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EFFECT OF DIFFERENT SURFACE TREATMENT METHODS ON THE SHEAR BOND STRENGTH OF ZIRCONIA BASED RESTORATIONS

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ABSTRACT

Statement of the Problem: Delamination of zirconia-veneered restoration is considered to be a very common failure in clinical practice. Therefore, using a chair side intra-oral repair option may be a simple alternative method to the total replacement of the restoration and may provide a clinically-acceptable and reliable immediate solution.

Aim of the Study: This study evaluated the shear bond strength of two different repairing systems (CoJet and Ceramic repair N) of zirconia-based restorations and evaluated the effect of high and low sandblasting pressure on the shear bond strength between zirconia and composite resin.

Materials and Methods: Thirty zirconia specimens were divided into two main groups according to the repairing systems: Group CJ: CoJet™ repairing system [chairside silica coating with 30 μm SiO_2 + silanization + adhesive] (3M ESPE) (15 specimens). Group CR: Ceramic Repair N system (Ivoclar Vivadent) [grinding with diamond stone + Monobond N universal primer adhesive] (15 specimens). Each group was further sub-divided into three sub-groups according to the surface treatment methods: Sub-groups (CJS 3, 2,1): CoJet Sandblasting at pressure 3,2,1 bar, Sub-group (CRG): Ceramic Repair Grinding with diamond stone and Sub-groups (CRS 2,1): Ceramic Repair Sandblasting with CoJet sand at pressure 2 and1 bar. Tetric N- ceram composite resin was polymerized on each conditioned specimen. The shear bond strength was tested using a universal testing machine, and fracture sites were examined with SEM. The data of bond strengths were statistically analyzed with two-way ANOVA.

Results: No statistically significant differences in the mean shear bond strength values between Cojet Group (11.31± 0.71 MPa) and Ceramic Repair-N Group (11.02± 0.81 MPa). There were no statistically significant differences in the mean shear bond strength values between 1 bar treated sub-group (11.13± 1.4 MPa), 2 bar treated sub-group (11.23± 1.5 MPa), grinding sub-group and 3 bar (control) sub-group (11.12±1.8MPa), ($P>0.05$).

Conclusion: Surface treatment of low pressure abrasion protocol or grinding following with Monobond N universal primer gave the similar shear bond strength values of the high pressure abrasion protocol.

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INTRODUCTION

Zirconia-based restorations use a high strength ceramic material for the substructure to provide sufficient resistance against forces of mastication. Clinical failures of veneered zirconia frameworks due to chipping of the veneering ceramic are reported to be at 13.0% after an observation period of three years and at 15.2% after five years [1].

In order to avoid an expensive replacement, numerous repair systems are now available to the dentist for the intra-oral repairing of ceramics. The most commonly used method is bonding composite resin materials to the fractured surface [2].

Optimal surface preparation techniques for chemical and/or mechanical bonding to ceramic substrate are crucial to ensure clinical success when placing indirect ceramic restorations as well as when repairing them intra-orally. A variety of surface preparation techniques have been advocated which includes the use of acids, particle abrasion, adhesives, and silane coupling agents [3, 4].

Zirconia-based ceramics are highly resistant to the chemical attack of hydrofluoric acid and different approaches if clinicians elect to bond these restorations using resin-based adhesives and luting cements [5,6].

Using high pressure particles abrasion has a bad effect on the mechanical properties of zirconia since cracks and flaws formation and transformation from the tetragonal to the monoclinic may occur, which is why authors recommend using low pressure particles abrasion [7].

Silane coupling agents (silanes) are well-known for forming covalent chemical bonds between dissimilar materials. Phosphate-monomer-containing agents is a new generation presented as universal primers to enhance the wetting and modify the zirconia chemistry. These primers contain silane and phosphate monomer [8-10].

Therefore, the hypothesis of this study was that ceramic repair system and sandblasting pressure will affect the shear bond strength between zirconia and composite resin.

