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Comparison of Microleakage and Fracture Strength of Veneering Techniques for Polyetheretherketone Cores

Polietereterketon Alt Yapılar İçin Kullanılan Veneer Tekniklerinin Mikrosızıntı ve Kırılma Dayanımlarının Karşılaştırılması

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ABSTRACT

Objective: This study aimed to compare both microleakage and fracture strengths of polyetheretherketone crowns manufactured via conventional composite layering and different computer-aided design and computer-aided manufacturing veneering techniques on polyetheretherketone cores.

Materials and Methods: In total, 40 cores with 0.7-mm thickness were milled from polyetheretherketone discs and separated into 4 groups: layering with composite resin, computer-aided design and computer-aided manufacturing-fabricated lithium disilicate veneer, computer-aided design and computer-aided manufacturing-fabricated hybrid ceramic veneer, and computer-aided design and computer-aided manufacturing-fabricated feldspathic veneer. Then, all cores were air abraded and an adhesive has applied to these surfaces. After the cores were connected to veneers, thermomechanical aging was applied in a chewing simulator. Evaluation of microleakage and fracture strength was performed via micro-computed tomography analysis and universal test machine, respectively. One-way analysis of variance was used to detect any statistically significant differences between test groups. Also, failure modes and the correlation between microleakage and fracture strength data were analyzed statistically.

Results: Statistical analyses between the groups showed significant differences for both microleakage and fracture strength values. The lowest microleakage was in the computer-aided design and computer-aided manufacturing-fabricated hybrid ceramic veneer group (0.02 ± 0.01 mm^3). The highest microleakage was in the layering with composite resin group (0.56 ± 0.21 mm^3). The lowest fracture strength values were in the computer-aided design and computer-aided manuf acturing-fabricated feldspathic veneer group (620.58 ± 114.02 N). The highest fracture strength was in the computer-aided design and computer-aided manufacturing-fabricated lithium disilicate veneer group (1245.82 ± 197.75 N). Also, there was no correlation between the microleakage and fracture strength groups.

Conclusion: The use of computer-aided design and computer-aided manufacturing-fabricated lithium disilicate and hybrid ceramic veneers can be an alternative to layering when its other advantages are considered.

Keywords: Polyetheretherketone, digital veneering, microleakage, fracture strength, adhesive dentistry, dental technology

ÖZ

Amaç: Bu çalışma, PEEK altyapı üzerinde geleneksel kompozit katmanlama ve farklı CAD/CAM veneerleme teknikleri ile üretilen polietereterketon (PEEK) kronların hem mikrosızıntı hem de kırılma dayanımlarını karşılaştırmayı amaçlamıştır.

Gereç ve Yöntemler: PEEK disklerinden toplamda 0,7 mm kalınlığında hazırlanan 40 altyapı örnek dört gruba ayrılmıştır: LCR; Kompozit reçine, LDV, CAD/CAM fabrikasyon lityum disilikat kaplama, HCV ile katmanlama; CAD/CAM tarafından üretilmiş hibrit seramik kaplama ve FFV; CAD/CAM fabrikasyon feldspatik kaplama. Daha sonra tüm örnekler hava ile tozlama sayesinde pürüzlendirilmiş ve bu yüzeylere adeziv uygulanmıştır. Kor örnekler veneer üst yapılara bağlandıktan sonra çiğneme simülatöründe termomekanik yaşlandırma uygulanmıştır. Mikrosızıntı ve kırılma dayanımının değerlendirilmesi sırasıyla mikro-CT analizi ve üniversal test cihazı ile yapılmıştır. Test grupları arasında istatistiksel olarak anlamlı farklılıkları tespit etmek için tek yönlü ANOVA kullanılmıştır. Ayrıca, kırılma paternleri ve mikrosızıntı ile kırılma dayanım verileri arasındaki korelasyon istatistiksel olarak analiz edilmiştir.

Bulgular: Gruplar arasındaki istatistiksel analizler, hem mikrosızıntı hem de kırılma dayanım değerleri için önemli farklılıklar göstermiştir. En düşük mikrosızıntı HCV grubunda (0,02 ± 0.01 mm^3). En yüksek mikrosızıntı LCR grubunda (0,56 ± 0,21 mm^3) tespit edilmiştir. En düşük kırılma dayanım değerleri FFV grubunda (620.58 ± 114.02 N) olmuştur. En yüksek kırılma mukavemeti LDV grubunda (1245,82 ± 197,75 N) tespit edilmiş olup mikrosızıntı ve kırılma dayanımları arasında bir korelasyon tespit edilmemiştir.

