IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 8 Ser. 3 (August. 2025), PP 05-08
www.iosrjournals.org

Comparison Of Three Intraoral Ceramic Repair Systems To Evaluate The Shear Bond Strength OfComposite To Zirconia After Various Surface Treatments: An In-Vitro Study.

Dr. Aashi Godani
BDS, Post-Graduate Student, Department Of Prosthodontics And Crown & Bridge, MGM Dental College And
Hospital, Navi Mumbai.

Dr. Janani Iyer,
MDS, Professor, Department Of Prosthodontics And Crown & Bridge, MGM Dental College And Hospital,
Navi Mumbai.

Dr. Jyoti Nadgere,
MDS, Professor & Head Of Department, Department Of Prosthodontics And Crown & Bridge, MGM Dental
College And Hospital, Navi Mumbai.

Dr. Anuradha Mohite
MDS, Professor, Department Of Prosthodontics And Crown & Bridge, MGM Dental College And Hospital,
Navi Mumbai

Abstract:
Statement of problem
The aim of this study is to test the bond strength of different ceramic repair systems tozirconia after various surface treatments which will help the clinician choose the most effective intraoral repair system and surface treatment for the restoration of fractured zirconia restoration.
Purpose
The purpose of this study was to address the following research question: "Is there a difference in the shear bond strength of three intra oral ceramic repair systems tozirconia after various surface treatments?"
Material and methods
A total of 42 samples of zirconia (3% yttria) (XTCERA) were fabricated and sintered according to the manufacturers instructions. The samples were then layered with 2mm of feldspathic porcelain (Ivoclar,vivadent). The samples were divided into two groups (one treated with silicone carbide paper abrasion and other with airbone borne particle abrasion with aluminium oxide particles based on the surface treatment. Both the groups were further subdivided into three subgroups based on the intraoral repair system used (A.C.E ceramic repair kit by Prevent denpro limited, Angelus repair kit by angelus and P and R repair kit by Shofu). Shear testing of all groups was performed on a universal testing machine (Instron®5960, U.S.A. Model No.3345R3092 at a crosshead speed of 0.5mm/min. The effects of the surface treatments and different repair systems was examined in a SEM Carl Zeiss Supra 55, Germany at 100 X magnification. Failure types was

categorized as adhesive between ceramic and composite (ADHES), and cohesive failure (COHES) and cohesive failure of the ceramic accompanied by adhesive failure at the interface (MIX).

Results

All the data obtained for the shear bond strength is expressed in megapascals (Mpa).

Normality of numerical data was checked using Shapiro-Wilk test and was found that the data did not follow a normal curve; hence non-parametric tests have been used for comparisons. Inter group comparison (2 groups) was done using Mann Whitney U test.Inter group comparison (>2 groups) was done using Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test. lowest shear bond strength value of 11.38+1.24 was seen for zirconia samples treated with alumina particle abrasion and repaired using Angelus repair system.Overall,highest shear bond strength value of 36.40+3.42 was seen for zirconia samples treated with silicone carbide bur and repaired using A.C.E. prevest repair system. The SEM examination of the specimens in the current study showed adhesive failure to be the common mode of failure for the specimens

Conclusion

Best bond strength between zirconia samples surface treated with silicone carbide bur and then repaired using A.C.E. prevest repair system (containing MDP primer) followed by zirconia samples surface treated with alumina particle abrasion and then repaired using A.C.E. prevest repair system.

Clinical Implications

One major limitation of using layered zirconia is the fracture of the layered structure causing exposure of the zirconia core resulting in a bond failure.This study will help clinicians choose the most effective repair system and surface treatment for the restoration of fractured zirconia prosthesis

---

Date of Submission: 02-08-2025 Date of Acceptance: 12-08-2025

I. Introduction

Today all ceramic restorations are used as an alternative to metal-ceramic restorations because of the known aesthetic and biological complications of metal-ceramic restorations.[1,2]

Zirconia as a material is called "ceramic steel" which has less silica content compared to glass ceramic systems making the optical properties of Zr questionable.[3,4]Therefore, the aesthetics of the Zr restoration has to be further enhanced by the addition of porcelain.[2,5,6] However, this euphoric attitude towards the material was questioned by the fracture of the layered structure causing exposure of the zirconia core resulting in a bond failure.[7,8,9,10]

