

The Effect of Different Surface Treatments on the Bond Strength of Ultra-Translucent Zirconia to Different Resin Cements

Thesis

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Dedication

This work is dedicated to ...

My beloved Parents, to whom I owe everything I ever did in my life and will achieve.

My sister for being always there for me and for her support and encouragement.

Finally **my husband** for his support and continuous encouragement from step to other higher step, **and my lovely daughter (Malak)** for being the light of my life.

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Early in dental field, gold and non precious alloy were used as clinical materials for the restorations of different fixed prosthesis. Metal-ceramic systems provide strength, form and function, it usually shows unaesthetic appearance from metal underneath. The increasing aesthetic demand in dentistry has led to the development of many bioceramic systems. Recently, zirconia technology has induced a rapid development of metal-free dentistry that supply material with high strength. ⁽¹⁾

In the field of indirect restoration, it has always been desirable to have the right blend of aesthetics and durability. The zirconia materials provide extreme precision, strength, and aesthetics. The zirconia restorations are opaque therefore must be veneered to improve their appearance. Porcelain chipping from zirconia core is one of the major problems encountered in veneering process. The recently introduced ultra-translucent zirconia adds to its appearance by having improved translucency. ⁽¹⁾

Due to their high fracture resistance, zirconium-oxide crowns and fixed partial dentures (FPDs) can be cemented using conventional cements recommended by the manufacturers. However, resin bonding between a tooth and the restoration is advocated for improving the marginal adaptation and retention as in short abutments or overtapering. ⁽²⁾

Dental zirconia is glass-free, acid-resistant & non-etchable. So the traditional methods of mechanical and adhesive bonding used on silica-based ceramics are not applicable for use with zirconia. In order to obtain the strong bond to dental zirconia, it is important for the fitting surface to be treated. Many surface pre-treatments have been performed to improve the bonding of zirconia as hot chemical etching solution, air abrasion, silica coating techniques, fusing glass pearls and glaze on technique. ^{(1), (2), (3), (4)}

Surface treatment of presintered zirconia represents a simple and time-saving method while its effect on the bond strength is still controversy. Also recent studies investigated the modification of the zirconia surface in the presintered phase and reported that sandblasting of zirconia before sintering is a useful method to increase surface roughness and additionally, the monoclinic phase percent of the abraded surface before sintering became zero after sintering which mean that the monoclinic phase associated with the abrasion was completely transformed to the tetragonal state during the subsequent sintering step.^{(3), (4)}

There are two types of resin cements used in bonding to zirconia restoration which are conventional and 10-methacryloyloxydecyl dihydrogen phosphate monomer (MDP) containing resin cements. The application of silane coupling agents has been proven to improve the bonding between conventional resin cement and silica-coated zirconia restoration. The 10MDP containing resin cement is known to increase the bond strength of zirconia ceramics via the chemical interaction between the hydroxyl groups of the oxide ceramic and organophosphate ester monomer of the MDP in the cement, especially when used with airborne-particle abrasion with Al_2O_3 particles.⁽²⁾

Therefore, this study is conducted to evaluate the effect of different surface treatments on the bond strength of ultra-translucent zirconia in the presintered stage to different resin cements.

I- Zirconia based ceramics

Evolution in dental materials introduced zirconia based ceramics which provide strong material with better fracture resistance and long term viability in comparison to other dental ceramics. Zirconium oxide (ZrO_2) is a metal oxide that was known as a reaction product of heating the gem, zircon, by Martin Heinrich Klaproth in 1789. ⁽⁵⁾

Zirconia is polymorphic and allotropic in nature, which means that it exists in three forms at different temperatures without change in its chemical structure. At room temperature, monoclinic form exists and remains stable up to 1170°C . Above this temperature it transforms to tetragonal form and then it transfers to cubic form at 2370°C . Change in the form of zirconia from cubic to tetragonal to monoclinic during cooling with increase in its volume (3–4 %) that can produce large stresses. The tetragonal phase is the most interesting one because of transformation toughening property. When a crack propagates on the surface, the stress concentration at the top of the crack causes the tetragonal crystals to transform into monoclinic crystals with associated volumetric expansion. This transformation can put the crack into compression, preventing its growth. Metal oxides as cesium oxide (CeO_2), magnesia (MgO), and yttria (Y_2O_3) have been used to produce a range of partially stabilized zirconia (PSZ) compositions. ^{(5), (6), (7), (8)}

