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IN VITRO SHEAR BOND STRENGTH ASSESSMENT BETWEEN CERAMIC REPAIR SYSTEM AND TWO BILAYERED CERAMICS HAVING DIFFERENT PERCENTAGES OF REMAINING CERAMIC VENEERS

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ABSTRACT

Statement of the problem Despite improvements in dental ceramics, failure of bilayered restorations mainly by chipping and delamination of veneer with different degrees remains a disadvantage of this type of restorations. Accordingly the need for ceramic restoration repair became a widespread alternative to replacement of defective restorations especially in complex cases . However it is not always easy for the clinician to select the best repair protocol when dealing with different ceramic types and different chipping patterns.

Purpose: The purpose of this study was to evaluate the shear bond strength between a commercially available repair system (Ceramic Repair kit) with a lithium disilicate glass ceramic (e.max CAD) and zirconia based ceramic (InCoris ZI) subjected to different degrees of veneering ceramic chipping..

Materials and Methods: A total of sixty ceramic samples were designed and fabricated in this study using the CAD/CAM technology . The samples were divided into two groups; Group 1: Thirty samples constructed from lithium disilicate glass ceramic (e.max CAD). Group 2: Thirty samples constructed from zirconia ceramic (InCoris ZI). Each of the previous groups was further subdivided into three equal subgroups depending on the amount of bonded repair material to the ceramic core and to the veneering ceramic: Subgroup 1 (control): Ten samples with ceramic repair material bonded directly onto the ceramic core (100% core). Subgroup 2: Ten samples with 25% of the ceramic repair material surface bonded to veneering ceramic surfaces, and the other 75% to ceramic core and Subgroup 3: Ten samples with 50% of the ceramic repair material surface bonded to veneering ceramic, and the other 50% to ceramic core. Shear bond strength test was done by loading the samples parallel to its the long axis at the composite ceramic interface at a crosshead speed of 0.5 mm/min until fracture . The maximum load at failure was recorded in Newtons (N) unit and was divided over the bonded area(mm^2) to convert to MPa unit. Data was then collected, tabulated and statistically analyzed.

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Results: Regarding the effect of ceramic material on mean shear bond strength, for the first subgroup (100% core), InCoris ZI (9.99±1.03 MPa) had insignificant higher mean shear bond strength (MPa) compared to IPS e.max CAD(9.11±1.16 MPa) at p=0.092. For second subgroup (75% core), the InCoris ZI (10.53±1.48 MPa) showed higher significant effect on mean shear bond strength (MPa) compared to IPS e.max CAD (8.64±1.4 MPa) at p=0.009. The same resulted for the third subgroup (50% core) where the InCoris ZI (13.34±1.22 MPa) showed higher significant effect on mean shear bond strength (MPa) compared to IPS e.max CAD (7.04±1.19 MPa) at p≤0.001. As for the effect of different bonded core surface; regarding the IPS e.max CAD, subgroup 1 (100% core ; 9.11±1.16 MPa) and subgroup 2 (75% core;8.64±1.4 MPa) showed highest significant mean shear bond strength (MPa) with insignificant difference between them followed by subgroup 3 (50% core ; 7.04±1.19 MPa) that showed the lowest significant mean shear bond strength at p=0.003. While for InCoris ZI, subgroup 3 (50% core ;13.34±1.22 MPa) showed highest significant mean shear bond strength (MPa) followed by subgroup 2 (75% core ;10.53±1.48 MPa) and subgroup 1 (100% core,9.99±1.03 MPa) that showed the lowest significant mean shear bond strength with insignificant difference between subgroup 2 and 1 at p≤0.001

Conclusions: 1) The repair bond strength relies on remaining amount of ceramic core and veneer depending on the type of ceramic, thus different repair approaches should be followed for each ceramic system. 2) In case of zirconia ceramics, the repair bond strength in the subgroup with more veneering ceramic was statistically significantly higher than other subgroups, this implies minimal preparation of the remaining veneering surface during the repair procedure to improve the bond strength. 3) In the glass ceramic group, the subgroups having larger surface of bonded core showed higher statistically significant repair bond strength than other subgroups with more veneering ceramic. Accordingly increasing the exposed area of ceramic core will enhance the repair bond strength.

