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Mechanical properties of zirconia reinforced lithium silicate glass-ceramic

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ABSTRACT

Objective. The aim of this study was to assess the mechanical properties of recently introduced zirconia reinforced lithium silicate glass-ceramic.
Methods. Two types of CAD/CAM glass-ceramics (Vita Suprinity (VS); zirconia reinforced lithium silicate and IPS e.max CAD (IC); lithium disilicate) were used. Fracture toughness, flexural strength, elastic modulus, hardness, brittleness index, and microstructures were evaluated. Data were analyzed using independent *t* tests. Weibull analysis of flexural strength data was also performed.
Results. VS had significantly higher fracture toughness (2.31 ± 0.17 MPa $m^{0.5}$), flexural strength (443.63 ± 38.90 MPa), elastic modulus (70.44 ± 1.97 GPa), and hardness (6.53 ± 0.49 GPa) than IC ($P < 0.001$). On the other hand, VS glass-ceramic revealed significantly a higher brittleness index ($2.84 \pm 0.26\ \mu m^{-1/2}$) (lower machinability) than IC glass-ceramic ($P < 0.05$). VS demonstrated a homogeneous fine crystalline structure while, IC revealed a structure with needle-shaped fine-grained crystals embedded in a glassy matrix. The VS glass-ceramic revealed a lower probability of failure and a higher strength than IC glass-ceramic according to Weibull analysis.
Significance. The VS zirconia reinforced lithium silicate glass-ceramic revealed higher mechanical properties compared with IC lithium disilicate glass-ceramic.

1. Introduction

In recent years, various CAD/CAM-machinable ceramic materials have been developed in order to enable the esthetic demands of prosthetic restorations to be accomplished [1]. This continuous enhancement is based on the excellent properties of ceramics including better esthetics, biocompatibility, wear resistance, and chemical stability [2,3]. The clinical selection of ceramic systems is based on the mechanical and optical properties of the materials [4].

Utilization of zirconia, as a core material, has enhanced the mechanical properties of all-ceramic restorations [5,6]. Zirconia copings for crowns or multi-unit frameworks still need application of veneering ceramics to achieve appropriate esthetics [5,6]. However, chipping/delamination of the

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veneering ceramic has been reported as the most frequent complication of bilayered zirconia restorations [7–10]. There are several factors that affect the adhesion between zirconia core and veneering ceramic due to the two dissimilar material phases, including chemical bonding, mechanical interlocking, wetting properties, and the degree of interfacial stress generated *via* thermal expansion mismatch and glass transition temperature differences [5,11]. Continuous searching and developing of ceramic materials with enhanced mechanical properties along with appropriate esthetics are required.

In recent years, monolithic glass-ceramic materials have been developed in order to provide exceptional esthetics without requiring a veneering ceramic [12]. It has been reported that greater structural integrity can be accomplished by eliminating the veneered ceramic and its requisite bond interface [12,13]. The relative strength of the available glass-ceramic material has typically been the limitation of these restorations [12].

Lithium disilicate ceramic restoration (IPS e.max CAD; Ivoclar Vivadent, Schaan, Lichtenstein) is one of monolithic ceramic systems that have gained popularity for anterior and posterior single crowns and partial coverage restorations because of its superior physical properties [4,14]. Lithium disilicate ceramic restorations can be fabricated with a heat-pressed or CAD/CAM fabrication process [15]. Lithium disilicate was firstly introduced as a substructure or core material characterized by better translucency than other high strength ceramic core materials [16]. Due to enhanced translucency and different shades of lithium disilicate makes feasible anatomically contoured monolithic restorations [17]. The machinable lithium disilicate ceramic blocks consist of a metasilicate phase and display a bluish color. After milling the restoration from the blank, the metasilicate phase is transferred to the final lithium disilicate structure, obtained by a crystallization firing at 840 °C for 25 min [18]. It has been reported that clinicians should be aware while choosing lithium disilicate as a single crown restoration due to medium-term survival is limited [19]. In addition, for fixed dental prostheses, caution is advised for the use of lithium disilicate until further clinical evidence shows favorable long-term results [19].

