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Effect of aging on the fracture resistance and microleakage of CAD-CAM-produced ceramic inlays

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Abstract

Aim: The aim of the study was to evaluate the fracture resistance and microleakage of different CAD-CAM inlay restorations.

Methodology: Inlay restorations from nine restorative materials as monolithic zirconia (TZI), resin nano ceramic (LU), hybrid ceramic (VE), feldspathic ceramic (CB), zirconia reinforced lithium silicate (VS), lithium disilicate (e.max), leucite reinforced glass ceramic (Emp), resin ceramic (GCS), and conventional composite resin (CR) were used (n=10). For evaluating the fracture resistance, restorations were cemented to resin teeth and subjected to thermomechanical aging. The data of fracture resistance were analyzed using One-way Analysis of Variance (ANOVA) and Games-Howel tests (a=0.05). For evaluating the microleakage, restorations were cemented on human teeth and subjected to thermocycling. The teeth were vertically sectioned into two parts and microleakages were assessed as yes or no.

Results: The highest and lowest fracture resistance values were found in TZI and LU groups, respectively ($p>0.05$). The most frequent microleakage was observed in TZI and CR groups, and the least microleakage was seen in the VE group. Microleakage was frequently found in cervical surfaces and followed by occlusal, axial, and pulpal surfaces.

Conclusion: Hybrid ceramics showed similar fracture resistance with the monolithic zirconia; besides, the lowest microleakage was observed for these ceramics. Hybrid ceramics may be a good alternative for inlay restorations.

Keywords: CAD-CAM, ceramic, inlays, aging, fracture resistance, microleakage

Introduction

Ceramic inlay restorations have been used for posterior restorations for four decades (1–3). However, previous generations of ceramic materials have presented issues such as poor strength and fit, microleakage, and cement-related failures (1, 4). In recent years, computer-aided design/computer-aided manufacturing (CAD-CAM) systems and chairside CAD-CAM restorative materials have gained popularity due to rising aesthetic demands. A variety of ceramic materials and manufacturing techniques currently exist for the fabrication of aesthetic all-ceramic restorations. One such dental application is the CAD-CAM system. The CEREC system employs CAD-CAM technology that was created in the 1980s. The hardware and software of this system have been thoroughly modified and enhanced. CEREC 3 for clinical applications and CEREC inLab for laboratory purposes are currently accessible. Ceramic restorations are fabricated from machinable ceramic blocks composed of ceramic powder fused at elevated temperatures to provide a consistent and homogeneous structure. Inlay restorations manufactured by CAD-CAM systems are preferred due to their superior aesthetics, biocompatibility, and mechanical properties (4, 5).

Currently, a wide range of chairside CAD-CAM materials exist in the dental market. These include different ceramics, resin-matrix ceramics, and composites, each with unique characteristics in terms of composition, microstructure, and processing methods. These differences may significantly affect the optical properties, the fit of the final restoration, and fracture resistance (6–8). CAD-CAM ceramics are reported to be more homogeneous and contain fewer flaws and cracks compared to laboratory-processed ceramics (9). Popular milling blocks include ceramic materials, leucite-reinforced glass ceramics (Empress CAD, Ivoclar Vivadent AG), lithium disilicate ceramics (IPS Emax CAD; Ivoclar Vivadent AG), feldspathic ceramics (Cerec Block; Dentsply Sirona), zirconia-reinforced lithium disilicate ceramics (Vita Suprinity; Vita Zahnfabrik), monolithic zirconia ceramics (InCoris TZI; Denstply Sirona), and resin-matrix ceramics, such as nanoparticle and nanocluster-filled resins (Lava Ultimate; 3M ESPE), resin-infused hybrid ceramics (Vita Enamic; Vita Zahnfabrik), and nanoparticle-filled resins (Cerasmart; GC Dental Products) (10).

Considering the array of recommended ceramic materials for inlay restorations and the limited number of studies on these new materials, choosing the appropriate material has become challenging. Therefore, it seems beneficial to evaluate which ceramic material will perform best in terms of fracture resistance and microleakage.

The objective of this study is to assess the fracture resistance and microleakage of mesio-occlusal inlay restorations fabricated from various CAD-CAM ceramics. The null hypotheses posited for this investigation were as follows: 1) there would be no variance in fracture resistance values among the tested ceramic materials following thermomechanical aging, and 2) the type of ceramic would not influence the microleakage of teeth restored with inlay restorations.

