Clinical Research

Evaluation of Repair Bond Strenght of Different Repair Methods and Systems to Zirconia Based Ceramics

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ABSTRACT

Objective: The purpose of this study is to evaluate the bond strength of different repair systems by using composite resin and ceramic cementation repair methods to zirconia-based ceramics.
Material and Method: All-ceramic blocks (IPS Empress II; Ivoclar Vivadent, Schaan, Liechtenstein) sized 4.00 mm in length, 5.4 mm in width, and 3.00 mm in height were fabricated by dental laboratory as thirty specimens. CAD/CAM zirconia blocks (n =40) (Prozir; SeramDent, Turkey) sized 5.00 mm in length, 5.4 mm in width and 13.0 mm in height by CEREC System were fabricated from fully sintered Y-TZP core. Zirconia specimens were randomly divided into seven groups for the following different intraoral repair systems(Clearfil, Cimara Zircon, Bisco) and a control group. Every ten specimens were repaired as same sized. Control group was fabricated by conventional firing as unbroken solid zirconia ceramic samples. Each specimen underwent 5000 cycles of thermocycling. The SBSt (Shear bond strength test) was performed by loading force on the repaired piece to record load-to-failure. Failure mode was evaluated using a digital microscope and SEM. SBSt data were analyzed using one-way ANOVA and Tukey's HSD test.
Results: Clearfil and Cimara Zircon systems significantly increased the bond strength for composite resin method when compared with the Bisco system (respectively p <0.001, p =0.001). All-ceramic method significantly increased the bond strength when compared with the composite resin in Bisco system (p <0.001).
Conclusion: Although the composite restoration method is effective for repair, the all-ceramic/zirconia repair method can be an option for repairing layered zirconia restorations.

Keywords: *Intraoral Repair Systems, Repair Bond Strength, Zirconia, Surface Treatment, SEM.*

ÖZ

Zirkonya Esaslı Seramiklerin Tamir Bağlanma Dayanımlarının Farklı Tamir Yöntemleri ve Sistemleri Kullanılarak Değerlendirilmesi

Amaç: Bu çalışmanın amacı, zirkonya esaslı seramiklere kompozit rezin ve seramik simantasyon tamir yöntemleri kullanılarak farklı tamir sistemlerinin bağlanma dayanımını değerlendirmektir.
Gereç ve Yöntem: 4.00 mm boyunda, 5.4 mm eninde ve 3.00 mm yüksekliğinde tam seramik bloklar (IPS Empress II; Ivoclar Vivadent, Schaan, Lihtenştayn), dental laboratuarda otuz adet olarak üretilmiştir. CEREC Sistemi ile 5.00 mm uzunluğunda, 5.4 mm genişliğinde ve 13.0 mm yüksekliğinde yetmiş (n=40) CAD/CAM zirkonya blok(Prozir; SeramDent, Türkiye) tamamen sinterlenmiş Y-TZP çekirdeğinden üretilmiştir. Zirkonya örnekleri farklı ağız içi tamir sistemleri (Clearfil, Cimara Zircon, Bisco) ve bir kontrol grubu olarak rastgele yedi gruba ayrıldı. Her on numune aynı boyutta tamir edilmiştir. Kontrol grubu, kırılmamış katı zirkonya seramik numuneleri olarak geleneksel fırınlama ile üretilmiştir. Her numuneye 5000 termal döngü uygulandı. SBSt (Kesme bağ mukavemeti testi), yüklemeden kopma oluncaya kadar olan durumu kaydetmek için onarılan parçaya kuvvet uygulanarak gerçekleştirilmiştir. Başarısızlık tipi, bir dijital mikroskop ve SEM kullanılarak değerlendirildi. SBSt verileri, tek yönlü ANOVA ve Tukey'in HSD testi kullanılarak analiz edildi.
Bulgular: Clearfil ve Cimara Zircon sistemleri, Bisco sistemi ile karşılaştırıldığında kompozit rezin yöntemi için bağlanma gücünü önemli ölçüde artırdı (sırasıyla p <0,001, p =0,001). Bisco sisteminde kompozit rezin ile karşılaştırıldığında tam seramik yöntemi bağlanma gücünü önemli ölçüde artırdı (p <0,001).
Sonuç: Kompozit restorasyon yöntemi etkili olsa da, tam seramik/zirkonya yöntemi katmanlı zirkonya restorasyonların tamiri için bir alternatif olabilir.
Anahtar Sözcükler: *Ağız İçi Tamir Sistemleri, Tamir Bağlanma Dayanımı, Zirkonya, Yüzey İşlemi, SEM.*

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Many clinical studies have shown that zirconia-based restorations (ZBR) have a high survival rate of up to 5 years in chewing (1). Y-TZP is a zirconia ceramic that creates a strong tetragonal structure with suitable features after sintering (2). Excellent esthetic restoration is achieved by consubstantiating poor veneer porcelain on a sturdy zirconia core (3, 4). Ceramic ingredients are superior to composite resins in point of their aesthetical

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aspect, biocompatibility, reliability, mechanic features, and reluctance to staining. At the same time, ceramics are constructionally more fragile meaning they are more prone to fracture. Otherwise, composite resins have a low abrasion ratio and easier to complete, polish, and repair (5).

