IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 1 Ver. VI (Jan. 2016), PP 85-88
www.iosrjournals.org

Flexure Strength of Zirconia Veneering Ceramics

Aneta Mijoska[1], Emilija Bajraktarova-Valjakova[2], Vesna Stevkoska-Korunovska[3], Nikola Gigovski[4], Biljana Kapusevska[5], Jagoda Bajevska[6]
[1, 2, 3, 4, 5, 6] *(Department of Prosthodontics, Faculty of Dentistry/ Ss. Cyril and Methodius University, Macedonia)*

Abstract: *All-ceramic zirconia restorations veneered with porcelain materials, show high strength, excellent bio compatibility and good estetic. Some mechanical damages happen during the functional masticatory load, and chipping is most common. There are several reasons for this complication, and they are lower bond strength, mismatch of the KTE (coefficient for thermal expansion) of both materials, premature contacts, and lower flexure strength of the veneering porcelain. The aim of the study is to evaluate and analyze the flexure strength of three veneering ceramics for all-ceramic restoration. Veneering porcelain for metal-ceramic restorations is used as control group. Results for flexure strength of the veneering ceramics showed that all-ceramic veneering materials have similar strength values, but they are still lower than strength value for control group of metal-ceramic material. There must be effort to improve strength properties of the veneering ceramics for zirconium pointed towards increasing of the mechanical strength and thermal coefficients adjutancy*
Keywords *zirconia, dental ceramic, flexure strength, chipping, all-ceramic*

I. Introduction

The need for better esthetic and biocompatibility in fixed prosthodontic is reason for greater use of yttrium-stabilized zirconia as core material for crowns and bridges. Manufacturing procedures of zirconia dioxide ceramic materials are few, but still CAD-CAM milling and veneering with porcelain materials are more often. Zirconia itself provides high strength and toughness, and its transformation forms play important role in good marginal fit and oral performance. Monoclinic, cubic and tetragonal form transitions on different temperatures, are associated with certain volume changes-expansion of 3-4 %, while after sintering shrinkage of 20-25% occur [1]. Due to high mechanical properties zirconia surface is compact and non-reactive, showing lower capacity for adhesion with veneering ceramic materials [2]. These material features must be taken in consideration, and when we are choosing the patients certain criteria must be followed also. Sufficient vertical dimension and inter occlusal space are must, and if patients have bruxism or some other para - functional habit they are not indicated for zirconia restorations [3]. Metal-ceramic restorations are successfully used for very long period of time, and some clinical studies have showed that mechanical fractures of the porcelain are more often presented in zirconia restorations [4]. Clinical significance, application and success of porcelain materials used for veneering depend on several factors, mostly mechanical characteristics and biocompatibility. Veneering fractures can occur as small fragments “chipping”, and sometimes simple smoothening of the edges is enough, while in some cases there is need for new restoration. There are several reasons for this complication, and they are lower bond strength, mismatch of the KTE (coefficient for thermal expansion) of both materials, premature contacts, and lower flexure strength of the veneering porcelain [5]. Certain adjustments of the thermal expansion and bonding procedures can be done, but providing sufficient porcelain strength without losing transparency and esthetic properties is harder task [6], [7].

The aim of the study is to evaluate and analyze the flexure strength of three veneering ceramics for all-ceramic restoration, and the relationship of strength to the thickness of ceramic material. Veneering porcelain for metal-ceramic restorations is used as control group.

II. Material And Methods

Evaluation of the veneering ceramic flexure strength according to the ISO standards is performed with different laboratory testing methods, mostly uniaxial and biaxial bending tests. Complexity of all-ceramic restorations leads to different strength data, but in vitro biaxial bending tests are most common. In vitro biaxial flexure strength test (Piston-on-three-ball) is standardize as ASTM F394 (EVS-EN ISO 6872:2008). It was performed on SHIMADZU ASX universal testing machine at the Laboratory for calibration of the force and moment of the force at the Faculty for Mechanical Engineering in Skopje. Ceramic discs were loaded on both opposite sides, with symmetrical forces and maximal loading force on the central surface of specimen.

Dentine ceramic powder (color A2) was mixed with modeling liquid in ceramic slurry according to the manufacturing instructions, and then put in isolated stainless steel mold. They were left for couple of hours to dry, removed from the mold and sintered in the oven. Sintered discs were processed under running water with diamond disc with fineness 30-40 μm, and then polished with polishing paste fineness 15-20 μm / 2 min. In order to remove any impurities the specimens were cleaned in an ultrasonic bath in distilled water for about 3 minutes and then dried in air. The dimensions of the spherical disks according to standards had 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. Ceramic Specimens

Thirty discs from every ceramic material from different manufactures 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 – Fluor apatite 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 control group for comparison of the flexure strength between metal-ceramic and all-ceramic materials (Table 1).