In such scenarios, remaking the restoration is the ideal treatment of choice but not the most practical owing to the replacement time and money required and additional trauma inflicted onto the tooth.[11] The intra-oral chair side porcelain repair technology is a quick, painless, and patient-acceptable procedure. The bonding between fractured surfaces and composite repair materials has been improved by the introduction of numerous mechanical and chemical bonding techniques[12,13,14]

Hence, this study aims at comparatively evaluating the Shear Bond Strength (SBS) of different ceramic repair systems to zirconia after various surface treatments. Thus the objective of this study is to help clinicians choose the most effective repair system and surface treatment for the restoration of fractured zirconia prosthesis.

II. Methodology

A total of 42 samples of zirconia(3% yttria) (XTCERA) were fabricated and sintered according to the manufacturers instructions. The samples were then layered with 2mm of feldspathic porcelain (Ivoclar,vivadent). The samples were divided into two groups (one treated with silicone carbide paper abrasion and other with airbone borne particle abrasion with aluminium oxide particles) based on the surface treatment. Both the groups were further subdivided into three subgroups based on the intraoral repair system used.

Fabrication of zirconia samples:

Zirconia specimens (7 mm × 7 mm × 2 mm) were produced by a CAD/CAM system using prefabricated CAD discs of conventional monolithic zirconia(3% yttria) (XTCERA) and then sintered according to the manufacturer's instructions. In order to facilitate loading of the samples in the universal testing machine, Zirconia specimens were embedded in liquid auto-polymerizing acrylic resin (RR Cold Cure; DPI) which were mixed according to the manufacturer's instruction in the ratio of 3:1 (polymer:monomer).The resin was allowed to polymerize at room temperature.

Layering of the zirconia samples:

The zirconia specimens after sintering were then layered with porcelain (Ivoclar,vivadent) to a thickness of 0.5mm by applying opaque, dentin, enamel and glaze layers respectively as per the manufacturers instructions. The porcelain was layered with a brush which was used to paint the layers over the fabricated samples. Then the layered disks were fired at 930 degrees in a porcelain furnace (VITA VGO,i-line)the specimens were then be finished using carborundum disks and abrasive paper to obtain the uniform final dimensions. The samples were divided into two groups according to the surface treatment. (Fig 1)

Surface alterations of the zirconia samples

The test surfaces of both the group specimens were divided into two groups according to the surface treatment employed silicone carbide bur or air borne particle abrasion.(Fig 2a and 2b)

Treating the zirconia samples with different intra oral systems :

The test specimens were then divided into three groups according to the intraoral repair system used. After surface treatment according to manufacturer's manual of each intraoral repair system, metal cap (5 mm × 5mm × 2 mm) was placed on the centre of the specimens, and composite resin (Z350, 3M ESPE, USA) was condensed into the mold and incrementally filled up. This ensured uniformity of thickness and proper condensation of composite. While each layer was light- polymerized for 40 seconds at a distance of 1 mm using a light-polymerizing unit light-curing unit (1200 mW/cm2) (Woodpecker, LED B) After removing the metal cap, an additional 40 seconds of polymerization was performed.

Thermocycling of the samples:

To simulate the clinical scenario, all the specimens were stored for 24 h at 37 degrees C in distilled water followed by thermocycling (5^0 C and 55^0 C; 1500 cycles) with a 30 s dwell and 5 s transfer time.

