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Comparative Evaluation of Tensile Bond Strength of Surface Treated Zirconia Copings Luted with a Resin Cement – an *In vitro* Study.

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ABSTRACT

The purpose of this study was to evaluate the effect of different surface conditioning agents on the tensile bond strength of zirconia copings luted with a resin cement. The specimens were distributed equally into 4 different groups (n=8): Group A(control), Group B(sandblasting), Group C(acid etching), Group D(sandblasting + acid etching). Zirconia copings were then prepared using CAD/CAM. The force of dislodgement was recorded and tensile bond strength was measured with the help of formula **$\sigma = P/A$,** where **σ** is the tensile bond strength (MPa), P is the maximum force (N), and A is the interfacial area (mm^2). A one way analysis of variance (ANOVA) was used to analyse the data. This test demonstrated that, the difference in mean tensile bond strength among the groups was found to be statistically significant and a significant difference was observed between four groups with respect to tensile bond strength. The Mean tensile bond strength for the four groups were 7.1, 11.1, 8.1, 11.7 MPa for Group A, Group B, Group C and Group D respectively. Within the limitations of this study, Group D specimens showed the maximum tensile bond strength scores and proved to be the best option for surface treatment of Zirconia copings.
Keywords: CAD/CAM, Surface Treatment, Zirconia, Acid Etching, Sandblasting

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INTRODUCTION

Zirconia is a crystalline dioxide of zirconium. Its mechanical properties are very similar to those of metals and its color is similar to tooth color. [1] With increasing demand in esthetics and biocompatibility, all-ceramic restorations have gained popularity in recent decade. Among all ceramic systems available, ZIRCONIA OXIDE ceramic has emerged as an excellent esthetic material for fabrication of crowns. The properties of zirconium oxide ceramics such as high strength, excellent mechanical properties & biocompatibility allow it to be used as a core material for all-ceramic crowns & fixed partial dentures.

Zirconia has mechanical properties similar to those of stainless steel. Its resistance to traction can be as high as 900-1200 MPa and its compression resistance is about 2000 MPa. Surface treatments, mechanically or chemically can modify the physical properties of zirconia. Exposure to wetness for an extended period of time can have a detrimental effect on its properties and is known as Zirconia ageing. Moreover, surface grinding can reduce toughness. Kosmac confirmed this observation and reported a lower mean strength and reliability of zirconium oxide after grinding.[1]

Zirconia is polymorphic in nature, meaning that it displays a different equilibrium (stable) crystal structure at different temperatures with no change in chemistry. It exists in three crystalline forms: monoclinic at low temperatures, tetragonal above 1170 ◦C and cubic above 2370 ◦C. A characteristic of this material is that it undergoes a change in crystal structure from tetragonal to monoclinic during cooling, resulting in a volume increase (3–4%) that can induce large stresses. These stresses can produce cracks that result in spallation, crumbing, and failure. Work by Ruff et al. showed that the cubic phase could be stabilized with the addition of small amount of calcia (CaO), making it possible to use Zirconium Oxide as an engineering material.[2] Yttrium-oxide (Y_2O_3 3% mol) is added to pure zirconia to control the volume expansion and to stabilize it in the tetragonal phase at room temperature. This partially stabilized zirconia has high initial flexural strength and fracture toughness. Tensile stresses at a crack tip will cause the tetragonal phase to transform into the monoclinic phase with an associated 3-5% localized expansion. [3]

MATERIALS & METHODS

The present in vitro study was conducted to compare the retentive strengths of zirconium oxide ceramic copings, after various bond strength enhancement surface treatments such as acid etching and sandblasting with Cera Etch &Aluminium Oxide particles of 110µm respectively and luted to natural human molar teeth using luting cement namely, Smart Cem 2.
The methodology in this study is described in the following order:

1. Materials
2. Armamentarium & Equipment
3. Method followed
    - Specimen Collection, Preparation & Standardisation

- Surface Treatments
- Bonding
- Testing
- Statistical Analysis

Materials

- 32 Extracted Human Molar teeth
- Auto polymerising Resin (DPI-RR Cold Cure TM/DPI Mumbai)
- Polyvinyl Siloxane Putty (Aquasil, Dentsply International USA)
- 1% Hydrogen Peroxide Solution
- Distilled water
- Zirconia Blocks (Cercon, DETREY DENTSPLY Ceramco, York, U.S.A.)
- Sodium Hypochlorite Solution
- Luting Cement
- Etching Agent
- Sandblasting Particles : Aluminium Oxide particles of 110 µm size

Type of Cement	Trade Name	Manufacturer
Self Etching Resin Cement	Smart Cem 2	Dentsply, International(U.S.A.)

