Effect of zirconia surface treatments on the shear bond strength of veneering ceramic

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ABSTARCT

Background: The aim of the study was to investigate the effect of surface treatments of zirconia (grinding and sandblast with 50µm, 100 µm) on shear bond strength between zirconia core and veneering ceramic.

Material and methods: Twenty-eight presintered Y-TZP ceramic specimens (IPS e.max ZirCAD, Ivoclar vivadent) were fabricated and sintered according to manufacturer's instructions. The core specimens were divided randomly in to 4 groups, group 1: no surface treatment, group2: zirconia specimens were ground with silicon carbide paper up to1200 grit under water cooling, group3: zirconia specimens were ground and sandblast with 100 µm alumina, group 4: zirconia specimens were ground and sandblast with 50 µm alumina. Surface roughness of specimens were analyzed by surface profilometer, then veneering ceramic (IPS e.max ceramic, Ivoclar vivadent) was applied on the specimens& fired according to manufacturer's instructions. All specimens were subjected to shear force in a universal testing machine at a crosshead speed of 1mm/min. The shear bond strength values were analyzed with one-way ANOVA; the fractured surfaces were examined with a stereo-microscope to observe the failure mode.

Results: The mean of shear bond strength values in MPa were 24.75 for group 4, (17.72) for group 3, (17.68) for group2, (14.61) for group 1.The airborne-particle abrasion with 50µm group showed significantly higher bond strength than other groups. The airborne-particle-abraded with 100 µm group was not significantly different from grinding group.

Conclusion: With limit of this study, the sandblast with 50 µm alumina was enhance the SBS between zirconia &veneering ceramic, and zirconia-veneering ceramic bonding is not only influenced by surface roughness. But also may be other factors.

Keywords: Zirconia specimens, veneering ceramic, sandblast, shear bond strength. (J Bagh Coll Dentistry 2014; 26(3):13-17).

الخلاصه

الغرض من هذه الدراسه لفحص تأثير الطرق المختلفه لمعامله السطح لماده الزركونيم على قوه الربط القصي بين هيكل الزركونيم وقشره السيراميك .

تم تحضير ثمان وعشرين عينه من ماده الزركونيم (زركاد ,ايماكس ,ايفوكلار فيفادينت) حسب تعليمات المصنّع،وتم توزيع العينات عشوائياً الى اربع مجاميع:المجموعه الاولى:لا توجد معامله للسطح ، المجموعه الثانيه::شحذ(حك) العينات بأستخدام اوراق الحك(سيلكون كاربايد) تدريجيا الى الحجم 1200مايكروميتر,المجموعه الثالثه :حك العينات ثم تخديشها بواسطه الالومينيوم اوكسايد حجم (100 مايكرون)، المجموعه الرابعه: حك العينات ثم تخديشها بواسطه الالومينيوم اوكسايد حجم (50 مايكرون)، بعد عمليات الحك والتخديش يتم فحص خشونه سطح العينات بواسطه جهاز قياس خشونه السطح(البروفايلوميتر)، ثم تم بناء ماده السيراميك على جميع العينات ثم تم صهر ماده السيراميك حسب تعليمات المصنّع،تم قياس قوه الربط باستخدام جهاز(الانسترون)،تم اجراء الاحصائي بواسطه ANOVA احادي الاتجاه، ثم تم فحص العينات بواسطه المايكرسكوب(ستيريو مايكرسكوب) لتحديد نوع الكسر لكل عينه.

اظهرت النتائج ان معدل قوه الربط للمجموعه الرابعه(24,75) ميكاباسكال,وللمجموعه الثالثه(17,72) ميكاباسكال,وللمجموعه الثانيه (17,68) ميكاباسكال،وللمجموعه الاولى(14,61) ميكاباسكال، قوة الربط للمجموعه الرابعه مجموعه الحك ثم التخديش ب50 مايكرون) كانت اعلى من المجاميع الاخرى,واظهرت النتائج انه لايوجد فرق بين المجموعه الثالثه(مجموعه الحك ثم التخديش ب 100 مايكرون) والمجموعه الثانيه(مجموعه الحك فقط).

ضمن حدود هذه الدراسه فان عمليه التخديش ب 50 مايكرون بعد عمليه الحك تزيد قوه الربط بين هيكل الزركونيم و قشره السيراميك,وقد اظهرت الدراسه ان قوه الربط بين المادتين لا تتأثر فقط بخشونه سطح الزركونيم .