Sonuç: CAD/CAM fabrikasyon lityum disilikat ve hibrit seramik veneerlerin kullanımı, PEEK altyapı üzerinde diğer avantajları da düşünüldüğünde katmanlama tekniğine alternatif olarak kullanılabilir.

Anahtar Kelimeler: Polietereterketon, dijital veneerleme, mikro sızıntı, kırılma dayanımı, adeziv diş hekimliği, dental teknoloji

INTRODUCTION

Developments in dental technology and the introduction of new materials, especially milled to fabricate dental prostheses, had led to greater utilization of computer-aided design and computer-aided manufacturing (CAD/CAM).[1] Polyetheretherketone (PEEK), one of these new materials, is a semi-crystalline, linear, and aromatic thermoplastic polymer.[1,2] The low melting temperature of PEEK makes it possible to process in various ways. Polyetheretherketone can be processed by pressing or milling with CAD/CAM systems. For CAD/CAM milling, industrially manufactured PEEK blanks under standardized parameters are used.[3,4]

Polyetheretherketone is a beneficial material for dental applications due to the material's superior mechanical properties and biocompatibility, as well as its chemical stability. It shows resistance to hydrolysis, high temperatures, and chemical wear.[5-8] Polyetheretherketone has a very low density of 1.265 g/cm^3, 3-4 GPa elastic modulus, and 343°C melting temperature.[9,10] Its dimensional stability, excellent mechanical, and physical and chemical properties make it applicable in dentistry.[1,11] The low weight of PEEK makes it possible to fabricate lightweight prostheses, providing patients comfort and pleasure. The use of PEEK in prosthetic and restorative dentistry includes frameworks for metal-free removable or fixed dental prostheses, implant-supported or retained dental prostheses, endocrowns, post and core restorations, resin-bonded fixed dental prostheses, and occlusal splints.[1]

Despite its advantages, PEEK has esthetic disadvantages that limit its monolithic usage.[4-6,12] Polyetheretherketone frameworks require veneering because of their grayish-brown or pearl-white opaque color.[1,4,5] Using composite veneering for better shape and translucency requires solving problems in achieving the bond strength between PEEK and composite resin.[5,13,14] Polyetheretherketone surfaces are hydrophobic and inherently inert, which can cause chipping, delamination, or fracture of the composite layer.[13] Several treatment methods, such as sandblasting,[15] silica coating,[16] piranha etching,[5] acetone,[7] sulfuric acid,[16] phosphoric acid,[17] plasma treatment,[13] laser treatment,[18] and adhesive[14] applications were used to provide better bond strength between PEEK and composite resin.

Several veneering methods can be workable alternatives to veneering PEEK frameworks. Generally, conventional layering with light polymerized composite resin is preferred for PEEK veneering, but premanufactured veneers and CAD/CAM fabricated veneers must also be considered as new approaches.[1] However, there are some important criteria in deciding which of these techniques provide similar and almost adequate aesthetics to use. One of these criteria is to evaluate which techniques present enough fracture strength to allow optimal use in the mouth. The other is the amount of leakage between PEEK cores and CAD/CAM veneers bonded with cement. This study aimed to evaluate the microleakage and fracture strength of PEEK crowns veneered with conventional composite resin and alternatively proposed CAD/CAM fabricated veneers cemented to PEEK cores following thermomechanical aging. The null hypothesis of the present study was that the different veneering applications do not affect the microleakage and fracture strength of PEEK crowns.

MATERIALS AND METHODS

The schematic workflow of the study design is given in Figure 1.

Fabrication of the Crowns

A maxillary first premolar made of hard, thermosetting plastic material (Phantom; Frasaco GmbH, Tettnang, Germany) was used for crown preparation. Preparation was performed with a 1-mm-wide chamfer finish line and 1.5-2 mm occlusal reduction. Sharp edges and undercuts of preparation were eliminated.

