Original Article

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The Effect of Glass Ceramic Layering on the Marginal Leakage of Zirconia Supported Crowns

Cam Seramik ile Tabakalamanın Zirkonya Destekli Kronlarda Marjinal Sızıntıya Etkisi

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ABSTRACT

Objective: The purpose of this study was to evaluate the effect of veneering with lithium-disilicate glass-ceramic material on the marginal microleakage of zirconia-supported crowns.

Methods: Ten freshly extracted human third molars were embedded in an acrylic mold from the roots. Crown preparation of each tooth half was handled differently. The distal half of each tooth was prepared with a chamfer-type margin (1.2 mm), while the mesial half was finished with a mini-chamfer (0.6 mm). Zirconia frameworks were designed and manufactured with computer-aided design/computer-aided manufacturing, and the frameworks were veneered on the distal surfaces of the framework using lithium-disilicate glass-ceramic. Specimens were thermocycled and immersed in a basic fuchsine dye solution for 24 hours. Four cross-sections were made from each specimen (n=40), and dye penetrations were recorded under a stereo microscope for microleakage measurements. The microleakage values were statistically analyzed with a Mann-Whitney U test (α=0.05).

Results: Mean microleakage values were recorded for each group. The values for the ceramic veneered margin group were noted as 1.17±0.69 mm, while the values for the zirconia margin group were noted as 1.03±0.74 mm. The results did not show significant differences for the compared groups (p=0.102).

Conclusion: Lithium-disilicate glass-ceramic veneering for zirconia-supported restorations did not enhance the marginal seal capability.

Keywords: Finish-line, glass-ceramic, marginal microleakage, zirconia

ÖZ

Amaç: Bu çalışmanın amacı, lityum-disilikat cam-seramik ile tabakalamanın zirkonya destekli kronlardaki marjinal sızıntıya etkisini değerlendirmektir.

Yöntemler: Yeni çekilmiş 10 adet yirmi yaş dişi akrilik ile doldurulmuş kalıplara kök hizalarından gömüldü. Her bir dişin distal yarısı chamfer basamak (1,2 mm), mezial yarısı ise mini-chamfer (0,6 mm) olacak şekilde prepare edildi. Zirkonya altyapılar bilgisayar destekli tasarım/bilgisayar destekli üretim yöntemiyle hazırlandı. Altyapıların distal yarısı lityum-disilikat cam-seramik ile tabakalandı. Örnekler ısıl döngüye tabi tutulduktan sonra 24 saat süreyle bazik fuksin boyayıcı solüsyona daldırıldı. Her örnekten dört kesit alındı (n=40) ve mikrosızıntı ölçümleri için boya penetrasyonları stereomikroskop altında kadyedildi. Mikrosızıntı değerleri Mann-Whitney U testi ile analiz edildi (α=0,05).

Bulgular: Her grup için ortalama mikrosızıntı değerleri kaydedildi. Cam-seramik ile tabakalanmış zirkonya grubunda ortalama değerler 1,17±0,69 mm olarak kaydedilirken zirkonya kenar grubunda 1,03±0,74 mm olarak kaydedildi. Gruplar arası fark istatistiksel olarak anlamlı değildir (p=0,102).

Sonuç: Zirkonya destekli restorasyonlarda lityum-disilikat cam-seramik ile tabakalamanın marjinal sızdırmazlığa katkısı gözlenmemiştir.

Anahtar Sözcükler: Bitim hattı, cam seramik, marjinal mikrosızıntı, zirkonya

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Introduction

In recent years, the increasing demand of patients for high esthetic restorations has contributed to the development of new restorative materials that aim to ensure the longevity of the restoration by improving its mechanical and optical properties and minimizing technical problems. Zirconia has many beneficial properties, such as excellent biocompatibility, high strength, and low plaque accumulation. The material also has low translucency owing to its crystalline microstructure. High-strength zirconia is usually used as a framework and should be layered with veneering ceramic to meet patients' esthetic expectations (1-3). With computer-aided design/computer-aided manufacturing (CAD/CAM) technology, it is possible to fabricate the optimal zirconia coping/framework for crown and bridge restorations. Despite its high costs CAD/CAM ensures reproducible results by reducing the technician errors that occur in the laboratory and providing standardization (4). After manufacturing the zirconia framework, glass-ceramics can be applied through several manufacturing processes, including the layering and press techniques (5,6). In the layering technique, ceramic powder is applied directly to the zirconia core before firing. In the press technique, a ceramic ingot is heated and forced under pressure after lost wax technique application (7).

