MECHANICAL PROPERTIES OF VENEERING PORCELAINS FOR ZIRCONIA CORE

Aneta Mijoska
Department of Prosthodontics, Faculty of Dentistry, Ss Cyril and Methodius University, Skopje, N Macedonia, amijoska@yahoo.com

Abstract: All-ceramic prosthetic restorations are developed for better esthetic and higher biocompatibility, and their clinical performances are not sufficiently investigated, yet. Zirconium dioxide ceramic materials posses excellent strength and chemical stability, they come in different dentine colors for achieving natural aesthetics after veneering of the core. Smaller fractures of the veneering ceramic "chippings" are most common complications, but the reasons for their appearance are not yet clarified. The aim of the investigation was to evaluate flexure strength of three different zirconium veneering ceramics and one metal-ceramic to provide data for mechanical properties of the materials. Thirty ceramic discs from four different ceramic veneering materials were prepared. Ceramic specimens were then loaded with symmetrical forces and maximal loading on the central surface in Piston-on-three-ball biaxial bending test. Statistical analysis of the results showed different flexure strength of all four examined ceramic materials. Results showed the highest values for biaxial flexure strength test in Cercon Ceram Kiss 84.9 ± 13 MPa, VITA VM 9 80.2 ± 8 MPa, and the lowest strength for IPS e.max Ceram 73.0 ± 10.6 MPa. However, all veneering ceramics for zirconium showed lower values than veneering ceramic VMK Master for metal core. Tested veneering ceramics are strong materials with high compressive strength, but they are brittle and sensitive to tensile stresses. Tensile ceramic strength is very important for clinical success of the restorations. Improvement of the mechanical properties of the veneering ceramic for zirconium such as flexure strength is imperative for further investigations.
Keywords: veneering ceramic, all-ceramic, zirconia, flexural strength, biaxial test, tensile

1. INTRODUCTION

The need for greater biocompatibility and better esthetics led to development of all-ceramic systems which are increasingly applied, although their clinical performances and success are not yet sufficiently investigated and studied (Giordano R., 1999). Metal-ceramic restorations have been used for many years with great clinical success. Despite advantages they possess, certain disadvantages that are consequences of the presence of metal alloy in their composition occur. Alloy can cause allergic or toxic reaction, electroplating, corrosion and sometimes gingival discoloration. All-ceramic restorations have ceramic core instead of metal alloy, veneered with ceramic porcelain.

Zirconium dioxide as core ceramic material possesses features such as excellent biocompatibility, high strength, chemical stability and dentine color which give the opportunity for better esthetics after veneering. The strength of zirconium dioxide (Y-TZP yttrium partially stabilized tetragonal zirconium polycrystalline) as material for all-ceramic restorations due to finer granulation of ceramic powder and tetragonal-monocyclic transformation plays an important role in the reduced distribution of fractures in the material.

Veneering techniques for the zirconium core are layering, hot pressing and file-splitting methods. The most commonly applied method is the layering technique, which is very delicate and depends on the skill of the technician, the homogeneity of the ceramic slurry, sintering, cooling and coefficient of thermal expansion of the material (Yoshinari M, Derand T, 1994).

Clinical significance, application and success of porcelain materials used for veneering depend on several factors, mostly mechanical characteristics and biocompatibility. Veneering porcelain for metal-ceramics possesses the same strength as the materials for veneering of the zirconia, but clinical practice showed that the prosthetic structures made of veneered zirconia were often damaged and fractured in the mouth (Anusavice KJ, 2006). Damage occurs during the mastication processes such as surface fracture, shearing off the fragments of porcelain mass and serious fractures of the zirconium base (Ritter JE, 1995).

Fractures of the fragments of porcelain veneering materials, the so-called "chipping" are common, but the reasons for their appearance today are not yet clarified. The three most often mentioned factors are: strength of veneering porcelain materials, adhesion between the contact surfaces and mismatch of the coefficient of thermal expansion of the materials (Ritter JE, 1995).

Evaluation of the veneering ceramic flexure strength according to the standards is done with different testing methods (uniaxial and biaxial bending tests). Complexity of all-ceramic restoration leads to different strength data, but in vitro biaxial bending tests are most common (Ban S, Anusavice KJ 1990).

The aim of the study was to evaluate the flexure strength of three different zirconium veneering ceramics compared to one metal-ceramic and provide data for mechanical properties of the materials.

2. MATERIAL AND METHODS

In vitro biaxial flexure strength test (Piston-on-three-ball) standardize as ASTM F394 (EVS-EN ISO 6872:2008) was done on SHIMADZU ASX universal testing machine in the Laboratory for calibration of the force and moment of the force at the Faculty for Mechanical Engineering in Skopje. Ceramic disc specimens were loaded on both opposite sides with symmetrical forces and maximal loading on the central surface.