Type of Acid	Trade Name	Manufacturer
Hydrofluoric Acid 9.6%	Cera Etch	Deor(Kochi, India)

Methodology

A total of 32 extracted human molar teeth were collected & stored in distilled water. They were cleaned of debris by placing them in 1% Hydrogen Peroxide solution & a liquid sterilant such as 0.5% Sodium Hypochlorite solution.

A wax block was prepared of 4cm x 1cm dimensions & putty index was made out of it. Self cure acrylic resin was poured into the putty index & teeth were embedded & mounted in it(fig 1). Then the extracted molars were prepared with a flat occlusal surface having 6 degree taper & 5 mm axial length. The preparations were standardized using 2 metal templates that would help in checking the teeth preparation in mesio-distal &bucco-lingual dimensions (fig 2). The surface areas of the prepared teeth were determined using a mathematical formula &vernier calliper.

Figure 1 : Mounted natural human molar teeth embedded in autopolymerising resin

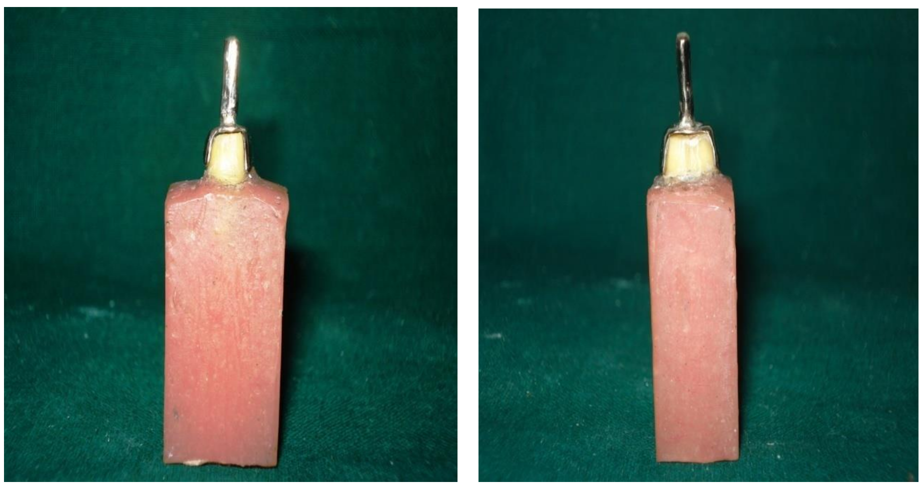


Figure 2 : Metal templates used for standardising the mesio-distal &bucco-lingual dimensions of the prepared tooth

The specimens were randomly selected & distributed equally in to 4 groups (n=8)

- Group A : Control Group
- Group B : Sandblasting Group
- Group C : Acid Etching Group
- Group D : Sandblasting + Acid Etching Group

Then the Zirconia Oxide Ceramic Copings were prepared using the CAD/CAM unit(fig 3,4 & 5). No surface treatment was performed in Group A specimens. The intaglio surface of each coping of Group B specimens were air borne particle abraded with Aluminium Oxide110 µm particles for a maximum of 13 seconds under 380 kpa. The intaglio surface of Group C specimens were Acid Etched with Hydrofluoric Acid 9.6% for 90 seconds & the cleaned & air dried(fig 6). Finally, the intaglio surface of Group D specimens were first air borne particle abraded with Aluminium Oxide110 μm particles for 13 seconds under 380 kpa & the Acid Etched with Hydrofluoric Acid 9.6% for 90 seconds.