In addition to the material's esthetic properties, strength, and biocompatibility, precise marginal fit and marginal seal are also fundamental requirements for the clinical success of dental restorations (1). The marginal finish lines of full-crown restorations can be classified as feather-edged, shoulder, mini chamfer, and chamfer (8). Studies have shown that finish line type, ceramic veneering procedures, differences in the thermal expansion coefficients between the core and the veneering ceramic, and veneering ceramic thickness affect the marginal adaptation of the restorations (9-12). An inadequate marginal adaptation can result in a gap between the restoration and the prepared tooth, thus accelerating the dissolution of the cement. Subsequently, oral bacteria and food debris accumulate in this space, leading to secondary caries, pulpal lesions, postoperative sensitivity, periodontal disease, and marginal discoloration (8,13-15). Also, the cementation process affects the marginal adaptation and, subsequently, the marginal microleakage of the restoration (12). The microleakage amount of a cemented restoration depends on many other factors, like tooth preparation, restoration material, restoration fabrication method, cement type, and cementation procedures (16,17).

In the literature, the effects of different manufacturing methods (18), various cement types (19), and finish line designs (20) on marginal microleakage of zirconia frameworks have been investigated. To the authors' best knowledge, there is limited study on the effect of the finish line material on the microleakage amount of zirconia-supported crown restorations. The zirconia-supported restorations mainly have zirconia finish lines. However, due to the absence of glass phase or silica in their structure, they do not show sufficient adhesion ability to the tooth as much as glass-ceramic (1). The surface roughening process, which is applied to glass-ceramics, such as hydrofluoric acid, before cementation, is not effective for zirconia due to its high volume of crystals and absence of glass matrix. It is easy to achieve strong, predictable adhesive retentions on silica-based ceramics, but zirconia has limitations in bonding with dental tissue due to its composition (21,22).

Finishing the margin area with lithium-silicate glass-ceramic material was thought to contribute to a better marginal seal and lower marginal microleakage with the help of increased adhesion to the tooth structure. Therefore, the purpose of this study was to evaluate the influence of veneering with lithium-disilicate glass-ceramic on the marginal microleakage of zirconia-supported crowns using optical image processing software.

The null hypothesis was that there would be no difference in marginal microleakage values between the two finish lines prepared with zirconia and lithium-disilicate glass-ceramic veneered zirconia.

Methods

This study was approved by the İstanbul Okan University Clinical Research Ethics Committee (approval number: 56665618-204.01.07, date: 22.07.2020).

Ten freshly extracted and cleaned third human molars were embedded in an acrylic mold (Figure 1a). The distal half of each tooth was prepared with a chamfer margin (1.2 mm), while the mesial half was finished with a mini-chamfer (0.6 mm) (Figure 1b). The preparations were carried out by the same researcher, and a new diamond bur (Brasseler, Savannah, GA, USA) was used under water cooling. The prepared teeth were then scanned with an intra-oral digital scanner (CEREC Omnicam, Dentsply Sirona, Bensheim, Germany). The crown frameworks were designed using computer-aided design software (CEREC 4.3, Dentsply Sirona) (Figure 1c). Margin lines were drawn, leaving a homogenous margin thickness of 0.6 mm in the zirconia margin halves. On the other half side, an additional space of 0.6 mm was left for veneering ceramic material in the ceramic veneered margin group. Partially sintered zirconia blocks (inCoris Z.I., Dentsply Sirona, Bensheim, Germany) were milled (CEREC inLab MC XL, Dentsply Sirona, Bensheim, Germany) for the fabrication of the frameworks (Figure 2). The milled frameworks were then sintered with a sintering furnace (inFire HTC speed, Dentsply Sirona, Bensheim, Germany) according to the manufacturer's instructions.

Following the sinterization period, the zirconia frameworks were cooled down carefully. Each zirconia framework was fitted on the corresponding prepared tooth and checked for optimal adaptation. The frameworks were veneered on the distal surfaces of the zirconia framework using a lithium-disilicate glass-ceramic (IPS e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein), which had a convenient coefficient of thermal expansion in terms of zirconia (Figure 2). The ceramic veneering process was completed in two firings using a ceramic furnace (Vita Vacumat 6000 M, Vita Zahnfabrik, Baden-Wurttemberg, Germany).

