Microtensile Bond Strength of Different Components of Core Veneered All-Ceramic Restorations. Part 3: Double Veneer Technique

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Abstract

Purpose: The bond strength of zirconia veneer has been considered a weak link in the layered all-ceramic restoration. In a previous study, this bond was improved using a new category of veneering ceramics adopting the pressing technique; however, the resulting esthetic quality lacked the individual characterization built using the layering technique. The aim of this work was to evaluate the effect of combining both press-on and layering veneer ceramics in one restoration on the bond strength with zirconia frameworks.
Materials and Methods: Zirconia discs (19.4 mm in diameter, 3-mm thick) were veneered with 3-mm thick press-on veneer ceramic or veneered with 1-mm thick press-on veneer ceramic and an additional 2-mm thick of layering veneer ceramic. Two commercial layering veneer ceramics were tested. The specimens were sectioned into microbars, and the zirconia veneer microtensile bond strength (MTBS) was measured in a universal testing machine. Scanning electron microscopy (SEM) was used to examine core veneer interface quality and to assess failure type. Energy dispersive X-ray microanalysis (EDAX) was used to analyze the chemical structure of the tested veneer ceramics, which may affect the structural integrity of the double veneered restoration. One-way analysis of variance and Tukey HSD post hoc tests were selected to analyze the data ($p < 0.05$ was significant).
Results: The MTBS of zirconia and press-on ceramic (34.4 ± 2.9 MPa) was not affected by the addition of a second layer of either veneer ceramic. SEM analysis revealed defect-free zirconia press-on veneer interface, while the interface between the press-on and the layering veneer ceramics demonstrated a different crystal structure and glass matrix, which did not affect wetting and contact between the two materials. EDAX analysis revealed differences, which account for the observed structural differences, in the chemical composition between the tested veneers.
Conclusion: The double veneer technique combines the high bond strength and superior interface quality achieved using press-on ceramics with the superior esthetics and individual characterization obtained using layering ceramics. The technique promises superior function and performance of the double veneered restoration.

Chemical stability and superior physical and mechanical properties, combined with CAD/CAM technology, have made zirconia-based materials the framework material of choice for fixed dental prostheses.[1,2] To achieve better esthetics, the zirconia framework is veneered with a ceramic material, which is built in successive layers, giving the final restoration individual optical characteristics that can barely be distinguished from the surrounding natural dentition.[3]

To ensure structural integrity of such layered restorations under functional loads and to prevent chipping and delamination of the veneer ceramic, the core veneer bond must be of a certain minimal strength. Because stress distribution in a two-phase material construction is more complex than a homogenous one-phase material construction, additional factors must be considered for layered zirconia restorations.[4] The thermal expansion behavior, firing shrinkage, interface toughness and roughness, and heating and cooling rates are all factors that must be handled carefully to prevent generation of undesired tensile stresses.[5]

In a previous study, the core veneer bond strength of different all-ceramic core and veneer materials was evaluated using a microtensile bond strength (MTBS) test. An interesting observation was the low MTBS of the zirconia framework to its recommended veneer ceramic (29.1 MPa), in contrast to other layered core materials such as lithium disilicate, which demonstrated a higher MTBS with its veneer ceramic (44.6 MPa).[6]

Recently, a new generation of ceramics has been introduced for veneering zirconia frameworks adopting pressing technology. The advantages of this system are simplicity, quickness, and defect-free structures, while the application of the lost wax method provides special anatomical characterization, which is difficult to achieve using the standard layering technique. The higher tensile strength of these press-on veneers, in addition to their superior interface quality and higher bond strength with zirconia frameworks, make them optimal materials to apply.[7] On the other hand, the major drawbacks of these materials are the inferior esthetic and optical qualities, as compared with the layered veneer ceramics, limiting their application in the esthetic zone of the mouth.

Combining the press-on and the layering ceramics in one restoration may provide both superior bond and interface quality with improved esthetics and thus enhance the overall performance of zirconia restorations. As layering and press-on veneer ceramics each have different chemical and physical properties and different thermal expansion coefficients, their combination in one restoration has not been previously evaluated. It was the aim of this research to study the effect of such double veneering on the bond strength with zirconia framework materials.

