Coll. Antropol. **37** (2013) 1: 121–125
Original scientific paper

Shear Bond Strength in Zirconia Veneered Ceramics Using Two Different Surface Treatments Prior Veneering

Lana Bergman Gašparić[1], Zdravko Schauperl[2] and Ketij Mehulić[1,3]

[1] University of Zagreb, School of Dental Medicine, Department of Fixed Prosthodontics, Zagreb, Croatia
[2] University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia
[3] University of Zagreb, Zagreb University Hospital Center, Dental Clinic, Zagreb, Croatia

ABSTRACT

Aim of the study was to assess the effect of different surface treatments on the shear bond strength (SBS) of the veneering ceramics to zirconia core. In a shear test the influence of grinding and sandblasting of the zirconia surface on bonding were assessed. Statistical analysis was performed using SPSS statistical package (version 17.0, SPSS Inc., Chicago, IL, USA) and Microsoft Office Excel 2003 (Microsoft, Seattle, WA, USA). There was a significant difference between the groups considering shear bond strength (SBS) values, i.e. ground and sandblasted samples had significantly higher SBS values than only ground samples (mean difference=–190.67; df=10, t=–6.386, p<0.001). The results of the present study indicate that ground and sandblasted cores are superior to ground cores, allowing significantly higher surface roughness and significantly higher shear bond strength between the core and the veneering material.

***Key words**: shear bond strength, zirconia, veneering ceramics, surface treatment*

Introduction

Although conventional metal-ceramic restorations have demonstrated superior fracture resistance over other types of ceramic restorations, due to the opaque appearance it may not be the first choice in patients with high aesthetic demands[1–3]. Kelly et al. identified core translucency as one of the primary factors in controlling aesthetics in ceramic materials[4,5]. Zirconia core allows some light transmission, and thus, veneering ceramics can be applied directly to the core without masking[6]. Zirconia is a crystalline dioxide of zirconium. Its mechanical properties are very similar to those of metals but its colour is similar to tooth colour[7]. Zirconia based all-ceramic restorations can be manufactured both in the anterior, as well as in the posterior dentition, which is an advantage to the lithium disilicate ceramics, which cannot withstand high forces and is therefore limited only to anterior dentition and for a short-span fixed partial dentures (FPD).

The zirconium-oxide all-ceramic material provides several advantages, including a high flexural strength (1000 MPa) and desirable optical properties, such as shading adaptation to the basic shades and a reduction in a layer thickness (compared to conventional ceramics) of the veneer ceramic required to achieve the desired colour[8,9]. Appropriate veneering ceramic can be applied onto zirconia core by either a hand-layered powder build up or a pressed technique[10]. Zirconia based ceramics may be used in posterior region where high occlusal forces are expected due to the high strength of a zirconia core material, but delamination (chipping) of veneering porcelain is described to be the most frequent failure reason. It is reported that chipping is multi-factorial. It may be caused by insufficient bond strength[11], excessive tensile stress due to a thermal mismatch between veneering porcelain and underlying zirconia framework[12], firing shrinkage of ceramics[13], the framework/veneer thickness ratio[14], restoration geometry and inadequate framework design[15].

There is not much information available about the bond quality between veneering ceramics and zirconia core. It has been reported that the bonding strength and

---

Received for publication November 23, 2011

the mode of failure were significantly affected by some surface treatments, such as airborne particles abrasion or use of liners and however a type of zirconia framework material[14,16]. Different manufacturers recommend different surface treatments.

The aim of the present study was to evaluate shear bond strength between veneering ceramics bonded to zirconia with two different methods of preparing zirconia surface prior to applying veneer ceramic material.

Materials and Methods

A total number of 12 zirconia core-veneer samples needed for the study was divided in two groups and prepared according to the following procedures:

Presintered Y-TZP IPS e.max ZirCAD blocks (Ivoclar Vivadent AG, Schaan, Lichtenstein) were used for this study. Sintering to full density in the Programat S1 furnace (Ivoclar Vivadent AG, Schaan, Lichtenstein) during 6 hours at the temperature of 1500 °C, the blocks gained dimensions of 10×10×10 mm needed for the study, so CAD/CAM grinding was not necessary.