The prepared crowns were cemented using a dual-curing resin cement (Multilink N, Ivoclar Vivadent, Schaan, Liechtenstein).

Following cementation, ten specimens were subjected to 5.000 cycles of thermal cycling between 5 °C and 55 °C with a dwelling time of 20 seconds (23). Then, the specimens were immersed in a basic fuchsine dye solution for 24 hours. After the specimens were removed from the solution, residual surface stains were cleaned with a toothbrush under running water. Four cross-sections were taken from each restoration-tooth complex for the microleakage measurements (n=40). A total of 80 measurements of dye penetration were recorded under a stereo microscope at a magnification of 20 (Leica Microsystems, Germany). Each microleakage value was defined and recorded as the distance of the stain penetrated from the outer border of each margin using optical image processing software. The recordings were then converted to a millimetric scale. Both zirconia and ceramic veneered zirconia halves of restorations were measured to compare the results.

Statistical Analysis

Statistical analysis was performed using SPSS 18.0 (SPSS, Chicago, USA) for Windows.

Results

The Shapiro-Wilk test was used to examine whether the data showed normal distribution. The microleakage values were analyzed with Mann-Whitney U test since the data did not show normal distribution. P-values less than 0.05 were considered statistically significant. Mean microleakage values were evaluated and the values for ceramic veneered margin group was 1.17±0.69 mm, (Figure 3a) while the values for non-veneered zirconia margin group was 1.03±0.74 mm (Table 1, Figure 3b). There were not significant differences between the two margin groups (p=0.102).

Discussion

The null hypothesis was accepted because veneering of zirconia frameworks with lithium-disilicate glass-ceramic did not cause a difference in marginal microleakage values.

Studies have investigated the effect of veneering ceramics in zirconia framework on marginal, internal, and horizontal discrepancies (24-26). However, not enough study was found on the effect of finish line material on microleakage after cementation. Pak et al. (27) evaluated the marginal fit of two different zirconia based crown systems (Digident CAD/CAM, Lava CAD/CAM) before and after ceramic veneering. The ceramic veneering process was found to have increased the marginal gaps between the teeth and the restorations for both groups (Digident increased from 61.52 to 83.15 µm; Lava increased from 62.22 to 82.03 µm). Kohorst et al. (26) also evaluated the marginal fit of two different, four-unit zirconia (VITA In-Ceram YZ Cubes, KaVo Everest ZS Blanks) frameworks after veneering with recommended ceramic systems. While frameworks from Everest ZS Blanks veneered

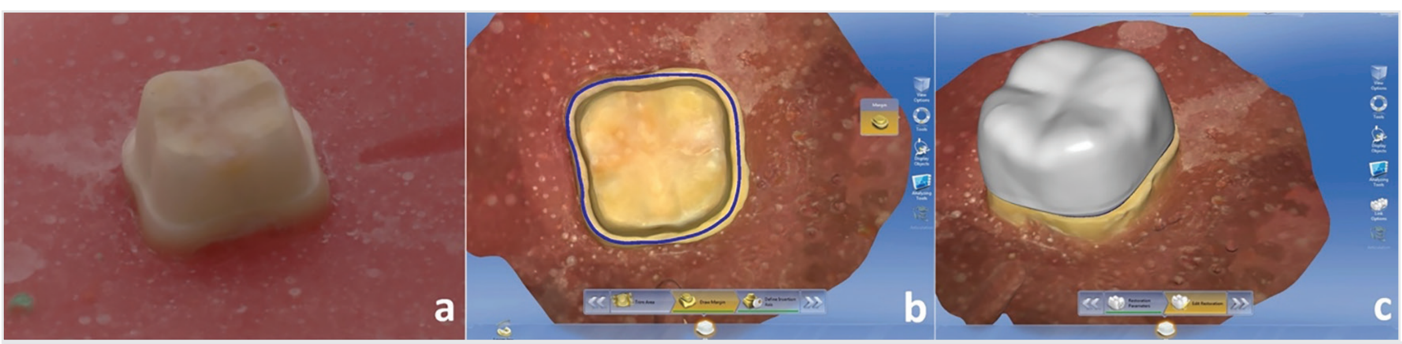

Figure 1. Representative image of a human third molar embedded in an acrylic mold (a), drawn margin lines for the zirconia framework (b), designed zirconia framework, using a computer-aided design software (Cerec 4.3, Sirona) (c)

