



# Shear Bond Strength of Two Repair Systems to Zirconia Ceramic by Different Surface Treatments

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## Abstract

**Introduction:** Intraoral repair has been suggested as a treatment option to repair the chipping or fracture of veneered zirconia; the success of the procedure is mainly determined by the bonding between zirconia and composite resin. The present study aimed to investigate and compare the shear bond strength (SBS) of two intraoral repair systems to zirconia ceramic treated with a laser or air-abrasion surface modification.

**Methods:** Ninety tube-shaped samples (diameter of 10 mm and height of 4 mm) were divided into three main groups: Group I (zirconia 100%, n=30); Group II (veneer ceramic 100% n=30); Group III (zirconia with a veneer ceramic n=30). Each main group was subdivided into two subgroups (n=15): Subgroup A: samples repaired with Ceramic Repair N; Subgroup B: samples repaired with the Cimara Repair System. The subgroup samples were further subdivided based on the treated surface (n=5 samples): Control (no surface modification), Er,Cr:YSGG laser surface modification, and air-abrasion surface modification. The SBS was employed using a universal testing machine. The mode of failure was observed using a stereomicroscope.

**Results:** Significant differences were observed in the mean SBS values between the different surface modifications ( $P<0.05$ ). Tukey's post hoc test showed that the air-abrasion surface modification of the veneer ceramic repaired with the Ceramic repair N system had the highest mean value (13.74 MPa) among the different groups, while no surface modification of zirconia repaired with the Cimara repair system had the lowest mean value (2.84 MPa). The control group (no surface modification) had the lowest mean value among all the treated groups.

**Conclusion:** The SBS is surface modification-dependent, and higher SBS is obtained by air-abrasion than Er, Cr:YSGG laser surface modifications with the selected parameters. The Ceramic repair N system had significantly higher SBS for all surface-treated substrates than the Cimara repair system.

**Keywords:** Laser; Shear bond; Surface modification; Veneer ceramic; Zirconia.

## Introduction

The term *ceramic* denotes any product manufactured from a non-metallic inorganic material. Products for all-ceramic restorations utilise a large variety of crystalline phases as reinforcing substances, and they are composed of more than 99% crystalline phase by volume. The nature, quantity, and size distribution of particles within the crystalline phase directly affect the mechanical properties of the material used. Zirconia has been utilised distinctly for all-ceramic frameworks; it occupies a brilliant part because of its incredible mechanical<sup>1</sup> and biocompatible characteristics<sup>2</sup> and enhanced aesthetics.<sup>3-5</sup>

Despite the ideal properties of zirconia ceramics, their utilisation is still accompanied by certain inconveniences in clinical use.<sup>6</sup> Many studies revealed that the CAD/CAM milled zirconia framework had lower resistance to fracture compared to milled metal and milled polyetheretherketone.<sup>7</sup> The problem is generally due to the separation of the veneer ceramic at the zirconia core interface which is considered the weakest area in the

form of chipping or cracking. This is due to thinning of the zirconium core, improper tooth preparation, and physical trauma with premature contact, particularly in the posterior teeth where the masticatory load is extensive.<sup>8,9</sup>

Replacement of all-ceramic restorations is expensive and less acceptable to the patient, and it has prolonged working time.<sup>10</sup> Different direct and indirect repair systems have been introduced according to the type of fracture of the restoration. The best technique is that it requires less time and fewer complications.<sup>11</sup>

Being less susceptible to etching than glass ceramics, zirconia does not respond optimally to adhesive procedures. Various zirconia surface modifications can be carried out, such as air abrasion with aluminium oxide ( $Al_2O_3$ ) particles, acid application, laser surface modification, and silane or adhesive application. A reliable bond with zirconia materials can be chemically bonded using agents containing a phosphate monomer (MDP).<sup>12</sup>

Recently, the silane coupling agent that chemically bonds with zirconia and enhances the zirconia-resin bond strength was produced. It is used as an intermediary between inorganic and organic materials and is a bifunctional molecule containing non-functional and functional molecules. The functional molecules in silane can polymerise with a functional group in the organic matrix of a composite resin.<sup>13,14</sup> The combination of air abrasion and silane application raises the success rate of repairing ceramic restorations.<sup>15,16</sup>

