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Research Paper

The effect of graded glass–zirconia structure on the bond between core and veneer in layered zirconia restorations

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ABSTRACT

Objective: The aim of this study was to test the hypothesis that a graded glass–zirconia structure can strengthen the core–veneer bond in layered zirconia materials.
Methods: A graded glass–zirconia structure was fabricated by infiltrating glass compositions developed in our laboratory into a presintered yttria tetrahedral zirconia polycrystal (Y-TZP) substrate by the action of capillary forces. The wettability of the infiltrated glass and Y-TZP substrate was investigated by the sessile drop technique. The microstructures of the graded glass–zirconia structure were examined by scanning electron microscopy (SEM). The phase structure characterization in the graded glass–zirconia structure were identified by X-ray diffraction (XRD) analysis. The elastic modulus and hardness of the graded glass–zirconia structure were evaluated from nanoindentations. Further, the shear bond strength (SBS) of the graded glass–zirconia structure and veneering porcelain was also evaluated.
Results: SEM images confirmed the formation of the graded glass–zirconia structure. Glass frits wet the Y-TZP substrate at 1200 °C with a contact angle of 43.2°. Only a small amount of *t*–*m* transformation was observed in as-infiltrated Y-TZP specimens. Nanoindentation studies of the glass–zirconia graded structure showed that the elastic modulus and hardness of the surface glass layer were higher than those of the dense Y-TZP layer. The mean SBS values for the graded glass–zirconia structure and veneering porcelain (24.35 ± 0.40 MPa) were statistically higher than those of zirconia and veneering porcelain (9.22 ± 0.20 MPa) ($P < 0.05$).

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Conclusions: A graded glass–zirconia structure can be fabricated by the glass infiltration/densification technique, and this structure exhibits a strong core–veneer bond.

1. Introduction

Owing to its good chemical properties, dimensional stability, and high mechanical strength and toughness, zirconia is currently widely utilized for fabricating prosthetic devices (Ozkurt and Kazazoğlu, 2010). Core materials of zirconia are usually added with translucent veneering porcelain for achieving better esthetics. However, the fracture rates of layered zirconia restorations have been reported to be significantly higher than those of metal ceramic restorations (Etman and Woolford, 2010). Fractures have been observed to originate from weak points, the veneer, or the core/veneer interface, resulting in chipping or delamination of the veneer and formation of cracks extending through the core materials (Rekow et al., 2011; Mochales et al., 2011). It has been reported that chipping and fracture result from chemical and physical mismatch, as well as inferior wetting of the zirconia core and veneering porcelain (Aboushelib et al., 2006). Therefore, in order to reduce clinical failures, considerable effort has been focused on increasing the bonding strength between veneering porcelain and zirconia.

Tyszblat fabricated a ceramic/glass composite with high mechanical strength and low sintering shrinkage via the infiltration of lanthanum borosilicate glass into porous alumina (Tyszblat, 1987). This technique was then adopted by VITA Zahnfabrik and was commercialized under the brand name In-Ceram after several years of research and development (Sorensen et al., 1998). However, the mechanical characteristics of In-Ceram alumina materials were reported to be inferior to those of metal–ceramic materials (Sailer et al., 2007).

Ceramics are brittle and therefore highly subject to premature failure from occlusal loading. In order to counter this brittleness, grading the material composition with a lower modulus at the external surfaces considered to be a good choice (Huang et al., 2007). Preliminary studies have demonstrated the feasibility of such a process, by infiltrating the surfaces of ceramic plates with an appropriate silicate glass (Zhang and Kim, 2009; Zhang and Ma, 2009). Zhang fabricated a functionally graded G/Z/G (glass/zirconia/glass) structure – with Young's modulus and hardness increasing from the surface to interior in accordance with a power law – by infiltrating glass compositions with a coefficient of thermal expansion and Poisson's ratio similar to those of zirconia into porous Y-TZP (Zhang and Kim, 2009; Zhang and Ma, 2009). A low-modulus glassy surface dissipates surface bending stress, rendering the graded zirconia–glass material superior in flexural capacity relative to monolithic zirconia (Zhang and Ma, 2009). The graded G/Z/G structure exhibited high strength, endurance, resistance to chipping fracture, and fatigue resistance (Zhang and Ma, 2010; Zhang et al., 2010, 2012). Graded zirconia blanks were further processed into anatomic restorations by the CAD/CAM technique; these restorations showed superior optical properties to monolithic zirconia restorations (Zhang et al., 2012). However, the translucency of the infiltrated products was not as high as that of layered zirconia restorations (Zhang et al., 2012). Thus, it can be said that layered zirconia materials are irreplaceable unless the zirconia can be made much more translucent. The abovementioned reports provided new insights into the design of functionally graded structures that can be highly beneficial for designing next-generation all-ceramic restorations. Thus, we hypothesized that a graded glass–zirconia structure may strengthen the core–veneer bond and enhance the durability of dental restorations.

The Schmitz–Schulmeyer test method (Schmitz and Schulmeyer, 1975), a planar interface shear bond test, is based on minimal experimental variables and has considered to be a reliably well-suited test set up for metal ceramic bond strength method (Hammad and Talic, 1996). Therefore, the method was then transferred for the application of all-ceramic systems (Luthardt et al., 1999) and chosen for the present study.

The purpose of this study was to evaluate the core–veneer bond of layered zirconia restorations by utilizing a glass–zirconia functionally graded material. In this study, a graded glass–zirconia structure was fabricated by infiltrating glass compositions into a presintered Y-TZP substrate by the action of capillary forces. The wettability of the infiltrated glass and Y-TZP substrate, as well as the microstructure and physical and mechanical properties of the graded glass–zirconia structure were also investigated.

2. Materials and methods

2.1. Preparation of specimens

2.1.1. Preparation of silicate glass compositions

A new family of glass – La_2O_3–SiO_2–B_2O_3–BaO–Al_2O_3–ZrO_2–Y_2O_3–TiO_2–CaO – was selected in this study. The main components

Table 1 – Chemical composition and coefficient of thermal expansion (CTE) of glass and Y-TZP.

Material	Manufacturer	Main components [wt%]	CTE [10^{-6} K^{-1}]
Glass compositions		La_2O_3 20.0; SiO_2 20.0; B_2O_3 15.0; BaO 15.0; Al_2O_3 10.0; ZrO_2 5.0; Y_2O_3 5.0; TiO_2 4.0; CaO 4.0	9.2 (Zhu and Yu, 2005)
Y-TZP	Tosoh, Tokyo, Japan	Y_2O_3 5.18, ZrO_2 94.82	10.5 (Zhang and Kim, 2009)
Vita VM9	Vita Zahnfabrik, Bad Säckingen, Germany	Confidential	9.1–9.2 (Kim et al., 2006)