in this scenario, sometimes leading to compromised esthetic results and adverse tissue reactions due to metal corrosion, which facilitated soft tissue inflammation and bone loss, leading to some degree of damage over time.1 More recently, ceramic abutments have been introduced and gained popularity because of their better esthetic results (avoiding the grayish aspect through gingival tissue)2 and better biologic properties due to lower biofilm adhesion and absence of corrosion.3,4 These abutments have been developed in the hybrid form, associating a metal base to attach to the implant, which decreases the number of catastrophic ceramic fractures in the implant connection area due to the limited abutment thickness in place.5 More recently, polyether ether ketone (PEEK) has been employed for dental prosthetic rehabilitations as an alternative to ceramic and metallic materials. PEEK shows high biocompatibility due to its inert conditions, also leading to low dental biofilm adhesion, compatible

1MSciD and PhD Post-Graduate Program in Dental Clinic, Prosthodontics Area, Piracicaba Dental School, Campinas State University (FOP/UNICAMP), Piracicaba, SP, Brazil.
2MSciD and PhD Post-Graduate Program in Dentistry, Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil.
3Private Practice, Passo Fundo, RS, Brazil.
4Post-Graduate Program in Dentistry, Meridional Faculty (IMED), Passo Fundo, RS, Brazil.

Correspondence to: Prof Dr Atais Bacchi, Rua Senador Pinheiro, 304, Bairro Rodrigues, 99070-220, Passo Fundo, RS, Brazil. Fax: +55(54)3045-6100. Email: atais_bacchi@yahoo.com.br

with or even lower than that of zirconia. This fact is important for gingival health, avoiding inflammation and retraction of soft tissues, and allowing proper esthetics (color through the gingival tissue and restorative material). In addition, it has adequate strength, is easy to mill and perform intraoral adjustment, allows faster production (absence of sintering period), and presents a lower cost.

The material is already commercially available in blocks for CAD/CAM milling and can be used as prosthesis infrastructure, healing abutments, or abutments for provisional restoration. Literature data on resistance to mechanical fatigue are scarce. However, some laboratory analysis has shown promising potential for its use to be considered as definitive abutments.

Despite having mechanical strength and modulus of elasticity lower than zirconia, the hybrid abutment metal base may provide adequate support for PEEK material to resist occlusal forces. In addition, it might provide adequate support for ceramic crowns, allowing its use as a definitive abutment material, and some manufacturing advantages such as purchase and laboratory costs, as well as biologic advantages for soft and hard tissue stability. Moreover, a higher toughness in comparison to zirconia may be beneficial for the implant-prosthesis assembly, due to the lack of elastic structures that absorb the masticatory stress (as the periodontal ligament in the case of tooth-supported restorations). Therefore, a material like PEEK could provide benefits in comparison to the brittle ceramic abutment.

Not only would the evaluation of the implant-abutment strength be important in the prosthetic rehabilitation, but the crown structure might also be the most affected due to the intimal contact with the abutment. The literature shows that the substrate nature plays a significant role in the crown mechanical behavior. All-ceramic crowns are indicated in the anterior regions because of their adequate esthetic properties and mechanical strength. Monolithic restorations, which are among the most-used crown systems, have been preferred because they constitute a structure without interface layers, increasing the strength, which is important for the case of implant-supported restorations where a limited dissipation of the induced stress occurs.

Regarding the materials used for monolithic all-ceramic crowns, lithium disilicate glass-ceramics have been highly utilized due to their ability to combine adhesive bonding and esthetics (ensured for a relevant amount of the glassy phase) with a relevant strength (as characteristic of the reinforcing lithium disilicate particles present in its structure). More recently, translucent zirconia polycrystals were introduced. This material is characterized by a very (almost absent) glassy phase (which ensures the mechanical strength of the material) and large polycrystal grains associated with a relevant amount of the cubic (c) phase, which provide adequate translucency to be applied in anterior restorations. Therefore, it would be relevant to evaluate the effects of the abutment material in the implant-abutment-crown conjunct when different restorative materials are employed for a single crown.

