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ORIGINAL RESEARCH

In vitro evaluation of the effect of different cleansing solutions on the shear bond strength of contaminated zirconia ceramics to resin cement

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ABSTRACT

Aim: The aim of this in-vitro study was to evaluate the effect of different cleansing solutions on the shear bond strength of contaminated zirconia ceramic to resin cement.

Materials and Methods: Fifty zirconia disc (Dental Direkt,YES Germany) of size 10mm x 3mm were fabricated and mounted in self-cure acrylic resin block using a customized jig. The samples (n=10) were grouped based on two cleansing solutions and sub grouped based on two contaminants. Group I (control), neither contaminated nor any cleansing solution used. Group IIA, contaminating with saliva, cleansed with water and Group IIB, contaminating with GC Fitchecker II, cleansed with water. Group IIIA, contaminating with saliva, cleansed with Zirclean and Group IIIB, contaminating with GC Fitchecker II, cleansed with Zirclean. Subsequently fifty composite buttons (5.5mm x 3mm) were fabricated and bonded to the test samples using resin modified glass ionomer cement (Riva Cem,SDI). Thermocycling, shear bond strength, scanning electron microscopy were carried out for all the groups. Statistical analysis was done using independent t test with SPSS software

Results: On comparison it was found that samples contaminated with saliva, cleansed with Zirclean showed a higher mean shear bond strength and the result was statistically significant ($P<0.001$). Samples contaminated with GC Fitchecker, cleansed with Zirclean showed a higher mean shear bond strength and the result was statistically significant ($P<0.001$). The result collaborated with SEM analysis of the debonded samples.

Conclusion: Zirclean can be used as an effective surface cleansing solution for zirconia restorations.

Keywords: Zirconia, Shear Bond Strength, Zirclean, Scanning Electron Microscopy

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INTRODUCTION

Porcelain fused metal restorations have traditionally been the mainstay of restorative dentistry due to their long-lasting mechanical properties and acceptable aesthetics. Despite its benefits, metal coping prevents the light from passing through, resulting in an opaque prosthetic and shade mismatch.[1,2] The search for newer materials with greater esthetic concern resulted in the widespread use of all ceramic restorative materials for crowns and veneers. This can also be credited to their high strength, superior aesthetics and simplicity of fabrication utilizing the advanced laboratory / CAD CAM procedures.[3]

Zirconia ceramic restorations have gained popularity due to their high flexural strength and mechanical stability. It has also been shown that (Y-TZP) ceramics can be made more translucent while retaining their strength properties.[4] Hence they are widely used in both anterior and posterior situations. Another advantage of zirconia restorations is that they can be cemented conventionally without any technique-sensitive bonding steps.

One of the important factors next to the selection of adhesive cement suitable for restoration is avoiding any contamination prior to cementation that can hinder the bonding of the zirconia restorations. Contamination can occur during the manufacturing in the dental laboratory and/or in the try-in appointment. During the try-in phase, the possible contaminants are saliva, blood, die stone and/or try-in pastes.[5,6]

Salivary contamination causes salivary proteins to adhere to zirconia and tooth surfaces, ensuring the production of an acquired enamel pellicle 10-20 nm thick that is free of bacteria in a matter of minutes.[7]

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The proteinaceous layer may become 100-1000 nm thick in 30 to 90 minutes if the protein transmission from saliva increases. The connection between the repair and the luting cement may be hindered by this layer.[8]

Zirconia's acid resistance renders it resistant to etching and silanization techniques; as a result, it might be difficult to achieve a strong and durable bond with a resin luting agent.[9] Any contamination on the cementation surfaces and insufficient removal of the impurities during intraoral try-in procedures increase the likelihood of bond failure.[6,10] It is impossible to completely eliminate contamination during the final cementation technique and try-in phase. The application of a contaminant-removing chemical may aid in achieving long-lasting adhesion and enhance the restoration's clinical effectiveness.

