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# Bonding Monolithic Ultra-Translucent Zirconia Restorations to Endodontically Treated Teeth Systematic Review

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## Objectives

Challenges in bonding to endodontically treated teeth, where a different medicament were used on dentin and how it affects bond strength. when zirconia indirect restorations (onlays and crowns) were used where indirect restorations, is the choice especially if bonded to endodontically treated tooth with enough tooth structure.

**Keywords:** Endodontically treated teeth; Dental restoration; Zirconia monolithic; Sandblasting; Bond strength

## Formulate the Research Question

### Bonding monolithic zirconia to endodontically treated teeth

PICO: P-Problem: Bond strength endodontically treated teeth.

I-Intervention: Adhesion of monolithic ultra-translucent zirconia with sandblasting surface treatment.

C-Comparison: Zirconia adhesion to endodontically treated teeth and vital teeth.

O-Outcome: Bond strength.

## Introduction

Restoration of root filled teeth could be challenging due to Structural difference between vital and non-vital teeth. Altered physical characteristics of the tooth structure remaining after endodontic therapy exhibit different changes, Calcified tissues of pulp less teeth have 9% less moisture content than in vital teeth [1]. The collagen too has fewer mature and more immature cross links. Changes in collagen cross linking and dehydration of the dentin result in 14% reduction in strength and toughness of endodontically treated molars. The combined loss of structural integrity, loss of moisture and loss of dentin toughness compromises, microstructural-composition changes, and changes in mechanical properties (bond strength, micro-hardness, nano-hardness, modulus of elasticity and tensile strength [2,3].

Treating dentin with 5% sodium hypochlorite for two minutes produces dissolution of collagen and collagen-mineral bond, as well as changes in apatite crystallinity, resulting in a surface rich in apatite crystals [4]. Therefore, the substrate becomes more brittle, decreases its physical properties and produces a very weak bond and that the only fact of treating dentine with sodium hypochlorite and EDTA reduces surface micro-hardness [5-7]. Zirconia is resistant to aggressive chemical agents solving agents. Such chemical stability predicts superior long-term performance under the tough conditions of the oral environment [8].

Various chemical products were developed that is, a phosphate ester monomer, 10-methacryloyloxydecyl di-hydrogen phosphate (MDP) [9,10]. Nevertheless, the established bond strength was not sufficient for retaining adhesive zirconia restorations, as debonding under function was previously reported [11]. Various silica- coating methods were investigated and proved inefficient in increasing the retention of zirconia crowns [12,13]. Airborne-particle abrasion and roughening with diamond points, also failed to establish adequate mechanical retention to zirconia substrates [14,15]. In case of insufficient remaining tooth structure with more than one marginal ridge lost and weak remaining tooth structure therefore indirect restorations such as zirconia crowns inlays or onlays are the treatment of choice [16-21]. Chelators such as EDTA interact with the mineral content of dentin causes dentin erosion and softening as they mainly deplete calcium through complex formation and also affect non-collagenous proteins: proteoglycans, dentin phosphoproteins and sialoprofens [22].

Biological oxidant such as NaOCl and $H_2O_2$ cause the oxidation of some of the components of the dentin matrix, particularly collagen. They form protein-derived radicals that compete with the propagating vinyl- free radicals generated by the photo-activation of resin adhesives, resulting in premature chain termination and incomplete polymerization in addition; they liberate oxygen, which causes strong inhibition of polymerization in the adhesive system [23].

Zinc oxide and eugenol sealers and most temporary cements leave behind an oily debris NaOCl and $H_2O_2$ form an oxygen rich surface in dentin. The oxygen-rich layer left behind NaOCl can be reversed by a reducing agent like sodium ascorbate or ascorbic acid Gonulol et al. [24] reported that, treatment of access cavities and pulp chambers with 10% sodium ascorbate solution following endo treatment restores the sealing ability of resin with root dentin. 10% sodium ascorbate hydrogel might be as effective as 20% sodium ascorbate hydrogel in neutralizing the oxidizing effect and increasing the bond strength [25]. Chlorhexidine can significantly improve the resin-dentin bond stability anti-collagenolytic activity, because of its broad-spectrum metalloproteinase (MMP)-inhibitory effect [26-28]. Zamany et al [29], Abdullah et al [30] found that fusion of glass beads and plasma spraying, gave promising results.