Dentine ceramic powder (color A2) was mixed with modeling liquid in a slurry according to the manufacturing instructions and put in stainless steel mold. After sintering in the oven, porcelain discs were processed under water with diamond disc with fineness 30-40 μm and polished with polishing paste fineness 15-20 μm / 2 min. To remove any impurities the spicemns were cleaned in an ultrasonic bath in distilled water for about 3 minutes and then dried with pressured air. The dimensions of the spherical discs according to standards are height of 1.2 - 2 mm, diameter of 12-16 mm and a smooth surface with the parallelism of the upper and lower surface of ± 0.05 mm (Figure 1) .

Fig.1. Spherical ceramic discs after sintering

Thirty discs from each type of ceramic were prepared: VMK Master- feldspathic porcelain for metal-ceramic (Vita Zahnfabrik, Bad Sackingen, Germany) and three ceramic materials for all-ceramic, IPS e. max Ceram – fluorapatite porcelain (Ivoclar Vivadent, Schaan, Liechtenstein), Cercon Ceram Kiss - feldspathic porcelain (DEGUDENT Hanau, Germany), VITA VM9- feldspathic porcelain (Vita Zahnfabrik, Bad Sackingen, Germany) (Table 1). VMK Master metal-ceramic veneering porcelain was used as a control group for comparison of the strength between metal-ceramic and all-ceramic restorations (Table 1).

Table 1.Ceramic veneering materials

group	Ceramic material	Manufacturer	Composition	CTE $10^{-6} K^{-1}$
A	**IPS e.max Ceram**	Ivoclar Vivadent, Schaan,Liechtenstein	Nano-fluorapatit glass ceramic	9,5
B	**Cercon Ceram Kiss**	Degudent Hanau, Germany	Feltspat ceramic	9.2
C	**VM9**	Vita Zahnfabrik, Bad Sackingen, Germany	Feltspat ceramic	8,8-9,2
D	**VMK Master**	Vita Zahnfabrik, Bad Sackingen, Germany	Feltspat ceramic with leucit	13,2-13,7

After preparing the specimens were tested in the testing jig on three steel balls with diameter 3.2 mm (2.5 – 6.5 mm), positioned 5 mm from the center on the supporting circle at 120°. Steel cross-head mounted on the upper part of the testing machine with diameter 1.5 mm and moving speed 1±0.5 mm/min loaded the testing specimens until the first fracture happened (Figure 2).

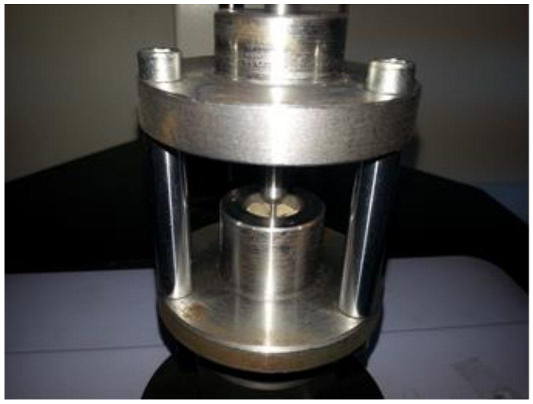

Fig.2. Ceramic specimen testing with fracture strength test

Tensile stress was calculated with the formula:

$$\boldsymbol{\sigma} = -0,238\ 7P\ (X-Y)/d^2, \text{ where}$$

$$X = (1+n)\ln(r_2/r_3)^2 + [(1-n)/2](r_2/r_3)^2 \quad Y = (1+n)[\ln(r_1/r_3)2] + (1-n)(r_2/r_3)^2,$$

σ – Maximum central tensile stress *(*MPa*);* P – total fracture loading *(N);* d – thickness of the specimen at the fracture point (mm); n - Poisson's coefficient 0.25 (for all-ceramic); r_1 – radius of the supporting circle (mm); r_2 radius of the loaded area (mm); r_3 specimen radius (mm).