CEREC Omnicam (Sirona Dental Systems GmbH, Bensheim, Germany) was used for digital impressions. The fabrication of the crowns core and veneer designs was performed simultaneously with InLab 16 (Dentsply Sirona), which eliminates the need for additional scanning of the core for veneer design. A uniform core was designed with 0.7 mm thickness following the manufacturer's recommendations. The thickness of the die spacer was selected as 120 µm. The veneer was designed with a total restoration thickness of 2 mm.

In total, 40 cores were milled from PEEK disc (breCAM.BioHPP; Bredent GmbH & Co., Senden, Germany). Specimens were randomly separated into 4 groups (n = 10) given below according to the veneering procedure and material used:

1. LCR: Layering with composite resin (crea.lign; Bredent GmbH & Co.) was performed by an experienced technician with a single transparent silicone mold for standardization of specimens' veneer thickness to minimize personal mistakes. This mold has been used to obtain similar size and shaped crowns.

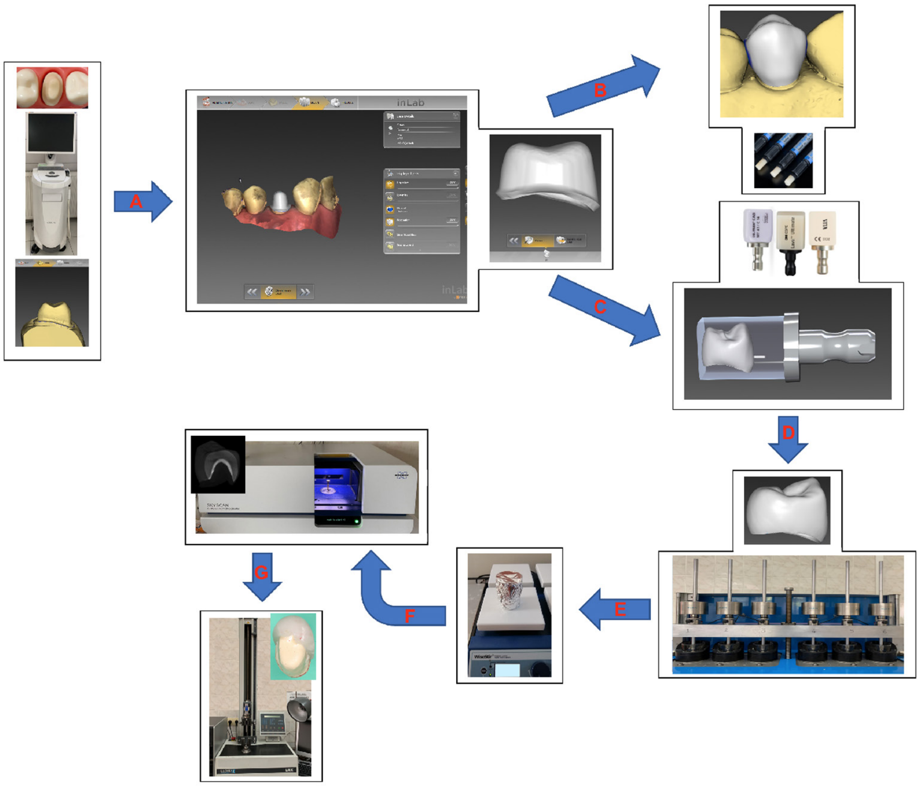

Figure 1. Schematic abstract of the study design.

2. LDV: CAD/CAM fabricated lithium disilicate veneer (IPS e.max® CAD for CEREC® and inLAB®; Ivoclar-Vivadent AG) cemented to PEEK core.
3. HCV: CAD/CAM fabricated hybrid ceramic veneer (LAVA™ Ultimate CAD/CAM Restorative; 3M ESPE) cemented to PEEK core.
4. FFV: CAD/CAM fabricated feldspathic veneer (Feldspatic Ceramic Blocks C; VITA Zahnfabric) cemented to PEEK core.

