ISSN: 2581 – 3633
PubMed - National Library of Medicine - ID: 101745081

International Journal of Medical Science and Advanced Clinical Research (IJMACR)

Available Online at: www.ijmacr.com

Volume – 5, Issue – 2, March - April - 2022, Page No. : 193 – 201

Comparing the different surface treatment of zirconia on the bond strength to resin cements- A Narrative Review

[1]Kamran Azad Bakht, Assistant Professor of Prosthodontic, Department of Prosthetics, School of Dentistry, Lorestan University of Medical Science, Khorramabad, Iran.

[2]Hamid Badrian, Assistant Professor of Operative Dentistry, Department of Operative Dentistry, School of Dentistry, Lorestan University of Medical Science, Khoramabad, Iran.

Corresponding Author: Hamid Badrian, Assistant Professor of Operative Dentistry, Department of Operative Dentistry, School of Dentistry, Lorestan University of Medical Science, Khoramabad, Iran.

How to citation this article: Kamran Azad Bakht, Hamid Badrian, "Comparing the different surface treatment of zirconia on the bond strength to resin cements- A Narrative Review", IJMACR- March - April - 2022, Vol – 5, Issue - 2, P. No. 193 – 201.

Type of Publication: Review Article

Conflicts of Interest: Nil

Background and Aim: A clinical problem in the use of zirconia structures is the achievement of strong bonds with different substrates. The aim of this study was to investigate different surface treatment methods of zirconia on bond strength to resin cements.

Materials and Methods: To conduct this study, all studies related to the subject under discussion, during the years 1973-2022, with a systematic search in internationally available databases including Web of Science, Science Direct, Scopus, PubMed and Google Scholar, evaluated. Finally, considered studies were selected to investigate the main objective.

Results: The results showed that the sandblasting method produces a higher shear bond strength (SBS) between zirconia and porcelain compared to laser application. In addition, glass coating on the surface of zirconia in the short term is as effective as sandblasting method in increasing the bond strength of resin cement, while colloidal silica coating reduces the bond strength of resin cement to zirconia.

Conclusion: Based on the results, it can be concluded that sandblasting, acid etching, radiation with different lasers, air abrasion with Al2O3 particles are the most widely used surface treatment methods to increase the bond strength of zirconia to resin cements, among which: Sandblasting provides the highest strength.

Keywords: Dentistry, Surface Treatment, Zirconia, Bond Strength, Resin Cements

Introduction

In the field of dentistry, the use of metal-free restorations is increasing day by day [1]. The use of different types of ceramics has significantly expanded in terms of various factors, including providing the desired beauty, light transmission, tissue compatibility, acid and plaque resistance, neutral nature, no corrosion, no display of dark edges of margins and lack of temperature sensitivity [2 and 3]. In addition, a lot of effort has been

made to make the ceramics used match the natural teeth in terms of color, surface texture and translucency [4].

Despite their resistance to pressure, ceramics are inherently brittle and weak against tensile and rotational stresses [5]. Of course, this problem can be solved by providing support from an infrastructure material such as metal, ceramic, etc. [6]. By adding 50% by weight of zirconia to porcelain glass, the flexural strength and fracture toughness increase by 20-80% compared to porcelain alone. In this regard, among all ceramic materials, the use of zirconia and lithium di-silicate is very common due to their mechanical properties [7].

In recent years, the use of zirconia in dentistry has increased and zirconia polycrystals have reduced the limitations of the use of all-ceramic materials [8]. Unique chemical stability, excellent mechanical properties, color beauty and simultaneous use of CAD / CAM technology in them have led to the use of zirconia as a core material of choice in various prosthetic treatments [9].

Also, zirconia bridges have shown more durability compared to other dental ceramics [10]. Zirconia in the form of Y-TZP or tetragonal polycrystalline zirconia stabilized by Yttrium oxide has a higher attractiveness compared to other ceramics due to the highest flexural strength (900-1000 MPa) and the highest fracture toughness (9-10 MPa) and It is more beautiful compared to other ceramics [11 and 12]. One of the disadvantages of zirconia-based restorations is that they are opaque. Although zirconia frames are more beautiful than metal ones, they are very white and opaque, so they should be covered with a translucent ceramic veneer to achieve a beautiful appearance [13].