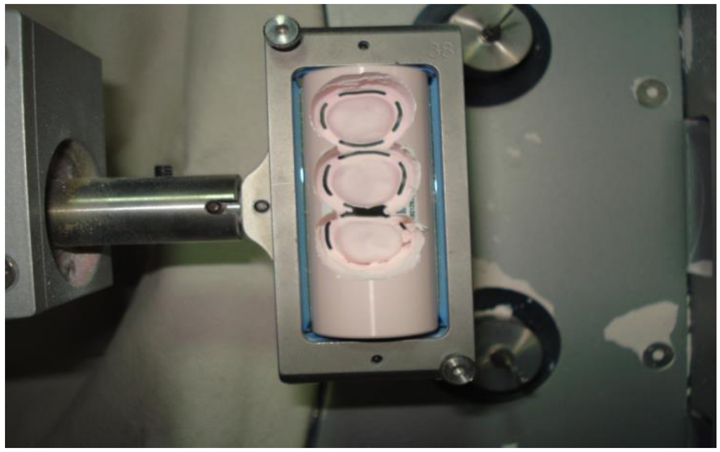


Figure 3: Milling process of copings

Figure 4: Milled copings

Figure 5: Sintered Zirconia copings

Figure 6: Hydrofluoric acid etchant &etchant applied onto the Zirconia Coping.

Figure 7: Smart Cem 2 resin cement used for cementing the specimens

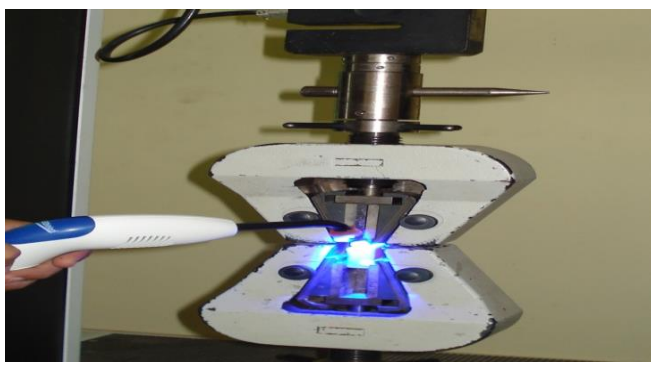


Figure 8 : Luting the specimen on to the prepared tooth

Figure 9: The Zirconium oxide ceramic copings subjected to tensile forces in the Universal Testing Machine

The specimens were then cemented using Self Adhesive Composite Resin Cement (SmartCem 2 DENTSPLY(USA)(fig 7) by applying the luting cement on the intaglio surface of the specimens& curing the margins with Light Cure unit. The Zirconia coping were then seated initially with firm finger pressure for 20 sec followed by a seating force of 10 kg per tooth which was delivered to the tooth specimen using a stylus mounted on to the Universal Testing Machine(fig 8). Excess cement was cleaned from the margins & then the specimens were with Light Cure Unit(IvoclarVivadent) & prepared specimens were stored in water for 24 hours. Then the specimens werewere subjected to Tensile stresses and removed along the path of insertion using a Universal Testing Machine at a cross head speed of 0.5mm/min (fig 9).

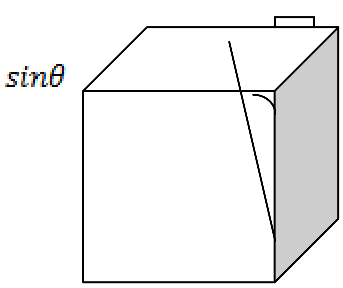
The force (N) at dislodgement was recorded & the stress of removal (MPa) was calculated using the surface area of each Preparation (mm^2) with the formula **σ = P/A** where **σ** is the tensile bond strength (MPa), P is the maximum force (N), and A is the interfacial area (mm^2).

Following coping dislodgement, the predominant nature of debonding was recorded by examining the surface of tooth & coping base on the criteria given in the table below:

<u>Characterization Of Failure Site</u>

Description	Nature
1. Cement principally on prepared tooth (.3⁄4 of axial surface)	Adhesive
2. Cement on ceramic coping and tooth	Adhesive
3. Cement principally on ceramic coping (.3⁄4 of axial surface)	Adhesive
4. Fracture of tooth or tooth removal	Cohesive
5. Fracture of coping	Cohesive

The mathematical formula used for calculating the surface area of each tooth:



Sin θ = AB / BC
AB = BC x Sinθ
AB = 5 x Sin 6°
AB = 5 x 0.104
= 0.52mm

So, 0.522mm is the discrepancy.
Surface Area = (length – 0.52) x (breadth – 0.52)

Statistical Analysis:

Following statistical methods were employed in the present study

- Descriptive Analysis – Mean and Standard Deviation
- ANOVA test- for multiple group comparisons.
  All hypothesis testing was conducted at the 95% level of confidence.
  p value of 0.05 or less was considered for statistical significance.