Angkasith et al. and Nejatidanesh et al. conducted a study wherein feldspathic porcelain was cleansed with 37 percent phosphoric acid. The acid washed away the impurities, restoring the bond strength values. The research suggested that adding phosphoric acid to zirconia surfaces can leave a phosphorous residue which could reduce the binding strength between the zirconia and the resin cement.[11]

Abrasion with airborne particles, application of 2 percent chlorhexidine, 5 percent sodium hypochlorite, or 37 percent phosphoric acid, immersion in 96 percent isopropanol, washing with 70 percent ethanol, and water rinsing is a few of the decontamination techniques used.[10,12,13]

Several surface decontaminating solutions/pastes have been introduced, and one such revolutionary cleaning gel is Zirclean, which consists of an alkaline suspension of potassium hydroxide particles. As the medium has greater particle size & concentration, the phosphate impurities that are present due to contamination are far more likely to adhere to the zirconium oxide available in Zirclean than to the ceramic restoration's surface.[14,15]

According to the manufacturer, this cleaning gel removes several types of phosphate contaminants from saliva and other human fluids, leaving a clean zirconium oxide surface.[14] However, limited studies have been reported on the usage of Zirclean as an effective surface-cleansing solution for zirconia restorations.

The study's objective is to assess the impact of various cleaning agents on the zirconia-resin interface's shear bond strength. The null hypothesis claims that after using various cleaning solutions, there would be no discernible variation in the shear bond strength of contaminated zirconia.

MATERIALS AND METHOD

Fifty zirconia discs (high translucent, Dental Direkt, YES Germany) of size 10 x 3 mm were dry milled (DMG MORI, Germany) and sintered at 16500 C for 8 hours in the sintering furnace (LNY-5F, Sinosteel Luoyan research, China). The samples were finished with acrylic burs, and the thickness was evaluated with an electronic digital vernier caliper. All the zirconia samples were embedded in auto-polymerizing acrylic resin with the help of a customized stainless-steel jig (Figure 1). The exposed surface of the samples was sandpapered with silicon carbide emery papers of 220, 320 and 400 grit and sandblasted with 50um Al2O3 at 0.25MPa for 15 seconds at a distance of 10mm. The samples were ultrasonically cleaned with distilled water for 180 seconds.

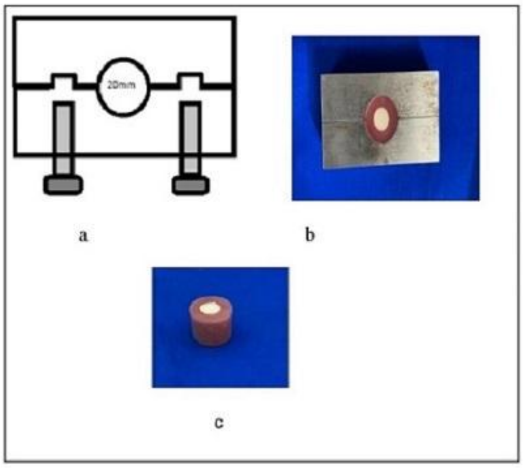

Figure 1: a) line diagram of customized jig; b) Zirconia sample embedded in autopolymerised resin; c) final sample

Grouping (n=10) was done based on the cleansing solutions used in the study: water and Zirclean (Bisco, United States) and on the contaminants used: artificial saliva (Wet Mouth IPCA health product, Mumbai) and GC Fitchecker II (GC Fuji, India). Group I (the control group) neither contaminated nor any cleansing solutions were used. Group II A was contaminated with saliva, and Group II B was contaminated with GC Fitchecker II. All the samples of Group II were cleansed with water. Group III A was contaminated with saliva, and Group III B was contaminated with GC Fitchecker II. All the samples of Group III were cleansed with Zirclean cleansing agent. Contamination of the samples with saliva was done by exposing the samples to artificial saliva for 15 seconds, water cleansing for 15 seconds with a water jet and air drying for 15 seconds. Contamination of the samples to GC Fitchecker II paste was done by applying the paste for 15 seconds, water cleansing for 15 seconds with a water jet and air drying for 15 seconds. Simultaneously 50 composite buttons (Restofill, Anabond India) of size 5.5mm x 3mm were fabricated, aligned with the help of a dental surveyor and luted to the zirconia samples with resin-modified glass ionomer cement (RivaCem, SDI Australia). Excess cement was removed via micro-tip brushes. The samples were put in the water bath at 37° Celsius for 24 hours after the manufacturer's advised setup time (4min).

In order to replicate six months of clinical usage, samples underwent thermocycling (Haake, W15, Germany) for 5000 cycles in a distilled water bath between 5oC and 55oC with a dwell time of 60 seconds and dry time of 10 seconds between warm and cold cycles. The samples were finished and placed in the corresponding containers with distilled water. Up until the zirconia resin bond failed, the shear bond test was conducted in the Universal testing device (Instron 3382 100 KN, UK) at a cross-head speed of 2 mm/min. Statistical analysis was done using SPSS software (SPSS Software Corp, Munich, Germany)

Three samples from each group were subjected to qualitative examination using a scanning electron microscope (S- 3400N, Hitachi High Technologies Corporation, Japan) magnified 2000 times. The collected photos were compared between the groups, and conclusions about the findings were made.