Previous studies have shown that despite the high strength of zirconia, the bond between the core and porcelain is weak [14]. This defect makes the restoration of ceramic veneer prone [15]. The effective bond between Y-TZP ceramics to porcelain veneers is a necessity for the long-term performance of ceramic restorations and for achieving the numerous benefits of core materials in dentures so that they can transfer functional stresses from cosmetic veneers to sub-frames [16, 17]. A weak porcelain veneer severely affects the success and durability of an infrastructure and may lead to its failure in the clinic [18].

In order to improve the bond strength between zirconia and ceramic veneer or cement, various surface operations such as acid etching [16], air abrasion [24-19], liner application [19, 21, 24 and 25], polishing [19 and 26], Wear [20], silica coating [19] and laser etching [24] have been performed on ceramic infrastructures. The purpose of zirconia surface treatment is to increase surface roughness, increase surface energy, increase wetting ability and thus improve adhesion between two surfaces [25]. Acid etching technique is not suitable due to the absence of glass phase in high strength ceramics such as zirconia [26]. Another widely used technique is air abrasion of the zirconia surface by aluminum oxide particles. Some studies show that air abrasion with different particle sizes of aluminum oxide increases the bonding surface and also removes the surface contaminant layers [27, 28].

Recently, due to advances in laser techniques, some studies have suggested its use to increase the bond strength of Y-TZP zirconia to tooth structure [29]. Simultaneously, Erbium-doped Yttrium Aluminum Garnet (Er: YAG) [30, 31], Neodymium-Doped Yttrium Aluminum Garnet (Nd: YAG) [33, 34] and CO_2 lasers were used to prepare the surface. Ceramics have been used and different results have been reported in this field

[36]. In view of the above, the purpose of this study is to compare different methods of surface treatment of zirconia on its bond strength with resin cements in the form of a narrative review study.

Material &Methods

To conduct this study, a systematic search of internationally available databases including Web of Science, Science Direct, Scopus, PubMed, and Google Scholar was performed between 1973 and 2022. Systematic review using Mesh terms "Dental", "Tooth", "Resin cements", "Zirconia", "Surface Treatment", "Laser Treatment", "Bond Strength", "Composite Resin", "Air Abrasion" and "Shear Strength", "Zirconium Oxide", "Fiber Post", "Quartz Fiber", "Glass Fiber" and "Fracture Resistances", "Posts Colored", "Ceramic Core", "Ceramic Post" and other similar keywords Done. For other databases, the same Mesh terms were used similarly. To ensure the completeness of the search, the references of the found studies were evaluated (Reference Checking) to minimize the possibility of not entering the studies. Citation tracing was also reviewed. In addition, unofficial reports, articles in letter to editor format, as well as unpublished articles and content posted on Internet sites were removed from the list of downloaded files. Finally, the results of the published articles were reviewed for the present review.

Results

Study Kamran et al. (2017) evaluated the effect of two types of surface operations including sandblasting and application of Er-YAG on shear bond strength (SBS) between zirconia and porcelain veneer. The results of this study showed that there is a significant difference between the mean SBS by the studied methods. SBS in zirconia surface sandblasting method was significantly higher than laser application method [37].

Results of electron microscope observations in the study of Calvacanti et al. (2009) showed that sandblasting is a very effective method in causing surface changes in the surface of Y-TZP zirconia in comparison with the laser method with the parameters used in their study [38].

Kara et al. (2011) investigated different methods of sandblasting, acid etching with laser and laser irradiation in surface roughness and bond strength of low fusing ceramics and reported that the SBS of the samples was affected by the type of preparation and sandblasting bond strength had more strength than other groups. On the other bond, the surface roughness of the sandblast group was higher than the other two groups, which may be the reason for the stronger bond in this group [39].

Elsaka et al. (2013) evaluated the effects of surface preparations on the surface properties of different types of zirconia and the adhesion of zirconia to porcelain veneers. The results of this study showed that surface preparation of zirconia by sandblasting method does not significantly improve the adhesion between zirconia and veneer [40].

Findings from the study of Kirmali et al. (2013) showed that the amount of bond strength increased in sandblast group and Er-YAG laser group, but the difference between Er-YAG laser group and control group as well as sandblast group and control group was not statistically significant [30].

