Revista Brasileira de Odontologia
Brazilian Journal of Dentistry
Associação Brasileira de Odontologia - Seção Rio de Janeiro
DOI: http://dx.doi.org/10.18363/rbo.v75.2018.e1089

Adhesiveness of zirconia and lithium disilicate after different surface treatments: literature review

Renata Ventura Azevedo Lopes,[1] Adriano Relvas,[1] Marina Medeiros Toste Coelho dos Santos,[1] Bárbara Vieira,[1] Laura Sotelo[1]

[1]Graduate Program in Prosthodontics, Pontifical Catholic University, Rio de Janeiro, RJ, Brazil

• **Conflicts of interest: none declared.**

Abstract

Objective: this study aims to evaluate, through a literature review, the adhesiveness of zirconia and lithium disilicate after different surface treatments and to establish a protocol to be followed in the clinic. **Material and Methods:** the methodology was developed from the electronic search in the database National Library of Medicine (PUBMED), using the terms "zirconia surface treatment bond strength" and "lithium disilicate surface treatment", including only clinical studies in humans, *in-vitro* or *in-vivo*, and literature reviews. All articles were published in the last 16 years and written in the English language. **Results:** after selecting the scientific articles following the inclusion and exclusion criteria, 26 studies remained for the literature review. **Conclusion:** after the review, it was concluded that cementation protocols for lithium disilicate and zirconia are different due to their different microstructures. Lithium disilicate should be conditioned with 4.5% hydrofluoric acid followed by phosphoric acid smearing, silane (hot air drying), and universal adhesive application. On the other hand, zirconia restorations should be sandblasted with silica-coated aluminum oxide followed by silanization or blasting with aluminum oxide, associated with zirconium primer application.

Keywords: Adhesiveness; Ceramics; Dental materials.

Introduction

Ceramics are inorganic and inert solid biomaterials consisting of one or more crystalline or amorphous phases.[1] The dental market provides a variety of ceramic materials that can be used for making onlays, inlays, crowns and laminates, such as feldspar-, lithium disilicate-, leucite-, zirconia-, and alumina-based ceramics, among others. They feature greater chemical surface stability than metallic and polymeric biomaterials. [1]

Ceramics can be classified according to their composition, being divided into glass ceramic (inorganic ceramic material that contain a glassy phase), polycrystalline (inorganic non-metallic ceramic material that does not contain glassy phases) and resinous ceramics.[2]

Resinous ceramics were introduced in the classification in 2013, when the definition proposed by the ADA Code of Dental Procedures and Nomenclatures classified ceramics as pressed, sintered, polished or machined materials containing mainly (+ 50% by weight) inorganic refractory components – including porcelains, glass, ceramics, and glass-ceramics.[2]

The main characteristics of ceramics classified into the polycrystalline group is a fine-grained crystalline structure that provides resistance to cracks, but it tends to have a limited translucence. In addition, the absence of a glassy phase makes the polycrystalline ceramics difficult to condition with hydrofluoric acid, requiring long conditioning times or higher temperature.[2] The zirconium dioxide, or zirconia (ZrO_2), is a metallic oxide with extremely low thermal conductivity, chemically inert and highly resistant to corrosion, being of great importance for dentistry due to its high fracture resistance. However, pure ZrO_2 is not very practical due to the formation of cracks because of the transformation from tetragonal to monoclinic phase. Most zirconia currently available as ceramic material for dental prostheses is based on tetragonal zirconia particles (TZP) that are fully stabilized with yttrium oxide (Y_2O_3).[3]

Glass ceramics feature a crystalline phase that may be composed of quartz, lithium disilicate crystals or leucite, coated by a glassy acid-sensitive matrix. The opacity of the crystals associated with the glass matrix translucency gives these restoration aesthetic characteristics like the dental element. Part of the group of glass ceramics, the lithium disilicate has been widely acknowledged as one of the most reliable restorative materials for indirect restorations, for aesthetic and functional rehabilitation. The ability to be adhesively glued to dental substrates, optimal mechanical properties, and its appearance similar to a natural tooth are very attractive for dentists and patients.[4]

Thus, the knowledge on the microstructure of different ceramic groups allows understanding the adhesive interface formation mechanisms, which are associated with the surface treatment of ceramic substrate and to the type of cement used - which are fundamental for the longevity of ceramic restorations.[5]

Such fact becomes essential in modern dentistry since restoration retention, which before relied only on the geometric shape of the preparation and on the cement resistance, can be improved if the cement agent is chemically united to the dental structures and restoration surface. In some situations, the geometric shape of the preparation became almost irrelevant, as in the case of ceramic laminates, which feature rounded and tapered formats.[6]

Therefore, the performance of adhesive systems depends on the treatment of the dental surface, the ceramics, and the correct clinical application. Based on that, the objective of this study is to formulate a clinical protocol for conditioning the lithium disilicate- and zirconia-based ceramics through a literature review of studies that address such themes.

