DENTAL MATERIALS 33 (2017) 191–197

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Reliability and mode of failure of bonded monolithic and multilayer ceramics

*Rodrigo Alessandretti, Marcia Borba, Paula Benetti, Pedro Henrique Corazza, Raissa Ribeiro, Alvaro Della Bona**

Postgraduate Program in Dentistry, Dental School, University of Passo Fundo, Brazil

ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form
24 November 2016
Accepted 29 November 2016

Keywords:
CAD/CAM
Ceramic
Multilayer structures
Sound detection
Fractography

ABSTRACT

Objectives. To evaluate the reliability of monolithic and multilayer ceramic structures used in the CAD-on technique (Ivoclar), and the mode of failure produced in ceramic structures bonded to a dentin analog material (NEMA-G10).

Methods. Ceramic specimens were fabricated as follows ($n = 30$): CAD-on- trilayer structure (IPS e.max ZirCAD/IPS e.max Crystall./Connect/IPS e.max CAD); YLD- bilayer structure (IPS e.max ZirCAD/IPS e.max Ceram); LDC- monolithic structure (IPS e.max CAD); and YZW- monolithic structure (Zenostar Zr Translucent). All ceramic specimens were bonded to G10 and subjected to compressive load in 37 °C distilled water until the sound of the first crack, monitored acoustically. Failure load (L_f) values were recorded (N) and statistically analyzed using Weibull distribution, Kruskal–Wallis test, and Student-Newman–Keuls test ($\alpha = 0.05$).

Results. L_f values of CAD-on and YZW structures were statistically similar ($p = 0.917$), but higher than YLD and LDC ($p < 0.01$). Weibull modulus (*m*) values were statistically similar for all experimental groups. Monolithic structures (LDC and YZW) failed from radial cracks. Failures in the CAD-on and YLD groups showed, predominantly, both radial and cone cracks.

Significance. Monolithic zirconia (YZW) and CAD-on structures showed similar failure resistance and reliability, but a different fracture behavior.

1. Introduction

Currently, most all-ceramic restorations have a high crystalline content infrastructure that provides resistance and a veneering ceramic that offers improved esthetics [1,2]. However, clinical studies have reported that ceramic restorations experience chipping, cracking, or delamination of the porcelain [2–4]. Failure of the veneering porcelain is a complex mostly associated to thermal and mechanical properties of the ceramics and geometry and dimensions of the restoration [2,5].

In addition to porcelain chipping, multilayer ceramic structures may present a poor bonding between layers with potential for delamination [1,6–8]. The material under tension, the thermal and mechanical interactions between ceramic layers, the restoration design, and the bonding to a substrate may influence the fracture resistance and the failure mode of multilayer structures [6,9–14]. In addition, compression forces can generate tensile stresses in the intaglio surface of the restoration [15], which corresponds to the fracture origin of clinically failed crowns [3,9,16,17].

The development of high crystalline content dental ceramics, particularly the yttria partially-stabilized tetragonal

* *Corresponding author at:* School of Dentistry, University of Passo Fundo, Campus I, BR285, km 171, Passo Fundo, RS 99052-900, Brazil.
E-mail address: dbona@upf.br (A. Della Bona).

http://dx.doi.org/10.1016/j.dental.2016.11.014

Table 1 – Median and interquartile range (IQR- lower (Q1) and upper (Q3) bounds) values of fracture loads (Lf) and their coefficient of variation (CV), in addition to the Weibull modulus (m) and characteristic fracture load (L0) with 95% confidence intervals (95%CI) for the experimental groups.

	Median (N)*	IQR: Q1–Q3 (N)	CV (%)	*m* (95%CI)*	L_0 (95%CI) (N)*
CAD-on	3727 a	3356–4145	15.8	7.3 (5.5–9.7) a	3950 (3751–4160) a
YLD	3175 b	2580–3486	19.9	5.6 (4.2–7.3) a	3338 (3119–3573) b
YZW	3824 a	3419–4012	14.1	8.8 (6.6–11.7) a	3915 (3752–4086) a
LDC	1068 c	977–1164	12.3	8.1 (6.3–10.4) a	1131 (1079–1186) c

* Values followed by same letter in the column are not statistically different ($p > 0.05$).

zirconia polycrystal (Y-TZP) because of its high fracture toughness, and the introduction of the CAD/CAM (computer aided design/computer aided manufacturing) technology increased the use of metal-free restorations in dentistry. CAD/CAM systems are mainly based on three steps: scanning and digitalization of tooth preparation, computer processing of structural design, and milling of prefabricated blocks. This technique may minimize internal flaws and imperfections resulting from other fabrication methods, improving reliability and offering greater quality control [18–20].