INTRODUCTION

Advancements in core materials such as glass ceramic, zirconia and alumina have led to the increased use of all-ceramic restorations over the past ten years[1]. High esthetic outcome is achieved in these bilayered type of ceramics by veneering the core with compatible feldspathic ceramics**.** Since these core ceramics have high strength and stability,framework fractures are uncommon.[2]However, issues such as structural defects at the core/veneer interface, mismatch in coefficient of thermal expansion, parafunctional habits, and inappropriate coping design may weaken bond strength between core and veneering ceramic.[3,4]Accordingly, delaminations of the veneering ceramic with the exposure of core material and minor chip-off fractures are cited as the most frequent reason for bilayered ceramic restoration failures.[5-7] . When dealing with these types of minor fractures in verneered ceramics, instead of following the conventional approach of defective restoration replacement, it can be repaired intraorally.[8] Replacement of a damaged restoration might be traumatic to abutments and dental tissues.[9] Besides, this procedure is costy and time consuming[10] Therefore, the need for intraoral ceramic restoration repair is widespread.

Several intraoral ceramic repair systems are available in the market. However, studies indicate that ceramic repair systems are not a permanent solution due to their limited bond strength.[11,12]. The bond strength of repair interface determines the clinical prognosis of the restoration [13] This bond depends on the type of repair composite [14] and the surface treatment used [13,15,16-18]

Earliest methods of repair depended on macro mechanical retention by preparing grooves or undercuts. Nowadays, due to advancements in adhesive dentistry, recent repair systems have developed which depend on micromechanical and chemical bond via different surface treatments of the core.[15] Micromechanical roughening of the core surface can be achieved by diamond bur, acid etching, air-borne particle abrasion or combination of the previous treatments while chemical bonding can be enhanced by using silane coupling agents and adhesive systems[16,17,19,20]. Selection of the surface treatment method depends mainly on the substrate type. Airborne-particle abrasion and acid etching have been recommended to achieve high bond strength in silica based ceramics [21,22]. However, their effectiveness on zirconia based ceramics are limited [23]. Therefore, adhesive primers and silane coupling agents may be used to enhance bonding after sandblasting or acid etching [24].

In different clinical situations, core material in veneered ceramics might be exposed with different degrees leaving variable amount of remaining veneers. The bond between the repair material and chipped restoration consisting of core and remaining veneer needs to be strong and durable to enhance the clinical durability of the repaired restoration. This results in different bond strengths depending on the exposed surface to be repaired. Furthermore, various studies[25,26] have reported failure modes of veneering ceramic fracture in all-ceramic crowns, however only a limited number of studies proposed solutions to deal with the remaining amount of veneering ceramic .

Hence, the objective of the present study was to evaluate the shear bond strength between a commercially available repair system (ceramic repair kit) with a lithium disilicate glass ceramic (e.max CAD) and zirconia based ceramic (InCoris ZI) subjected to different degrees of veneering ceramic chipping.

The hypothesis of the study was that there would be no difference in repair bond strengths among the two ceramic materials, however the subgroups with more veneering ceramic would show higher bond strength.

MATERIALS AND METHODS

A total of sixty ceramic samples were designed and fabricated in this study using the CAD/CAM technology . The samples were divided into two groups; Group 1: Thirty samples constructed from lithium disilicate glass ceramic (e.max CAD) . Group 2: Thirty samples constructed from zirconia ceramic (InCoris ZI). Each of the previous groups was further subdivided into three equal subgroups depending on the amount of bonded repair material to the ceramic core and to the veneering ceramic: Subgroup 1 (control): Ten samples with ceramic repair material bonded directly onto the ceramic core (100% core). Subgroup 2: Ten samples with 25% of the ceramic repair material surface bonded to veneering ceramic surfaces, and the other 75% to ceramic core and Subgroup 3: Ten samples with 50% of the ceramic repair material surface bonded to veneering ceramic, and the other 50% to ceramic core .