Despite these advantages in CAD/CAM materials, they can break because of insufficient interconnection or insufficient occlusal arrangement, internal tensions, parafunctional habits, fatigue load, inadequate thickness, mismatch of coefficient thermal expansion between core and veneered ceramic, and porosities formed during the manufacturing stage (6-8). Additionally, zirconia sintering process and constructional failures, surface treatment techniques such as sandblasting, etching and grinding, stylize of the structure, continuous porcelain firings, finish-line designs, luting operations, and zirconia aging can all cause probable chipping of ZBR (9-15). Micro-fracture spreads start from these stratums of the restorations and chippings can consist undesirably. Following this, the underlying zirconia core can come into the open or the breakage can keep in the porcelain veneer. Dentists have consistently faced this type of failure (8).

Broken restorations should be replaced instantly with new restoration or repaired using suitable repair material (1, 16). Restoration replacement is time-consuming, pricey, and there is also a major risk of damaging the prepared tooth when an enterprise is made to extract the faulty restoration (17). In addition, ZBR is usually cemented with resin or resin-modified glass ionomer cement, which has the ability to chemically bond to the tooth structure (18). Furthermore, the removal of the zirconia ceramic substructure will ineluctably outcome in injury to the underlying abutment tooth. Therefore, replacing restorations in these conditions is crucial in terms of the risk to the tooth structure, as well as a need for laboratory work, the additional cost of producing an entirely new restoration. Intraoral repair of ZBR is an applicable remedy when there is local damage at the restoration. Repairing broken porcelain in the mouth is a comparatively appropriate alternate to the patient and the treating clinician in terms of more cheaper and time-saving, with the sufficient restoration of function and appearance (19).

Dental aerosol-generating operations create an excessive amount of splashes and aerosols that cause a great worry for airborne illness contamination, such as COVID-19 (20). The generation of aerosol and splash constitutes a great risk for airborne transmission in the clinical atmosphere (21). Most of routine dental operations are creating a concoction of splashes, droplets, and aerosols that include saliva, blood, irrigant water, and alive microorganisms such as bacteria and viruses. Much more caution has been focussed on dental aerosol-creating treatments due to the coronavirus disease 2019 epidemic (COVID-19). The airborne contamination of disease via salivary, bioaerosols creates an important risk to health workers that practice near to the face and oral tissues, such as dental clinic staff (22). Nowadays, intraoral ceramic repairment should be preferred by comparison restoration replacement with a new one due to a large amount of dental aerosol-generating procedures such as removal of restoration with sectioned using a diamond bur and preparation arrangement procedures.

Some authors have recommended the usage of an intraoral repair kit using a composite resin. Method usages a porcelain–resin bonding system to bond composite resin with broken restoration. Various studies have been managing to evaluate the shear bond strength among the ceramic repair kits and framework materials (23-25). In the literature, studies on the impact of intraoral repair kits on the bond strength of composite resin to new CAD/CAM ceramics are restricted.

Resin cements maintain to improve with advanced features. With the development of CAD/CAM technology, the composition of resin cements and upper-durability ceramic materials may be one of the choices for repairing fractured veneer ceramics (26). Nevertheless, there are not enough studies on the use of this composition as a repair method.

Mechanical or chemical surface conditioning techniques have been used to increase the bond strength of resin to the ceramic materials, improve the function of fractured ceramic restorations and protract their time of life. These surface treatment procedures are mainly; grinding with a bur, tribochemical silica coating, laser irradiation, zirconia primers, acid etching (e.g. hydrofluoric acid (HF), acidified phosphate fluoride, and phosphoric acid (PA)), airborne particle abrasion with aluminum oxide (27-32). There are different repair systems recently on the market with varied conditioning protocols. This makes it difficult for clinicians to choose the most correct system to obtain a reliable result (33, 34).

Based these informations, the aim of this study was to evaluate the repair bond strengths of three commercially available ceramic repair systems that applied with two different repair methods.

The null hypotheses tested were; i) there would be no difference in repair bond strengths between the three ceramic repair systems; ii) there would be no difference in repair bond strengths veneered zirconia restorations repaired with the creation of the fractured part by composite resin or bonding of the fractured part by resin cement.

MATERIAL AND METHOD

The design and dimensions of the test samples used in this study were determined in accordance with the Schmitz Schulmeyer specimen (35). Thirty specimens fabricated by dental laboratory all-ceramic blocks with sized 4.00 mm in length, 5.4 mm in width, and 3.00 mm in height (IPS Empress II; Ivoclar Vivadent, Schaan, Liechtenstein) were selected as ceramic substrates. CAD/CAM zirconia blocks with sizes 5.00 mm in length, 5.4 mm in width, and 13.0 mm in height for

