EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 3277:3290, October, 2023

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 01-08-2023 • Accept Date : 31-08-2023 • Available online: 20-10-2023 • DOI : 10.21608/EDJ.2023.226586.2666

IMPACT OF DIFFERENT SURFACE TREATMENTS ON BOND STRENGTH OF CAD/CAM FABRICATED Y-TZP CERAMIC ONLAYS SUBJECTED TO THERMO-MECHANICAL CYCLIC LOADING

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ABSTRACT

Objectives: The aim of this study intended to evaluate the effect of various surface treatments on the adhesion of CAD/CAM fabricated Y-TZP ceramic onlays.

Materials and methods: Forty-eight, cracks-free extracted human molars have been acquired in the study. The specimens have been divided randomly according to surface treatment of Zirconia into four main groups of twelve specimens each as follows (n=12): group1: tribochemical silica coating; group 2: sandblasting; group 3: sandblasting with primer; and group 4: sandblasting and laser with primer. The first half of the specimens were put through the tests right away, whereas the other half were put through the tests after being subjected to thermo-mechanical cyclic stress. Buehler Isomet 4000 Cutting Machine (IsoMetTM 4000, Buehler Ltd, Lake bluff, LL, USA) was used for the preparation of standardized onlays cavities. Then micro-tensile bond strength test µTBS was performed. Data were statistically analyzed using the Shapiro-Wilk, post hoc-Tukey, student t-test, and one-way ANOVA tests.

Results: The outcome of the study revealed statically significant differences in µTBS between all groups. The most favorable bonding was in the group of sandblasting with primer (12.50 ± 2.40) and the least was with the tribochemical silicoating (3.70 ± 0.96) (P=0.002).

Conclusions: Within the parameters of this study, the different surface treatments had a significant difference in µTBS. Sandblasting with primer consider the most favorable outcome of the current study. However, thermomechanical cyclic loading deteriorates the bond strength when using sandblasting alone.

KEYWORDS: Bond strength; CAD/CAM; Cyclic loading; Ceramic; Onlays

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INTRODUCTION

In the modern era of restorative dentistry, CAD/CAM technology is used to offer quick and accurate results, and this chairside service facilitates better, faster, and more efficient product quality.[1-3] Fewer material failures are anticipated to occur during manufacturing and clinical application.[4] When compared to hand-built materials, CAD/CAM blocks have fewer defects, resulting in higher reliability.[5, 6]

Zirconia-based materials have seen increased application in recent years owing to their biocompatibility, strong flexural strength, and aesthetic capability.[7] Moreover, zirconia is taking an increasingly essential role in dentistry, with a wide range of clinical applications including indirect restorations.[8] For example, onlays indirect restorations are a useful treatment option for posterior teeth with severe cavities caused by caries because they not only give superior aesthetics but also reduce tooth tissue loss.[9]

Nonetheless, the topic of how to cement and bond zirconia becomes increasingly demanding. inevitably, unlike glass ceramics, zirconia is not susceptible to erosion, making it difficult to apply adhesives. Implementing safe and standardized zirconia adhesive protocols is required to complete the treatment plan effectively.[10,11] Therefore, various zirconia surface treatments, primers or adhesives, and resin cement varieties have been tested. To date, no standardized adhesive cementation method that yields reliable results has been established.[12, 13]

Furthermore, to create a strong bond between a resin and ceramic, retention is required both mechanically and chemically. For that reason, some of the surface treatments have been proposed for resin bonding to zirconia such as sandblasting, sandblasting with primers, tribochemical silica coating, and laser irradiation.[14]

The application of sandblasting generates a rough surface for cement which could successfully enhance the zirconia bonding strength. Whereas, the use of primers containing 10-MDP which is frequently followed by alumina sandblasting improves the adhesion strength of zirconia to resins resulting in chemical bonding of 10-MDP and yttrium-stabilized zirconium oxide blocks (Y-TZP) maintaining a straightforward process for ceramic substrates for producing excellent bonding.[11, 12, 15-17]

