Short Communication

Effect of Veneering Method on the Fracture and Bond Strength of Bilayered Zirconia Restorations

Moustafa N. Aboushelib, DDS, PhD[a]/Marcel de Kler[a]/Jef M. van der Zel, PhD[b]/Albert J. Feilzer, DDS, PhD[b]

This study evaluated the fracture strength and microtensile bond strength of a new computer-aided design (CAD) veneering method for zirconia frameworks. A new CAD/computer-assisted manufacture system was used to fabricate a resin replica of the esthetic ceramic required to veneer a zirconia framework. The replicas were processed using press-on technology. Identical manually layered zirconia specimens served as a control (n = 18; α = .05). Statistical analysis revealed that the fracture strength (442.8 ± 25 N) and microtensile bond strength (26.6 ± 2 MPa) of CAD-veneered zirconia were significantly higher (P < .001) compared to the control (346 ± 24 N and 15.1 ± 1 MPa, respectively). CAD veneering is a reliable method for veneering zirconia frameworks. *Int J Prosthodont 2008;21:237–240.*

With state-of-the-art computer-aided design/computer-assisted manufacture (CAD/CAM) technology, the production of complex and large zirconia frameworks with higher accuracy and reduced processing time and cost is just a click away. On the other hand, manual layering of the veneer ceramic is operator dependent and primarily relies on the skills of the ceramist. A recently introduced type of veneering ceramic uses press-on technology to overcome the limitations of manual layering and enhance the bond with zirconia frameworks.[1] In an effort toward digitizing the veneering process, a new CAD/CAM system was used to fabricate a resin replica of the esthetic ceramic required to veneer zirconia frameworks. The resin replica is further processed using the press-on technique. The hypothesis of this study was that the CAD veneering method would improve the fracture strength and increase the veneer bond strength to a zirconia framework compared with manual layering.

[a]Researcher, Department of Dental Materials Science, Academisch Centrum Tandheelkunde Amsterdam, Universiteit van Amsterdam and Vrije Universiteit, The Netherlands.

[b]Professor, Department of Dental Materials Science, Academisch Centrum Tandheelkunde Amsterdam, Universiteit van Amsterdam and Vrije Universiteit, The Netherlands.

Correspondence to: *Moustafa N. Aboushelib, Department of Dental Materials Science, ACTA, Louwesweg 1, 1066 EA, Amsterdam, The Netherlands. E-mail: dentalmaterials@acta.nl*

Materials and Methods

Preparation of the Specimens

A standard full-crown preparation was carried out on a mandibular right molar, which was laser scanned using the CYRTINA system (Oratio). The scanning unit consists of a light section laser triangulation scanner and scan-design software. The scanner uses a laser line (640 nm) section projection with a resolution of 13.9 µm and "in flight" registration of the deformed laser line at 50-µm steps using 2 cameras. The scanned preparation surface consisted of a point cloud of 245,000 points. Thirty-six identical zirconia frameworks with a round margin and a thickness of 0.5 mm were produced and sintered at 1,450ºC for 2 hours.

Half of the sintered zirconia frameworks were individually placed on the prepared die, which was scanned again using CYRTINA CAD 20 (Oratio). The design software was used to digitally build the required form of the veneer ceramic, taking into account the occlusal and proximal contacts and the emerging profile of the cervical region. The CAD veneer was brought into contact digitally with the antagonist teeth, resulting in 15 contact points, defined as being within 50 µm vertical distance from the antagonist surfaces. After a simulated articulator movement with average settings, approximately 5 contact points remained. The data obtained were used to mill a carving resin block to the required form with a melting point of 116°C (Matt Carving Resin, Du-Matt).[2]

Fig 1 Milled carving block demonstrating the outer and inner surfaces of the resin veneer replica.