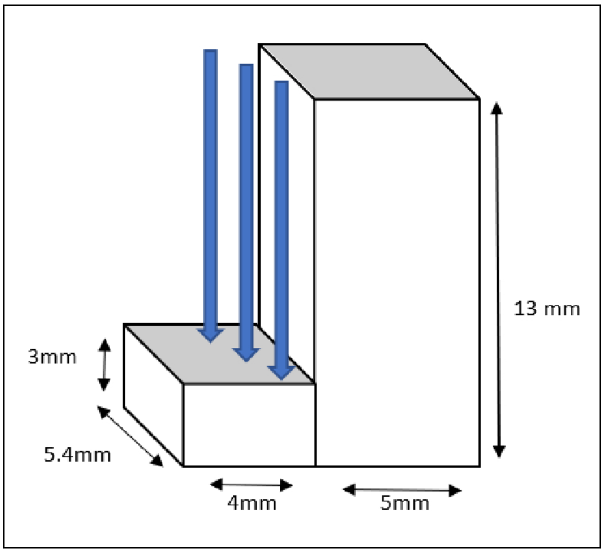
CEREC System (Prozir; SeramDent, Turkey) were selected from fully sintered Y-TZP core. The prepared models were divided into 6 groups according to the application of 3 different repair systems and the use of 2 different repair methods, with 10 samples (n =10) in each group. A total of 70 samples(n =70) were prepared together with the control group. In terms of being economical, ceramic and composite samples were adhered to the opposing surfaces of the zirconia samples. Group I (ZBK group): After the surface treatments of the Bisco repair kit were applied on the zirconium blocks, this side was completed in the same dimensions as the all-ceramic blocks using composite resin (Clearfil Majesty; Kuraray, Osaka, Japan). Group II (ZBS group): After applying the Bisco repair kit and resin cement surface treatments to the zirconium and all-ceramic blocks, the blocks were bonded to each other using resin cement. Group III (ZCK): After the surface treatments of the Clearfil repair kit was applied on the zirconium blocks, this side was completed in the same dimensions as the all-ceramic blocks using composite resin (Clearfil AP-X; Kuraray, Osaka, Japan). Group IV (ZCS): After applying the Clearfil repair kit and resin cement surface treatments to the zirconium and all-ceramic blocks, the blocks were bonded to each other using resin cement. Group V (ZZK): After the surface treatments of the Cimara Zircon repair kit was applied on the zirconium blocks, this side was completed in the same dimensions as the all-ceramic blocks using composite resin (Grandio SO; Voco GmbH, Germany). Group VI (ZZS): After applying the Cimara Zircon repair kit and resin cement surface treatments to the zirconium and all-ceramic blocks, the blocks were bonded to each other using resin cement. Group VII (Control group): Control group samples were fabricated by dental laboratory with conventional methods by layering porcelain in the size of all-ceramic samples on zirconia blocks of specified sizes. Porcelain mixture was fired using a titanium mold to ensure identical dimensions with all-ceramic blocks. Surface treatments for each repair system were applied to all groups according to the manufacturer's instructions (Table 1).

Table 1. *Repair systems and their application procedures.*

Repair Set	Application Procedures	Lot No	Manufacturer
Bisco	**For zirconia** 1) Applied Z Prime Plus (leave for 30 seconds) and dried **For all-ceramic** 1) Applied porcelain etching (9.5% hydrofluoric acid for 90 seconds) rinsed, and dried 2) Applied porcelain primer (leave for 30 seconds) and dried 3) Applied one-step plus bonding resin and light cured (for 15 seconds)	1100006465	Bisco, Schaumburg, USA
Clearfil	**For zirconia** 1) Applied surface roughening with diamond bur 2) Applied alloy primer 3) Mixed the Clearfil SE Bond Primer and porcelain bond activator (for 5 seconds) 4) Applied the bonding agent, air drying, and photo-polymerization(for 10 seconds) **For all-ceramic** 1) Applied surface roughening with diamond bur 2) Applied K-etchant gel (40% phosphoric acid for 5 seconds) rinse, and dry 3) Mixed the Clearfil SE Bond Primer and porcelain bond activator (for 5 seconds) 4) Applied the bonding agent, air drying, and photo-polymerization(for 10 seconds)	041333	Kuraray, Osaka, Japan
Cimara Zircon	**For zirconia** 1) Applied surface roughening with stone bur 2) Applied Cimara Zircon Primer (for 5 seconds) 3) Cimara Zircon Bond (for 10 seconds) followed by air drying and photo-polymerization **For all-ceramic** 1) Applied surface roughening with diamond and stone bur 2) Applied silane (leave for 2 min; dried) 3) Applied Cimara bonding agent (for 10 seconds) followed by air drying and photo-polymerization (for 20 seconds)	1205533	Voco GmbH, Germany

In our study, the opaquers in repair kits were not used since the zirconia infrastructure does not cause any color reflection. A thin layer was applied to the zirconia and all-ceramic surfaces by mixing the resin cement (Panavia F 2.0; Kuraray, Osaka, Japan). The all-ceramic specimens were cemented to zirconia blocks by the resin cement which was polymerized with a LED light curing device (Hılux LED 550; Ankara, Turkey). The light was directed for 20 seconds from 5 different surfaces of bonding areas. After applying the surface treatment processes of the repair systems to the zirconia surfaces it was considered to prepare a transparent mold so that composite resins could be restored to the same dimensions of all-ceramic specimens. For this purpose, an impression from zirconia-ceramic samples (control group) is taken by using elastomeric impression material (Zhermack Elite P&P putty and light; Kouigo, Italy) in a plastic tray and a clear impression surface is provided. Transparent acrylic casts were created from the taken impressions. Acrylic replicas placed in a vacuum machine and covered under heat and pressure with 0.4 mm orthodontic transparent SX plaque. The corners of the transparent plates were notched and aligned for easy placement of zirconia blocks. SX plaques can facilitate manipulation and polymerization during layered composite stacking

because they are transparent. In this way, accurate sized, homogeneous, and smooth composite restorations can be made. Two mm thickness composite resin was polymerized and layered for all groups.
Samples were left in distilled water for 24 hours after polymerization. The kept samples were taken into the thermal cycle process (SD Mechatronik Thermocycler; Julabo GmbH, FT 200, Seelbach, Germany) (between 5 - 55°C, 30 seconds dwell time, 2 seconds waiting time between baths, 5000 cycles). The specimens were fixed in a steel mold and seated in the shear testing jig. SBSt was implemented in a universal testing machine (Instron; Canton, Norwood, USA), the shear load was performed in a direction parallel to the bonded interface at a crosshead speed of 0.5 mm/min. The force was applied onto repaired piece (Figur 1).