Testing for the shear bond strength:

Shear testing of all groups was performed on a universal testing machine (Instron®5960, U.S.A. Model No.3345R3092 at a crosshead speed of 0.5mm/min. A knife-edge blade apparatus was used to direct a parallel shearing force as close as possible to the interface of the ceramic and the composite cylinder. The shear debonding forces was recorded in N. The failure loads (N) was divided by the bonding areas ($25mm^2$), and then the shear debonding forces was converted into MPa. If debonding occurred before the shearing tool touched the cement, the bonding strength was defined as 0 MPa.(Fig 3)

Scanning Electron Microscopic Examination:

The effects of the surface treatments and different repair systems was examined in a SEM Carl Zeiss Supra 55, Germany at 100 X magnification. Failure types was categorized as adhesive between ceramic and composite (ADHES), and cohesive failure (COHES) and cohesive failure of the ceramic accompanied by adhesive failure at the interface (MIX). Fig 4)

Statistical analysis:

Data collected was subjected to statistical analysis using an appropriate package like SPSS software. (SPSS v 26.0, IBM).Normality of numerical data was checked using Shapiro-Wilk test and was found that the data did not follow a normal curve; or for graded data, hence non-parametric tests have been used for comparisons. Inter group comparison (2 groups) was done using Mann Whitney U test.Inter group comparison (>2 groups) was done using Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test.For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

III. Results:

The shear bond strength values of the test specimens was determined by using a Universal Testing Machine. All the data obtained for the shear bond strength is expressed in megapascals (Mpa).

Normality of numerical data was checked using Shapiro-Wilk test and was found that the data did not follow a normal curve; hence non-parametric tests have been used for comparisons. (table 1)

Inter group comparison (2 groups) was done using Mann Whitney U test.(Table 2) Inter group comparison (>2 groups) was done using Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test.(Table 3)

The intergroup comparison test revealed that there was a statistically highly significant difference seen for the values between the subgroups ($p<0.01$) for maximum load (N) with higher values in sg 1a shear Bond Strength (MPa) with higher values in sg 1a. There was a statistically highly significant / significant difference seen for the values between all the pairs of groups (p<0.01, 0.05) Except for subgroup 1b vs 2c where there was a statistically non significant difference seen (p>0.05). (table 4)

The mean shear bond strength for group one where silicone carbide bur was used is 22.63+ 6.19.The shear bond strength for group two where alumina particle abrasion was used is 21.55+11.25. Thus, there was a statistically non significant difference seen for the values between the groups #600 grit silicone carbide bur and alumina particle abrasion (p>0.05) for Shear Bond Strength.

Mean shear bond strength of composite resin to layered zirconia samples is 22..09+8.99. In group 1 (zirconia samples treated with silicone carbide bur) highest shear bond strength value of 36.40+3.42 was seen for group 1a i.e. repair done using A.C.E prevest repair system and lowest value of 15.84+2.06 was seen for group 1b i.e. repair done using Angelus repair system.In group 2 (zirconia samples treated with alumina particle abrasion) highest shear bond strength value of 29.46+2.36 was seen in group 1a i.e. repair done using A.C.E prevest repair system and lowest value of 11.38+1.24 was seen for group 1b i.e. repair done using Angelus repair system.

Overall, lowest shear bond strength value of 11.38+1.24 was seen for zirconia samples treated with alumina particle abrasion and repaired using Angelus repair system.Overall,highest shear bond strength value of 36.40+3.42 was seen for zirconia samples treated with silicone carbide bur and repaired using A.C.E. prevest repair system. The SEM examination of the specimens in the current study showed adhesive failure to be the common mode of failure for the specimens

Thus, suggesting best bond strength between zirconia samples surface treated with silicone carbide bur and then repaired using A.C.E. prevest repair system followed by zirconia samples surface treated with alumina particle abrasion and then repaired using A.C.E. prevest repair system. The graph also depicts a statistically insignificant difference in the strength of samples surface treated with SiC bur when compared to Alumina particle abrasion.(fig 6) (graph)

IV. Discussion:

Various surface treatments to increase the mechanical bonding are grinding, tribochemical silica coating, laser etching. roughening with burs or air abrasion with aluminium oxide to condition the surfaces of the ceramic restorations. These mechanical methods act as an adjunct to the chemical surface treatments to enhance the bond between the zirconia core and composite.[(14,15)]

In the present study, shear bond strength of three ceramic repair systems after two different surface treatments are evaluated, they are A.C.E Ceramic Repair kit by Prevest Denpro,Angelus porcelain repair kit by angelus and P&R Repair kit of Shofu. A.C.E ceramic repair kit has 5% Hydrofluoric acid, silane X, 10MDP universal bond and flowable composite. Angelus ceramic repair kit has 10% hydrofluoric acid, silano angelus(The silane coupling agent used in Angelus repair kit is pre activated, solvent based on ethanol for less evaporation),opak 0.5 and A3. P and R repair kit of shofu has primer, ceraresin bond 1 and 2 and applicator tips.