RESULTS

Qualitative and quantitative assessment at the zirconia–resin interface was done for all the groups by subjecting the samples to shear bond strength and SEM analysis after contaminating and cleansing the zirconia test samples.

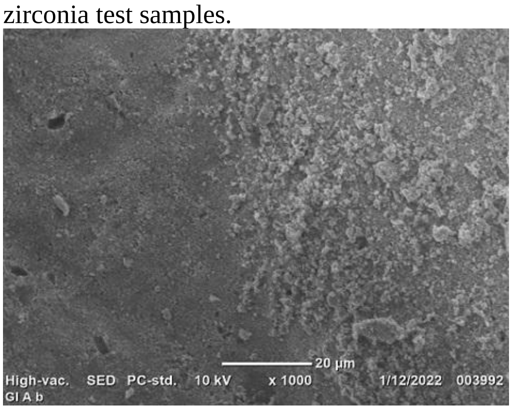

Figure 2: SEM photomicrograph of representative test sample of Group IIA under 2000X magnification

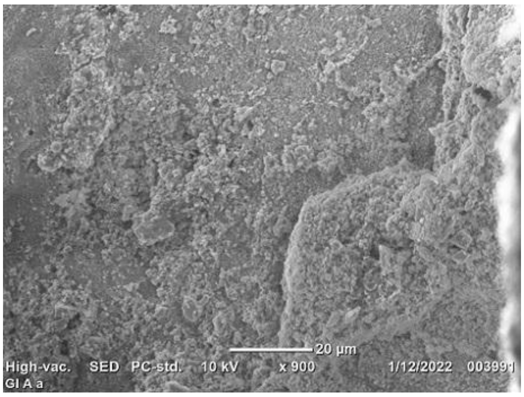

Figure 3: SEM photomicrograph of representative test sample of Group IIB under 2000X magnification

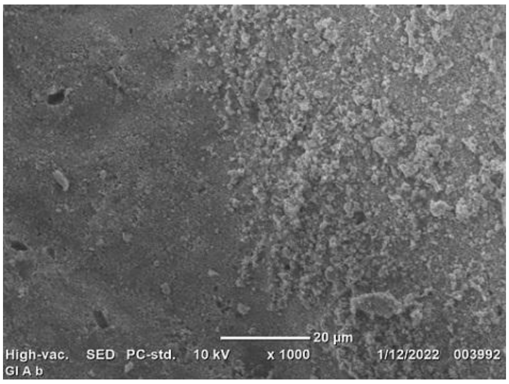

Figure 4: SEM photomicrograph of representative test sample of Group IIIA under 2000X magnification

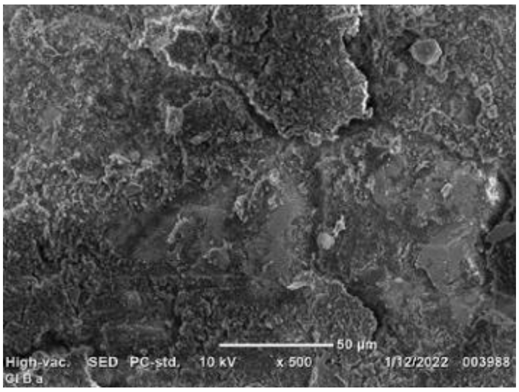

Figure 5: SEM photomicrograph of representative test sample of Group IIIB under 2000X magnification

Groups	No of Samples	Mean Shear Bond Strength (MPa)
Group I (control)	10	10.97
Group II A	10	7.242
Group II B	10	7.87
Group III A	10	8.96
Group III B	10	8.79

Table 1: Comparative evaluation of the mean shear bond strength between all the groups (Group I, Group II A; II B and Group III A; III B)

The values obtained from shear bond strength testing were tabulated. The basic data and mean shear bond strength value of each group were determined and statistically analyzed using the Independent ‘t-test. In comparison, Group 1 (control) showed the highest mean shear bond strength value of 10.97 MPa [Table 1]. Between Group II A and III A, samples contaminated with saliva and cleansed with Zirclean (Group III A) had a higher shear bond strength mean value (8.96 MPa), and the difference was statistically significant (P<0.001) [Table 2]. Between Group II B and III B, samples contaminated with GC Fitchecker II and cleansed with Zirclean (Group III B) had a higher shear bond strength mean value (8.79 MPa), and the difference was statistically significant (P<0.001) [Table 3]

