DENTAL MATERIALS 31 (2015) e151–e156

Available online at www.sciencedirect.com

ScienceDirect

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

Effect of repeated firings on flexural strength of veneered zirconia

A. Vichi[a,*], M. Sedda[a], G. Bonadeo[a], M. Bosco[b], A. Barbiera[a], N. Tsintsadze[a], M. Carrabba[a], M. Ferrari[a]

[a] *Department of Medical Biotechnologies, University of Siena, Italy*
[b] *Department of Dentistry, University of Pavia, Italy*

ARTICLE INFO

Article history:
Received 28 March 2014
Received in revised form
16 January 2015
Accepted 24 April 2015

Keywords:
Zirconia
Ceramic
Chipping
Fracture load
Ceramic firing
CAD/CAM
Ceramic veneering

ABSTRACT

Objective. Chipping and/or delamination represent a clinical failure of porcelain fused to zirconia (PFZ) prostheses. Causes and solutions have not been completely clarified. The present study was aimed at evaluating the effects of number of firings on the flexural strength of PFZ specimen.

Methods. Forty-five zirconia specimens in shape of bars were cut, sintered and divided in 3 groups ($n = 15$). Group 1: veneering ceramic was layered "in bulk" and fired. Group 2: veneering ceramic was layered in three layers, individually fired. Group 3: veneering ceramic was layered in five layers, individually fired. Each layer thickness was controlled by the use of calibrated molds. The total veneering ceramic thickness for all the specimens was 1.2 mm, and the total thickness of the specimen of 2.0 mm. Three-point bending test was performed. Fracture load was recorded in Newton and MPa value was calculated taking into account the bi-layered nature of the specimen. Data were statistically analyzed.

Results. Specimens obtained with on single firing cycle obtained a statistically significant ($p < 0.001$) lower flexural strength (54.61 ± 8.98 MPa) than specimens veneered with 3 or 5 firing cycles. The last two obtained very similar results (77.63 ± 13.17 MPa and 73.62 ± 12.38 MPa respectively) and the differences was not statistically significant.

Significance. In bi-layered PFZ specimen, three to five layers and firings determine higher flexural resistance when compared to a single firing. Thus, a 3-layers veneering procedure is recommended to increase flexural resistance. If a 5-layer procedure is necessary to improve esthetics, it does not decrease flexural resistance.

1. Introduction

Porcelain fused to metal restorations (PFM) are still considered the gold standard in fixed prosthodontics, mainly due to their resistance and marginal fit that lead to excellent long-term results [1–6], but demand for improved esthetics has led to the development of new systems in dentistry based on the use of metal free materials and on adhesive cementation procedures.

* *Corresponding author at*: Department of Medical Biotechnologies, University of Siena, Italy Policlinico "le Scotte", Viale Mario Bracci, 53100 Siena, Italy. Tel.: +30 0577 233131; fax: +39 0577 233117.
E-mail address: alessandrovichi1@gmail.com (A. Vichi).

http://dx.doi.org/10.1016/j.dental.2015.04.012

Enhancement of CAD/CAM technology led to the introduction in the dental market of zirconium oxide, a highly resistant material, suitable to replace metal-ceramic systems in manufacturing dental crowns and bridges [7]. Yttria partially stabilized zirconia (Y-TZP – Yttria Tetragonal Zirconia Polycrystals) offers superior mechanical properties in comparison to other ceramic materials, particularly thanks to the mechanism 'transformation toughening' [8–11] and can be machined at relatively low thickness [12–14]. Concerning with esthetics, the white color of zirconia limits per se the problem of "black lines" [15] and by adding colorants a better mimic of the color of dentin can be achieved. Conversely, the translucency of Y-TZP is far from ideal, and great efforts are being made to further increase this aspect [16]. For this reason, to obtain an appropriate esthetics, once the zirconia framework is machined the feldspathic ceramic has to be layered with a traditional veneering technique. However, chipping and delamination of the veneering ceramic have been reported to occur in a higher rate than PFM [17–24].

Several reasons have been analyzed and reported as possible reasons for chipping, among which zirconia sintering process and structural defects [25,26], decrease of zirconia strength due to sandblasting procedures [27–29], framework design [30–33], type of finishing margins [34], luting procedures [35–37], zirconia aging [38,39].

