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Self-glazed zirconia reducing the wear to tooth enamel

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ABSTRACT

The wear behaviors of a newly developed grade of self-glazed zirconia against the enamel of freshly extracted teeth were investigated under simulated oral stresses and chemical environment. It was revealed that an inherently formed enamel-like surface on self-glazed zirconia that is very smooth on micrometer scale yet with nanoscale roughness has almost the same frictional coefficient against tooth enamel as the well-polished zirconia surface. The wear scars observed on the worn surface of enamel against self-glazed zirconia and well-polished zirconia surface revealed that in both cases fatigue wear is the dominating wear mechanism. It was concluded that the friction and wear performances of both the well-polished and self-glazed zirconia ceramics against natural enamel were very similar, which bears a very strong implication for the clinical safe use of the full contour zirconia restorations, yet the self-glazed zirconia provides sufficiently improved aesthetic appearance that ensures its potential for direct clinical uses.

1. Introduction

Veneered zirconia restorations exhibited high failure rates due to veneering porcelain fractures [1–3]. As an alternative approach for overcoming this problem encountered often in clinical practice, milling of a pre-sintered blank to full-contour has been established for zirconia monolithic restorations [4,5]. In this way the common use of a thick ceramic veneer layer can be avoided, but a thin stain and glaze coating layer still need to be applied, otherwise the surface has to be well polished before use in order to reduce the wear of a rough surface to the enamel of the opposite teeth. Although these full-contour monolithic restorations are ideally suited to cases where only minimal space is available, the risk of clinical failures by the progressive occlusal height reductions initiated by the friction and wear between restorations and opposite natural teeth under mastication cycles in oral environment has to be considered [6–8].

In order to eliminate as many as possible manual operation steps in traditional dental labs such as sandblasting, polishing, veneering, staining and glazing, it is desirable to prepare strong, reliable and nature looking dental restorations completely by digital technology. By applying a precision wet-chemistry technology in which local plastic deformation is facilitated to pack nano-sized grains on the surface of dental restorations a new grade of self-glazed zirconia ceramics has been developed recently. The inherent formation of an enamel-like surface ensures no further need of veneering or glazing thereby avoiding breakable interfaces. This appears for the first time as a real monolithic restoration that can be directly applied with minimal clinical adjustment.

Zirconia restorations used to be blamed to increase the risk of wear to the opposite teeth due to their higher hardness compared to that of the silicate based veneer porcelains and the lithium disilicate glass-ceramics. Recent studies have, however, confidently demonstrated that the wear of a dental restoration to the opposite tooth mainly depends on the surface roughness of the former [6,8]. Different from the traditional blank-machined zirconia, which appears like a rough sand parchment, the self-glazed zirconia restorations have very smooth surfaces that may protect the opposite natural teeth from excessive wear. It is the aim of this work to investigate the wear behaviors of the self-glazed zirconia against natural enamel by in vitro friction tests under simulated oral stresses and chemical environment using zirconia ceramics with well-polished surface as a reference.

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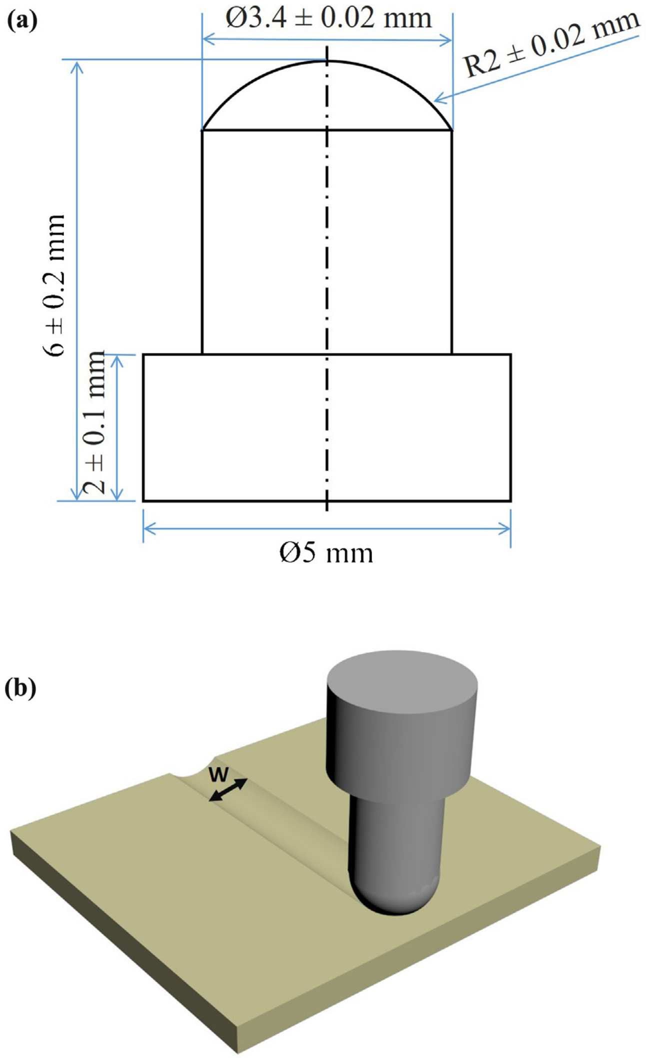

Fig. 1. A 2D (a) draw and a 3D (b) illustration showing the size and geometry of the cylindrical test sample and the setup of a wear pair in reciprocating ball on plat pattern style.

