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Effect of the infrastructure material on the failure behavior of prosthetic crowns

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ABSTRACT

Objectives. To evaluate the effect of infrastructure (IS) material on the fracture behavior of prosthetic crowns.

Methods. Restorations were fabricated using a metal die simulating a prepared tooth. Four groups were evaluated: YZ-C, Y-TZP (In-Ceram YZ, Vita) IS produced by CAD-CAM; IZ-C, In-Ceram Zirconia (Vita) IS produced by CAD-CAM; IZ-S, In-Ceram Zirconia (Vita) IS produced by slip-cast; MC, metal IS (control). The IS were veneered with porcelain and resin cemented to fiber-reinforced composite dies. Specimens were loaded in compression to failure using a universal testing machine. The 30° angle load was applied by a spherical piston, in 37 °C distilled water. Fractography was performed using stereomicroscope and SEM. Data were statistically analyzed with Anova and Student–Newman–Keuls tests ($\alpha = 0.05$).

Results. Significant differences were found between groups ($p = 0.022$). MC showed the highest mean failure load, statistically similar to YZ-C. There was no statistical difference between YZ-C, IZ-C and IZ-S. MC and YZ-C showed no catastrophic failure. IZ-C and IZ-S showed chipping and catastrophic failures. The fracture behavior is similar to reported clinical failures.

Significance. Considering the ceramic systems evaluated, YZ-C and MC crowns present greater fracture load and a more favorable failure mode than In-Ceram Zirconia crowns, regardless of the fabrication type (CAD-CAM or slip-cast).

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1. Introduction

Porcelain is a glass-based ceramic with low tensile strength and excellent esthetics [1,2]. Thus, metal infrastructures were often used to produce large and/or posterior restorations, such as fixed partial dentures. The development of high crystalline content ceramics and the introduction of new fabrication methods allowed for the replacement of metal infrastructures [3]. These all-ceramic restorations are also built in layers due to the opacity of the high crystalline content ceramic infrastructure [4–6].

Alumina and zirconia show several toughening mechanisms that could improve the mechanical behavior of ceramic materials. For alumina, toughening is primarily due to grain bridging in the wake of the propagating crack, which shields

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the crack tip from the applied load [7]. Zirconia crystals are associated to a well-known phase transformation toughening mechanism responsible for the enhancement of the material's fracture toughness [8,9]. Thus, zirconia-based ceramics, such as In-Ceram Zirconia (IZ) and yttria partially stabilized tetragonal zirconia (Y-TZP), can be used as infrastructure materials for crowns and fixed partial dentures. Zirconia-based structures are considered the best candidates to replace metal infrastructures [6]. In-Ceram Zirconia is an alumina-based zirconia-reinforced glass-infiltrated ceramic [10] and Y-TZP is a polycrystalline ceramic composed by tetragonal zirconia stabilized by yttria [1,8,11].

In addition to the differences in composition and crystalline content, there are differences in the fabrication methods used to produce ceramic restorations, which are related to microstructural features, such as pore and crystal distribution, presence of inclusions and flaws, which could influence the mechanical behavior of materials [1,11,12]. The majority of dental ceramics is available as blanks for processing using CAD-CAM technology (computer aided design–computer aided manufacture). The use of CAD-CAM blanks and standardized scanning and milling procedures could minimize the influence of the dental laboratory technician in the fabrication process resulting in restorations with a more uniform microstructure, less processing flaws and better adaptation [13–15]. However, literature findings are controversial [11,12,16].

Clinical studies report high survival rates for all-ceramic restorations. Infrastructure failures are unusual when the ceramic material is correctly indicated, varying from 2 to 6% [17–22]. Yet, the failure mode most frequently observed is chipping of the veneering material. This type of failure has been observed mainly when zirconia-based infrastructures are used, showing chipping rates that vary from 0 to 50%, depending on the follow-up period [17,19,23,24]. Yet, failure has been described as crack propagation from a contact damage zone throughout the veneering porcelain, reaching or not the interface, which can lead to delamination and exposure of the infrastructure material in the oral environment [25]. Among the factors related to such failure are: lack of porcelain support provided by the infrastructure [26,27], thermal incompatibility [28,29], low bond strength between materials and porcelain cooling protocol [30–32]. In addition, studies suggested that the chipping rate for metal-ceramic restorations is significantly lower, around 2% [19,33]. Therefore, the investigation of the failure behavior of prosthetic crowns produced with different infrastructure materials and fabrication methods should offer relevant clinical and scientific findings.

In vitro tests are frequently used to characterize the mechanical behavior of dental materials. However, these tests usually fail to induce the same stress state in which restorations are subjected in the oral cavity [34,35]. In vitro testing protocols that provide clinically valid information should be developed. To achieve this goal, the fractographic analysis is an important tool. Fractography is the analysis of the fracture surface that contains characteristic features produced by the interaction of the crack tip in propagation with the material's microstructure and stress fields. Through this analysis it is possible to identify the crack size and initiation site [36,37]. The failure behavior observed in vitro can be correlated with the behavior reported for restorations that failed in vivo [38–43].

Thus, considering the clinical problems of high porcelain chipping rates, this study investigated, in vitro, the influence of the infrastructure material on the failure behavior of prosthetic crowns. Two types of ceramic (In-Ceram Zirconia and Y-TZP) and a metal infrastructure (IS) were evaluated. The hypothesis tested is that different IS materials result in different fracture load values and failure modes. In addition, the influence of the fabrication method (CAD-CAM or slip-cast) on the failure behavior of In-Ceram Zirconia prosthetic crowns was also studied.

2. Materials and methods

The materials and fabrication methods used in this study are shown in Table 1. Ten restorations were produced for each experimental group.

The prosthetic crowns were designed based on a type 304 stainless steel die simulating a prepared first lower premolar, with 4.5 mm height, 6° axial taper and a 120° chamfer [16]. Impression (polyvinyl siloxane, Aquasil™ Soft Putty, high viscosity paste, and Aquasil™ Low Viscosity, Dentsply, Petropolis, RJ, Brazil) of the master metal die was taken and

Table 1 – Materials, composition and fabrication methods of the experimental groups ($n = 10$).

Group	IS material	Fabrication method	IS material composition	Porcelain[a]
YZ-C	Vita In-Ceram YZ[a]	CAD-CAM	Yttria partially-stabilized tetragonal zirconia polycrystal	Vita VM9
IZ-C	Vita In-Ceram ZIRCONIA[a]	CAD-CAM	Alumina-based zirconia-reinforced glass-infiltrated ceramic	Vita VM7
IZ-S	Vita In-Ceram ZIRCONIA[a]	Slip-cast	Alumina-based zirconia-reinforced glass-infiltrated ceramic	Vita VM7
MC	Wironia® light[b]	Casting	NiCr metal alloy	Vita VM13

[a] Vita Zahnfabrik, Bad Sackingen, Germany.
[b] BEGO, Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany.

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