RESULTS

The present study was aimed to compare & evaluate the Tensile Bond Strength of specimens from 4 different groups after different surface treatments and luted with a resin cement. The different surface treatments used were sandblasting, acid etching and combination of both.

All the 32 prepared teeth were randomly distributed into 4 different groups(n=8). And the preparations were standardised using 2 metal templates. The mean surface area for different groups was Group A = 45.26 mm^2, Group B = 45.77 mm^2, Group C = 45.20 mm^2, Group D = 45.48 mm^2. This reflects a uniform distribution of preparations by surface area for the 4 groups.

All the specimens were luted with SmartCem 2 resin cement.
Samples in group A were given no surface treatment (n=8)
Samples in group B were sandblasted with Al_2O_3 particles (n=8)
Samples in group C were acid etched with Hydrofluoric Acid 9.6% (n=8)
Samples in group D were first sandblasted with Al_2O_3 particles and the acid etched with Hydrofluoric acid 9.6% (n=-8)

The table 1 shows the different groups, force at which there was dislodgement of the copings, surface area and the calculated stress of dislodgement/tensile bond strength (MPa) Formula for calculating stress of dislodgement/tensile bond strength is **$\sigma = P/A$,** where **σ** is the tensile bond strength (MPa), P is the maximum force (N), and A is the interfacial area (mm^2).

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Table 1

S.NO.	GROUP(A,B,C,D)	SURFACE AREA(mm$^{2)}$	FORCE(N)	TENSILE BOND STRENGTH(MPa)
1.	GROUP A	44.26	334.1	7.54
2.	GROUP A	44.71	187.6	4.19
3.	GROUP A	46.50	298.4	6.41
4.	GROUP A	46.95	331.2	7.05
5.	GROUP A	45.60	312.7	6.85
6.	GROUP A	44.26	386.1	8.72
7.	GROUP A	44.71	401.1	8.97
8.	GROUP A	45.15	344.8	7.63
9.	GROUP B	46.05	361.0	7.83
10.	GROUP B	46.50	475.4	10.22
11.	GROUP B	45.15	579.7	12.83
12.	GROUP B	44.71	487.7	10.90
13.	GROUP B	46.05	616.1	13.37
14.	GROUP B	45.60	641.4	14.06
15.	GROUP B	46.95	582.2	12.40
16.	GROUP B	45.15	358.4	7.93
17.	GROUP C	45.15	371.0	8.21
18.	GROUP C	45.15	281.7	6.23
19.	GROUP C	45.15	241.1	5.33
20.	GROUP C	45.60	345.4	7.57
21.	GROUP C	46.05	402.3	8.73
22.	GROUP C	44.71	377.3	8.43
23.	GROUP C	44.71	523.6	11.71
24.	GROUP C	45.15	420.1	9.30
25.	GROUP D	45.15	553.1	12.25
26.	GROUP D	45.60	625.4	13.71
27.	GROUP D	44.71	616.7	13.79
28.	GROUP D	45.15	751.1	16.63
29.	GROUP D	46.05	251.1	5.45
30.	GROUP D	45.60	651.9	14.29
31.	GROUP D	46.05	321.7	6.98
32.	GROUP D	45.60	482.3	10.57

Statistical Analysis

Null Hypothesis: There is no significant difference in the mean tensile bond strength (Newtons) of the three groups i.e. $\mu_1 = \mu_2 = \mu_3$

Alternate Hypothesis: There is a significant difference in the mean tensile bond strength (Newtons) of the three groups i.e. $\mu_1 \neq \mu_2 \neq \mu_3$

Level Of Significance: α=0.05

Statistical Technique Used: One-way Analysis of Variance (ANOVA).

ISSN: 0975-8585

Decision Criterion: The decision criterion is to reject the null hypothesis if the p-value is less than 0.05. Otherwise we accept the null hypothesis. If there is a significant difference between the groups, we carry out multiple comparisons (post-hoc test) using Newman-Keuls test procedure.

