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Review article

POSSIBILITIES OF IMPROVING THE SHEAR STRENGTH BETWEEN DIFFERENT TYPE OF CEMENT AND ZIRCONIA CERAMICS: LITERATURE REVIEW

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ABSTRACT

Background: Zirconia ceramics are a modern dental material which has a wide range of application in restoration of frontal and distal teeth. This is due to its improved mechanical properties and aesthetics.

Aim: This literature review analyses the possibilities for improvement of the bond strength between zirconia ceramics and different types of cement which are used for fixation of prosthetic constructions.

Review Results: The evidence from the literature indicates that preliminary treatment of zirconia ceramics increases the bond strength significantly to the cement. In this respect, different methods and materials are used for the treatment of the zirconium dioxide surface. Some of them include only mechanical treatment with diamond burs, a different type of lasers and sandblasting with aluminum oxide. Other methods have chemical action by the use of hydrofluoric acid and fluoride compounds. According to some data, zirconium structure does not allow etching which leads to application of different type of primers for increasing the shear strength. Studies show that silane application significantly improves the shear bond strength to the cement, as well as, zirconium tensile strength. Optimal results are registered with a combination of treatment with mechanical methods and silane application.

Conclusion: Preliminary mechanical and chemical treatment of zirconia surface improves the shear bond strength considerably to the cement. The variety of surface treatment methods complicates the establishment of a standard protocol for fixation of zirconium prosthetic constructions.

Keywords: zirconia ceramics, cement for zirconium dioxide ceramics.

BACKGROUND

Modern concept for aesthetic prosthetic treatment motivates the wide application of ceramic materials in dentistry [1]. Their main advantages refer to the enhanced ability to reach a high level of aesthetic and good biological tolerance [2]. They are commonly used to the fabrication of crowns, bridges and indirect restorations- inlays, onlays, overlays [3]. Their manufacturing through modern laboratory technologies allows the achievement of optimal occlusal and approximal contacts in the restoration of frontal and distal teeth [3]. The main disadvantages of ceramic materials are related to their mechanical properties and resistance [4]. This led to the development of new zirconia ceramics which have high flexural strength and fracture resistance [5]. The basis for these improved mechanical properties is yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) which are applied in different percentage ratios [6]. Research findings indicate the stability of the crystal structure and high flexure strength, which can reach 2000 Mpa [7]. This provides significantly higher durability of the prosthetic constructions, compared to lithium disilicate ceramic and high-strength glass-ceramic, infiltrated with leucite [8]. The main difference is found with respect to the flexural strength, which is considerably higher in comparison to other ceramics [9]. Zirconia materials (IPS e.max ZirCAD) have 60-70% higher fatigue resistance compared to lithium disilicate (IPS e.max Press) [10]. Studies show that increased mechanical properties of zirconium dioxide do not cause an abrasive effect on antagonists [11].

The main problems in the application of zirconium materials are related to its transparency and providing of a strong bond to the cement [6]. The assurance of reliable bond strength has a key role in treatment efficacy, as it requires the development of different techniques and methods for preparation and fixation of the prosthetic constructions [12].

AIM

This literature review analyses the possibilities for improvement of the bond strength between zirconia ceramics and different types of cement which are used for fixation of prosthetic constructions.

REVIEW RESULTS

Studies show that treatment of the ceramic surface significantly increases the bond strength to the cement [13]. In this context, Comba A. et al. [14] conduct surface treatment with diamond burs and demonstrate that it provides better bond in comparison to Er: YAG lasers treatment. Studies by Gamal AE et al. [15] show that laser surface treatment of lithium disilicate (Emax CAD) and zirconium ceramics (Emax ZirCAD) increases the shear bond strength. Data reveal that the application of Er, Cr-YSGG lasers in low power of 2,0 W, increases shear bond strength near to the value when the silicon dioxide bond is applied [16]. According to another study, treatment with CO_2 laser increases microhardness of lithium disilicate (Emax CAD) with 6.32 GPa, whereas the application of Nd-YAG laser in zirconia materials reduces microhardness with 1.46 GPa [17].

CHEMICAL TREATMENT OF THE CERAMIC SURFACE

Additional chemical treatment is required in order to provide stable adhesion between ceramic materials and cement. Acid-sensitive ceramics, such as feldspath ceramic, leucite and lithium disilicate ceramic allow etching which provides micromechanical retentive surface (table 1).