Group	Contaminant	Cleansing solution	Mean shear bond strength (MPa)	Standard Deviation	P - value
Group II A	Saliva	Water	7.242	1.40	<0.001
Group III A	Saliva	Zirclean	8.96	1.15	

Table 2: Comparative evaluation of the mean shear bond strength between Group II A and Group III A

Group	Contaminant	Cleansing solution	Mean shear bond strength (MPa)	Standard Deviation	'P' value
Group II B	GC Fitchecker II	Water	7.87	1.19	<0.001
Group III B	GC Fitchecker II	Zirclean	8.79	0.94	

Table 3: Comparative evaluation of the mean shear bond strength between Group II A and Group III A

Qualitative observations made by SEM images at 2000X magnification collaborated with the statistical findings. Mixed mode of failure was observed in all the samples. Samples cleansed with Zirclean and bonded with RMGIC showed a denser network of bonds in comparison to the samples cleansed with water alone. The overall result of the study revealed that Zirclean is more effective than water in decontaminating the zirconia surface.

DISCUSSION

Zirconia-based restorations have increased in popularity recently because of the increased demand for tooth-colored restorations brought on by advances in ceramic technology, decreased laboratory costs, and the ease with which zirconia may be milled.[16] Both traditional and resin cement can be used to cement zirconia restorations. Zirconia ceramic surfaces have many chemical properties similar to those of metal surfaces, and the presence of hydroxyl groups (O-H) is essential for chemical bonding. The interaction between these hydroxyl groups and the luting cement's polar functional group is what makes the luting cement work.[2]

In the present study, RMGIC has been used in bonding the zirconia surface to the fabricated composite button. The cement was chosen primarily for its ability to create strong adhesive bonds as well as for its ease of manipulation, low cost and wide range of applications. Similar studies conducted by Yang et al. showed that zirconia to RMGIC had stronger shear bond strength and bond durability than a conventional composite cement free of phosphate-ester-monomer.[17] A durable restoration must be achieved by forming a strong link between the tooth structure and the restorative material. One of the prevalent reasons for bond failure is to decontaminate the bonding surface. Thus, it's crucial to make sure that none of the bonding surfaces are contaminated.[15]

Phark et al. and Pak Tunc et al. demonstrated that contaminating the zirconia surface during the try-in procedure with saliva, blood, fit checkers, dies stone or silicone disclosing media might weaken the bond strength of cemented zirconia.[18,19] Both mechanical and chemical cleaning techniques can be used to clean the zirconia's contaminated intaglio surface. Sandblasting with alumina oxide particles is the most efficient mechanical cleaning technique. The tetragonal phase can change to the monoclinic phase as a result of air abrasion, followed by an increase in flexural strength.[1,2,3,20] Yet, the presence of this monoclinic phase layer may also be accompanied by micro-cracks and flaws that endanger the ceramic's durability and dependability.[21,22] Chemical cleansing agents were therefore advised in order to restore the binding strength.

When a restoration comes into contact with saliva, a thin proteinaceous coating is immediately created. This layer is made up of adsorbed proteins, several enzymes, glycoproteins, and other macromolecules. Salivary phosphate groups produce phospholipids, which bond to the zirconium oxide to create zirconia-phosphate complexes,[21] resulting in a change in the zirconia surface's chemical makeup. The same has been shown using an X-ray photoelectron spectroscopy (XPS) study, which demonstrates that when salivary proteins stick to zirconia's surface, the levels of carbon, nitrogen, and silica increase while zirconia levels decrease.[8,10,23,24,25] For adhesion, it is essential that these precipitates be removed right away.

The various chemical cleansing agents mentioned in the literature include alcohol, organic solvent, and acidic solutions such as hydrofluoric acid, 37% phosphoric acid, sodium dodecyl sulphate, hydrogen peroxide and sodium hydroxide solution.[8,9,11,26,27] Alcohol cleaning proved ineffective in eliminating organic pollutants, according to research by Yang et al.[17,19] According to a related finding by Quaas et al., alcohol washing had no impact on improving the binding between the resin cement and ceramic surface.[6]