MATERIALS AND METHODS

Incoris ZI blocks (Sirona, Germany) with block size 40/19: 15.5 x 19 x 39 mm were used to obtain (30 specimens). Each specimen has a square shape with 13.3x13.3 x 3.3 mm dimensions. The cutting process occurred using a precision cutting instrument and diamond-coated cutting discs IsoMet 4000 microsaw Buehler, USA. After cutting the specimens, they were placed in the ultrasonic cleanser, and then dried. The Sirona infire HTC speed furnace, sintering furnace, sirona Germany. After a sintering process, the dimension of each specimen was approximately 10x10x2mm.

A total of 30 zirconia specimens were divided into two main groups according to the repairing systems: Group CJ: CoJet intra -oral repairing system (15 specimens), group CR: Ceramic Repair N system (15 specimens).

Each group was further sub-divided into three sub-groups according to the surface treatment methods: sub-group (CJHS 3): CoJet High Sandblasting at pressure 3 bar (n=5),sub-group (CJAS 2): CoJet Average Sandblasting at pressure 2 bar (n=5),sub-group (CJLS 1): CoJet low Sandblasting at pressure 1 bar (n=5),sub-group (CRG): Ceramic Repair Grinding with diamond stone (n=5),sub-group (CRAS 2): Ceramic Repair Average Sandblasting at pressure 2 bar (n=5), sub-group (CRLS 1): Ceramic Repair Low Sandblasting at pressure 1 bar (n=5).

Specially designed Teflon moulds were fabricated in the present study in order to standardize the dimensions and positions of the repair composite discs.

Mould (Z): It consisted of an inner Teflon mould, square in shape, with a central hole of (10 x10 x2) mm, which holds the zirconia specimens.

Mould (C): It consisted of an inner splitted Teflon mould, circular in shape, with a central hole of 6 mm diameter, 4 mm length mm, circular in shape which holds the composite material, which is placed directly above the mould (Z), while its central hole is placed directly above the center of the zirconia specimen. An outer stabilizing ring was fabricated for the whole assembly of the moulds together.

To standardize the distance between the nozzle of the micoblaster and the special holder was fabricated. It consists of three parts attached to each other. The first part is a holder fabricated from wood to hold the zirconia specimen, the second part is a metal ring to hold the microblaster and fix it with two screws, and the third part is a metal arm to hold the first and second parts together in order to achieve a perpendicular relationship between the nozzle of the microblaster and the center of zirconia specimens (figure1).

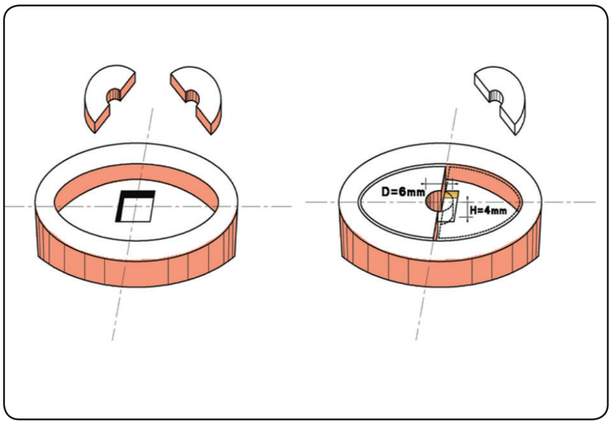

Fig. (1): A diagram showing moulds assembly within the ring.

Application of zirconia repairing systems:

All sub-groups, except Ceramic Repair Grinding (CRG), were subjected to sandblasting using the intraoral microblaster with Cojet sand (30 μm aluminum particles modified with silica) for 15 seconds at a fixed distance of (10 mm). The microblaster was attached to a

1. Application of CoJet intraoral repairing system (n=15):

The specimens of all sub-groups of CoJet system group were subjected to CoJet sandblasting as follows: (CJHS 3): CoJet High Sandblasting at pressure 3 bar (n=5), sub-group (CJAS 2): CoJet Average Sandblasting at pressure 2 bar (n=5), and sub-group (CJLS 1): CoJet low Sandblasting at pressure 1 bar (n=5).

After sandblasting, the specimens were rinsed with a water spray for 30 seconds to clean the surface from the residual sand particles, and then dried with oil-free air. The specimens were treated with a prehydrolyzed silane-based primer (RelyX™ Ceramic Primer) and then dried with oil-free air for 30 seconds. A bonding agent (Adper ™ Single Bond 2 Adhesive) was used to apply a thin layer with a disposable brush and then light cured for 10 seconds.