On the other hand, the tribochemical silica coating method roughens and chemically activates ceramic surfaces, thereby, the implanted silica and alumina particles chemically react with the silane coupling agent as a result of blasting pressure.[18] In addition laser irradiation is another surface treatment technology, that way the use of lasers to change the surface of zirconia ceramics has been suggested.[19] However, the best method for treating zirconia to achieve a strong chemo-mechanical bond with cement materials is uncertain.[20]

In vitro, studies have demonstrated that aging and thermocycling loading are two significant elements that contribute to a reduction in the bond's strength. Therefore, to investigate the exposure of materials and teeth to temperature ranges comparable to those that occur in the oral cavity, we will use thermo-mechanical cyclic loading on different surface treatments to Y-TZP zirconia. This will allow us to determine whether or not such exposure could produce adverse consequences.[21] Also several testing procedures have been recommended, including microtensile test.[22] The microtensile bond strength (MTBS) test, in particular, is a useful tool for determining intra-cavity bond strength before and after simulated clinical stress.[23]

Even though the bonding effectiveness between the luting agent and the zirconia surface has not been well researched, thereby scientific evidence on the bonding behavior of various surface treatments of the new CAD/CAM materials is scarce. So, this research will examine resin bond strength and favored treatment protocols for this novel and widespread materials.**Materials Utilized in the current study:** The IPS e.max ZirCAD blocks (Ivoclar Vivadent, Amherst, NY), G-CEM® Capsule self-adhesive (Hasunuma-cho, Itabashi-ku, Tokyo, Japan), Airborne particle abrasion material (Renfret GmbH, Untere Geisseisen Hilzingen, Germany), Laser system (Nd: YAG) (Amplitude Laser, Boston, USA), and Silica-coated aluminum oxide particles (3M ESPE, St.Paul, MN, USA).

Brand names, characteristics, manufacturers, compositions, and application processes of the restorative devices are presented in Table 1. The luting resin cement system employed in the current investigation, its composition, and application processes are described in Table 2.

Study Design

This laboratory study evaluated the microtensile bond strength of CAD/CAM fabricated ceramic onlays Y-TZP using one independent variable which is the surface treatment.

Specimen preparation

In this particular investigation, a total of forty-eight extracted human molars that were devoid of carious lesions and cracks were collected. The collected teeth extracted due to periodontal disease reasons and were collected from the Oro-Maxillofacial Surgery Department clinic, Faculty of Dentistry, Mansoura University. The Faculty of Dentistry Ethical Committee approved infection control requirements for the collecting of teeth (A25080622). After using a manual scaler to remove any remaining soft tissue and calculus (Zeffiro, Florence, Italy), the next step was to polish the teeth. To check for preexisting abnormalities, the teeth were cleaned with a rubber cup and fine pumice water slurry.

Only intact, non-carious, and unrestored teeth were included in the study. The teeth were examined under a stereomicroscope (Olympus model SZ-PT, Tokyo, Japan) to ensure the standardization of this study.

The teeth were stored in distilled water at 37±1 °C until use, however, the distilled water was changed constantly every 5 days throughout the study and was removed only during the test procedure to avoid any dehydration. Teeth were preserved in 1% percent chloramine-thymol solution (Chloramine-T) as a disinfectant for 72 hours before performing restorative procedures. The selected teeth have approximately the following crown dimensions, mesio-distal width (9.6 mm to 11.3), bucco-lingual dimension (9.02 mm to 11.1), and cervico-occlusal height (8.31 mm (± 0.75)) that were measured with a digital caliper.

The specimens were divided randomly according to surface treatment of Zirconia into four main groups of twelve specimens each as follows (n=12): Group 1: sandblasting; Group 2: sandblasting with primer; Group 3: sandblasting with tribochemical silica coating; and Group 4: sandblasting with laser; Half of the specimens were tested immediately, and the other half were tested after Thermo-mechanical cyclic loading.

To achieve a smooth dentin surface, the outer layers of dentin and enamel were removed from each tooth. This exposed the dentin in the tooth's mid-coronal region. Using a diamond (IsoMetTM 4000, Buehler Ltd., Lake bluff, LL, USA) low-speed automated saw and a water coolant (Cool 2 water-soluble anticorrosive cooling lubricant, Buehler Ltd., Lake Bluff, IL, USA) with a lubricant:water proportion of 1:33, the teeth were cut perpendicular to the longitudinal axis of each individual tooth.