Study Akyil et al. (2010) showed that zirconia samples exposed to Nd-YAG laser had lower SBS generated by the this laser compared to sandblast and Er-YAG laser, while the highest bond strength was obtained by Er-YAG laser [41].

Akin et al. (2011) evaluated the effect of air abrasion methods with Al_2O_3 particles and different lasers on SBS between resin and zirconia. The results of this study showed that Nd-YAG laser and Er-YAG laser radiation in contact type had a significantly higher amount of SBS than other groups [42].

Study Matani et al. (2014) To investigate the effect of experimental coating on improving the bond strength between zirconia and ceramic veneers. The results of this study showed that the experimental coating group showed the highest amount of SBS and surface roughness and the lowest amount of monoclinic phase compared to the air abrasion group and the Er. YAG laser group. Also, based on the results, air abrasion improves SBS only marginally [36].

In addition, the results of the study by Matani et al. (2014) showed that all groups showed statistically higher SBS values compared to the control group. The Er-YAG laser group also showed higher SBS and higher surface roughness than the control group and abrasion group, while this difference was not statistically significant [36].

Study Yilmaz-Savas et al. (2016) which was performed on SBS to evaluate different surface treatments, the results showed that the sandblast group, control group and Er-YAG laser group had the highest SBS, respectively. But statistically there was not significant difference between the control group and treated groups [43].

The study of Moezzyzadeh et al. (2013) was performed to investigate the effect of different coating methods on the bond strength of resin to zirconia. The results of this study showed that the average bond strength with silica coating was significantly lower than sandblast. In contrast, there was no significant difference between the average bond strength with different glass and sandblast coatings. In other words, there was no difference between sandblasting and different types of glass coating in terms of bond strength. In addition, the thickness of the coating layer in the slurry group was significantly less than the other groups [44].

In the study of Valentino et al. (2012) which used glaze layer (Cercon Ceram Liner, Degu dent) as a coating, after etching and application of selenium, no significant increase in bond strength values was observed. In addition, the results of the study showed that the use of glaze layer has a higher bond strength than the sandblast group (with 50µ alumina particles) [45].

Cura et al. (2012) reported that zirconia surface etching acid increased the SBS of resin cement after applying glaze layer and using silane, but in cases where primer containing MDP was used instead of silane, etched glaze layer was not effective in increasing bond strength [46].

In the study of Usumez et al. (2013) reported that MDP-containing primers in the glaze and etched groups were not as effective as the sandblast group [47]. In the study of Kitayama et al. (2009) reported that the application of sealant on the coated porcelain layer (Cercon Ceram Kiss, Degu dent) significantly increased the bond strength of the resin cement [48].

In the study by Kabiri et al. (2021), the effect of three different surface treatments including sandblasting, tribochemical preparation and laser application on the SBS of zirconia ceramic to composite resin was investigated. The results of this study showed that SBS generated by sandblasting and tribochemical preparation is significantly different from the method of laser irradiation. In addition, the results showed that the SBS produced by sandblasting and tribochemical preparation methods were not significantly different [49].

In the study of Mirzaei et al. (2008) evaluated six types of surface treatments to increase bond strength in three types of prefabricated posts including Match post, Glassix and Cosmo post with resin cement. Surface preparation methods (sand blasting using Cojet and alumina particles with and without silane) significantly improved the bond strength of resin cement to fiberglass (Glassix) and ceramic (Cosmo post) posts. In Match post posts, none of the surface preparation methods were effective. In addition, the results showed that higher bond strength causes a higher percentage of cohesive failure inside the cement [50].

Discussion

Effective bonding between zirconia and porcelain is a prerequisite for reliable durability and a necessity for the long-term performance of zirconia restorations [18, 37]. Clinical failure of zirconia FPDs often occurs due to fracture or chipping of ceramic veneers. This problem should be solved by getting more adhesion between zirconia core and porcelain veneer [42]. To eliminate these fractures, researchers have performed various surface treatments on zirconia to improve the bond strength of porcelain veneer with zirconia [15]. Study Kamran et al. (2017), which was an experimental laboratory study, evaluated the effect of two types of surface preparation including sandblasting and application of Er-YAG on SBS between zirconia and porcelain veneer [37]. Sandblasting is one of the methods that is often used to create superficial roughness [16]. The positive effect of sandblasting method on increasing SBS porcelain to zirconia, in the study of Kamran et al. (2017) [37] was confirmed and the findings of the study showed that the sandblasting method by Al2O3 particles had the highest SBS with zirconia Y-TZP compared to other methods; This fact in the studies of Cal Vacanti et al. (2009) [38] and Kara et al. (2011) [39] proved. While the findings of the study Elsaka et al. (2013) showed that surface treatment of zirconia with sandblasting method does not significantly improve the adhesion between zirconia and veneer [40].

