Shear bond strengths of five porcelain repair systems to zirconia infrastructures

Purpose
This study aimed to investigate the effect of five porcelain repair systems on shear bond strength in composite and zirconia infrastructures and to identify the bond failure mode after thermocycling.

Materials and Methods
Disk-shaped zirconia samples (n=50) were divided into five groups (n=10) according to repairing system type. Each repair system was applied to the zirconium samples and a hybrid composite was used for repairing. Shear bond testing of all groups was carried out using a universal testing machine after thermocycling.

Results
Repair systems demonstrated no significant difference in repairing zirconia except Single Bond. Single Bond was the weakest in repairing the infrastructures. The highest and lowest mean bond strength values for the zirconia groups were 18.91 MPa and 3.63 MPa, respectively.

Conclusion
The three repair systems, Ivoclar, Clearfil, and Bisco, were more effective than the Single Bond and Ultradent repair systems in repairing zirconia, and their bond failure modes were both mixed and adhesive.

Keywords: Repair system, zirconia, shear bond, adhesive system, bond failure

Introduction
Although the use of all-ceramic restorations have become widespread in recent years due to their aesthetic superiority, metal-ceramic restorations are still the most frequently used restorations due to their mechanical durability (1,2). Due to the increasing cost of gold alloys in the 1960s, the use of alternative alloys for prosthetic restorations became more popular. The mechanical properties of these materials allow for thinner but more robust restorations (3). Due to cost and rigidity nickel-chromium and cobalt-chromium alloys are preferred (4).

The increase in the aesthetic expectations of individuals in recent years has led to the development of different types of dental ceramic restorations (5–7). The chemical properties of the ceramics and their superior performance in mimicking dental tissues were the main reasons behind the widespread use of these dental materials (8). Zirconium material was first introduced in dentistry in 1990 as a crown prosthetic and as an infrastructure material in fixed prostheses (9).

Most all-ceramic materials have been developed to achieve esthetic restoration. One of the most used all-ceramic esthetic restorations is zirconia, which differs from others by its resistant mechanical properties. Zirconia has three forms: monoclinic, tetragonal, and cubic; it structure is...
monoclinic at room temperature and transforms to the cubic and tetragonal phases with increasing temperature (9).

Porcelain veneer fractures have been reported to be the most common reason for the replacement of metal-ceramic crowns and bridges (10,11). The failure of veneered porcelain may occur from inadequate metal framework design, tooth preparation and occlusal adjustment (12,13).

The most frequent complication is the small chip-off fracture of veneered ceramic. Although replacing them with ceramic restorations is a common approach, they can be repaired intraorally when they are not completely damaged (14–16). During the replacement of a fractured ceramic restoration trauma may damage the remaining teeth and tissues. This procedure costs more than repairing the chipped part (17). Numerous commercial intraoral ceramics repairing systems has been developed for repairing these kinds of restorations. On the other hand, scientific studies reveal that ceramic repair systems cannot create a persistent solution due to their weakened bond strength (18,19).

The bonding strength between the cracked restoration and the repair material must be strong enough. When the bond strength of ceramic repair systems is at clinically acceptable levels, the time and money spent on making a new restoration will be reduced (7).

In the present study, five ceramic repair systems were used to simulate chairside zirconia infrastructure repair using composite resin. The aim was to compare the effects of the five repair systems on the shear bond strength (SBS) between the composite and zirconium to analyze the mode of failure in each experimental group. The null hypothesis is as follows: there is no difference in the bond strength of the different ceramic repair systems in repairing a zirconia infrastructure.

### Materials and methods

#### Study design and sample preparation

50 disk-shaped zirconia samples with a 10 mm diameter and a 3 mm thickness were used in the present study. The zirconia disks were prepared from presintered blocks (H.C. Starck, Berlin, Germany) according to the manufacturer’s instructions using a CAD/CAM system (CORITEC T 350i loader,谙-es, Eiterfeld, Germany) and sintered to the final dimension (10 mm in diameter and 3 mm thick) in a special high-temperature furnace. Table 1 shows the materials used and their manufacturer’s information.

All disk specimens were properly polished by a special polishing machine (Tegrapol-11;Struers, Ballerup, Germany) using wet silicon carbide paper ground with 600, 800, and 1,000 grit under cool water for 1 min. All zirconia disks were treated with airborne-particle abrasion device (Airsonic Mini Sandblaster, Hager & Warken, Duisburg, Germany) with a 50-μm particle size aluminum-oxide for 10 seconds at a pressure of 0.3 MPa and from 10 mm distance.