600 grit silicon carbide paper was used to smear the exposed dentin surfaces into a uniform thickness. All surfaces were carefully observed under a stereo-microscope (model AZ61, Olympus Inc., Tokyo, Japan) to be sure that there was no residual enamel or remaining caries on the dentin surface. Using the required sequence of particular

TABLE (1). Current research restoration materials

Material	Description	Composition		Manufacturer	Batch Number	Step by step guideline
IPS e.max ZirCAD	Yttrium-stabilized zirconium oxide	Matrix	Matrix degree	Vivadent, Ivoclar, Amherst, NY	Y43302	1. The internal surface of all onlays have been blasted with Al_2O_3, 25-70 µm at 1 bar. 2. Then treated with Monobond N for 60s. 3. Then bonded by G-Cem Capsule.
		ZrO_2 Y_2O_3 HfO_2 AL_2O_3	87-95 wt.% > 4.5% ≤ 7% ≤ 5.0%			
Airborne particle abrasion material	Aluminum oxide. Al_2O_3	Al2O3		(Renfret GmbH, Untere Geisseisen 278247 Hilzingen, Germany)		1. Air-borne particle abraded using size 50 µm Al2O3 particle. 2. The pressure applied was 0.25 MPa for 30 seconds 3. The distance is approximately 10 mm.
Laser system	Nd:YA`G			Amplitude Laser, Boston, USA)		1. Laser irradiation using Nd: YAG Laser with 1064 wavelength, 7 ns pulse width 2.The light source was perpendicular to the zirconia ceramic surface with a working distance of 10 cm.
Silica coated aluminum oxide particles	Cojet sand			3M ESPE, St.Paul, MN, USA		1. Silica-coat using size 50 µm silica- coated Al_2O_3 particle (CoJet sand, 3M) 2. The pressure of 0.25 MPa for 30 seconds

diamond tools (IsoMetTM 4000, Buehler Ltd., Lake bluff, LL, USA), one operator completed all of the preparatory stages, Figure.

Surface treatment

Every restoration's intaglio surface was blasted with airborne particles and coated with silica using a Bio-art blaster (Bio-Art; Sao Carlo, SP, Brazil). According to the kind of surface treatment used, the restorations were separated into four distinct groups (n=48 total). For the silica-coat treatment, the surfaces of Subgroup A (n=12) were subjected to 0.25 MPa pressure for 30 seconds at a distance of about 10 mm, using silica-coated Al_2O_3 particles of size 50 m (CoJet sand, 3M). Group B (n=12) received an airborne particle abrasion treatment with Al_2O_3 particles of size 50 m abraded at a pressure of 0.25 MPa for 30 seconds at a distance of about 10 mm.

Subgroup C (n=12) was sandblasted and primed with 50 µm Al2O3 particles at 0.25 MPa for 30 seconds at a distance approximately of 10 mm then application of primer which is the Monobond N (Ivoclar, Vivadent, Schaan, Liechtenstein) by using a disposable brush size 0.3mm for all the internal surface of the specific group. Sandblasting followed by Laser irradiation utilising a 1064 nm Nd: YAG Laser at 10 Hz repetition rate, 0.8 cm beam

Table 2. System of luting resin composite used in this investigation

Material	Description	Constructor	Batch Number	Steps of Application
Try-In Paste	Glycerin, mineral fillers and dyes	Schaan, Liechtenstein, Ivoclar Vivadent	7405413	1. First the paste was spread on the fitting surface of ceramic restoration. 2. Then, the ceramic was positioned in the correct position.
Liquid Strip	Glycerin gel		740436	1. Spread the coating throughout the whole margin prior to light polymerization. 2. Apply a light cure for 10 seconds on each part. 3. Then rinse and dry
Monobond N	Ethanol, 3-trimethoxysilyl propyl, methacrylate silane, methacrylated phosphoric acid ester, sulphide methacrylate		Z02CPK	1. With a brush and a gentle scrubbing motion, apply one layer of the bond. 2. Let 5 seconds for a gentle air drying. 3. Light curing for 10 seconds
G-Cem Capsule	Powder and liquid: initiator, pigment, silica powder, dimethacrylate, phosphoric acid ester, fluoroaluminosilicate glass, initiator, trimellitic acid, monomer, water, urethane dimethacrylate, stabilizer 65-70%wt, 4-methacryloxyethyl	Hasunuma-cho Itabashi-ku Tokyo, Japan	141928	1.First the capsule was activated. 2. Then mix for 10s using an amalgamator. 3. Spread cement within the ceramic. 4. Secure the ceramic. 5. Brush excess cement. 6. Light cure each surface for 40s.

