Interfacial strength and mechanisms of failure in porcelain veneer-zirconia core dental restorations

T Sui¹, AM Korsunsky¹ and TK Neo²,³

². Specialist Dental Group, Mount Elizabeth Medical Centre, Singapore
³. Faculty of Dentistry, National University of Singapore, Singapore

Email: tan.sui@eng.ox.ac.uk
Keywords: all-ceramic dental restoration, interface bonding, failure mode

Recent decades witnessed a considerable and continuous increase in demand for highly esthetic and natural-appearing dental restorations. Meanwhile, development of strong engineering ceramic materials took place. The above trends led to the adoption of sintered ceramics as new load-bearing components used in dental prosthetics [1]. Zirconia is one of the most attractive restorative materials due to its advantageous mechanical properties, biocompatibility and esthetic appearance. Veneering porcelains with mechanical properties far inferior to zirconia are used to coat the surface of zirconia to enhance the esthetic appearance of prostheses [2-4]. Nevertheless, porcelain-veneered zirconia restorations are prone to failure primarily by the fracture of the veneering layers [5]. In literature, the fracture of veneering layer has been the dominant failure mode [5,6]. Although many studies in this area have been published [2-4], further research is still needed.

In this paper, two samples of porcelain-veneered sintered zirconia restorations were supplied for analytical examination as examples of clinical failure. Environmental Scanning Electron Microscopy (ESEM) with Energy-Dispersive X-ray (EDX) analysis was carried out to investigate the nature of interfacial bonding and fracture. It is hoped that recommendations about possible procedures are likely to help avoid such failures in clinical practice.

EDX analysis was conducted on the broken surfaces within the region shown in Fig. 1. There is evidence of mutual diffusion of zirconium (Zr) and Si-rich porcelain to the depths of 300µm, which is the origin of good mechanical bonding between zirconia ceramic copings and porcelain veneers.

In most cases, the chippings were contained entirely within the porcelain layer without reaching the interface of zirconia core. Fig. 2 shows the surface of a porcelain-initiated crack in the chipping with crack located at or close to the occlusal surface. The localization of crack initiation was aided by identifying certain common features that are often observed in ceramic fractures, namely “wake hackle” and “arrest line”. Fig. 2(b) is the magnification of rectangular white box in Fig. 2(a), where the wake hackle and arrest line features are identified. Fractographic analysis shows that crack propagated from the two origins in Fig. 2(a). The observed cohesive fracture through the porcelain layer is in agreement with literature [7]. However, in some cases, the crack initiated close to or at the veneering surface may propagate across the unit and through the interface to cause final failure. Therefore, further investigation of the nature of interfacial fracture was conducted. Fig. 3(a) illustrates a region of oblique fracture in porcelain that propagated towards and along the interface of the underlying zirconia core structure (top left to bottom right), with distinct surface profile patterns. Further confirmation was sought by EDX analysis (Fig. 3(b)). It is apparent that the top left region of fracture surface is Si-rich (porcelain), while the bottom right region is rich in zirconium (core). Hence, for this case of very shallow crack location with respect to the interface, cohesive crack propagation within porcelain veneer eventually gives way to interfacial debonding that exposes the zirconia coping (adhesive failure), and a transition can be observed between interfacial fracture modes [2].

The preparation procedure used for porcelain naturally leads to the formation of gas bubbles that persist as defects within the veneering layer. Internal defects, lying close to the occlusal surface, increase the likelihood of crack initiation under the applied mastication load, and may lead to chipping mode cracking by connecting different defects.

Conclusions are made based on the ESEM and EDX analysis conducted for this paper. The strength of the zirconia-porcelain interface is derived from mutual diffusion of zirconium and silicon at the interface. Chipping mode fractures observed in the veneering porcelain indicated the dominance of the cohesive fracture. Adhesive fracture may only be observed in the case of crack
travelling at a very shallow angle to the interface. Failure of all-ceramic zirconia-based restorations by porcelain veneer chipping is a complex process that depends on a large number of factors. Pre-existing defects in the porcelain veneer may lead to chipping mode cracking and final failure. Exercising control over these fabrications appears to be a critical requirement for clinical practice.

References


Figure 1. EDX analysis results of interfacial bonding

Figure 2. Fractographic features in porcelain layer

Figure 3. EDX analysis of interfacial adhesive fracture