dental materials xxx (2018) xxx–xxx

Available online at www.sciencedirect.com

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Crystallographic and morphological analysis of sandblasted highly translucent dental zirconia

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ARTICLE INFO

Article history:
Received 21 June 2017
Received in revised form
22 November 2017
Accepted 20 December 2017
Available online xxx

Keywords:
Zirconia
Alumina sandblasting
Stress
XRD
Micro-Raman

ABSTRACT

Objective. To assess the influence of alumina sandblasting on four highly translucent dental zirconia grades.

Methods. Fully sintered zirconia disk-shaped specimens (15-mm diameter; 0.5-mm thickness) of four highly translucent yttria partially stabilized zirconia (Y-PSZ) grades (KATANA HT, KATANA STML, KATANA UTML, Kuraray Noritake; Zpex Smile, Tosoh) were sandblasted with 50-μm alumina (Al_2O_3) sand (Kulzer) or left 'as-sintered' (control) (n = 5). For each zirconia grade, the translucency was measured using a colorimeter. Surface roughness was assessed using 3D confocal laser microscopy, upon which the zirconia grades were statistically compared for surface roughness using a Kruskal–Wallis test (n = 10). X-ray diffraction (XRD) with Rietveld analysis was used to assess the zirconia-phase composition. Micro-Raman spectroscopy was used to assess the potentially induced residual stress.

Results. The translucency of KATANA UTML was the highest (36.7 ± 1.8), whereas that of KATANA HT was the lowest (29.5 ± 0.9). The 'Al_2O_3-sandblasted' and 'as-sintered' zirconia revealed comparable surface-roughness Sa values. Regarding zirconia-phase composition, XRD with Rietveld analysis revealed that the 'as-sintered' KATANA UTML contained the highest amount of cubic zirconia (c-ZrO_2) phase (71 wt%), while KATANA HT had the lowest

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https://doi.org/10.1016/j.dental.2017.12.008

amount of c-ZrO_2 phase (41 wt%). KATANA STML and Zpex Smile had a comparable zirconia-phase composition (60 wt% c-ZrO_2 phase). After Al_2O_3-sandblasting, a significant amount (over 25 wt%) of rhombohedral zirconia (r-ZrO_2) phase was detected for all highly translucent zirconia grades.

Significance. Al_2O_3-sandblasting did not affect the surface roughness of the three highly translucent Y-PSZ zirconia grades, but it changed its phase composition.

1. Introduction

Zirconia-based restorations are now frequently applied in dentistry, thanks to their esthetics, biocompatible properties, easier and even cheaper fabrication as compared to the conventional porcelain-fused-to-metal (PFM) restorations [1,2]. Since 2014, more esthetic highly-translucent zirconia has been introduced into dentistry. According to Makhija et al., full-contour restorations made by highly translucent zirconia are becoming the first choice to restore posterior teeth in the US [3].

Interestingly, the phase composition of the highly translucent zirconia is different from that of conventional yttria-stabilized tetragonal zirconia polycrystals (Y-TZP). Due to a higher Y_2O_3-stabiliser content (up to 9.42 wt% as compared to approximately 5.15 wt% for conventional zirconia, both according to the product information of zirconia powder from Tosoh), this highly translucent zirconia contains a significant amount of cubic zirconia (c-ZrO_2) phase and lower amount of alumina (Al_2O_3), rendering this zirconia more translucent. Moreover, such highly translucent zirconia ceramics are hydrothermally stable, because c-ZrO_2 grains do not transform to the monoclinic zirconia (m-ZrO_2) phase. A large amount of c-ZrO_2, on the other hand, results in a decrease in mechanical properties, especially in terms of strength and fracture toughness.

In order to adhesively lute zirconia-based restorations, specific pre-treatments are necessary to improve the surface properties and bonding receptiveness. According to a recent meta-analysis on the bonding effectiveness to zirconia ceramics, the combined mechanical and chemical surface pre-treatment of the zirconia surface was found essential to achieve durable bonding to zirconia [4]. Because zirconia ceramics exhibit stress-induced transformation, sandblasting will transform the surface structure, i.e. constrain as well as damage, which may influence its long-term performance [5,6]. At the moment, however, only few papers reported on the influence of surface treatments on highly translucent zirconia [7–9]. The objective of this study was therefore (1) to investigate the translucency and crystallographic characteristics of four highly translucent zirconia grades and (2) to assess the influence of Al_2O_3 sandblasting on the same four highly translucent dental zirconia grades. The null hypotheses tested were (1) that there is no difference in translucency and crystallographic characteristics among the four highly translucent zirconia grades and (2) that Al_2O_3 sandblasting does not affect the surface and crystallographic properties of highly translucent dental zirconia.

2. Materials and methods

The study design is schematically explained in Fig. 1. A summary of the characteristics and properties of the investigated highly translucent zirconia is provided in Table 1. Fully sintered zirconia disk-shaped specimens (15-mm diameter; 0.5-mm thickness) of four highly translucent yttria partially stabilized zirconia (Y-PSZ) grades (KATANA HT, KATANA STML, KATANA UTML, all Kuraray Noritake, Tokyo, Japan; Zpex Smile, Tosoh, Tokyo, Japan) were provided by the manufacturer, Kuraray Noritake (Table 1). One side of the specimens was ground and mirror polished to obtain the standardized thickness. All specimens were obtained in the form of sintered disks from the supplier and all surface treatments were directly applied to the pristine "as-sintered" side, which was not ground, nor polished during specimen preparation. The specimens were ultrasonically cleaned in acetone for 10 min and thoroughly dried with compressed air. All specimens of each grade were assigned into two groups of four specimens each and either were kept as-sintered (untreated) or sandblasted with 50-μm Al_2O_3 sand (Kulzer, Hanau, Germany) at 0.2 MPa for 15 s/cm^2 at a distance of 10 mm using a sandblasting device (Jet Blast II, Morita, Tokyo, Japan). Only the top surface received the surface treatment.

For each zirconia grade, the color and spectral reflectance were measured using a colorimeter (CR-13; Konica-Minolta Sensing, Tokyo, Japan). In this procedure, only the as-sintered specimens (n = 5) from each zirconia grade were measured over a black (CIE L^* = 28.4, a^* = −1.1 and b^* = −0.1) and a white (CIE L^* = 94.1, a^* = −0.4 and b^* = 1.1) background using a coupling medium (glycerin) applied between the zirconia specimens and the white and black background boards [10]. The as-sintered and mirror polished surface was used as the top- and backside, respectively. The translucency was obtained by calculating the color difference between the specimen with a white and black background: $TP = [(L_B - L_W)^2 + (a_B - a_W)^2 + (b_B - b_W)^2]^{1/2}$, where the subscripts refer to the color coordinates with, respectively, the black (B) and white (W) background [11]. The translucency was statistically compared for the four zirconia grades using one-way ANOVA followed by Tukey post hoc test.

One specimen from each zirconia grade was used for microstructural investigation using scanning electron microscopy (SEM, JSM-6701F, JEOL, Japan). After coating with a thin layer of osmium (Neo Osmium Coater, Meiwafosis, Tokyo, Japan), secondary electron SEM images were acquired in vacuum (10^{-5} mbar), an acceleration voltage of 10 kV and a beam current of 144 μA. The applied magnification was ×10,000 for