Fractographic Study of the Interface Between Zirconia Y-TZP and Its Veneering Ceramic After Shear Strength Testing

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This study analyzed the shear strength and fracture characteristics of the interface between zirconia samples and their veneering ceramic compared with a metal-ceramic and a lithium disilicate glass-ceramic control group together with an assessment of the possible relationship between the fracture characteristics and the recorded shear strength. The greatest shear strengths corresponded to the lithium disilicate glass-ceramic control group followed by the metal-ceramic control group, with lesser strengths in the zirconia groups. Since the fractographic study showed cohesive-type failure to predominate in the zirconia samples, it is concluded that improvements are needed in the veneering ceramic and liner used in zirconia restorations. *Int J Prosthodont 2015;28:432–434. doi: 10.11607/ijp.3873*

The clinical results obtained with zirconia restorations are good. However, zirconia restorations suffer chipping of the veneering ceramic after three years in 11% to 25% of all cases.[1,2] In contrast, the veneer chipping rate with metal-ceramic crowns is 3% after 15 years.[3]

This study evaluated the shear strength and fracture characteristics of the interface between zirconia samples and their veneering ceramic compared with a metal-ceramic and a lithium disilicate glass-ceramic control group and assessed the possible relationship between the fracture characteristics and the recorded shear strength.

Materials and Methods

One hundred fourteen samples were prepared, each consisting of a cylindrical core measuring 15 mm in length and 8 mm in diameter, together with a cylindrical veneer measuring 2 mm in length and 8 mm in diameter, adhered to one of the extremities of the core (Fig 1).

Six groups of 19 samples each were established (four zirconia core groups, one metal-ceramic control group, and one lithium disilicate glass-ceramic control group). Table 1 describes the different groups and materials used.

Shear Strength Testing

Following manufacture, the samples were subjected to shear strength testing as described by Scolaro et al.[4] A universal testing machine (model 4204, Instron) with a 5-kN load was used for this purpose. The selected crosshead speed was 0.05 mm/min.

Fractographic Analysis

After shear strength testing of the samples, the fracture surface was examined first under the light microscope (LM) (Nikon) with ×10 magnification and then by scanning electron microscopy with back scattered electrons (SEM-bse) (JSM-6300, Jeol) to define the fractographic surface.

To better identify each of the materials, the images were processed as grayscale and color histograms (INCA software, Oxford Instruments). The different tones of gray afforded by the back scattered electrons result from the different atomic numbers of the surface materials (Fig 2).

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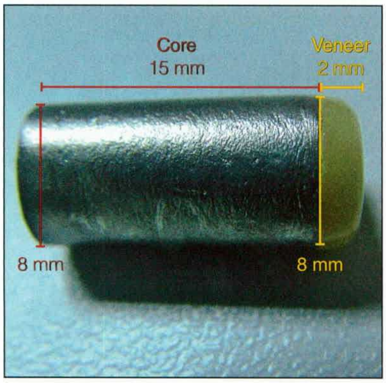

Fig 1 Dimensions of each of the elements used in the study samples (core/veneer).

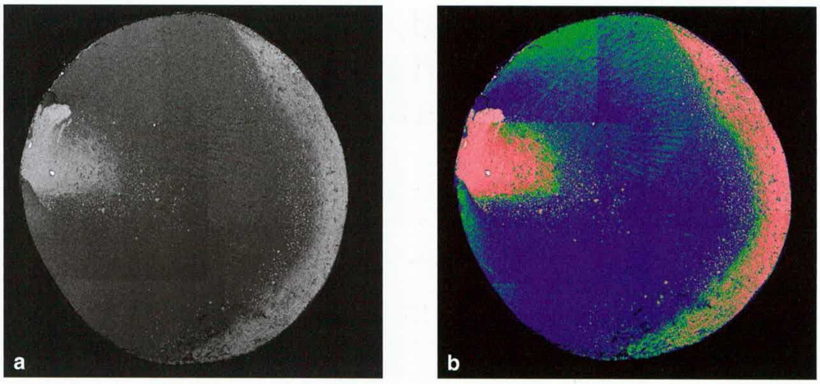

Fig 2 **(a)** Fractographic surface of sample GR 5.11 observed with SEM-bse (×25). **(b)** The same fractographic surface with color coding.

Table 1 Study Groups and Materials, Manufacturing Technique, Shear Strength Values and Weibull Modulus

Group	Core technique	Veneer technique	Mean (SD)*	Weibull modulus
1	CrNi (Rexillium V, PentronAlloys), casting	IPSd.SIGN (Ivoclar), layered	14.35 (3.05)[a]	4.36
2	IPS e.max Press, injected	IPS e.max Ceram (Ivoclar), layered	22.86 (5.85)[b]	3.99
3	IPS e.max ZirCad (Ivoclar), CAD/CAM	IPS e.max ZirPress (Ivoclar), injected	11.87 (3.28)[c]	3.03
4	IPS e.max ZirCad (Ivoclar), CAD/CAM	IPS e.max Ceram (Ivoclar), layered	6.79 (2.39)[d]	2.61
5	Lava Frame (3M), CAD/CAM	Lava Ceram (3M), layered	8.03 (4.17)[d]	0.77
6	Lava Frame (3M), CAD/CAM	IPS e.max Ceram (Ivoclar), layered	5.68 (3.05)[d]	1.37

CAD/CAM = computer-aided design/computer-assisted manufacture.
*Values with the same superscript letter are not statistically different (Mann-Whitney *U* test) ($P < .05$).

