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Effect of core ceramic grinding on fracture behaviour of bilayered zirconia veneering ceramic systems under two loading schemes

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ABSTRACT

Objective. The aim of this *in vitro* study was to evaluate the effect of core ceramic grinding on the fracture behaviour of bilayered zirconia under two loading schemes.
Methods. Interfacial surfaces of sandblasted zirconia disks (A) were ground with 80 (B), 120 (C) and 220 (D) grit diamond discs, respectively. Surface roughness and topographic analysis were performed using a confocal scanning laser microscope (CSLM) and a scanning electron microscopy (SEM). Relative monoclinic content was evaluated using X-ray diffraction analysis (XRD) then reevaluated after simulated veneer firing. Biaxial fracture strength (σ) and Weibull modulus (m) were calculated either with core in compression (subgroup Ac-Dc) or in tension (subgroup At-Dt). Facture surfaces were examined by SEM and energy dispersive X-ray spectroscopy (EDS). Maximum tensile stress at fracture was estimated by finite element analysis. Statistical data analysis was performed using Kruskal–Wallis and one-way ANOVA at a significance level of 0.05.
Results. As grit size of the diamond disc increased, zirconia surface roughness decreased ($p < 0.001$). Thermal veneering treatment reversed the transformation of monoclinic phase observed after initial grinding. No difference in initial ($p = 0.519$ for subgroups Ac-Dc) and final fracture strength ($p = 0.699$ for subgroups Ac-Dc; $p = 0.328$ for subgroups At-Dt) was found among the four groups for both loading schemes. While coarse grinding slightly increased final fracture strength reliability (m) for subgroups Ac-Dc. Two different modes of fracture were observed according to which material was on the bottom surface. Components of the liner porcelain remained on the zirconia surface after fracture for all groups.

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Significance. Technician grinding changed surface topography of zirconia ceramic material, but was not detrimental to the bilayered system strength after veneer application. Coarse grinding slightly improved the fracture strength reliability of the bilayered system tested with core in compression. It is recommended that veneering porcelain be applied directly after routine lab grinding of zirconia ceramic, and its application on rough zirconia cores may be preferred to enhance bond strength.

1. Introduction

Core veneered all-ceramic dental prostheses have become a popular restoration of choice for dental crown and fixed partial denture (FPD) applications because of their excellent chemical durability, biological compatibility and aesthetic outcomes [1]. Both lithium disilicate glass-ceramic (LDG) and zirconium-oxide ceramic (Zirconia) are the most frequently used dental ceramics, with LDG having higher translucency and lower mechanical strength than zirconia [2,3]. Chipping and delamination in the porcelain veneering layer have been suggested to be the most common modes of failure in zirconia [4]. Recent clinical researches and systematic reviews have revealed a high rate of veneer chipping for zirconia-based fixed dental prosthesis that varies between 13% and 28% over a 3- to 10-year period [5–7], while the chipping rate of LDG is reported to be 10% during a 8-year observation period [8–10]. Since the stability of composite structures is related to its weakest part, core–veneer bond can essentialy affect the crown reliability. An *in vitro* study showed that the zirconia–veneer bond strength was inferior to LDG systems suggesting that the layered zirconia frameworks are more susceptible to delamination and chipping under function [11]. Delamination failures in all-ceramic restorations either originate from the veneer and propagate to the interface, or from the ceramic/veneer interface [12]. A study on failure behavior of ceramic FPDs has reported that approximately 70–78% of connector fractures originate from the core/veneer interface [13]. Accordingly, the interface of core and veneer ceramics is deemed to be linked for the most part to the successful performance of core/veneer bilayered restorations.

The success of veneered zirconia restorations depends on mechanical adhesion between the veneering ceramics and zirconia core [14]. Grinding of zirconia ceramic is an inevitable lab procedure which enables adjustment of the marginal fit and the framework occlusion before applying veneering ceramics [15]. Grinding results in the development of an interface with complex topography, roughness and phase transformation of zirconia crystals. These changes may affect the interfacial adhesion as well as the mechanical integrity.

Surface roughness is related to zirconia/veneer interfacial failure [11] and surface residual stresses [16], but the effect of interfacial roughness on fracture behavior of bilayered ceramic structures remains a topic with divergent viewpoints. From one perspective it was assumed that a rough interface may transfer localized high tensile stresses from core to veneer layer and lower the strength of the veneering porcelain, and consequently promote fracture at the interface [17]. In comparison, a smooth core-veneer interface was suggested to increase fracture strength of bilayered specimens of In-Ceram Alumina [18]. On the other hand, surface topography change of LDG-ceramic materials after technician grinding was deemed not to be detrimental to the strength of a bilayered system after veneer application [19]. The above findings, however, were only for glass infiltrated alumina and LDG ceramic [18,19]. In comparison with the present study methods, those studies only considered air-abrasion [20], liner application [21] and surface agents [22] on bilayered zirconia systems tested with veneer in tension.

The aim of this study was to assess the effect of core ceramic grinding on fracture behaviour of a veneered zirconia system. Two different loading schemes were used to represent schematic clinical stress distributions in bilayered crowns and connector areas of FPDs, respectively. The primary null hypothesis was that grinding of zirconia ceramic had no influence on the fracture behavior of the bilayered structure.

2. Materials and methods

2.1. Sample preparation

152 zirconia core specimens disks (1.2 mm in height, 15 mm in diameter) were fabricated with the Katana system (Kuraray Noritake Dental Inc., Tokyo, Japan) and then were airborne-particle abraded (Silfradent SRL, Sofia, Italy) with 50 μm Al_2O_3 at 0.2 MPa pressure for 20 s with a distance of 10 mm according to the manufacturer instructions. All specimens were cleaned in an ultrasonic cleaner with distilled water for 5 min prior to further treatments.

2.2. Treatment of core interfacial surface

To generate a similar core–veneer interfacial topography to that ground with diamond burs in the clinical situation and form a comparable flat surface of the core specimens, a series of MD-Piano diamond discs (Struers, Ballerup, Denmark) were used for grinding on an automatic metallographic lapping machine (Tegramin-30, Struers, Ballerup, Denmark).

The prepared core specimens were randomly divided into 4 groups (n = 41) according to the grinding procedures as follows: Group A without any grinding as control; Group B ground with MD-Piano diamond disc of 80 grit (equivalent coarse-grit diamond burs); Group C ground with MD-Piano diamond disc of 80 grit and then 120 grit (equivalent medium-grit diamond burs); Group D ground successively with 80, 120 and 220 grit MD-Piano diamond discs (equivalent fine-grit diamond burs).