## Material and Methods

Two phases of the study selection were conducted

1. Abstracts and titles were selected.

2. Full tests of the selected titles were obtained and read to determine the final sample set through 2000 and 2019.

Also Nonrandomized longitudinal experimental clinical studies, longitudinal prospective studies, and longitudinal retrospective studies were reviewed. The choice of key words was intended to be broad to collect as much relevant data as possible both manually and electronically also, the references were thoroughly inspected for more possible candidates till May 20, 2019.

## Inclusion and Exclusion Criteria

A search was performed in MEDLINE and PubMed for in vivo and vitro trials on zirconia restorations published between 2000 and 2019.

The main keywords used for the search; number of articles produced were:

1) ‘‘Zirconia and clinical’’-329 articles

2) ‘‘Zirconia and fixed partial dentures’’- 130 articles

3) ‘‘Zirconia and FPD’’-23 articles

4) ‘‘Zirconia and implant abutments’’-61 articles

5) ‘‘Zirconia and single crowns’’-73 articles

In addition, a manual hand search was conducted through the literature to identify any possible clinical trials on Y-TZP, monolithic zirconia which may have not been listed on MEDLINE and PubMed. The articles found were read to identify ones which satisfied the following inclusion and exclusion criteria:

### Inclusion Criteria

1. Human in vivo.
2. In-vitro studies.
3. Study has a set inclusion and exclusion criteria.

### Exclusion Criteria

1. Case reports.
2. Animal studies.
3. Patients with bruxism or any para-functional habits.

## Result

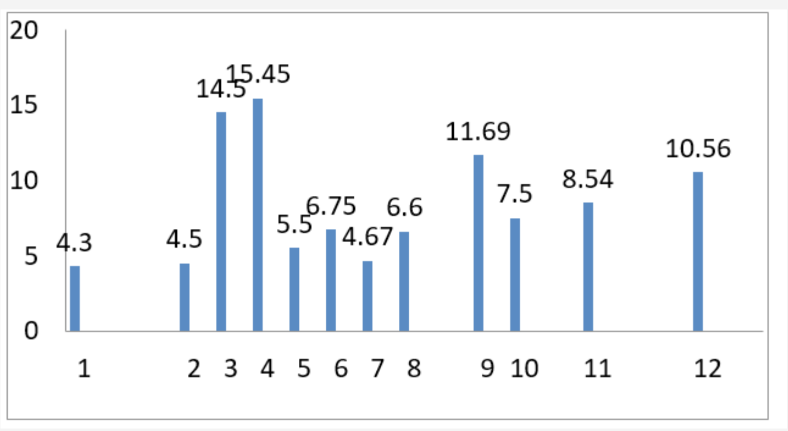


**Figure 1:** Showed that highest surface treatment was found in sandblasting techniques followed by airborne particles by silicone dioxide.

The search yielded 12 articles and abstracts involving Y-TZP restorations which satisfied the inclusion criteria (Figure 1). From all retrieved papers the ones that described techniques developed to increase bond strength of $ZrO_2$ to resin cement and their relationship with the material's composition were selected. Bond strength methods of selected papers were: Shear tests (19 papers), Microshear tests (3 papers), Tensile tests (5 papers), Microtensile tests (11 papers), and pull-out tests (01 paper). Just one paper employed both micro-tensile and shear bond strength methods, observing similar results (Table 1-3, Figure 2, Table 4, Figure 3-7).

Only zirconia-based ceramics BS measurements were listed in the table. Treatments were divided into: Chemical surface treatments, Mechanical surface treatments, and Alternative treatments.