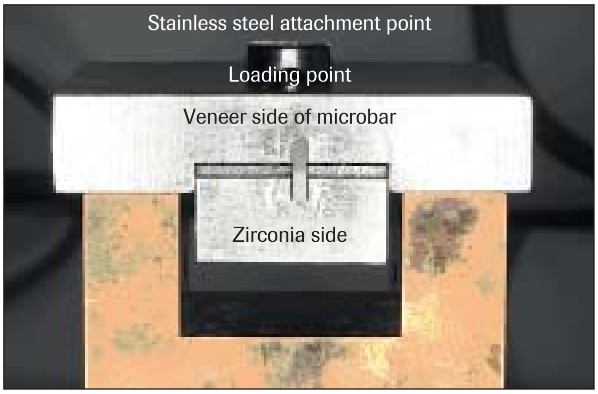

Fig 2 Zirconia veneer microbar attached to the attachment unit using a light-polymerized adhesive resin. As the 2 plates of the attachment unit are separated, the interface is subjected to tensile stresses.

The resin veneer replica (Fig 1) was seated on the zirconia framework and processed according to the press-on technique (IPS e.max Zirpress, Ivoclar Vivadent).[1] The specimens were attached to the plastic muffle of a disposable paper ring using 2-mm wax sprues. The ring was filled with a vacuum-mixed investment material (IPS pressVest, Ivoclar Vivadent), and after a setting time of 45 minutes, the ring was placed in a preheated burnout furnace (850ºC) for 60 minutes. A ceramic pellet of the required shade (A3.5) was inserted in the muffle, followed by an alumina plunger. The ring was then transferred to a computer-controlled press furnace (EP500, Ivoclar Vivadent), which pressed the molten ceramic pellet under vacuum. The remaining zirconia frameworks were manually layered (IPS e.max Ceram, Ivoclar Vivadent) and used as a control group (n = 18).

Fracture Strength Test

Each specimen was bonded to a resin die (Filtek Z250, shade A3.5, 3M ESPE) and axially loaded to failure (Instron 6022, Instron) at a crosshead speed of 1 mm/min. To avoid generation of cone cracks, a sheet of tough rubber (0.5 mm in thickness) was inserted between the restoration and the loading indenter.[3]

Evaluation of Zirconia Veneer Bond Strength

The bond between the 2 types of veneers and the zirconia framework was measured using a microtensile bond strength test. Bilayered zirconia veneer disks (19.5 mm in diameter and 4 mm in thickness) were prepared as previously described, and 2 perpendicular cuts were made (Isomet 1000, Buehler). The obtained microbars (4 mm long with a cross section of 1 mm^2) were individually glued to the attachment using a light-polymerized adhesive resin (Clearfil SE, Kuraray). The zirconia veneer bond strength was measured by delivering axial load perpendicular to the bonded area, which tended to separate the 2 plates of the attachment unit, thus subjecting the zirconia veneer interface to tensile stresses (Fig 2).[4]

Scanning electron microscopy (SEM) was used to examine the fractured specimens and assess the quality of the zirconia veneer interface (XL 20, Philips). For statistical analysis, the data were entered into SPSS 10.0 computer software (SPSS). The independent-samples t test was used to analyze the data ($\alpha = .05$).

Results

There were significant statistical differences in terms of fracture strength ($t = 11.8$, $P < .001$) and microtensile bond strength test ($t = 24.4$, $P < .001$) between the CAD-veneered specimens and the manually layered specimens. These data are summarized in Table 1. SEM analysis revealed that the CAD-veneered specimens failed cohesively because the crack origin was located in the veneer ceramic, while manually layered specimens demonstrated primarily an interfacial failure pattern because the crack origin was located at the zirconia veneer interface, resulting in delamination of the veneer ceramic (Fig 3). All zirconia frameworks remained intact because the test was stopped at the first failure sign as indicated by a sudden drop in the recorded load. Additionally, the CAD-veneered zirconia interface demonstrated good contact between the 2 materials (Fig 4). On the other hand, structural defects and air bubbles were observed at the manually layered zirconia interface, primarily in the liner material (Fig 5).

Table 1 Means (SDs) of the Fracture Strength and Microtensile Bond Strength (MTBS) of the Tested Specimens

	Fracture strength (N)*	MTBS (MPa)**
CAD-veneered specimens	442.8 (25)	26.6 (1.6)
Manually layered specimens	346 (24)	15.1 (1.3)

*$P < .001$, $t = 11.8$.
**$P < .001$, $t = 24.4$.