The surface treatments employed were air abrasion with alumina particles considered as the standard protocol and Silicon carbide bur as the test group. The bond strength values for alumina particle abrasion was 21.55 + 11.25 and for silicone carbide bur was 22.63 +6.19.The difference between the values was statistically non significant.The results of this study are in agreement with Wojtek Libecki [(22)] who stated significantly higher bond strength values for both the silicone carbide bur and air borne particle abrasion with a statistically non significant difference between the two groups.Suliman et al [(23)] also stated that higher bond of intraoral repair systems were obtained with roughening with diamond bur and etching with hydrofluoric acid (16.98 MPa) than air abrasion alone (16.86 MPa); although the difference between the values were statistically non-significant The high bond strength of the groups could be related to the higher surface roughness achieved by both surface treatment methods. This confirms the co-relation between surface roughness and bond strength confirms that a higher surface roughness improves bonding.[(21,23)]

The ideal requirement of material should have a bond value similar to reported porcelain to zirconia bond strength (16–24 MPa).[(17)] The average masticatory forces are reported to be between 20 and 830 N in the literature. The masticatory forces between the incisors vary between 155 and 222 N and are higher for molars up to 830 N.[(18)] Since, the strength is directly proportional to the masticatory forces and inversely proportional to area (Strength = F/A), it may be assumed minimum bond strength required for intraoral repair material is 8–9 MPa[(18,19,20)] It is interesting to note that in this study we were able to depict that both the groups showed significantly higher shear bond strength values(mean shear bond strength value 22.09+8.99). The highest mean shear bond strength was noted with group 1a (for zirconia samples treated with silicone carbide bur and repaired using A.C.E. prevest repair system.) at 36.40MPa, with a highest value of 40.23MPa and standard deviation of 3.42. The lowest shear bond strength values were noted for group 2b (samples treated with alumina particle abrasion and repaired using Angelus repair system) with a mean of 11.38MPa lowest value of 9.73MPa and a standard deviation of 1.24.

These results are in line with previous studies by Han et al [24],Kim et al [13] as they concluded that the MDP monomer which is also present in the A.C.E. prevest repair system reacts with the hydroxyl group on the ceramic surface and chemically bonds with zirconia and is not hydrolyzed since it contains a long carbonyl chain which improves the wettability of the rough zirconia.

The results of this study hence depict that both the surface treatments i.e silicone carbide bur and air borne particle abrasion showed statistically non significant differences. However, among the intraoral repair systems, silicone carbide bur with A.C.E (Prevest) might be considered as the treatment of choice.

As per the results of this study, the null hypothesis was rejected since there is a difference in the shear bond strength of the three intra oral composite repair systems to zirconia after different surface treatments.

There are three modes of failure of layered ceramic or repaired composite over zirconia core. They can be adhesive, cohesive or mixed. The SEM examination of the specimens in the current study showed adhesive failure to be the common mode of failure for the specimens. This finding is in line with Kocaagaoglu et al.'s[25] research findings on ceramic repairs,Adhesive failure occurred when the repaired composite separated from the zirconia core, possibly due to vertical wedging forces during testing.

Some of the limitations of this study were that the forces of a intraoral prosthesis in use are not the same as those simulated in studies to determine the bond strengths of the repair material and substructures. In contrast to the intraoral prostheses, which are subject to mixed forces, bond tests only apply forces in one direction. As a result, the specimens used in bonding tests do not accurately represent the intraoral condition. Also, the shape of the specimens chosen were square for ease of testing,however a more realistic approach for testing the mechanical properties of the layered Zr would have been the fabrication of the test specimens in the form of crowns, for simulating the clinical scenario. The investigations are nonetheless helpful in understanding the bonding properties of the repair systems and the substructures even though it is challenging to compare results from various tests and research because of the lack of simulation of prosthesis and the testing or material variances. More research is required on the bonding characteristics of various materials to layered zirconia because such studies are sparse.