After controlling the adaptation of core and CAD/CAM veneers, each core was air abraded using 110 µm Al_2O_3 particles with 2 bar pressure and 10 mm distance for 15 seconds. Then, an adhesive (visio.link PMMA & Composite Primer; Bredent GmbH & Co.) was applied to core surfaces. The adhesive was polymerized using a polymerization unit (bre.Lux Power Unit; Bredent GmbH & Co.) that provides an energy wavelength of 370-400 nm for 90 seconds. Then, all LCR specimens were veneered with the composite resin using a single transparent silicone mold that was prepared from digitally fabricated crowns to provide standardization of the final form of the crowns. After placing the resin material on the PEEK cores with the mold, the crowns were polymerized with this transparent silicone mold. Finally, the veneers were polymerized using the same unit for 180 seconds. For the other test groups, the veneers' intaglio was treated with 9% hydrofluoric acid (Ultradent Products, Inc., South Jordan, Utah, USA) for 60 seconds and the crowns were rinsed thoroughly with deionized water for 10 seconds, then dried at room temperature. After this procedure silane agent (Clearfil Ceramic Primer Plus; Kuraray Noritake Dental Inc., Okayama, Japan) was applied to these surfaces according to the manufacturer's instructions. The cores were connected to veneers by dual-polymerized resin cement (Panavia V5 Adhesive Resin Cement System; Kuraray Noritake Dental Inc.) by applying finger pressure by the same researcher. Excess cement was removed. Resin cement was light-polymerized from all aspects for 20 seconds (bre.Lux; Bredent GmbH & Co.).

Aging Procedure

Crowns were embedded in acrylic resin (Ortocryl; Dentaurum) dies, and thermomechanical aging was applied in a chewing simulator (MOD; Esetron). Crowns were occluded against 2 mm diameter, sphere-shaped stainless-steel tips touching two lateral ridges of the restorations for standardized simulation. A total of 240 000 cycles were applied with an occlusal load of 50 N at a frequency of 1.3 Hz to simulate approximately 1 year in vivo. Additionally, thermal cycling was applied during loading from 5°C to 50°C every 60 seconds.

Evaluation of Microleakage

Following aging, the crowns were sealed with 2 layers of nail varnish except for a 1 mm thick area around the restoration margin and allowed to dry for 10 minutes. The coated crowns were stored in 50% w/v ammoniacal silver nitrate solution (50% $AgNO_3$; Sinopharm) in the dark for 24 hours and then rinsed with running water for 2 minutes. The crowns were immersed in a photo-developing solution (RPXOMAT; Kodak) and exposed to daylight for 8 hours. Then, ultrasonic cleaning was applied for 1 minute with a toothbrush to eliminate silver deposits on the surface.

Each specimen was scanned using a micro-computed tomography (Skyscan; Kontich) with an X-ray source of 100 kV/100 mA. Each specimen was rotated 360° with a rotation step of 0.2. A 1 mm copper filter was used to interrupt soft X-rays and to avoid shooting artifacts. Each specimen was scanned for nearly 40 seconds. One-thousand-eight hundred projections were taken for each sample. The pixel size of the image resolution was 18 µm. The projections were reconstructed with NRecon software (SkyScan) to eliminate radiologic defects and create axial images of the

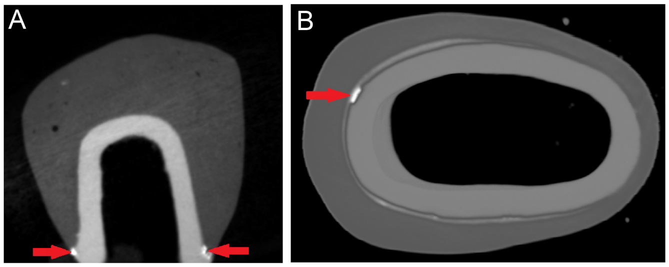

Figure 2. Demonstrative images of micro-CT depicting cervical microleakage measuring according to a depth of $AgNO_3$ presence between the core and veneer interfaces. (A) Sagittal view of sample. (B) Axial view of the sample. CT, computed tomography.

specimens. These images were uploaded to Dataviewer software (SkyScan), and then the sample was viewed with axial, coronal, and sagittal axes. Samples were flattened, and angular corrections were made so that the restoration margins corresponded to equal sections. To calculate the amount of $AgNO_3$ that has penetrated the margins, the upper and lower boundaries of the restorations were determined with this program, and other sections were excluded from the analysis. A volume of interest containing each slice, the full object was chosen.