One of the new surface modifications explored was laser irradiation. In 2001, laser technology application was approved in the medical and dental fields by Convissar and Goldstein.<sup>17</sup> Nowadays, with laser innovation headways, lasers are utilised to alter the surface texture of materials, enhancing their bonding property to the dental structure.<sup>18</sup> Some experimental studies have revealed the use of lasers, such as Er:YAG (erbium-doped yttrium aluminium garnet laser), diode, and CO<sub>2</sub>, for improving the SBS between resin cement and zirconia ceramics. The rise in temperature and surface pulverisation due to laser absorption by the ceramic material causes some pores on the outer surface, leading to micromechanical retention of the zirconia ceramic.<sup>19</sup> Other studies have shown that with different zirconia surface modification strategies such as sandblasting or Er:YAG, Nd:YAG (erbium-doped yttrium, scandium, gallium and garnet) laser application are not effective in increasing the bond strength, and sometimes they reduce it.<sup>20,21</sup> The present study aimed to investigate and compare the shear bond strength (SBS) of two intraoral repair systems for a zirconia ceramic treated with a laser or air-abrasion surface modification. The null hypothesis of the present study was that neither the surface modifications of zirconia/veneering ceramics nor different repair systems would affect the SBS between the repaired material and the zirconia/veneering ceramic.

**Materials and Methods**

Materials used in the study are listed in Table 1. In this study, a total of 90 disc samples (10 mm in diameter and 4 mm in height) were finished to test the SBS of the zirconia (DD BioZ Wiso, Dental Direkt GmbH, Industriezentrum 106, 32139 Spenge, Germany) and veneering ceramic (VITA VM<sup>®</sup> 9 VITA Zahnfabrik.Spitalgasse3, 79713 Bad Säckingen, Germany), repaired by different repair systems with different zirconia/ceramic surface modification methods. The tested samples (Figure 1) were divided into three main groups<sup>22</sup>:

1. Group I: 30 samples fabricated from zirconia 100%
2. Group II: 30 samples fabricated from veneer ceramic 100%
3. Group III: 30 samples fabricated from zirconia with veneer ceramic.

According to the zirconia repair systems, each main group was arbitrarily subdivided into two subgroups as follows:

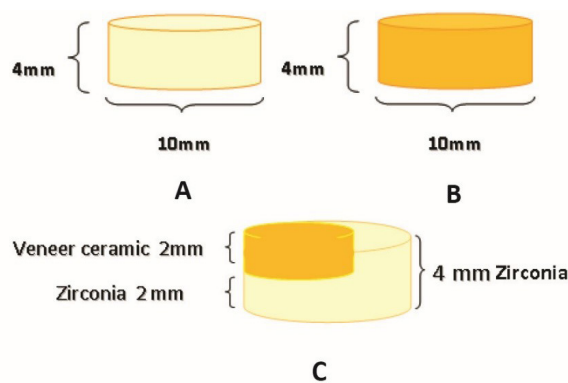
Subgroup A: 15 samples using Ceramic Repair N as a repair material.

Subgroup B: 15 samples using the Cimara Repair System as a repair material.

The subgroup samples were further subdivided based on surface modification as follows (n = 5 samples): Control (no surface modification), laser surface modification, and air-abrasion surface modification.