The clinical significance of this research is that it provides clinicians with the ideal choice of introral repair system matrix for fractured or chipped zirconia restorations. It also provides insights on the ideal surface treatment recommended of the systems. Thus, based on the findings of the current research, the most recommended system would be A.C.E ceramic repair system with SiC carbide bur surface roughening as a potent alternative to air particle abrasion.

V. Conclusions:

1) The shear bond strength of composite resin to zirconia after the two surface treatments are as per the standards of use in dental materials and there was a statistically non significant difference between the two treatments.
2) Among the three intraoral repair systems used, A.C.E ceramic repair system showed the best mean shear bond strength value suggesting that primer containing MDP has better bond strength values compared to the other systems.
3) Combination of mechanical and chemical retentive treatments give enhanced bond strength values compared to mechanical or chemical treatments used alone.
4) Thus, suggesting best bond strength between zirconia samples surface treated with silicone carbide bur and then repaired using A.C.E. prevest repair system (containing MDP primer) followed by zirconia samples surface treated with alumina particle abrasion and then repaired using A.C.E. prevest repair system.

References

[1] Coffman, Curt &Amp; Visser, Chris &Amp; Soukup, Jason &Amp; Peak, Michael. (2018). Crowns And Prosthodontics: Principles And Practice.

[2] Wilson NA,Whitehead SA,Mjor IA,Wilson NH.Reasons For The Placement And Replacement Of Crowns In General Dental Practice.Primary Dental Care.2003 Apr(2):539.

[3] 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(1):31-44.

[4] 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(5):343-348.

[5] Ozer F, Mante FK, Chiche G, Saleh N, Takeichi T, Blatz MB. A Retrospective Survey On Long-Term Survival Of Posterior Zirconia And Porcelain-Fused-To-Metal Crowns In Private Practice. Quintessence Int. 2014 Jan1;45(1):31-8.

[6] Yadav JS, Dabas N, Bhargava A, Malhotra P, Yadav B, Sehgal M. Comparing Two Intraoral Porcelain Repair Systems For Shear Bond Strength In Repaired Cohesive And Adhesive Fractures, For Porcelain-Fused-To-Metal Restorations: An In Vitro Study. J Indian Prosthodont Soc. 2019 Oct 1;19(4):362–8.

[7] Triwatana P, Nagaviroj N, Tulapornchai C. Clinical Performance And Failures Of Zirconia-Based Fixed Partial Dentures: A Review Literature. J Adv Prosthodont. 2012; 4:76–83.

[8] Chaiyabutr Y, Mcgowan S, Phillips KM, Kois JC, Giordano RA. The Effect Of Hydrofluoric Acid Surface Treatment And Bond Strength Of A Zirconia Veneering Ceramic J Prosthet Dent. 2008; 100:194–202.

[9] Jang GW, Kim HS, Choe HC, Son MK. Fracture Strength And Mechanism Of Dental Ceramic Crown With Zirconia Thickness. Procedia Eng. 2011; 10:1556–1560

[10] Habib SR, Bajunaid S, Almansour A, Abuhaimed A, Almuqrin MN, Alhadlaq A, Zafar MS. Shear Bond Strength Of Veneered Zirconia Repaired Using Various Methods And Adhesive Systems: A Comparative Study. Polymers. 2021 Mar 16;13(6):910.

[11] Hatta M, Shinya A, Yokoyama D, Gomi H, Vallittu PK, Shinya A. The Effect Of Surface Treatment On Bond Strength Of Layering Porcelain And Hybrid Composite Bonded To Zirconium Dioxide Ceramics. J Prosthodont Res. 2011; 55:146–153.

[12] 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.

[13] Cheng CW, Yang CC, Yan M. Bond Strength Of Heat-Pressed Veneer Ceramics To Zirconia With Various Blasting Conditions. J Dent Sci. 2018;13(4):301-310.