**Table 1:** Retrieved papers from PubMed database search are, grouped in accordance with bond strength (BS) tests, type of ceramics, surface treatment method (STM), resin cements and results for BS improvement.

| Name of Author Year | BS Method and Value | Type of Ceramics | STM | Methods | Results |
|---|---|---|---|---|---|
| JR Piascik, EJ Swift, JY Thompson, S Grego, BR Stoner, 2009. | MTBS | Zir CAD and Pro CAD | 50 $\mu$mAl2O3 AA+2.6nm $SixOy$; 50$\mu$mAl2O3 AA+23 nm $SixOy$; CoJet | Surface modification for enhanced silanation of zirconia ceramic | Analyzed using single-factor ANOVA (p<0.05). Pre-treatment to deposit ultra-thin silica-like seed layers can improve adhesion to zirconia using traditional silanation and bonding techniques. This technology could have clinical impact on how high strength dental materials are used today. |
| RM Foxton, AN Cavalcanti, M Nakajima et al., 2011. | Shear | Y-TZP | 53$\mu$mAl2O3 AA; YAG laser | Durability of resin cement bond to aluminium oxide and zirconia ceramics after air abrasion and laser treatment | A significant statistical interaction between the resin cements and surface treatments was detected (p=0.004). In the surface-treated groups (air abrasion and Er: YAG laser irradiation), the Bis-GMA-based resin cement had higher bond strength than the MDP-based cement. Both materials presented similar bond strengths when no surface treatment was used. With the groups cemented with the MDP-based material, air abrasion resulted in significantly higher bond strengths, while laser irradiation and the absence of surface treatment presented similar results. |
| M Ozcan, C Cura, LF Valandro, 2011. | Shear | Y-TZP | Silica coating; 50 $\mu$m Al2O3 AA; MPS and/or 4-META silanes | Early bond strength of two resin cements to Y-TZP ceramic using MPS or MPS/4-META silanes | Results When the ceramic surfaces were silica coated and Super Bond cement was used, mean bond strength was not significantly However, when Panavia F 2.0 cement was used, mean bond strength was significantly higher. |
| RC De Oyague, F Monticelli, M Toledano, E Osorio,M Ferrari, and R. Osorio, 2009. | MTBS | Y-TZP | 125 $\mu$m Al2O3 AA, TBC | Influence of surface treatments and resin cement selection on bonding to densely sintered zirconiumoxide ceramic | The highest shear bond strength values were observed in Groups IV and V. The lowest shear bond strength values were observed in Group I. Using 10-methacryloyloxy-decyl dihydrogenphosphate monomer-containing priming agents, e.g. Monoband Plus and Z-PRIME Plus, combined with sandblasting can be an effective method for resin bonding of zirconia restorations. Discover the world's research |
| 39RC Oyague, F Monticelli, M Toledano, E Osorio, M Ferrari, R Osorio, 2009 | MTBS | Y-TZP | 125 $\mu$mAl2O3 AA, Co Jet | Effect of water aging on microtensile bond strength of dual-cured resin cements to pre-treated sintered zirconium-oxide ceramics | RESULTS: Significant changes in zirconia surface roughness occurred after sandblasting (p<0.001). Bond strength of Clearfil cement to zirconia was significantly higher than that of Rely x Unicem and Calibra, regardless of the surface treatment (p<0.001). When using Calibra, premature failures occurred in non-treated and silica coated zirconia surfaces. SIGNIFICANCE: The phosphate monomer-containing luting system (Clearfil Esthetic Cement) is recommended to bond zirconia ceramics and surface treatments are not necessary. |
| SS Atsu, MA Kilicarslan, HC Kucukesmen, PS Aka 2006 | Shear | Y-TZP | 125 $\mu$mAl2O3 AA, Clearfil-silanes, MDP solution, and CoJet | Effect of zirconium-oxide ceramic surface treatments on the bond strength to adhesive resin | |
| M Ozcan, H Nijhuis, and LF Valandro, Effect of various, 2008 | Shear | Y-TZP | 50 $\mu$m Al2O3 AA; Korox; Rocatec; flame treatment | surface conditioning methods on the adhesion of dual-cure resin cement with MDP functional monomer to zirconia after thermal aging | Data were statistically analyzed (one-way ANOVA, α=0.05), whereby no significant differences were found among the four groups (8.43±1.3, 8.98±3.6, 12.02±6.7, and 8.23±3.8 MPa) (p=0.1357). Therefore, the performance of chairside conditioning methods used for zirconia was on par with the laboratory alternative tested. |