Computations: The following table gives us the various computations and results from ANOVA and the P-Value.

Descriptive statistics:

Highest mean retention is observed in group D samples compared to other groups followed by group B and group C. The lowest mean retention is observed in group A. The mean Tensile Bond Strength was 7.1, 11.1, 8.1, 11.7 MPa for Group A, Group B, Group C and Group D respectively.

Table 2: Mean, SD, SE and coefficient of variation of tensile bond strength in four groups (Group A, Group B, Group C and Group D)

Groups	N	Mean	Standard deviation	Standard error	Coefficient of variation
Group A	8	7.17	1.49	0.53	20.80
Group B	8	11.19	2.39	0.85	21.38
Group C	8	8.19	1.94	0.69	23.71
Group D	8	11.71	3.82	1.35	32.66

ANOVA

From the ANOVA results of the above table, it can be seen that, a significant difference was observed between four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength ($F=6.0239$, $p<0.05$)i.e. $0.0027<0.05$ at 5% level of significance. The ANOVA P value was 0.0027. It means that, the tensile bond strength scores are different in four groups (Group A, Group B, Group C and Group D).

Table 3: Comparison of four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength by one way ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	P-value
Between groups	3	119.00	39.6654	6.0239	0.0027*
Within groups	28	184.37	6.5846		
Total	31	303.37			

Further, to know the pairwise comparison of four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength by applying the Newman-Keuls post hoc procedures and the results are presented in the following table.

Table 4: Pair wise comparison of four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength by Newman-Keuls post hoc procedures

Groups	Group A	Group B	Group C	Group D
Mean	7.1700	11.1925	8.1888	11.7088
SD	1.4912	2.3930	1.9412	3.8236
Group A	P=1.0000			
Group B	P=0.0109*	P=1.0000		
Group C	P=0.4340	P=0.0267*	P=1.0000	
Group D	P=0.0075*	P=0.6906	P=0.0276*	P=1.0000

*P<0.05

From the results of the above table, it can be seen that,

1. A significant difference was observed between Group A and Group B with respect to tensile bond strength at 5% level of significance (P<0.05). It means that, the tensile bond strength scores are significantly higher in group B as compared to group A.

2. A significant difference was observed between Group A and Group D with respect to tensile bond strength at 5% level of significance (P<0.05). It means that, the tensile bond strength scores are significantly higher in group D as compared to group A.

3. A non-significant difference was observed between Group A and Group C with respect to tensile bond strength at 5% level of significance (P>0.05). It means that, the tensile bond strength scores are similar in group C as compared to group A.

4. A significant difference was observed between Group B and Group C with respect to tensile bond strength at 5% level of significance (P<0.05). It means that, the tensile bond strength scores are significantly higher in group B as compared to group C.

5. A non-significant difference was observed between Group B and Group D with respect to tensile bond strength at 5% level of significance (P>0.05). It means that, the tensile bond strength scores are similar in group B as compared to group D.

6. A significant difference was observed between Group C and Group D with respect to tensile bond strength at 5% level of significance (P<0.05). It means that, the tensile bond strength scores are significantly higher in group D as compared to group C.