The repairing procedure was performed by the same operator (S.A.). Each repair system used in this study was applied to the zirconium samples according to the manufacturer’s instructions, as explained in Table 2.

Hybrid composite resin was incrementally packed with a hand instrument using a specially designed epoxy glass mold (6 mm diameter and 3 mm thickness). Each layer was light-cured with a light polymerizing unit (3M Elipar S10, 3M Espe, Germany) for 40 s at a distance of 1 mm with an output of 1,000 mW/cm2. The wavelength of the light polymerizing unit was measured by a spectroradiometer (Model 77702, Oriel Instrument, Danbury, CT, USA), power density was measured using a radiometer (Radiometer LED, Demetron/Kerr, Danbury, CT, USA) prior to every specimen curing.

The bonding process was conducted by the same operator during experiments. After polymerization, the assembly of the repaired samples was removed from the mold, and light curing was repeated in five aspects of all blocks (upper and lateral) for 20 s per side.

#### Experimental groups

The samples (N = 50) were divided into five groups (n = 10): zirconia with the Bisco repair system (ZB), zirconia with the Clearfil repair system (ZC), zirconia with the Ivoclar ceramic repair system (ZI), zirconia with Single Bond (ZS), and zirconia with the Ultradent repair system (ZU).

#### Thermocycling protocols

The samples were all stored in distilled water at 37 °C for 24 hours and then subjected to thermal cycling (Silburski Technica Termal Siklus, Istanbul, Turkey) of 1,200 cycles at 5–55 °C, with a dwell time of 20 s at each temperature and a transfer time from one bath to the other of 10 s.

#### Testing protocols

All samples were fixed by chemically cured acrylic resin in a steel mold. Shear bond testing of all groups was carried out using universal testing machine (Instron 3345, Instron Corp., Norwood, Illinois, USA) at a crosshead speed of 1 mm/min. SBS values were calculated by dividing the maximum load at failure (N) by the bonding area (mm2) and recorded in megapascals (MPa). The failure modes of the bond related to the fractured surfaces were analyzed visually by using a stereomicroscope (EMS-405, Esman, Turkey) at 20x magnification. The failure areas were classified as adhesive, cohesive, or mixed type.

#### Statistical analysis

Statistical analyses were performed by the Number Cruncher Statistical System 2007 (NCSS, Utah, USA) software for Windows. The Shapiro–Wilk test was used to analyze if the measured parameters met the assumptions of normal distribution. The results of the test indicated that the data were normally distributed. Therefore, data were analyzed using the one-way ANOVA and the Tukey’s HSD was performed to determine the group responsible for the difference. p-values less than 0.05 were considered statistically significant.

### Results

Table 3 shows maximum, minimum, mean values and standard deviation values of the SBS test for the groups. The lowest and highest mean bond strength values for the zirconia groups were 18.91 MPa and 3,63 MPa respectively. When the SBS values of the repair systems applied to the zirconia groups were compared, both Ultradent (ZU) and single bond (ZS) repair systems showed lower SBS values than the
Table 1: Details of the materials used in the study.