Fig 3 SEM image demonstrating the interfacial fracture pattern of manually layered specimens. Zirconia grains are evident at the fracture site. (Magnification ×3,500.)

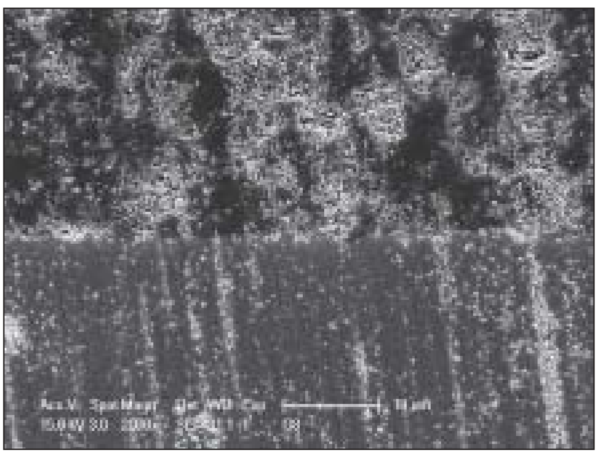

Fig 4 SEM image demonstrating the structural integrity of the zirconia-CAD veneer interface. (Magnification ×2,000.)

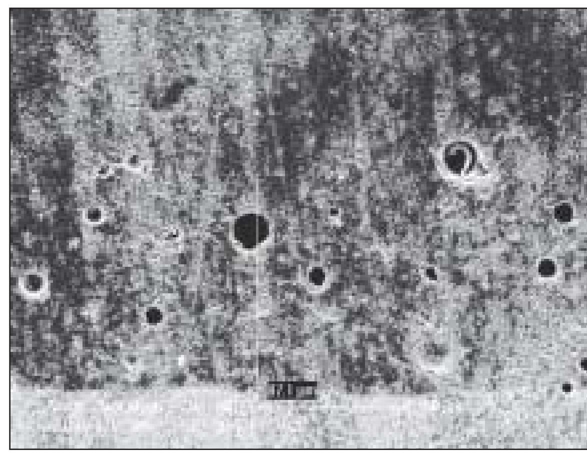

Fig 5 SEM image demonstrating the structural defects and air bubbles at the zirconia-layered veneer interface. (Magnification ×500.)

Discussion and Conclusion

Fracture strength tests make it possible to compare the failure loads of the tested specimens to the expected functional loads during a masticatory cycle, thus indicating the expected performance of these restorations under clinical conditions. Previous studies reported failure loads for core veneered all-ceramic crowns ranging from 630 to 2,000 N, which is much higher than the values reported in the present study.[5–9] Such a wide variation could be attributed to several factors, including the mechanical properties of the materials used, the cementation technique, anatomic differences in shape and thickness, and the loading method. Two factors deserve further attention. First, the use of a stress breaker between the loading indenter and the restoration would result in better distribution of the loading stresses.[10] Second, determination of the failure point could also have a wide effect on the results. In the present study, failure was determined by the initial damage that was observed, and this was indicated by the sudden drop in the applied load as observed on the load displacement diagram. Further, loading beyond this point would only result in crushing the restoration and giving false higher readings.[11] Considering these factors, more clinically relevant fracture strength data were obtained for metal-ceramic and all-ceramic crown restorations.

In a study by Potiket et al,[12] there were no significant statistical differences in the failure loads (381 to 405 N) between metal-ceramic and all-ceramic crown restorations. This indicates that failure of these restorations is dependent on factors other than the strength of the supporting core.[13]

The core veneer bond strength and interface quality emerged as important factors that could significantly influence the mechanical properties of layered restorations. Selection of a proper test methodology is important to obtain clinically relevant data. Since the standard ISO bond strength tests were originally developed for metal-ceramic systems, preparation of a standard-size all-ceramic specimen would result in increasing the volume percentage of structural defects, which beyond a certain load become the dominant failure sites even before the tested bond strength value is reached. Accordingly, the use of shear bond strength tests with bilayered ceramics results in a higher tendency for cohesive failure of the weaker ceramic because of the abnormal stress concentration in the brittle specimens.[14] On the other hand, the microtensile bond strength test requires small specimens where the loading stresses are perpendicular to the bonded area, resulting in a more accurate evaluation of the bond strength and less scattering of the data.