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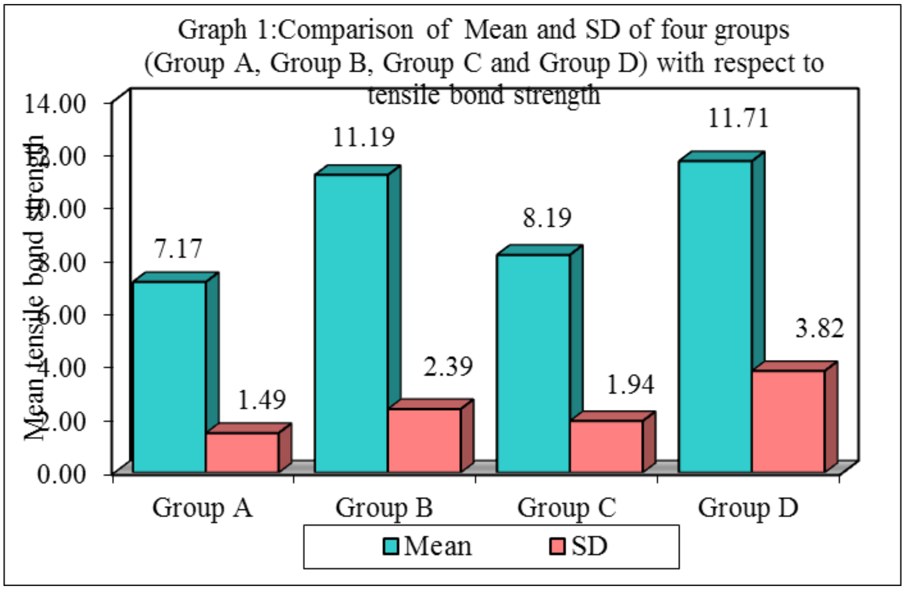
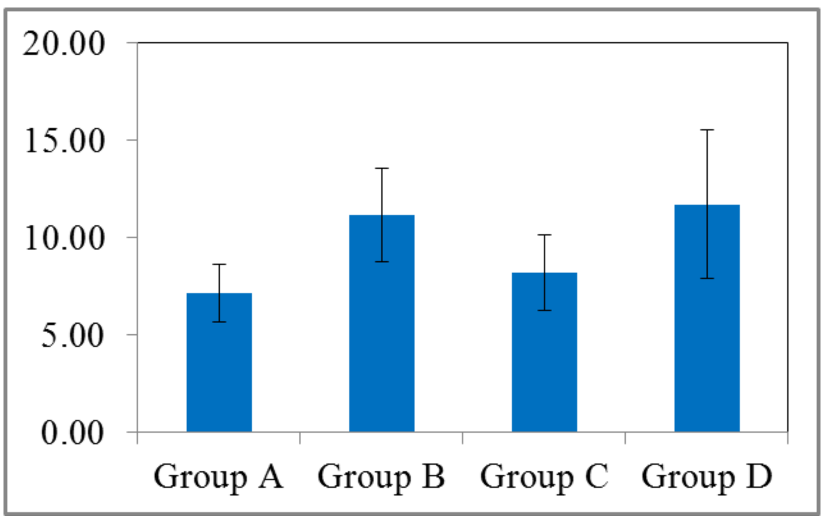


Graph 1:The above graph represents the mean & SD of tensile bond strength values according to 4 groups (A,B,C,D), in which, tensile bond strength values are higher in Group D followed by Group B, then Group C & Group A.



Graph 2: Comparison of four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength

DISCUSSION

The achievement of reliable bonds between zirconium oxide ceramics and resin-based luting agents is a prerequisite for ensuring clinical success and longevity. Several studies have been focused on cement selection in the attempt to attain optimal retention of bonded zirconia crowns and bridges. However, concerns still remain regarding the identification of the best luting methodology: the lack of chemical interaction between some resin-based cement systems and this high-strength core ceramic, makes zirconia surface pre-treatments helpful for achieving stronger and long-lasting bonded joints.[4]

All ceramic restorations are fabricated by CAD-CAM or heat pressing technique. Various pressable ceramics and CAD/CAM ceramics in the market are Vitablocs (Vita), Optimal Pressable Ceramic(Jeneric Pentron, Wallingford, Conn), IPS ProCAD(Ivoclar Vivadent), IPS Empress 2 (Ivoclar-Vivadent), Lava (3M ESPE), Cercon (Dentsply Ceramco), Procera (Nobel Biocare), In-Ceram Zirconia (Vita), In-Ceram Alumina (Vita), DC-Zirkon (DCS Dental AG).[3]

The recent introduction of zirconia-based ceramics as restorative dental materials has generated considerable interest in the dental community. The mechanical properties of zirconia are the highest ever reported for any dental ceramic. This may allow the realisation of posterior fixed partial dentures and permit a substantial reduction in core thickness.[5]

Although many types of zirconia-containing ceramic systems are currently available, only three are used to date in dentistry. These are yttrium cation-doped tetragonal zirconia polycrystals (3Y-TZP), magnesium cation-doped partially stabilized zirconia (Mg-PSZ) and zirconia-toughened alumina (ZTA).[5]

The retention of copings/crowns depends on the following factors: preparation design of the prepared tooth surface, any surface treatments given on the intaglio surface of the copings/crowns, type of resin cements used. In this study Zirconia Oxide Blanks (ZrO_2 stabilized by Y_2O_3) from Cercon (Dentsply, USA), were used to prepare the copings by CAD/CAM on the prepared human molar teeth with 5 mm axial length and 6 degrees of taper, to evaluate the influence of different surface treatments on the Zirconia surface, surface treatments used were sandblasting with Al_2O_3 particles and acid etching with Hydrofluoric acid 9.6% and combination of both.