| Material | Composition | Manufacturer | Lot no. |
|----------|-------------|--------------|---------|
| Zirconia (Z) | ZrO2/HfO2/Y2O3>99, Al2O3 <0.10, Fe2O3 <0.10, Na2O 3<0.04 | H.C.Starck, Berlin, Germany | 50574292 50575967 |
| Clearfil repair system (C) | K-etchant gel: 40% phosphoric acid, Clearfil-SE Bond Primer: 10-methacryloyloxydecyl dihydrogen phosphate (MDP), HEMA, dimethacrylate monomer, water, photoinitiator, Clearfil-SE Bond: silanated colloidal silica, Bis-GMA, 10-MDP, Clearfil Porcelain bond activator: bisphenol A polyethoxy dimethacrylate 3-methacryloxypropyltrimethoxy silane (MPS) | Kuraray Co., Osaka, Japan | 000016 |
| Bisco repair system (B) | 9.5% Hydrofluoric acid, Silane with methacrylate Solution: Alcohol, One step: bis-GMA, BPDM, HEMA, CO, p-dimethylaminobenzoic acid (co-initiator), acetone, 8.5% glass fillers | BISCO Dental Products, Illinois, U.S.A. | 1700001601 |
| Ivoclar repair system (I) | Monobond+ Plus a Primer: Alcohol solution of silane methacrylate, phosphoric acid methacrylate and sulphide methacrylate. HelioBond – a light-curing bonding agent: Bis-GMA and triethylene glycol dimethacrylate (99 wt.%), initiators and stabilizers (<1%). | Ivoclar Vivadent Inc., Liechtenstein, Switzerland | T42712 |
| Ultradent repair system (U) | Etch: 9% hydrofluoric acid, Ultradent silane: 8% methacryloyloxypropyl-trimethoxysilane, isopropyl alcohol, acetic acid, Peak Universal Bond: 7.5% ethyl alcohol, 0.2% chlorhexidine, methacrylic acid, 2-HEMA | Ultradent Products GmbH, Cologne, Germany | BFC4 |
| Single bond (S) | MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond Copolymer Filler, Ethanol, Water, Initiators, Silane | 3M, ESPE, St., Paul, MN, USA | 604724 |
| Filtek Z250 (shade C2) | Matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA, Filler: zirconia, Silica | 3M, ESPE, St., Paul, MN, USA | NS66178. NS545065 |

Table 2: Application procedures and contents of the repair systems used in this study.

| Application procedures | Content |
|------------------------|---------|
| Bisco Repair System (B) | Apply 1 coat of Z-PRIME Plus to the exposed zirconia, dry with an air syringe for 3-5 seconds. Apply a thin layer of PORCELAIN BONDING RESIN to the repair site. Spread composite evenly over the surface and light cure. Repair was completed using composite resin and light cured for 40 seconds |
| Clearfil Repair System (C) | K-etching gel, Clearfil SE Bond Primer and porcelain bond activator were mixed for 5 seconds. Bonding agent was applied for 10 seconds (air drying) and photopolymerization for 40 seconds. Repair was completed using composite resin and light cured for 40 seconds |
| Ivoclar Repair System (I) | Monobond Plus was applied and allowed to react for 60 seconds and after air dried. Thin layer of HelioBond was applied and light cured for 90 seconds. Repair was completed using composite resin and light cured for 40 seconds |
| Ultradent Porcelain Repair system (U) | Apply Hydrofluoric acid on metal surface for 90 second. Apply silane and leave 1 minute. Apply Peak Universal bond for 10 second and light cure for 20 second |
| Single Bond universal adhesive (S) | Apply on surface of Zirconium leave it for 20 second dry with air for 5 second. Light cure for 20 seconds |
Veneering porcelain fracture is a common complication that can occur in all dental ceramic systems. The incidence of chipping fractures is significantly higher for metal-ceramic and zirconia-based fixed dentures than for framework fractures. For both restorations, veneer chipping can be treated by polishing or repairing rather than replacing the restorations (20).

Five different repair systems were compared in this study. According to the results of the study, the null hypothesis was rejected. The SBS of zirconia to composite resin was significantly different among different repair systems. The samples were subjected to thermocycling for 1,200 cycles at 5–55°C. According to Gale and Darvell (21-23), 10,000 cycles could represent a year of service, as 20–50 cycles are equal to one day. The thermal cycle procedure has been applied similarly in many other studies, and thus we used the same protocol to compare our results with theirs.

Generally, shear bond tests or tensile bond tests are used to measure bond strength. The tensile bond strength test is extremely affected by sample form and the formation of non-uniform stress distributions throughout load applications. The shear bond strength test is the most widely used test for bond strength because of its simple usage, clear test protocol, and rapid production of the test result (23,24). For these reasons, the shear bond tests were performed to evaluate the bond strength in our study as in previous studies (23-25).

Sandblasting provides micromechanical retention and a stronger composite-metal bond when performed on zirconia. In comparing the different repair systems in this study, the surface treatments were not changed, and the sandblasting process, which is one of the most effective methods, was performed for all groups (25). Matsumura et al. (26) reported the SBS value of 10 MPa as the minimal to obtain clinically acceptable results. According to the results of the present study, all the repair systems, except ZS and ZU, have exceeded 10 MPa. Statically significant differences were found between the repair systems, and thus the null hypothesis was rejected. Kocaagaoglu and Gurbulak (27) evaluated the SBS between two porcelain repair kits and zirconia or a nonprecious metal alloy. After thermocycling for 1,200 cycles, the SBS of the zirconia group using the Clearfil repair system was 8.80 MPa, and the SBS of metal was 19.75 MPa. We evaluated the SBS of the five porcelain repair systems and the zirconia infrastructure materials after thermocycling for 1,200 cycles. The result of the Clearfil repair system was 18.61 MPa. The difference may be due to the use of a rotary cutting instrument, as 30 μm is not sufficient to roughen a zirconia surface. Zirconia has superior hardness and needs to be ground with coarse diamond rotary instruments (28).