Materials and Methods

Specimen preparation for fracture resistance test

This study utilized the upper-right second premolar phantom tooth (ANA-4 ZE Standard Replacement Teeth; Frasaco GmbH, Tettnang, Germany), chosen for its comparable mechanical properties to natural teeth.

An inlay restoration cavity was meticulously prepared on the second premolar, which was then seated in the phantom model (Standard model ANA-4; Frasaco GmbH). Dimensions of the inlay cavity were determined mesio-distally (2/3 of the mesio-distal width of the tooth and 1/2 of the distance between the buccal and palatal cups) and cervico-occlusally (1.5 mm occlusal reduction and 1 mm proximal cavity width).

The cavity, terminating 1 mm above the enamel-cement junction, was meticulously crafted by an investigator. The pulpal wall of the cavity was flattened and positioned 1.5 mm deeper from the occlusal surface, perpendicular to the entryway.

Subsequently, the prepared tooth within the phantom model, along with the opposite arch, underwent buccal bite scanning using an intraoral scanner (CEREC Omnicam; Dentsply Sirona, Bensheim, Germany), generating digital models. Restoration margins were delineated on the digital model, with a cement thickness set at 50 µm. The restoration design was executed using CEREC 4.4 software (Dentsply Sirona), followed by milling using the Cerec MC XL milling unit (Dentsply Sirona) (Fig. 1).

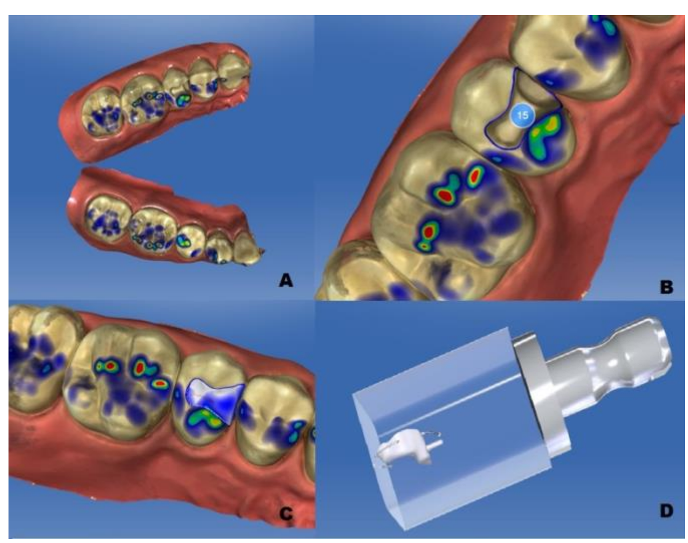

Figure 1. Production process of the CAD-CAM inlays (A) Virtual models, (B) Preparation design, (C) Design of restoration, (D) Milling