diameter, and 2 w power setting was used to treat the surfaces of the members of Subgroup D (n=12). At a distance of 10 cm and at a perpendicular angle to the zirconia ceramic surface, 30 bullets were fired without chilling the bonding region.

Digital impression

Forty-eight preparations were scanned using intraoral scanning equipment (Cerec Omnicam, Dentsply Sirona, Charlotte, NC, USA) before and after specimen preparation. Furthermore, forty-eight yttrium stabilized zirconium oxide onlays were planned and machined using the CEREC system using IPS e.max ZirCAD blocks.

Fabrication of onlay restorations

All restorations were created by a technician using a consistent process and the manufacturer's guidelines. A Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) approach were used to create all indirect restorations. Digital scanning was used to scan the samples before and after processing. The program created indirect restorations based on the Cerec software's Biogeneric Copy feature, restoring the produced samples to their original form.

Indirect restorations (IPS e.max ZirCAD) are milled using a milling equipment (InLab MC XL, Dentsply Sirona, Bensheim, Germany). Finally, the indirect restorations are sintered at 1500 degrees Celsius, glazed, and burnt at 710 degrees Celsius (Programat EP 5000, Ivoclar Vivadent, Schaan, Lichtenstein). Two stain firing cycles were performed on the samples as recommended by the manufacturer. IPS e.max Ceram Glaze paste (Lot H24056, Ivoclar-Vivadent) was used to glaze the specimens.

The final finish was accomplished by using a napless cloth that was impregnated with a 1 m fine particle diamond suspension (Hyprez Liquid Diamond type K Standard concentration, Batch 2028, Engis Corporation, Wheeling, IL, USA) on a polishing unit (Kent 3 Automatic polishing unit, Engis Ltd., Oxon, UK) at 150 rpm for 5 minutes. The polishing unit was operated by Engis Corporation. After being washed with detergent and having running water run over them, the specimens were then subjected to an ultrasonic cleaning in water for five minutes.

Adhesive bonding of onlays' restorations

All operations were performed in accordance with the manufacturer's insytructions. Restorations were tried in withy Try-in paste to ensure a proper marginal fit. Any excess paste was then removed from the cavity and any imperfections were patched up, and finally, the interior of each onlay was cleaned using various methods.

Cementation of the restorations:

After the try-in procedures, the bonding of onlays restorations was performed using s dual-curing luting resin cement G-CEM® CAPSULE (Hasunuma-cho, Itabashi-ku, Tokyo, Japan), according to the manufacturer's instructions following specific procedures IPS e.max ZirCAD restorations had their inner surfaces sprayed with water and dried with oil-free air. All restorations inside surfaces were then brushed with a thin layer of universal priming agent Monobond N (Ivoclar, Vivadent, Schaan, Liechtenstein) and given 60 seconds to react. A powerful gust of air was used to remove any leftover surplus. The same procedures were followed for each specimen to ensure standardization for this study. G-CEM® CAPSULE (Hasunuma-cho, Itabashi-ku, Tokyo, Japan), was applied to the restoration surface, then the restoration was cemented to the pretreated surface using finger pressure. Excess cement was removed with an explorer, then a liquid Strip was applied along the restoration margins to avoid the formation of an oxygen inhibition layer during polymerization. Each specimen was light polymerized for 40 seconds in each direction through a liquid strip using a light curing unit (LED Bluephase C5, Ivoclar, Vivademt, Amherst, NY, USA) with a wavelength between 350-520 nm at 1200 mW/cm^2 intensity.