INTRODUCTION

Zirconia-based materials are used as a core for crowns and fixed dental prostheses (FDPs) in restorative dentistry, due to their superior esthetics, biocompatibility and mechanical properties. To achieve optimal esthetics, zirconia frameworks are veneered with a ceramic material, adding veneer ceramics in layers provides the definitive restoration with individual optical characteristics [(1)].

However, clinical failures (chipping and/or delamination of veneering ceramic) of veneered yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) frameworks were reported in 15% of cases after 2 years follow-up [(2)]. According to Fischer et al, bond strength is determined by a range of factors, including chemical bonds, mechanical interlocking, type and concentration of defects at the interface, wetting properties, and the degree of compressive stress in the veneering layer [(3)].

Mechanical or chemical surface treatments promote an increase in the porosity and roughness of dental ceramics, improving wetability [(4)]. It was reported that the bonding strength and the mode of failure were significantly affected by some surface treatments such as air-borne particle abrasion or use of liner material [(5,6)].

Airborne-particle abrasion is a routine way to roughen and clean porcelain bonding surfaces of zirconia, although its role in zirconia to porcelain bonding has not been confirmed [(7)]. It is important to consider that airborne particle abrasion results in a phase transition at the surface, changing the crystal structure from tetragonal to monoclinic.

These crystal structures exhibit different coefficients of thermal expansion (CTE). The coefficient of thermal expansion of monoclinic

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zirconia ($7.5 \cdot 10^{-6}$/ K) is significantly lower than that of tetragonal zirconia ($10.8 \cdot 10^{-6}$/K). The effect of sandblasting on the mechanical strength of Y-TZP and the bond quality to veneering ceramics is a discussed subject [3].

The aim of this study was to investigate the effect of surface treatments of zirconia: grinding and sandblast with (50µm, 100 µm) alumina on shear bond strength between zirconia core and veneering ceramic.

MATERIALS AND METHODS

The presintered Y-TZP block (IPS e.max zircad, Ivoclar Vivadent, Schaan, Liechtenstein) were divided to specimens (dimensions: 8mm in height, 15.5mm in width,19mm in length). Then the specimens were sintered in furnace (InFire HTC speed sintering furnace, Sirona) According to the cycle recommended by manufacturer. After sintering, approximately 25% shrinkage was occurred in zirconia specimens. After sintering, the dimensions of specimens was (11.7 mm in width, 14.3 mm in length, 6mm in height), Then (28) zirconia specimens were divided randomly to four groups according to the surface treatment, each group contains (7) specimens,

Group 1 (control group) zirconia specimens were remained without any surface treatment.

Group2 (grinding group): zirconia specimens were ground by using the grinder\ polisher device (MOpao 160E, china)with silicon carbide paper up to1200 grit [8] under water cooling at speed (600 rpm) for 10 sec for each direction.

Group 3 (grinding and sandblast with (100) µm alumina): zirconia specimens were ground in the same manner as in group 2.Then zirconia specimens were abraded vertically on ground surface with (100µm) alumina (AL_2O_3) particles (Garreco, Inc., United States) at an air pressure (0.3) MPa for (10) second and at fixed distance of (10) mm between the nozzle and the surface of the specimens [8].

Group 4 (grinding and sandblast with 50 µm alumina): zirconia specimens were ground in the same manner as in the group 2.Then the zirconia specimens were abraded vertically on ground surface with (50µm) alumina (AL_2O_3) particles (cobra, Renfert-GmbH, Germany) at an air pressure (0.3) MPa for (10) second and at fixed distance of (10) mm between the nozzle and the surface of the specimens [8].

Application of veneering ceramic

All specimens were cleaned with 70%ethyl alcohol for (10) minutes in a digital ultrasonic cleaner (model cd-4820\china), and air dried. A Liner was applied to all specimens by using a brush to create an even layer [7].Then zirliner was fired in calibrated porcelain furnace (P3000, ivoclar vivodent, Schaan, Liechtenstein) according to the manufacturer's recommendations. Then the ceramic was added incrementally onto the customize- made stain less steel mold (on the prepared surfaces of the zirconia) by using brush, the excess liquid sucked off with paper tissue, the veneering procedure was continued until the mold completely filled. Then, firing of ceramic\dentin was performed in a calibrated porcelain furnace (p 3000, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's recommendations.

