

Bonding measurement —Strength and fracture mechanics approaches

Chuchai ANUNMANA and Wiroj WANSOM

Department of Prosthodontics, Faculty of Dentistry, Mahidol University, 6 Yothi st., Rajthewi, Bangkok 10400, Thailand
Corresponding author, Chuchai ANUNMANA; E-mail: Chuchai.anu@mahidol.edu

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This study investigated the effect of cross-sectional areas on interfacial fracture toughness and bond strength of bilayered dental ceramics. Zirconia core ceramics were veneered and cut to produce specimens with three different cross-sectional areas. Additionally, monolithic specimens of glass veneer were also prepared. The specimens were tested in tension until fracture at the interface and reported as bond strength. Fracture surfaces were observed, and the apparent interfacial toughness was determined from critical crack size and failure stress. The results showed that cross-sectional area had no effect on the interfacial toughness whereas such factor had a significant effect on interfacial bond strength. The study revealed that cross-sectional area had no effect on the interfacial toughness, but had a significant effect on interfacial bond strength. The interfacial toughness may be a more reliable indicator for interfacial bond quality than interfacial bond strength.

Keywords: Interfacial toughness, Fractography, Microtensile, Zirconia

INTRODUCTION

Esthetic dental restorations have long been used with success. Introduced in the late 1940s, porcelain-fused to-metal (PFM) fixed dental prostheses (FDPs) have been continued to be the most common complete-coverage anterior restorations. This type of restoration has lessened in popularity due to esthetics, biocompatibility, and a concern of metals. Recently, the newly developed high-strength core ceramics, such as zirconia and alumina were introduced as alternatives for metals. Zirconium dioxide or zirconia (ZrO_2) has a flexural strength similar to that of steel, and it has been used as an alternative to metal for substructure of fixed dental prostheses. Nevertheless, high strength cores are used to support more esthetic, more translucent, but weaker glass veneers. In addition, since all-ceramic restorations are usually fabricated as bilayered structures, failures were frequently reported as delamination or chipping of the glass veneer as a risk of using these materials. An increasing number of clinical failures have been reported as the crack extension in the veneering glass¹⁻⁶.

Shear and microtensile bond tests have been used to investigate the bond strength of two substrates, however, shear bond test creates the fracture away from the interface because of the nonuniform stress distribution⁷ and specimen geometry⁸. Microtensile bond test first developed to determine the bond strength between tooth structure and adhesive materials⁹, and was also used to test bond strength of core-veneer ceramics¹⁰. Microtensile test produces relatively uniform stress distribution. However, most of the tests did not identify the failure origins or all the failure modes were included in the bond strength value. When the interfacial strength is comparable to the cohesive strength of the

substrates, the failures tend to appear in the weaker substrate because of the higher probability of finding critical flaws in substrate due to the larger volume of the substrate than that of the interface. Moreover, the microtensile bond strength value is inversely related to the surface area of test specimens¹¹⁻¹⁴.

Veneering techniques either slurry-condensed (SC) or hot-pressing (HP) techniques have been studied and developed aiming to obtain the ultimate bond strength with zirconia substructure. Recent studies tried to overcome limitations of manual layering, such as voids or defects from nonhomogeneous material condensation, and therefore enhanced the core-veneer bond strength of zirconia restoration with hot-pressing technology^{1,10,15-17}. However, the depth of layered esthetics may be limited when pressable glass veneer was used because of the one-shade ingot¹⁸.

Concept of fracture toughness is generally accepted as an appropriate method comparing with the strength approach to determine the mechanical property. Because the strength value can vary with specimen dimensions and flaw distribution, the value will be higher if the smaller sizes of specimens are investigated. This is because the higher probability of finding the critical flaw in the larger specimens. The fracture toughness is assumed to be constant regardless of specimen dimension.

Fractographic analysis and fracture mechanics had been applied to dentistry in order to study experimentally and/or clinically failed specimens^{19,20}. Ceramics are prone to fracture that occurs with limited or no plastic deformation. Fortunately, their fracture patterns and fracture surface markings provide usefully interpretable information. An important step in fractographic analysis is pattern recognition. Fracture leaves telltale fracture patterns on the fracture surfaces. The existence of four distinct regions surrounding the failure initiation site

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