Table 1: Some types of ceramics used in dentistry

- Feldspath ceramic (Vita Cerec, Dicor)
- Leucite ceramic (leucite-reinforced pressed ceramic)
- Lithium disilicate ceramic (IPS e-max Press, IPS e-max CAD)
- Stabilized zirconia ceramics – Y-TZP (Yttrium tetragonal zirconia polycristal, 2%-3% of mol yttria Y_2O_3) IPS e-max ZirCAD

Structural analysis of etching surface shows differences depending on concentration, time of application and the type of the etching agent – hydrofluoric acid (HF), ammonium bifluoride (ABF), acid phosphate fluoride (APF) [18]. Studies show the efficiency of hydrofluoric etching in lithium disilicate ceramic when combined with silane for optimal shear bond strength [19]. This technique is defined as an optimum protocol, and research findings show stable adhesion even after thermocycling [20]. Etching with hydrofluoric acid, as well as, silane application of leucite-reinforced ceramic increase the adhesion to the glass-ionomer types of cement as well [21]. Nevertheless, studies find that etching the zirconium ceramic with 9,6% hydrofluorid acid (HF) does not provide effective adhesion [18, 22]. Similar data are accessed by Özcan M et Vallittu PK [23] when treating zirconia-reinforced alumina ceramics (In-Ceram Zirconia). They explain the development with low quantity of glass phase. The scholars measure 8.1 MPa shear bond strength in etching with HF, 16.5 MPa in sandblasting with alumina oxide and 17.4 MPa in Rocatec system treatment. Studies by Ruyter EI et al. [24] show that better adhesion to the zirconia can be achieved through etching with fluoride compounds (Ammonium hydrogen difluoride, potassium hydrogen difluoride) and silane application. According to others [25], zirconium structure cannot be etched, which requires the use of primers for better shear bond strength. Nakayama D et al. [26] examine the primer effect on the bond strength to the yttria-stabilized zirconia (Katana, Noritake Dental Supply). Zirconia disks are treated with primers Acryl Bond (Shofu), All Bond II Primer B (Bisco), Alloy Primer (Kuraray), Estenia Opaque Primer (Kuraray), Eye Sight Opaque Primer (Kanebo), M.L. Primer (Shofu), MR. Primer (Tokuyama Dental) and Super-Bond liquid (Sun Medical) with Tri-n-butylborane (TBB). The measured shear bond strength varies from 0.7 MPa to 30.8 MPa before and from 0.3 MPa to 17.6 MPA after thermocycling. The highest value is observed in the case of Alloy Primer and Estenia Opaque Primer, which can be explained with the presence of 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) in their composition. The research findings by Torabi Ardakani M. et al. [27] have similar results. They prove that zirconia primer, which is based on organophosphate/carboxylic acid monomers, increases shear bond strength. The opinion of Murakami T. et al. [28] is the opposite. They apply zirconia primer, which contains Tetra-n-propyl zirconate, and report higher shear bond strength in comparison to the MDP ceramic bond.

The aim for improving primers' efficiency is the reason for the inclusion of bisphenol A-glycidyl methacrylate (BisGMA) in their composition. Studies show that it does not affect phosphate-based zirconia primers; however, it reduces the efficiency of silicone primers [29]. Wang C et al. [30] consider that even application of zirconia primer followed by drying with pressured air of 0.2 MPa enhances bond stability. Others recommend preliminary cleaning of zirconia surface with chemical agent and bond application which increase shear bond strength during the initial 24 hours [31].

Kim SM et al. [32] conduct a comparative study of shear bond stability between zirconia and resin types of cement with and without primer application. The cement varieties Panavia F2.0 (P), Panavia F2.0 with primer PRIME Plus (Bisco Inc) (PZ), Superbond (S) and Superbond C&B with SZ primer are included in the research. The measured values from 265,15 ± 35,04 N (P), 318,21 ± 22,24 N (PZ), 445,13 ± 78,54 N (S) and 508,21 ± 79,48 N (SZ) show significant higher bond strength in Superbond when compared to Panavia F2.0.