Materials and methods

Preparation of the specimens

Materials tested and their properties are summarized in Table 1. Fifteen zirconia discs (19.4-mm diameter, 3-mm thick) were prepared by cutting CAD/CAM milling blocks (Cercon® Base) followed by polishing with 600 grit silicon carbide paper and sintering in the manufacturer's recommended furnace. After firing, the discs were sandblasted with 120-μm aluminum oxide at pressure of 3.5 bar. The discs were equally divided into three groups according to the structure of the veneer:

1. A control group composed of zirconia and 3-mm thick press-on veneer.
2. Two double veneered test groups each composed of zirconia, 1-mm thick press-on veneer, and an additional 2-mm thick layering veneer ceramic. A different layering ceramic was used for each of these groups: Noble Rondo zirconia or Cercon ceram kiss.

Wax discs (19.4-mm diameter) were fused to the sandblasted surface of the zirconia discs and were processed according to manufacturer's instructions for press-on veneer ceramic (Cercon ceram express). After devesting and cleaning, the specimens were seated in an adjustable aluminum mold where a layer of dentine ceramic slurry, either Noble Rondo zirconia or Cercon ceram kiss, was condensed, blot dried, and pressed under pneumatic plunger to ensure good condensation of the material. Finally the double veneered specimens were fired according to the manufacturer-recommended program (Austromat 3001, Dekema Dental-Keramiköfen GmbH & Co, Freilassing, Germany).

MTBS test

All specimens were cut into microbars ($6 \times 1 \times 1$ mm^3) using a diamond-coated disc under water cooling (Ecomet, Buehler Ltd, Evanston, IL). The microbars were examined under a stereomicroscope, and 18 sound bars were selected from each group ($n = 18$). This sample size was based on a power analysis in which the power was set at 0.8, the significance level at 0.05, and a large effect size ($f = 0.4$), which in terms of measuring MTBS value represents clinical relevance. The selected microbars were glued to a special attachment unit using a light-cured adhesive resin (Clearfil SE Bond, Kuraray Medical, Inc., Okayama, Japan) taking care to center the zirconia veneer interface at the free space of the attachment unit.[8] The microbars were loaded to failure at a crosshead speed of 1 mm/min (Instron 6022, Instron Limited, High Wycombe, UK).[9]

Scanning electron microscopy (SEM)

To evaluate the fracture type, the broken bars were ultrasonically cleaned, gold sputter-coated, and examined under SEM (XL 20, Philips, Eindhoven, The Netherlands). Failure type was classified into two groups according to the fracture initiation site: interfacial fracture across zirconia press-on veneer interface or cohesive fracture in the veneer ceramic. Sound sections

Table 1 Material properties

Material	Manufacturer	Batch	Composition	Thermal Expansion Coefficient (ppm/°C)
Cercon base	Degudent GmbH, Hanau-Wolfgang, Germany	20010301	Zirconium oxide (92%vol), yttrium oxide (5%vol), hafnium oxide (2%vol), alumina and silica (<1%vol)	10.5
Cercon ceram kiss		31273	Feldspathic porcelain for layering technique	9.2
Cercon ceram express posterior		305892A	Glass ceramic for pressing technique	10.5
Nobel Rondo zirconia dentine	Nobel Biocare AB, Gotenborg, Sweden	0105	Fine grained homogenous feldspathic porcelain for layering technique	9.3

from each test group were polished and examined under high magnification to examine the zirconia veneer interface as well as the interface between the press-on and the layering veneers.

Energy dispersive X-ray microanalysis (EDAX)

To study whether the chemical composition of the added layering veneer ceramic is a factor affecting the zirconia veneer bond strength, polished sections of the double veneered specimens were carbon coated and examined with EDAX at 30 KV. To assess the chemical structure of each of the tested veneer ceramics, the beam (spot size 1 μm) was focused on the center of the examined ceramic.

Statistical analysis

One-way analysis of variance (ANOVA) and Tukey HSD post hoc tests were selected to analyze the data (SPSS 12.0.1, SPSS, Inc., Chicago, IL). P-values <0.05 were considered significant. Statistical power analysis was used as described elsewhere.[10]

Results

There was no statistically significant difference in the zirconia veneer MTBS among the three groups ($p = 0.28$, $\eta^2 = 0.055$). Based on Cohni's criteria, a partial η^2 value of 0.055 suggests that only approximately 6% of the MTBS variance was related to the veneer configuration. Thus, the MTBS of zirconia and press-on veneer ceramic double layered with either Noble Rondo zirconia (36.7 ± 5.1 MPa) or Cercon ceram kiss (36.6 ± 5.1 MPa) was not statistically significantly different from the bond strength value of the control specimens composed of zirconia veneered with the press-on ceramic alone (34.4 ± 2.9 MPa) (Table 2). SEM analysis of the broken microbars of the control group revealed entirely cohesive failure between zirconia and press-on veneer ceramic (Fig 1), while for the other two groups interfacial failure type was observed (Fig 2, Table 2).

