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Improving the functional design of dental restorations by adding a composite interlayer in the multilayer system: multi-aspect analysis

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Abstract

The performance of dental restorations has been a concern of dentists and engineers. One of the topics that have concentrated most effort has been the study of the properties of the interface between the veneering porcelain to metallic or ceramic substrates, namely on the improvement of the adhesion between the two materials and its behaviour under oral conditions. This paper discusses the benefits of placing a composite interlayer (50% metal + 50% ceramic, vol.%) at interface between metal and ceramic in a dental restoration. The discussion covers the following aspects: performance of this system under thermomechanical fatigue conditions, thermal and mechanical properties of the composite interlayer, thermal residual stresses arising after porcelain sintering and technical feasibility on a prosthetic laboratory.

Keywords: Metal-ceramic restoration; composite; mechanical properties; thermal properties; thermal residual stresses; thermal cycling; bond strength.

1. Introduction

Teeth are often lost due to disease or trauma that can affect mastication and aesthetics. The metal-ceramic restorations are still the most used prosthetics solution for missing teeth. A metal-ceramic dental prosthesis consists on a strong and stiff metallic substructure that is veneered by aesthetic porcelain that mimics the teeth appearance. These are considered reliable prostheses although the clinical failure due to fracture and exfoliation of the porcelain are reported as being up to 10% in periods of 10 years [1]. Achieving a good bond between the metal and ceramic can result in the production of more reliable restorations with lower failure rates. The following treatments have shown good results in the bond strength improvement between metal and ceramic: the addition of easy-oxide forming elements to noble alloys [2,3]; the coating of reactive metals surfaces (e.g. titanium alloys; CoCrMo alloys) with oxide-controlling elements [4-6]; the use of bonding agents [7,8]; pressure aided techniques [9,10], among others. Nevertheless, a significant increase in bond strength was demonstrated when a metal-ceramic composite was used as interlayer between the metallic substructure and the ceramic veneer [11-15]. The overall benefits of the employment of such composites are presented and discussed in this paper.

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2. Performance under thermomechanical fatigue conditions

Previous studies conducted by the same authors of this paper evaluated the presence of a composite interlayer on the bond strength of porcelain to metallic substrates in load to failure tests [11,12] and significant improvements in adhesion were observed relative to conventional metal-ceramic sharp transition interface configuration. Specimens with composite interlayer also showed better performance under thermomechanical fatigue tests [13]. In this study two interface designs were analyzed: A) a conventional sharp transition between metal and porcelain, and B) a composite interlayer (50%metal + 50%porcelain, vol.%) placed at the interface between metal and porcelain (Figure 1). Specimens with a sharp transition were produced by the conventional porcelain-fused-to-metal technique. The specimens having the composite interlayer were obtained by hot pressing, an equivalent process to porcelain injection used in dental prosthetic laboratories. Specimens were manufactured and standardized in cylindrical format and then submitted to thermal (3000, 6000 and 12000 cycles; between 5ºC and 60ºC; dwell time: 30s) and mechanical (25000, 50000 and 100000 cycles under a load of 50N; 1.6Hz) cycling, simulating the degradation at intra-oral conditions. The shear test was used to assess bond strength between metal and ceramic. The shear bond strength tests were carried out at room temperature and performed in a universal testing machine (Instron 8874, MA, USA), with a load cell of 25 kN capacity and under a crosshead speed of 0.5mm/s. Tests were performed in a custom-made stainless steel apparatus similar to that described by Henriques et al. [15].

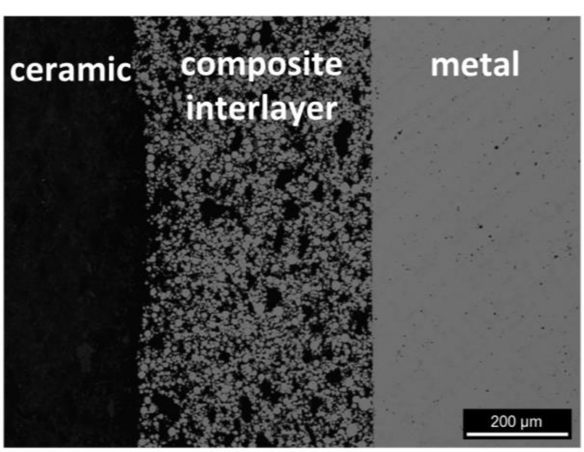

Fig. 1. Micrograph of the composite interlayer (at the center) between the metal (right) and porcelain (left).

The apparatus consisted in two sliding parts A and B, each one with a hole perfectly aligned to the other. After aligning the holes, the specimens were inserted and loaded at the interface until fracture. The shear bond strength (MPa) was calculated by dividing the highest recorded load (N) by the cross sectional area of resistant porcelain (mm^2).

The specimens with the composite interlayer performed significantly better under thermomechanical fatigue conditions, exhibiting significantly higher bond strength values after fatigue tests than those revealed by specimens with sharp transition (Figure 2). The improvement in bond strength exhibited by the former specimens relative to conventional sharp transition ones, before thermomechanical fatigue tests, was in excess of 130%. This value rose to 240% after the fatigue tests. The bond strength loss after thermomechanical fatigue tests was 11% for specimens with the composite interlayer and 43% for specimens with the conventional sharp transition.

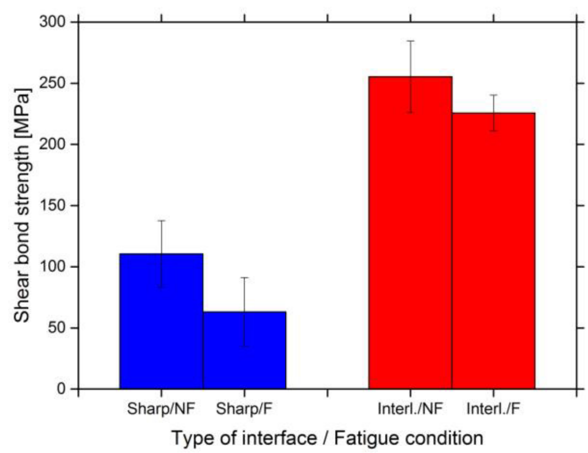

Fig. 2. Shear bond strength results of the two types of metal-ceramic interface designs (Sharp – sharp transition between metal and ceramic; Interl. – composite interlayer between metal and ceramic) and fatigue conditions (NF – Non submitted to fatigue conditions; F – submitted to fatigue conditions). Adapted from Henriques et al., 2012 [13])

The bond strength improvement mechanisms were explained by the bridging effects resultant from the bonds between the metallic particles and the metallic substrate and also between the metallic particles themselves [13,14]. The higher fracture toughness of the composite interlayer relative to the monolithic porcelain was also considered to be important.

Unlike conventional sharp transition specimens, where cracks propagated freely throughout the