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# Influence of veneering thickness on biaxial bond strength of titanium and zirconia veneered with Triceram®

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## Introduction

To obtain today´s required esthetics, framework structures should be layered with veneering ceramics. Triceram is a ceramic which can be used for titanium and zirconia restorations due to a similar thermal expansion coefficient of the substrate materials. To investigate the bond strength between each combination, it´s necessary to determine the stress that causes the separation of the materials. An unstandardised test method dependent on the biaxial flexural test (ISO 6872) was used. For crowns and bridges, a veneering thickness of at most 2 mm is recommended.

## Aim of the study

The aim of the study was to test the influence of three different veneering thicknesses on the biaxial bond strength of titanium and zirconia.

## Materials and Methods

From each substrate material, 3x30 discs with a diameter of 12 mm and a thickness of 0.8 mm were prepared. For each veneering thickness of 1.0, 1.5 and 2.0 mm, 30 specimens were veneered to the substrate materials using a special holder (Fig. 3). With each specimen, the firings (for titanium: Bonder, Opaquer 1 and 2, Dentin 1 and 2, Glaze; for zirconia: Liner, Dentin 1 and 2, Glaze; furnace: Dekema, Freilassing) were done according to the firing instructions for titanium and zirconia. With each sample, the biaxial test was performed with a universal testing machine (Zwick Z010, Zwick, Ulm; software: testexpert V12; crosshead speed: 1 mm/min) using test equipment according to ISO 6872 (Fig. 1, 2a, 2b). With all samples, the veneered part was put on the balls. For each veneering thickness and substrate, the forces were calculated for the biaxial flexural strength on the bottom using the equation according to C.H. Hsueh. From both substrates, Weibull statistics were calculated according to ISO 6872, depending on veneering thickness. Microscopic images were taken with a stereo microscope.

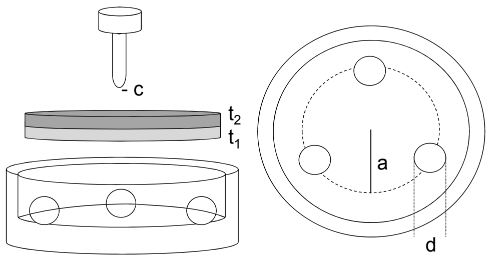

*Fig. 1: Schematic drawing of the test equipment*

*Fig. 2a: Test equipment*

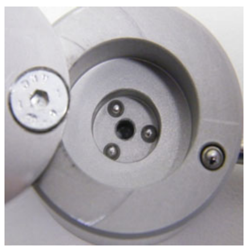

*Fig. 2b: Arrangement of the sample support*

*Fig. 3: Holder for adjusting the veneering thickness*

### Equation used to calculate the biaxial strength according to Hsueh et al. [1]

$$\sigma_{Bottom} = \frac{6M}{t_2^{\,2}Kp}\left[\frac{E_1t_1(1-\nu_2^{\,2})}{E_2t_2(1-\nu_1^{\,2})} + \frac{t_2}{t_1}\,\frac{(1-\nu_2^{\,2})(1+t_1/t_2)(1+E_2t_2/E_1t_1)}{(1+E_2t_2/E_1t_1)^2-(\nu_2+\nu_1E_2t_2/E_1t_1)^2}\right]$$

$$M = \frac{P}{8\pi}\left\{(1+\nu_e)\left[1+2\ln\left(\frac{a}{c}\right)\right]+(1-\nu_e)\left[1-\frac{c^2}{2a^2}\right]\frac{a^2}{R^2}\right\};\ \nu_e=\nu_2\frac{Kq}{Kp}$$

$$Kq = 1+\frac{E_1\nu_1t_1^{\,3}(1-\nu_2^{\,2})}{E_2\nu_2t_2^{\,3}(1-\nu_1^{\,2})}+\frac{3(1-\nu_2^{\,2})(1+t_1/t_2)^2(1+\nu_1E_2t_2/\nu_2E_1t_1)}{(1+E_2t_2/E_1t_1)^2-(\nu_2+\nu_1E_2t_2/E_1t_1)^2}$$

$$Kp = 1+\frac{E_1t_1^{\,3}(1-\nu_2^{\,2})}{E_2t_2^{\,3}(1-\nu_1^{\,2})}+\frac{3(1-\nu_2^{\,2})(1+t_1/t_2)^2(1+E_2t_2/E_1t_1)}{(1+E_2t_2/E_1t_1)^2-(\nu_2+\nu_1E_2t_2/E_1t_1)^2}$$

