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THE SURFACE TREATMENT OF DENTAL CERAMICS: AN OVERVIEW

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ABSTRACT

This review proposes to present some aspects of dental ceramics surface treatments, which involve the related physical and mechanical properties, as well as new technologies. The correct cementation of prosthetic restoration is essential for clinical success. However, the adhesive technique is a very recent procedure and clinicians should have a more detailed knowledge about the technique and related materials so that they can use them in their day-to-day clinical practice. Information about the the principles, indications and contraindications of adhesive cementation technique were obtained from the literature. The studies indicate that the adhesive system seems to be a valid option for fixed prosthesis cementation, since it has several advantages over conventional cementation method, especially in all-ceramic restorations. In clinical practice, the clinician should always keep in mind the characteristics of the material they are working with, so that they can select the best technique and the best cement for each clinical situation. Although more research is required in this field, there are no scientific reasons to contraindicate in routine practice.

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INTRODUCTION

There is an increasing search for aesthetic treatments in dentistry, which leads to a great interest in the development of new materials and techniques in order to supply such demand. In this context, materials, such as adhesive systems, composite resins, resin cements, and dental ceramics have been increasingly improved[1].

The less invasive restorative techniques have been stimulated by the evolution of resinous agents. More conservative partial preparations, such as inlays, onlays, and laminate veneers, although more adhesive-dependent, may be indicated with better result predictability. Therefore, more durable and efficient adhesive techniques, related to both the restorative material and dental substrate, become indispensable[2].

Conditioning of the dental structure surface and restorative materials help reducing the postoperative sensitivity and marginal micro leakage, as well as increasing fracture resistance and restoration retention. Proper conditioning application on the ceramic surface helps maintain durability of the restorative procedure[2,3].

Conditioning that has good adhesive strength results for one ceramic may not show the same result for other ceramics. In this way, each ceramic system presents different conditioning protocols. The micromechanical and chemical bonding to the ceramic substrate depends essentially on its physical properties and chemical composition. Therefore, its chemical constituents will define the most effective treatment method from the adhesive point of view[3,4].

Based on the foregoing, this literature review proposes to present some aspects of dental ceramics, which involve the related physical and mechanical properties, as well as new technologies. Having a better understanding of the recent procedures and techniques of adhesive cementation will help improve oral rehabilitation with fixed prostheses.

REVIEW

1. DENTAL CERAMICS

Because of its little plastic behavior, ceramic becomes a susceptible friable material, with low malleability. For that reason, its use is contraindicated for load bearing areas. Therefore, distinct mechanisms were considered to improve its characteristics, thus reducing failures under masticatory stress. These mechanisms include strengthening the ceramic structures by means of an inner support, to provide effective bonding and adequate strength in order to transfer the tensile/compressive load from one substrate to the other[5].

1.2 CLASSIFICATION ACCORDING TO ACID SENSITIVITY

1.2.1 ACID-RESISTANT CERAMICS

Ceramics containing high crystalline content (aluminum oxides and/or zirconia) are named "acid-resistant" and have shown superior clinical performance to acid-sensitive ceramics. This increase in mechanical strength is due to an increase in the crystalline phase of the ceramic and a decrease in the glassy phase, causing a resistance to acid etching, being unable to develop an adequate adhesion of the ceramics to the resin cements[6].

Used as infrastructure for all-ceramic restorations, they are ceramics that suffer little or no surface degradation by the action of hydrofluoric acid, enabling a limited micromechanical bonding by the conventional method. These ceramics are subjected to sandblasting with silica or aluminum oxide particles that will promote changes in topography, generating surface roughness and microporosity, which, in turn, allows to increase the surface area available for adhesion, and helps the mechanical bonding for the retention of silane coupling agents[7].

Examples of such ceramics include glass infiltrated ceramics (In-Ceram Spinell, Alumina and Zirconia systems), densely sintered aluminized ceramics (Procera AllCeram), and ceramics based on zirconia partially stabilized by yttrium oxide.