Table 1. Materials used in this study

Material	Abbreviation	Content	Manufacturer	Surface treatment
Incoris TZI	TZI	**Monolithic zirconia** $ZrO_2+HfO_2+Y_2O_3 \geq 99.0\%$ $Y_2O_3 > 4.5 - \leq 6.0\%$ $HfO_2 \leq 5\%$ $Al_2O_3 \leq 0.5\%$ Other oxides ≤ 0.5%	Denstply Sirona, Bensheim, Germany	Inner surfaces of the restorations were sandblasted with 50 µm aluminum oxide particles at 2 bars pressure.
Lava Ultimate	LU	**Resin nano ceramic** 80% ceramic (69% SiO_2, 31% ZrO_2) 20% polymer Urethane dimethacrylate	3M ESPE, Seefeld, Germany	Inner surfaces of the restorations were sandblasted with 50 µm aluminum oxide particles at 2 bars pressure, cleaned with alcohol, and air dried.
Vita Enamic	VE	**Hybrid ceramic** Fine-structure feldspar ceramic 86% by weight SiO_2 58-63% Al_2O_3 20-23 Na_2O 6-11 B_2O_3 0.5-2 CaO < 1 TiO_2 < 1 Polymer 14% by weight	Vita Zahnfabrik, Bad Säckingen, Germany	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 60 seconds and ultrasonically cleaned. Silane was applied to the etched surfaces.
Cerec Block	CB	**Feldspathic ceramic** % by weight SiO_2 56-64% Al_2O_3 20-23% Na_2O 6-9% K_2O 6-8% CaO 0.3-0.6% TiO_2 0-0.1%	Denstply Sirona, Bensheim, Germany	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 60 seconds and ultrasonically cleaned. Then silane was applied to the etched surfaces.
Vita Suprinity	VS	**Zirconia reinforced lithium silicate** SiO_2 56-64% Li_2O 15-21% K_2O 1-4% P_2O_5 3-8% Al_2O_3 1-4% ZrO_2 8-12% CeO_2 0-4% La_2O_3 0.1% Pigments 0-6%	Vita Zahnfabrik, Bad Säckingen, Germany	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 20 seconds and ultrasonically cleaned. Then silane was applied to the etched surfaces.
IPS e.max CAD	e.max	**Lithium disilicate** SiO_2 58-80% Li_2O 11-19% K_2O 0-13% ZrO_2 0-8% Al_2O_3 0-5%	Ivoclar Vivadent AG, Schaan, Liechtenstein	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 20 seconds and ultrasonically cleaned. Then silane was applied to the etched surfaces.
IPS Empress CAD	Emp	**Leucite reinforced glass ceramic**	Ivoclar Vivadent AG, Schaan, Liechtenstein	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 60 seconds and ultrasonically cleaned. Then silane was applied to the etched surfaces.
GC Cerasmart	GCS	**Resin ceramic**	GC Dental Products, Tokyo, Japan	Inner surfaces of the restorations were etched with 5% hydrofluoric acid gel for 60 seconds and ultrasonically cleaned. Silane was applied to the etched surfaces.
Filtek Bulk Fill Posterior Composite	CR	**Composite resin** Filler 75% by weight Non-agglomerated/ non-aggregated 20-nm silica filler, non-agglomerated/ non-aggregated 4-nm to 11-nm zirconia filler, aggregated zirconia/silica cluster filler, ytterbium trifluoride filler consisting of agglomerate 100-nm particles, ERGP-DMA, diurethane-DMA, 1, 12-dodecane-DMA	3M ESPE, Seefeld, Germany	The composite material was directly applied into the inlay cavity in one-step and cured.

Nine different experimental groups were generated as (n = 10):

- **Group 1:** Monolithic zirconia (Incoris TZI; TZI),
- **Group 2:** Resin nano ceramic (Lava Ultimate; LU),
- **Group 3:** Hybrid ceramic (Vita Enamic; VE),
- **Group 4:** Feldspathic ceramic (Cerec Block; CB),
- **Group 5:** Zirconia reinforced lithium silicate (Vita Suprinity; VS),
- **Group 6:** Lithium disilicate (IPS Emax CAD; e.max),
- **Group 7:** Leucite reinforced glass ceramic (IPS Empress CAD; Emp),
- **Group 8:** Resin ceramic (GC Cerasmart; GCS),
- **Group 9:** Composite resin (Filtek Bulk Fill Posterior Composite; CR).

Following the milling process of the restorations, specimens in Group 1 underwent drying and sintering in a sintering furnace (InFire HTC; Dentsply Sirona). Specimens in Groups 5 and 6 were crystallized in a porcelain furnace (Programat P300; Ivoclar Vivadent, Schaan, Liechtenstein). Specimens in the remaining groups did not undergo any firing processes.

The prepared tooth was duplicated using autopolymerized acrylic resin material to create resin teeth, resulting in a total of 90 resin teeth fabricated. Inlay cavities of the resin teeth were sandblasted using 50 µm aluminum oxide particles and subsequently cleaned in distilled water using an ultrasonic cleaner before the cementation procedures.

Surface treatments were applied to the inner surfaces of the inlay restorations, with the material properties and applied surface treatments detailed in Table 1.

Inlay restorations were cemented to the resin teeth using self-adhesive resin cement (Panavia SA; Kuraray-Noritake, Okayama, Japan) and left for 24 hours to obtain adequate polymerization. All specimens were mechanically polished using an intraoral polishing kit (OptraFine; Ivoclar Vivadent).