Goncalo et al. tested the effect of a surface treatment and primer application on the composite SBS to zirconia. The zirconia prime plus group, which is present in the Bisco repair system and is similar to our ZB group, was higher, and the scores were similar to those in our study (29,30).

Table 3: Shear bond strengths values (MPa) of the groups.

| Groups (n=10) | Minimum | Maximum | Mean  | Std. Deviation |
|--------------|---------|---------|------|----------------|
| ZB           | 14.29   | 27.65   | 18.91| 4.33           |
| ZC           | 9.33    | 28.37   | 18.61| 5.37           |
| ZI           | 8.76    | 23.51   | 15.24| 5.30           |
| ZS           | 2.73    | 4.80    | 3.63 | 0.62           |
| ZU           | 4.99    | 9.87    | 6.63 | 1.50           |

Table 4: Pairwise comparisons of the repair systems.

| Tukey Multiple Comparisons Test | P     |
|--------------------------------|-------|
| ZS/ZB                          | 0.0001|
| ZS/ ZC                         | 0.0001|
| ZS / ZI                        | 0.447 |
| ZS / ZU                        | 0.999 |
| ZB / ZC                        | 0.249 |
| ZB / ZU                        | 0.0001|
| ZC / ZI                        | 0.331 |
| ZC / ZU                        | 0.0001|
| ZI / ZU                        | 0.0001|

Discussion

Veneering porcelain fracture is a common complication that can occur in all dental ceramic systems. The incidence of chipping fractures is significantly higher for metal-ceramic and zirconia-based fixed dentures than for framework fractures. For both restorations, veneer chipping can be treated by polishing or repairing rather than replacing the restorations (20).
a ceramic repair system (Ivoclar), 7.80 MPa for a CoJet repair system, and 8.98 MPa for a Signum Zirconia Bond (30). The SBS of the ceramic Ivoclar repair system was weak even without thermocycling. The score for Ivoclar of the ZI group in our study was 15.24 MPa, which was higher than that in the previous study. This may be due to the fact that a zirconia surface should be sandblasted, which is a more effective method for roughening a zirconia surface. Kocaoglu et al. (31) examined the effect of three intraoral ceramic repair systems on the bond strength between composite resin and zirconia (31). The SBS was 10.85 MPa for the Clearfil repair system and 12.64 MPa for the Bisco intraoral repair kit. Compared with the results of our study, the results were lower in Kocaoglu et al’s study (31). We sandblasted the zirconia samples before application, and this could have enhanced the retention.

No significant difference was found among Clearfil, Bisco, and the ceramic repair system used for repairing the zirconia infrastructure properly because the three repair systems, which contained bonding agents and organophosphate monomers (e.g., 10-methacryloyloxydecyl dihydrogen phosphate [MDP]), were developed to improve the bond strength of resin-based materials to a silica-free zirconium structure (32, 33). Previous studies showed that commercial phosphate-monomer-containing zirconia primers, improved both the initial and long-term resin bond strength to zirconia ceramic substrates significantly (34–40). The pretreatment of zirconia with MDP-containing adhesive systems can lead to satisfactory adhesion between the different composite resins and ceramic surfaces even after the artificial aging process (41). Moreover, similar to our study, the surface treatment of air-abrasion and phosphate-monomer-containing primer application improved the durability of zirconia-resin bond strength (42–45).

A significant difference was found among the three repair systems (Bisco, Ultradent, and Clearfil) and between the other two repair systems (Ultradent and Single Bond adhesive), probably because Ultradent and Single Bond adhesive depend on silane as a surface treatment. Silane materials were often used for coupling with silica-based ceramics through the formation of a chemical covalent bond to obtain a chemical bond between resin and zirconia, which have silica-free and relatively nonpolar surfaces. They are chemically much more stable than silica-based ceramics, and thus traditional silane chemistry is not usually effective for zirconia (41).