1.2.2 ACID-SENSITIVE CERAMICS

Acid-sensitive ceramics are those in which the hydrofluoric acid degrades its surface, enabling the micromechanical bonding with resinous cements and the chemical bonding by using silane coupling agents. The hydrofluoric acid etching dissolves the crystalline and vitreous components of this type of ceramic, significantly altering its surface morphology, causing irregularities represented by retentive micropores, grooves, and cracks. That way, they have the property of increasing the cement wettability on the surface[8].

Corrosion of the sensitive ceramic surface is stimulated by the action of fluoride ions on the silicon-oxygen mesh, reinforcing this effect by decreasing the pH and increasing the concentration of the fluoride ion in the acid used. Fluoride ions in acidic environment attack the vitreous components of the ceramics forming water-soluble fluorsilicate, thereby altering their physical and aesthetic properties, and rendering the ceramic surface irregular[9].

In this category, some ceramics are recommended for partial onlay, inlay and laminate veneer restorations, such as feldspathic ceramics, leucite-enhanced feldspathic ceramics (IPS Empress), and lithium disilicate (IPS Empress II) ceramics.

1.3 CERAMIC SURFACE TREATMENT

1.3.1 CONDITIONING WITH HYDROFLUORIC ACID

The chemical process of conditioning with hydrofluoric acid causes a reaction with the glassy phase of leucite-reinforced ceramics, resulting in hexafluorsilicate. These silicates are removed by the jet of water forming a honeycomb surface that is ideal for the cement micromechanical retention[10].

This is the surface treatment of choice for ceramics with feldspar or vitreous silica in a 2.5-10 percent of hydrofluoric acid for 20 seconds to 3 minutes, and subsequent application of silane[11]. The 10% hydrofluoric acid conditioning is designed for two minutes. However, it may vary according to the composition of the ceramic used[10]. The hydrofluoric acid conditioning in leucite and feldspathic ceramics has been well-studied and has confirmed the effectiveness of the treatment in this type of ceramic[12].

Hydrofluoridic acid conditioning does not exert any effect on systems with high alumina content, such as the aluminzed and zirconium-based ceramic system. This may be due to the low content of glassy phase and silica, even though in some cases there is a reduction in bond strength of resin cement when it is applied[13].

1.3.2 BLASTING WITH ALUMINUM OXIDE (Al_2O_3)

Blasting is a method that consists of taking substances against the internal surface of the restoration, capable of creating roughness. Aluminum oxide is the longest used substance for this purpose[13].

This surface treatment consists of blasting with aluminum particles of about 50 µm in diameter at a pressure of 80 lbs/in^2 for 15 seconds in order to cause micro-retentions. It is one of the available methods for increasing bond strength between ceramic restorations and cement resins. This treatment generates superficial irregularities in the ceramic surface, helping the interaction with cement[14].

It is advisable to work with smaller particles and, if necessary, to increase the pressure as a way of achieving greater effectiveness, especially if the yttria-stabilized zirconia ceramic, since large shocks on this ceramic surface lead to its structural modification, which can compromise its resistance[12,14].

1.3.3 SILANIZATION

In dentistry, silane coupling agents can have several applications. They can be used as surface pre-treatment for ceramic adhesion to a composite of dental restorations, in intraoral repairs of ceramic surfaces or resins, and to attach a bionic layer to titanium implants[15].

Silane is a bifunctional molecule that, on the one hand, reacts with the organic matrix of the resin cement through the organic-functional radical, and on the other hand, interacts with vitreous components of the glass ceramic (SiO_2) by means of the inorganic radical[13]. As the silane will react with the hydroxyl group of the porcelain surface, it allows for the chemical adhesion by making it more reactive to the composite[15].