Specimens were embedded in acrylic resin for thermomechanical aging (TCML) in a chewing simulator (Mastication Simulator; Esetron Smart Robotechnologies, Ankara, Türkiye). Thermal cycling (2000 cycles at 5 °C and at 55 °C in water) and mechanical cycling (500,000 cycles with vertically applied 50 N loads at approximately 2 Hz frequency) were performed simultaneously. Fracture resistance testing was then performed using a universal testing machine (Compression/Tension Device; Esetron Smart Robotechnologies) at 0.5 mm/min crosshead speed. Fracture loads of the specimens were recorded in newtons.

Specimen preparation for microleakage measurement

This part of the study was approved by the Clinical Researches Ethics Committee of Ankara University's Faculty of Dentistry (approval number: 362906007117). A total of 90 extracted caries-free human permanent upper premolar teeth with approximately similar dimensions were used in the study. The teeth were washed in water to clean away residual tissue and stored in distilled water until the restorations were prepared. Standardized inlay cavities were prepared on each tooth as previously described. The prepared teeth were randomly divided into nine groups (n = 10). Digital impressions were obtained from each tooth before the production processes in the CAD-CAM system were performed as explained in the first section of the study. All of the inlay restorations were cemented using self-adhesive resin cement (Panavia SA; Kuraray-Noritake), and the specimens were stored in distilled water at 37 °C for 24 hours and subjected to 1000 thermal cycles. Two coats of nail varnish were applied to 2 mm below the restoration margins. Dye penetration was achieved by immersing the specimens in a 0.5% basic fuchsine solution for 24 hours. The teeth were rinsed in water and vertically sectioned into two parts with a water-cooled diamond disc, and palatal and buccal sections were obtained. For each specimen, digital photographs of the two sectioned surfaces were taken and dye penetrations were examined under a light microscope at 20× magnification and using the Leica QWin Plus program (Leica Microsystems Imaging Solutions Ltd; Cambridge, UK). A total of 360 surfaces were examined (palatal-cervical, palatal-axial, palatal-pulpal, palatal-occlusal, buccal-cervical, buccal-axial, buccal-pulpal, and buccal-occlusal) in 90 specimens. Microleakages on the axial, pulpal, gingival, and occlusal surfaces (Fig. 2) of each buccal and palatal section were assessed as "yes" or "no" by two calibrated examiners (Fig. 3).

Statistical analysis

Analyses were performed by using SPSS software (IBM SPSS Statistics version 20.0, IBM Inc., Armonk, NY, USA).

The normality of the fracture resistance data was tested with the Shapiro-Wilk test. The data was found to be optimal for the normal distribution. Fracture resistance data from the test groups were analyzed by one-way ANOVA, and pairwise comparisons were completed by Games-Howell tests. Results were considered to be significant when α = 0.05. Specimens whether microleakage was observed or not are shown in the table.

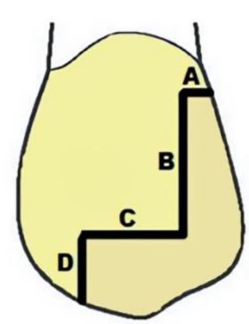

Figure 2. Microleakage evaluation from the natural tooth surfaces (A) Cervical, (B) Axial, (C) Pulpal, (D) Occlusal

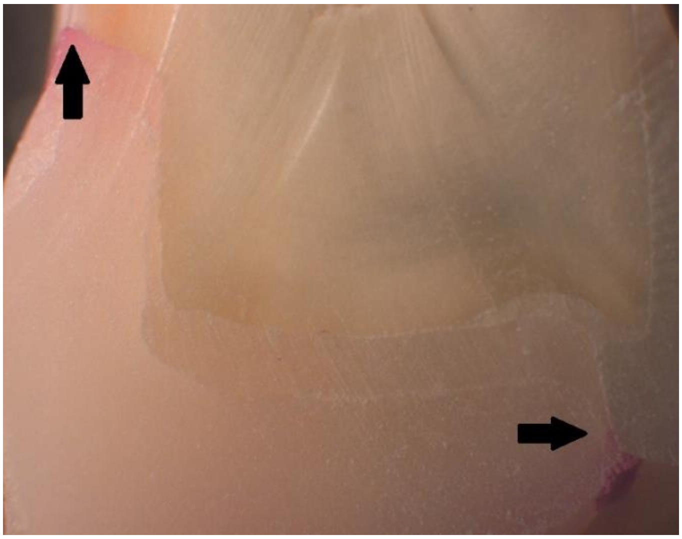

Figure 3. Microleakage assessment from tooth surfaces (arrows are showing existing microleakage)

Results

Fracture resistance values for different CAD-CAM inlay restorations are shown in Table 2.