**Table 2**

| Name of Author | Year | Title | Method | Result | Conclusion |
|---|---|---|---|---|---|
| Başaran G, Başaran Eg, Ayna E Değer Y, Ayna B, Tuncer Mc | 2019 | Microtensile bond strength of root canal dentin treated with adhesive and fiber-reinforced post systems | Important characteristics of fiber-reinforced posts involve a modulus of elasticity similar to dentin and their ability to be cemented by an adhesive technique. A total of 36 maxillary incisors were divided into four groups. In this study, four adhesively luted fiber-reinforced (glass fiber, quartz glass fiber, zirconia glass fiber and woven polyethylene fiber ribbon) post systems were used. Post spaces were prepared by employing drills according to the protocol established for each group, and each post was adhesively luted with one of three adhesive systems. Three segments per root apical to the cementoenamel junction (CEJ) were obtained by sectioning the root under distilled water with a carbon spare saw. The samples (total of 108 sections) were 2.0±0.1 mm in thickness and they were stored individually in black film canisters with sterile distilled water. In order to determine the bond strength, the bonding area of each specimen was measured, and specimens were attached to a device to test microtensile strength at a speed of 1 mm/min. | The coronal portion of root dentin showed significantly higher bond strength values. However, there were no significant differences between the coronal-middle or middle-apical portions. The analyses revealed no statistically significant differences between the adhesive systems and fiber-reinforced posts. ($P > 0.05$). However, the coronal portion of the root dentin had the highest bond strength. Adhesive systems used along with fiber-reinforced resin posts demonstrated reliable bonding. | The bonding mechanism to root canal dentin was not influenced by the type of fiber post. But according to the biomechanical properties of root dentin; Several studies have shown that retention is a relevant problem with intraradicular posts. One of the main reasons for failure is the poor adhesion between the fiber post and resin systems. Fiber post debonding from the root canal occurred due to poor retention. Failures may begin at the cement-dentin or cement-post interface. It is important to provide higher bond strength at these interfaces. The use of adhesive systems, resin cements, and surface conditioning agents is widespread. |
| Laikuan Zhu, Yuping Li, Yung-Chung Chen, Carola A Carrera, Chong Wu & Alex Fok | 2018 | Comparison between two post dentin bond strength measurement methods. | The push-out (PO) test and the diametral compression (DC) test were performed to compare the merits of two post-dentin bond strength measurement methods. Compared with the push-out test, the disk in DC provided post-dentin bond strength measurements that were more precise. The load-displacement curves from the DC test were much smoother and more linear up to the point of fracture when compared to those from the PO test. | Compared to the PO test, DC is easier to perform for determining the bond strength between posts and dentin. No specimen alignment is needed in the DC test, and it produces a smaller standard deviation in the measured bond strength. The main disadvantage of the DC test, however, is that finite element analysis (FEA) is required to calculate the bond strength. | The shear bond strength given by the PO test based on the simple formula is not valid, though, and the peak failure load is dependent on friction at the post-dentin interface.<br><br>For the PO test, the shear bond strength was calculated using the formula $P/\pi dh$, where P is the failure load, d is the inner diameter of the disk, and h is the height of the disk. |

