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Effects of two grading techniques of zirconia material on the fatigue limit of full-contour 3-unit fixed dental prostheses

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ABSTRACT

Objective. This study evaluated the effects of two grading techniques of zirconia material on the fatigue limit of full-contour 3-unit fixed dental prostheses (FDPs).

Methods. Presintered blocks of 3Y-TZP were milled to obtain sixty-nine 3-unit FDPs, which were divided into three groups (n = 23). The control group (CTL) was sintered and glazed following manufacturer's instructions. In the two experimental groups presintered FDPs received a surface silica/glass infiltration treatment before the sintering process. Silica sol–gel group (SSG) was graded by the sol–gel processing route, while the glass-zirconia-glass group (GZG) was graded by an enameling technique. Graded groups did not receive a glaze layer after sintering. All FDPs were then luted with a dual-curing resin cement on composite abutments, embedded in polyurethane and stored in water for five days. The initial load of the fatigue test was calculated based on the results of the monotonic testing applied on three specimens of each group. To determine the fatigue limit, 20 samples of each group were subjected to staircase testing (100,000 cycles/5 Hz).

Results. The fatigue limits (in Newtons) were CTL = 1607.27, SSG = 1824.31, and GZG = 2006.57, and the Dixon and Mood test indicated statistically significant differences among groups (95% confidence interval) (GZG > SSG > CTL).

Significance. The infiltration of silica and glass on bulk zirconia, by two different grading methods, increased the fatigue limits of monolithic zirconia FDPs.

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1. Introduction

The advances in CAD/CAM (computer-aided design and manufacturing) technology made possible to produce full-contour or monolithic zirconia restorations with occlusal design that do not need to be veneered, thus avoiding the clinical problem of chipping of the veneering porcelain [1–3]. Conservative monolithic zirconia restorations with less than 1 mm thickness can be milled and still present strength similar or superior to that of metal–ceramic and lithium disilicate crowns [4–6]. However, concerns like the challenge of promoting enhanced adhesion between substrate and zirconia ceramic [7], aging (hydrothermal degradation) [8,9], and wear of antagonist teeth [10] have limited the use of monolithic zirconia.

When subjected to fatigue and moisture, zirconia-based materials suffer from stress corrosion, and their strength is compromised [9,11–14]. In the veneered zirconia restoration, the overlay porcelain protects zirconia against direct exposure to moisture, pH and temperature variations, and impact from chewing forces [11]. Conversely, monolithic zirconia restorations would have only a thin glaze layer on top. Indeed, investigators [15] have shown that glaze application prevents hydrothermal degradation. But, we must also consider that such a thin layer may be removed during function (wear) [16] and, consequently, that zirconia would again be prone to aging. In fact, recent research has shown that a glazed zirconia surface causes greater wear of the antagonist tooth relative to an as-polished surface [16,17]. Nevertheless, Hmaidouch and Weigl [2] considered that studies on this topic are subject to both evaluation and confounding bias, making it impossible to associate tooth wear with any specific causal agent.

A promising technique recently proposed for dental applications is the grading of zirconia [18–20]. The glass infiltration method, proposed by Zhang and Kim [20], on the surfaces of 3Y-TZP aims to promote better stress distribution, resulting in enhanced flexural strength compared with that achievable with monolithic zirconia [21]. The glass layer on the external surface also protects against hydrothermal degradation, avoids antagonist wear, and allows for color variations, improving the esthetics of monolithic restorations [22]. At the same time, the glass layer formed on the cementation surface of the restoration makes etching and silanization possible, improving adhesion to resin cements [23].

The main feature of functionally graded materials (FGM) such as the zirconia described above is a gradual variation of composition and/or phases, and consequently properties, inside the same material [24–26]. Another FGM processing route is silica infiltration of zirconia by a sol–gel method, which allows for the modification of the zirconia surface by reactive diffusion of silica into zirconia during the sintering process. This method does not require additional thermal treatment and forms a zirconium silicate, which affects the mechanical properties of zirconia and improves its structural homogeneity [27].

However, the ability of these next-generation functionally graded 3Y-TZP multiple-unit FDPs to resist fatigue damage remains unknown. Therefore, the purpose of this current study was to evaluate the effect of glass/silica infiltration on the fatigue limit of 3-unit fixed dental prostheses manufactured with monolithic 3 mol% Y-TZP. The null hypothesis was that the fatigue limit of monolithic zirconia bridges would not be affected by glass/silica infiltration.

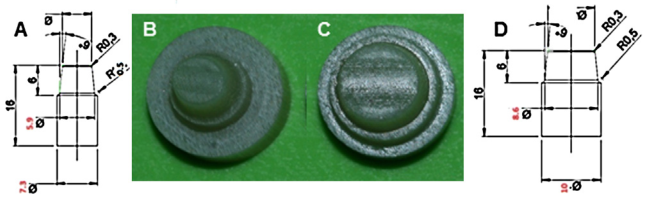

Fig. 1 – Specifications for premolar (A) and molar (D) preparations; (B, C) the dies were milled from dentin composite analogue (NEMA grade G10). Based on Campos et al. [28], 2016.

2. Materials and methods

2.1. Materials

Sixty-nine presintered 3Y-TZP blocks (40 × 15 × 14 mm, VITA In-Ceram YZ Vita for inLab, VITA) were milled to obtain 3-unit FDPs extending from the second mandibular premolar to the second mandibular molar. Main composition of the VITA In-Ceram® YZ for inLab® provided by the manufacturer is: zirconium dioxide (ZrO_2) 92.6 %mol, yttrium oxide (Y_2O_3) 5.3% wt %, hafnium oxide (HfO_2) < 3 wt%, aluminum oxide (Al_2O_3) and silicon dioxide (SiO_2) < 1 wt%.

2.2. Specimen preparation

The dies (2nd mandibular premolar and 2nd mandibular molar) were milled from a dentin composite analogue (NEMA grade G10, Accurate Plastics Inc., Falmouth, MA, USA). The prosthetic preparations had the following caracteristics [28]: 6 mm in height; 120° circumferential chamfer (radius = 0.5 mm); 6° occlusal convergence angle (Fig. 1A, D); all transitions from the axial to the occlusal surfaces were rounded, and a central mesiodistal sulcus was simulated on the occlusal surface (Fig. 1B,C).

Using a adapted surveyor for keeping long-axis of preparations perpendicular to the ground (x axis), the abutments were embedded into polyurethane (F 16Polyol e F 16 ISO, Axson Technologies, Eaton Rapids, MI, USA) at distances of 17 mm from each other. The obtained sets were scanned (InEos, Sirona Dental Systems GmbH, Bensheim, Germany), and the corresponding three-unit FDPs were created in a CAD system (inLab SW4.2, Sirona) according to the requirements for full anatomic restorations of posterior teeth: the minimum wall thickness was 0.7 mm in the occlusal area, 0.7 mm from the bottom of the fissure, 0.5 at the lateral walls, and 0.2 mm at the cervical region, and anatomical connectors were within the minimum section area of 9 mm^2. The milling of the restorations was performed with a CAM unit (CEREC InLab MC XL, Sirona Dental Systems GmbH, Bensheim, Germany), under constant water cooling. After being milled, the restoration was separated from the block-holder, and each one of them was evaluated by stereomicroscopy (Discovery V20, Carl Zeiss,