Recently, a zirconia reinforced lithium silicate glass ceramic (Vita Suprinity; Vita Zahnfabrick, Bad Säckingen, Germany) for dental CAD/CAM applications for the fabrication of inlays, onlays, partial crowns, veneers, anterior and posterior crowns and anterior and posterior single tooth restorations on implant abutments has been introduced to the dental market. This new glass ceramic is enriched with zirconia (≈10% by weight). It is the first zirconia reinforced lithium silicate ceramic. The manufacturer has claimed that this newly developed generation of glass ceramic materials combines the positive material characteristics of zirconia (ZrO_2) and glass ceramic. The zirconia particles are incorporated in order to reinforce the ceramic structure by crack interruption. It has been supposed that the structure which is obtained after crystallization, exhibits enhanced mechanical properties and fulfills the highest esthetic requirements. It is anatomically contoured as monolithic restoration due to enhanced translucency and different shades [20]. Thus, the aim of this study was to evaluate and compare the mechanical properties of recently introduced zirconia reinforced lithium silicate glass-ceramic with lithium disilicate. The null hypothesis tested was that there is no difference in the mechanical properties between the two CAD/CAM glass-ceramic materials.

2. Materials and methods

Two types of ceramics were used in this study: zirconia reinforced lithium silicate glass-ceramic (Vita Suprinity; VS) and lithium disilicate glass-ceramic (IPS e.max CAD; IC). The manufacturers and the compositions of the materials used in this study are presented in Table 1. The VS and IC specimens with the required dimensions for each test were cut out from respective blocks using water cooled low-speed diamond saw (Isomet, Buehler GmbH, Düsseldorf, Germany) and polished. After that, the specimens were fully crystallized using a Programat P500 furnace (Ivoclar-Vivadent, Schaan, Liechtenstein) following the respective manufacturer's recommendations.

2.1. *Fracture toughness*

Fracture toughness (K_{Ic}) was evaluated using the V-notched-beam test according to the ASTM C1421-10 standard [21]. Thirty bar-shaped specimens (18 mm × 4 mm × 3 mm) of each glass-ceramic material were fabricated from their respective CAD/CAM blocks using a diamond saw (Isomet, Buehler). The specimens were polished using a series of SiC papers (Struers, Copenhagen, Germany) followed by 1 μm diamond paste (Buehler, Düsseldorf, Germany). The V-notch was formed using a razor blade attached to a customized metallic device that applied a constant load of 10 kg on the razor blade with a constant back-and-forth movement. The notch tips were polished using 3 μm and 1 μm diamond paste (Buehler, Düsseldor). The notch depth was 0.8–1.0 mm. The specimens were cleaned in a sonic (Bandelin Sonorex, Bandelin, Berlin, Germany) bath filled with alcohol for 5 min and then fully crystallized. The specimens were tested in a three-point bending fixture mounted in a universal testing machine (Model TT-B, Instron Corp., Canton, MA, USA) and loaded until fracture with a cross-head speed of 0.5 mm/min [22,23]. The K_{Ic} (MPa $m^{0.5}$) was calculated using the following equation [21]:

$$K_{Ic} = g\left[\frac{P_{max}S_0 10^{-6}}{BW^{3/2}}\right]\left[\frac{3[a/W]^{1/2}}{2[1-a/W]^{3/2}}\right] \quad (1)$$

where

$$g = g\left(\frac{a}{W}\right)$$

$$= \frac{1.99-[a/w][1-(a/w)][2.15-3.93[a/w]+2.7[a/w]^2]}{1+2[a/w]} \quad (2)$$

P_{max} is the load to failure (N), S_0 is the distance between the center of the rollers (16 mm), W is the specimen width, B is the specimen thickness, and a is the depth of the notch. The fractured specimens were sputtered with a gold layer (SPI-Module Sputter Coater, Structure Probe Inc., West Chester, PA, USA) and then examined using a scanning electron microscopy