| | | | | | |
|---|---|---|---|---|---|
| Khoroushi M ,Feiz A , Khodamoradi R | 2010 | Fracture Resistance of Endodontically-treated Teeth: Effect of Combination Bleaching and an Antioxidant | This in vitro study assessed the fracture resistance of endodontically-treated teeth undergoing combination bleaching with 38% and 9.5% hydrogen peroxide gels as in-office and at-home bleaching techniques, respectively. In addition, the effect of an antioxidizing agent, sodium ascorbate, was investigated. Methods and Materials: Sixty maxillary premolars were endodontically-treated, received a glass ionomer barrier as a mechanical seal and were embedded in acrylic resin up to the cemento-enamel junction. The specimens were divided into four groups (n=15) as follows: G I: no bleaching, access cavity restored with resin composite (negative control); G II: bleached for three weeks daily using 9.5% hydrogen peroxide for two hours and three sessions of in-office bleaching using 38% hydrogen peroxide every seven days, then restored (positive control); G III: bleached similar to G II and restored after one week; G IV: bleached similar to G II, along with the use of an antioxidizing agent for 24 hours, then restored. In each in-office and athome bleaching session, the whitening gels were applied to the buccal surface of the tooth and placed inside the pulp chamber (inside/outside bleaching technique). Finally, the specimens underwent fracture resistance testing; the data were analyzed using ANOVA and Scheffé's test ($\alpha$=0.05). | Significant differences were observed among the study groups (p0.05). | Within the limitations of the current study, it can be concluded that the fracture resistance of endodontically-treated teeth decreases after combination bleaching. The use of sodium ascorbate can reverse decreased fracture resistance |
| Reza Talebian, Zahra Khamverdi,1 Maryam Nouri,2 and Shahin Kasraei; | 2014 | Effect of ascorbic acid on bond strength between the hydrogen peroxide-treated fiber posts and composite resin | This study evaluated the effect of 10% ascorbic acid on the bond strength between fiber post and composite resin core after applying 24% hydrogen peroxide. Materials and Methods: Twenty-four hydrogen peroxide-treated fiber posts were divided into 4 groups (n = 6). Group 1 was the control group with no treatment. In groups 2-4, post surfaces were treated with 10% v ascorbic acid solution for 10, 30 and 60 minutes, respectively. Cores were built up using flowable composite resin. Two sticks were prepared from each specimen. Microtensile bond strength test was performed for each stick. Failure modes of sticks were evaluated under a stereomicroscope (×20). Surface morphologies of two fractured sticks from each group were assessed by SEM. | Data were analyzed using one-way ANOVA and Tukey HSD tests ($\alpha$ = 0.05).The highest microtensile bond strength was observed in Group 4 (20.55 ± 2.09) and the lowest in Group 1 (10.10 ± 0.55). There were significant differences in microtensile bond strength between all the groups ($P < 0.05$). | It is concluded that ascorbic acid application increased the microtensile bond strength between the hydrogen peroxide treated fiber post and composite resin core. The increase is dependent on the duration of exposure to the antioxidant. |

| | | | | | |
|---|---|---|---|---|---|
| Nihan Gonulolay , Elif Kalyoncuo glu, Ertan Erta | 2015 | Effect of sodium ascorbate on dentin bond strength after treatment with oxidizing root canal irrigants. | The aim of this study was to evaluate the effect of 10% sodium ascorbate solution on dentin bond strength after being treated with different oxygenreleasing root canal irrigants. Materials and methods: Twenty-one human third molars were used in this study. The specimens were randomly divided into seven groups according to irrigation solutions, as follows: Group C (control group), distilled water; Group SH, 5.25% sodium hypochlorite (NaOCl); Group SHA, 5.25% NaOCl þ 10% sodium ascorbate solution; Group HP, 10% hydrogen peroxide (H2O2); Group HPA, 10% H2O2 þ 10% sodium ascorbate solution; and Group OW, ozonated water; Group OWA, ozonated water þ 10% sodium ascorbate solution. A two-step self-etching adhesive system (CLEARFIL SE Bond) was applied to the surfaces, and resin core buildups (Filtek Z550) were placed. specimens were sectioned into 1-mm2 beams and tested in a microtensile bondstrength (mTBS) testing machine at a crosshead speed of 1 mm/minute. Fractured specimens were examined with a stereomicroscope to determine the mode of failure (adhesive, cohesive, or mixed). | The data were analyzed by one-way analysis of variance and Tukey tests (P<0.05). Results: The ozonatedwater-treated groups showed the lowest mTBS values among all the groups. | Although the 10% sodium ascorbate application increased dentin bond strength in Group OW, the difference was not significant (P>0.05). With ozonated water only as irrigant. |