**Specimen Preparation**

Zirconia/veneering ceramic tested samples were produced to simulate the fracture type of ceramic veneer restoration intraorally, and the planned size of the sample was shaped after sintering to comply with the manufacturer’s instructions. The planned designed dimensions were as follows: zirconia specimens (group I) were 10 mm in diameter and 4 mm in height (Figure 1A); veneer ceramic specimens (group II) were 10 mm in diameter and 4 mm in height (Figure 1B); veneer zirconia/ ceramic specimens (group III) were 10 mm in diameter and 4 mm in height with the interface in the middle; a 2 mm thick ceramic was applied over the surface of the zirconia sample with good condensation and blotting (Figure 1C). The sintering cycle for zirconium was done by using a sintering furnace (VITA ZYRCOMAT<sup>®</sup> 6100 MS, Germany. The chamber



**Figure 1.** Tested Samples (A: Zirconia 100%, B: Veneer ceramic 100%, C: Zirconia veneered with the veneer ceramic).

**Table 1.** Materials Used in the Study

Products	Manufacturer	Batch No.	
Zirconia	DD BioZ Wiso, Dental Direkt GmbH, Industriezentrum 106, 32139 Spenge, Germany	32139	
Veneer ceramic	VITA VM <sup>®</sup> 9 VITA Zahnfabrik.Spitalgasse3, 79713 Bad Säckingen, Germany	0124	
Zirconia Repair systems	Ceramic Repair N Cimara	Ceramic Repair N <sup>®</sup> , Ivoclar Vivadent AG 9494 Schaan/Liechtenstein Cimara <sup>®</sup> , VOCO GmbH, Anton-Flettner-Straße1-3, 27472 Cuxhaven, Germany	649118 091099

heated up to 900°C at (8°C/min) for 30 min, then heated to reach a final temperature of 1450°C at (3°C/min) for 120 min, and cooling to 200°C at 10°C/min. The veneered ceramic samples were fired at 910 °C under a vacuum for 17 min. in a porcelain furnace (VITA VACUMAT® 6000 M, Germany).

#### *Laser Surface Modification*

In this group, Er,Cr:YSGG laser irradiation (Waterlase MD,Er,Cr:YSGg 2780, USA) was used to prepare the zirconia surface. The laser energy was delivered using the MZ6 tip with a diameter of 600 µm and length of 9 mm, and the laser was operated at a wavelength of 2780 nm, set at 300 mJ, 3 W, frequency of 10 Hz and pulse duration of 140 µs. The surface modification was done by scanning perpendicular to an imaginary circular plane (diameter 4 mm) at the center of the sample, and the hand piece was used at a distance of 6 mm (focusing distance of the hand piece) above the surface (non-contact mode) for 10 seconds accompanied with water and air spray.

#### *Air Abrasion*

The surfaces of all prepared samples were air- abraded (sandblasted) with 50 µm aluminum oxide particles using a chair-side (intraoral) sandblasting unit (BIO-ART Microjato, Microblaster, Brazil). The samples were held in a specially designed stand to standardize the distance between the samples and the nozzle of the sandblaster (approximately 10 mm). The nozzle was adapted to be at a 90° angle to the bonding surface of the sample, and the sandblasting time was 5 seconds under a pressure of 80 Psi with slightly circular motions. Then, the bonding surfaces were rinsed with 99.8% ethyl alcohol followed by distilled water for 20s, and dried with oil-free air spray for 5 seconds.

#### *Application of Repair Systems*

A circular area of 4 mm in diameter was demarcated at the centre of the bonding surface of each sample through the application of an adhesive tape with a circular hole of 4 mm in diameter on the prepared surface of the sample so that the applied adhesive agents would be confined to a standardised area on the surface. The margins of the tape were burnished to ensure complete adaptation of the tape to the bonding surface. Each repair system component was added following the manufacturer's instructions:

#### *Ceramic Repair N system*

According to the manufacturer's instructions the Ceramic Repair N System was applied to the demarcated area of the bonding surface by the following steps:

1. Application of the primer: Monobond plus primer was used in a single drop and brushed on the demarcated area of (zirconia, ceramic, and zirconia veneered ceramic) surface, and it allowed the

material to react for 60 seconds, and then dried for 10 seconds with an oil-free air syringe.