Figur 1. *Schmitz Schulmeyer (SBSt) specimen, arrows show that direction of load application during shear bond testing.*

Force was applied until the composite and all-ceramic blocks showed separation or fracture from the zirconia block. The failure load was recorded in Newtons (N). Data were calculated in newtons and then converted to megapascals (MPa).
Following SBSt, all specimens were observed under an optical microscope (Leica MZ 12; Leica Microsystems GmbH, Wetzlar, Germany) at 20 X magnification to examine the fracture type. After that, they were classified as an adhesive (failure in the zirconia-ceramic or zirconia-composite interface), composite cohesive (failure within the composite resin), ceramic cohesive (failure within the ceramic), and mixed (both fracture types). The surfaces of the dried samples were sputter-coated with gold-palladium and they were also observed under a scanning electron microscope SEM (Zeiss Sigma VP; Carl Zeiss, Oberkochen, Germany).
Post-Hoc Power Analysis: The calculated power (1-beta) based on One-Way ANOVA is 1, considering type I error (alfa) of 0.05, sample size of 10, and effect size of 1.91.

Statistical Analysis: SBSt data were analyzed using Statistical Package for the Social Sciences (SPSS) 15 (IBM, Chicago, IL, USA) statistical package program. Kolmogorov Smirnov test was applied to identify whether the data were normally distributed. In addition, the control of variance homogeneity was applied using Levene's test. One-Way Analysis of Variance (ANOVA) was applied, followed by the Tukey HSD test which was used for post hoc comparing of the strength of repair systems. Independent Samples t-test was used for comparing the strength of repair methods. Results were evaluated with confidence interval (95%) and level of significance was determined as ($p < 0.005$).

RESULTS

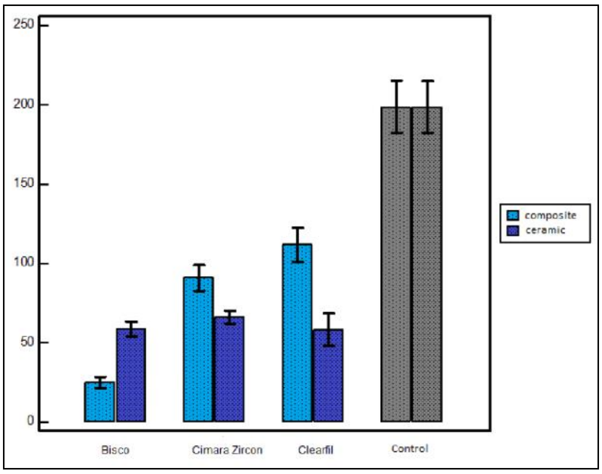
The SBSt results of repair systems used in the repair method with the cementation of the ceramic are summarized in table 2.

Table 2. *SBSt values and statistical analysis results for repair method with the cementation of the all-ceramic p <0.005.*

Group	Mean (MPa)	SD
Control (CNTRL)	12.26	3.22
Cimara Zircon Repair System (ZZS)	4.08	0.78
Bisco Repair System (ZBS)	3.62	0.95
Clearfil Repair System (ZCS)	3.59	2.01

**Post-Hoc values: fort the CNTRL-(ZZS, ZBS, ZCS): p <0.001, ZZS-ZBS: p =0.954, ZZS-ZCS: p =0.946, ZBS-ZCS: p =1.*

Control group showed the highest result (12.26 ±3.22MPa). ZZS group showed the second-highest result (4.08 ±0.78MPa). The lowest shear bond strengths were obtained by ZCS group (3.59±2.01MPa). The SBSt results of repair systems used in the repair method with the restoration of the composite resin are summarized in table 3. Control group showed the highest result (12.26 ±3.22MPa). ZCK group showed the second-highest result (6.90±2.13MPa). The lowest shear bond strengths were obtained by ZBK group (1.54±0.69MPa). In this study, where we measured the repair strength, test groups with the highest strength were identified as control, ZCK, ZZK, ZZS, ZBS, ZCS, ZBK, respectively (Figur 2).



Figur 2. *Average values of the data obtained according to the strength parameter.*

Statistically, a significant difference was found among the groups (exception Clearfil and Cimara Zircon kits) in terms of bond strength values of repair kits in composite resin restoration (Table 3).