Where $t_1$=thickness of the bottom layer; $t_2$=thickness of the top layer; $E_1$=Young´s modulus of the bottom layer; $E_2$=Young´s modulus of the top layer; a=radius of the circle of support points; c=radius of the loading piston; R=radius of the plate; P=load at fracture; $\upsilon_e$=equivalent Poisson´s ratio; $\upsilon_1$=Poisson´s ratio of the bottom layer; $\upsilon_2$=Poisson´s ratio of the top layer

## Results

### Failure load and biaxial strength

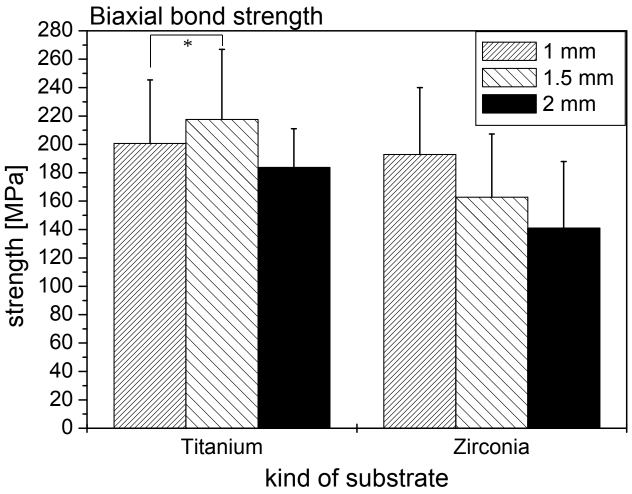

*Fig. 4: Flexural failure stresses of the titanium and zirconia groups (* statistically not significant)*

| | Thickness [mm] | n | Failure load [N] Mean ± SD | Flexural strength [MPa] Mean ± SD |
|---|---|---|---|---|
| **Titanium** | 1.0 | 30 | 353.31 ± 79.54 | 200.67 ± 44.71 |
| | 1.5 | 30 | 609.82 ± 143.92 | 217.62 ± 49.31 |
| | 2.0 | 30 | 769.10 ± 109.22 | 183.76 ± 27.31 |
| **Zirconia** | 1.0 | 30 | 426.73 ± 104.29 | 192.85 ± 47.18 |
| | 1.5 | 30 | 568.46 ± 156.00 | 162.78 ± 44.48 |
| | 2.0 | 30 | 724.22 ± 240.79 | 141.06 ± 46.91 |

*Tab.1: Results of mean failure load, mean biaxial strength and standard deviation of each group*