Construction of CAD/CAM samples

For purpose of standardization, a specially constructed copper mold was designed to fabricate square shaped ceramic samples having dimensions of (10mm×10mm×2 mm). Samples were designed and milled with a CAD/CAM system “Cerec inLab” (Sirona dental, Bensheim, Germany) according to the manufacturer’s instructions from presintered lithium disilicate glass-ceramic blocks (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) and zirconia blocks (InCoris ZI, Sirona dental, Bensheim, Germany). Optical impressions of the copper mold were obtained with “inEos X5 scanner” (Sirona dental, Bensheim, Germany). The software “Cerec inLab S.W 4.2” was then used to evaluate the clarity of the scanning process. The specimen shape was selected from the available designs within the computer software library. Scanning and design were performed by the same clinician. After designing the specimens, the information was electronically sent to the milling unit "Cerec MCXL Premium" (Sirona dental, Bensheim, Germany). Following the completion of the milling process, the specimens were separated with a diamond cutting instrument from the rest of the block. For the e.max group,final crystallization of IPS e.max CAD restorations was performed after the milling procedure following the manufacturer's instruction. The crystallization temperature was 840°C and the dwell time was 7 minutes. Glazing (IPS e.max Ceram Glaze Paste Ivoclar Vivadent, Schaan, Liechtenstein) with a standard cooling procedure was applied as final treatment. The InCoris ZI samples were milled oversized which attained their final strength properties and accurate size following sintering process. To avoid damage during sintering, the InCoris ZI discs were dried in the drying cabinet by putting it 30 minutes at 80°C . Sintering was done in the sintering furnace (Sirona inFire HTC) for approximately six hours. Sintering cycle started by gradually heating up to 1510 °C with heat rise rate of 15 °C/min; then the temperature held for 2 hours, then cooled down over 2 hours according to manufacturer instructions.

Preparation of specimens

In Subgroups 2 and 3:

Slot measuring $3 \times 3 \times 1mm^3$ was prepared into the testing surface in e.max CAD core and InCoris ZI core blocks as previously made by Lee et al [9] (Figure 1). A veneering ceramic powder (IPS e.max ceram) was mixed with liquid and the slurry obtained was applied into the prepared slot before being condensed, dried, and fired following the manufacturers recommendations. The bonding surfaces of all specimens of the three subgroups blocks were ground using a medium grit abrasive diamond bur using a high speed hand piece under copious air -water irrigation in one direction for 4 s on each surface. A new set of burs was used after every 5 preparations. No ultrasonic cleaning was performed since it is impossible during an intraoral repair.

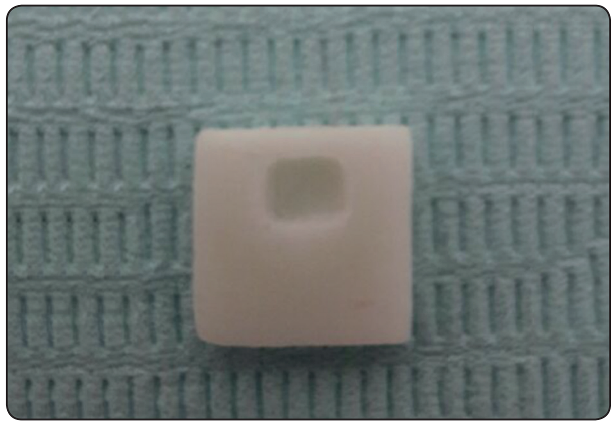

Fig. (1) Slot prepared in the ceramic core to recieve the veneering ceramic.

All specimens were subjected to conditioning procedures, according to the surface conditioning protocol of the composite repair kit used (Ceramic repair kit, Ivoclar Vivadent, Schaan, Liechtenstein). Silane coupling agent (Monobond plus) was applied on the treated surfaces of the samples for 1 min using a brush. The samples were dried for 10 s with oil/water free compressed air. Adhesive resin (Heliobond) was applied using a brush, lightly thinned with compressed air. Light emitting diode curing unit of high intensity 1500 mW/cm2 was used to cure the bonding agent for 20 s.