The following question remains in the literature: What would be the mechanical fatigue of monolithic crowns of lithium disilicate or translucent zirconia supported by PEEK abutments? Therefore, the aim of this study was to evaluate PEEK as an alternative material to zirconia for customized definitive hybrid abutments. In addition, the study also looked at the effect of the abutment material on two of the most used monolithic all-ceramic crowns: lithium disilicate and translucent zirconia. The hypotheses of the study were: (1) zirconia material and PEEK hybrid abutments would promote similar fatigue levels regardless of the crown materials, and (2) translucent zirconia monolithic or lithium disilicate crowns would promote similar fatigue levels regardless of the abutment materials.

**MATERIALS AND METHODS**

**Specimen Manufacturing**

Forty dental implants 4.0 mm in diameter and 11 mm in length were randomly assigned into four groups to be restored with custom hybrid dental abutments made of PEEK or zirconia, and restored with all-ceramic monolithic crowns of translucent zirconia or lithium disilicate (Fig 1). The materials used in the study are specified in Table 1, and the experimental study design is shown in Table 2.

The implants were connected to a surveyor and included in epoxy resin (F160 A+B, Axson), perpendicularly to the PVC cylinder base (x-axis). A titanium cylinder was connected to one of the implants, and a maxillary central incisor was made with low-shrink acrylic resin (Pattern Resin LS, GC). Care was taken so the palatal portion of the crown would promote a passive contact with the piston used during mechanical fatigue testing. After that, the acrylic resin pattern was scanned to serve as reference for the final crown dimension. Subsequently, reductions of 2 mm in the incisal edge, 1.5 mm in the axial walls, and a rounded chamfer with 1.2 mm were performed, and the crown preparation was scanned to serve as reference for the abutment dimension.

Titanium bases were connected to the implants, and abutments were milled in PEEK and zirconia materials. After milling, zirconia abutments were sintered as recommended by the manufacturer. For the luting procedure, the internal surface of abutments was air-abraded with 50 µm of aluminum oxide particles. Zirconia abutments were treated with a 10-MDP-based...
primer (Metal/Zirconia Primer, Ivoclar Vivadent). All abutments were luted to the titanium bases with self-adhesive resin cement (RelyX U200, 3M ESPE) and light activated for 20 seconds at each surface with energy of 1,200 mW/cm².

The inner bonding surface was sandblasted with aluminum oxide particles (50 µm) and treated with 10-MDP-based primer (Metal/Zirconia Primer, Ivoclar Vivadent). For the lithium disilicate crowns, wax patterns were milled and included in a cast investment, and lithium disilicate ingots were pressed and finished as the manufacturer recommended. The inner surface was sandblasted with aluminum oxide particles (50 µm) and treated with 10-MDP-based primer (Metal/Zirconia Primer, Ivoclar Vivadent).
of lithium disilicate crowns was treated with 10% hydrofluoric acid for 20 seconds followed by the silane application. All crowns were luted with resin-based self-adhesive luting agent (Reliant X U200, 3M ESPE) and light activated for 20 seconds at each surface with energy of 1,200 mW/cm².

**Fatigue Testing**

The specimens were tested under intermittent cyclical loading using a step-stress fatigue test in dedicated equipment (Instron ElectroPuls E3000, Instron). The load was applied in the tooth palatal surface at a 45-degree angle using a 6-mm-diameter stainless steel ball with the specimen immersed in water. An insulation tape (110 µm) was used to enhance the contact between the piston and specimen (a similar testing approach was already used in prior studies), aiming to facilitate stress distribution on the crowns during the mechanical loading. The loading frequency was defined (20 Hz), and then 5,000 cycles were initially run on a relatively low load (200 N), aiming to set the specimen and adjust the piston/specimen contact. Subsequently, 10,000 cycles were performed at progressive load levels (step-size) of 50 N (starting at 250 N, followed by 300 N, 350 N, 400 N, etc), until the detection of failure by transillumination and visual inspection. The values of fatigue failure load (FFL) and number of cycles until failure (CF) were recorded for statistical analysis. The value of piston displacement, the difference between the initial contact position where the minimum load was applied and the final position observed at the maximum load in each cycle, into each step was also recorded for all samples. The test would be stopped if 3 mm of deformation of the conjunct occurred, even without any fracture; this failure criterion was included in the study design to simulate what would be clinically considered as a failure.

**Failure Analysis**

After failure detection, the surfaces were analyzed in a stereomicroscope (Discovery V20, Carl-Zeiss) to determine the failure pattern.