Table 3. *SBSt values and statistical analysis results for repair method with the restoration of the composite resin p <0.005***.**

Group	Mean (MPa)	SD
Control (CNTRL)	12.26	3.22
Cimara Zircon Repair System (ZZK)	5.62	1.56
Bisco Repair System (ZBK)	1.54	0.69
Clearfil Repair System (ZCK)	6.90	2.13

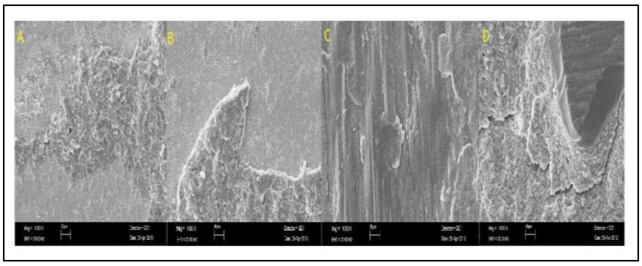
Post-Hoc values: fort the CNTRL-(ZZK, ZBK, ZCK): p <0.001, ZZK-ZBK: p =0.001, ZZK-ZCK: p =0.536, ZBK-ZCK: p <0.001.

Statistically, a significant difference was found also in the same kit (exception Cimara Zircon kit (p =0.012)) according to different repair methods (for the Bisco p <0.001, for the Clearfil p =0.002). Furthermore, repair method with the restoration of the composite resin was found to cause more roughness rather than the other method.
Among the repair kits, only the Bisco kit (ZBS) showed higher bond strength in the repair of made with all-ceramic cementation than the repair made with composite restoration, in the other kits, the repair with composite restoration showed higher bond strength and more desirable mixed fractures were more common than adhesive fractures.
In this study, the number of failure modes that occurred in the samples is given in table 4.

Table 4. *Failure modes of test groups.*

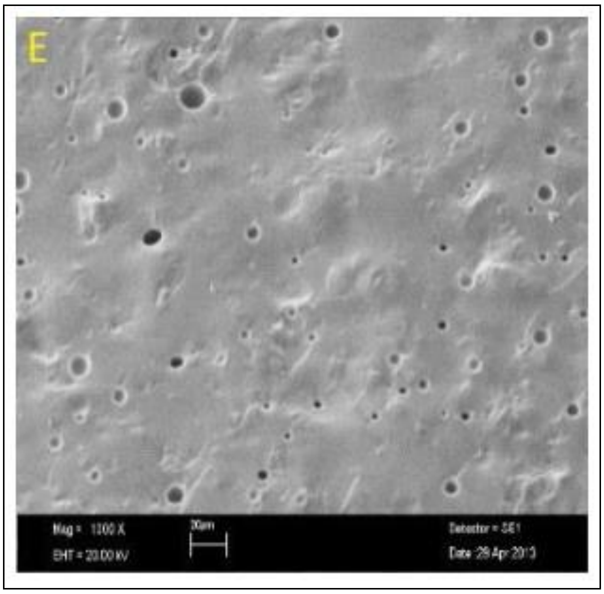
Groups	Adhesive	Cohesive	Mix
ZBK	5	-	5
ZCK	-	-	10
ZZK	-	-	10
ZBS	10	-	-
ZCS	10	-	-
ZZS	10	-	-
CONTROL	-	3	7

All of the separations between zirconium substructure and composite or ceramic superstructures realized place in the interface during the test. In the study, a total of 35 adhesives, 32 mixed, and 3 cohesive fracture types occurred. All fracture modes were observed in SEM. Adhesive fracture modes were observed in all of the repairs made with ceramic cementation and half of the ZBK specimens among the repairs made with composite restoration. Surface treatments traces and remnants of resin cement are seen on the zirconia surfaces (Figur 3).



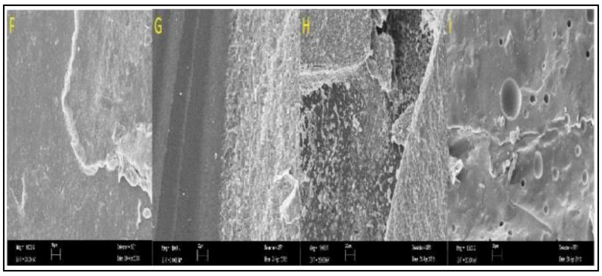
Figur 3. *Micrographs of an adhesive failure case in A:ZBK, B:ZBS, C:ZCS and D:ZZS groups on zirconia surfaces, respectively (1000 × magnification).*

Cohesive fracture modes were observed in the only control group. Pores of porcelain are completely observed on the zirconia surface (Figur 4).



Figur 4. *Micrograph of a cohesive failure case in E: Control group on zirconia surface (1000 × magnification).*

Mix fracture modes were observed in half of the ZBK specimens, all other repair kits repaired with composite restorations, and most of the control group. Surface treatments traces and layers of composite resin and porcelain are seen on the zirconia surfaces (Figur 5).



Figur 5. Micrographs of a mix failure case in F: ZBK, G: ZCK, H: ZZK and I: Control groups on zirconia surfaces, respectively (1000 × magnification).