Application of composite:

Using a circular metal mold having 4mm diameter and 2mm thickness, composite blocks (tetric evoceram) were built up and bonded on the treated surfaces by three different surface configurations (Fig 2) and cured for 40 seconds from five directions, resulting in a total of 200 seconds curing

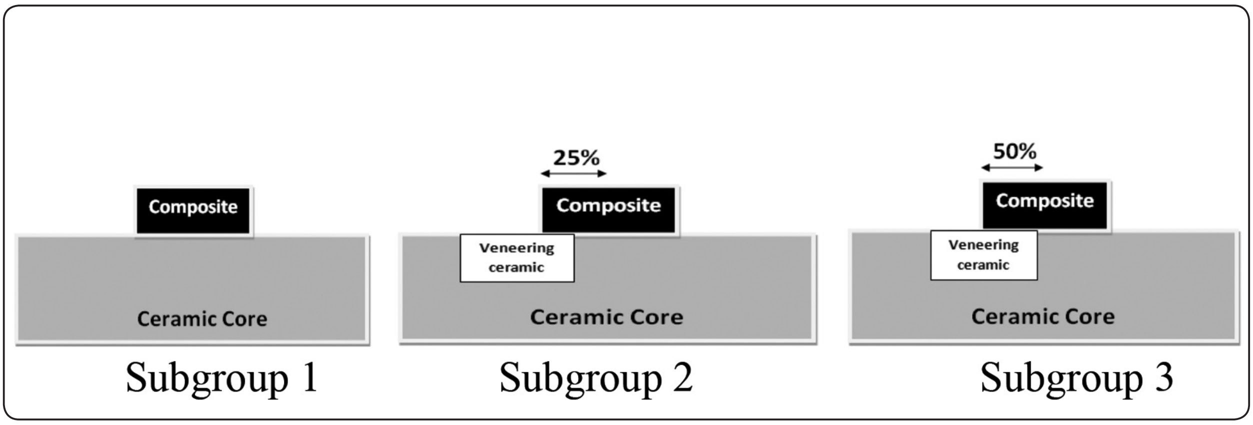

Fig. (2) Diagrammatic illustration for different subgroups

time with a light-curing unit. All 60 specimens were stored in a saline solution at 37˚C for 72 hours before shear bond strength testing.

Shear bond strength test

The specimens were placed in a metal holder in a universal testing machine (Instron 3345, High Wycombe, Bucks, UK). Loading was applied parallel to the long axis of the specimen at the composite ceramic interface at a crosshead speed of 0.5 mm/min until fracture as shown in figure 3. The maximum load at failure was recorded in Newtons (N) unit and was divided over the bonded area(mm^2). to convert to MPa unit. Data was then collected, tabulated and statistically analyzed.

Statistical analysis

Data was statistically described in terms of mean and standard deviation (SD).Data was explored for normality using Kolmogorov Smirnov test. Independent t-test was used to compare between different CAD/CAM ceramic blocks within each subgroup.One-Way ANOVA used to compare between different subgroups followed by Tucky's post hoc test for pairwise comparison for mean shear bond strength (MPa). Significant level set at $p<0.05$. Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 24 for Windows

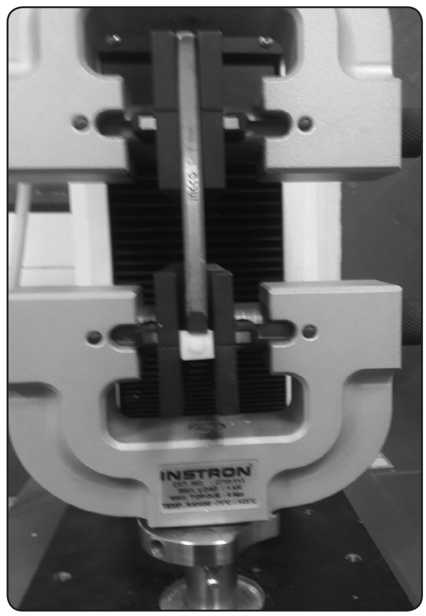

Fig. (3) Bonded specimen mounted in the universal testing machiune

RESULTS

Shear bond strength results (MPa)