Evaluating the mode of failure of specimens is important to demonstrate the quality of the bond to treated zirconium and composite resins. In this study, the tested specimens exhibited adhesive failure with the Ultradent and Single Bond repaired specimens, indicating that the Single Bond adhesive and Ultradent repaired specimens obtained a weak bond with the composite. As in previous studies, a higher mean SBS value is related to the predominance of mixed failure modes (45–46).

None of the repair methods resulted in cohesive failures in the zirconia specimens. This may be due to the effect of thermocycling on the bond between zirconia and composite resin.

No significant difference was observed in the mode of bond failure of the Bisco, Ultradent, and Clearfil repair systems. This result may be related to the presence of MDP, which increases the bond between zirconia and composite resin.

This study has the following limitations: the number of thermal cycles was limited, only one surface roughness method was investigated, and the experimental device can not fully simulate the oral environment. Further studies with higher number thermal cycles and those focusing on other types of surface roughness should be performed to provide more reliable information about repair systems.

**Conclusion**

Within the limitations of the present experimental study, the three repair systems, namely Ivoclar, Clearfil, and Bisco, could be used effectively for repairing chipped veneered porcelain for zirconia infrastructures. The observed failure modes indicate that Ivoclar, Clearfil, and Bisco repair systems could have advantages over others.

**Türkçe Özet:** Beş farklı porselen tamir sisteminin Zirkonya alta yapılara bağlanma dayanımının karşılaştırılması. Amaç: Bu çalışmanın amaç, termal siklus sonrası beş farklı porselenin kompozit ve zirkonya altı yapılan arastırdaki bağlanma dayanımı üzerindeki etkisi, ve meydana gelen ayrımlar tıplerinin artırılmasıdır. Gereç ve Yöntem: Disk şekilde oluşturulmuş örnekler (n=50), Z’ten yapıldı, tamir sistemi tipine göre beş alt grubu (n=10) ayrıldı. Herbir tamir sistemi zirkonyum numunelerine uygulandı ve onarım için hibrit kompozit kullanıldı. Tüm grupların bağlanma dayanımı testleri, termodoksiklik sonrasında Universal test makinesi kullanılarak gerçekleştirildi. Bulgular: Zirkonya altı yapımında Single bond tamir sistemi haric diğer tamir sistemlerinde anakromlar bir farklılık belirlenmedi. Single bond altı yapısının tamirinde en zayıf olarak bulunmuştur. Zirkonya grupları için en yüksek ve en düşük ortalamalı bağlanma dayanımı değerleri sırasıyla 18.91 MPa ve 3.63 MPa olarak ölçülmüştür. Sonuç: Zirkonya altı yapımında üç tamir sisteminin (Ivoclar, Clearfil ve Bisco), Single bond ve Ultradent tamir sistemine göre daha etkili olduğu saptanmış ve ayrımlar tıpleri mixed ve adeziv olduğu görülmüştür. Anahtar kelimeler: Tamir sistemi; zirkonya; bağlanma dayanımı; adeziv sistem; ayrımla tıpleri.

**Ethics Committee Approval:** Not required.

**Informed Consent:** Not required.

**Peer-review:** Externally peer-reviewed.

**Author contributions:** SA, FE, and MÇG designed the study. SA, FE, and MCG generated data for the study. SA, FE, and MCG gathered data. SA, FE, and MCG wrote the manuscript. All authors approved the final version of this paper.

**Conflict of Interest:** The authors declared that they have no conflict of interest.

**Financial Disclosure:** The authors declared that this study received no financial support.

**References**

1. Kelsey WP, 3rd, Latta MA, Stanislav CM, Shaddy RS Comparison of composite resin-to-porcelain bond strength with three adhesives. Gen Dent 2000;48:418-21. PMID: 11199616
2. Tulunoglu IF, Beydemir B. Resin shear strength to porcelain and a base metal alloy using two polymerization schemes. J Prostheth Dent 2000;83:181-6.[CrossRef]
3. Sced IR, McLean JW. The strength of metal/ceramic bonds with base metals containing chromium. A preliminary report. Br Dent J 1972;132:232-4.[CrossRef]
4. Prado RA, Panzeri H, Fernandes Neto AJ, Neves FD, Silva MR, Mendonca G Shear bond strength of dental porcelains to nickel-chromium alloys. Braz Dent J 2005;16:202-6.[CrossRef]
5. Ikemura K, Tanaka H, Fuji T et al. Development of a new single-bottle multi-purpose primer for bonding to dental porcelain, alumina, zirconia, and dental gold alloy. Dent Mater J 2011;30:478-84. [CrossRef]