This bonding agent must be used in the ceramic with a disposable brush for one minute. Then, it must be air-dried using a triple syringe for five seconds before applying the adhesive system[13]. In order to stimulate the reaction between the silane coupling agent and the inorganic surfaces of the ceramic, the reaction can be catalyzed by heating the silane agent. This thermal treatment allows for the silane agent to increase the bond strength between the resin cement and the ceramic[16].

1.3.4 SILICATIZATION

The use of silica prior to cementation involves the following steps. First, surface blasting with aluminum oxide (110 µm); second, deposition of aluminum oxide modified by silicon acid (30µm or 100 µm); and third, silanization. This process will lead to the imbibition of silica particles by the ceramic, making its surface micro-retentive and chemically more reactive to the resin cement through the silane coupling agent[12].

The protocol for the blasting system is made at a distance of 10 mm and perpendicular to the surface for 20 seconds at a pressure of 2.8 bars, after which the silane is applied for 5 minutes[17,18].

A study on the effect of silica deposition on an aluminized and densely sintered ceramic and a resin cement in a shear test was carried out to investigate the effects related to the adhesive strength, which confirmed that silicatization increases the bond strength values[12].

The association of silanization, silicatization, and cementation with MDP resin cements (phosphate monomer) provides high bond strength values for acid-resistant ceramics (alumina and zirconium oxide, and densely sintered alumina oxide-based structures)[10].

On essentially ceramic surfaces, it is totally dependent on the type of ceramic that was used within the restoration, more specifically, its silica content. Thus, lithium or feldspathic disilicate ceramics are frequently used with 10% hydrofluoric acid and silane application. Ceramic types with a low silica content do not use hydrofluoric acid for conditioning. Adhesion of poor silica surfaces to resin cements is made through silicatization (silica particle deposition) applied on the inner surface of the restoration[19].

DISCUSSION

Bonding between dental and ceramic structures is a very important process for the longevity of all-ceramic restorations. Reinforced ceramics with a high content of crystals, such as aluminized, can be fixed to the dental preparation through conventional techniques, by applying the glass ionomer or zinc phosphate cements. However, adhesive fixation is the procedure of choice for this type of material, which makes the internal surface treatment of the restoration, the resin cement and the adhesive system decisive agents for the cementation of these prosthetic restorations. Therefore, it is important for the internal surface of the ceramic restoration to be susceptible to surface treatments, with the objective of developing micromechanical retentions with the resinous agents, as well as chemical bonding between the resin cement and the ceramic[20].

The silicatization system is the surface treatment mode of reinforced ceramics that provides the most interesting results of adhesive resistance to resin cementing agents[17]. However, this bonding durability is only obtained by the combination of silica deposition with resin-based Bis-GMA cements. The use of surface treatment with Al_2O_3 blasting associated with the use of resin-cements with phosphate monomers also demonstrates good adhesive resistance results, similar to those achieved with feldspathic porcelains conditioned with hydrofluoric acid and silane coupling agent[21].

The use of dual-cured resin cement associated with the silane agent revealed an effective adhesion between aluminized ceramic surface treated with 5% hydrofluoric acid or blasted with aluminum oxide particles. However, recent studies have demonstrated that surface treatment with aluminum oxide blasting or hydrofluoric acid application does not produce good adhesive resistance between resin cement and reinforced ceramic. According to Özcan et al.[22], aluminized ceramic surface treatment with hydrofluoric acid and micro-alloying with Al_2O_3 showed inferior bonding results as compared to the silicatization system, which offers a more reliable bonding between this type of ceramic and resin cements.

In the case of aluminum oxide air-abrasion, there is no standard for particle size, distance from the apparatus to the substrate, pressure of the blasting system, as well as treatment time[21]. Authors have reported all requirements cited above, and stated that surface treatment with aluminum oxide blasting is one of the available methods that may be aimed at increasing bond strength between ceramic restorations and resin cements[13].

The same applies to systems using silica oxide. This is confirmed by the assertion that the limited knowledge does not elucidate if micromechanical retention, caused by larger or smaller particles, increases the adhesive strength of the reinforced ceramics of different microstructures and chemical compositions[21]. In a study carried out to measure the adhesive strength, Aras and Leon[12] have reported that there was evidence showing that silicatization increased bond strength values.