Material and Methods

The integrative literature review was performed by a single researcher who started the activities with a search on the electronic database *U.S. National Library of Medicine* (PUBMED).

For article selection, the search terms were "*zirconia surface treatment bond strength*" and "*lithium disilicate surface treatment*". A total of 360 studies was initially selected. Titles and abstracts of the studies found by the search strategy were evaluated and a total of 203 studies remained. Of these, 41 were excluded from the review because they were not related to the topic. The other articles were evaluated according to the inclusion and exclusion criteria listed below:

Inclusion criteria:

- Studies published in the last 16 years;
- Studies published in the English language;
- Clinical studies in humans;
- *In vitro* or *in vivo* studies;
- Literature review studies.

Exclusion Criteria:

- Studies published prior to 2002;
- Studies publish in a language other than English;
- Case reports;
- Clinical studies in animals.

Results

After reading the scientific articles and following the inclusion and exclusion criteria, 29 studies were selected for the literature review.

Literary works and scientific articles in Portuguese were also used, but only as a complement to elaborate the introduction.

Literature Review

Adhesiveness quality is determined by bond mechanisms that are partially controlled by the specific surface treatment used to promote micro-mechanical or chemical retention to the ceramic substrate. Morphology modification of the ceramic surface can be performed to promote better bond strength.[7]

Therefore, treatments for ceramic surfaces prior to the cement application play an important role in the clinical success of many indirect ceramic restorations.[8]

Given the many possibilities of surface treatment for lithium disilicate- and zirconia-based ceramics, the articles reviewed analyzed the clinical success of different protocols through the assessment of hydrofluoric acid conditioning in different times and concentrations, aluminum oxide sandblasting, silica-coated aluminum oxide, thermocycling, conditioning with metal primers, silane, and laser irradiation.

In vitro studies revealed that the conditioning with 10% hydrofluoric acid for 20 seconds for IPS Empress 2 (Ivoclar Vivadent, Schaan, Liechtenstein); 60 seconds for IPS Empress (Ivoclar Vivadent, Schaan, Liechtenstein) and Cergogold (Degussa Dental, Hanau, Germany); and 2 minutes for In-Ceram Alumina, In- Ceram Zirconia and Procera (Vita Zanfabrik, Seefeld, Germany) could change the IPS Empress and Cergogold ceramic surfaces, creating an ideal surface for micromechanics retention. However, the In-Ceram Alumina and In-Ceram Zirconia presented no surface changes, resulting in relatively smooth surfaces.[9,10]

In addition to changes in surface roughness, the flexural resistance of lithium disilicate decreases when this glass ceramic is submitted to long periods of conditioning. Thus, it is important to consider the time required to promote a better chemical retention, without weakening too much the restoration process.[11]

In turn, Kalavacharla *et al.*[12] evaluated the importance of the use of silane prior to the universal adhesive (Scotchbond Universal - 3M ESPE, St Paul, MN, USA) and worked with different concentrations of hydrofluoric acid under varied application times, concluding that both hydrofluoric acid and silane treatments have significantly improved the bond strength between resin and lithium disilicate when associated with the universal adhesive.

Moreover, heat treatment has been proposed to improve the silane technique. It increases the adhesiveness of the ceramic surface to resinous cements since it removes the unstable top layer of the silane, thus improving the chemical adhesion.[13-17]

Thermocycling studies, whose goal is to simulate the aging of the oral cavity restoration by the continuous action of water in the cement-ceramic-resin interface, showed a significant reduction of the bond strength between cement and ceramics, both zirconia[18] as lithium disilicate[8]. Luthy *et al.*[19] found that, after thermocycling, the bond strength of a tribochemically silica-coated zirconia (Rocatec - 3M Espe, Seefeld, Germany) with resinous cement (Nexus - Kerr, Orange, USA) were higher than for those without this treatment.

