Biaxial Flexural Strength of Zirconia-Based Ceramic Core with Veneering Porcelain from Various Manufacturers

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Abstract

Objective: To evaluate the biaxial flexural strength (BFS) of zirconia-based ceramic veneering with porcelain from the same and different manufacturers.

Materials and Methods: Zirconia core material (Katana) and 4 veneering porcelains (Cerabien ZR, Lava Ceram, Cercon Ceram Kiss and IPS e.max Ceram) were selected. The bilayered disc specimens (diameter: 12.50 mm, thickness: 1.50 mm; core 0.75 mm, veneer 0.75 mm) were prepared into 4 groups according to veneering porcelain (n = 12), using the powder/liquid layering technique. After 20,000 times of thermocycling, BFS following ISO standard 6872:2008 were tested using universal testing machine (Instron). The data were analyzed with one-way ANOVA and Tukey Post Hoc multiple comparison tests ($\alpha = 0.05$).

Results: The mean ± SD of BFS were as followed, Cerabien ZR = 489.56 ± 67.00, Lava Ceram = 602.55 ± 76.31, Cercon Ceram Kiss = 705.94 ± 65.89 and IPS e.max Ceram = 496.94 ± 64.78 MPa. The statistical analysis showed that Cercon Ceram Kiss had significantly highest BFS, followed by Lava Ceram. The BFS of Cerabien ZR and IPS e.max Ceram were not significantly different but were significantly lower than the other two veneering porcelains.

Conclusion: To obtain the good strength, zirconia core might not be used to pair with veneering porcelain from the same manufacturer as recommended.

Key words: Biaxial flexural strength (BFS), Bilayered disc specimen, Thermocycling, Veneering porcelain, Zirconia core

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Introduction

The rising popularity of zirconia-based restoration is due to the potential for excellent esthetics, biocompatibility, long-termed stability, metal-free and its more reliable strength [1-7]. The widely dental use of zirconia is in the form of yttria tetragonal zirconia polycrystal (Y-TZP), because of its transformation toughening property that tetragonal phase transforms into monoclinic phase in excellent proportion by adding certainly amount of stabilizing oxides, Yttrium Oxide (Y_2O_3) [5]. However, the problem of veneering porcelain chipping was found clinically. The study of Swain found that high rates of veneering porcelain chipping in all ceramic might be due to residual stress from a CTE mismatch [8]. Most manufacturers recommend to use zirconia core together with veneering porcelain from the same manufacturer for the best result. However, from the survey of dental laboratories in Bangkok, they do not use zirconia core and veneering porcelain from the same manufacturer as recommended. There are many studies about pairing zirconia core with different veneering porcelains and they found that the bond strength were significantly different [9-11]. The reasonable suspicion was brought about necessity of core-veneer pairing from the same manufacturer that do or do not affect the strength of the restoration.

The aim of the study is to evaluate the BFS of zirconia-based ceramic veneering with porcelain from the same and different manufacturers.

Materials and Methods

Zirconia core (Katana, Kuraray Noritake Dental Inc., Japan) and four veneering porcelains; Cerabien ZR (Kuraray Noritake Dental Inc., Japan), Lava Ceram (3M ESPE, USA), Cercon Ceram Kiss (Degudent GmbH, Hanau-Wolfgang, Germany) and IPS e.max Ceram (Ivoclar Vivadent AG, Schaan, Liechtenstein) were selected in this study. The method of BFS test was done following ISO standard 6872:2008. The specimens were designed for bilayered zirconia/veneer disc (diameter: 12.50 mm, thickness: 1.50 mm), as shown in Fig. 1(a) and prepared into 4 groups according to veneering porcelain's manufacturers (n=12). The Katana zirconia block was cut into disc. Raw cores were sintered according to manufacturer's program, then finished and polished with wet abrasive papers No. 360, 600, 800 and 1,000 respectively. Digital vernier caliper was used to measure the diameter (12.50 ± 0.05 mm) and thickness of cores for 0.75 ± 0.005 mm. The VITA In-ceram testing liquid was used to find the crack line. Any core that had a crack line must be excluded. Sandblast with aluminium oxide powder (110 μm at 3.5 psi) was done with the distance of 10 mm from the tip to the side that contact to the veneer porcelain, 45^o to the flat surface. Then cores were ultrasonic cleaned in acetone solution for 15 minutes. After blotted, veneering porcelains were prepared on the cores with powder/liquid layering technique in the enlarged silicone mold to compensate the shrinkage and sintered according to manufacturer's program. Sintered specimens were finished, polished and measured for the proper thickness. Crack test was done again to confirm crack after veneer sintering. The specimens were then thermocycled 20,000 times (55°C, 30sec/5°C, 30 sec).