Mean and standard deviation (SD) for Shear bond strength (MPa) for different groups and subgroups are shown in Table 1

Effect of different ceramic material

As shown in figure 4,regarding the first subgroup (100% core), InCoris ZI (9.99±1.03 MPa) had insignificant higher mean shear bond strength

TABLE (1) Mean and standard deviation (SD) for shear bond strength (MPa) for different groups and subgroups:

	Ceramic Blocks								p-value
	Group 1 (IPS e.max CAD)				Group 2 (InCoris ZI)				
	Mean	SD	95.0% Lower CL for Mean	95.0% Upper CL for Mean	Mean	SD	95.0% Lower CL for Mean	95.0% Upper CL for Mean	
Subgp1:100% core	9.11[a]	1.16	8.28	9.95	9.99[b]	1.03	9.25	10.72	0.092 NS
Subgp2:75% core	8.64[a]	1.40	7.65	9.64	10.53[b]	1.48	9.47	11.58	0.009*
Subgp3: 50% core	7.04[b]	1.19	6.19	7.89	13.34[a]	1.22	12.47	14.22	≤0.001*
p-value	0.003*				≤0.001*				

Means with the same letter within each column indicates insignificant difference at p≥0.05

****=significant, NS= Non-Significant***

(MPa) compared to IPS e.max CAD (9.11±1.16 MPa) at p=0.092. For second subgroup (75% core) the InCoris ZI (10.53±1.48 MPa) showed higher significant effect on mean shear bond strength (MPa) compared to IPS e.max CAD (8.64±1.4 MPa) at p=0.009. The same resulted for the third subgroup (50% core) where the InCoris ZI (13.34±1.22 MPa) showed higher significant effect on mean shear bond strength (MPa) compared to IPS e.max CAD (7.04±1.19 MPa) at p≤0.001.

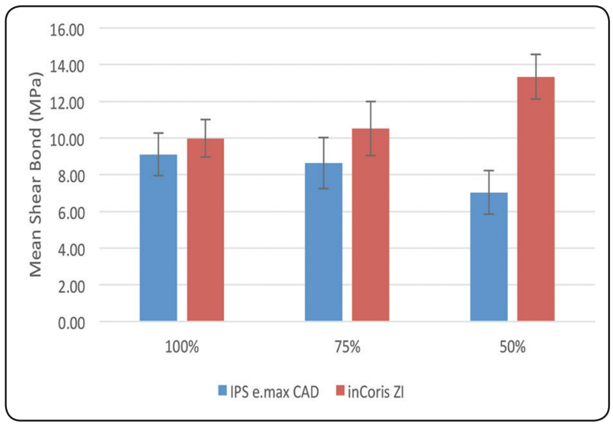

Fig. (4) Bar chart showing the mean Shear bond strength (MPa) for different CAD/CAM ceramic

Effect of different bonded core surface

As shown in figure 5, regarding the IPS e.max CAD, subgroup 1 (100% core ; 9.11±1.16 MPa) and subgroup 2 (75% core; 8.64±1.4 MPa) showed highest significant mean shear bond strength (MPa) with insignificant difference between them followed by subgroup 3 (50% core ;7.04±1.19 MPa) that showed the lowest significant mean shear bond strength at p=0.003

While for InCoris ZI, subgroup 3 (50% core; 13.34±1.22 MPa) showed highest significant mean shear bond strength (MPa) followed by subgroup 2 (75% core ;10.53±1.48 MPa) and subgroup 1 (100% core, 9.99±1.03 MPa) that showed the lowest significant mean shear bond strength with insignificant difference between subgroup 2 and 1 at p≤0.001