6. Yavuz T, Dilber E, Kara HB et al. Effects of different surface treatments on shear bond strength in two different ceramic systems. Lasers Med Sci 2013;28:1233-39. [CrossRef]

7. Lee SJ, Cheong CW, Wright RF, et al. Bond strength of the porcelain repair system to all-ceramic copings and porcelain. J Prosthodont 2014;23:112-6. [CrossRef]

8. Della Bona A, Mecholsky JJ, Jr, Barrett AA, et al. Characterization of glass-infiltrated alumina-based ceramics. Dent Mater 2008;24:1568-74. [CrossRef]

9. 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. [CrossRef]

10. Gordon SR, Lloyd PM. Fixed prosthodontics in the elderly population. Life expectancy of fixed restorations, failures, and retreatment methods. Dent Clin North Am 1992;36:783-95.

11. Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: length of service and reasons for replacement. J Prosthodont Dent 1986;56:416-21. [CrossRef]

12. Leibrock A, Degenhart M, Behr M, Rosentritt M, Handel G. In vitro study of the effect of thermo- and load-cycling on the bond strength of porcelain repair systems. J Oral Rehabil 1999;26:130-7. [CrossRef]

13. Ozcan M. Fracture reasons in ceramic-fused-to-metal restorations. J Oral Rehabil 2003;30:265-9. [CrossRef]

14. Casucci A, Monticelli F, Goracci C, et al. Effect of surface pretreatments on the zirconia ceramic-resin cement microtensile bond strength. Dent Mater 2011 Oct;27(10):1024-30. [CrossRef]

15. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc 2008;139:8-13. [CrossRef]

16. Burke FJ. Repair of metal-ceramic restorations using an abrasive silica-impregnating technique: two case reports. Dent Update 2002;29:398-402. [CrossRef]

17. dos Santos JG, Fonseca RG, Adabo GL, et al. Shear bond strength of metal-ceramic repair systems. J Prosthodont Dent 2008;24:1568-74. [CrossRef]

18. Kim BK, Bae HE, Shim JS, et al. The influence of ceramic surface treatments on the tensile bond strength of composite resin to all-ceramic coping materials. J Prosthodont Dent 2006;96:165-73.

19. Ozcan M, van der Slee RN, Kurumaki H, et al. Comparison of repair methods for ceramic-fused-to-metal crowns. J Prosthodont 2006;15:283-8. [CrossRef]

20. Kimmich M, Stappert CF. Intraoral treatment of veneering porcelain chipping of fixed dental restorations: a review and clinical application. J Am Dent Assoc 2013;144:31-44. [CrossRef]

21. Yoo JY, Yoon HI, Park JM, Park EJ. Porcelain repair - Influence of different systems and surface treatments on resin bond strength. J Adv Prosthodont 2015;7:343-8. [CrossRef]

22. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent 1999;27:89-99. [CrossRef]

23. Dündar M, Ozcan M, Gökbostan C, Çomlekoglu E, Leite F, Valandro LF. Comparison of two bond strength testing methodologies for bilayered all-ceramics. Dent Mater 2007;23:630-6. [CrossRef]

24. Hadavi F, Hey JH, Ambrose ER, Louie PW, Shinkevsky DJ. The effect of dentin primer on the shear bond strength between composite resin and enamel. Oper Dent 1993;18:61-5.

25. Schneider, W. Powers, J.M. & T Pierpoint, H.P. Bond strength of composites to etched and silica coated porcelain fusing alloys. Dent Mater 1992;8:211-5. [CrossRef]

26. Matsumura H, Yanagida H, Tanoue N, Aota M, Shimo S. Shear bond strength of resin composite veneering material to gold alloy with varying metal surface preparations. J Prosthodont Dent 2001;86:315-9. [CrossRef]

27. Kocaagaoğlu HH, Gürbülak A. An assessment of shear bond strength between ceramic repair systems and different ceramic infrastructures. Scanning 2015;37:300-5. [CrossRef]

28. Ohkuma K, Kazama M, Ogura H. The grading efficiency by diamond points developed for yttria partially stabilized zirconia. Dent Mater J 2011;30:511-6. [CrossRef]

29. Barraqan G, Chasquiera F, Arantes-Olivera S, Portugal J. Ceramic repair: influence of chemical and mechanical surface conditioning on adhesion to zirconia. Oral Health Dent Manag 2014;13:155-8.