SEM examination of the polished sections revealed a defect-free interface between zirconia and press-on veneer ceramic (Fig 3). There was a structural difference in the crystal structure and the glass matrix between the press-on and the layering ceramics that did not result in structural defects as was demonstrated by the good contact observed between the two materials (Fig 4).

EDAX analysis revealed differences in the chemical structure between the tested veneer ceramics. The percentage of potassium ions, and to a lesser degree sodium ions, was lower in the press-on veneer than in the layering ceramics. On the other hand, the percentage of aluminum was almost double in the Noble Rondo zirconia compared with the other ceramics (Table 3).

Table 2 MTBS (MPa) and fracture type of the tested groups

Structure of test specimen	MTBS (MPa)*	Failure type
Zirconia/press-on veneer/Noble Rondo zirconia	36.7 ± 5.1	72% cohesive
Zirconia/press-on veneer/Cercon ceram kiss	36.6 ± 5.1	77% cohesive
Zirconia/press-on veneer	34.4 ± 2.9	100% cohesive

*There was no statistically significant difference in MTBS values among the tested groups.

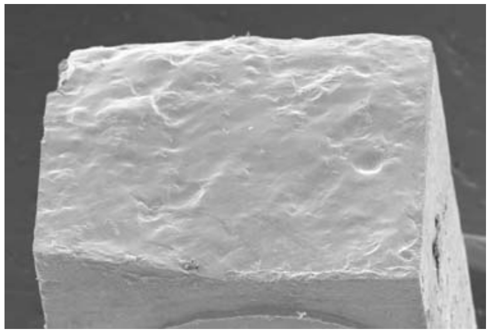

Figure 1 SEM image of zirconia side of a broken microbar demonstrating a cohesive fracture. Fracture originated and propagated in the press-on veneer ceramic.

Discussion

Various test methodologies previously used to measure or evaluate core veneer bond strength include shear test, three point and four point flexure, and biaxial flexure strength test. Estimating the bond strength values from these tests was very complicated due to the structural damage associated with the testing method and with the fracture mechanism.[1,11–13] Delamination of the veneer ceramic from intact zirconia frameworks was previously reported, but was not directly related to a weak core veneer bond strength.[1,3,14] Using the MTBS test to determine the core veneer bond strength resulted in more standardized and less scattered data, as the applied forces are perpendicular to the bonded surface, and the small cross-sectional area of the microbars ensures minimal incorporation of structural flaws, which significantly affect test readings.[6,9,15] On the other hand,

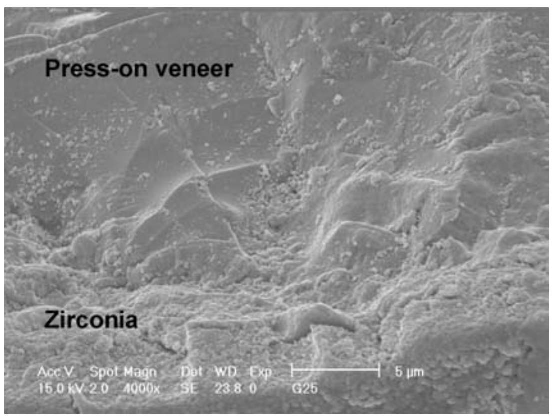

Figure 2 SEM image of zirconia side of a broken double veneered microbar demonstrating an interfacial fracture. Fracture originated at zirconia press-on ceramic interface leaving exposed zirconia grains.

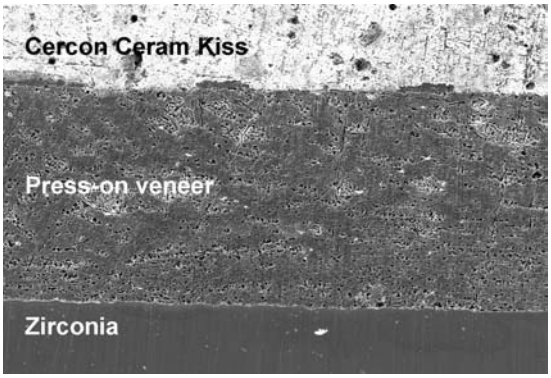

Figure 3 Polished cross section demonstrating good contact between zirconia and press-on veneer and between press-on and layering veneer ceramics.

using MTBS to measure core veneer bond strength requires careful attention during cutting the brittle specimens in order to avoid creation of cutting defects or unexpected cracking of the microbars. Using sharp new cutting discs at high cutting speeds and low loads reduces vibrations and ensures fine cutting of the specimens.