Madani et al.[21] have claimed that the adhesion of phosphate monomer-based resin cement to the aluminized infrastructure can improve by selecting the appropriate surface treatment. In addition, the organic matrix of the new resin systems contains multifunctional phosphoric acid methacrylates that favor chemical bonding between the cement charge particle and the hydroxyapatite of the dental structure. According to Hikita et al.[23], these cementitious agents exclude acid conditioning prior to cementation and are capable of preparing dental surfaces for adhesion. However, little information is available on the effect of adhesion of silica-coated crystalline ceramics to phosphate monomer-containing resin cement.

Furthermore, the application of the cementing agents in structurally distinct ceramics generates more variables in the formation of the bonding interface and, consequently, there are different adhesive strength values. Assessment of the study results revealed that there was no consensus regarding the ideal surface conditioning method. The microstructural characteristics of ceramics seem to determine the most appropriate surface treatment. The protocol for direct and indirect bonding restorative materials to dental substrates is well-established in the literature[24].

Ozcan and Vallittu[24] emphasized that, although the effectiveness of hydrofluoric acid is recognized, it cannot be applied to ceramics devoid of silica, and thus it is used as an “acid-resistant” material. Moreover, Lu et al.[25] have reported that the effects of different sandblasting conditions on the In-Ceram surface and the bond strength of this ceramic to the resin cement have not been well-studied yet. Contrary to most of the selected works, there is the one that advocates the use of phosphoric acid, due to its less aggressive nature as compared to hydrofluoric acid, and it is capable of producing the same effects if associated with the application of silane[26].

CONCLUSION

Given the variety of cements available, dental surgeons cannot choose one type of cement for all cases. They should always keep in mind the characteristics of the material they are working with, so that they can select the best technique and the best cement for each clinical situation.

Previous preparation for the restoration and the tooth surface to be cemented are extremely important steps when using the adhesive cementation technique. Adhesive strength of the restoration is not only dependent on the properties of the resin cement, but also on the treatment of dental and interior surfaces of the restoration. In this context, it should be remembered that the application of silane after the surface treatment has proven to be an important tool that will increase considerably the bond strength between the tooth and the restoration.

REFERENCES

1. Kelly, J.R., Nishimura, I., Campbell, S.D.J. Ceramics in dentistry: historical roots and current perspectives. *J. Prosthet. Dent.*, 1996;75:18.32.

2. Borgia Botto, E., Baró, R., Borgia Botto, J.L. Clinical performance of bonded ceramic inlays/onlays: A 5- to 18-year retrospective longitudinal study. *Am. J. Dent.*, 2016;29:187.192.

3. Luthra, R., Kaur, P. An insight into current concepts and techniques in resin bonding to high strength ceramics. *Aust. Dent. J.*, 2016;61:163.173.

4. Kussano, C.M., Bonfante, G., Batista, J.G., et al. Evaluation of shear bond strength of composite to porcelain according to surface treatment. *Braz. Dent. J.*, 2003;14:132.135.

5. Ersu, B., Yuzugullu, B., Ruya Yazici, A., et al. Surface roughness and bond strengths of glass-infiltrated alumina-ceramics prepared using various surface treatments. *J. Dent.*, 2009;37:848.856.

6. Song, J.Y., Park, S.W., Lee, K., et al. Fracture strength and microstructure of Y-TZP zirconia after different surface treatments. *J. Prosthet. Dent.*, 2013;110:274.280.

7. Karimipour-Saryazdi, M., Sadid-Zadeh, R., Givan, D., et al. Influence of surface treatment of yttrium-stabilized tetragonal zirconium oxides and cement type on crown retention after artificial aging. *J. Prosthet. Dent.*, 2014;111:395.403.