All samples were ground under water spray jet incorporated in the hand-piece with a 90 μm grit diamond bur (Komet, Salzburg, Austria). Surface grinding was carried out at the maximum revolutions/min (200,000 rpm) and with minimal pressure to ensure a consistent grinding speed. The cubes were cleaned with 70% ethanol by wiping their surfaces with cotton, then steam cleaned during 10 seconds and air dried. Six samples were left for veneering and other six samples were additionally sandblasted (Renfert duo pro, GmbH, Hilzingen, Germany) with 110 μm Al_2O_3 particles (Cobra; Renfert, GmbH, Hilzingen, Germany) at 2.5 bar pressure for a period of 5 seconds, steam-cleaned and air-dried.

All samples were submitted to the Surface Electron Microscope (SEM) analysis (TESCAN VEGA TS. 5136LS, Tescan, Brno, Czech Republic). Zirconia surface was evaluated under different magnifications to assess the surface topography (Figure 1a, b, c and d). SEM measurements were performed at the Department of Materialography, (Faculty of machine and naval engineering, University of Zagreb, Croatia). Measurement of surface roughness was performed using the Stylus instrument Perthometer S8P (Perthen, Mahr, Göttingen, Germany). During the measurement the stylus was moved at a constant speed across the samples with a measuring force of 1.3 mN. Measurements were performed by using Gauss filter with cut-off value of $\lambda c = 0.8$ mm and the evaluation length ln = 5.6 mm. Mean roughnes (Ra) and Z values (the distance from the highest to the lowest point of measurement along the observed line) were recorded for each sample and were statistically analysed.

After the SEM analysis and determination of surface roughness, all zirconia samples were veneered using a layering technique. The veneering ceramic IPS e.max Ceram powder (Ivoclar Vivadent AG, Schaan, Lichtenstein) was mixed with an appropriate amount of the respective liquid according to the manufactureržs instructions and the obtained slurry was plotted with absorbent paper to draw excess water. After that, the samples were fired according to the firing program of the manufacturer in a firing furnace Programat P700 (Ivoclar Vivadent AG, Schaan, Lichtenstein). To compensate for the porcelain shrinkage during the sintering process, two separate firings under the same conditions were required to establish the correct dimensions of the veneering ceramics (10×5×3 mm).

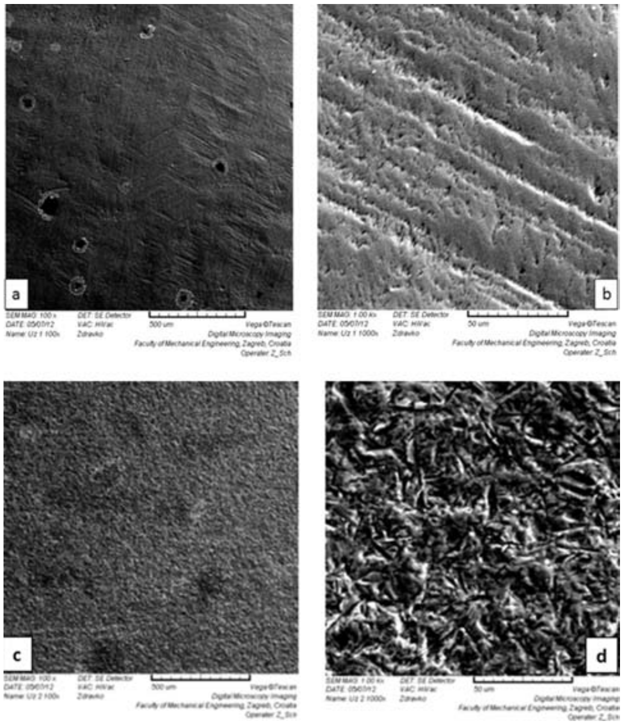

Fig. 1. a and b. SEM micrographs: a and b = ground samples; c and d = ground and sandblasted samples; a and c = magnification 100x; b and d = magnification 1000x.