A progression of finishing and polishing discs (coarse, medium, fine, and superfine) mounted on

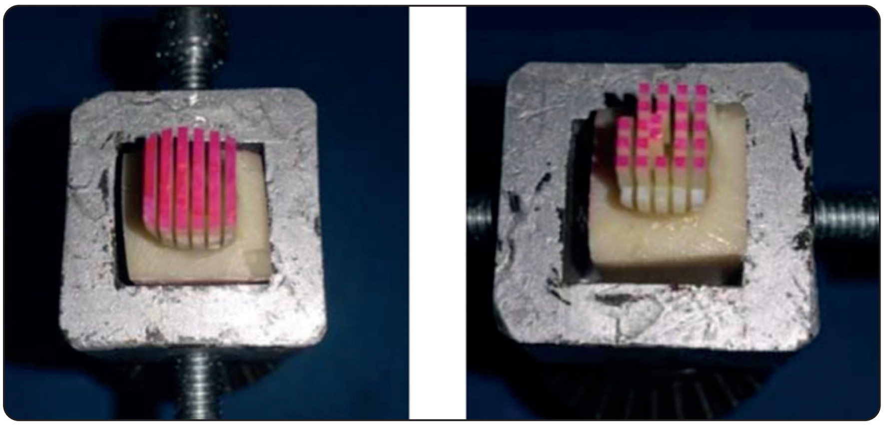

Figure. Marked composite surface after sectioning in bucco-lingual and mesio-distal directions to obtain beams flexible discs (Sof-Lex XT Pop On, 3M ESPE) was used to smooth out the rough edges of the cement. All the samples were kept in distilled water at 37±1 Celsius for 24 hours after the restorations had been cemented.

TESTING

Microtensile bond strength

To create bonded beams per tooth, with a cross-sectional area of around 1*1 mm2, an Ismoet cutting machine (Isomet3345, Buehler, Lake Bluff, IL, USA) was used to make longitudinal sections of the teeth across the bonded interface in both the "x" and "y" directions. A digital calliper (Absolute Digimatic, Mitutoyo, and Tokyo, Japan) was used to measure the beams' cross-sectional areas to the closest 0.01 mm for use in determining the true bond strength values.

Beams for MTBS were mounted on a universal testing machine (Instron 3345, Canton, Massachusetts) using a rectangular Geraldieli's jig, with each beam's end fixed in the jig's centre groove using cyanoacrylate-based adhesive (Zapit, DVA Inc., USA). At a cross-head speed of 0.5 mm/min, a tensile force will be given to the specimen until bond failure occurs. Bluehill Lite software (Instron3345, MA, USA) was used to determine the bond strength in Mega-Pascals.

After 48h of water storage, all cemented samples were thermo-mechanically cycled. Using a customised cone-shaped stainless-steel bar, a masticatory simulator (Chewing Simulator CS-4.2 economy line; SD Mechatronik GmbH, Feldkirchen-Westerham, Germany) applied mechanical cycles of axial compressive stresses at 60 mm/s.

Each restoration's central fossa was subjected to a force of 50 N from the simulator. Using a machine (Thermo-cycling TC-3; SD Mechatronic GmbH) customised for the chewing simulator, thermal cycling was conducted in tandem with the mechanical cycling without compromising the equipment's individual capabilities.

Distilled water was used for the thermo-cycling, which was carried out between 5 and 55 degrees Celsius (41- and 98-degrees Fahrenheit) over the course of 30 seconds. For eighteen hours, we subjected each sample to 43 heat cycles and 6,550 mechanical cycles every hour. Therefore, 120,000 mechanical cycles were performed on each repair. These numbers are meant to represent 6 months of oral service. Afterward, all pieces were analyzed under a stereomicroscope (Nikon SMZ-10; Nikon Corporation, Tokyo, Japan) at 40x magnifications to verify that no fracture had occurred on the onlays.

Statistical Analysis

In terms of the material's bond strength, the data underwent statistical analysis with the Shapiro-Wilk, post hoc-Tukey, student t-test, and one-way ANOVA tests. The Shapiro-Wilk test was carried out to ascertain whether or not the force distribution was uniform under the most extreme conditions of compression. The value of $p<0.05$ was chosen to denote a statistically significant correlation.