2. Experimental

2.1. Sample preparation

Two kinds of 3Y-TZP samples (ZrO_2 doped with 3 mol% Y_2O_3) were prepared for test, being the self-glazed zirconia with a smooth surface and the zirconia with a polished surface down to 1 μm finishing, with the latter one as a reference. As a 2D draw and a 3D illustration shown in Fig. 1 demonstrate, the cylindrical test samples were fabricated to have a hemisphere head at one end, with the radius of 2 mm, to simulate the dimension of natural tooth cusp with the radius of 2–4 mm. The hemispherical geometry was produced by CAD/CAM milling of a green body formed by a wet process in case of self-glazed zirconia sample and of a pre-sintered blank in case of zirconia with milled rough surface and polished surfaces, respectively. All the milled samples were pressure-less sintered at 1450 °C for 2 h in air atmosphere to achieve a relative density above 99.9%. After sintering the self-glazed zirconia sample was used directly for wear test without applying any additional post-sintering treatment, whereas one zirconia sample milled from pre-sintered blank was polished by diamond suspension down to 1 μm finishing before wear test. The smooth surface on self-glazed zirconia was inherently formed by local plastic deformation introduced during a precision wet-chemistry process that assured dense packing of nano-sized grains on the surface of dental restorations. The self-glazed zirconia sample reveled a finer grain structure than the blank-machined zirconia samples, being 100–250 nm versus 200–600 nm of the grain size for the former and later, respectively. In both cases, a newly developed 3Y-TZP powder is used as the precursor. The powder is a semi-product with the potential of being commercialized in the near future and, thus, the producer will not be disclosed at this point. The powder consists of 100–150 nm spherically-shaped particles. The single, secondary particle is composed of loosely aggregated primary nanoscaled crystallites of 27 nm in average size. The specific surface area of the powder is 18.2 m^2/g.

Table 1
The chemical composition of artificial saliva.

NaCl(g)	0.4
KCl(g)	0.4
$CaCl_2 \cdot 2H_2O$(g)	0.795
$NaH_2PO_4 \cdot 2H_2O$(g)	0.78
$Na_2S \cdot 9H_2O$(g)	0.005
Urea(g)	1
Distilled (ml)	1000

A premolar without obvious wear scar, extracted for orthodontic demand, was collected from a 13-year aged young male, and preserved in distilled water at 4 °C for sample preparation. The tooth was embedded in epoxy resin (SY-668-3, SenMeiYa, China) after pulpless, with the enamel of buccal surface (at least 5 × 5 mm area) exposed. The enamel surface was then grounded by carborundum sand papers in water, gradually from 180 to 1500 mesh, and polished by 1 μm diamond sand papers. The final dimension of the epoxy resin block was 30 mm in diameter and 10 mm in thickness. The sample was stored in distilled water during the whole test process.

2.2. Friction and wear tests

The wear pairs of the plate of natural tooth and hemispherical zirconia with two types of surfaces were tested by a micro friction and wear testing apparatus (UMT-2, CETR, USA) in a reciprocating ball on plate pattern style. Throughout the testing procedure the natural tooth was always immersed in artificial saliva, even during the cleaning of the samples before the experiment. The friction and wear tests were controlled by a computer. The relation between surface friction and displacement at every cycle was recorded. The frictional coefficient was automatically calculated and recorded by the UMT-2 control software. The average width of each wear track on enamel surface was calculated from five measurements in the middle part of the track. The spacing between neighbor measurements is 10% of the maximum track length. The Artificial saliva was used to simulate the actual oral condition and its composition was showed in Table 1 [9]. The enamel sample was tested with antagonist made by zirconia samples with well-polished and self-glazed surfaces, respectively, under constant static load, vertical load 4 N, and cyclic friction with back-and-forth movement pattern. Every sample was tested with four different antagonists, each for 5000 cycles, at frequency 2 Hz and sliding displacement 1 mm.

2.3. Microstructure characterization

The surface microstructure of the self-glazed zirconia, polished zirconia, and blank-machined zirconia ceramics was characterized by using a scanning electron microscope (SEM, JSM-7401F, JEOL, Tokyo, Japan). The samples were washed by water and acetone in an ultrasonic bath before loaded into the SEM and the SEM observation was carried out on the surface without any coating. Accelerating