8. Reich, S., Fischer, S., Sobotta, B., et al. A preliminary study on the short-term efficacy of chairside computer-aided design/computer- assisted manufacturing- generated posterior lithium disilicate crowns. *Int. J. Prosthodont.*, 2010;23:214.216.

9. Corazza, P.H., Duan, Y., Kimpara, E.T., et al. Lifetime comparison of Y-TZP/porcelain crowns under different loading conditions. *J. Dent.*, 2015;43:450.457.

10. Silva, L.H.D., Lima, E., Miranda, R.B.P., et al. Dental ceramics: a review of new materials and processing methods. *Braz. Oral. Res.*, 2017;31(suppl 1):e58.

11. Martins, L.M., Lorenzoni, F.C., Farias, B.C., et al. Biomechanical behavior of dental ceramics: review. *Ceramic.*, 2010;56:148.155.

12. Isgró, G., Addison, O., Fleming, G.J. Transient and residual stresses in a pressable glass-ceramic before and after resin-cement coating determined using profilometry. *J. Dent.*, 2011;39:368.375.

13. Heintze, S.D., Albrecht, T., Cavalleri, A., et al. A new method to test the fracture probability of all-ceramic crowns with a dual-axis chewing simulator. *Dent. Mater.*, 2010;27:10-19.

14. Prado, R.D., Pereira, G.K.R., Bottino, M.A., et al. Effect of ceramic thickness, grinding, and aging on the mechanical behavior of a polycrystalline zirconia. *Braz. Oral. Res.*, 2017;31:e82.

15. Luthra, R., Kaur, P. An insight into current concepts and techniques in resin bonding to high strength ceramics. *Aust. Dent. J.*, 2016;61:163.173.

16. Erdem, A., Akar, G.C., Erdem, A., et al. Effects of different surface treatments on bond strength between resin cements and zirconia ceramics. *Oper. Dent.*, 2014;39:E118.127.

17. Sciasci, P., Abi-Rached, F.O., Adabo, G.L., et al. Effect of surface treatments on the shear bond strength of luting cements to Y-TZP ceramic. *J. Prosthet. Dent.*, 2015;113:212.219.

18. Fischer, J., Schott, A., Märtin, S. Surface micro-structuring of zirconia dental implants. *Clin. Oral. Implants. Res.*, 2016;27:162.166.

19. Nishigawa, G., Maruo, Y., Irie, M., et al. Various effects of sandblasting of dental restorative materials. *PLoS. One.*, 2016;11:e0147077.

20. Valian, A., Moravej-Salehi, E. Surface treatment of feldspathic porcelain: scanning electron microscopy analysis. *J. Adv. Prosthodont.*, 2014;6:387.394.

21. Madani, M., Chu, F.C.S., McDonald, A.V., et al. Effects of surface treatments on shear bond strengths between a resin cement and an alumina core. *J. Prosthet. Dent.*, 2000;83:644.647.

22. Ozcan, M., Alkumru, H.N., Gemalmaz, D. The effect of surface treatment on the shear bond strength of luting cement to a glass-inflitrated alumina ceramic. *Int. J. Prosthodont.*, 2001;14:335.339.

23. Hikita, K., Meerbeek, B., Muncky, J., et al. Bonding effectiveness of adhesive luting agents to enamel and dentin. *Dent. Mater.*, 2007;23:71.80.

24. Ozcan, M., Vallittu, P.K. Effect of surface conditioning methods on the bond strength of luting cement to ceramics. *Dent. Mater.*, 2003;19:725.731.

25. Lu, Y.C., Tseng, H., Shih, Y.H., et al. Effects of surface treatments on bond strength of glass-infiltrated ceramic. *J. Oral. Rehab.*, 2001;28:805.813.

26. Moravej-Salehi, E., Moravej-Salehi, E., Valian, A. Surface topography and bond strengths of feldspathic porcelain prepared using various sandblasting pressures. *J. Investig. Clin. Dent.*, 2016;7:347.354.