Two failures were observed in the specimens during the aging process. One specimen from the CB (feldspathic ceramic) group was fractured catastrophically, and one specimen from the TZI (monolithic zirconia) group was decemented. Therefore, fracture resistances were not tested for these specimens. Among the experimental groups, TZI had the highest fracture resistance; however, statistically significant differences were not observed among the TZI, GCS, CR, and VE groups (p>0.05). The LU group showed the lowest fracture resistance value in the study, but the differences among the Emp, e.max, and CB groups, as well as between the VS and LU groups, were not statistically significant (p>0.05). The microleakages on axial, pulpal, gingival, and occlusal surfaces in each buccal and palatal section of all specimens CAD-CAM groups are shown in Table 3.

Table 2. Fracture resistance values of the experimental groups.

Material	n	Mean (±SD)	Minimum value	Maximum value
TZI	9	843.51 (±159.57) A	594.04	1140.84
LU	10	372.12 (±110.91) CD	189.17	579.83
VE	10	708.33(±137.51) AB	423.02	876.20
CB	9	460.18 (±154.20) CEF	222.89	663.23
VS	10	380.20 (±39.95) DF	329.47	430.97
e.max	10	480.72 (±85.71) CD	317.02	594.71
Emp	10	567.12(±142.86) BC	333.20	791.44
GCS	10	824.47 (±185.14) AB	551.72	1090.99
CR	10	677.37 (±95.50) ABE	461.51	787.23

SD: Standard deviation, Same capitals indicate that mean values of the experimental groups were not significantly different (p<0.05).

Table 3. The amounts of microleakage on axial, pulpal, gingival and occlusal surfaces in each buccal and palatal sections of the CAD-CAM inlay restorations

Material	Palatal section								Buccal section							
	Cervical		Axial		Pulpal		Occlusal		Cervical		Axial		Pulpal		Occlusal	
	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
InCoris TZI	0	10	4	6	8	2	2	8	2	8	8	2	8	2	1	9
Lava Ultimate	3	7	10	0	9	1	9	1	3	7	9	1	10	0	6	4
Vita Enamic	7	3	10	0	9	1	10	0	5	5	10	0	9	1	8	2
Cerec Blok	4	6	9	1	8	2	4	6	5	5	9	1	7	3	3	7
Vita Suprinity	5	5	9	1	10	0	7	3	3	7	7	3	8	2	6	4
IPS e.max CAD	0	10	10	0	10	0	6	4	2	8	8	2	10	0	4	6
Empress CAD	0	10	10	0	10	0	6	4	2	8	10	0	10	0	5	5
GC Cerasmart	4	6	10	0	10	0	9	1	4	6	7	3	10	0	8	2
Composite resin	4	6	7	3	7	3	4	6	2	8	5	5	10	0	1	9
Total	27	63	79	11	81	9	57	33	28	62	73	17	82	8	42	48

N: No, Y: Yes

In all materials, microleakage was mostly seen on gingival and occlusal margins at palatal and buccal sections. Microleakage was found in all specimens of TZI, e.max, and Emp at the gingival margins of palatal section. In two specimens of TZI, microleakage was also seen in the pulpal region. In resin-infiltrated ceramic materials, microleakage was not seen in many specimens. Microleakage was found mostly in LU at gingival and occlusal margins.

Discussion

One of the purposes of this study was to determine and compare the fracture resistances of CAD-CAM ceramic inlays made of different materials after aging in a chewing simulator. Based on the data of the present study, the first hypothesis—fracture resistance values would vary among the CAD-CAM inlays fabricated from different ceramic materials during thermal and mechanical aging (TCML)—was rejected. Current studies have investigated CAD-CAM partial crown restorations differing in material type and restoration design; however, the results of these studies cannot be directly compared with the present study, because there were so many different parameters that may affect the fracture resistance.