As the introduction of zirconia to dentistry as a framework material is relatively new compared with other core materials, related materials and techniques are frequently introduced without sufficient clinical and laboratory data concerning the performance of these systems. Press-on veneer ceramics were recently introduced with claims of improved performance and better bonding to zirconia frameworks compared with older versions of layering veneer ceramics.[7] Application of these veneer ceramics was limited by their monochromatic color compared with the customized superior esthetics built using the layering technique.

The zirconia press-on ceramic bond strength was comparable to a previously published value of 38.6 MPa using the same materials.[7] The addition of a layering ceramic over already pressed-on veneer did not result in weakening its bond strength with zirconia framework or in the creation of structural defects across the zirconia veneer interface (Fig 3), even though the

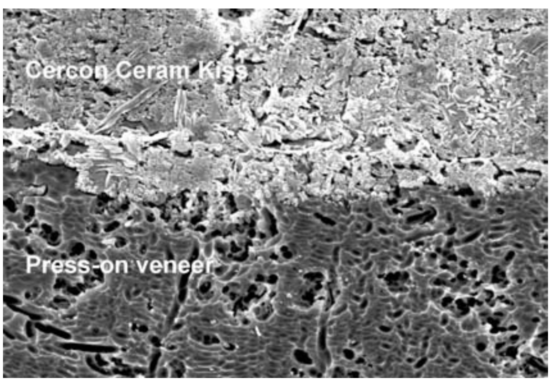

Figure 4 Defect-free interface between the press-on and the layering veneer ceramics demonstrating different crystal and glass matrix structures.

Table 3 EDAX analysis of the tested veneer ceramics

		Element composition (wt%)*					
Beam location	Veneer ceramic	Si	K	Al	Na	Pt	Ca
Center of specimen	Press-on veneer	31.8	0.5	5.8	5.2	0.6	—
	Noble Rondo zirconia	33	7.8	9.8	7.6	—	—
	Cercon ceram kiss	32.7	8.22	5.5	7.84	7.3	2.7

*Oxygen was a balance for the chemical composition.

specimens were subjected to an additional firing cycle. Additionally, the zirconia veneer bond strength was not affected by the type of the layering ceramic used: Cercon ceram kiss or Noble Rondo zirconia.

On the other hand, it was observed that the addition of the layering veneers resulted in an increase in the percentage of interfacial failure compared to the control group, which demonstrated 100% cohesive failure (Table 2). The difference in the thermal expansion coefficient between the press-on and the layering ceramics (1.3 ppm/°C, Table 1) is a factor responsible for generation of undesirable residual tensile prestresses, which could explain the observed interfacial failure.[16,17]

SEM examination of zirconia press-on veneer interface revealed porosity-free veneer and interface structures, which are advantages of the pressing technique,[18] while the interface between the press-on and the layering ceramics demonstrated differences in the crystal and the glass matrix structures. The press-on veneer demonstrated less crystallization compared with the two tested layering ceramics (Fig 4).

This structural difference could be explained by EDAX analysis of the press-on ceramic, which indicated a substantially lower content of potassium ions in addition to a slightly lower content of sodium ions—both necessary for the formation and the growth of the crystal phase.[19] On the other hand, the percentage of aluminum in Noble Rondo zirconia was almost double compared with the other used ceramics (Table 3). The percentage of aluminum ions is important for controlling the crystallization kinetics of dental ceramics,[20] which could explain the fine homogenous structure and the high tensile strength characteristic for this material.[7] Nevertheless, the interface between the press-on and the layering veneers demonstrated good contact between the two materials which could explain the similar MTBS values observed for the three tested groups (Table 2).

Zirconia veneer bond strength is sensitive to many interacting variables, such as the type of veneer ceramic and its method of application and the surface preparation of the zirconia framework. Careful selection of a veneer ceramic and a matching surface preparation will result in a good bond between the framework material and the esthetic veneer.[6,7]

Conclusion

The double veneer technique did not result in weakening the MTBS of the zirconia framework with its press-on veneer ceramic. This technique combines the high bond strength and superior interface quality achieved using press-on ceramics with the superior esthetics obtained using layering ceramics. The technique promises superior function and performance of the double veneered restoration.

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