The software quantified (as a percentage) the amount of each of the materials appearing in each image, thus allowing precise characterization of the type of fracture in each case.

Statistical Analysis

The Kolmogorov-Smirnov test, Kruskal-Wallis test, and Mann-Whitney *U* test were used for the statistical analysis. The latter test was used to determine differences between pairs of combinations. The analytical variables were shear strength and the percentage distribution of materials on the surface. A 5% level of significance was considered in all cases ($\alpha = .05$).

Results

Shear Strength Testing

The mean shear strength values and the Weibull modulus in each of the groups are shown in Table 1. Statistically significant differences ($P < .05$) were observed between the different groups, except between the three zirconia layered veneering ceramic groups.

Fractographic Analysis

Light microscopy revealed adhesive failures in all groups.

SEM-bse showed cohesive-type fractures to be the most frequent type of fracture in the lithium disilicate glass-ceramic control group as well as in the metal-ceramic group, since the predominant surface materials were the opaquer and veneering ceramic in the latter. Cohesive-type fractures were also the most frequent type of fracture in the zirconia groups, since the predominant surface materials were the veneering ceramic and liner. The distribution of the materials in the different groups is shown in Fig 3 (Group 2 was omitted for not proving of interest to the research). The Kruskal-Wallis test revealed statistically significant differences in the distribution of the different materials on the fracture surface of the different groups. These differences were referred to the veneering ceramic and liner ($P < .05$), while distribution of the core proved similar in all groups, with no statistically significant differences among them ($P = .182$). No relationship was found between shear strength and the type of fracture found in the different groups.

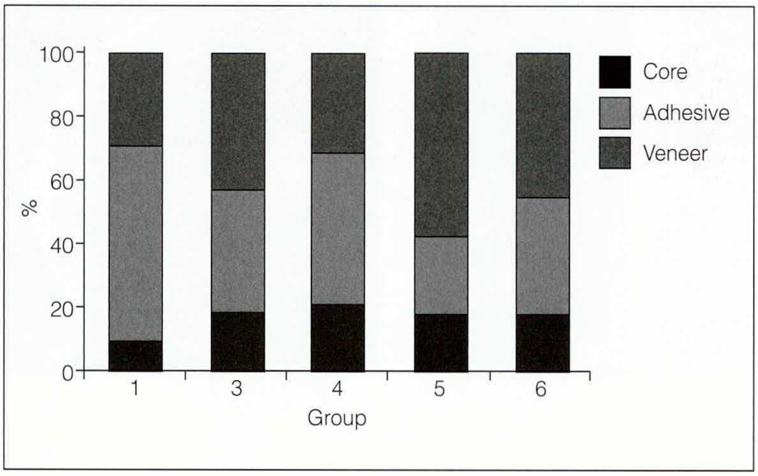

Fig 3 Mean distribution of percentage materials in each of the tested groups. Group 1: CrNi/d.SIGN; Group 3: e.max ZirCad/e.max ZirPress; Group 4: e.max ZirCad/e.max Ceram; Group 5: Lava Frame/Lava Ceram; Group 6: Lava Frame/e.max Ceram.

Discussion

In agreement with the findings of the present study, Al-Dohan et al[5] recorded higher shear strength values in the metal-ceramic control group than in the zirconia groups.

The present results indicated that the groups with low Weibull modulus will exhibit low reliability and their strengths will be broadly distributed (Table 1).

In relation to the fractographic study, different authors[6-8] have reported a predominance of cohesive-type fractures in the veneering of the zirconia groups, in accordance with our own observations.

In the SEM study, the fracture surface of both the metal-ceramic samples and the zirconia samples showed a fine layer of opaquer or liner, respectively, adhered to the core. This was not detected by light microscopy; as a result, many of the fractures classified as adhesive fractures under the light microscope were actually mixed or cohesive failures in the opaquer and veneer. This indicates an interface shear strength greater than that of the liner and veneering ceramic.

In agreement with the observations of Fischer et al,[7] these findings suggest the existence of chemical binding between the zirconia and silicone.

Conclusions

The zirconia groups showed adequate shear strengths, though the values were lower than in the metal-ceramic and lithium disilicate glass-ceramic control groups. Since failure in the zirconia groups is fundamentally of the cohesive type, improvements should be introduced in the veneering ceramic and liner in these groups. The use of SEM-bse images is crucial for defining the fracture characteristics, with no relationship being found between the fracture pattern and the shear strength recorded in any of the tested groups.

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