An important procedure applied in this in-vitro study is artificial accelerated aging, because ceramic restorations in the oral cavity are exposed to different media and cyclic loads (11). Repetitive stresses that lead to subcritical crack growth in ceramic structure may occur during the function of mastication or, in some cases, during parafunction. No standard protocol for simulating the intraoral aging of dental materials in laboratory conditions has been reported in the literature. In the present study, artificial aging was applied to the specimens using a chewing simulator that approximated clinical conditions. Since there were not any accepted standards regarding loading parameters for testing ceramic restorations in a chewing simulator, previous research was considered when choosing simulator test parameters such as cycling load and frequency, loading position, and thermal cycling conditions (12-14).

A variety of factors, such as cavity preparation design, cementation, and bonded substrate, affect the fracture resistance of the ceramic materials (15). In this study, all these factors were standardized for each specimen of ceramic restorations.

All inlay restorations were fabricated using the CEREC system with a 50-micrometer cement thickness setting and cemented with the same resin cement, except for the direct composite resin inlays. Natural teeth were not used for the fracture resistance test because of their disadvantages, such as structural variations and the waiting time after their extraction.

The fracture resistance values of CAD-CAM fabricated inlay restorations from a wide range of blocks differing in structural properties revealed that monolithic zirconia have the highest resistance, in accordance with previous studies (16, 17). The high mechanical strength of zirconia has been shown in several studies, even for posterior crown and fixed partial restorations subject to high loads (18-20). A remarkable finding obtained from this study is that two resin-infiltrated materials have approximate fracture load values similar to that of zirconia inlays. Resin-infiltrated ceramic materials have gained popularity for chairside CAD-CAM restorations owing to their advantages, including having reduced brittleness and an elastic behavior similar to dentin, being milled faster than other blocks, providing better marginal quality for the restorations, and requiring an easier polishing procedure compared with glass ceramics. In this study, three resin-infiltrated ceramic materials—with commercial product names Lava Ultimate (LU), Vita Enamic (VE), and GC Cerasmart (GC)—were tested. All inlay restorations milled from resin-infiltrated ceramics survived during the artificial aging test, regardless of the brand. The fatigue resistance and high mechanical strength of resin-infiltrated ceramic materials may be attributed to the material's elasticity modulus, which is similar to that of dentin. Aboushelib and Elshafi (21) pointed out that TCML generate fewer negative effects on the resin-infiltrated ceramics compared with glass ceramics. As well as fatigue resistance, resin-infiltrated ceramic materials exhibit high mechanical resistance under chewing forces. In this study, GCS and VE showed higher fracture resistance than the other ceramic blocks, except for TZI (monolithic zirconia). This finding contrasts with that of an investigation that reported significantly higher fracture toughness for IPS e.max CAD and Lava Ultimate than for Vita Enamic or GC Cerasmart (22). However, the study design was different; therefore, the results are not directly comparable. Mechanical defects can be manifested by tooth fractures and fractures in the restoration itself (23). Similar to our study's findings, Awada and Nathanson (10) reported that GC Cerasmart, a nanoparticle-filled resin, has a statistically significant higher flexural strength than feldspathic and polymer-based materials (Vitablocks Mark II and Paradigm MZ100). In this study, LU showed the lowest fracture resistance value (372.12 N) among resin-infiltrated ceramic groups. However, no failure was seen after the thermomechanical aging; therefore, the high reliability of this material makes it appropriate to be used in premolar and anterior restorations.

The e.max, Emp, VS, CB, and TZI that were compared in this study are generally more popular for chairside inlay restorations. However, the differences in the mechanical properties of all the materials are reason to question which material can survive longer, especially in the posterior regions of the mouth.

In this study, the fracture resistance values of e.max, Emp, VS, CB, and TZI were 480 N, 567 N, 380 N, 460 N, and 843 N, respectively. VS, a zirconia-reinforced glass ceramic material, had a significantly lower fracture resistance value, although no fracture occurred in it during the TMCL. In contrast, previous studies reported that the mechanical strength of zirconia-reinforced lithium silicate was similar to or higher than that of a lithium disilicate material (20, 24). The lower fracture strength of the inlays made of zirconia-reinforced lithium silicate may be explained by the possible negative effects of TMCL on the zirconia component of the glass ceramic. TMCL may have different effects on restorative materials. In the feldspathic ceramic group (CB), which was made of the most brittle glassy material, one specimen was fractured during TMCL. On the other hand, in the monolithic zirconia group (TZI), which was made of the toughest material, one specimen was decemented. A direct composite resin inlay was tested, as well as inlays made of CAD-CAM blocks, and the fracture resistance of the composite resin inlays differed from that of the high-strength CAD-CAM inlays, although the difference was not statistically significant.