2. Application of the bonding agent: Heliobond (light-curing bonding agent) was applied in a single drop to the conditioned surface of (zirconia, ceramic, and zirconia veneered ceramic) with a brush tip, thinned with compressed air for 15 seconds, and then light-cured for 10 seconds.
3. Application of the composite resin: A clear translucent standardized plastic cylinder with an inner diameter of 4 mm was sectioned with sharp scissors in a perpendicular way to its long axis to form cylinders of 4 mm in height. The translucent plastic cylinder was put appropriately over the hole of the adhesive tape that was placed over the bonding surface of each sample. Subsequently, the composite resin was packed directly against the demarcated bonding surface through the translucent plastic cylinder with an ash plastic instrument and adapted to avoid air entrapment in two increments, the first layer of 2 mm thickness and the second layer of 2 mm thickness; each layer was light-cured for 10 seconds following the manufacturer's instructions using light-curing unit (LEDition) at an intensity of 500 mw/cm<sup>2</sup>. The composite was cured for 10 seconds at four points all around to ensure complete polymerization of the composite.

#### *Cimara Repair System*

The Cimara Repair system was applied to the demarcated area of the bonding surface following the manufacturer's instructions:

1. Silanisation: A capsule of a silane coupling agent was opened and dispensed single drop in to a mixing dish. The silane agent was brushed on to the (zirconia, ceramic, and zirconia veneered ceramic) surface and left to react and evaporate for 2 minutes without the use of an air jet.
2. Application of the bonding agent: The Cimara light-curing bonding agent was brushed to the conditioned surface of the (zirconia, ceramic, and zirconia veneered ceramic) surfaces with a brush tip, thinned with air for 15 seconds and then light cured for 20 seconds.
3. Application of the composite resin: The placement of the composite resin of the Cimara Repair System was performed exactly in the same procedure mentioned in the Ceramic Repair N System except the composite resin, and it followed the recommended manufacturer's instructions for the composite; the curing time for each 2 mm layer of the composite was 40 seconds.

#### *Storage and Thermocycling*

The ninety repaired tested samples were stored in distilled

water at 37°C for 7 days in an incubator (Fisher Scientific, Germany) before being thermocycled. After the storage period, the samples were thermocycled for 300 cycles with a dwell time of 30 seconds, and the transfer time between baths was 4 seconds, at temperatures ranging from 5 ± 2°C to 55 ± 2°C.<sup>23</sup>

**Shear Bond Strength Testing**

Following storage and thermocycling, each repaired sample was fitted into a specially constructed jig and tested with a universal testing machine (Universal testing machine, SJX-500N-200 mm electric push pull test station 500N, Model; AEL.1000-400, China) with a knife-edged rod of 0.5 mm width at a crosshead speed of 1 mm/min. that was applied to the composite/substrate interface until the fracture occurred. The SBS was calculated by dividing the load at failure (N) by the surface area of the bonded surface (12.56 mm<sup>2</sup>) and expressed in Mega Pascal (MPa): S = F/A

Where S = Shear bond strength (MPa), F = load at failure (N), A = π r<sup>2</sup> (12.56 mm<sup>2</sup>), π = 3.14, and r = radius of the bonding area

**Failure Mode Evaluation**

Each sample was examined at the composite/substrate interface under a stereomicroscope lens (Hamilton Altay, Italy) at 40× magnification, and images were captured using a computer program. The mode of failure was recorded as follows: *cohesive* (failure within the substrate or within the repaired material), *adhesive* (failure at the composite-substrate interface), or *combination* (areas of adhesive and cohesive failure).

**Statistical Analysis**

The SPSS software application (SPSS Inc., version 19.0; Chicago, IL, USA) was used to analyse the collected data. A one-way analysis of variance (ANOVA) was utilised to detect the significant difference between all different surface modifications, and a two-way ANOVA was utilised to detect the significant differences between the tested groups (surface modifications and type of repair systems). P values of < 0.05 were considered statistically significant. Student’s t test was applied to evaluate the differences between the two tested groups of repair systems. Tukey’s post hoc test was used to compare the significant groups.

**Results**

The mean, standard deviation (SD), and SBS of the tested samples made from zirconia, veneer ceramic, and zirconia veneered with ceramic repaired with two different zirconia repair systems following different surface modifications are listed in Table 2.

