

available at www.sciencedirect.comjournal homepage: www.intl.elsevierhealth.com/journals/dema

Effect of fatigue on biaxial flexural strength of bilayered porcelain/zirconia (Y-TZP) dental ceramics

Handan Yılmaz^a, Seçil Karakoca Nemli^{a,*}, Cemal Aydın^a, Bilge Turhan Bal^a,
Tülay Tıraş^b

^a Department of Prosthodontics, Faculty of Dentistry, Gazi University, 8, CADDE, 82, SOKAK, 06510 Emek-Ankara, Turkey

^b Department of Physics, Faculty of Science, Anadolu University, Eskişehir, Turkey

ARTICLE INFO

Article history:

Received 2 August 2010

Received in revised form

24 October 2010

Accepted 30 March 2011

Keywords:

Zirconia

Bilayer

Fatigue

Biaxial flexural strength

Formulas

Raman spectroscopy

ABSTRACT

Objectives. The aim of this study was to evaluate the effect of fatigue on biaxial flexural strength of bilayered disks of two Y-TZP cores.

Methods. Twenty bilayered veneer/zirconia disks were fabricated from each material (Lava veneer + core, 3 M/ESPE, and Cercon veneer + core, Densply). Ten specimens from each material were tested for biaxial flexural strength either with or without being subjected to fatigue (20,000 cycles, 2 Hz, 200 N load) in a universal testing machine (1 mm/min). Stresses generated at the core and the veneer, at the top and the bottom surfaces, and the interface of bilayered disk were calculated using Huesh's solutions. Data were statistically analyzed using Weibull statistics. The fractured core was also examined via Raman spectroscopy and the monoclinic fraction was calculated at the top, the middle of thickness, and the bottom of the cross-section of fractured core. The results of monoclinic fraction were statistically analyzed by Three-Factor ANOVA with Repeated Measures on One Factor.

Results. Weibull modulus (m) of Cercon control (CC), Cercon fatigue (CF), Lava control (LC) and Lava fatigue (LF) were between 11.8 and 14.3, 7.1 and 13.1, 9.4 and 13, and 7.1 and 8.2, respectively. There were no significant differences between characteristic strength (σ_0) of CC (970.9 MPa) and CF (947.7 MPa) ($p > 0.05$). For Lava, σ_0 of LF (1444.8 MPa) was significantly higher than LC (1240.5 MPa) ($p < 0.05$). At the interfaces, σ_0 values of CC and CF groups were not significantly different while LF showed significantly higher σ_0 than LC. The monoclinic zirconia was significantly lower for CF than CC and significantly higher for LF than LC.

Significance. Fatigue showed different effects on the strength of Cercon and Lava ceramic systems. Decreases in m values were observed at the interfaces of two materials after fatigue.

© 2011 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.

1. Introduction

A recent dental ceramic is yttria-stabilized zirconium oxide polycrystals (Y-TZP-zirconia). These materials are manufactured from fine particles of ZrO_2 and 3–5% Y_2O_3 which form a partially stabilized tetragonal structure at roomtemperature

after heat treatment. Due to optical opacity of these materials, zirconia cores are covered with veneering ceramics. The combination of this two-step process gives the core material its properties [1–3]. While substantial improvement has been achieved in the field of ceramic engineering regarding the development of all-ceramic core-veneer systems, veneer layer fracture has been leading failure mode during function

* Corresponding author. Tel.: +90 3122034182; fax: +90 3122239226.

E-mail address: secilkarakoca@yahoo.com (S.K. Nemli).

0109-5641/\$ – see front matter © 2011 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.

doi:10.1016/j.dental.2011.03.019

[3]. In clinical application, chipping of the veneer is described to be the most frequent occurrence that reduces the success rate of zirconia fixed partial dentures (FPD) [4].