DISCUSSION

It is required to obtain a sturdy and resistantly resin/zirconia bond for successfully repaired zirconia restorations. The present study was undertaken to evaluate the bond strength of restored composite resin/cemented all-ceramic using different ceramic repair systems to zirconia core materials after 24 hours of storage in water and 5000 thermal cycles. The results of this study represented that there is a difference among the repair systems and repair method with the restoration of the composite resin acted better than repair method with the cementation of the ceramic. For this reason, the null hypotheses were partially rejected.
Oral cavity warmth changes may cause mechanical stresses and fracturing then their propagation in resin-including materials, especially due to differences in the thermal expansion coefficient of the filler and resin matrix (36, 37). Concomitant use of water storage and thermal cycling are generally utilized to mimic intraoral environments. This aging process allows assessment of the bonding steady of the resin-zirconia. Clinically aging will directly affect the mechanical, chemical, and physical features of the material and thus its repairability. The number of cycles in the literature varies between studies and it has been reported that 5000 cycles correspond to an in vivo aging term of 6 months (38). Thermal cycling has been reported to decrease bond strength in general (39). The test specimens in our study were exposed to 24 hours water storage and 5000 thermal cycles before the SBSt.
Different bond strength measurement techniques are used in in-vitro studies such as shear, tensile, microtensile, and three-point bending in dentistry. The SBSt is more generally used than the alternatives due to the method's ease of use, basic, rapid, repeatable, and requirements no furthermore sample processing of the densely sintered zirconia. Most contributors have chosen SBSt in their studies that are bound up with intraoral ceramic repairment(30, 40). SBSt was used in the present study to measure the repair bond strength of the repaired specimens.
The supply of an upper and resistant bond strength between ceramic and repairing material is very important in dental restorations to provide their clinical achievement. Mechanical and chemical retention is necessary to succeed in upper bond strength between ceramic and repairing materials. Mechanical retention can be obtained with acid etching, burs (diamond, stone, etc.), and sandblasting. Chemical retention can be obtained with a primer and silane coupling agent. Acid etching and then primer or silane agent implementation is the most common ceramic surface conditioning (23). The whole ceramic repair systems used in the present study contain acid etching and silane coupling agents, outside of the Cimara Zircon repair system. Cimara Zircon repair system does not need acid etching, which is the concern of the producers.
Gul and Altınok-Uygun (41) applied the surface treatments of different repair kits to different cad/cam ceramic blocks in their study and then nanohybrid resin composite was layered onto treated blocks surfaces. The samples were subjected to thermal cycling prior to the implementation of the repair systems and after the implementation of the composite resin. After microtensile bond strength test was applied to the bar-shaped (1 × 1 × 12 mm3) blocks. In their study, the bond strength values of all repair kits were compared. The obtained values are ordered from the highest to the lowest as Cimara Zircon, Clearfil, Bisco repair kits. The other different results may be due to the use of micro-tensile bond strength test (MTBSt).
In the study of Kumchai et al (26). beveled cylindrical shaped (Ø 10.5 mm, height 7.5 mm) veneered Zirconia crowns were repaired with bonded ceramic and restorative composite resin, similar to our study. In this study, the ceramic cementation process was applied to the beveled porcelain surface, while in our study it was applied to the fully exposed zirconia surface. In this study, veneered zirconia crowns repaired with cemented CAD/CAM ceramic materials had majorly upper bond strength than veneered crowns repaired with resin composite. In our study, the repair procedures performed only with the Bisco kit are parallel to the results of this study. The reason for the lower bond strength values in the repair method made with ceramic cementation of Clearfil and Cimara Zircon repair kits in our study may be the differences in the surface treatments with this study or the use of different resin cement and composite resin.
In the study by Cınar and Kırmalı (39) disc shaped veneer ceramic, zirconia, and veneer ceramic-zirconia specimens (7 mm in diameter and 3 mm in height) were bonded to composite resin using clearfil repair kit after different thermal cycles. Similar to our study using the Clearfil repair kit, the bond strength value of the repair performed on the zirconia surface was higher than on the ceramic surface.
In the study performed by Kocaagaoglu et al (42) in which the same repair kits used in our study were used, surface treatments applied for each repair system were to disk-shaped zirconia ceramic, alumina ceramic, glass ceramic materials (10 mm in diameter, 2 mm thick), and then the composite resin was incrementally condensed onto the infrastructure material surfaces. In this study, although the bond strength ranking of the repair kits in the alumina ceramic group was similar to the

repair group made with ceramic cementation in our study, the bond strength ranking of the repair kits applied to zirconia was the opposite of our study (Bisco>Cimara Zircon>Clearfil). The reason for the different results may be the difference in sample sizes or the application of more thermal cycles in our study.

In another study performed by Kırmalı et al (40), different intra-oral repair systems were applied to the disc-shaped zirconia surfaces (7 mm in diameter and 3 mm in height) and then resin composite built-up. In this study, in which all repair kits used in our study were used, bond strengths were listed as Cimara Zircon (17.31±3.62 MPa) > Clearfil (16.97±2.68 MPa) > Bisco Z-Prime Plus (14.92±2.78 MPa). Although the bond strength values were lower in our study, the lowest bond strength value was found in the Bisco kit, similar to the study in the repair method performed with composite restoration. The reason of these different results may be the thermal aging application in our study.

If there are many cracks on the surface of the coating ceramic remaining after the fracture, due to the attenuation in the unity of the construction, fracture creation may happen again after repairs. It has been reported that fractures after intraoral repair with composite are caused by masticating forces, trauma, or wrong bonding processes (43). Prior to starting the repair procedure, the reason of the fracture such as bruxism and premature occlusal contacts in the lateral movements must be detected and removed in order to refrain from unsuccess. Additionally, suitable ceramic repair material and surface conditioning are crucial for long-term clinical achievement (44).