For both zirconia repair systems, one-way ANOVA showed that there was a significant difference in the mean values of SBS between different surface modifications for all groups (P < 0.05) (Table 3).

Tukey’s post-hoc test showed that the air-abrasion surface modification of the veneer ceramic repaired with the Ceramic repair N system (group II) had the highest mean value (13.74 MPa) among the different groups, while no surface modification of zirconia repaired with Cimara repair system (group I) showed the lowest mean value (2.84 MPa) (Table 2).

Two-way ANOVA (Table 4) showed that there was a

**Table 2.** Mean, Standard Deviation of the Shear Bond Strength (MPa)

Repair System	Substrate Groups	Surface Treatments, Mean ± (SD)			N
		No Surface Treatment	Air Abrasion	Er,Cr: YSGG Laser	
Ceramic Repair N	Group I	5.55 ± (0.10) e	10.41 ± (0.38) b	6.38 ± (0.23) d	5
	Group II	7.20 ± (0.48) d	13.74 ± (1.28) a	11.24 ± (0.31) b	5
	Group III	4.48 ± (0.35) e	8.24 ± (0.33) c	6.36 ± (0.42) d	5
Cimara	Group I	2.84 ± (0.27) f	6.91 ± (0.48) d	6.00 ± (0.39) d	5
	Group II	6.49 ± (0.62) d	12.64 ± (0.36) a	10.90 ± (0.07) b	5
	Group III	3.48 ± (0.35) e	8.02 ± (0.33) c	5.03 ± (0.42) e	5

Abbreviation: SD, standard deviation.

Number of samples = 5; Different letters are statistically significantly different according to Tukey’s test.

**Table 3.** One-Way ANOVA of the Shear Bond Strength for All Groups With Different Surface Treatments Repaired by Ceramic Repair N and Cimara

Repair System		Sum of Squares	df	Mean Square	F Value	P Value
Ceramic Repair N	Between groups	370.112	8	46.264	159.475	0.000*
	Within groups	10.444	36	0.290		
	Total	380.556	44			
Cimara	Between groups	411.543	8	51.443	327.353	0.000*
	Within groups	5.657	36	0.157		
	Total	417.201	44			

\*Significant differences, df = degree of freedom.



significant difference in the mean value of SBS for both zirconia repair systems and surface modifications ( $P < 0.05$ ).

An independent  $t$  test (Table 5) showed that there was a significant difference in the mean value of SBS for the zirconia (group I) ( $P < 0.05$ ) repaired with different repair systems (Ceramic repair N, Cimara). However, there was no significant difference in the mean value of SBS for the veneer ceramic (group II) and zirconia veneered ceramic (group III) ( $P > 0.05$ ) repaired with different repair systems (Ceramic repair N, Cimara).

The examination of the samples, the *cohesive* failure within the veneer ceramic was the dominant mode of failure in the samples were repaired by both Ceramic Repair N and Cimara repair systems (Cohesive 90%, 55% respectively) (Figure 2A). The *cohesive* failure within the veneer ceramic material showed that the bond strength of the repair materials to this substrate was strong, and it was better than the strength of the substrate itself. The results (Figure 2D) showed that the *mixed failure* at the zirconia-composite interface was the dominant feature mode of failure for most substrates repaired by Cimara Repair N (mixed 85%) and *adhesive failure* with Cimara systems (Adhesive 60%) (Figure 2B).

## Discussion

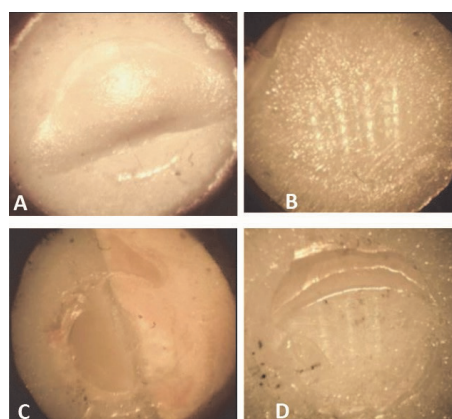
In the present study, the efficacy of two different commercially available repair systems, namely the Ceramic repair N system and the Cimara repair system, was compared with air abrasion and laser surface modifications on the SBS to the zirconia veneered ceramic. The null hypothesis of the present research was partially accepted based on the results obtained. Therefore, the control group (no surface modification) showed the lowest SBS compared to the other surface-treated samples. The highest mean SBS value was recorded in air abrasion surface modification, followed by laser surface modification for both repair systems. This can be attributed to different factors affecting bond strength, including the types of zirconia and veneer ceramics, types

of repair systems that contain different silane coupling agents, bonding agents, composite resins, and methods of surface modification.