In the present study we have prepared the human molar teeth with 5 mm axial length and 6 degrees of taper, because they usually possess the most excessive taper and shortest axial walls. In a previous study, the largest surface areas were found in the 5 mm height groups at 2 to 10 degrees of taper. According to Bahadir et al, preparations designs with higher axial walls and less taper showed the best retention. Optimizing these factors will allow the clinician to produce the largest possible surface area, thus enhancing the performance of the luting agent and the resistance form of the restoration.[6]

Out of the 4 groups divided for this study, Group A was control, Group B was sandblasting group, Group C was acid etching group & Group D was combination of both. The results achieved required the rejection of null hypothesis, since differences in the mean retentive values were observed ($p<0.05$) between the experimental groups. Highest mean retention was observed in Group D followed by Group B & Group C. The mean stress of dislodgement was 7.1, 11.1, 8.1, 11.7 MPa for Group A, Group B, Group C and Group D respectively.

Hydrofluoric acid selectively dissolves glassy or crystalline components of the ceramic and produces a porous irregular surface that increases the surface area and facilitates the penetration of the resin into the micro retentions of the etched ceramic surfaces. However, in a study by M.Ozcam et al, while acid etching demonstrated higher results for glass ceramics (Finesse and IPS Empress 2), it did not improve the bond strength of the luting cement to high-alumina ceramics or zirconium oxide ceramic. The differences obtained in bond strength can be explained on the basis of varieties in surface morphology. Finesse and IPS Empress 2 are glass ceramics as the first one is a leucite reinforced and the latter a lithium disilicate ceramic. The primary function of leucite is to raise the coefficient of thermal expansion, consequently increasing the hardness and fusion. The Finesse ceramic includes 8–10% leucite crystals which are very receptive to hydrofluoric acid etching before bonding with the resin cement.[7] The results of this study was however in agreement to the results of the present study, where acid etching did not produce much difference to the surface of zirconia ceramics. In this study the range of stress of dislodgement of group C was 5.33-11.71 MPa with the mean of 8.1 MPa which was less than that of group D(11.7 MPa) & group B(11.1 MPa) but it was more than that of control group A.

Zirconia ceramics are relatively resistant to the majority of the conditioning treatments employed with conventional ceramics. Several studies evaluated different combinations of surface treatments and resin cements type in the attempt of achieving optimal bonding to zirconia crowns and/or bridges. Airborne particle abrasion is considered today the most effective method for treating zirconia ceramics, improving surface roughness and creating micro-mechanical interlocks with the luting agent. However, it may also induce micro-cracks formation at the intergrain level that would be detrimental for the longevity of the ceramic restoration.[8] In a study by A.Casucci et al, which evaluated the effect of surface treatments on three different zirconium oxide ceramics, the results were in agreement to the present study which showed Airborne particle abrasion increased the average surface roughness of Cercon(DETREY DENTSPLY Ceramco, York, USA) and Adava Zr(GC corp., Tokyo Japan) ceramics, while no significant differences were produced on Lava(3 M ESPE, Seefeld, Germany).[8] In this study the range of stress of dislodgement for group B and group D was 7.83-14.06 MPa with mean of 11.1 MPa and 5.45-16.63 MPa with mean of 11.7 MPa respectively, which is more than that of group C(8.1 MPa) and group A(7.1 MPa), thus sandblasting showed the best results of mean stress of dislodgement in comparison with acid etching and control group.