2. Application of Ceramic repair N system (n=15):

In Ceramic Repair N group, (CRG) sub-group according to the manufacturer's instruction were subjected to grinding and roughening using a diamond stone (n=5) (figure 19), while (CRAS) was subjected to sandblasting with cojet sand at pressure 2 bar (n=5) and (CRLS) was subjected to sandblasting with cojet sand at pressure 1 bar (n=5). After sandblasting, the specimens were rinsed with a water spray then dried with oil-free air, and then Monobond N was applied on the zirconia specimens and allowed to react for 60 seconds, then dried with oil-free air.

According to the manufacturer's instructions, a thin layer of bonding agent (Heliobond) was applied, then light cured for 10 seconds.

After surface treatment and application of the bonding agents, the light cure nano-hybrid composite Tetric N-ceram was applied on all specimens inside the mould (c) increment by increment, the maximum increment depth is 2mm, and light cured for each layer for 10 second, and the moulds were removed.

Each specimen was then mounted in the universal testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK). Equipped with a load cell of 5 kN at cross-head speed of 0.5 mm/min and data were recorded using computer software (Nexygen-MT; Lloyd Instruments) until failure occurred. The mode of failure was classified as either cohesive failure in the composite resin, or interfacial adhesive failure at the zirconia-resin interface.

RESULTS

Effect of repairing systems:

Regardless to surface treatment pressure, totally it was found that CoJet group recorded statistically non-significant (P>0.05) higher shear bond strength mean value (11.31± 0.71 MPa) than ceramic repair group (11.02± 0.81 MPa) as indicated by two-way ANOVA test. **Table (1) and Figure (2).**

TABLE (1): Comparison between total shear bond strength results (Mean values± SDs) as function of repair system

Variable		Mean	SD	Statistics (P value)
Repair system	Cojet	11.31	0.71	0.7195 ns
	Ceramic repair	11.02	0.81	

Different letter in the same column indicating statistically significant difference (p< 0.05) (p<0.05) S; Significant (p< 0.05) NS; Non-Significant (p>0.05)

Effect of surface treatment pressure:

Regardless to repair system, totally it was found that 2 bar treated subgroup recorded statistically non-significant (P>0.05) highest shear bond strength mean value (11.23± 1.5 MPa) followed by 1 bar treated sub group (11.13± 1.4 MPa) then while control subgroup recorded statistically non-significant (P>0.05) lowest shear bond strength mean value (11.12±1.8MPa) as indicated by two-way ANOVA test. **Table (2) and Figure (3).**

TABLE (2) Comparison between total shear bond strength results (Mean values± SDs) as function of surface treatment pressure

Variables		Mean	SD	Statistics (p-value)
Surface treatment pressure	Control	11.12	1.8	0.9923 ns
	2 bar	11.23	1.5	
	1 bar	11.13	1.4	

Different letter in the same column indicating statistically significant difference (p<0.05) S; Significant (p< 0.05) NS; Non-Significant (p>0.05)