3. RESULTS

We used Statistica 7.1 for Windows for statistical analysis. The results from the measurement in the experiment showed different flexure strength of all four examined ceramic materials: VMK Master ceramics (Vita Zahnfabrik, Bad Sackingen, Germany), IPS e.max Ceram ceramic (Ivoclar Vivadent, Schaan, Liechtenstein), Cercon Ceram Kiss (DEGUDENT Hanau, Germany), VITA VM9 (Vita Zahnfabrik, Bad Sackingen, Germany).
The results showed that the highest values for biaxial flexure strength test showed Cercon Ceram Kiss (84.9 ± 13 MPa) and VITA VM 9 (80.2 ± 8 MPa), and the lowest strength showed IPS e.max Ceram (73, 0 ± 10, 6 MPa). However, all veneering ceramics for zirconium showed lower values than veneering ceramic VMK Master for metal core (Table 2).
In the relation of groups A/B/ C/ D (samples with a thickness of 1.20 mm without water bath) for F = 14.17 and $p < 0.001$ ($p = 0.000$) there is a significant difference in bending strength. The bending force in group A (M = 254.99 MPa) for $p > 0.05$ ($p = 0.99$) is slightly higher than the bending force in group B (M = 252.26 MPa), compared to group C (M = 265.34 MPa) for $p > 0.05$ ($p = 0.99$) is slightly lower, and compared to group D (M = 333.78 MPa) for $p < 0.001$ (p = 0. 0002) is significantly smaller.

Table 2. Intergroup differences from post-hoc analysis

Intergroup differences	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
A; B; C; D	66846,62	3	22282,21	88046,39	56	1572,26	14,17	**0,000**

4. DISCUSSION

Ceramic specimens made of four different veneering ceramic materials were tested in the universal testing machine SHIMADZU Autograph AGS-X (measuring range 10 kN at a speed of 0.001-1000 mm / min). They were tested with Biaxial Piston-on-three-ball bending test for flexure strength of veneering ceramic materials (Fischer J, Stawarczyk B, Hammerle CHF, 2008, Giordano R., L'Hherault R, Jackson M 2009). This is considered to be the most appropriate test because the specimens can be easily prepared and they have simple shape like discs, and not bars or beams as in an uniaxial bending tests (three-point and four-point tests)
(Pjetursson BE, Sailer I, et al., 2007, Wagner WC, Chu TM, 1996).
Loading force in this test is at the larger area in the central part of the specimen and defects at the edges that lead to an early failure in biaxial tests are less effective (Morrell R et al. 1999, Fett T, Rizzi G.2004).Different ceramics for veneering zirconium dioxide core showed very similar flexure strength, but still many clinical studies showed a high

rate of chipping in all-ceramic restorations after 3-4 years. For metal-ceramic restorations failure rates after 5 years, caused by chipping of the veneer are reported to be 0.4% for single crowns (Stawarczyk B, Özcan M et al.2012) and 2.9% for fixed partial dentures (J.B. Quinn, G.D. Quinn, J.R. Kelly, S.S.2005).

The veneering dental ceramic material is the weakest part of all-ceramic restorations and several factors have important influence such as: thermal expansion mismatch, overload at the premature contacts and ceramic strength (17, 18). The linear coefficient of thermal expansion (CTE) is determined by per unit length for 1 degree change in temperature (1 Kelvin). The CTE is utilized to identify potential stress levels that the ceramic may have in conjunction with the framework and layering material. As a consequence, the coefficient of thermal expansion (CTE) of the layering material should be lower than that of the more rigid framework material. Coefficients of thermal expansion in metal-ceramic restoration are compensated by plastic flow of the alloy, while rigid zirconium core does not yield to the excessive tensile stress enough (B.E. Pjetursson, I. Sailer, 2007). High destructive stress is formed in the veneer layer and that is why the strength of the veneering ceramic is crucial for restorations longevity and it must be as strong as metal veneering porcelain (Sui T, Dragnevski K, et al. 2013, Lawn BR, Deng Yet al, 2013).

Very often chippings spread entirely in the porcelain layer without fracture of the zirconia core, and it is so called cohesive fracture, but when the cracks initiate at the veneering surface they may propagate across the unit and through the interface to cause the final failure (Lawn BR, Deng Y et al.2005). These are the cases with so-called adhesive fracture of the ceramic (S.S. Scherrer, J.B. Quinn et al, 2007). Tested veneering ceramic materials are strong materials with high compressive strength, but they are brittle and sensitive to tensile stresses (Cattell MJ, Clarke RL et al.1997). Tensile ceramic strength is very important for the clinical success of the restoration (Shetty DK, Rosenfield AR et al.2007).

Improvement of the overall mechanical properties of the veneering ceramic for zirconium such as flexure strength is imperative for further examinations and adjusting of the coefficients of thermal expansion, too.

5. CONCLUSION

Within the limitations of this in vitro study, the following conclusions were drawn: Biaxial flexure strength test for evaluating of the fracture resistance of four veneering ceramic gave sufficient data to conclude mechanical properties of the tested materials. The results for strength of veneering ceramics showed that all-ceramic veneering materials have similar strength values, but they were still lower than strength value for the control group of metal-ceramic material. Additional efforts must be made in order to improve the strength properties of the veneering ceramics for zirconium towards increasing the mechanical strength and thermal coefficients adjutancy/adjustment.

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