Given this context of surface treatment for zirconia, the use of metal primers has been recommended by the literature. The 3 most used metal primers: MDP-based metal primer (Kuraray Medical Inc, Okayama, Japan), MEPS-based metal primer (GC Corporation, Tokyo, Japan) and MTU-6-based Metaltite primer (Tokuyama Dental Corporation, Tokyo, Japan) feature similar performance patterns regarding bond strength, significantly increasing the the bond strenght of the tetragonal zirconia fully stabilized by yttrium (Y-TZP) to the resinous cements studied.[20,21] The universal primer containing silane and phosphate monomer (Monobond Plus, Ivoclar Vivadent, Schaan, Liechestenstein) provides a better bond strenght of silica-coated zirconia ceramic when compared to the use of conventional silane.[22]

Abrasion of silica-coated aluminum oxide particles (APA) creates a rough zirconia surface, among other functions, to increase the mechanical bracing. Zirconia surfaces, whether sandblasted by small (25µm, 50µm) or larger grains (110µm), do not present significant differences, although a larger grain size does create a rougher surface since the bond strength is not influenced. The use of APA in grains smaller than 100µm, however, may change the surface from a tetragonal to a monoclinic phase, which in turn can reduce the material's mechanical properties. Some manufacturers suggest the heating after APA to invert the conversion or the use of APA before the final sintering.[23-25]

Aluminum oxide sandblasting, 30µm, for 10s, and under pressure exceeding 100KPa in lithium disilicate-based restorations considerably reduces the flexural resistance, creating highly concentrated areas of mechanical stress and microcracks on the surface and, even though it increases the irregularity of the glass ceramic surface, it does not produces adhesiveness results statistically superior to those obtained for surfaces without this treatment.[9,26,27] On the other hand, the association of aluminum oxide sandblasting (0,05MPa or 0,25MPa) with the application of a metal primer or a resinous cement with phosphate monomer in zirconia-based restorations provide a long-term bond between tooth and ceramic substrate.[28]

The Er:YAG laser irradiation (500mJ energy with 10W of power), combined with the aluminum oxide sandblasting, can be an effective alternative method to improve the bond of resinous cements to the zirconia surface, being required further studies to prove its advantages. [29]

Conclusion

Lithium disilicate should be conditioned with 4.5%-10% hydrofluoric acid for 20s; silanized for 60s (hot air drying) and treated with universal adhesive.

Zirconia, in turn, must be sandblasted with aluminum oxide coated with silica (APA) and then receive silane application for 60s (hot air drying). An alternative conditioning for zirconia, proposed by the literature, would be the sandblasting with aluminum oxide (particles above 100µm) and application of zirconia primer.

Therefore, as they present different microstructures, the cementing protocols are different for lithium disilicate and zirconia. In addition, most articles signaled that further studies should be made to establish a gold standard as for the protocol to be followed.

References

1. Sinhoreti MAC, Vitti RP, Sobrinho LC. Biomateriais na Odontologia: panorama atual e perspectivas futuras. Rev Assoc Paul Cir Dent. 2013;67(4):31-6.
2. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. J Prosthodont. 2015;28(3):227-35.
3. Anusavice KJ, Shen C, Rawls HR. Materiais dentários. 11ª ed. Rio de Janeiro (RJ): Elsevier, 2005. p. 764.
4. Sunfeld D, Sobrinho LC, Pini NIP, Costa AR, Sundfeld RH, Pfeifer CS, et al. The Effect of Hydrofluoric Acid Concentration and Heat on the Bonding to Lithium Disilicate Glass Ceramic. Braz Dent J. 2016;27(6):727-33.
5. Aras WMF, León BLT. Surface treatment and adhesive cementing of glass infiltrated alumina ceramic: review of the literature. Rev de Odont UNESP. 2009;38(2):93-8.
6. Namoratto LR, Ferreira RS, Lacerda RAV, Filho HRS, Ritto FP. Cimentação em cerâmicas: evolução dos procedimentos convencionais e adesivos. Rev Bras Odontol. 2013;70(2):142-7.
7. Yavuz T, Dilber E, Kara HB, Tuncdemir AR, Ozturk AN. Effects of different surface treatments on shear bond strength in two different ceramic systems. Lasers Med Sci. 2013;28(1):1233-9.
8. Guarda GB, Correr AB, Gonçalves LS, Costa AR, Borges GA, Sinhoreti MA, et al. Effects of surface treatments, thermocycling, and Cyclic Loading on the Bond Strength of a resin cement bonded to a Lithium disilicate glass ceramic. Operat Dent. 2013;38(2):208-17.
9. Borges GA, Sophr AM, de Goes MF, Sobrinho LC, Chan DC. Effect of etching and airborne particle abrasion on the microstructure of different dental ceramics. J Prosthet Dent. 2003;89(5):479-88.
10. Casucci A, Osorio E, Osorio R, Monticelli F, Toledano M, Mazzitelli C. Influence of different surface treatments on surface zirconia frameworks J Dent. 2009;37(11):891-7.
11. Zogheib LV, Bona AD, Kimpara ET, McCabe JF. Effect of hydrofluoric acid etching duration on the roughness and flexural strength of a lithium disilicate-based glass ceramic. Braz Dent J. 2011;22(1):45-50.
12. Kalavacharla VK, Lawson NC, Ramp LC, Burgess JO. Influence of Etching Protocol and Silane Treatment with a Universal Adhesive on Lithium Disilicate Bond Strength. Oper Dent. 2015;40(4):372-8.
13. Fabianelli A, Pollington S, Papacchini F, Goracci C, Cantoro A, Ferrari M, et al. The effect of different surface treatments on bond strength between leucite reinforced feldspathic ceramic and composite resin. J Dent. 2010;38(1):39-43.
14. Hooshmand T, van Noort R, Keshvad A. Bond durability of the resin-bonded and silane treated ceramic surface. Dent Mater. 2002;18(2):179-88.
15. Monticelli F, Toledano M, Osorio R, Ferrari M. Effect of temperature on the silane coupling agents when bonding core resin to quartz fiber posts. Dent Mater. 2006;22(11):1024-8.
16. Pereira CNB, Buono VTL, Mota JMLM. The influence of silane evaporation procedures on microtensile bond strength between a dental ceramic and a resin cement. Indian J Dent Res. 2010;21(2):238-43.
17. Shen C, Oh WS, Williams JR. Effect of post-silanization drying on the bond strength of composite to ceramic. J Prosthet Dent. 2004;91(5):453-8.
18. Matinlinna JP, Lassila LVJ, Vallittu PK. Pilot evaluation of resin composite cement adhesion to zirconia using a novel silane system. Acta Odontol Scand. 2006;65(1):44-51.
19. Luthy H, Loeffel O, Hammerle CHF. Effect of thermocycling on bond strength of luting cements to zirconia ceramic. Dent Mat. 2006;22(2):195-200.
20. Cavalcanti AN, Foxton RM, Watson TF, Oliveira MT, Giannini M, Marchi