**Data Analysis**

A verification of normality (Shapiro-Wilk test) and homogeneity (Levene test) of data distribution was performed for fatigue failure load, cycles for failure, and displacement at the step where failure occurred during fatigue testing (difference between the position of the minimum load – 10 N and the maximum load where failure occurred) in specific software (SPSS version 21, IBM). To measure the influence of each factor (abutment and crown material) and the interaction of them in the outcomes (fatigue failure load, cycles for failure, and displacement), a two-way analysis of variance (ANOVA) was performed (α = .05). Subsequently, a survival analysis (Kaplan-Meier followed by Mantel-Cox/log-rank test) considering fatigue failure load and cycles for failure outcomes was also performed (α = .05). The tabulation of these outcomes in relation to the probability indices of survival and the tabulation of the displacements in all steps during the fatigue testing were obtained for each group. In addition, Weibull analysis of fatigue failure load and cycles for failure data was performed in software (Super SMITH Weibull 4.0k-32) to obtain the Weibull modulus of each outcome.

**RESULTS**

For the fatigue data (fatigue failure load and cycles for failure), two-way ANOVA showed that only the factor “crown material” was statistically significant (P = .026, F = 5.39), while the factor “abutment material” and their interactions were not significant (P = .398, F = 0.73; P = .808, F = 0.06, respectively). Translucent zirconia crown associated with zirconia abutment showed a statistically superior value (Table 3). Survival analysis for both fatigue failure load and cycles for failure supported these results, since only the group translucent zirconia crown with zirconia abutment showed better survival rates, ie, longer time under fatigue without failure (Table 4; Fig 2). Weibull analysis showed similar modulus for all evaluated conditions (Table 3).
Regarding the observed displacement through fatigue testing (difference between the position of the minimum load – 10 N and the maximum load for each step), when considering the final measurement upon failure occurrence, statistical differences were not observed for both factors and their interactions (abutment material $P = .216$, $F = 1.585$; crown material $P = .088$, $F = 3.072$; interaction $P = .941$, $F = 0.05$; two-way ANOVA). Despite that, in Table 5, it becomes clear that at the final steps before failure, the PEEK abutment groups had an increase in displacement compared with the zirconia groups.

Failure analysis showed heterogenous failure patterns in all groups. Those failures were categorized and are described in Table 6 and Fig 3. When the PEEK abutment was used associated with a translucent zirconia crown, a chance of reversible failure was emphasized, because no damage to the restorative set was observed.

Table 4  Survival Rates—Probability of Specimens to Exceed the Respective FFL and Number of CFF Steps Without Crack Propagation, and Respective Standard Error Values

<table>
<thead>
<tr>
<th>Groups</th>
<th>200/5,000</th>
<th>250/15,000</th>
<th>300/25,000</th>
<th>350/35,000</th>
<th>400/45,000</th>
<th>450/55,000</th>
<th>500/65,000</th>
<th>550/75,000</th>
<th>600/85,000</th>
<th>650/95,000</th>
<th>700/105,000</th>
<th>750/115,000</th>
<th>800/125,000</th>
<th>850/135,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD-PEEK</td>
<td>1</td>
<td>1</td>
<td>0.90 (0.10)</td>
<td>0.80 (0.13)</td>
<td>0.70 (0.15)</td>
<td>0.70 (0.15)</td>
<td>0.70 (0.15)</td>
<td>0.50 (0.16)</td>
<td>0.20 (0.13)</td>
<td>0.20 (0.13)</td>
<td>0.10 (0.10)</td>
<td>0.0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>TZ-PEEK</td>
<td>1</td>
<td>1</td>
<td>0.90 (0.10)</td>
<td>0.90 (0.10)</td>
<td>0.90 (0.10)</td>
<td>0.70 (0.15)</td>
<td>0.60 (0.16)</td>
<td>0.50 (0.16)</td>
<td>0.50 (0.16)</td>
<td>0.30 (0.15)</td>
<td>0.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>LD-YZ</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.60 (0.16)</td>
<td>0.50 (0.16)</td>
<td>0.40 (0.16)</td>
<td>0.20 (0.13)</td>
<td>0.10 (0.10)</td>
<td>0.10 (0.10)</td>
<td>0.0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>TZ-YZ</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.90 (0.10)</td>
<td>0.80 (0.13)</td>
<td>0.70 (0.15)</td>
<td>0.40 (0.16)</td>
<td>0.40 (0.16)</td>
<td>0.20 (0.13)</td>
<td>0.20 (0.13)</td>
<td>0.0</td>
<td>–</td>
</tr>
</tbody>
</table>

TZ = translucent zirconia crown; LD = lithium disilicate crown; YZ = zirconia abutment; PEEK = polyether ether ketone abutment; FFL = fatigue failure load; CFF = cycles for failure; – = absence of specimens being submitted to the respective category.

