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Impact of gastric acidic challenge on surface topography and optical properties of monolithic zirconia

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ABSTRACT

Objective. To evaluate the surface topography and optical properties of monolithic zirconia after immersion in simulated gastric acid.

Materials and methods. Four partially stabilized (PSZ) and one fully stabilized (FSZ) zirconia materials were selected for the study: Prettau (PRT, Zirkonzahn), Zenostar (ZEN, Ivoclar), Bruxzir (BRX, Glidewell), Katana (KAT, Noritake) and FSZ Prettau Anterior (PRTA, Zirkonzahn). IPS e.max (Ivoclar) was used as a control. The specimens ($10 \times 10 \times 1.2$ mm, $n = 5$ per material) were cut, sintered, polished and cleaned before immersed in 5 ml of simulated gastric acid solution (Hydrochloric acid (HCl) 0.06 M, 0.113% solution in deionized distal water, pH 1.2) for 96 h in a 37 °C incubator. Specimens were weighed and examined for morphological changes under scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscopy (EDX). Surface roughness was evaluated by a confocal microscope. Surface gloss and translucency parameter (TP) values were determined by a reflection spectrophotometer before and after acid immersion. The data was analyzed by one-way ANOVA followed by Tukey's HSD post hoc test ($p < 0.05$).

Results. PRTA displayed the most weight loss (1.40%) among the zirconia specimens. IPS e.max showed about three times more weight loss (3.05%) than zirconia specimens as an average. SEM examination indicated areas of degradation, bead-like shapes and smoothening of the polishing scratches after acid immersion. EDX displayed ion interactions and possible ion leaching from all specimens. S_a and S_q values for PRTA, ZEN and IPS e.max were significantly lower ($p < 0.05$) after acid immersion. TP values increased significantly for PRT, ZEN and IPS e.max ($p < 0.05$), while the surface gloss of ZEN, PRTA and IPS e.max increased ($p < 0.05$).

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Significance. Monolithic zirconia materials show some surface alterations in an acidic environment with minimum effect on their optical properties. Whether a smoother surface is in fact a sign of true corrosion resistance or is purely the result of an evenly progressive corrosive process is yet to be confirmed by further research.

1. Introduction

Over the last 20 years, dental erosion causes, diagnosis and management has become a topic of interest in general dentistry. The awareness of the potential ramifications of erosive acids has shown an increase in recent years. Dental erosion is defined as the "loss of tooth structure due to nonbacterial chemical causes" [1]. The acid attack dematerializes the tooth surface, rendering it prone to further abrasive wear [2], thus the term "erosive tooth wear" was coined [3]. The erosive acids can be of intrinsic origin as in stomach acid, or extrinsic as in acidic beverages and food [4]. The pH and erosive ability of gastric acid is significantly greater than dietary acids and so the level of destruction is normally more severe. Gastric acid gains access to the oral cavity through vomiting or regurgitation. Eating disorders such as anorexia and bulimia nervosa are well-known etiologic factors in the development of dental erosion. While regurgitation, defined as involuntary movement of the gastric contents from the stomach into the mouth, has also been acknowledged as a common cause of severe dental erosion [5]. A common feature of medical conditions causing gastric acid movement into the oral cavity is gastroesophageal reflux disease (GERD). It has been reported that 10–20% of the population suffers from GERD [6]. The correlation between GERD and dental erosion is either presented as patients with GERD who are then found to have dental erosion and patients with dental erosion who are then found to have GERD. A recent systematic review by Pace et al. reported the prevalence of dental erosion in GERD patients as 24% and that about 33% of patients with dental erosion have GERD [7]. Gastric acid has an extremely low pH (<2.0), way below the critical pH of enamel (5.5), thus the potential for erosive damage of the tooth is rather high. Sufficient salivary flow and salivary buffering capacity acts as antagonists to acid attacks. GERD is an involuntary response not coordinated by the autonomic nervous system. Therefore, there may be insufficient time for saliva to act before erosion occurs [8]. For the aforementioned reasons, and in addition to gastric acid composition, which is mainly composed of 0.1 M Hydrochloric acid (HCl) (pH around 0.5%), gastric acid may be considered the most dangerous erosive acid to induce loss of the dental hard tissues, and can eventually lead to reduction of the person's vertical dimension of occlusion. Rehabilitation of such cases can be rather challenging, and the strive is to save as much tooth substance as possible.

Restoring eroded tooth structure can be executed with either direct or indirect restorations. Only few studies in the literature have focused on the behavior of such restorations under acidic and erosive conditions. It is evident that hybrid and nano-hybrid composite resins have shown resistance to acid attacks, in contrast to glass-ionomer and polyacid-modified composite materials (compomers) [9,10]. In regards to indirect restorations, whether all ceramic or ceramic fused to metal/zirconia restorations, it has been reported that a 24 h immersion in simulated gastric acid (pH1.2) had no detectable effect on the surface roughness of different ceramics [11]. Another study reported that significant differences occurred among leached ion concentrations as a function of material type, solution pH and exposure time and conclude that ceramic veneers and glazes may be susceptible to considerable degradation in low and high pH buffer solutions [12]. The diversity of opinions is most likely due to differences in the compositions and microstructures of the evaluated ceramics but could also be the result of differences in experimental conditions. However, there is distinct evidence that strong acids as hydrofluoric acid, used to etch the intaglio surface of glass-based and feldspathic ceramic restoration before adhesively luting them to dental hard tissue, and acidulated phosphate fluorides (APF's) are able to etch the surface of glass and feldspathic-based ceramic materials. Chemical degradation of dental ceramics can lead to increased surface roughness, which may further promote abrasion of the opposing dentition, increase plaque accumulation and possibly release harmful elements from the ceramics [13]. Increased surface roughness may also cause stress concentrations to the material and provocate crack initiation and propagation.

With the increasing demands for esthetic restorations, possibility to produce full contour crowns and the assumed enhancements in bonding ability, monolithic zirconia has gained attention as a suitable material for restoring worn dentitions. To the knowledge of the authors, there has been no study examining the behavior of monolithic zirconia to gastric acid. Therefore, this study was set out to investigate the impact of simulated gastric acid on the surface topography and optical properties of monolithic zirconia materials.

2. Materials and methods

2.1. Specimen preparation

Monolithic zirconia specimens ($n = 5$/subgroup) of different brands and IPS e.max CAD (as a control) (Table 1) were prepared into square shaped specimens ($10 \times 10 \times 1.2$ mm) using a cutting device (Struers Secotom-50, Copenhagen, Denmark). Four partially stabilized zirconia (PSZ) materials and one fully stabilized zirconia (FSZ) (PRTA, Zirkonzahn) were selected for the study. The specimens were sequentially ground to the specific thickness using silicon carbide grinding paper (FEPA nos. 1200, 2400, 4000) (LaboPol 21, Struers A/S, Rodovre, Denmark). All PSZ specimens were cut and ground in their green stage.