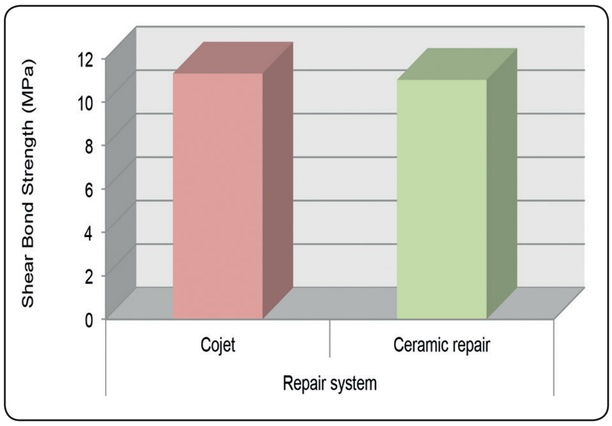

Fig. (2): Effect of repair system

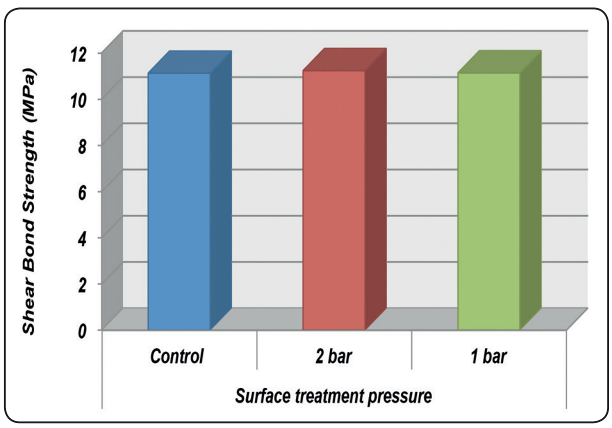

Fig. (3): Effect of surface treatment pressure

DISCUSSION

The increase of patients' desire for esthetics has resulted in the use of ceramic restorations in the anterior region as well as the posterior region. The acceptance of ceramic restorations has increased because of their inherent esthetics, excellent biocompatibility, and improved physical properties [11-14].

A weak bond between the veneering porcelain and zirconia core can result in the fracture or delamination of the veneer itself. According to a study by Sailer et al., the clinical failure rate caused by chipping of the veneering porcelain was reported to be at 13% after three years and at 15.2% after five years [15-18].

Cojet™ System was used in the present study as many authors recommended the use of this system to improve the bond strength of composite resin to zirconia through the embedding of silica particles in the zirconia surface which makes a micromechanical pore in zirconia, followed by silane coupling agent to make a chemical bond between zirconia and resin[19-21].

Ceramic Repair N System was the other repairing system used in the present study to compare it with Cojet system and evaluate its effect on the shear bond strength in case of combination with Monobond plus universal primer which contains both an MDP monomer and a silane monomer 3-MPS, which creates a durable bond strength to zirconia [22,23].

In addition, the sandblasting pressure was decreased in to 2 bar, and to 1 bar, since many authors recommended the use of low air pressure in sandblasting of the zirconia to avoid micro flaws and cracks creation which decreases the mechanical properties of zirconia and also may cause phase transformation of zirconia from the tetragonal to the monoclinic phase [24].

The hypothesis of this study was that ceramic repair system and sandblasting pressure will affect the shear bond strength between zirconia and composite resin. This hypothesis was rejected.

The results showed that there were no statistically significant differences in the mean shear bond strength values between Cojet Group and Ceramic Repair Group (P>0.05). These results are in agreement with the results of Yong J. J. et al. (2015) [17].

The minimum acceptable value of the shear bond strength is 10-13 MPa. If the value was greater than 13MPa between the zirconia and the composite, the cohesive failure occurs. In the present study, the values of shear bond strength are within this limit, which led to the adhesive failure. However, many studies recorded values more than this range but with different methodologies [25].

The chemical components of the zirconia (traces such as Li2O, Na2O, K2O, CaO, MgO) are bound to each other by strong covalent bonds with hydroxyl groups at the zirconia surface. When the surface is air abraded, this would generate more hydroxyl groups on the surface and also enhances the micromechanical retention [26-29].

The silane molecules react with water forming silanol groups (-Si-OH) from methacryloxy groups (-Si-O-CH3). Silanol groups react with the silica deposited on the zirconia surface to form a siloxane network (-Si-O-Si-O-). The monomeric ends of the silane react with the methacrylate groups of the resin material [30-32].

The results showed that there were no statistically significant differences in the mean shear bond strength values between 1 bar treated sub-group, 2 bar treated sub-group, grinding sub-group, and 3 bar (control) sub-group (P>0.05).

These abovementioned results, which reported no significant differences between high and low sandblasting pressure, are in agreement with Kern et al. (2009), Yang B. et al. (2010) and Re D. et al. (2012) [33,34,35].

The limitations of the present study are that its procedures were done outside the mouth (Invitro) on discs, not on restorations and in absence of oral conditions such as: saliva or masticatory forces. Another shortage in the present study is the use of one type of composite resin.

CONCLUSION

Surface treatment of low pressure abrasion protocol or grinding following with Monobond N universal primer gave the similar shear bond strength values of the high pressure abrasion protocol.

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