Grayscale thresholds were established to distinguish $AgNO_3$ from penetrating the leak between PEEK core and veneers. Then, the silver leak volume was automatically calculated in 3D and volumetrically (Figure 2).

Fracture Strength

A single static load failure test was applied using a universal test machine (Instron; Instron Corp., Fareham, UK). A 2-point contact between the tip and the occlusal surface of the crown was provided like the aging procedure. The load was applied with a 2.5 mm diameter stainless steel tip at a 1 mm/min crosshead speed until fracture. The tip was applied vertically at the center of the occlusal surface. The fracture pattern of each crown was evaluated (Figure 3).

Statistical Analyses

Statistical analysis was performed by PAWS Statistics for Windows, Version 18.0.0 (SBAS Hong Kong Headquarters, Quarry Bay, Hong Kong). One-way analysis of variance (ANOVA) was used to analyze both fracture strength and microleakage data. The homogeneity of the data was analyzed with the Shapiro–Wilk test. Fracture strength data showed normal distribution in all groups (P > .05). Microleakage data showed no homogeneous distribution with the FFV group (P < .05). For microleakage data, Tamhane's post hoc test was used to determine the differences between the groups since variances were not homogeneous (P < .05). For fracture strength data, Tukey's post hoc test was used to determine the differences between the groups since variances were homogeneous (P < .05).

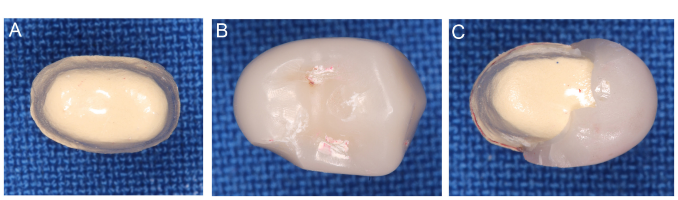

Figure 3. The different fracture patterns of samples. (A) Adhesive. (B) Cohesive, (C) Mixed failures.

Spearman's rho correlation coefficient evaluated the correlation between microleakage and fracture strength data in each group.

RESULTS

One-way ANOVA test between the groups showed significant differences for microleakage data (F = 60.807). The maximum and minimum microleakage values, mean, and standard deviation with statistical differences are shown in Table 1 (P < .05). The lowest microleakage was observed for the HCV group (0.02 ± 0.01 mm^3). The highest microleakage was obtained in LCR (control) group (0.56 ± 0.21 mm^3).

One-way ANOVA test between the groups showed significant differences in fracture strength values (F = 28.085). The maximum and minimum fracture strength values, mean, and standard deviation with statistical differences are shown in Table 2 (P < .05). The lowest fracture strength value was observed in the FFV group (620.58 ± 114.02 N). The highest fracture strength was obtained in the LDV group (1245.82 ± 197.75 N). The fracture patterns of the crowns in each group were given in Table 3.

When the correlation between each group's microleakage and fracture strength data was evaluated by Spearman's rho correlation coefficient, there was no correlation (P > .05). However, the CAD/CAM groups with lower microleakage showed higher fracture strength (LDV and HCV) except FFV.

DISCUSSION

The present study evaluated both the microleakage and fracture strength of PEEK crowns veneered using different veneering materials and procedures. The results showed that veneering material and procedure are effective on microleakage and fracture

Table 1 . Mean, Maximum and Minimum Microleakage Values (mm^3), Standard Deviation with Statistical Differences Between the Groups (P < .05)

Group	Mean ± Standard Deviations	Minimum-Maximum
LCR	0.56^c ± 0.21	0.32-0.91
LDV	0.03^a ± 0.02	0.01-0.07
HCV	0.02^a ± 0.01	0.01-0.03
FFV	0.08^b ± 0.03	0.01-0.12

FFV, computer-aided design and computer-aided manufacturing-fabricated feldspathic veneer; HCV, computer-aided design and computer-aided manufacturing-fabricated hybrid ceramic veneer; LCR, layering with composite resin; LDV, computer-aided design and computer-aided manufacturing-fabricated lithium disilicate veneer.
P < 0.05

Table 2 . Mean, Maximum and Minimum Fracture Strength Values (N), Standard Deviation with Statistical Differences Between the Groups (P < .05)