GM. Bond strength of resin cements to a zirconia ceramic with different surface treatments. Oper Dent. 2009;34(3):280-7.
21. Cura C, Özcan M, Isik G, Saracoglu A. Comparison of alternative adhesive cementation concepts for zirconia ceramic: glaze layer vs Zirconia primer. J Adhes Dent. 2012;14(1):75-82.
22. Attia A, Lehmann F, Kern M. Influence of surface conditioning and cleaning methods on resin bonding to zirconia ceramic. Dent Mat. 2011;27(1):207-13.
23. Tzanakakis EGC, Tzoutzas IG, Koidis PT. Is there a potential for durable adhesion to zirconia restorations? A systematic review. J Prosthet Dent. 2016;115(1):9-19.
24. Özcan M, Bernasconi M. Adhesion to zirconia used for dental restorations: a systematic review and meta-analysis. J Adhes Dent. 2015;17(1):7-26.
25. Silva EM, Miragaya L, Sabrosa CE, Maia LC. Stability of the bond between two resin cements and an yttria-stabilized zirconia ceramic after six months of aging in water. J Prosthet Dent. 2014;112(3):568-75.
26. Menees TS, Lawson NC, Beck PR, Burgess JO. Influence of particle abrasion or hydrofluoric acid etching on lithium disilicate flexural strength. J Prosthet Dent. 2014;112(5):1164-70.
27. Brum R, Mazur R, Almeida J, Borges G, Caldas D. The influence of surface standardization of lithium disilicate glass ceramic on bond strength to a dual resin cement. Oper Dent. 2011;36(5):478-85.
28. Yang B, Barloi A, Kern M. Influence of-air-abrasion on zirconia ceramic bonding using an adhesive composite resin. Dent Mat. 2010;26(1):44-50.
29. Yavuz T, Dilber E, Kara HB, Tuncdemir AR, Ozturk AN. Effects of different surface treatments on shear bond strength in two different ceramic systems. Lasers Med Sci. 2013;28(1):1233-9.

Mini Curriculum and Author's Contribution

1. Renata Ventura Azevedo Lopes – DDS. Contribution: bibliographical research, article writing and final approval.
2. Adriano Relvas – DDS. Contribution: article writing, review, and final approval
3. Marina Medeiros Toste Coelho dos Santos – DDS. Contribution: article writing, review, and final approval.
4. Bárbara Vieira – DDS. Contribution: article writing, review, and final approval.
5. Laura Sotelo – DDS and PhD. Contribution: article writing, review, and final approval.

Submitted: 01/05/2018 / Accepted for publication: 02/24/2018

Corresponding Author

Adriano Relvas

E-mail: relvasrj@yahoo.com.br