Limitations of this study:

1. Not using saliva; The bond strength of a resin material is sensitive to mechanical or chemical effects in intraoral circumstances (17),
2. Not using the chewing simulator; The shearing test was not able to simulate the loading strengths alone owing to formed during chewing non-homogeneous stress dispersion (44),
3. Not using the micro-tensile bond strength (MTBS); SBS outcomes in upper values of variety according to MTBS because of the wider bonding surface field analyzed in the shear test. This wider bonding surface has more defects than narrower surfaces in MBTS (45).

Other directions of the test, such as the influence of repair dimension, loading angulation, and periodic fatigue must be conducted for a more exhaustive assessment of repair systems. Further in vitro and in vivo studies should be studied to identify the right repair methods using more compositions of repair systems, testing devices, specimen materials, and sample design (44, 45).

Conclusion

Within the limitations of this study, the following conclusions could be drawn:

1. Cimara Zircon repair system had the highest bond strength between repair systems for repair method with the cementation of the all-ceramic.
2. Clearfil repair system had the highest bond strength among repair systems for repair method with the restoration of the composite resin.
3. With the exception of the Bisco repair system, the repair method with the restoration of the composite resin showed higher bond strength.
4. In zirconia ceramic fractures; It may be recommended to restore the broken part with composite resin in cases where it breaks to pieces and crumbles, to bond the broken facet or fabricated all-ceramic in cases where the broken part is separated as a facet or broken with a regular margin.

Conflıct of Interest

The authors deny any conflicts of interest related to this study.

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REFERENCES

1. Burke FJ, Crisp RJ, Cowan AJ, Lamb J, Thompson O, Tulloch N. Five-year clinical evaluation of zirconia-based bridges in patients in UK general dental practices. J Dent 2013; 41: 992-9.
2. Guess PC, Kulis A, Witkowski S, Wolkewitz M, Zhang Y, Strub JR. Shear bond strengths between different zirconia cores and veneering ceramics and their susceptibility to thermocycling. Dent Mater 2008; 24: 1556-67.
3. Cristoforides P, Amaral R, May LG, Bottino MA, Valandro LF. Composite resin to yttria stabilized tetragonal zirconia polycrystal bonding: comparison of repair methods. Oper Dent 2012; 37: 263-71.
4. Thompson JY, Stoner BR, Piascik JR, Smith R. Adhesion/cementation to zirconia and other non-silicate ceramics: where are we now? Dent Mater 2011; 27: 71-82.

5. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent Mater 2013; 29: 419-26.
6. Ustun O, Buyukhatipoglu IK, Secilmis A. Shear Bond Strength of Repair Systems to New CAD/CAM Restorative Materials. J Prosthodont 2018; 27: 748-54.
7. Tan K, Pjetursson BE, Lang NP, Chan ES. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years: III. Conventional FPDs. Clin Oral Implants Res 2004; 15: 654-66.
8. Sailer I, Pjetursson BE, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal–ceramic reconstructions after an observation period of at least 3 years. Part II: fixed dental prostheses. Clin Oral Implants Res 2007; 18: 86-96.
9. Lorente MC, Scherrer SS, Richard J, Demellayer R, Amez-Droz M, Wiskott HA. Surface roughness and EDS characterization of a Y-TZP dental ceramic treated with the CoJet™ Sand. Dent Mater 2010; 26: 1035-42.
10. Comlekoglu M, Dundar M, Özcan M, Gungor M, Gokce B, Artunc C. Influence of cervical finish line type on the marginal adaptation of zirconia ceramic crowns. Oper Dent 2009; 34: 586-92.
11. Fischer J, Grohmann P, Stawarczyk B. Effect of zirconia surface treatments on the shear strength of zirconia/veneering ceramic composites. Dent Mater J 2008; 27: 448-54.
12. Inokoshi M, Kameyama A, De Munck J, Minakuchi S, Van Meerbeek B. Durable bonding to mechanically and/or chemically pre-treated dental zirconia. J Dent 2013; 41: 170-9.
13. Kokubo Y, Tsumita M, Kano T, Fukushima S. The influence of zirconia coping designs on the fracture load of all-ceramic molar crowns. Dent Mater J 2011; 30: 281-5.
14. Lughi V, Sergo V. Low temperature degradation-aging-of zirconia: A critical review of the relevant aspects in dentistry. Dent Mater 2010; 26: 807-20.
15. Monaco C, Tucci A, Esposito L, Scotti R. Microstructural changes produced by abrading Y-TZP in presintered and sintered conditions. J Dent 2013; 41: 121-6.
16. Crisp R, Cowan A, Lamb J, Thompson O, Tulloch N, Burke F. A clinical evaluation of all-ceramic bridges placed in patients attending UK general dental practices: three-year results. Dent Mater 2012; 28: 229-36.
17. Lee SJ, Cheong CW, Wright RF, Chang BM. Bond strength of the porcelain repair system to all-ceramic copings and porcelain. J Prosthodont 2014; 23: 112-6.
18. Gargari M, Gloria F, Napoli E, Pujia AM. Zirconia: cementation of prosthetic restorations. Literature review. Oral Implantol 2010; 3: 25.
19. Agingu C, Zhang C-y, Jiang N-w, Cheng H, Özcan M, Yu H. Intraoral repair of chipped or fractured veneered zirconia crowns and fixed dental prosthesis: clinical guidelines based on literature review. J Adhes Sci Technol 2018; 32: 1711-23.
20. Han P, Li H, Walsh LJ, Ivanovski S. Splatters and Aerosols contamination in dental aerosol generating procedures. Appl Sci 2021; 11: 1914.
21. Zemouri C, de Soet H, Crielaard W, Laheij A. A scoping review on bio-aerosols in healthcare and the dental environment. PLoS One 2017; 12: e0178007.
22. Peng X, Xu X, Li Y, Cheng L, Zhou X, Ren B. Transmission routes of 2019-nCoV and controls in dental practice. Int J Oral Sci 2020; 12: 1-6.
23. Kim B-K, Bae HE-K, Shim J-S, Lee K-W. The influence of ceramic surface treatments on the tensile bond strength of composite resin to all-ceramic coping materials. J Prosthet Dent 2005; 94: 357-62.
24. Ozcan M, Van Der Sleen JM, Kurunmäki H, Vallittu PK. Comparison of repair methods for ceramic-fused-to-metal crowns. J Prosthodont 2006; 15: 283-8.
25. Ozcan M, Valandro LF, Pereira SM, Amaral R, Bottino MA, Pekkan G. Effect of surface conditioning modalities on the repair bond strength of resin composite to the zirconia core/veneering ceramic complex. J Adhes Dent 2013; 15: 207-10.
26. Kumchai H, Juntavee P, Sun AF, Nathanson D. Comparing the Repair of veneered zirconia crowns with ceramic or composite resin: an in vitro study. Dent J 2020; 8: 37.
27. Yoo J-Y, Yoon H-I, Park J-M, Park E-J. Porcelain repair-Influence of different systems and surface treatments on resin bond strength. J Adv Prosthodont 2015; 7: 343-8.
28. Shin YJ, Shin Y, Yi YA, Kim J, Lee IB, Cho BH, et al. Evaluation of the shear bond strength of resin cement to Y-TZP ceramic after different surface treatments. Scanning 2014; 36: 479-86.
29. Usumez A, Hamdemirci N, Koroglu BY, Simsek I, Parlar O, Sari T. Bond strength of resin cement to zirconia ceramic with different surface treatments. Lasers Med Sci 2013; 28: 259-66.
30. Han I-H, Kang D-W, Chung C-H, Choe H-C, Son M-K. Effect of various intraoral repair systems on the shear bond strength of composite resin to zirconia. J Adv Prosthodont 2013; 5: 248-55.
31. Tylka DF, Stewart GP. Comparison of acidulated phosphate fluoride gel and hydrofluoric acid etchants for porcelain-composite repair. J Prosthet Dent 1994; 72: 121-7.
32. Kupiec KA, Wuertz KM, Barkmeier WW, Wilwerding TM. Evaluation of porcelain surface treatments and agents for composite-to-porcelain repair. J Prosthet Dent 1996; 76: 119-24.

