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Bio-inspired nacre-like zirconia/PMMA composites for chairside CAD/CAM dental restorations

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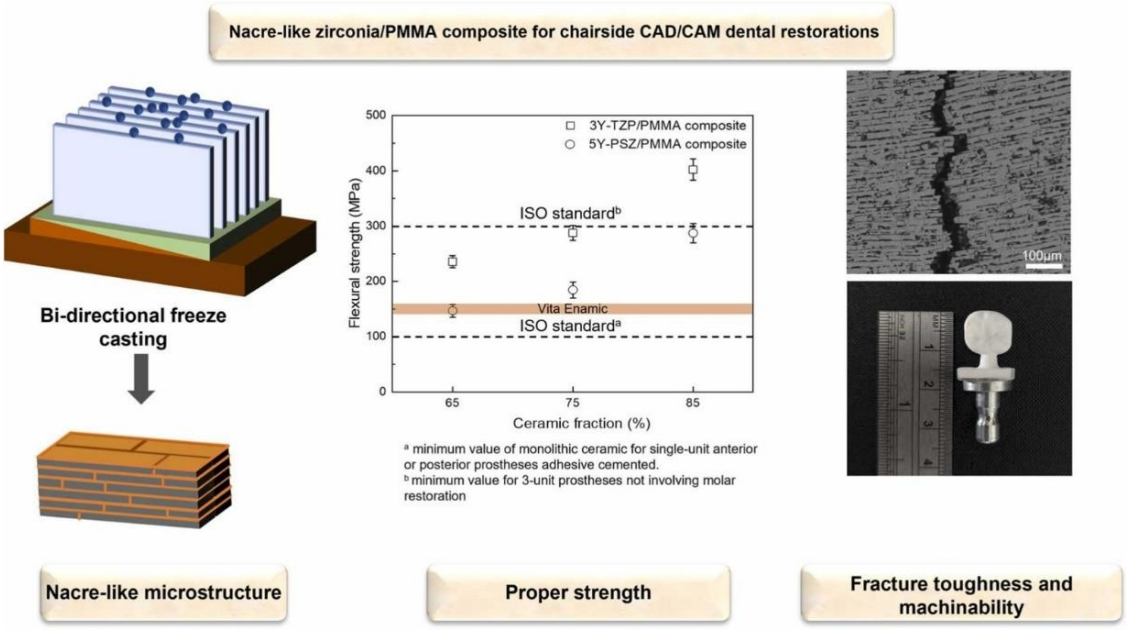
Project: Bio-inspired nacre-like zirconia/PMMA composites for dental chairside CAD/CAM restorations



Abstract

Zirconia is a promising ceramic material with outstanding strength in dental CAD/CAM applications. However, the mismatched hardness and modulus with the human tooth and the chipping and fracture caused by its higher brittleness compared to other restorative dental materials, like dental resin composite, limit its clinical performance. On the other hand, most of the current dental zirconia could not be applied as a chairside CAD/CAM material due to its high hardness. Zirconia can be endowed with different properties by adding stabilisers such as yttria

with different content. Among them, the three mol% yttria stabilised tetragonal zirconia polycrystal (3Y-TZP) is characterised by outstanding mechanical properties, while the five mol% yttria partially stabilised zirconia (5Y-PSZ) present better aesthetics and ageing-resistance, but inferior mechanical properties.

On the other hand, the polymer-infiltrated-ceramic-network (PICN), with a sintered porous ceramic matrix infiltrated with polymer, offers a way to achieve proper strength, crack resistance and tooth-matched hardness, has been used as a promising chairside CAD/CAM dental material. Moreover, efforts of bio-inspiration have been made to fabricate composite mimicking the 'brick and mortar' microstructure of nacre, which has both high strength and toughness. As a result, zirconia could be incorporated into PICN with a nacre-like microstructure to fabricate dental CAD/CAM restoration.

This study fabricated two types of bio-inspired nacre-like zirconia/PMMA composite via bi-directional freeze casting. The hierarchical structure is presented as a similar 'brick and mortar' structure of the nacre. Excellent flexural strength (up to 350 MPa and 230 MPa for 3Y-TZP/PMMA and 5Y-PSZ/PMMA composite, respectively), hardness and modulus within the range of those of enamel and dentine, and an increasing crack-resistance behaviour during crack propagation have been shown in both zirconia composites. Several extrinsic toughening mechanisms, such as crack deflection, ceramic bridges, and pull-out of the ceramic walls, were characterised under in-situ SEM during the fracture toughness testing. In addition, the 5Y-PSZ/PMMA composite presented better total transmittance in the trans-layer direction than the 3Y-TZP/PMMA composite.

These two zirconia/PMMA composites exhibit dental CAD/CAM application potential. Their mechanical properties are competent to be used as dental restorations and matched to those of human enamel. The nacre-mimetic-originated crack resistance could ensure better long-term clinical performance.