The conventionally available zirconia restorations are yttria-tetragonal zirconia polycrystals ceramics which consists of approximately 2-3% Y_2O_3 as a stabilizing agent. Transformation toughening property is considered to be the basis for the high strength of yttria-tetragonal zirconia polycrystal. The opaqueness is due to the large grain size and the presence of porosity which is clearly seen at the microstructural level. These restorations have

poor esthetics outcomes in comparison to lithium disilicate and leucite reinforced ceramics, so they must be veneered with a layer of porcelain. ⁽⁵⁾

1- Monolithic zirconia

The prefabricated zirconia blocks are white in color and chalk-like with minimum or no translucency. Zirconia restorations are constructed with zirconia core layered or pressed with feldspathic porcelain. It is well known that this layering technique was subjected to mechanical failures as porcelain chipping. ^{(9), (10), (11), (12), (13)}

Thus monolithic zirconia restorations which are fully contoured without veneering porcelain have been introduced in dental field to minimize bi-layered technique mechanical failure. There are two main methods have been introduced for coloring zirconia restorations to overcome this problem. In one of them, pigments are added to the zirconia powder before pressing the milling blocks. In the second method, zirconia restorations are immersed in coloring liquids before sintering to reach the desired shade. ^{(13), (14), (15)}

CeO₂, Fe₂O₃, and Bi₂O₃ are the oxides which were added to the coloring liquids by the manufacturers to reach different shades. There are different studies about the effects of coloring liquids on the mechanical properties of zirconia. ^{(13), (16), (17), (18)}

a- Translucent zirconia:

Newer translucent zirconia have been developed in order to improve their transmittance, so they can be used in esthetics zone. Using translucent zirconia as a full contour monolithic restoration has the potential to eliminate chipping of the veneering ceramic, which has been known to be a main

clinical problem and also reduce the amount of tooth reduction. Its flexural strength is 900 MPa. ^{(19), (20), (21)}

When the potential of molecular nanotechnology had been emphasized. Two approaches have been followed in production of nanoparticles, namely Top down approach and Bottom up approach. In Top down approach, small features are made by starting with larger materials patterning and carving down to make nanoscale structures in precise patterns. Materials reduced to nanoscale can suddenly show very different properties. In Bottom up approach, arranging smaller components into more complex assembly. This method is much cheaper than the top down approach but could be potentially overwhelmed as the size and complexity of the desired assembly increases. ⁽²²⁾

The production of non-agglomerated 3 nm nanocrystalline zirconia powder using a revolutionary bottom up nanotechnology technique known as gas phase condensation. This method consists of colliding high energy yttrium, zirconium and oxygen ions together in an energetic gaseous phase and condensing yttria zirconia nanocrystal particles resulting from atomic collisions during flight in the gas phase. The condensed yttria zirconia nanocrystal particles are separated from the gas phase and collected in the form of nanocrystalline powder. Gas phase condensation nanotechnology for producing nanozirconia will allow us to overcome the polycrystalline birefringence barrier to manufacturing a transparent, high strength monolithic dental ceramic product. ⁽²³⁾

Conventional nanozirconia powder is typically produced by "top-down" nanotechnology methods such as hydrothermal synthesis (calcining followed by ball-milling). Many of the nanozirconia powders available on the market today are comprised of hard-agglomerated nanocrystals with a

primary crystal size of approximately 30 nm. After sintering, typical nanozirconia grain size is between 500-1000 nm. The top-down method is widely used to produce nanocrystalline materials by breaking down larger particles and agglomerates into smaller ones, typically by ball-milling. The bottom-up nanotechnology method builds up nanoscale materials atom by atom or molecule by molecule. Bottom-up nanoscale science and technology is the state of the art for producing the next generation nanoscale materials and devices. The bottom-up method has a lower scale limit on the atomic or molecular level. Additionally, the bottom-up-produced nanocrystalline structures are not altered during the process of forming the nanoscale crystals, whereas top-down methods alter the crystal structure and surface chemistry.⁽²³⁾

Kim et al.⁽²⁴⁾ found that yttria-stabilized tetragonal zirconia polycrystalline ceramics (3Y-TZP) can be made more translucent, while retaining their strength properties depending on sintering conditions. They concluded that less sintering time at the optimal temperature produces smaller grain sizes and enhanced translucency

Moreover, these zirconia modifications allow the production of fully anatomic zirconia crowns and fixed dental prostheses in the posterior region. The clinical advantage of these restorations is defined by a significantly reduced material thickness in comparison with veneered restorations or other monolithic materials.^{(25), (26), (27)}

A study by Beuer et al.⁽²⁸⁾ reported that glazed full contour zirconia crowns showed similar translucency, contact wear of the restoration and contact wear at antagonist as veneered zirconia crowns. However, glazed full contour zirconia crowns showed higher fracture loads than veneered zirconia crowns.