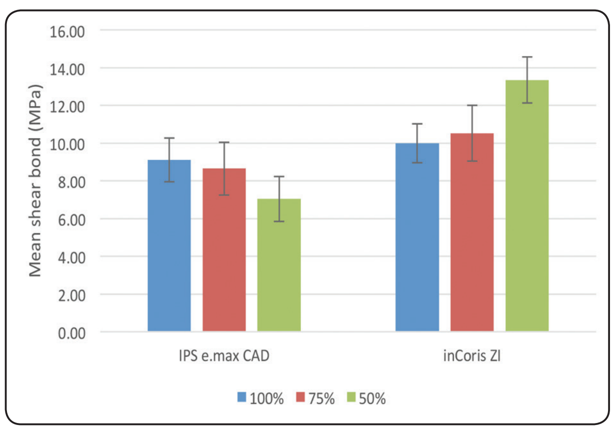

Fig. (5) Bar chart showing the mean Shear bond strength (MPa) for different bonded core surfaces

DISCUSSION

In spite of the improvements in dental ceramics, failure of these restorations, notably by chipping remains a common complication[27-29], This made ceramic restoration repair become an urgent demand. However it is not an easy task for clinicians to deal with the type of fracture and to select the repair protocol in order to achieve the best clinical outcome. Thus the present study was undertaken to evaluate the shear bond strength between a commercially available repair system (ceramic repair kit) with two most commonly used type of ceramics (e.max CAD and InCoris ZI) subjected to different degrees of veneering ceramic chipping. Although in vitro studies cannot be directly translated to the clinical condition, yet they still remain a valuable tool to predict the potential clinical performance of a repair system. Accordingly, the findings of the present study provide an opportunity to reason out the selection of repair protocol and prognosis for repaired ceramic restorations

In the present study, shear bond strength between one ceramic repair composite and coping material of two most commonly used ceramic restorations was evaluated. In addition other subgroups were added representing different combinations of remaining ceramic veneer and core since numerous studies have evaluated the bond strength of resin material to veneering ceramic only or metal[10,30-32] and several studies have evaluated the bond strength of resin composites to coping ceramics subjected to several surface treatments[33-35]. However studies evaluating repair bond strength to different substrates (core and veneer) were still scarce which made it the point of interest in the following research.

Although, various in vitro bond strength tests are used in dentistry, including shear, tensile, and three point bending. Yet,the shear bond strength test is more widely used than the others, due to its easy methodology.[36] In addition, anterior restorations are subjected primarily to shear stresses, and the shear test is considered appropriate for quantifying the strength of porcelain repairs.[37] Also it was reported that shear bond test is the method where the standard deviation and a variation coefficient of the results for different bonded substrates are minimum and stable.[38] Thus it was used by many authors including this study to evaluate intraoral ceramic repair efficiency.[4,10,39-41]

Bond strength between the ceramic and the repair resin determines the clinical longevity of the ceramic repair . This bond is achieved either by chemical or mechanical surface treatment of the ceramic surface or by combination of both [20,42] .Diamond bur roughening was selected in this study as a mechanical treatment to the ceramic surface [36], due to ease of use, cost effectiveness as well as its compatibility to be used as an abrasive conditioning method for different types of ceramics used in this study [37].

Although hydrofluoric acid (HF) surface treatment has been recommended by many authors for the glass ceramics repair as it selectively etches and dissolves the glass ceramic causing physical alteration of the surface creating micromechanical retention[43,44], yet it was not used in this study. Instead, alternative repair protocol was used to give the chance of less hazardous intervention . It has been suggested that the intraoral use of this acid should be restricted, if not eliminated, to reduce potential health hazards to both clinician and the patient[45]. A recent review disscussed the potentially unsafe local and systemic effects of intraoral hydrofluoric acid [46].

To achieve chemical bond with the applied resin, Ceramic repair system with separate silane step (Monobond plus and Heliobond adhesive) was selected as it is considered one of the commonly used repair approaches. Silanes are known to act as adhesion promoters capable of forming chemical bonds between inorganic and organic phases through double molecular interaction. Silanes also enhance the bond by promoting the wetting of the ceramic surface, making the penetration of the resin into the microscopic porosities of the ceramic more complete [31,47-50].