After the veneer porcelain was sintered to zirconia cubes, each sample was embedded in the customized polytetrafluoroethylene (PTFE) molds using the PMMA resin AcryFix (Struers Co, Ballerup, Denmark) to allow shear bond testing (Figure 2a). The samples were inserted in the holder of the universal testing machine

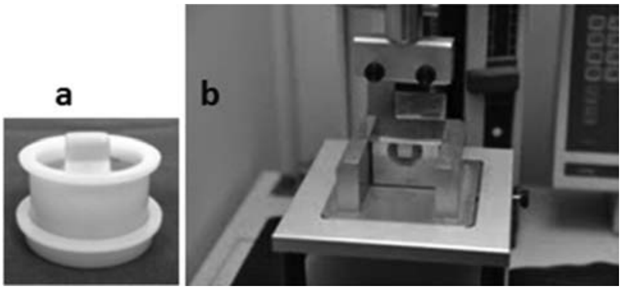

Fig. 2. a = sample in a mold, b = sample placed in a shear bond testing machine.

(model LRX, Lloyd Instruments, Fareham, Great Britain) which had the same diameter as the above mentioned molds, with the core-veneer interface positioned at the level of the jig. Then shear force was applied as close as possible to the veneer-core interface at a crosshead speed of 1 mm/min until fracture occurred (Figure 2b). Load deflection curves and ultimate load to failure were recorded automatically and displayed by the computer software of the testing machine (Nexygen, Lloyd Instruments, Fareham, Great Britain).

Statistical analysis was performed using SPSS statistical package (version 17.0, SPSS Inc., Chicago, IL, USA) and Microsoft Office Excel 2003 (Microsoft, Seattle, WA, USA). Independent samples t-test was used to test the difference between ground samples and ground and sandblasted samples. P value of less than 0.05 was considered statistically significant.

Results

Mean roughness (Ra) of ground zirconia core samples (N=6) and ground and sandblasted zirconia core samples (N=6) are presented in Figure 3. T test for independent samples revealed that there was a statistically significant difference between two sample groups (mean difference= 0.1933; df=10, t=–9.522, p<0.001). Ground and sandblasted samples had significantly higher values.

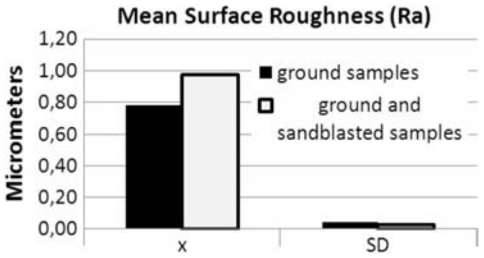

Fig. 3. Ra values of ground and ground + sandblasted samples.

Mean Z values of ground zirconia core samples (N=6) and ground and sandblasted zirconia core samples (N=6) are presented in Figure 4. There was a significant difference between the groups considering Z values, i.e. ground and sandblasted samples had significantly higher z values than only ground samples (mean difference=–1.491; df= 10, t=–26.11, p<0.001).

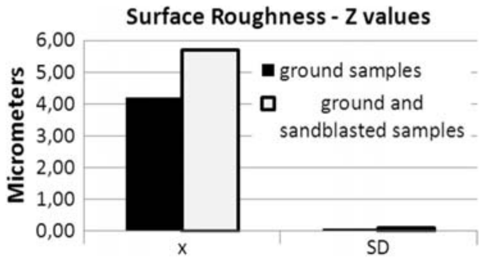

Fig. 4. Z values of ground and ground + sandblasted samples.

Shear bond strength values of ground zirconia core samples (N=6) and ground and sandblasted zirconia core samples (N=6) are presented in Figure 5.