Table 5  Mean and SD of Displacement (Difference Between Position When Minimum Load Was Applied – 10 N and Maximum Load for Each Step) Observed in Each Step During Fatigue Testing

<table>
<thead>
<tr>
<th>Groups</th>
<th>200/5,000</th>
<th>250/15,000</th>
<th>300/25,000</th>
<th>350/35,000</th>
<th>400/45,000</th>
<th>450/55,000</th>
<th>500/65,000</th>
<th>550/75,000</th>
<th>600/85,000</th>
<th>650/95,000</th>
<th>700/105,000</th>
<th>750/115,000</th>
<th>800/125,000</th>
<th>850/135,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD-PEEK</td>
<td>0.15 (0.04)</td>
<td>0.17 (0.05)</td>
<td>0.20 (0.04)</td>
<td>0.23 (0.05)</td>
<td>0.28 (0.06)</td>
<td>0.33 (0.08)</td>
<td>0.35 (0.06)</td>
<td>0.40 (0.06)</td>
<td>0.41 (0.08)</td>
<td>0.56 (*)</td>
<td>0.62 (*)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>TZ-PEEK</td>
<td>0.15 (0.02)</td>
<td>0.15 (0.02)</td>
<td>0.18 (0.02)</td>
<td>0.21 (0.03)</td>
<td>0.24 (0.04)</td>
<td>0.28 (0.07)</td>
<td>0.30 (0.06)</td>
<td>0.33 (0.04)</td>
<td>0.33 (0.02)</td>
<td>0.37 (0.02)</td>
<td>0.48 (0.07)</td>
<td>0.53 (0.05)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>LD-YZ</td>
<td>0.17 (0.05)</td>
<td>0.19 (0.04)</td>
<td>0.22 (0.05)</td>
<td>0.26 (0.04)</td>
<td>0.28 (0.06)</td>
<td>0.30 (0.05)</td>
<td>0.31 (0.06)</td>
<td>0.34 (0.07)</td>
<td>0.34 (0.06)</td>
<td>0.36 (0.07)</td>
<td>0.34 (*)</td>
<td>0.36 (*)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>TZ-YZ</td>
<td>0.15 (0.03)</td>
<td>0.18 (0.04)</td>
<td>0.24 (0.06)</td>
<td>0.24 (0.07)</td>
<td>0.28 (0.08)</td>
<td>0.29 (0.08)</td>
<td>0.31 (0.07)</td>
<td>0.34 (0.07)</td>
<td>0.33 (0.04)</td>
<td>0.36 (0.05)</td>
<td>0.37 (0.05)</td>
<td>0.41 (0.03)</td>
<td>0.46 (0.18)</td>
<td>–</td>
</tr>
</tbody>
</table>

TZ = translucent zirconia crown; LD = lithium disilicate crown; YZ = zirconia abutment; PEEK = polyether ether ketone abutment; – = absence of data, which occurred by the specimens not being submitted to the respective step during test or by fracture occurrence prior to acquisition of such data being enabled at the respective step; (*) = impossibility of obtaining SD value because only one sample was tested in such step.

Regarding the observed displacement through fatigue testing (difference between the position of the minimum load – 10 N and the maximum load for each step), when considering the final measurement upon failure occurrence, statistical differences were not observed for both factors and their interactions (abutment material $P = .216$, $F = 1.585$; crown material $P = .088$, $F = 3.072$; interaction $P = .941$, $F = 0.05$; two-way ANOVA). Despite that, in Table 5, it becomes clear that at the final steps before failure, the PEEK abutment groups had an increase in displacement compared with the zirconia groups.

Failure analysis showed heterogenous failure patterns in all groups. Those failures were categorized and are described in Table 6 and Fig 3. When the PEEK abutment was used associated with a translucent zirconia crown, a chance of reversible failure was emphasized, because no damage to the restorative set was observed.
observed, and debonding between hybrid abutment layers occurred in 40% of the group.