[14] De Lima E, Meira JB, Özcan M, Cesar PF. Chipping Of Veneering Ceramics In Zirconium Dioxide Fixed Dental Prosthesis. Curr Oral Health Reports. 2015; 2(4):169-173.

[15] Kalra A, Mohan M, Gowda M. Comparison Of Shear Bond Strength Of Two Porcelain Repair Systems After Different Surface Treatment. Contemp Clin Dent 2015; 6(2): 196-200.

[16] Ferrando JMP, Graser GN, Tallents R H, Jarvis R. Tensile Strength &Amp; Micro Leakage Of Porcelain Repair Materials J Prosthet Dent 1983; 50: 44-50.

[17] Jochen DG, Caputo AA, Matyas J. Effect Of Opaque Porcelain Application On Strength Of Bond To Silver-Palladium Alloys. J Prosthet Dent. 1990;63(4):414-418.

[18] Bailey JH. Porcelain-To-Composite Bond Strengths Using Four Organosilane Materials. J Prosthet Dent. 1989;61(2):174-177.

[19] Appeldoorn RE, Wilwerding TM, Barkmeier WW. Bond Strength Of Composite Resin To Porcelain With Newer Generation Porcelain Repair Systems. J Prosthet Dent. 1993;70(1):6-11.

[20] Atsu SS, Kilicarslan MA, Kucukesmen HC, Aka PS. Effect Of Zirconium-Oxide Ceramic Surface Treatments On The Bond Strength To Adhesive Resin. J Prosthet Dent. 2006;95(6):430-436.

[21] Jain S, Parkash H, Gupta S, Bhargava A. To Evaluate The Effect Of Various Surface Treatments On The Shear Bond Strength Of Three Different Intraoral Ceramic Repair Systems: An In Vitro Study. J Indian Prosthodont Soc. 2013;13(3):315-320.

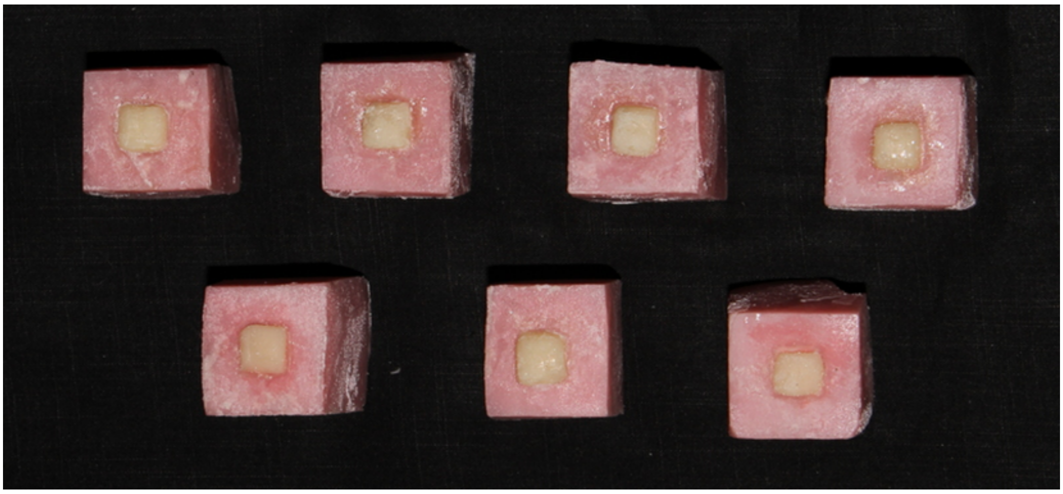
[22] Libecki W, Elsayed A, Lehmann F, Kern M. Efficacy Of Different Surface Treatments For Intraoral Repair Of Veneered Zirconia Frameworks. J Adhes Dent.2017;19(4):323-9.

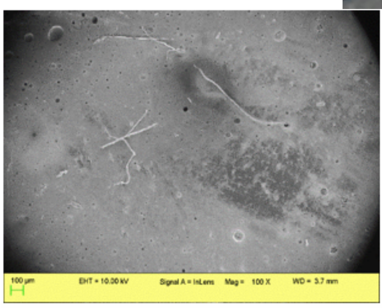
[23] Suliman AA, Swift JE, Perdigo J (1993) Effect Of Surface Treatment And Bonding Agents On Bond Strength Of Composite Resin On Porcelain. J Prosthet Dent 70:118-120.