RESULTS

Data were analyzed using Statistical Package for Social Science software computer program version 26 (SPSS, Inc., Chicago, IL, USA). Microtensile bond strength values (MTBS) were subjected to the Shapiro-Wilk confidence test, which proved that data from all groups were normally distributed ($p > 0.05$). One-way ANOVA (Analysis of variance) followed by post-hoc Tukey test was used for comparing more than two different groups of parametric data while student's t-test was used for comparing two different groups of parametric data. Thereby, *a P* value less than 0.05 was considered statistically significant.

Thereby, one-way ANOVA revealed a statistically significant difference in MTBS between sandblasting and tribochemical silicoating groups without thermocycling (p= 0.002). Also, a significant difference was detected between sandblasting with primer and tribochemical silicoating groups without and after thermocycling (p= 0.001). Furthermore, MTBS values showed a significant difference between sandblasting with the primer group and sandblasting group without (p= 0.005) and after thermocycling (p= 0.001).

Additionally, a significant difference was found between laser with the primer group and sandblasting with the primer group without and after thermocycling (p <0.001). Moreover, the post-hoc Tukey test revealed a significant difference between sandblasting group without thermocycling and sandblasting group after thermocycling (p < 0.05) as shown in **Tables 3, 4.**

TABLE (3). Comparison of microtensile bond strength (mTBS) between all groups

		Tribochemical silicoating	Sandblasting	Sandblasting with primer	Sandblasting, laser with primer	P[a]
No Thermocycling	Microtensile bond strength	3.70 ± 0.96	8.30 ± 2.20	12.50 ± 2.40	5.70 ± 1.70	<0.001*
	Post-hoc		P1= 0.002*	P1= <0.001* P2= 0.005*	P1= 0.29 P2= 0.11 P3= <0.001*	
Thermocycling	Microtensile bond strength	3.20 ± 0.80	5.30 ± 2.20	10.50 ± 1.90	5.10 ± 2.60	<0.001*
	Post-hoc		P1= 0.29	P1= <0.001* P2= 0.001*	P1= 0.37 P2= 0.99 P3= <0.001*	
P[b]		0.35	0.04*	0.14	0.64	

Data expressed as mean ± SD ***SD: standard deviation*** ***P: Probability *: significance <0.05***

Test used: One way ANOVA followed by post-hoc tukey ***P[b]: Student's test (unpaired)***

P1: significance vs Group Tribochemical silicoating, P2: significance vs Sandblasting, P3: significance vs Sandblasting with primer

TABLE (4)**.** Post-hoc tukey test for comparison of microtensile bond strength (μTBS) values between all groups

		Tribochemical silicoating	Sandblasting	Sandblasting with primer	Sandblasting, laser with primer
No Thermocycling	Microtensile bond strength	3.70±0.96 [c]	8.30±2.20 [b]	12.50±2.40[a]	5.70±1.70[bc]
Thermocycling	Microtensile bond strength	3.20±0.80 [b]	5.30±2.20 [b #]	10.50±1.90[a]	5.10±2.60 [b]

Data expressed as mean ± SD; SD: standard deviation; test used: One way ANOVA followed by post-hoc tukey for comparison between groups & student's t-test for comparison between No Thermocycling & Thermocycling within each group; different alphabetical letters indicate difference in significance between groups in same raw; #: indicate significance between Thermocycling vs No Thermocycling in same column

DISCUSSION

Zirconia-based materials have seen increased application in recent years owing to their biocompatibility, strong flexural strength, and aesthetic potential.[7] The use of zirconia for indirect restorations is only one example of the material's expanding importance in the field of dentistry.[8] Indirect restorations, such as onlays, may help treat severely decayed posterior teeth due to caries since they not only improve the tooth's aesthetics but also reduce the amount of tooth tissue lost throughout the treatment process.[9]

In recent years, there has been an increase in interest in the research of adhesion to Y-TZP ceramics. This is because the microstructure and chemical composition of these ceramics makes them resistant to conditioning by hydrofluoric acid. Therefore, the binding strength to resin cement is being improved using a variety of Y-TZP surface treatment procedures that are currently under development.[24-27]