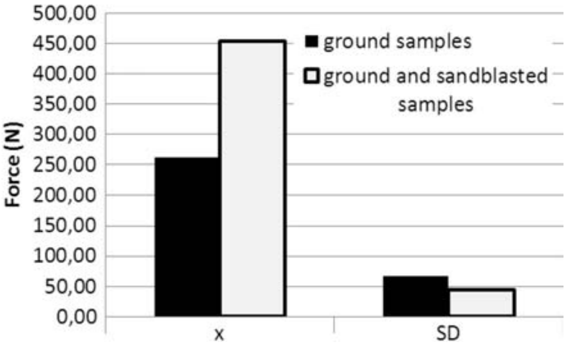

Fig. 5. Shear bond strength values of ground and ground + sandblasted samples.

There was a significant difference between the groups considering shear bond strength (SBS) values, i.e. ground and sandblasted samples had significantly higher SBS values than only ground samples (mean difference= –190.67; df=10, t=–6.386, p<0.001).

Discussion

Dental ceramic materials exhibit many desirable material properties, including biocompatibility, aesthetics, diminished plaque accumulation, low thermal conductivity, abrasion resistance, surface smoothness and colour stability. The popularity of metal-ceramic restorations is large, due to predictable strength with reasonable aesthetics. Zirconia based ceramics have been introduced in prosthodontics due to superior aesthetic properties. In a field of restorative dentistry, zirconia has been used for root canal posts since 1989, for implant abutments since 1995, and for all-ceramic posterior FPDs since 1998[17]. Among all-ceramic materials, zirconia-based ceramics are gaining popularity due to their superior biocompatibility, chemical stability, flexural strength, fracture toughness, and the development of CAD/CAM technologies which allow fabrication of all-ceramic crowns and fixed partial dentures[16,18–20]. High strength core materials are used to reinforce veneering ceramics and also allow clinicians to use a wide range of conventional or adhesive luting protocols during fixation of the restoration[21,22]. It should also be emphasized that adequate tooth preparation and carefully managed laboratory procedures, including maintaining a smooth, uniform thickness of the veneering ceramic on the cores, are also important[23].

The layering technique has been the principal method of applying veneering ceramics to the core material. Sufficient bond strength is a concern for long term clinical success of zirconia restorations and many studies have addressed the associated high failure rate of zirconia-veneering ceramics[12,24–28]. Clinical failures of veneered yttria-stabilized tetragonal zirconia polycristal (Y-TZP) frameworks were reported in 15% of patients after 2 years, and in 13.0% and 15.2% after 3 and 5 years, respectively[15,29–31]. In contrast, failure rates of metal ceramic FDPs were between 8 and 10% after 10 years[32,33]. In a survey of the literature, few articles utilized various bond strength test methods for all-ceramic core and veneering ceramic such as the shear bond strength test[16,24–27,34–37], three and four point loading test[38], biaxial flexure strength test[39] and the microtensile bond strength test[12,26,35].

Using the SBS test to determine the core-veneer bond strength results in more standardized data than using three or four point flexure and biaxial flexure strength test, because the applied forces are perpendicular to the bonding area, and the small cross-sectional area of the bonded surfaces eliminates the incorporation of the structural flaws, which significantly affects test readings[12,40,41]. Therefore the SBS test was used in this study. Surface of the core material was treated in two ways prior layering: zirconia cubes were ground only and ground + sandblasted. After the surface analysis and statistical analysis of the obtained values, it was obvious that ground and sandblasted specimen from the second group had significantly increased surface roughness in comparison to ground samples (Figures 3 and 4). Moreover, second group samples had also significantly higher shear bond strength values than the first group samples ($p< 0.01$, Figure 5). It seems that increased surface roughness enabled consequently an increase of shear bond strength values. Posterior occlusal forces are usually not over 600 N[42,43]. However, the SBS forces can only be of a smaller amount, as they are formed through mandibular excursions during masticatory process. The SBS values for ground and sandblasted samples are probably high enough to withstand many chewing cycles without chipping, even in posterior dentition.

Further studies will be needed to validate recent results and to provide additional information of long term clinical performance.

Conclusion

The results of the present study indicate that ground and sandblasted cores are superior to ground cores, allowing significantly higher surface roughness and significantly higher shear bond strength between the core and the veneering material.

