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Short Communication

Influence of nano-ZrO_2 additive on the bending strength and fracture toughness of fluoro-silicic mica glass–ceramics

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ABSTRACT

Fluoro-silicic mica glass–ceramics were prepared by a sintering process and different proportions of nano-ZrO_2 particles (3Y-TZP) were integrated during the process. Bending strength and fracture toughness were evaluated using a three-point bending test and a Vickers indenter, respectively. The bending strength and fracture toughness improved in significantly with the increase in the quantity of nano-ZrO_2 additives. The highest bending strength of 324.3 ± 12.3 MPa and fracture toughness of 4.2 ± 0.11 MPa $m^{1/2}$ were obtained with 30% (wt.) nano-ZrO_2. Good results were also obtained in morphological observations. The glass–ceramic is homogenous and the ZrO_2 grains embed in the lamellar structures of the fluoro-silicic mica homogenously and completely and array well and compactly. On the fracture surface, both the transgranular fracture and the intergranular fracture can be observed clearly.

1. Introduction

Dental ceramic materials possess good biological properties and natural tooth-like color and luster, and thus have potential for providing excellent aesthetic qualities for dental prostheses. Fluoro-silicic mica glass–ceramic is a common dental glass–ceramic material in which lamellar mica crystals are evenly spread in a glass substrate. The phase interfaces in this compound are relatively weak and the crystal particles are dissociated easily, making the material machinable [1,2]. Fluoro-silicic mica glass–ceramics are thus commonly applied in advanced dental computer aided design/computer aided manufacture (CAD/CAM) systems for processing dental prostheses [3–5]. However, high fragility and low strength make it difficult for fluoro-silicic mica glass–ceramics to meet the demands of the mechanical properties (bending strength: 300 MPa) required for dental prostheses [6,7]. These disadvantages have hampered its application in the dental clinical field, and currently it is only used to process veneers, in-lays and crowns with a low bending strength requirement.

Studies have shown that Zirconium dioxide (ZrO_2) can toughen glass–ceramics. ZrO_2 has been applied in the preparation of baria–silica system glass–ceramics, lithium–silica system glass–ceramics and fluoro-calcium mica glass–ceramics [8,9]. However, there are no reports on the application of ZrO_2 in fluoro-silicic mica glass–ceramics.

Melting and sintering are the main processes used in the preparation of fluoro-silicic mica glass–ceramic blocks used in the dental CAD/CAM systems. Compared with the melting process, the sintering process has the advantage of having a lower processing temperature, shorter processing time and a higher proportion of crystal phases. It is also easier to integrate other useful materials into the glass–ceramic during the sintering process. Fluoro-silicic mica glass–ceramics ($KMg_{2.5}Si_4O_{10}F_2$) were prepared here using the sintering method, and the toughening effect of nano-ZrO_2 particles was evaluated.

2. Experimental

2.1. Sample preparation

Analytical reagent powders of raw materials were mixed in the proportion [13.5 MgF_2–2.25 Al_2O_3–4.5 B_2O_3–3 P_2O_5–15 MgO–84 SiO_2–21 K_2O–4.5 rest (wt.%)]. The mixed powder was melted in a platinum crucible at 1475 °C for 2 h and then the melt was quenched in cold water to obtain the glass frit. Nanoscale ZrO_2 particles (Nano-ZrO_2, particle size: 50 nm) of Y_2O_3 (3.0 mol.%) stabilized tetragonal Zirconia polycrystalline (3Y-TZP) were added to the glass frit in the different proportions, which were 0 wt.% (ZrO_2-0 group), 5 wt.% (ZrO_2-5 group), 10 wt.% (ZrO_2-10 group), 20 wt.% (ZrO_2-20 group) and 30 wt.% (ZrO_2-30 group) as shown in Table 1.

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