Microleakages and marginal gaps are important factors of successful fixed partial restorations because the gap between the tooth and the restorative material causes gingival problems and secondary caries. The extent of a microleakage depends on many factors, such as the luting agents. Some studies have reported that the type of cement can affect the extent of a microleakage in ceramic inlays (25, 26). In addition, the space where luting cement is applied is digitally adjusted in CAD-CAM systems, and adequate die spacing is a substantial parameter of the accuracy of restoration margins (27). To eliminate the effect of this parameter in the present study, the cement film thickness was standardized by using the same resin cement and setting its thickness at 50 µm during the restoration design. Therefore, the effect of the material type on a microleakage could be evaluated under standardized cementation procedure conditions.

Many techniques have been used to assess microleakages, and there is no consensus on which is the best method. However, in this study, a dye penetration method was used, as it has been widely used in past studies (25, 28). Moreover, all of the specimens used in the microleakage measurements in this study were subjected to thermal cycling to consider the effects of thermal expansion and contraction challenges on the specimen margins. This is because the linear coefficient of thermal expansion has been found to be an important factor of microleakages and to be influenced by the composition of the restorative materials (29-31). Indeed, one of the null hypotheses of the present study is that the ceramic type does not affect the extent of microleakages in inlay restorations, because the extent of the microleakage changed according to the material type. In the present study, the microleakages of CAD-CAM-fabricated ceramic inlays were investigated.

In this study, a variety of inlays were made from prefabricated CAD-CAM blocks, and these were then compared with composite resin (CR) inlays. In all materials, microleakage was mostly seen on the gingival and occlusal margins at both sections. MA Bergman (32) reported that there was less microleakage around ceramic inlays than around direct (CR) restorations in some of the in-vitro studies. In this study, CR inlays were evaluated as a control material, and in many of the specimens, microleakage was seen at all regions. Microleakage was found in all specimens of TZI, e.max, and Emp at the gingival margins of the buccal section; and in two specimens of TZI, microleakage was also seen in the pulpal region. In resin-infiltrated ceramic materials, microleakage was not seen in many of the specimens. Microleakage was found to be mostly in LU at the gingival and occlusal margins. The different microleakage results of inlays produced from different ceramic types might be explained by variations in chemical composition and different marginal adaptations. All ceramic materials that were tested in this study were fabricated by the CEREC system, but after the milling process, along with the procedure of firing or glazing, the materials differed. Several studies evaluated the maximum clinically acceptable marginal gap, and different results were seen in the literature depending on the type of restoration (33, 34); however, there were limited studies regarding the microleakage of new CAD-CAM ceramic materials. Bankoğlu Güngör et al (35) reported that resin-infiltrated hybrid ceramics have marginal and internal gaps that are clinically more acceptable than monolithic zirconia crowns. Yıldırım et al (36) evaluated the marginal and internal adaptation of hybrid and nanoceramics. They go on to discuss the clinically acceptable marginal and internal gaps reported for these materials. In this study, marginal adaptation was not investigated; however, in resin hybrid ceramics, microleakage was not seen in many specimens when compared with other ceramic materials. Schlenz et al (28) advised the use of CAD-CAM material, with its luting system, to avoid microleakage in CAD-CAM composite blocks.

The limitations of this study include the lack of evaluation regarding the marginal-gap values of the ceramic materials. Also, the in-vitro tests give limited information on the properties of the materials as it cannot simulate clinical conditions. The effect of cement space and the type of resin cement on the fracture resistance of inlays that are fabricated from different materials might be evaluated in further research.

Conclusion

Fracture resistance and microleakage are the important factors for clinical success in regard to inlay restorations. Thus, CAD-CAM-produced inlays need to be evaluated in terms of these two factors.

Monolithic zirconia showed the highest fracture resistance but also the highest microleakage.

Hybrid ceramic showed similar fracture resistance to the monolithic zirconia while the lowest microleakage was observed.

Therefore, hybrid ceramics may be a good alternative for inlay restorations.

Disclosures

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