It has been also reported that the repair bond strength is affected by the composite filler type[3] Large or hybrid particle size composites have showed superior bond strengths than small particle sized composites at the ceramic interface.[24,51]In this study, nanohybrid composite resin (tetric evoceram) was used for the repair to give better outcome of the repaired restoration .

According to the results of our research, The first hypothesis of the study postulating that there would be no difference in repair bond strengths among the two ceramic materials was accepted for the first subgroup (100% core). However, it was rejected for second (75% core) and third (50% core) subgroups where the zirconia samples showed higher statistically significant mean shear bond strength than the e.max samples. Regarding the second part of the hypothesis, stating that subgroups with more veneering ceramic would show higher bond strength, this was accepted for zirconia group and was rejected for the e.max group.

Results of the present study showed that the mean shear bond strengths for all repaired samples ranged from (7.04 - 13.34 MPa) . These values were in accordance with previous authors who evaluated shear bond strength for the intraoral repair systems and informed bond strength values in the range of 5.56–29.9 MPa [10,18,36,39,52-56]

In this study, no significant difference was found among the core materials of the two ceramic systems. Kocaağaoğlu et al [57] in a previous study evaluated ceramic repair bond strengths among different coping materials including glass and zirconia ceramics and found no significant difference between them. These findings are consistent with the current study. However, the results were in disagreement of previous studies that showed significant higher bond strength in glass ceramics compared to zirconia ceramics[58]. This inconsistency might be attributed to different surface treatments, repair materials and testing procedures.

When observing the effect of bonded core surface on repair bond strength in zirconia ceramic group, it was noticed that subgroup 3 with 50% bonded core surface had the highest significant mean values compared to other subgroups. This might be due to the significantly higher silica content in veneering, ceramics (60% to 65% wt) than that of zirconia core ceramic having a high crystalline microstructure. The silica aids in micromechanical interlocking, created from surface treatment and chemical interactions with a silane coupling agent. This results in an increased shear bond strength in the subgroups having more bonded surface of veneering ceramic. These results were similar to previous study by Lee et al who demonstrated that the shear bond strength of composite to a 50% surface of core ceramics and 50% surface of veneering ceramics was statistically higher than that of composite bonded to only core ceramics. [9] Accordingly, it can be suggested that increasing the surface of veneering ceramic in case of repairing chipped zirconia restoration improves the repair bond strength. This dictates wise preparation of the fractured site by preserving maximum amount of the veneer ceramic surface. Besides, it can be assumed that repaired zirconia restoration with minimal ceramic veneer chipping would have better prognosis than repaired restoration with larger chipping areas.

However, regarding the e.max group, the results showed that the subgroups 1 and 2 having 100% and 75% bonded core surface had higher significant repair bond strength than subgroup 3 with 50% bonded core surface.This might be due to the fact that e.max cad blocks have silica content of approximately (57 to 80 wt%) as declared by the manufacturer while that of the IPS e.max ceram (veneering ceramic) ranges from 60 to 65 wt%.

As emphasized before, increasing silica content plays a major role in increasing the bond strength with the applied repair resin . These results indicate that a stronger bond was formed between the repair composite resin and the substrate containing higher silica particles. This was in accordance with previous studies. [(9)]

A limitation of this study is that it was not able to simulate clinical long-term aging conditions as that occuring in the complex oral environment. However it was useful to give information about relative repair bond strength of two commonly used ceramics subjected to different amounts of veneer chipping under controlled laboratory conditions. In future studies, the effect of different aging conditions on repair bond strength can be examined.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were withdrawn:

1. The repair bond strength relies on remaining amount of ceramic core and veneer depending on the type of ceramic, thus different repair approaches should be followed for each ceramic system.

2. In case of zirconia ceramics, the repair bond strength in the subgroup with more veneering ceramic was statistically significantly higher than other subgroups, this implies minimal preparation of the remaining veneering surface during the repair procedure to improve the bond strength.

3. In the glass ceramic group, the subgroups having larger surface of bonded core showed higher statistically significant repair bond strength than other subgroups with more veneering ceramic. Accordingly increasing the exposed area of ceramic core will enhance the repair bond strength.

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