SURFACE TREATMENT WITH ALUMINUM OXIDE

Other methods of zirconia ceramics surface treatment include aluminum oxide sandblasting for better micromechanical retention. However, studies by Dérand P et Dérand T. [22] show that this has a very weak effect on bond strength. Tostes BO et al. [33] do not support this opinion. They treat yttria-stabilized ceramics (Y-TZP) with air abrasion with different size of Al_2O_3 particles and conclude that air abrasion leads to phase transformation, increases roughness and transforms Y-TZP elementary compound irrespectively of particles' type or size. Nevertheless, comparative research demonstrates optimal results in the application of Al_2O_3 with particles of 50 ìm which provides 50.5 MPa shear bond strength in comparison to 33.1 MPa when zirconia primer is applied [34]. Studies by Chen L [35] show that sandblasting with aluminum oxide increases the bond strength, the silane application does not affect it, whereas the use of organophosphate/ carboxylic based primer (Exp Z-Prime) doubles the strength. Inokoshi M et al. [36] demonstrate that preliminary treatment with silicon dioxide of system CoJet (3M ESPE) together with the application of resin types of cement containing 10-Methacryloyloxydecyl dihydrogen phosphate deliver permanent bond between zirconia and the cement (table2).

Table 2: Suggested treatment of internal ceramic surface

Ceramic surface treatment	Cleaning of the ceramic surface - application for
• Roughened with diamond bur	20 seconds, washing and drying
• Acid etching (9.6% hydrofluorid acid)	• IvoClean
• Sandblasting with Al_2O_3 (50 µm)	• ZirClean
• Laser treatment (Er, Cr-YSGG, CO_2, Nd-YAG)	• Ultrasound

SILANE TREATMENT OF THE CERAMIC SURFACE

Most authors [37, 38, 39] consider that silane application significantly increases the bond between the ceramic surface and resin composite cement through the creation of the stable chemical connection. The application of silane (SC—Cojet, 3M-Espe) increases the shear bond strength to the cement and tensile strength in zirconia-reinforced glass-ceramics (IZ-Vita In-Ceram Zirconia) [38]. Chai J et al. [39] investigate the surface treatment effect when tribochimic silicon coat (silane compound) is applied. They study shear bond strength in 12 models of zirconia (YZ Zirconia) and zirconia glass-ceramic (In-Ceram Zirconia) which is divided into three groups – without surface treatment (control group), silane system CoJet and laboratory system Rocatac for tribochimic silane coating. Findings show shear bond strength values for In-Ceram Zirconia (control group) of 5,7 ± 4,3 MPa, CoJet -11,4 ± 5,4 MPa and Rocatec - 6,5 ± 4,8 MPa. Respectively, the measured values in the case of the YZ zirconia are 8,2 ± 5,4 MPa, 9,8 ± 5,4 MPa and 7,8 ± 4,7 MPa. Researchers suggest that silane coating can significantly improve the bond strength between resin composite cement and In-Ceram Zirconia (table 3).

Table 3: Silane treatment of the ceramic surface

• **Silane coupling** - 10Methacryloyloxydecyl dihydrogen phosphate (MDP), Z-Prime, Monobond Plus
• **Tribochemical coating** – CoJet (with SiO_2)

According to Siwen L et al. [40], aluminum oxide sandblasting followed by silicon oxide coating is the most effective technique for increasing the bond strength between zirconia ceramic and the dentin. Lung CY et al. [41] consider that modern silane products are far from being a perfect solution; however, they can fulfill the minimum requirements for improving bond strength to the zirconia. Researchers conclude that further studies and development of new methods are necessary in order to overcome the problem with adhesion durability.

There are different studies assessing the surface treatment effect on the bond strength. Shin YJ et al. [42] investigate shear bond strength of Y-TZP (Yttria-Tetragonal Zirconia Polycrystal ceramic and resin composite types of cement with 10-Methacryloyloxydecyl dihydrogen phosphate (MDP). Zirconia blocks (LAVA, 3M ESPE, St. Paul, MN) are distributed in five groups depending on the conducted surface treatment: (1) without any additional surface treatment (control group); (2) sandblasting with Al_2O_3 particles; (3) conditioning with primer Z-PRIME Plus (Bisco, Schaumburg, IL), applied on polished zirconia; (4) primer Z-PRIME Plus after sandblasting and (5) tribochimic coating with silicon dioxide on the CoJet system (3M ESPE). Two composite types of cement are used per each group - Panavia F2.0 (Kuraray, Kurashiki, Okayama, Japan) and Clearfil SA Luting (Kuraray). Findings indicate that primers significantly increase bond strength in relation to both types of cement when the former is applied after abrasion. The control group has the lowest value of shear bond strength.