Because of the volumetric shrinkage during firing of porcelain, the additional porcelain was added by same previous technique and fired under the same conditions to achieve the desired dimensions of ceramic(10mm in length,5mm in width,3mm in height) [8].

Surface roughness evaluations

The surface roughness of working surface was analyzed for all specimens before and after surface treatment by surface roughness tester (TR 200 – EN 104, time group inc., China). Six measurement were performed for each specimen and the average value were calculated [9].

Shear bond strength test

The specimens were placed in a custom-made holder and mounted in a universal testing machin . Load was applied parallel to the long axis of the specimens and as close as possible to the interface, with a chisel- shaped piston at a constant crosshead speed of 1 mm/min until failure [3]. The maximum force (N) was recorded, and shear bond strength (SBS) in (MPa) was calculated by dividing the load (N) by the surface area of bonded area (mm^2).

Types of failure

All specimens were examined under the stereo-microscope (X 20) to investigate the type of bonding failure. [10] Failure modes were classified as follow: [5] cohesive failure, adhesive failure, Combination.

Statistical analysis

One –way ANOVA test to see if there is any statistical significant difference among and within the groups, t -test was performed to examine the source of differences.

RESULTS

Surface roughness result

The result showed that the highest mean of surface roughness is related to group 1 (no surface treatment) which was (1.13 µm), followed by group 3 (the grinding and sandblast with 100µm) which was (0.88µm) followed by group 4 (grinding and sandblast with 50µm) which was (0.5 µm) followed by group 2 (grinding only) which was (0.039 µm) as shown in the table (1).

Table 1: Descriptive statistics of the surface roughness of zirconia specimen in (µm)

Groups	mean	SD (±)	Min	Max
Group 1 (Control)	1.13	0.07	1.018	1.242
Group 2 (Grinding only)	0.039	0.007	0.03	0.049
Group 3 (Grinding and sandblast with 100µm)	0.88	0.08	0.758	0.985
Group 4 (Grinding and sandblast with 50µm)	0.5	0.03	0.458	0.562

Shear strength result

The result showed that the highest mean of SBS is related to group 4 (the grinding and sandblast with 50µm) which was (24.75Mpa), followed by group 3 (grinding and sandblast with 100µm) which was (17.72 Mpa) followed by group 2 (grinding only) which was (17.68 Mpa) followed by group 1 (control group) which was (14.61Mpa). This is clearly shown in Bar-chart. Fig (1).

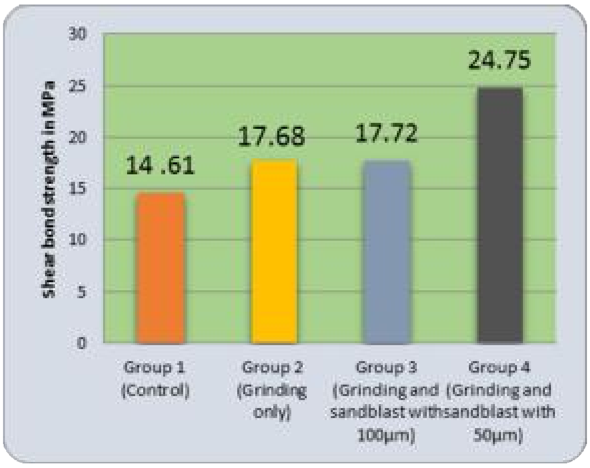

Figure 1: Bar –chart according to mean value of shear bond strength (in Mpa) for total value of four groups.

DISCUSSION

Sufficient bond strength between the veneering ceramic and the substructure is important for the long-term clinical success of zirconia restorations. Bond strength is determined by many factors: strength of the chemical bonds, mechanical interlocking, type and concentration of defects at the interface, wetting properties, and the degree of compressive stress in the veneering layer due to a difference in the coefficients of thermal expansion between zirconia and the veneering ceramic **[11,12]**.

One or more surface treatment is typically used to increase the bond strength, zirconia surface treatment, such as airborne-particle abrasion or the application of a liner, had a significant effect on bond strength [13].

In this study, zirconia specimens (zircad, Ivoclar Vivadent) were veneered with their manufacturer-recommended veneering ceramics (e.max ceram, Ivoclar Vivadent) to ensure the compatible CTE between zirconia specimens and ceramic veneer because the high CTE mismatch between zirconia specimens and ceramic veneer resulted in a region of high stress above the ceramic-core interface Consequently, a crack initiated and propagated in the vicinity of the interface in the veneering ceramic **[14]**. Liners can be applied as an intermediate layer between the zirconia substrate and the veneering ceramic to mask the framework and increase the wetting properties of the zirconia surface. The application of liner material is only recommended for layering veneer ceramics, where it improves bond strength with zirconia substrate and reduces the interfacial failure percentage **[13]**. In this study, according to manufacture, liner (IPS e.max ZirLiners are suitable for the application on IPS e.max ZirCAD) was applied and fired before the veneer ceramic was applied.