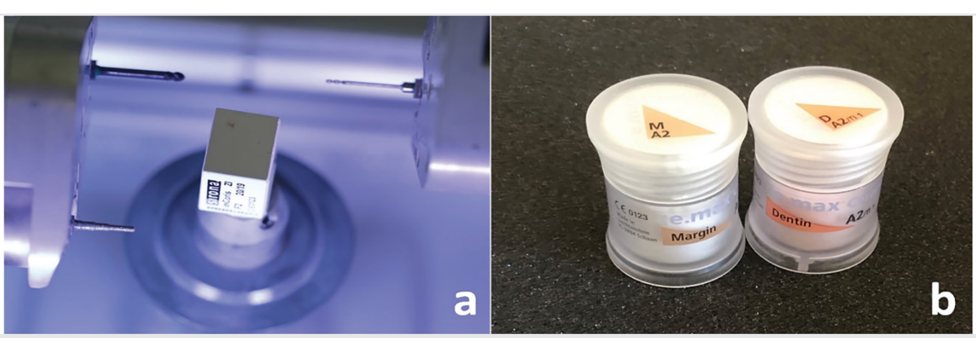

Figure 2. Representative image of a CAD/CAM zirconia block (a) and lithium-disilicate glass-ceramic layering material (b) used in the study

CAD/CAM: Computer-aided design/computer-aided manufacturing with GC Initial Zr ceramic showed decreased marginal gap (p=0.019) and internal gap (p=0.001); frameworks from In-Ceram YZ Cubes veneered with VITA VM9 ceramic showed no differences after the veneering process. It was concluded that, extend of distortions after the veneering process depended on the type of zirconia and ceramic combination. Vigolo and Fonzi (28) evaluated the marginal fit of three different ceramic veneered zirconia systems (Everest veneered with Vita D-ceramic, Procera veneered with NobelRondo Zirconia, Lava veneered with Lava Ceram). The measurements were handled before ceramic application, after ceramic firing and after glaze firing. It was reported that ceramic firing cycles and glaze cycles did not alter the marginal fit of zirconia based ceramic restorations. The results were in accordance with the results of the present study. In the present study, the ceramic veneered margin group showed similar microleakage values to the non-veneered zirconia group. Different from the mentioned studies, in the present study, the effect of ceramic veneering on zirconia frameworks were evaluated by measuring the marginal microleakage values after cementation on natural human teeth. Single type of a veneering ceramic and a zirconia material was used; therefore, the methodology differences might contribute to the different conclusions.

In the present study, the layering technique was used as a veneering method. Both the layering technique and the press technique can be utilized to veneer zirconia frameworks (1,6). The layering technique achieves superior esthetic results far more often than the pressing technique by means of individual contouring of the ceramic veneer. This veneering technique, which comprises a firing procedure at a high temperature (750-900 °C) followed by a cooling process, is often performed two to five times of firing cycle (29). Balkaya et al. (11) investigated the effect of the firing cycles on the marginal fit of ceramic crowns, and reported that porcelain firing cycle altered the marginal adaptation of the ceramic crowns. Numerous firing processes could bring about a distortion and a decrease in the marginal adaptation of the framework (27). However, in the present study, ceramic veneering was completed after two firings. Therefore, the increased microleakage values due to distortion and poor adaptation created by repeated firings were tried to be eliminated. Furthermore, distinctions in the ceramic materials' structures and different manufacturing methods may create different results (30).

In the literature, shoulder, chamfer, and mini-chamfer finish lines of CAD/CAM-fabricated crowns have been investigated (8,30-32). Comlekoglu et al. (8) recommended rounded shoulder and chamfer preparation for the finish line designs of zirconia-supported restorations as they showed better marginal adaptation than feather-edged finish line. Komine et al. (32) also evaluated the marginal adaptation of three types of finish lines as shoulder, rounded shoulder, and chamfer. The three groups had no significant differences, and marginal adaptation values were within clinically acceptable limits. Al-Zubaidi and Al-Shamma (30) evaluated the effect of 90° shoulder and deep chamfer finish lines on the marginal adaptation of zirconia crowns and reported that the deep chamfer finish line was better than the shoulder, especially for zirconia crowns. Pan et al. (33) concluded that chamfer-type finish line with a 0.4-0.6 mm or shoulder-type finish line with a 0.5 mm thickness showed lower peak stress values than feather-edged finish lines in zirconia restorations. In the present study, 0.6 mm thickness chamfer finish line was prepared for the zirconia support.