**Table 3:** Characteristics of zirconia after surface treatment (Mean ± SD).

| Surface Treatment | Mean BS.SD |
|---|---|
| HFP | 8.88±5.15 |
| APP | 11.69±5.97 |
| HFNPP | 13.26±5.75 |
| Laser treatment | 7.502±5.23 |

**Table 4:** Means and standard Deviations for Shear Bond Strength Results (MPa) According to the Different Surface Treatment and Multilink Speed Cement.

| Priming Conditions | Surface Conditions | |
|---|---|---|
| | No Air-Abrasion(polished) | Air-Abrasion |
| None | 3.91(0.72) A | 10.56(3.32) B |
| Monoband-Plus | 4.86(1.77) A | 8.93(3.13) B |
| Z-Prime plus | 8.27(2.79) B | 16.50(2.26) C |
| Cojet and ESPE Sil | 8.54(3.98) B | |

## Discussion

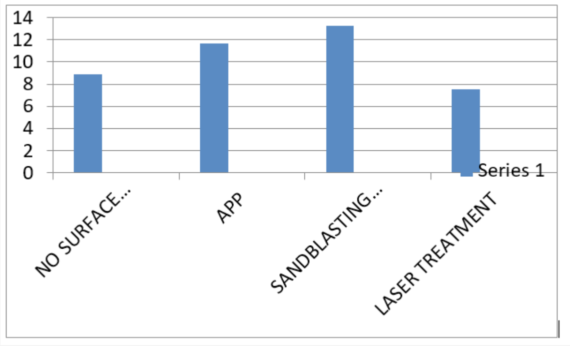


**Figure 2:** Showed highest surface treatment in sandblasting following by air-borne particles app then lowest by laser treatment where cracks also found.