In this study, the SBS test was used. The SBS test has been widely used because of its relative simplicity and ease of use compared to the micro tensile bond strength (MTBS) test. Other advantages of SBS testing are ease of specimen preparation, a clear test protocol, and rapid production of test results **[5]**.

In this study, the results of roughness for control group showed higher roughness than other groups, but the result of SBS for control group showed lower than other groups, this may be due to the amount of monoclinic zirconia in control group high compared with other groups. The coefficient of thermal expansion of monoclinic zirconia is 7.5×10^{-6}/k, and that of tetragonal zirconia is 10.8×10^{-6}/k. While the coefficient of thermal expansion of veneering ceramic (IPSe.max ceram) is $9.5 \pm 0.25 \times 10^{-6}$ /k.

Accordingly, an increase in the difference in the coefficient of thermal expansion between the TZP framework and the veneering ceramic leads to tensile stress in the veneering layer due to the quite low coefficient of thermal expansion of the monoclinic phase and lead to decrease in bond strength [15].

The results agree with results by Oguri et al.[16] The result of this study disagree with results by Teng et al.[8] , this difference may be due to the use of different study methods and conditions.

In spite the result of surface roughness of grinding group was showed lower than other groups, the SBS of this group higher than control group. According to kosmac et al, this may be due to the locally developed temperature during severe machine grinding, in spite the water cooling, may have exceeded the T→M transformation temperature (about 700 C) above which the tetragonal zirconia is thermodynamically stable[17] The finding of this study disagrees with the result of Mosharraf et al.[10] who found the grinding dramatically decreased the SBS especially in white zirconia group and this difference may be due to the hand grinding was used in the mentioned study, while the machine grinding was used in present study.

In spite the results showed the surface roughness of group 3 (grinder and sandblast with 100µm) higher than group 2 (grinding only) and group 4 (grinder and sandblast with 50µm) but the SBS of group 3 showed no significant difference with group 2and significantly lower than group 4, this is due to the zirconia surface roughness and the proportion of the monoclinic phase was correlated directly with abrasive particle size. [18]

According to Grigore et al**.** the application of coarse sandblasting involves higher kinetic energy, thus creating a greater defect zone, surface roughness, and monoclinic content in the subsurface layer [18] **.**This finding is in agreement with Fischer et al. [3] who stated increased surface roughness of zirconia by sandblasted did not enhance shear strength. The results of this study disagree with the results Gašparić et al. [19]. This difference may be due to the use of different methods and surface modification (grinding procedure, sandblast pressure, sandblast time).

the result of group 4 (the grinding and sandblasted with 50 µm) showed the highest SBS this may be due to the sand blast 50 µm after grinding provide moderate roughness and porous so provide adequate retention for the veneering ceramic and induce less t-m transformation compared with group 3 and group 1, .This finding disagrees with the result of Fischer et al. [3] and Teng et al. [8]. this difference may be due to the grain size of sandblast particle in the mentioned studies was (110µm) larger than (50 µm) which was used in group 4 of this study.

Most of the specimens demonstrated combined failure or cohesive failure and none of surface treated group's demonstrated adhesive failure, and only control group showed adhesive failure with 28.5%, this result indicated the surface treatment decrease the interfacial (adhesive) failure between zirconia core and veneering ceramic. The results of this study agree with kim et al., 2011 who stated all specimens demonstrated combination fracture mode (adhesive and cohesive failure). [7]

Within the limitation of this study, it was possible to conclude that:

1. The surface treatment (grinding and\or sandblast with alumina particles) of zirconia core is significantly increased the shear bond strength between zirconia framework and veneering ceramic.
2. Shear bond strength (SBS) value of the sandblast with 50µm alumina after grinding is significantly higher compared with other surface treatments.
3. There is no different in SBS between grinding group and sandblast with 100 µm, this result suggested that zirconia-veneering ceramic bonding is not only influenced by surface roughness. But also may be other factors.
4. The surface treatments of zirconia framework is decreased the adhesive failure of veneering ceramic.

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