After thermocycled, BFS were tested using universal testing machine (Instron version 8872, Instron, UK) as shown in Fig. 1(b) and calculated to find BFS by the formula for two layer disc, shown in Fig. 2 [12-13].

The data were analyzed with one-way ANOVA and Tukey post Hoc multiple comparison tests (α = 0.05).

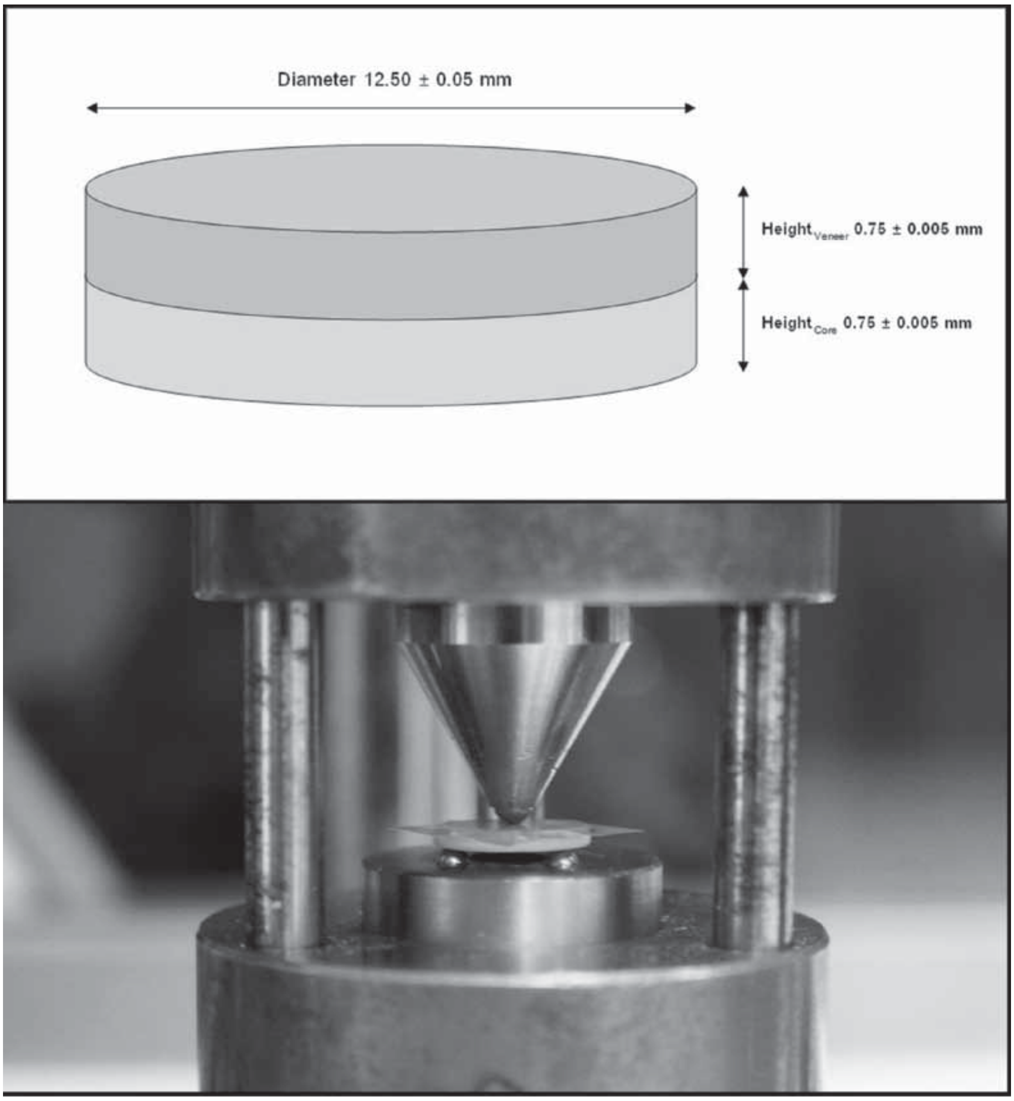

Figure 1. showed the design of specimen (a) and biaxial flexural strength test using universal testing machine with piston on three balls (b).