Keshvad A and Hakimaneh SMR [43] study the effects of different surface treatment on the shear bond strength between composite cement with lithium and zirconia ceramics. The zirconia samples (IPS e.max ZirCAD) are sandblasted + silane (ZiSa); sandblasted + laser + silane (ZiSaLa); laser + silane (ZiLa). The lithium disilicate ceramics (IPS e.max CAD) are: sandblasted + HF + silane (LiSaE); sandblasted + silane (LiSa); sandblasted + laser + silane (LiSaLa). The study reports no significantly significant difference between LiSaE and LiSa test groups (p> 0,05); however, there are statistically significant differences between ZiSaLa and ZiSa groups (p> 0,05). Laser treated test groups have lower values of shear bond strength in comparison to the other ones.

Sakrana AA and Özcan M. [44] study the adhesion of self-adhesive cement (RelyX Unicem Aplicap, 3M ESPE) to the zirconia (IPS e.max ZirCAD, Ivoclar Vivadent) after different surface treatment methods: C: without surface treatment (control group); AS: air abrasion (50 µm Al_2O_3) in low pressure (0.2MPa) and silane application (Monobond Plus, Ivoclar Vivadent); MC: methylene chloride treatment for 60 seconds; CE: solution for chemical treatment for 60 seconds in 100° C. The highest surface abrasion is achieved in group CE (0,52 µm) and the lowest one in group C (0,25 µm). The weakest bond strength is registered in group C (5.11 ± 0.5MPa) in comparison to the rest test groups where the values vary from 34.6 ± 1.5 to 51.2 ± 1.1 Mpa. The highest shear bond strength is registered in group CE - 51,2 ± 1,1 MPa. The authors view chemical etching as a successful substitute for air abrasion.

Bielen V et al. [45] analyze the efficiency of adhesion to the zirconia with different surface treatment. IPS e.max ZirCAD (Ivoclar Vivadent) ceramics are divided into four groups: (1) samples without surface treatment; (2) sandblasted with 50 µm Al_2O_3, (3) tribochimic sandblasting with silicon dioxide (CoJet-3M ESPE) and (4) silicon dioxide treatment SilJet (Danville). After processing, the blocks are treated with 10-MDP/silane ceramic primer (Clearfil Ceramic Primer, Kuraray Noritake) and fixed to each other with resin composite cement (RelyX Ultimate, 3M ESPE). Then, the shear bond strength test is performed. The accessed results show the highest bond strength, where silicon dioxide (CoJet, SilJet) sandblasting method is applied.

Baldissara P et al. [46] conduct a similar study and investigate shear bond strength (SBS) between two types of cement (Panavia F è RelyX Unicem) and two Y-TZP ceramics (Lava and ZirCAD) subjected to different surface treatment: without surface treatment (control group); silicon dioxide sandblasting (30 µm, CoJet Sand) or coating with liners Lava Ceram for Lava and Intensive ZirLiner for IPS e.max ZirCAD. Findings show the most stable bond strength when CoJet Sand and liners are applied.

Stefani A et al. [47] measure the shear bond strength of different types of resin composite cement (RelyX ARC, Multilink Automix, Clearfil SA) to zirconia ceramics by applying two primers (Metal-Zirconia Primer, Alloy Primer). The study is conducted based on 50 zirconia blocks (ZirCad) with the size of 12 mm × 5 mm × 1,5 mm thickness which is sandblasted with aluminum dioxide particles and cleaned by ultrasound. The primers and types of cement are applied in accordance with the manufacturer's instructions. Conventional resin composite cement RelyX ARC without primer is used as a control group. Finding show shear bond strength equal to 28.1 MPa in RelyX ARC; Multilink Automix - 37.6 MPa; Multilink Automix + Metal-Zirconia Primer - 55.7 MPa; Clearfil SA - 46.2 MPa and Clearfil SA cement + primer - 47.0 MPa.