Group	Mean ± Standard Deviation	Minimum-Maximum
LCR	931.95^b ± 128.09	704.16-1168.45
LDV	1245.82^a ± 197.75	977.07-1658.68
HCV	1134.60^a ± 196.93	796.49-1392.63
FFV	620.58^c ± 114.02	458.37-788.03

FFV, computer-aided design and computer-aided manufacturing-fabricated feldspathic veneer; HCV, computer-aided design and computer-aided manufacturing-fabricated hybrid ceramic veneer; LCR, layering with composite resin; LDV, computer-aided design and computer-aided manufacturing-fabricated lithium disilicate veneer.
P < 0.05

Table 3. Fracture Pattern of the Crowns in Each Group

Group	Adhesive Failure	Cohesive Failure	Mix Failure
LCR	10		
LDV	6	4	
HCV	7	3	
FFV	5		5
Total	28	7	5

FFV, computer-aided design and computer-aided manufacturing-fabricated feldspathic veneer; HCV, computer-aided design and computer-aided manufacturing-fabricated hybrid ceramic veneer; LCR, layering with composite resin; LDV, computer-aided design and computer-aided manufacturing-fabricated lithium disilicate veneer.

strength of PEEK crowns. Therefore, the null hypothesis of the present study was rejected.

The chemical composition and low surface energy of PEEK may give rise to bonding problems with resin composites despite being increasingly used in dental practice. Therefore, PEEK surfaces should be treated for adequate bond strength to resin composites for restorative applications. According to Çulhaoğlu et al,[7] shear bond strengths higher than 10 MPa would be accepted as sufficient. For that purpose, from airborne particle abrasion to laser irradiation, some viable surface treatment modalities may improve PEEK material bonding. Sandblasting is a commonly used surface treatment method that cleans the surface, increases the bonding area,[19] and increases the surface wettability.[6] Sandblasting is reported to increase the bond strength between composite resin and PEEK and is recommended for the surface conditioning of PEEK.[20-22] Thus, the bonding surfaces of PEEK frameworks were sandblasted in the present study. Also, the usage of adhesive systems is essential for bonding between PEEK and veneer materials.[5,14,15,18] Additionally, the chemical composition of the adhesive system influences the adhesive strength between the PEEK and veneering materials.[12,14] Most studies showed that methylmethacrylate-based adhesives provide an adequate bond to PEEK.[12,19,23,24] Therefore, visio.link PMMA & Composite Primer was used at the PEEK veneer interface, considering the manufacturer's suggestion and instructions. According to the manufacturer's instructions, the inner surfaces of the CAD/CAM veneers were etched to provide mechanical bonding and increase the bonding area. Due to thermal aging volumetric changes, mechanical stresses and cracks can occur at the core and veneer interface and veneer edges, affecting the fracture strength values.[3,5] All crowns were subjected to thermomechanical aging to simulate intraoral conditions.

Microleakage is the migration of saliva, molecules, bacteria, and/or ions between the hard dental tissues and a restorative material or between 2 materials. Microleakage occurs when the adhesion at an interface is missed due to insufficient bond, thermal and mechanical stresses, or lack of accuracy during laboratory fabrication.[25] Previous studies have evaluated marginal gap and marginal adaptation associated with PEEK crowns; however, there has been no adequate study about microleakage between the PEEK core and its veneers.[26,27] The present study evaluated the microleakage between the core and different veneering materials. The results indicate that the type of the veneering material and the veneering procedure applied were effective factors in microleakage at the core veneer interface. The highest microleakage was observed for the LCR group (0.56 ± 0.21 mm^3), while the lowest microleakage was observed in the HCV group (0.02 ± 0.01 mm^3). As a result, less microleakage detection in all CAD-CAM veneering demonstrated that bonding the veneer material with resin cement reduces leakage compared to the conventional layering process. This result can be attributed to because of the larger polymerization shrinkage towards the light source when the resin veneer material with a larger volume is polymerized on the PEEK core, and thus the breakdown of adhesion between the surfaces in the LCR group. On the other hand, the high compatibility of digitally manufactured veneers and the filling of strong resin cement between the PEEK cores and the veneers reduced microleakage in veneering groups.