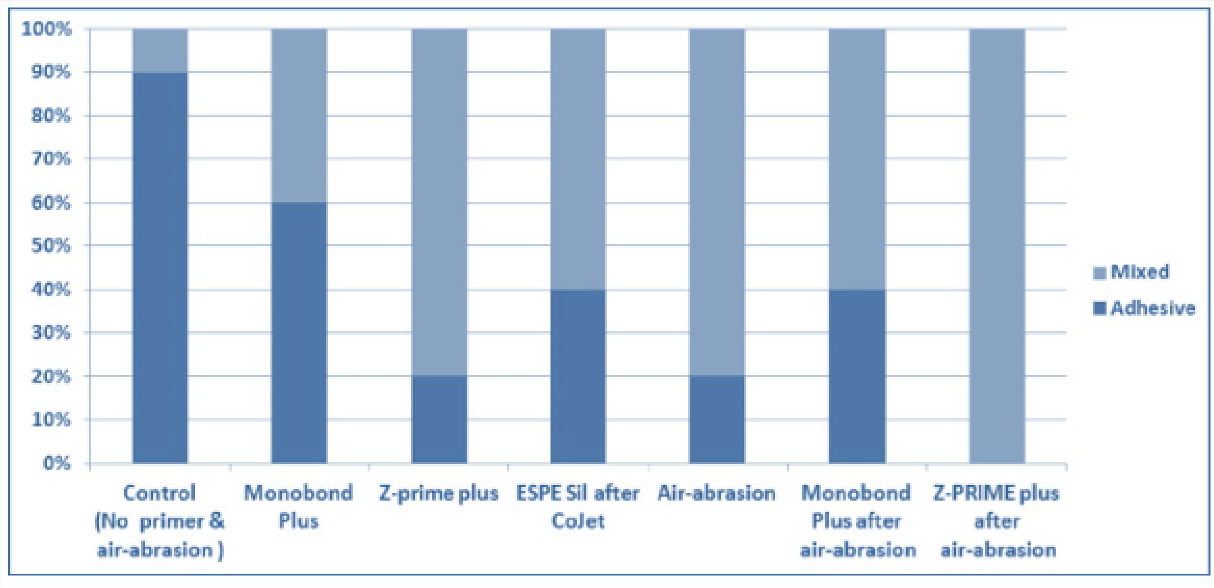


**Figure 3:** Bond Strength Between Y-TZP Ceramic and Resin Cement.

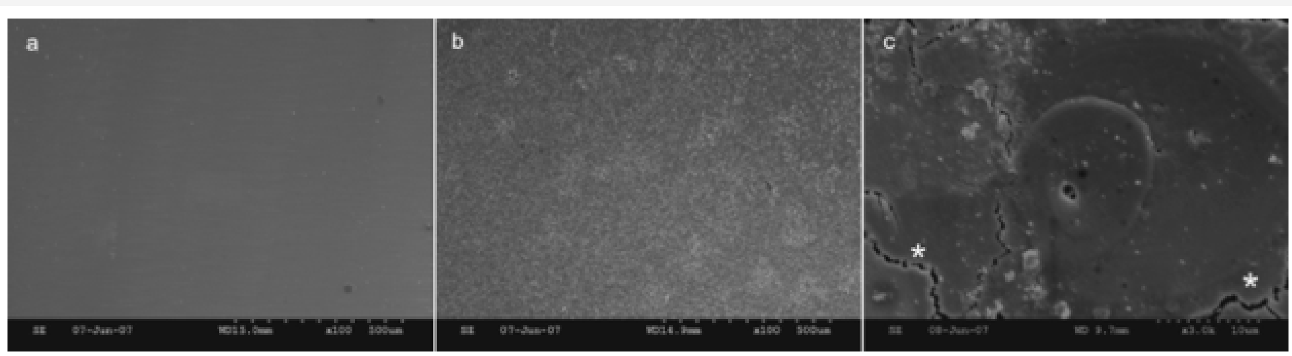


**Figure 4:**a) Y-TZP surface untreated.
b) Y-TZP surface treated air abrasion with 53 μm Al2O3 particles.
c) Y-TZP surface irradiated with the Er: YAG laser.

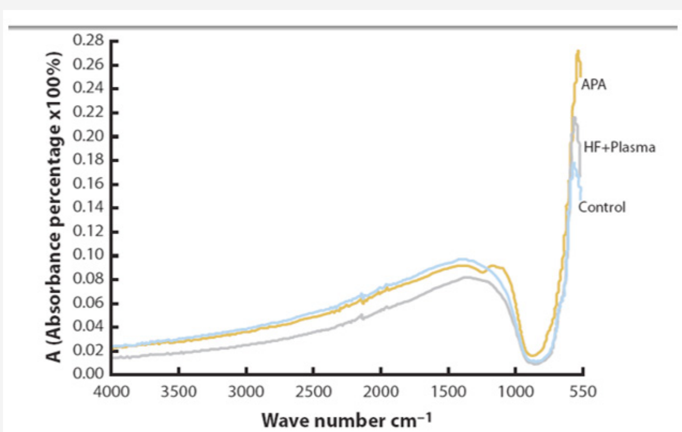


**Figure 5:** Fourier transform infrared spectrometer analysis. Similar absorbance peaks for zirconia surface after sandblasting and after hydrofluoric plus plasma application. APA, airborne particle abrasion; HF, 10% hydrofluoric acid.

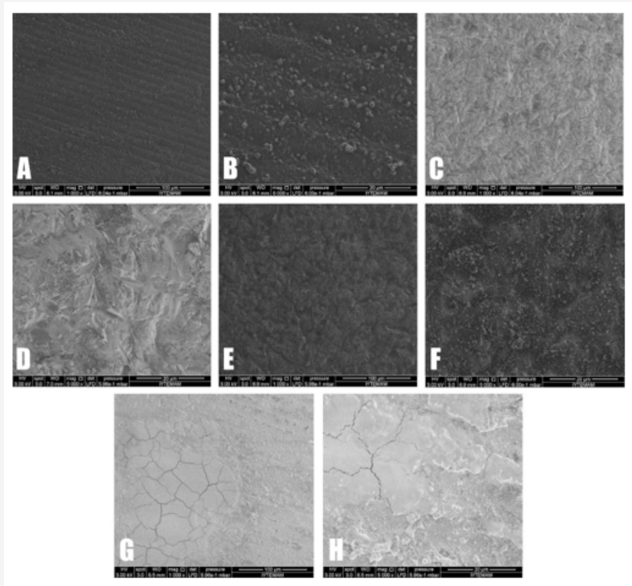

**Figure 6:** (A and B) no surface treatment.
(C and D): Airborne particle abraded.
(E and F): Tribochemical silica coated.
(G and H): Laser applied.