Mechanical properties such as strength are the first parameter to be assessed to understand the clinical potential and limitations of a dental ceramic. Compared to the uniaxial flexural strength, the biaxial flexural strength data are more useful for the material design because dental materials are generally subjected to multiaxial loading during service applications [5,6]. International Organization for Standardization (ISO) described piston-on-three-ball test in the ISO 6872 for strength measurement of dental ceramics [7]. However, the application of ISO 6872 has been limited to the case of monolayered discs. While all-ceramic dental crowns are usually fabricated into layered structures with esthetic veneer porcelains on strong ceramic cores, modification of the current standard to extend its applicability to multilayered discs is essential [8]. Within the dental literature, a number of analytical solutions have been reported to calculate the failure stresses in multilayered specimens that subjected to biaxial flexural loading [1,2,9–12]. Timoshenko's [12] thin plate analyses for small deflections were used to calculate estimated failure stresses of bilayered specimens. Alternatively Roark's formulas [10] were used to evaluate the biaxial flexural strength of bilayered discs. However, only the equations for biaxial stresses on the top and the bottom surfaces of the disc were given in Roark's formulas. Depending upon the elastic constants and thicknesses of the constituent layers, the maximum tension can occur at the interface rather than the surfaces in a multilayered disc. In this case, the maximum tension cannot be obtained from Roark's formulas. Also, it was indicated that Roark's formulas were valid for a simply supported plate at its edge [8]. Another solution was reported by Rosenstiel et al. [13] to calculate the interfacial stresses as a function of the elastic modulus mismatch and layer thickness ratio of the two materials. Then, Hsueh et al. [11,14] advanced analytical solutions allowing the calculation of the stress distribution through the thickness of bilayered specimens tested in a number of biaxial flexure testing configurations. They obtained the solutions for multilayered disks subjected to biaxial flexure tests from the existing solutions for monolayered systems. The neutral surface position and the flexural rigidity of monolayered disks were replaced with those of multilayered disks. Their solutions also verified by finite element analysis results. Hsueh's analyses enable the calculation of failure stresses at the fractographically derived origin of failure and additionally account for specimen edge support overlap and Poisson's ratio mismatches. More recently, Hsueh and Kelly [8] reported a simple solution that enables the calculation of failure stresses at the top and the bottom surfaces of the disk and at the interfaces of two layers.

Another consideration with dental ceramics is intermittent forces during mastication. Under functional loading in the oral environment, zirconia-based materials, despite their remarkably high strength undergo fatigue [15]. This time-dependent stress failure is attributed to the presence of micro defects within the material [16] and fatigue of a ceramic restoration refers to the slow growth of subcritical cracks [17]. Therefore, fatigue tests are very important to evaluate the mechanical

performance of ceramic materials [18]. The forces applied on the materials in the oral cavity develop cyclic loads that can be simulated by mechanical cycling. Mechanical cycling tends to be close to the physiological conditions generated by the chewing cycle [18]. Current literature [2,3,16,19,20] have focused on the effect of fatigue testing on mechanical behavior of Y-TZP crown and FPD as fracture resistance, fracture strength, load bearing capacity, and failure mode. White et al. [21] reported 3-point flexural strength of bilayered Lava system. However meaningful comparisons cannot be made between uniaxial flexural strength data and biaxial flexural strength data. According to the literature research, one study reported the effect of cyclic loading on the biaxial flexural strength of veneered Y-TZP disks [22].

The feature that makes Y-TZP both strong and fatigue resistant is its ability to transform from tetragonal to monoclinic (t-m) phase under stress. The stress-induced phase transformation and phase compositions can be analyzed using X-ray diffraction (XRD) analysis or Raman spectroscopy; however XRD tends to be used for bulk analyses or large area surface analyses. Raman spectroscopy has the ability to analyze very small and specific areas on a sample surface without any sample preparation because of the small spatial resolution achieved [23]. Additionally, different phases of ZrO_2 are well characterized by their Raman spectra [24,25]. As monoclinic ZrO_2 is a stronger Raman scatter than tetragonal ZrO_2 , Raman spectroscopy is superior in discerning the monoclinic phase. Particularly, when the monoclinic fraction is small, the Raman spectrum of monoclinic ZrO_2 is easily distinguished from that of the tetragonal ZrO_2 by the strong doublet at, 185 cm^{-1} . Therefore, Raman spectroscopy can be a useful tool in determining the amount of the monoclinic phase in the tetragonal-rich tetragonal-monoclinic two-phase zirconia such as fractured TZP [26]. Despite these advantages, the use of Raman spectroscopy in the Y-TZP materials research has been limited [23,27].

Although the strength of Y-TZP ceramics is well documented [5,6,17,28], data on the effect of mechanical cycling on biaxial flexural strength of veneered Y-TZP core materials is limited [2]. The purpose of this study was to investigate and compare biaxial flexural strength of two different commercial veneer/Y-TZP core systems and to test the hypothesis that cyclic loading causes a decrease in strength of veneer/Y-TZP core composites. Furthermore, crystallographic phases of the fractured surfaces of Y-TZP cores were analyzed using Raman stereoscopy analyses.

2. Materials and methods

Two veneer-core systems were investigated in this study. Cercon base (Cercon, DeguDent, Hanau, Germany) and Lava All-Ceramic System (Lava, 3M ESPE, Seefeld, Germany) cores were veneered with Cercon Ceram Kiss (Cercon, DeguDent, Hanau, Germany, Lot # 65248) and Lava Ceram Veneer (Lava, 3M ESPE, Seefeld, Germany, Lot # 8323G), respectively. The veneering materials were feldspathic porcelains that specifically developed to be used on zirconia cores.

Download English Version:

<https://daneshyari.com/en/article/1421173>

Download Persian Version:

<https://daneshyari.com/article/1421173>

[Daneshyari.com](https://daneshyari.com)