“Table” 1.Ceramic materials manufacturer and CTE range

VENEERING PORCELAIN	MANUFACTURER	CTE RANGE
VMK®Master	Vita Zahnfabrik, Bad Sackingen, Germany	13,1–13,610·10-6 $\cdot K^{-1}$
IPS e.max Ceram	Ivoclar Vivadent,Schaan, Liechtenstein	13,8–15,2 ·10-6 $\cdot K^{-1}$
Cercon Ceram Kiss	Degudent Hanau, Germany	9,2-10,5 ·10-6 $\cdot K^{-1}$
VITA VM9	Vita Zahnfabrik, Bad Sackingen, Germany	9.0 – 9.2 · 10-6 $\cdot K^{-1}$

The specimens were put 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 with diameter 1, 5 mm and speed 1±0, 5 mm/min, loaded the testing specimens until first fracture happened (Figure 2).

"Fig." 2. Testing jig with ceramic specimen

Tensile stress was calculated with formula (1):

$$\sigma = -0,238\,7\,P\,(X-Y)/d^2, \quad (1) \quad \text{where}$$

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

$$Y = (1+n)\,[\ln(r_1/r_3)^2] + (1-n)\,(r_2/r_3)^2, \quad (3)$$

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).

The results from testing experiment were statistically analyzed with Descriptive Statistics, and differences in the values were tested with Analysis of Variance (F / p) and Kruskal-Wallis ANOVA by Ranks (H / p).

III. Results

Statistical analysis of the results 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 highest values for biaxial flexure strength test had VITA VM 9 ceramic 265, 34 MPa, IPS E. max Ceram ceramic 254, 99 MPa, and lowest strength showed Cercon Ceram Kiss 252,26 MPa. However all veneering ceramics for zirconium showed lower values than veneering ceramic VMK Master for metal core 337,14 MPa.

IV. Discussion

Ceramic specimens made of four different veneering ceramic materials were tested in 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 [8], [9]. This test is most appropriate because specimens can be easily prepared and they have simple shape like discs, not bars or beams as in uniaxial bending tests (three-point and four-point tests) [10], [11]. 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 [12], [13], [14]. Different ceramics for veneering zirconium dioxide core showed very similar flexure strength, but still many clinical studies showed 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 [15] and 2.9% for fixed partial dentures [16].Veneering ceramic 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 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 doesn’t yield to the excessive tensile stress enough [19]. High destructive stress is formed in the veneer layer and that is why strength of the veneering ceramic is crucial for restorations longevity and it must be as strong as metal veneering porcelain [20], [21]. Very often chippings spread entirely in the porcelain layer without fracture of the zirconia core, and it is cohesive fracture, but when cracks initiate at the veneering surface they may propagate across the unit and through the interface to cause the final failure.

These are cases with so called adhesive fracture of the ceramic [22], [23], [24]. Tested veneering ceramic materials are strong materials with high compressive strength, but they are brittle and sensitive to tensile stresses [25, [26]. Tensile ceramic strength is very important for clinical success of the restorations [27].Improvement of the 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.

V. Conclusions

Within the limitations of this in vitro study, next conclusions can be drawn:

1. Biaxial flexure strength test (Piston on three balls) used for evaluating of the fracture resistance of four different veneering ceramic materials, gave us sufficient experimental data to conclude mechanical properties of the tested materials.
2. The results for strength of veneering ceramics showed that all-ceramic veneering materials have quite similar strength values, but they are still little lower than strength value for control group of metal-ceramic veneering material.
3. Additional effort of the manufacturers have to improve mechanical strength features of the veneering materials for zirconium, without setting back of the esthetic and further thermal coefficients adjutancy is needed.

References

[1]. R Giordano. A comparison of all-ceramic restorative systems. Gen Dent, 47(6), 1999, 566-70.
[2]. M Yoshinari , T Derand. Fracture strength of all-ceramic crowns. Int J Prosthodont, 7(4), 1994, 329-38.
[3]. KJ Anusavice. Mechanical properties of dental materials. 'Phillips' science of dental materials'. 93 (11), 2003, 521-530.
[4]. JE Ritter. Critique of test methods for lifetime predictions. Dent Mater, 11(2), 1995, 147- 51.
[5]. JE Ritter. Predicting lifetimes of materials and material structures. Dent Mater, 11(2), 1995, 142-146.
[6]. ANSI/ADA.Specification No.69-1991. Revised American National Standard/American Dental Association Specification No. 69 DENTAL CERAMIC
[7]. S Ban, KJ Anusavice. Influence of test method on failure stress of brittle dental materials. Journal of Dental Research, 69 (12), 1990, 1791-1799.