The CAD-on technique (Ivoclar) was developed as an attempt to overcome the susceptibility of porcelain chipping from veneered zirconia restorations. This ceramic system produces ceramic restorations with a Y-TZP framework veneered by a lithium disilicate-based glass-ceramic, which are fabricated by CAD/CAM and fused together with a glass. As a recent method, the literature is still scarce and little is known about the multilayer structure obtained from this technique. Thus, this study aimed to evaluate: (1) the reliability of monolithic and multilayer ceramic structures bonded to a dentin analog e subjected to compressive load and (2) the mode of failure produced by loading such ceramic structures, testing the hypotheses that there is no significant difference in the Weibull modulus (*m*) among the evaluated ceramic structures and that radial crack is the predominant failure origin for the ceramic structures.

2. Materials and methods

Four ceramic structures were fabricated (n = 30) as follows:

– CAD-on: Trilayer structure (1.8 mm thick) made of a Y-TZP (YZC- IPS e.max ZirCAD, Ivoclar Vivadent, Schaan, Liechtenstein) framework (1 mm thick) and a 0.7 mm thick lithium disilicate-based glass-ceramic veneer (LDC- IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) fused together with a glass (IPS e.max CAD Crystall./Connect, Ivoclar Vivadent, Schaan, Liechtenstein) of about 0.1 mm thick. The YZC and LDC blocks were ground (Ferdimat CA51H, São José dos Campos, Brazil) using a diamond stone (Tyrolit TN 634709, Cabreuva, Brazil) into a cylindrical shape, which were cut in slices (discs) by a metallographic cutter (Strues Minitron, Copenhagen, Denmark) using a diamond disc under water cooling. The disc-shaped specimens were polished (Strues Abramin, Copenhagen, Denmark) up to 1200-graded SiC sandpapers under water cooling. YZC discs were sintered (Zirkonofen 600/V2, ZirkonZahn, Gais, South Tyrol, Italy) according to manufacturer's instructions (Ivoclar Vivadent). The YZC and LDC discs were united using the fusion ceramic (IPS e.max CAD Crystall./Connect). The capsule containing the powder and liquid of the fusion ceramic was mixed by vibration (Ivomix, Ivoclar Vivadent, Schaan, Liechtenstein) for 10 s. The capsule was opened and the material was applied to the LDC disc surface and, immediately, bonded to the YZC disc. The trilayer structure was placed under a load of 750 g [21] and the excess of fusion ceramic was removed before sintering. The fusion process and crystallization of LDC were conducted simultaneously (Programat EP5000, Ivoclar Vivadent, Schaan, Liechtenstein) following manufacturer's instructions.
– YLD: Bilayer structure (1.8 mm thick) fabricated with a YZC framework (1 mm thick) veneered with a glass-ceramic (LDT- IPS e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein). The YZC was fabricated as described for the CAD-on group. A thin layer (about 0.1 mm) of IPS e.max ZirLiner (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the YZC and fired (Programat EP5000) according to manufacturer's instructions. The YZC discs were placed into a silicone matrix (Zetaplus, Zhermack SpA, Badia Polesine, Italy) and a LDT layer (0.7 mm thick) was applied over it using the conventional layering technique. The excess moist from LDT was removed using sonic vibration and absorbent paper, and the ceramic was sintered according to manufacturer's instructions.
– YZW: Monolithic structure (1.8 mm thick) of Y-TZP (Zenostar Zr Translucent, Wieland Dental, Rosbach vor der Höhe, Germany). A cylindrical pattern was scanned (Cerec InLab, Sirona Dental Company, Bensheim, Germany) and data was transferred to the milling machine (InLab MC X5, Sirona Dental Company, Bensheim, Germany) that milled the large YZW disc-shaped blocks to obtain several YZW cylinders. They were cut in slices with a diamond disc under water cooling using a metallographic cutting machine (Strues Minitron, Copenhagen, Denmark). The disc-shaped specimens were sintered (Zirkonofen 600/V2) according to manufacturer's instructions (Ivoclar Vivadent).
– LDC: Monolithic structure (1.8 mm thick) of lithium disilicate-based glass-ceramic (IPS e.max CAD) fabricated as described for the CAD-on group. LDC structures were crystallized (Programat EP5000) according to manufacturer's instructions.

All ceramic structures were bonded to a fiber-reinforced epoxy resin-based (G10- NEMA G10, International Paper, Hampton, SC, USA) structure (dentin analog), which presents an elastic modulus (E = 18.6 GPa) similar to dentin (E = 18 GPa). Resin bond to G10 is similar to dental structure [22,23]. G10 is