The development of new zirconia-based materials requires the application of advanced types of cement [48, 49, 50]. Passia N et al. [51] conduct laboratory experiments in order to assess tensile strength of three new generations of universal adhesion systems to the zirconia ceramics (Max ZirCAD) - Monobond Plus/Multilink Automix, NX3, Scotchbond Universal/RelyX Ultimate. Findings show an average bond strength of 21.7-28.8 MPa in RelyX Ultimate, with and without Scotchbond Universal and substantially lower values from 15.4 MPa in Monobond Plus/Multilink Automix. The weakest strength value is reported in NX3 - 6.6MPa.

Salem RST [52] studies the shear bond strength (SBS) between the cement and zirconia before and after thermocycling. Sandblasted discs of monolithic zirconia (10 × 3 mm) are used as samples. The specimens are divided into three groups according to the applied adhesive system: Z-PRIME Plus/ DUO-LINK (Bisco); Clearfil Ceramic Primer Plus/PANAVIA SA (Kuraray); Universal bond/RelyX Ultimate (Single Bond) (3M ESPE). The highest and lowest values are measured in the systems Kuraray (12.52 ± 1.34 MPa) and Bisco (5.32 ± 0.54 MPa) in thermocycler groups (P <.05). Kuraray has the highest (16.47 ± 1.5 MPa) and Bisco the lowest (7.43 ± 1.06 MPa) SBS values in the short-term storage groups (P <.05). The author concludes that thermocycling reduces SBS significantly with respect to all test groups and recommends the use of resin composite types of cement with Methacryloyloxydecyl dihydrogen phosphate for permanent adhesion to the zirconia.

DISCUSSION

There are numerous studies from the available literature focused on examining the bond strength between zirconia ceramics and different type of cement. The conclusion that preliminary zirconia surface treatment increases the strength and durability of fixation is unanimous. Different methods and means are used for this purpose. Some authors recommend only mechanical treatment with diamond burs, a different type of lasers and aluminum dioxide sandblasting. The data about these methods' efficiency are controversial, as the most serious variations exist regarding the type and power of lasers. Most authors suggest that sandblasting with aluminum dioxide is an optimal method for mechanical treatment of the zirconia surface and good micromechanical retention. Comparative studies show the achievement of best results when 50 ìm Al_2O_3 particles are used [33, 44, 45].

Other methods for creation of stable adhesion between zirconia ceramic and cement are chemical agents for surface treatment, such as hydrofluoric acid of fluoride compounds. Data determine this as an ineffective treatment method, which is explained by the specifics of zirconia structure. This requires coating with primers for increasing the adhesion to the cement. Some authors recommend primers with 10-Methacryloyloxydecyl dihydrogen phosphate (MDP), while others suggest tetra-n-propoxyl zirconate (TPZr).

Research findings show that the combination of mechanical treatment methods followed by the application of bonding agent significantly increase the bond strength to the cement. According to some data, sandblasting with aluminum dioxide followed by silicon dioxide coating is the most effective technique for increasing the bond strength between zirconia ceramics and the cement. Others claim that the strongest adhesion is created after sandblasting with silicon dioxide (CoJet, SilJet) and silane coating. Irrespectively of the controversial information, the consensus opinion shows that the combined technique of mechanical treatment and silane application increase the bond strength.

There are numerous studies regarding the application of different cement in fixed prosthetic treatment. The dominant opinion suggests that silane coating provides a stable chemical connection between the ceramic surface and composite cement; thereby, increasing the bond strength [37, 38, 39]. Research findings show that preliminary treatment with silicon dioxide with CoJet (3M ESPE) system combined with resin composite cement with 10-Methacryloyloxydecyl dihydrogen phosphate provide permanent adhesion of zirconia to the cement. Due to the diversity of cement there are various, often conflicting data on their efficiency and durability.

CONCLUSION

The analysis of the literature review demonstrates that there are no universal methods, techniques or materials for fixing zirconia constructions. Findings unequivocally show that preliminary mechanical and chemical treatment of zirconia surface significantly improves the shear bond strength. There are diverse and often conflicting opinions regarding the choice of the optimum treatment method for zirconia surface preparation. The variety of cement further complicates the selection and creation of a standard clinical protocol for working with this type of ceramic.

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