[8]. J Fischer , B Stawarczyk , CHF Hammerle. Flexural strength of veneering ceramics for zirconia. Journal of dentistry. 36 (5), 2008, 316 – 321.
[9]. R Giordano, R L'Hherault, M Jackson. Precision Flexural Strength of YPT Zirconia Sintered Using Conventional and Microwave Sintering. (Miami Beach Convention Center). 2009.
[10]. BE Pjetursson, I Sailer, M Zwahlen, CHF Ha¨mmerle. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: single crowns. Clinical Oral Implant Research, 18 (1),2008, 73–85.
[11]. WC Wagner, TM Chu. Biaxial flexural strength and indentation fracture toughness of three new dental core ceramics. The Journal of Prosthetic Dentistry, 76 (2), 1996, 140-144.
[12]. R Morrell, NJ McCormick, J Bevan, M Lodeiro, J Margetson. Biaxial disc flexure-Modulus and strength testing. British Ceramic Transactions, 98, 1999, 234-240.
[13]. T Fett, G Rizzi. 3-balls-on-3-balls test on ceramic disks: a finite element study. Kalsruhe: Helmholtz-Gemeinschaft Deutscher Forschugszentrum, 2004. ISSN 0947-8620.
[14]. DK Shetty, AR Rosenfield, GK Bansal, WH Duckworth. Biaxial fracture studies of a glass-ceramic. Journal of the American Ceramic Society, 64 (1),1981, 1-4.
[15]. B Stawarczyk, M Özcan, A Trottmann, CHF Hämmerle, M Roos. Evaluation of flexural strength of hipped and presintered zirconia using different estimation methods of Weibull statistics. J Mech Behav Biomed Mater, 10, 2012, 227-234.
[16]. J.B. Quinn, G.D. Quinn, J.R. Kelly, S.S. Scherrer, Fractographic analyses of three ceramic whole crown restoration failures, Dent Mater, 21, 2005, 920-929.
[17]. G Isgro, P Pallav, JM van der Zel, AJ Feilzer. The influence of the veneering porcelain and different surface treatments on the biaxial flexural strength of a heat-pressed ceramic. The Journal of Prosthetic Dentistry 90, 2003, 465-473.
[18]. E.D. Rekow, N.R.F.A. Silva, P.G. Coelho, Y. Zhang, P. Guess, and V.P. Thompson, Performance of dental ceramics challenges for improvements, J Dent Res, 90, 2011, 937-952.
[19]. B.E. Pjetursson, I. Sailer, M. Zwahlen, C.H. Hammerle, A systematic review of the survival and complication rates of all-ceramic and metal–ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns, Clin Oral Implants Res., 18, 2007, 86-96.
[20]. T Sui, K Dragnevski, TK Neo, AM Korsunsky. Mechanisms of failure in porcelain-veneered sintered zirconia restorations. 13th International Conference on Fracture June 16–21, 2013, Beijing, China
[21]. BR Lawn, Y Deng, VP Thompson. Use of contact testing in the characterization and design of all-ceramic crown like layer structures: a review. J Prosthet Dent ,86, 2001495–510.
[22]. J.B. Quinn, G.D. Quinn, J.R. Kelly, S.S. Scherrer, Fractographic analyses of three ceramic whole crown restoration failures, Dent Mater, 21, 2005, 920-929.
[23]. S.S. Scherrer, J.B. Quinn, G.D. Quinn, H.W. Wiskott, Fractographic ceramic failure analysis using the replica technique, Dental Mater, 23, 2007, 1397-1404.
[24]. B. Taskonak, J. Yan, J.J.Jr Mecholsky, A. Sertgozc, A. Kocak, Fractographic analyses of zirconia-based fixed partial dentures, Dental Mater, 24, 2008, 1077-1082.
[25]. Cattell MJ, Clarke RL, Lynch EJR. The biaxial flexural strength and reliability of four dental ceramics—part II. Journal of Dentistry, 25, 1997,: 409–14.
[26]. C Sinmazisik, ML O¨Vecoglu. Physical properties and microstructural characterization of dental porcelains mixed with distilled water and modeling liquid. Dental Materials, 22, 2006, 735–45.
[27]. DK Shetty, AR Rosenfield, WH Duckworth, PR. A biaxial-flexure test for evaluating ceramic strengths. Journal of the American Ceramic Society, 66, 1983, 36–42.