$$BFS = \frac{6M}{t_a^2 K_{2p}} \left[\frac{E_b t_b (1-\nu_a^2)}{E_a t_a (1-\nu_b^2)} + \frac{t_a (1-\nu_a^2)\left(1+\left(\frac{t_b}{t_a}\right)\left(1+\frac{E_a t_a}{E_b t_b}\right)\right)}{t_a\left(1+\frac{E_a t_a}{E_b t_b}\right)^2 - \left(\nu_a \frac{\nu_b E_a t_a}{E_b t_b}\right)^2} \right]$$

$$R = \sqrt{1.6B^2 + d^2} - 0.675d$$

$$M = \frac{W}{4\pi}\left[(1+\nu)\log\frac{A}{R} + 1\right]$$

$$K_{2p} = 1 + \frac{E_b t_b^3 (1-\nu_a^2)}{E_a t_a^3 (1-\nu_b^2)} + \frac{3(1-\nu_a^2)\left(1+\frac{t_b}{t_a}\right)^2\left(1+\frac{E_a t_a}{E_b t_b}\right)}{\left(1+\frac{E_a t_a}{E_b t_b}\right)^2 - \left(\nu_a + \frac{\nu b E_a t_a}{E_b t_b}\right)^2}$$

R = equivalent radius of loading

M = maximum bending moment (N)

W = work load (N)

P = maximum work load (N)

ν = Poisson's ratio (0.25)

A = support circle's radius (5 mm)

B = piston's radius (0.75 mm)

C = specimen's radius (6.25 mm)

d = specimen's thickness (1.50 mm)

t_a = upper layer's thickness (0.75 mm)

t_b = lower layer's thickness (0.75 mm)

E_a = Young's modulus of upper layer, veneering porcelain

(CZR 76, Lava Ceram 80, Cercon Ceram Kiss 65, IPS e.max Ceram 95 GPa)

E_b = Young's modulus of lower layer, Katana zirconia core (205 GPa)

Figure 2. showed the formula for finding BFS (two layer disc).

Results

The results of the BFS were shown in Table 1. The statistical analysis showed that specimen Cercon Ceram Kiss had significantly highest BFS, followed by Lava Ceram. The BFS of the specimen with Cerabien ZR and IPS e.max Ceram were not significantly different but they were significantly lower than the other two veneering porcelains.

Table 1. Groups of specimens and means ± SD of BFS and homogeneous subsets are grouped with Tukey HSD (a, b and c)

Zirconia core	Groups of veneering porcelains	n	BFS (Mean ± SD, MPa)
Katana (Kuraray Noritake Dental Inc., Japan)	1. Cerabien ZR : (CZR) (Kuraray Noritake Dental Inc., Japan)	12	489.56 ± 67.00[a]
	2. Lava Ceram : (LV) (3M ESPE, USA)	12	602.55 ± 76.31[b]
	3. Cercon Ceram Kiss : (CC) (Degudent GmbH, Hanau-Wolfgang, Germany)	12	705.94 ± 65.89[c]
	4. IPS e.max Ceram : (EM) (Ivoclar Vivadent AG, Schaan, Liechtenstein)	12	496.94 ± 64.78[a]

Discussion

The BFS test, piston on three balls, was used in this study because it is more reliable to reduce the sensitivity of the defect in the specimen at the loaded position. In BFS tests of zirconia, Salimee and Thammawasi found that core should be at least half of the thickness and the fracture mostly start at the core-veneer interface. In addition, many studies showed that the bottom layer of bilayered restoration was tensile stress zone and determined the overall strength [14-16]. It was found in the testing that the number of specimen's fragmented pieces was possibly related to high value of BFS. The greater number of fragments, the higher BFS was recorded.

From the result of this study, the BFS could be divided significantly into 3 groups. Cercon Ceram kiss provided the highest BFS, followed by Lava Ceram and the lowest BFS were found in Cerabien ZR and IPS e.max Ceram. Notably, Cerabien ZR that was recommended to use with Katana showed the lowest BFS. According to the study of Swain, the high rates of veneering porcelain chipping on all ceramic might be due to residual stress from a CTE mismatch [8]. We found that among the veneering porcelain used in this study, the CTE of Cerabien ZR was the most different from that of Katana zirconia core (Katana: 10.5, Cerabien ZR: 9.1, Lava Ceram: 10, Cercon Ceram Kiss: 9.6 and IPS e.max Ceram: 9.25-9.75; 10-6*K-1). Furthermore, there might be other factors such as sintering frequency, sintering temperature that affect bonding of zirconia core and veneering porcelain.

Conclusion

From the result of the study, zirconia core and veneering porcelain from the same manufacturer did not show the good result of BFS. Zirconia core might not be necessary to pair with the same manufacturer's veneering porcelain as recommended. Matching of veneering porcelain to zirconia core should consider other influent factors, such as CTE or firing temperature, etc.

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