Since the early '80s, several studies have shown that chipping of the veneering layer can result from the residual thermal stresses due to thermal incompatibility between the coefficients of thermal expansion (CTE) of core material and veneering ceramic (thermal mismatch) [40–48]. To reduce the residual thermal stresses the use a veneering ceramic with a CTE as close as possible to that of the framework has been advised. This aspect has been investigated for zirconia/ceramic restorations as well [20,49–53] and it has been reported that the processes of slow heating and slow cooling increase chipping resistance [20–23]. The possible effect of multiple firings has also been investigated. It has been reported that the number of firings does not influence the strength of zirconia itself [54–56], while it has been reported to affect the bond strength to the core material [57–59] as well as the flexural resistance of the veneering ceramic tested without the zirconia substrate [60]. No literature indications were found about flexural resistance of veneering layer in a bi-layered specimen, with the veneering ceramic fired on a zirconia substrate.

Therefore, the aim of the present study was to evaluate the influence of the number of firings on the flexural resistance of the veneering layer of porcelain fused to zirconia (PFZ) in bi-layered specimens. The tested null-hypothesis was that the number of firings does not affect the flexural strength of the veneering layer in PFZ process.

2. Materials and methods

2.1. *Specimens preparation*

Blocks of Aadva Zr pre-sintered zirconia (GC Europe, Leuven, Belgium) were cut with a low speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA). Dimensional changes occurring during sintering were taken into consideration in specimen cut. Specimens were sintered by the zirconia manufacturer (GC Europe, Leuven, Belgium) and wet-finished with silicon-carbide papers of 600, 1200 and 2400 grit, until dimensions of 16 ± 0.2 mm length, 4 ± 0.2 mm width, and 0.8 ± 0.2 mm thickness were achieved. The obtained 45 specimens were randomly assigned to three groups ($n = 15$), numbered, and then measured in thickness by means of a digital caliper with an accuracy of ± 0.01 mm. A thin layer of modifier (Initial Zr-Fs Frame Modifier, GC Europe, Leuven, Belgium) was applied and fired for all the specimens in each group. Then, specimens were treated as follow:

2.1.1. *Group 1 (1 firing cycle)*

Veneering ceramic (Initial Zr-Fs Ceramic Dentin, GC Europe, Leuven, Belgium and Initial Zr-Fs Ceramic Enamel, GC Europe, Leuven, Belgium) was layered positioning the zirconia bar within a silicone mold that allowed placing/adding the veneering ceramic to a total height of 2 mm. Then the specimen was gently removed from the mold and fired.

2.1.2. *Group 2 (3 firing cycles)*

Each zirconia bar was positioned into a silicone mold that allowed to apply approximately 1/3 of the veneering ceramic space (about 0.4 mm). For the first layer the Initial Zr-Fs Ceramic Dentin was applied, while for the second and third layer the Initial Zr-Fs Ceramic Enamel was added. Each layer was individually fired.

2.1.3. *Group 3 (5 firing cycles)*

The samples were treated as in the Group 2 but the thickness of the silicon mold was approximately 17% of the veneering ceramic space (about 2.5 mm). For the first two layers the Initial Zr-Fs Ceramic Dentin was applied, while for the third, fourth and fifth layers the Initial Zr-Fs Ceramic Enamel was used. Each layer was individually fired. No adjustment procedure by grinding was performed on each single layer.

The Initial Zr-Fs Ceramic was always mixed with the proprietary liquid Zr-Fs modeling liquid, reported as plastifying agent-free from the manufacturer. For all the groups, at the end of the ceramic firings, an auto-glaze firing was performed. The firing cycles are reported in Table 1.

After the firing procedures, all the specimens were again wet-finished using silicon-carbide papers of 600, 1200 and 2400 grit, to obtain the total height of 2 mm, with approximately 0.8 mm of zirconia core and 1.2 mm of veneering ceramic. After the finishing procedure, each specimen was again measured with the same procedure as for the initial measurement of the zirconia layer, so that it was possible to calculate by difference the thickness of the veneering ceramic.

2.2. *Test methods*

For flexural strength evaluation, a three-point bending test (3PBT) appliance was used. The tip and the supports were made in Cobalt-HSS (high speed steel), using polished rollers 2.0 mm in diameter. The remaining part of the rig was milled from a stainless steel (A.I.S.I. type 316) block. The span was set at 13.0 mm. Specimens were tested dry and at room temperature. Tests were performed in a universal testing machine