

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

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Abstract:

Statement of problem

The aim of this study is to test the bond strength of different ceramic repair systems to zirconia 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 to zirconia 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 airborne 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 Kruskal 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 airborne 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° C and 55° 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 (25mm²), 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 Kruskal 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 Kruskal 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, cerasin 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 36.40 MPa, with a highest value of 40.23 MPa 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 11.38 MPa lowest value of 9.73 MPa 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:

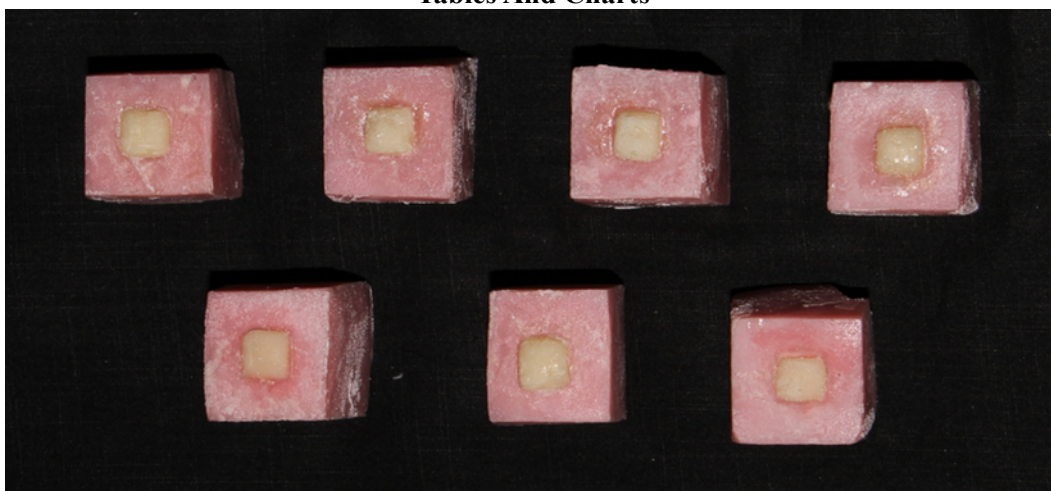
- 1) The shear bond strength of composite resin to zirconia after the two surface treatments are as per the standards of use in dental materials and there was a statistically non significant difference between the two treatments.
- 2) Among the three intraoral repair systems used, A.C.E ceramic repair 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.

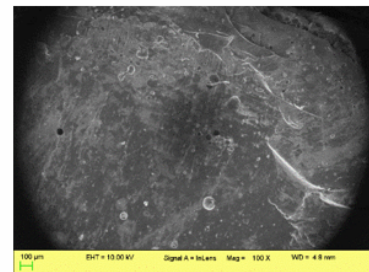
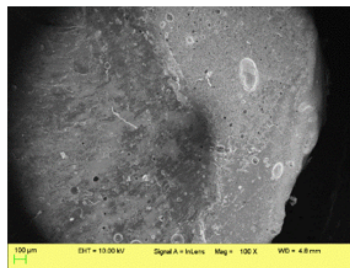
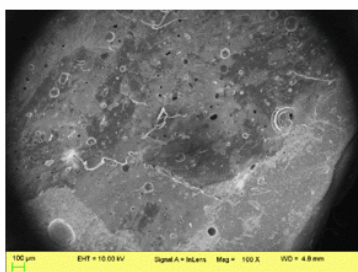
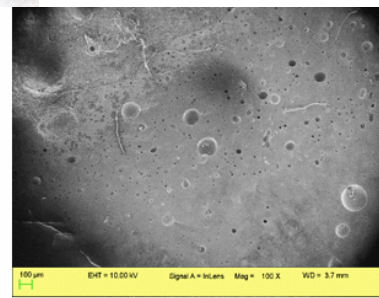
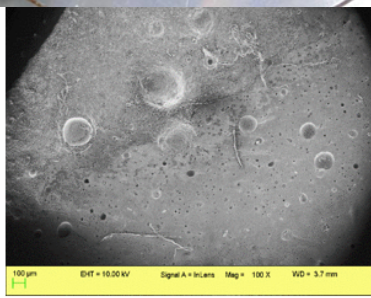
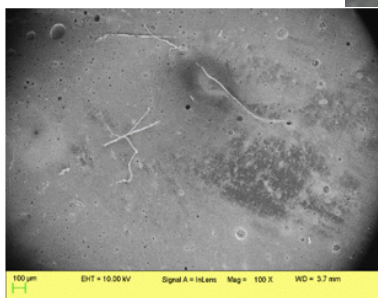
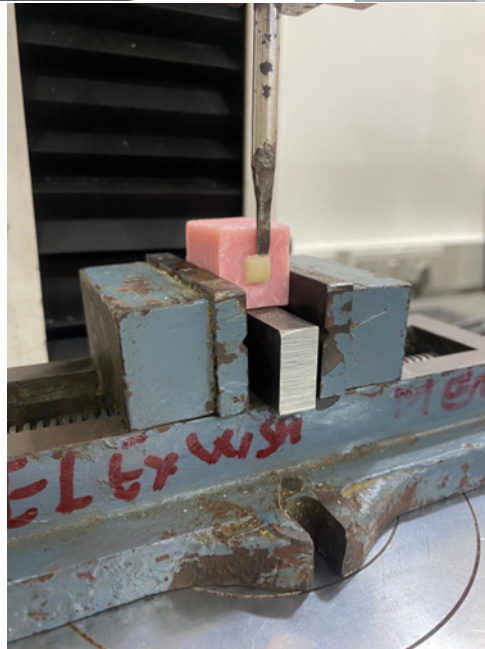
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Tables And Charts





	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**