In a study on feldspathic porcelain. Wattanasirmkit et al. cleaned the restoration's intaglio surface after salivary contamination with 37% phosphoric acid. The contaminants were eliminated by the acid and which also restored the bond strength values. However, it was noted that using phosphoric acid to clean the zirconia surface may leave a phosphorous residue that weakens the bond between zirconia and resin cement.[28] In a study by Zandparza et al., it was discovered that silica-based ceramics may have the ideal surface texture and roughness by acid etching using hydrofluoric acid (HF) or ammonium bifluoride. However, neither silanization nor hydrofluoric acid etching could provide a suitable resin bond to zirconia due to its high concentration and different chemistry from other conventional silica-based materials.[29]

Dental products have been manufactured to produce specialized cleaning solutions made especially for zirconia to address the issues faced with mechanical and chemical surface cleaning. The claim is that these solutions can effectively decontaminate the undersurface of the restoration and simultaneously improve the resin bond strength.[15,30] Nevertheless, there are few studies and scant information about the effectiveness of these products.

In the present study, two common contaminants, saliva and GC Fitchecker, as well as two cleansing solutions – water, which is frequently used as a cleansing medium before cementing fixed partial prostheses, and another solution named Zirclean, a commercially available product was considered. Thermocycling was done to stimulate 6 months of intra-oral usage, and the samples underwent a shear bond strength test and SEM analysis to evaluate the debonded surfaces. The results showed that Group I, which is neither contaminated nor any cleansing solutions used, had resulted in the highest mean shear bond strength value (10.97 MPa). Followed by Group III A and Group III B (8.96 MPa, 8.79 MPa, respectively). The least value was noticed in Groups II B and II A (7.87 MPa, 7.242 MPa, respectively).

As no contaminants and no cleansing solution were used in Group I, the samples were bonded directly using RM GIC. Zirconium oxide existing on the zirconium surface was free to make direct connections with the adhesive cement. The SEM image confirmed a similar conclusion, revealing a solid adhesive bond between zirconia and RM GIC, with the bond failure being primarily cohesive in character. With saliva acting as the common contaminant, Group II A was cleaned with water, whereas Group III A was cleaned with Zirclean. It was discovered that Group III A had a higher shear bond strength mean value (8.96 MPa), and the difference was statistically significant (P 0.001).

The phosphate groups in saliva have been discovered to have a stronger affinity for zirconia, resulting in the formation of a zirconia phosphate complex that interferes with the link strength between zirconia and cement, according to earlier studies.[8,11,23,31,32] Salivary proteins cannot be interacted with or broken down by water alone, and the zirconia surface cannot be cleaned.[19] Zirclean, on the other hand, is an alkaline extra-oral universal ceramic cleanser that has a reputation for being more potent at restoring contaminated ceramic surfaces. Its alkalinity comes from the potassium hydroxide, which disintegrates the ionic contact formed between the saliva and the zirconia surface.[15,30] Test samples from Group II A primarily showed adhesive failure, while test samples from Group III A primarily displayed cohesive failure, as shown in the SEM image (Fig 2,4). RM GIC and zirconia now have a stronger adhesive bond due to the use of Zirclean as a surface cleanser.

When GC Fitchecker was used as the common contaminant in a comparison between Group II B and Group III B, where Group II B was cleaned with water and Group III B with Zirclean, it was found that Group III B had a higher shear bond strength mean value (8.79 MPa), and the difference was statistically significant ($P < 0.001$). Silicon-based Fitchecker has the tendency to create a residue on the bonding surface, which can affect the bond strength. In our testing, water and Zirclean both worked well at getting rid of any leftovers, and their respective mean shear bond strengths were 7.87 MPa and 8.79 MPa. Comparatively, Zirclean showed to be more effective with a higher bond strength value. The test samples from Groups II B and III B primarily displayed cohesive failure, which was corroborated by the SEM image (Fig 3,5). Strong bonding at the zirconia-resin interface was indicated by the mode of failure pattern.

The current investigation found a statistically significant variation in the shear bond strength of contaminated zirconia after applying several cleaning solutions, rejecting the null hypothesis. The present study has certain limitations because it only employed one type of zirconia and luting cement. Commercial cleaning agent comparisons between various brands were not taken into account. The investigation excluded other contaminants like blood and die stones.

CONCLUSION

The findings of the current study demonstrated that zirconia's bond strength was diminished when exposed to contaminants such as saliva and GC Fitchecker. Zirconia can be effectively cleaned with Zirclean to remove contaminants and create a surface that is ideal for bonding. Further research in this area is necessary to comprehend how various commercial cleaning chemicals and adhesive cement affect the bond strength of zirconia.

CONFLICT OF INTEREST

There is no conflict of interest

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