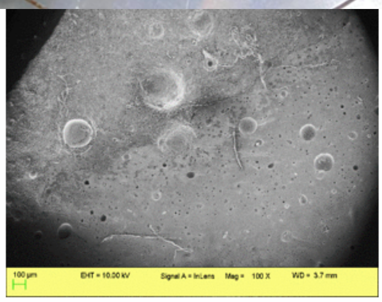
[24] Han IH, Kang DW, Chung CH, Choe HC, Son MK. Effect Of Various Intraoral Repair Systems On The Shear Bond Strength Of Composite Resin To Zirconia. J Adv Prosthodont. 2013;5(3):248–55.

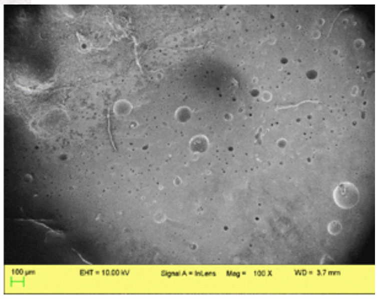
[25] Kocaağaoğlu H, Manav T, Albayrak H. In Vitro Comparison Of The Bond Strength Between Ceramic Repair Systems And Ceramic Materials And Evaluation Of The Wettability. J Prosthodont. 2017;26(3):238-243.