Acknowledgements

This research was supported by the Ministry of Science, Education and Sports of the Republic of Croatia under the Project 065-0650446-0435.

REFERENCES

1. MEHULIĆ K, SVETLIČIĆ V, ŠEGOTA S, VOJVODIĆ D, KOVAČIĆ I, KATANEC D, PETRIČEVIĆ N, GLAVINA D, ČELEBIĆ A, Coll Antropol, 34 (2010) 235. — 2. PERŠIĆ S, MILARDOVIĆ S, MEHULIĆ K, ČELEBIĆ A, Int J Prosthodont, 24 (2011) 523. — 3. MILARDOVIĆ S, VISKIĆ J, ŠTEFANČIĆ S, RENER SITAR K, VOJVODIĆ D, MEHULIĆ K, Coll Antropol, 36 (2012) 213. — 4. KELLY JR, NISHIMURA I, CAMPBELL SD, J Prosthet Dent, 75 (1996) 18. — 5. MCLEAN JW, J Esthet Dent, 7 (1995) 141. — 6. BALDISSARA P, LLUKACEJ A, CIOCCA L, VALANDRO FL, SCOTTI R, J Prosthet Dent, 104 (2010) 6. — 7. PICONI C, MACCAURO G, Biomaterials, 20 (1999) 1. — 8. DELLA BONA A, ANUSAVICE KJ, HOOD JA, Int J Prosthodont, 15 (2002) 248. — 9. DERAND P, DERAND T, Int J Prosthodont, 13 (2000) 131. — 10. BONFANTE EA, COELHO PG, GUESS PC, THOMPSON VP, SILVA NR, J Dent, 38 (2010) 318. — 11. DE JAGER N, PALLAV P, FEILZER AJ, Dent Mater, 21 (2005) 242. — 12. ABOUSHELIB MN, DE JAGER N, KLEVERLAAN CJ, FEILZER AJ, Dent Mater, 21 (2005) 984. — 13. MANICONE PF, ROSSI IOMMETTI P, RAFFAELLI L, J Dent, 35 (2007) 819. — 14. SAITO A, KOMINE F, BLATZ MB, MATSUMURA H, J Prosthet Dent, 104 (2010) 247. — 15. SAILER I, FEHER A, FILSER F, LUTHY H, GAUCKLER LJ, SCHARER P, FRANZ HAMMERLE CH, Quintessence Int, 37 (2006) 685. — 16. KIM HJ, LIM HP, PARK YJ, VANG MS, J Prosthet Dent, 105 (2001) 315. — 17. GLAUSER R, SAILER I, WOHLWEND A, STUDER S, SCHIBLI M, SCHÄRER P, Int J Prosthodont, 17 (2004) 285. — 18. RAIGRODSKI AJ, J Prosthet Dent, 92 (2004) 557. — 19. CASUCCI A, OSORIO E, OSORIO R, MONTICELLI F, TOLEDANO M, MAZZITELLI C, FERRARI M, J Dent, 37 (2009) 891. — 20. GUAZZATO M, QUACH L, ALBAKRY M, SWAIN MV, J Dent, 33 (2005) 9. — 21. PALACIOS RP, JOHNSON GH, PHILLIPS KM, RAIGRODSKI AJ, J Prosthet Dent, 96 (2006) 104. — 22. ERNST CP, COHNEN U, STENDER E, WILLERSHAUSEN B, J Prosthet Dent, 93 (2005) 551. — 23. BONFANTE EA, DA SILVA NR, COELHO PG, BAYARDO GONZALEZ DE, THOMPSON VP, BONFANTE G, Eur J Oral Sci, 117 (2009) 194. — 24. FISCHER J, GROHMANN P, STAWARCZYK B, Dent Mater J, 27 (2008) 448. — 25. FISCHER J, STAWARCZYK B, TROTTMANN A, HAMMERLE CH, Dent Mater, 25 (2009) 419. — 26. ABOUSHELIB MN, KLEVERLAAN CJ, FEILZER AJ, Dent Mater, 22 (2006) 857. — 27. AL DOHAN HM, YAMAN P, DENNISON JB, RAZOOG ME, LANG BR, J Prosthet Dent, 91 (2004) 349. — 28. GUESS PC, KULIS A, WITKOWSKI S, WOLKEWITZ M, ZHANG Y, STRUB JR, Dent Mater, 24 (2008) 1556. — 29. VULT VON STEYERN P, CARLSON P, NILNER K, J Oral Rehabil, 32 (2005) 180. — 30. SAILER I, FEHER A, FILSER F, GAUCKLER LJ, LUTHY H, HAMMERLE CHF, Int J Prosthodont, 20 (2007) 383. — 31. RAIDGORSKI A, CHICHE G, POTIKET N, HOCHSTEDLER J, MOHAMED S, BILLIOT S, J Prosthet Dent, 96 (2006) 237. — 32. CREUGERS NH, KAYSER A, VAN'T HOF MA, Commun Dent Oral Epidemiol, 22(1994)448. — 33. SCURRIA MS, BADER JD, SHUGARS DA, J Prosthet Dent, 79 (1998) 459. — 34. DUNDAR M, OZCAN M, COMLEKOGLU E, GUNGOR MA, ARTUNC C, Int J Prosthodont, 18 (2005) 71. — 35. DUNDAR M, OZCAN M, GOKCE B, COMLEKOGLU E, LEITE F, VALANDRO LF, Dent Mater, 23 (2007) 630. — 36. MOSHARRAF R, RISMANCHIAN M, SAVABI O, ASHTIANI AH, J Adv Prosthodont, 3 (2011) 221. — 37. CHOI BK, HAN JS, YANG JH, LEE JB, KIM SH, J Adv Prosthodont, 1 (2009) 129. — 38. WHITE SN, MIKLUS VG, MCLAREN EA, LANG LA, CAPUTO AA, J Prosthet Dent, 94 (2005) 125. — 39. ISGRO G, PALLAV P, VAN DER ZEL JM, FEILZER AJ, J Prosthet Dent, 90 (2003) 465. — 40. ABOUSHELIB MN, KLEVERLAAN CJ, FEILZER AJ, J Prosthodont, 17 (2008) 13. — 41. FISCHER J, STAWARCZYK B, HAMMERLE CHF, J Dent, 36 (2008) 316. — 42. ĆELIĆ R, BRAUT V, PETRIČEVIĆ N, Coll Antropol, 35 (2011) 709. — 43. LAJNERT V, FRANČIŠKOVIĆ T, GRŽIĆ R, KOVAČEVIĆ PAVIČIĆ D, BAKARČIĆ D, BUKOVIĆ D, ČELEBIĆ A, BRAUT V, FUGOŠIĆ V, Coll Antropol, 34 (2010) 1415.