In the study of Kamran et al. (2017), air abrasion process was performed with Al2O3 particles with a size of 80 microns, a pressure of 3 bar, a distance of 10 mm from the ceramic surface for 10 seconds. The reason for the difference in the results of the mentioned studies with the study of Elsaka et al. (2013) [40], can be caused by differences in parameters such as rougher aluminum oxide particles, longer wear and higher pressures, as well as the type of zirconia. When the sandblast method uses larger particles, more pressure, and longer time, a change from the tetragonal to the monoclinic phase occurs at the zirconia level. Increasing the monolithic phase leads to the formation of microcracks in the ceramic-veneer glass phase, which can reduce SBS [51].

The use of laser beams is an alternative and innovative method to increase surface roughness [52]. Laser surface preparation method, which is known as laser etching method, causes dimples and depressions in the surface of zirconia due to heat generation. This action is responsible for creating a mechanical adhesion between the surface of zirconia and porcelain veneer, which is the etching pattern in the study of Foxton et al. (2011) was also observed in electron microscope view [29]. Findings from the study of Kirmali et al. (2013) showed that the amount of bond strength increased in sandblast group and Er-YAG laser group, but the difference between Er-YAG laser group and control group as well as sandblast group and control group was not statistically significant [30]. In the study of Kamran et al. (2017) [37], Er-YAG laser and sandblasting also increased the

bond strength, but only the difference between the sandblast group and the control group was statistically significant, perhaps due to the difference in the use of more pressure in sandblasting in Kamran et al. al. (2017) [37] than study of Kirmali et al. (2013) [30]. Findings of the study Akyil et al. (2010) showed that the SBS generated by Nd-YAG laser was lower than that of sandblast and Er-YAG laser groups, while the highest SBS was generated by Er-YAG laser [41]. In addition, the results of the study by Akin et al. (2011) showed that Nd-YAG laser and Er-YAG laser radiation in contact type had significantly higher SBS than other groups [42].

Results of the study Matani et al. (2014) showed that the experimental coating group showed the highest amount of SBS, surface roughness and the lowest amount of residual monoclinic phase compared to the air abrasion and Er. YAG laser groups [36]. Observations of electron microscope images in the study of Kamran et al. (2017) [37] showed that the Er-YAG laser increased the roughness of the zirconia surface without cracking but did not significantly increase the porcelain band. The Er-YAG laser does not absorb the zirconia surface well, so to increase energy absorption, the zirconia ceramic surface is coated with graphite powder. Perhaps one of the reasons for the differences in the results of the study Kamran et al. (2017) [37] with the study of Matani et al. (2014) [36], the lack of coating of zirconia surface with graphite powder during the use of Er-YAG laser.

In various studies, the samples were evaluated after debanding to determine the type of failure using a light microscope. In this regard, the results of studies by Kamran et al. (2017) [37], Cal Vacanti et al. (2009) [38], Akin et al. (2011) [42] and Kirmali et al. (2013) [30] showed that adhesive failure is the most common type of failure. Observing a high percentage of adhesive failure, it may indicate that none of the surface treatment methods during SBS augmentation has been able to increase the strength to an ideal level.

Conclusion

Based on the results, it can be concluded that the sandblasting method creates a higher shear bond strength (SBS) between zirconia and porcelain compared to the application of Er-YAG laser. In addition, glass coating on zirconia surface in the short term as sandblasting method is effective in increasing the bond strength of resin cement, while colloidal silica coating reduces the bond strength of resin cement to zirconia. Sandblasting using Cojet and alumina particles increases the bond strength in fiberglass posts (Glassix) and zirconia ceramics (Cosmo post). In general, the bond strength of resin cement to posts is affected by the type of post and surface treatment methods.

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