30. Han IN, Kang DW, Chung CH, Choe HC, Kyong M. Effect of various intraoral repair systems on the shear bond strength of composite resin to zirconia. J Adv Prosthodont 2013;5:248-55. [CrossRef]

31. Kocaagaoğlu H, Manay 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. [CrossRef]

32. Tanaka R, Fujishima A, Shibata Y, Manabe A, Miyazaki T. Cooperation of phosphate monomer and silica modification on Zirconia. J Dent Res 2008;87:666-70. [CrossRef]

33. Magne P, Paranhos MP, Burnett LH Jr. New Zirconia primer improves bond strength of resin-based cements. Dent Mater 2010;26:345-52. [CrossRef]

34. Cura C, Ozcan M, Isik G, Saracoglu A. Comparison of alternative adhesive cementation concepts for Zirconia ceramic: Glaze layer vs Zirconia primer. J Adhes Dent 2012;14:75-82.

35. Koizumi H, Nakayama D, Komine F, Blatz MB, Matsumura H Bond of resin-based luting cements to Zirconia with and without the use of ceramic priming agents. J Adhes Dent 2012;14:385-92.

36. Attia A, Kern M. Long-term resin bonding to Zirconia ceramic with a new universal primer. J Prosthodont 2011;10:319-27. [CrossRef]

37. Ural C, Küllük T, Küllük S, Kurt M, Baba S. Determination of resin bond strength to Zirconia ceramic surface using different primers. Acta Odontol Scand 2011;69:48-53. [CrossRef]

38. Kitayama S, Nakayama D, Komine F, Blatz MB, Matsumura H Comparison of two bond strength testing methodologies for dental restorations. J Dent 1999;27:89-99. [CrossRef]

39. Alhmadi S, et al. Ceramic repair: influence of chemical and mechanical surface conditioning on adhesion to zirconia. Oral Health Dent Manag 2014;13:155-8. [CrossRef]

40. P.C. Pott, M. Stiesch, M. Eisenburger, Influence of artificial aging and cleaning methods on resin bonding to zirconia ceramic. J Am Dent Assoc 2013;144:31-44. [CrossRef]

41. Kimmich M, Stappert CF. Intraoral treatment of veneering porcelain chipping of fixed dental restorations: a review and clinical application. J Am Dent Assoc 2013;144:31-44. [CrossRef]

42. Kern M, Barlo O, Yang B. Surface conditioning influences Zirconia ceramic bonding. J Dent Res 2009;88:817-22. [CrossRef]

43. Akungor G, Sen D, Aydin M. Influence of different surface treatments on the short-term bond strength and durability between a Zirconia post and a composite resin core material. J Prosthodont Dent 2008 May;99:388-99. [CrossRef]

44. Thompson JY, Stoner BR, Piascik JR, Smith R. Adhesion/strength of testing methods on the bond strength of resin to zirconia. Oper Dent 2008;33:675-81. [CrossRef]

45. Lehmann F, Kern M. Durability of resin bonding to zirconia ceramic using different primers. J Adhes Dent 2009;11:479-83.

46. P.C. Pott, M. Stiesch, M. Eisenburger, Influence of artificial aging on the shear bond strength of zirconiacoating. Journal of Dental Materials and Techniques 2018;10:308-14. [CrossRef]

47. Lindgren J, Smeds J, Sjögren G. The effect of surface treatments and aging in water on bond strength to Zirconia. Oper Dent 2008;33:675-81. [CrossRef]

48. Kern M, Barlo O, Yang B. Surface conditioning influences Zirconia ceramic bonding. J Dent Res 2009;88:817-22. [CrossRef]

49. Kitayama S, Nakayama D, Komine F, Blatz MB, Matsumura H Comparison of two bond strength testing methodologies for dental restorations. J Dent 1999;27:89-99. [CrossRef]

50. Thompson JY, Stoner BR, Piascik JR, Smith R. Adhesion/strength of testing methods on the bond strength of resin to zirconia. Oper Dent 2008;33:675-81. [CrossRef]