The combination of CAD veneering and press-on technology offered a controlled environment in which the design and processing of the veneer ceramic are both optimized. During pressing, the molten ceramic pellet is brought into contact with the zirconia framework under pressure and in a vacuum, resulting in improved wetting and contact between the 2 materials (Fig 4). The air bubbles and structural defects observed at the zirconia layered veneer interface (Fig 5) may have formed because the liner material was applied as a thin wash layer over the framework material, which requires a higher liquid-powder ratio compared to the consistency of normal veneering slurry.[15] Such findings may explain why the zirconia veneer interface was previously reported as a failure site of zirconia specimens.[16]

The superior quality of the CAD-veneered zirconia interface may also explain the improved bond strength between the 2 ceramics, the higher fracture strength values, and the reduced tendency toward delamination failure compared to the manually layered specimens. Based on these data, the proposed hypothesis was accepted. Previous studies reported a zirconia veneer bond strength ranging from 17 to 41 MPa, which was also directly related to the quality of the zirconia veneer interface and to the surface finish of the framework material, which is in agreement with the present study.[1,4] In another step toward complete automation, CAD veneering eliminated design and processing errors and improved the performance of zirconia restorations.

References

1. Aboushelib MN, Kleverlaan CJ, Feilzer AJ. Microtensile bond strength of different components of core veneered all-ceramic restorations: Part II: Zirconia veneering ceramics. Dent Mater 2006;22:857–863.
2. Vlaar ST, van der Zel JM. Accuracy of dental digitizers. Int Dent J 2006;56:301–309.
3. Aboushelib MN, de Jager N, Kleverlaan CJ, Feilzer AJ. Effect of loading method on the fracture mechanics of two layered all-ceramic restorative systems. Dent Mater 2007;23:952–959.
4. Aboushelib MN, de Jager N, Kleverlaan CJ, Feilzer AJ. Microtensile bond strength of different components of core veneered all-ceramic restorations. Dent Mater 2005;21:984–991.
5. Attia A, Kern M. Influence of cyclic loading and luting agents on the fracture load of two all-ceramic crown systems. J Prosthet Dent 2004;92:551–556.
6. Attia A, Kern M. Fracture strength of all-ceramic crowns luted using two bonding methods. J Prosthet Dent 2004;91:247–252.
7. Chen HY, Hickel R, Setcos JC, Kunzelmann KH. Effects of surface finish and fatigue testing on the fracture strength of CAD-CAM and pressed-ceramic crowns. J Prosthet Dent 1999;82:468–475.
8. Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J 1995;40: 17–21.
9. Sundh A, Sjogren G. A comparison of fracture strength of yttrium-oxide-partially-stabilized zirconia ceramic crowns with varying core thickness, shapes and veneer ceramics. J Oral Rehabil 2004;31:682–688.
10. Kelly J. Clinically relevant approach to failure testing of all-ceramic restorations. J Prosthet Dent 1999;81:652–661.
11. Dong X, Darvell B. Stress distribution and failure mode of dental ceramic under Hertizian indentation. Dent Mater 2003;19:542–551.
12. Potiket N, Chiche G, Finger IM. In vitro fracture strength of teeth restored with different all-ceramic crown systems. J Prosthet Dent 2004;92:491–495.
13. Strub JR, Beschnidt SM. Fracture strength of 5 different all-ceramic crown systems. Int J Prosthodont 1998;11:602–609.
14. Dundar M, Ozcan M, Gökce B, Cömlekoglu E, Leite F, Valandro LF. Comparison of two bond strength testing methodologies for bilayered all-ceramics. Dent Mater 2007;23:630–636.
15. Fleming GJ, Shaini FJ, Marquis PM. An assessment of the influence of mixing-induced variability on the bi-axial flexure strength of dentine porcelain discs and the implications for laboratory testing of porcelain specimens. Dent Mater 2000;16:114–119.
16. Studart AR, Filser F, Kocher P, Luthy H, Gauckler LJ. Mechanical and fracture behavior of veneer-framework composites for all-ceramic dental bridges. Dent Mater 2007;23:115–123.