**DISCUSSION**

The zirconia and PEEK materials used to make hybrid custom abutments promote similar fatigue levels regardless of the crown materials; therefore, the first study hypothesis was accepted. These two materials have some significantly different properties, such as their stiffness, with elastic modulus of 4 GPa for PEEK and 210 GPa for zirconia. As observed in a previous study, these differences could influence the fatigue strength level of the restorative materials, with better performance for some stiffer substrates.

In the present study, both abutment materials were single fixed to a titanium base. This fact might promote similar and adequate support levels for restorative crowns. Moreover, this would be confirmed by the failure pattern type occurring in the specimens, since in the lithium disilicate crowns, the number of fractures (radial crack) was similar among groups, with 60% for the PEEK abutment and 50% for zirconia. For translucent zirconia crowns, the majority of fractures occurred in the screws or implant platforms (50% for PEEK and 40% for zirconia), a result that also showed that the abutment material does not influence the crown fracture.

The present investigation also clarified the findings of a previous study using finite element analysis, where higher stress was shown in single crowns associated with PEEK abutments compared with zirconia material. Besides the observations of the aforementioned previous study, it is possible to assume that the difference in elastic modulus of these materials was not sufficient to promote a lower fatigue level for the crowns fixed on PEEK hybrid abutments. In addition, a recent study evaluating the monotonic fracture strength of lithium disilicate crowns fixed on hybrid PEEK or zirconia abutments showed results without statistically significant differences among materials, with values of 623 N for the zirconia group and 602 N for PEEK.

The second study hypothesis was rejected, as monolithic translucent crowns showed higher fatigue failure load and cycles for failure values than lithium disilicate material when fixed in zirconia abutments. This difference in fatigue performance of the two materials might be due to the different characteristics involving composition, microstructure, and mechanical properties. Lithium disilicate is a glassy ceramic composed of ~30% vitreous phase reinforced by crystals. On the other hand, translucent zirconia is essentially composed of crystals with an almost absent vitreous phase. Therefore, the subcritical crack growth is more likely to occur in lithium disilicate structures, since the crack propagates through the vitreous structure or at the glass-crystal interfaces. That fact is represented by the fracture toughness (K_Ic) property, which represents the ability of a brittle material to resist crack propagation. Previous studies have characterized the K_Ic as up to 2.7 MPa·m^{1/2} for translucent zirconia and 2.0 MPa·m^{1/2} for lithium disilicate.

Some other mechanical properties might explain the superiority of translucent zirconia crowns over lithium disilicate crowns, eg, the bending properties. Tensile and compressive forces are generated inside a loaded structure, and the fracture is likely to occur when these forces exceed the material's threshold strength. Previous reports characterized the translucent zirconia as having improved flexural strength (569 MPa vs 460 MPa of lithium disilicate), flexural modulus (210 GPa vs 95 GPa of lithium disilicate), and higher compressive strength (1,900 MPa vs 1,150 MPa for lithium disilicate).

The present results for the fatigue performance of the all-ceramic crowns corroborate the data of a previous report. In that study, translucent zirconia structures tested in disk-shaped specimens showed higher

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**Table 6  Failure Analysis**

<table>
<thead>
<tr>
<th>Group code</th>
<th>Radial crack restricted to the crown</th>
<th>Fracture restricted to the crown</th>
<th>Fracture of the screw</th>
<th>Fracture of the screw and implant platform</th>
<th>Fracture of the screw, implant platform, and abutment</th>
<th>Fracture of the screw, implant platform, and abutment</th>
<th>Debonding between hybrid abutment layers with fracture and/or crown</th>
<th>Debonding between hybrid abutment layers without damage to the substrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD-PEEK</td>
<td>5 (50%)</td>
<td>2 (20%)</td>
<td>–</td>
<td>1 (10%)</td>
<td>–</td>
<td>–</td>
<td>1 (10%)</td>
<td>1 (10%)</td>
</tr>
<tr>
<td>TZ-PEEK</td>
<td>–</td>
<td>–</td>
<td>5 (50%)</td>
<td>1 (10%)</td>
<td>–</td>
<td>–</td>
<td>4 (40%)</td>
<td>–</td>
</tr>
<tr>
<td>LD-YZ</td>
<td>6 (60%)</td>
<td>2 (20%)</td>
<td>–</td>
<td>–</td>
<td>1 (10%)</td>
<td>1 (10%)</td>
<td>1 (10%)</td>
<td>–</td>
</tr>
<tr>
<td>TZ-YZ</td>
<td>1 (10%)</td>
<td>1 (10%)</td>
<td>1 (10%)</td>
<td>4 (40%)</td>
<td>2 (20%)</td>
<td>–</td>
<td>1 (10%)</td>
<td>–</td>
</tr>
</tbody>
</table>