For all-ceramic fixed restorations, the zirconia core-ceramic veneering interface is considered the weakest part.<sup>23,24</sup> The SBS between zirconia and veneered ceramic is mainly influenced by the kind of veneering ceramic utilised.<sup>25</sup> This is because veneered ceramic restorations have various coefficients of thermal expansion, where the veneer ceramic is slightly lower than zirconia, leading to a mismatch or differences in the coefficient of thermal expansion between the zirconia core and the veneered ceramic being utilised, which leads to residual stress on crown restoration.<sup>26</sup> In addition, SBS is influenced by the strength of the veneered ceramics, zirconia core, and conditioning surface interface between them. On zirconia, SBS is affected by not only surface roughness but also processing techniques such as blasting or milling.<sup>27</sup>

Intraoral restoration repair is a more acceptable method than a replacement for both patients and dentists; it is time saving and less costly. Generally, the principal zirconia adhesion methods include mechanical or chemical adhesion promoters.

Air abrasion is considered a more efficient strategy to



**Figure 2.** Stereomicroscope Images of the Specimens: (A) ceramic cohesive failure, (B) zirconia adhesive failure, (C), zirconia/ceramic mixed failure, (D), zirconia mixed failure

**Table 4.** Two-Way ANOVA of the Shear Bond Strength Between Repair Systems and Surface Treatments for All Groups

Variable	Sum of Squares	df	Mean Square	F	P Value
Repair system	812.46	17	47.79	213.71	0.000*
Surface treatments	5131.58	1	5131.58	22947.28	0.000*
Repair system × surface treatments	812.46	17	47.79	213.71	0.000*

\*Significant differences, df = degree of freedom.

**Table 5.** Independent Samples  $T$  Test of Shear Bond Strength for All Groups Between Two Repair Systems

Shear Bond Strength	Substrate Group	Ceramic Repair N				Cimara			
		t	df	SE	P Value	t	df	SE	P Value
	Group I	2.661	28	0.75	0.013*	2.661	18	0.75	0.013*
	Group II	0.698	28	1.02	0.491	0.698	18	1.02	0.491
	Group III	1.203	28	0.76	0.239	1.203	26.3	1.10	0.239

\*Significant difference, SE = Standard Error, df = degree of freedom.

modify the surface of hard zirconia than laser irradiation due to the roughening of the surface of the material, increased surface area, and clean and enhanced surface wettability that produces mechanical interlocking between the core zirconia or veneer ceramic and repair material.<sup>28,29</sup> This finding was supported by the SBS results. Some researchers have expressed that the micro porosities induced by surface modifications may consider a crack initiator, which leads to the weakening of ceramic materials.<sup>30</sup> In addition, sandblasting can produce damage, defects, or cracks on the surface of zirconia.<sup>31</sup> Many authors have explained that sandblasting improves the SBS of the ceramic to zirconia,<sup>32</sup> but other studies have shown that this method does not affect the SBS between them. In this study, the tested zirconia substrates air-abraded with 50 µm alumina oxide showed appropriate roughness to advance the bond of the repair material to the veneer ceramic and core zirconia.