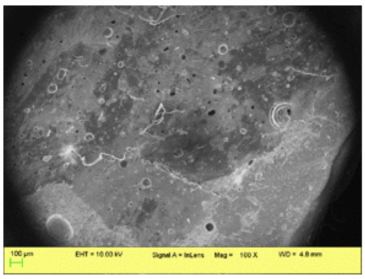
Tables And Charts

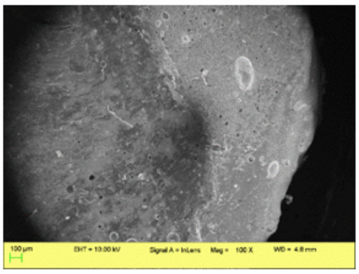


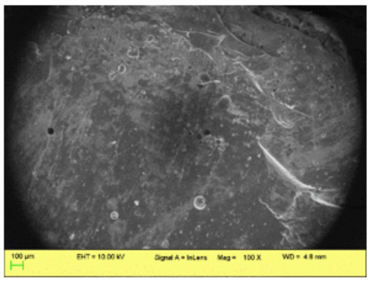

100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 3.7 mm


100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 3.7 mm


100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 3.7 mm


100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 4.8 mm

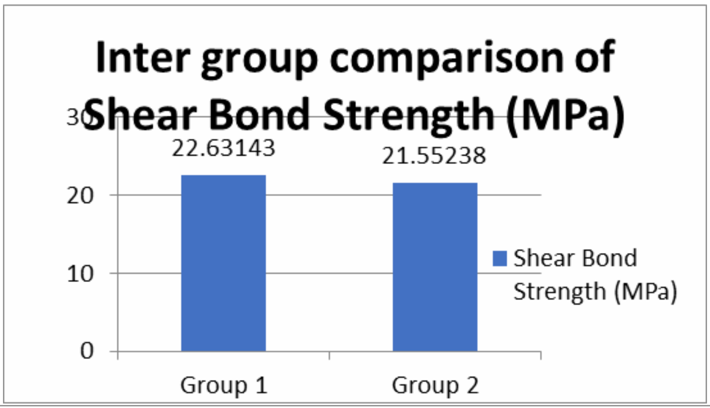

100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 4.8 mm

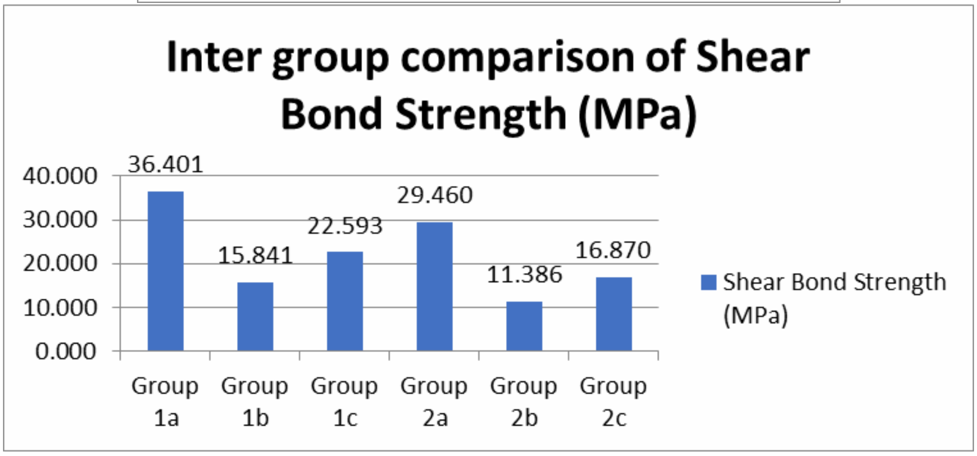

100 µm
EHT = 10.00 kV
Signal A = InLens
Mag = 100 X
WD = 4.8 mm

	Group	Shapiro-Wilk		
		Statistic	df	p value
Maximum load (N)	1	.915	21	.068
	2	.824	21	.002
Shear Bond Strength (MPa)	1	.915	21	.068
	2	.823	21	.002

	Sub groups	N	Mean	Std. Deviation	Median	Chi square value	p value of Kruskal-Wallis Test
Maximum load (N)	1a	7	363.73286	34.248905	378.940	38.316	.000**
	1b	7	158.32143	20.679534	157.160		
	1c	7	225.78000	31.614035	217.850		
	2a	7	294.38143	23.677613	301.970		
	2b	7	113.65857	12.603181	117.850		
	2c	7	168.58714	23.929149	176.490		
	Total	42	220.74357	89.877675			
Shear Bond Strength (MPa)	1a	7	36.40143	3.422360	37.930	38.316	.000**
	1b	7	15.84143	2.067079	15.720		
	1c	7	22.59286	3.165953	21.800		
	2a	7	29.46000	2.369705	30.220		
	2b	7	11.38571	1.248704	11.800		
	2c	7	16.87000	2.395607	17.650		
	Total	42	22.09190	8.992361			
	Group	N	Mean	Std. Deviation	Mann-Whitney U value	Z value	p value of Mann-Whitney U test
Maximum load (N)	1	21	226.16095	61.935844	177.000	-1.094	.274#
	2	21	215.32619	112.526500			
Shear Bond Strength (MPa)	1	21	22.63143	6.199251	177.000	-1.094	.274#
	2	21	21.55238	11.257274			

Group	vs group	Mann-Whitney U value	Z value	p value of Mann-Whitney U test
1a	1b	0.000	-3.130	0.002**
1a	1c	3.000	-2.747	0.006**
1a	2a	1.000	-3.003	0.003**
1a	2b	0.000	-3.130	0.002**
1a	2c	0.000	-3.130	0.002**
1b	1c	0.000	-3.130	0.002**
1b	2a	0.000	-3.130	0.002**
1b	2b	0.000	-3.130	0.002**
1b	2c	18.000	-0.831	0.406
1c	2a	0.000	-3.130	0.002**
1c	2b	0.000	-3.130	0.002**
1c	2c	0.000	-3.130	0.002**
2a	2b	0.000	-3.130	0.002**
2a	2c	0.000	-3.130	0.002**
2b	2c	1.000	-3.003	0.003**


Inter group comparison of Shear Bond Strength (MPa)
30
20
10
0
22.63143
21.55238
Group 1
Group 2
Shear Bond Strength (MPa)


Inter group comparison of Shear Bond Strength (MPa)
40.000
30.000
20.000
10.000
0.000
36.401
15.841
22.593
29.460
11.386
16.870
Group 1a
Group 1b
Group 1c
Group 2a
Group 2b
Group 2c
Shear Bond Strength (MPa)