33. Blum IR, Nikolinakos N, Lynch CD, Wilson NH, Millar BJ, Jagger DC. An in vitro comparison of four intra-oral ceramic repair systems. J Dent 2012; 40: 906-12.
34. Ozcan M, Valandro LF, Amaral R, Leite F, Bottino MA. Bond strength durability of a resin composite on a reinforced ceramic using various repair systems. Dent Mater 2009; 25: 1477-83.
35. Schmitz K, Schulmeyer H. Determination of the adhesion of dental metal-porcelain bonding systems. Dent Labor 1975; 23: 1416-20.
36. Blackburn C, Rask H, Awada A. Mechanical properties of resin-ceramic CAD-CAM materials after accelerated aging. J Prosthet Dent 2018; 119: 954-8.
37. Celik Koycu B, Imirzalıoglu P. Heat transfer and thermal stress analysis of a mandibular molar tooth restored by different indirect restorations using a three-dimensional finite element method. J Prosthodont 2017; 26: 460-73.
38. Subası MG, Alp G. Repair bond strengths of non-aged and aged resin nanoceramics. J Adv Prosthodont 2017; 9: 364-70.
39. Cınar S, Kırmalı O. Repair bond strength of composite resin to zirconia restorations after different thermal cycles. J Adv Prosthodont 2019; 11: 297-304.
40. Kirmali O, Kapdan A, Harorli OT, Barutcugil C, Ozarslan MM. Efficacy of ceramic repair material on the bond strength of composite resin to zirconia ceramic. Acta Odontol Scand 2015; 73: 28-32.
41. Gul P, Altınok-Uygun L. Repair bond strength of resin composite to three aged CAD/CAM blocks using different repair systems. J Adv Prosthodont 2020; 12: 131.
42. Kocaagaoğlu H, Manav T, Albayrak H. In vitro comparison of the bond strength between ceramic repair systems and ceramic materials and evaluation of the wettability. J Prosthodont 2017; 26: 238-43.
43. Ozcan M, Niedermeier W. Clinical study on the reasons for and location of failures of metal-ceramic restorations and survival of repairs. Int J Prosthodont 2002; 15: 299-302.
44. Mohamed FF, Finkelman M, Zandparsa R, Hirayama H, Kugel G. Effects of surface treatments and cement types on the bond strength of porcelain-to-porcelain repair. J Prosthodont 2014; 23: 618-25.
45. Akay C, Cakırbay Tanıs M, Sen M. Effects of hot chemical etching and 10-Metacryloxydecyl Dihydrogen Phosphate (MDP) monomer on the bond strength of zirconia ceramics to resin-based cements. J Prosthodont 2017; 26: 419-23.