Surface modification by laser application has been recommended by many authors as an alternative method to change the surface texture of zirconia, enhance surface topography,<sup>33</sup> and surface roughness,<sup>34,35</sup> and activate micromechanical bonding to the resin repair material.<sup>36</sup> Laser effects on zirconia could be inherent in ablation or vaporization, which is reasoned as a micro-explosion of portions of material heated higher than the melting point.<sup>37</sup> Both Er:YAG and Er,Cr:YSGG lasers are erbium-pulsed lasers with different pulse mechanisms for stimulating the flash lamp. Er,Cr:YSGG uses a technical method named pulse-forming network (PFN). The Er,Cr:YSGG laser is less effective but penetrates deeper and it is not as localized as Er:YAG.<sup>38</sup>

Some studies claimed that laser surface modification of zirconia significantly increased SBS because of an increase in surface roughness.<sup>39</sup> It was proposed that Nd:YAG lasers used with varying power settings and different times of irradiation successfully roughened zirconia and ceramic surfaces.<sup>36</sup> Others have suggested that Nd:YAG lasers have a little effect on enhancing the bond strength between zirconia and ceramics.<sup>40</sup>

A few micrometers were the optical penetration depth of the Er:YAG laser. This might be a beneficial characteristic of the surface modification of dental ceramics, as structural modifications are restricted to the outermost surface.<sup>41</sup>

Studies examined the use of Nd:YAG, Er,Cr:YSGG lasers to enhance the repair bond strength of zirconia and ceramics. Some authors have mentioned that Er,Cr:YSGG, and Nd:YAG lasers, when combined with sandblasting, enhanced the bond strength between zirconia and the composite resin interface. Er,Cr:YSGG can be used for surface modification as a chairside method in dental clinics to repair zirconia ceramics.<sup>42,43</sup>

Er,Cr: YSGG (2780 nm) is a good competitor for the removal of hard and delicate dental tissues. Erbium

lasers remove hard dental substances via a process called thermal ablation. This mechanism removed the explosive tissue mediated by water. This happens as the eventual outcome of the rapid warming of the sub-surface water present underneath the hard tissue framework which consequently assimilates infrared laser light. The warming of these water particles extends their sub-atomic vibrations and therefore the subsurface pressure. At last, a “blast” of tissue achieves the removal of tooth material or some other hard materials like zirconia or ceramics.<sup>44,45</sup>

Subsequently, in the present experimental study, a low-power irradiation laser (Er,Cr:YSGG) was used with water cooling. The SBS results demonstrated that surface modification with the laser was insufficient or unsuccessful in enhancing the SBS compared with the air-abrasion method for all tested groups. This could be owing to the small surface modification caused by the reduced heat generated by laser power.

The heat creation induced a damaged layer on the surface of the laser-modified substrate. This damaged layer includes microcracks, creating a weak micromechanical bond with the outer layer of zirconia, and because of the deficient bond strength of the tested sample, it tends to break after applying little force during testing. The distance of irradiation and the utilisation of a cooling system during exposure irradiation could influence these findings, resulting in lower mean SBS values compared with the higher values obtained using the sandblasting method.<sup>19,46</sup>

The silane coupling agent was viewed as chemically well bonded to the substrate surface. These strategies improve surface roughness and enhance SBS for both the veneer ceramic and chemically inert zirconia.<sup>47</sup> Silane coupling agents are notable for forming covalent chemical bonds between organo-functional monomers and glassy ceramics, but they cannot react directly with inert zirconia.<sup>48</sup>

Monobond plus primer contains a mixture of the silane coupling agent, 3-methacryloxypropyltrimethoxysilane (3-MPS), which compels for bonding the resin to silica-based substrates such as feldspathic porcelain, and phosphoric acid methacrylate: 10-methacryloxydecyl dihydrogen phosphate (10-MDP) functional groups that have a high affinity for responding to silica-free substrates.<sup>49</sup>

These outcomes can be clarified by the fact that the Cimara Repair System contains only 3-MPS, which is an adhesion promotion agent between silica-containing surfaces, such as the feldspathic veneer ceramic and composite resin, whereas the zirconia substrate does not provide a reliable bond if it is alone.<sup>50</sup> This can be explained by the presence of silica on the ceramic surface, which is essential for durable siloxane bonding. The Si–O–Z (Z = zirconia) bonds on the zirconia surface are hydrolytically less stable than the bonds (Si–O–Si)

formed on the ceramic surface. 10-MDP- primers are used for this reason, and they give a terminal group with phosphoric acid, which reacts in turn with zirconia and creates stable P-O-Zr chemical bonds. The molecule at the other end combines with a vinyl terminal group, facilitating copolymerisation with the resin. The carbon chain separates the two functional groups to provide viscosity, rigidity, hydrophobicity, and solubility.<sup>51,52</sup>