In another study by Borges et al, they have shown that the efficiency of the surface treatment is highly dependent on the composition of the ceramics. Both hydrofluoric acid etching and airborne particle abrasion promoted irregularities in IPS Empress, IPS Empress 2, and Cergogold. These irregularities may be instrumental in improving the bond strength with resin luting agents. For the In-Ceram Alumina, In-Ceram Zirconia, and Procera, neither the hydrofluoric acid nor the airborne particle abrasion was effective in increasing irregularities on the ceramic surface.[9]

However, there are other methods by which we can enhance the surface irregularities and increase the bonding strength of zirconia to the tooth structure, such as silane coupling agents, primers-silica coating. It has been observed that due to lack of silica in ZrO_2, silica coating techniques have been explored to utilize the chemical bonding provided by silanization.[10] Although there are studies indicating that air abrasion affects the surface of zirconia ceramic which leads to a reduction of the flexural strength of these ceramics , there are other authors who showed that air abrasion might even strengthen zirconia ceramics. Furthermore, a negative effect of the micro cracks on the ceramic surface caused by air abrasion on the clinical performance of resin-bonded all ceramic restorations is questionable.[11]

In most of the earlier studies dealing with zirconia specimens, various surface pretreatments —such as sandblasting or tribochemical silica coating followed by silanization — were used. However, mechanical treatments of zirconia should be done with caution because it has been demonstrated that heat treatment, sandblasting, and grinding can influence its mechanical properties. Another important factor is the time for which the specimens were subjected to sandblasting, according to Sundh and Sjogren, it was stated that the effect on the fracture resistance of zirconia depended on, the time the specimens were subjected to sandblasting. This is probably because sandblasting treatment and/or grinding can induce compressive stresses and/or phase transformation on the surface, which increases the strength; at the same time, they also induce flaws and other defects which reduce the strength. Therefore, to find the best possible technique of improving bonding durability, more studies are needed to determine the effects of surface treatment on the bond strength and mechanical properties of zirconia ceramics.[12]

According to a study by Attia et al, air-borne particle abrasion and silica coating are most effective to improve resin bonding to zirconia and alumina ceramics. Airborne particle abrasion principally cleans and increases the surface area, resulting in higher bond strength due to mechanical retention.[10]

The results of this study showed that there is a significant difference in the mean stress of dislodgement of group D (11.7 MPa) specimens as compared to group C(8.1 MPa) and group A(7.1 MPa), and between group B(11.1 MPa) as compared to group C(8.1 MPa) and group A(7.1 MPa), but there is not much difference between group D(11.7 MPa) and group B(11.1 MPa) . Within the limitations of this study, sandblasting is considered to be the best method to increase the bond strength of Zirconium Oxide Ceramic copings to the tooth structure.

Limitations of the study:

The present study was an in-vitro study and has some limitations;

- Limited sample size.
- Other parameters in tensile testing like the thermal cycling or aging was not included, which made the study much simpler.
- Limited storage time in distilled water for 24 hours when compared to storage time of 3 days and 150 days in other in-vitro studies.

All the above mentioned things can be verified by further studies in future.

Scope for further research

- Further studies can be undertaken to assess the surface roughness and tensile bond strength by using silane coupling agent or silica coating primers.
- Further studies can be undertaken to assess the bond strength of various other commercially available resin cements

CONCLUSION

This study evaluated the tensile bond strength of Zirconium Oxide Cearmics after air abrasion with Alumina particles and acid etching with Hydrofluoric acid when luted with a resin cement namely SmartCem 2. Within the limitation of this study, the following conclusions were drawn:

1. The mean stress of dislodgement was 7.1, 11.1, 8.1, 11.7 MPa for Group A, Group B, Group C and Group D respectively. Lower mean retention is observed in Group A and highest mean retention is observed in Group D specimens. From the ANOVA results we observe that there is a significant difference observed between four groups (Group A, Group B, Group C and Group D) with respect to tensile bond strength ($F=6.0239$, $p<0.05$)i.e. $0.0027<0.05$ at 5% level of significance. The ANOVA P value was 0.0027. It means that, the tensile bond strength scores are different in four groups (Group A, Group B, Group C and Group D).

2. Although the Tensile bond strength of Group B (11.1 MPa) and Group D(11.7 Mpa) specimens did not show statistical significance, hence it can be said that acid etching did not increase the bond strength of zirconium oxide copings to the tooth structure.

3. The Group D specimens (combination of air abrasion with alumina particles and acid etched) showed the maximum tensile bond strength scores and air abrasion proved to be the best option for surface treatment of Zirconium Oxide Ceramic copings.

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