The question of how to cement and bond zirconia becomes more crucial. Zirconia, on the other hand, cannot be etched as glass or ceramics, which makes it difficult to apply adhesives using traditional techniques. To finish the treatment plan acceptably, it is essential to establish zirconia adhesive techniques that are safe and consistent.[10,11] As a result, several zirconia surface treatments, primers, or adhesives, and numerous varieties of resin cement have been tested. There is not yet a defined procedure for adhesive cementation that provides results that are both clear and reliable.[12, 13]

There is some evidence that materials having a chemical affinity for metal oxides might be used to increase the adhesive bonding of Y-TZP ceramics.[28, 28, 30, 31] Phosphate ester monomers, such as MDP (10-methacryloyloxyi-decyl-dihydrogenphosphate), chemically react with zirconium dioxide to form a water-resistant bond with densely sintered zirconia ceramic.[29] According to Heikkinen[32] and Blatz et al.[33] Not only do the molecules of Monobond Plus operate as hybrid inorganic-organic bifunctional molecules that copolymerize with the organic matrix of the resin cement, but they also work to increase the surface energy and wettability of zirconia in resin cement. This is because Monobond Plus molecules act as hybrids between organic and inorganic molecules. Thermo-mechanical cyclic loading was used to imitate the temperature changes that occur in the mouth and to accelerate the aging process.[31, 34] The samples underwent 120,000 mechanical cycles between 5-55C°. According to in-vitro research, it is regarded as a significant element that decreases bond strength.[33]

The microtensile bond strength test MTBS is more efficient than the shear bond strength test and the tensile bond strength test. The shear bond strength test is popular owing to its simple application techniques. Nevertheless, because of the inhomogeneous stress distribution in the bonding interference region, this test often produces cohesive fractures.[35,36] Concerning conventional tensile strength, the difficulties of specimen alignment may also result in an uneven distribution of stress. Specimens were aligned in parallel using a specifically constructed attachment for microtensile testing. This results in a more uniform distribution of stress during loading, allowing for a more accurate prediction of bond strength and fewer cohesive breakdowns.[37,38]

In the current investigation, many alternative surface treatments of zirconia ceramic were carried out in order to offer micromechanical retention. This was done both to increase the binding strength between composite resin cement and zirconia ceramic, which was measured.[39,40] The surface treatment technique that was used had a significant impact on the binding strength of resin cement to Y-TZP zirconia ceramic, which ranged from (3.70 ± 0.96 to 12.50 ± 2.40) MPa. These findings were given in this research.

Moreover, one-way ANOVA revealed a statistically significant difference in MTBS between sandblasting and tribochemical silicoating groups without thermocycling ($p= 0.002$). Also, a significant difference was detected between sandblasting with primer and tribochemical silicoating groups without and after thermocycling ($p= 0.001$). Furthermore, MTBS values showed a significant difference between sandblasting with the primer group and sandblasting group without ($p= 0.005$) and after thermocycling ($p= 0.001$).

Additionally, a significant difference was found between laser with the primer group and sandblasting with the primer group without and after thermocycling ($p <0.001$). Moreover, post-hoc Tukey test revealed a significant difference between sandblasting group without thermocycling and sandblasting group after thermocycling ($p < 0.05$). Therefore, with the highlights of the result, the null hypothesis was rejected and the highest outcome of this study was group C (Sandblasting with primer).

Sandblasting was recommended as a preferred surface treatment method for densely sintered oxide ceramics by Nothdurft et al,[41] Cavalcanti, et al.[42] and Zhu et al.[43] Moreover, in this study deposition distance was controlled using a specially constructed device as recommended by Ozcan et al.[44]

Sandblasting was identified as an important element in forming a persistent connection between the luting agent and the ceramic when paired with MDP monomer included in either the adhesive primer (as in the current work) or the cement itself.[45,46] Oyagüe, et al.[45] hypothesized that AL_2O_3 abrasive particles eliminated any organic contaminants, produced an activated micro-roughened zirconia surface, increased the bonding area, and modified the surface energy and wettability, thereby enhancing the bond strength by permitting micromechanical interlocking of the resin cement. [47]

In the current investigation, Si-O bonds were accessible across the whole Y-TZP surface, enhancing the silane coupling agent's ability to accomplish chemical adhesion.[48] These findings are comparable with those of Derand et al.[49]who demonstrated that applying a silane coupling agent on the zirconia surface enhances the tensile binding strength of the resin cement.