The hydrolysis of the silane coupling agents was directly affected by differences in pH and concentration. Silanes with a low pH and low concentration are hydrolytically stable. Silanes with a high pH and high concentrations are more inclined to undergo hydrolytic degradation. Subsequently, the bond strength was reduced after water storage.<sup>53</sup> This clarified the superiority of the SBS of Ceramic Repair N, which has a low pH (4.0) and low concentration (1% MPS), compared to the substrates repaired with Cimara Repair, which has a high pH (5.5) and high concentration (3% MPS).

The bonding agents of the two repair systems were tested in the current study and varied in chemical composition and viscosity: (Heliobond: bonding agent of Ceramic Repair N System) containing (Bisphenol-glycidyl methacrylate Bis-GMA, and Triethylene glycol dimethacrylate TEGDMA monomers 99wt.%) has low viscosity because (TEGDMA) monomer is a low-molecular weight compound and reduces the viscosity of the bonding agent; the low viscosity of the bonding agents increases their capability of diffusion into microscopic undercuts on the surface of substrates to gain total wetting and increase their bond strength to these substrates.<sup>54</sup> (Cimara Opaquer liquid: bonding agent of Cimara Repair System) contained (Bis-GMA and Urethane dimethacrylate UDMA). These differences were likely identified as the variation in the mean SBS values of these repair systems.

Binding between the resin composite and zirconia ceramic can be achieved micromechanically and chemically. In the current investigation, two types of composite resins were utilised: the first type, Tetric<sup>®</sup> N-Ceram (nanohybrid composite), is composed of dimethacrylates (19–20 wt%). The fillers contained ytterbium trifluoride, mixed oxide, barium glass, and prepolymer (80–81 wt%) and had an organic filler content about (55–57 vol%) and a particle size between 40 nm and 3000 nm. The second type of Arabesk Top (microhybrid composite) has a low filler content of approximately (56 % wt) and particle size of micro fillers (0.05 µm) and small particle fillers (0.7 µm). The size, shape, and amount of the filler particle play an important role in the final properties of composite restorations. Because of the reduction in the particle size and wider distribution, filler loading could be increased. A high filler content results in a reduction in volumetric shrinkage, followed by a reduction in the contraction stress value. Thus, it has been reported that

a combination of reduced shrinkage and decreased stress improves bond strength. Nano-filled composite resins were introduced with a higher filler content, which led to an improvement in composite restoration properties like abrasion resistance, shear and tensile strength, and microhardness.<sup>55,56</sup>

Fillers differ in size and amount within the two types of composite resin, probably associated with the increase in the mean values of SBS for the samples repaired with the Ceramic Repair N System, which contains a nanohybrid composite resin, compared with the samples repaired with the Cimara Repair System, which contains a microhybrid composite resin.

Recently, nanohybrid composite resins containing nanoparticles and nanoclusters have provided particular physical and mechanical properties like reduction in shrinkage, coefficient of thermal expansion, and water absorption, but they have indicated high bond strength and durability, which are directly related to the filler level and size, distribution, orientation, and quantity consolidation.<sup>57</sup>

### Conclusion

The SBS is surface modification-dependent, and a higher SBS is obtained by air abrasion than Er,Cr:YSGG laser surface modification with the selected parameters. The Ceramic repair N system had a significantly higher SBS for all surface-treated substrates than the Cimara repair system.

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### Conflict of Interests

The authors declare that they have no conflict of interest

### Ethical Considerations

The present study was approved by the Research Ethics Committee board (the University of Mosul, College of Dentistry, REC reference No. UoM. Dent/ DML 9/20).

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