Marginal discrepancies can be detected using various measurement techniques, such as a direct view of the crown on a die, the impression replica technique, observation with scanning electron microscopy (SEM), light microscopy, or X-ray microtomography (12,34). In the present study, the effects of different finish-line materials on the marginal microleakage

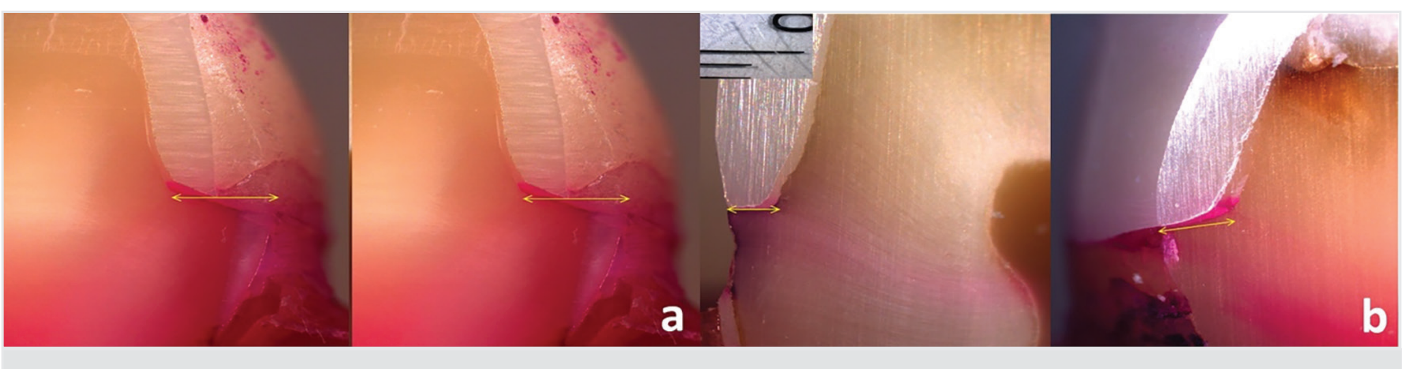

Figure 3. Optical image analysis of microleakage in ceramic veneered margin group (a), Optical image analysis of microleakage in zirconia margin group (b)

Table 1. Microleakage scores (mm) between test groups with means and standard deviations (mean ± SD)

	Mean ± SD	Min.	Max.	Median	Interquartile range
Ceramic veneered margin group	1.17±0.10	0.30	3.17	0.99	0.50
Zirconia margin group	1.03±0.11	0.26	3.88	0.87	0.42

SD: Standard deviation, Min.: Minimum, Max.: Maximum of veneered zirconia crowns were evaluated using a stereo microscope. Groten et al. (35) investigated both SEM and light microscopy while evaluating marginal adaptation and concluded that there was no significant difference in validity between these imaging techniques. On the other hand, obtaining a small number of cross-sections from a specimen is a limitation of the evaluation with a microscope (12).

Study Limitations

In the present study, one type of resin cement was used while luting the crowns, different cementing procedures and cements might result in different marginal leakage values. Also, one type of zirconia and veneering ceramic was used, further studies were required to measure the marginal microleakage values of different zirconia and compatible veneering ceramic combinations. Various techniques may be combined while evaluating the marginal microleakage values to eliminate the technique-related limitations.

Conclusion

Within the limitations of this *in vitro* study, the non-veneered zirconia margin group showed similar microleakage values to the ceramic veneered margin group. It could be concluded that lithium-disilicate glass-ceramic veneering for zirconia-supported restorations did not enhance the marginal seal capability.

Ethics

Ethics Committee Approval: This study was approved by the İstanbul Okan University Clinical Research Ethics Committee (approval number: 56665618-204.01.07, date: 22.07.2020).

Informed Consent: Informed consent is not required.

Authorship Contributions

Concept: M.E.Ç., Design: M.E.Ç., Data Collection or Processing: G.P., B.E., Analysis or Interpretation: G.P., B.E., Literature Search: G.P., B.E., Writing: G.P., B.E.

Conflict of Interest: No conflict of interest was declared by the authors.

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