Kern and Wegner[29] and Blatz et al.[33] Air-abrasion combined with an MDP-containing resin composite produces a stronger long-term shear bond strength than silica-coated zirconia connected to Bis-GMA resin cement.

The results of this study are in agreement with those obtained by Della Bona et al.[47] Who indicated that a silica coating may enhance the surface roughness of zirconia. In contrast, Ozcan et al.[44] found that the surface roughness (Ra) of zirconia samples increased the most when they were sandblasted with 50mm Al_2O_3. This was in comparison to samples that had been coated with silica. After ageing caused by water storage or thermocycling, a number of investigations have demonstrated that the binding strength values between zirconia and resin cement have reduced.[50,51]

It has been reported that the surface treatment with Nd: YAG laser irradiation did not increase the binding strength of zirconia ceramics to resin cement, which is in agreement with our results.[52] The surface layer of zirconia ceramic may experience thermal degradation as a result of exposure to Nd: YAG laser, and the fragile link that exists between this layer and below layers may cause debonding to occur.

It has been reported that when zirconia ceramic is irradiated, both its outer and inner layers melt.[53] It's possible that this has something to do with the fluctuations in volume that take place during the solidification of molten ceramic, as well as the phase shift from cubic to tetragonal that takes place during this process. Zirconia's mechanical properties might become compromised as a result of these alterations.[53] In contrast to our results, a number of studies have tested the hypothesis that exposing dental zirconia ceramics to Nd: YAG laser irradiation may increase the binding strength of resin cement to zirconia ceramics. [54,55]

Previous researchers have usually documented a decrease in resin binding strength to zirconia after various artificial aging protocols. Kern et al.[29] examined the binding strength of resin to zirconia following water storage for 150 days and 2 years and heat cycling. The scientists determined that APA and a resin luting agent containing MDP produced the highest permanent bond strength and cohesive failures.

Artificial aging with thermal cycling reduced the tensile bond strength of resin to silicoated (Rocatec; 3M ESPE) zirconia by about one-third. The scientists also found that thermal cycling had a bigger influence on the endurance of the resin-to-zirconia ceramic connection than constant-temperature water storage. After artificially aging for 180 days paired with heat cycling (12,000 cycles, 5-60°C), Blatz et al.[33] showed a substantial loss in bond strength. The scientists concluded that a coupling agent comprising an adhesive phosphate monomer may generate improved long-term bonding with airborne particle abrasion zirconia restorations.

In a different investigation by Blatz et al.[56], airborne particle abrasion paired with a composite resin comprising adhesive phosphate monomers or tribochemical silicoating mixed with a resin luting agent produced improved long-term shear bond strength after 180 days of water storage and 12,000 temperature cycles. The present research has several constraints. The use of static loading as opposed to dynamic loading is regarded to more accurately mimic intraoral loading circumstances.

The long-term impact of mechanical surface modification on the flexural strength of zirconia has not been investigated. The findings of this research cannot be extrapolated to other resin cement since they were based on the usage of a single cement. Future studies should examine longer storage thermal cycling periods to better analyze the endurance of the resin bind to zirconia.

The limitation of this study was some of the reports didn't give the full names of the things that were used. One reason for the difference was that different bond strength tests were used (shear, pull-out, extrusion, tensile, and microtensile strength tests). Most of the studies that were included used a shear bond strength test, which is easy to use but has less even stress distribution than a tensile bond strength test. Also, research done in the past has shown that micro-bond tests are more accurate than macro-bond tests.[57]

The limited usefulness of bond strength tests, such as shear loading, is another interesting topic that should be looked into in the future. As they don't fully reflect the real clinical situation, which has a complex pattern of stress distribution when it fails, more methods should be used to predict how ceramic restorations will behave in the real world. So, the results of fatigue tests under cyclic loading, which are a way to simulate chewing, should be looked at.[58]

CONCLUSION

Within the parameters of this study, the different surface treatments had a significant difference in MTBS. Sandblasting with primer consider the most favorable outcome of the current study.

Conflict of Interest

The authors of this article confirm that they have no ownership, financial, or other personal interest in the products, services, and/or companies featured in this article.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY

Data supporting this study are included within the article and supporting materials upon request.

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