Sintering shrinkage seen in pressed PEEK substructures is avoided in CAD/CAM PEEK substructures, leading to compatible margins. Additionally, higher fit and trueness are reported for CAD/CAM fabricated PEEK.[28] Misfit of margins can adversely affect not only microleakage properties but also fracture strength. Also, CAD/CAM milling was reported to produce higher fracture strength than pressing.[3-5] The CAD/CAM milling PEEK substructure was used in this study because of its advantages compared to pressed PEEK.

Maximum masticatory load at the molar region is reported to reach up to 900 N.[29,30] Fracture load values reported for composite layered PEEK in previous studies are acceptable for posterior use. For example, Jin et al[31] reported a fracture load of 1518 N for 3-unit composite layered modified PEEK restorations following aging (5000 thermal cycles of 5°C-55°C, mastication simulation of 4.9 N load for 10 minutes). Also, Shetty et al[10] reported that higher fracture resistance was obtained with composite-layered PEEK crowns than composite-layered zirconia crowns. The mean fracture strength of composite layered PEEK was 2134.64 MPa before thermocycling and 1765.01 MPa after thermocycling (5000 cycles of 5°C-55°C). Taufall et al[4] evaluated fracture loads of different veneered PEEK fixed partial dentures. They used CAD/CAM fabricated composite resin veneer, 2 different composite resins as conventional composite veneers, and premanufactured veneers under thermocycling conditions from 5°C to 55°C for 10 000 cycles. They reported that the highest fracture load was obtained with CAD/CAM fabricated veneers (2021 N). The superior mechanical properties of milled composites are explained by providing a more homogenous structure and higher material quality. Moreover, the stability of CAD/CAM fabricated veneers is explained by eliminating faults in the manufacturing process. The only manual step during application is the bonding of the veneer to the PEEK framework for this technique.[4,29] In the present study, the mean fracture strength value was 931.95 MPa for the LCR group, while mechanical aging was applied in addition to thermal aging. Considering the artificial aging parameters of the present study are more difficult, it is seen that the results obtained for layering are similarly scaled to these studies. Similarly, Ghodsi et al[32] reported a mean fracture resistance of 843.56 N for composite veneers on PEEK abutments in a study that compared zirconia and PEEK abutments with thermomechanical aging (3000 cycles, 5°C-55°C and 500 000 cycles, 50 N force).

As seen, CAD/CAM fabricated and layered composite veneers were evaluated in previous studies. In addition, some studies evaluated the sole fracture resistance of ceramic or hybrid veneering materials.[33,34] However, there is inadequate information about other CAD/CAM fabricated veneers for PEEK, especially lithium disilicate or feldspathic ceramics. Although the strength of the material is an important parameter, when considered clinically, the compatibility between the core and the veneer in terms of the fracture strength of the restoration may also affect the result. In this study, the highest fracture strength was observed for the LDV group (1245.82 ± 197.75 N), while the lowest values were observed for the FFV group (620.58 ± 114.02 N). LDV and HCV groups showed statistically higher fracture strength values compared to the LCR group. The CAD/CAM groups with lower microleakage showed a higher fracture strength except for FFV. Nevertheless, the FFV group also presented the least adhesive failure compared with the other groups. Additionally, the LCR group presented fully adhesive failure. Accordingly, LDV and HCV groups could present more fracture strength through both their adhesive success and structural strength which depend on mineral contents like lithium disilicate. On the other hand, the FFV group and the LCR group are less strong because of their fragile structure and less adhesion to PEEK cores respectively.

When fracture patterns were evaluated, the LCR group showed the highest adhesive failures associated with the highest microleakage values. CAD/CAM veneering groups, especially lithium disilicate and hybrid ceramic veneers, presented the lowest microleakage values. According to these results, it can be discussed whether the less adhesive failure between PEEK and the veneering materials indicates the lower microleakage at the veneer core interface. Nevertheless, even if thermomechanical aging used in this study is a good way to simulate clinical conditions, clinical studies are still needed.

CONCLUSION

Within the limitations of the present study, the use of CAD/CAM fabricated veneers can be an alternative to layering when its advantages are considered. Although this study could not imitate all clinical variations, it is thought that the use of CAD/CAM fabricated lithium disilicate and hybrid ceramic veneers can be an alternative to layering when its advantages are considered.

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