TZ = translucent zirconia crown; LD = lithium disilicate crown; YZ = zirconia abutment; PEEK = polyether ether ketone abutment.
<table>
<thead>
<tr>
<th>Catastrophic</th>
<th>Reversible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial crack restricted to the crown</td>
<td>Debonding between hybrid abutment layers without damage to the substrates</td>
</tr>
<tr>
<td>Fracture restricted to the crown</td>
<td></td>
</tr>
<tr>
<td>Fracture of the screw</td>
<td></td>
</tr>
<tr>
<td>Fracture of the screw and implant platform</td>
<td></td>
</tr>
<tr>
<td>Fracture of the screw, implant platform, and abutment</td>
<td>Debonding between hybrid abutment layers with fracture of the abutment and/or crown</td>
</tr>
<tr>
<td>Fracture of the screw, implant platform, and crown</td>
<td></td>
</tr>
</tbody>
</table>

Fig 3  Illustrative figures of the patterns of failure in each category considered for the failure analysis.
values than the lithium disilicate when luted to three distinct substrates with different elastic modulus: fiber-reinforced composite (14.9 GPa), titanium (115 GPa), or zirconia (210 GPa).12

The failure analysis revealed that the fracture pattern was more influenced by the crown material than by the abutment material. For lithium disilicate crowns, most of the failures occurred as a radial crack restricted to the crown (50% with PEEK and 60% with zirconia). For translucent zirconia crowns, the most prevalent failure pattern was fracture of the screw and implant platform (50% with PEEK and 40% with zirconia abutment), which corroborates the data of a previous study where major complications in PEEK abutments restored with translucent zirconia crowns were screw loosening or fracture.37 This result can be accredited to the aforementioned greater structural strength of translucent zirconia crowns, which resisted stresses generated by the load application and lead to the failure at implant-related structures. The screw, specifically, is regarded as the weakest structure in an implant-supported system.38 Another important finding about the failure pattern observed was that for the PEEK abutment with translucent zirconia crown group, debonding between hybrid abutment layers without damage to the substrates occurred in 40% of the cases, providing reversible failure, as the structures could be rebound. The development of improved luting agents and surface treatments for improving the bonding to PEEK is also of interest.

Still, regarding the failure patterns, as mentioned, a relevant number of fractures of the implant platform could be observed, and thus, this study differs from other laboratory data where some failures restricted to screws are generally seen.37 This might be attributed to the fact that the implant adopted in the present study has a novel 6.6-mm-deep internal joint that combines a conical sealing (at the cervical portion) and an anti-rotational index at the middle portion, which ensures great mechanical stability of the abutment into the implant, resulting in absence of overloading at the screw structure. Moreover, the number of implant fractures or plastic deformations observed in laboratory studies are usually greater than that seen in the clinical practice because the failure load necessary to cause damage to the system and ensure the final outcome to the tested specimen is probably higher than the general mean occlusal load.

Besides some laboratorial evidence on the use of PEEK as a definitive abutment, very scarce clinical data have been observed in the literature involving a case report39 and case series being presented,40 which suggested adequate clinical application. Therefore, based on the low evidence present on this subject, some clinical studies should be considered.

CONCLUSIONS

Based on the evidence of this study, the following conclusions are considered: (1) hybrid abutments made of PEEK provide similar mechanical fatigue performance compared with those made of zirconia, irrespective of the crown material, which is an attractive alternative in terms of cost-benefit, ease of production, and intraoral adjustments; (2) monolithic crowns made of translucent zirconia provide superior mechanical fatigue performance compared with lithium disilicate crowns when used with zirconia abutments; and (3) lithium disilicate monolithic crowns have a similar mechanical fatigue performance compared with that of translucent zirconia when used with PEEK custom abutments.

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REFERENCES