L. Bergman Gašparić

University of Zagreb, School of Dental Medicine, Department of Fixed Prosthodontics, Gundulićeva 5, 10000 Zagreb
e-mail: bergman@sfzg.hr

UTJECAJ OBRADE POVRŠINE CIRKONIJEVOG OKSIDA PRIJE NANOŠENJA OBLOŽNE KERAMIKE NA VEZNU ČVRSTOĆU

SAŽETAK

Svrha istraživanja bila je testom vezne čvrstoće utvrditi utjecaj poliranja dijamantnim svrdlom i pjeskarenja površine cirkonij oksidne keramike na veznu čvrstoću s obložnom keramikom. Statistička analiza provedena je koristeći SPSS statistički program (17.0, SPSS Inc., Chicago, IL, USA) i Microsoft Office Excel 2003 (Microsoft, Seattle, WA, USA). Postoji značajna razlika u veznoj čvrstoći među uzorcima, polirani i pjeskareni uzorci imali su značajno veću veznu čvrstoću od samo poliranih uzoraka (aritmetička sredina razlike=–190.67; df=10, t=–6.386, p<0.001). Rezultati su pokazali da se pjeskarenjem dobiva hrapavija površina cirkonijevog dioksida što omogućuje bolju vezu s obložnom keramikom.