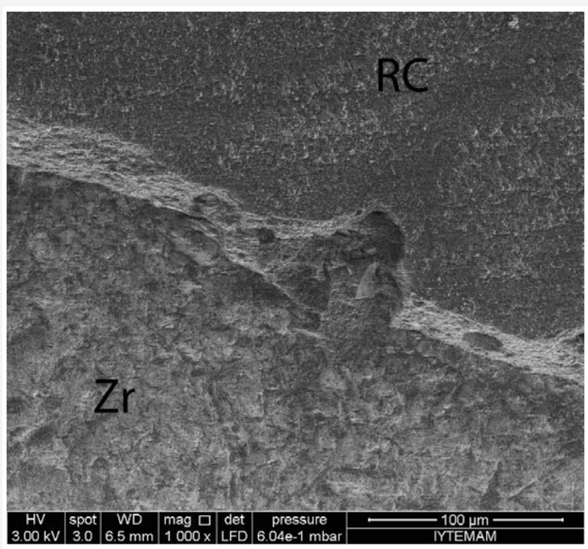


**Figure 7:** SEM photograph. (10003 original magnification) of APA treated/Rely X U100 adhesive cement failed surface (RC, resin cement; Zr, zirconia).

According to the analysis of the selected papers it could be seen that the use of $Al_2O_3$ air-abrasion followed by application of phosphate monomers-based primers or resin cement tends to produce more reliable results. Several surface treatment methods have been proposed to overcome intrinsic acid resistance of $ZrO_2$; however, these methods have presented controversial results about their effectiveness on bond strength improvement. Nonetheless it seems important to select multifunctional methods, which mix the ability to create a rough surface for micromechanical interlocking and increase the surface area to establish chemical bond with reactive substances.

Yang et al. [9], agreed and stated that a reliable bond strength after air-abrasion at 2.5 bars or the combination of low-pressure air-abrasion and priming with MDP-containing primers. Proper restoration of endodontically treated teeth begins with a good understanding of their physical and biomechanical properties, restorative and occlusal principles. Although many new restorative materials have become available over the past several years, some basic concepts in restoring endodontically treated teeth remain the same. One of the main concerns in this systematic review is the Bonding in Endodontically Treated Teeth and how affect in bond strength to zirconia restoration. Reduced bond strength after endodontic treatment demonstrated clinically by debonding of zirconia restoration and showed to increase the bond strength and this may be due to reverse the oxidative effect on dentin this is agreed with Başaran G et al. [31], Laikuan Z et al. [32], Khoroushi M [34]. Who stated that the antioxidant ability of sodium ascorbate helps neutralize and reverse the oxidizing effects of the NaOCl. And Nihan Gonulol ay, et al. [35] who stated that 10% sodium ascorbate for one minute restores the original bond strengths allows free-radical polymerization of the adhesive to proceed without premature termination, reversing the compromised bond strength could be very effective in modifying dentin surface and hence affecting its bond strength to other materials Therefore they could also increase the resistance of dentin to biodegradation and hence stabilize the resin adhesive-dentin interface by attacking any residual bacteria or inhibiting the degradation of the hybrid layer.

## Conclusion

Within the limitation of this systematic review it can be concluded that: Sodium ascorbate may restore strengths allow free adhesive to precede, reversing the change in dentin surface and consequently increase bond strength. The changed dentin will resist bacterial biodegradation.

## Acknowledgement

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## Conflict of Interest

No conflict of interest.

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