### Weibull statistics

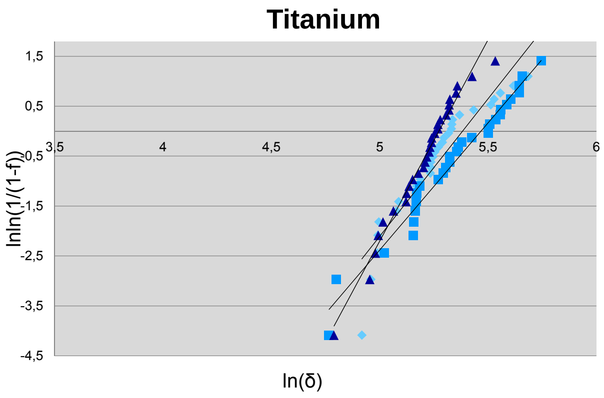

*Fig. 5: Weibull plots - titanium*

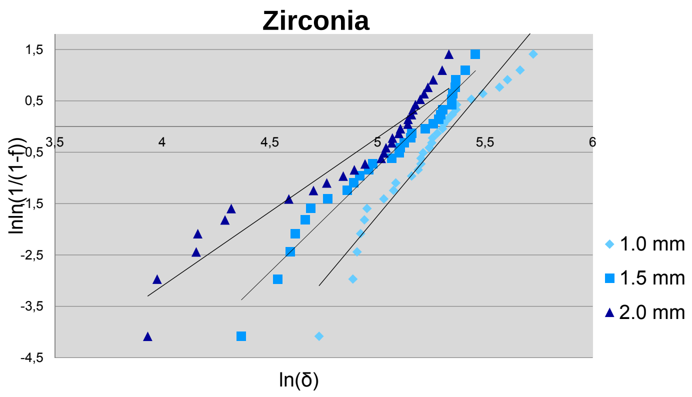

*Fig. 6: Weibull plots - zirconia*

| | thickness [mm] | n | Weibull modulus m | Weibull strength $\delta_0$ [MPa] |
|---|---|---|---|---|
| **Titanium** | 1.0 | 30 | 5.51 | 217.46 |
| | 1.5 | 30 | 5.09 | 236.75 |
| | 2.0 | 30 | 8.07 | 195.00 |
| **Zirconia** | 1.0 | 30 | 5.01 | 209.98 |
| | 1.5 | 30 | 4.10 | 179.47 |
| | 2.0 | 30 | 2.89 | 159.81 |

*Tab. 2: Calculated parameters from Weibull plots*

### Microscopic images

After reassembling the fracture fragments, each bilayered specimen was inspected using a stereo microscope at a magnification of 7x (Fig. 7).

All titanium frameworks remained unbroken. The specimens with a veneering thickness of 1.0 mm resulted in radial cracking on the tensile layer. The ones with 1.5 and 2.0 mm resulted additionally in partial delamination at the interface. The specimens with zirconia substrate broke into 2-5 parts and resulted in radial cracking as well as delamination. Similar to the titanium group, the number of delaminated parts increased with the veneering thickness. While the dentin layer of the ones with a veneering thickness of 1.0 and 1.5 mm separated from the core layer nearly without any leavings, specimens with 2.0 mm showed partial remains of thin dentin deposits.

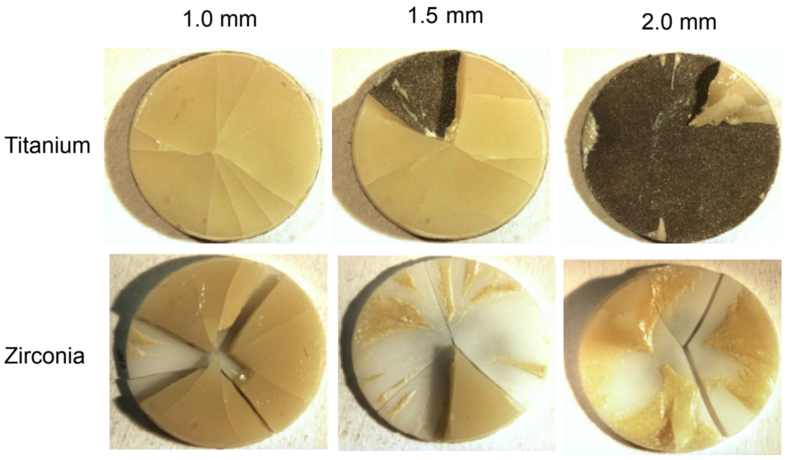

*Fig. 7: Exemplary microscopic image of each group*

## Summary

- The calculated biaxial bond strength for 1.0, 1.5 and 2.0 mm veneering thicknesses was 200.7±44.7, 217.6±49.3 and 183.8±27.3 MPa for titanium and 192.9±47.2, 162.78±44.5 and 141.1±46.9 MPa for zirconia.
- The calculated Weibull modulus m for 1.0, 1.5 and 2.0 mm veneering thicknesses was 5.51, 5.09 and 8.07 for titanium and 5.01, 4.10 and 2.89 for zirconia. The Weibull strength was 217.5, 236.8 and 195.0 MPa for titanium and 210.0, 179.5 and 159.8 MPa for zirconia.

## Conclusion

Biaxial flexural bond strength tests and Weibull statistics revealed that the bonding quality and strength of titanium/triceram is more homogenous and slightly higher compared to zirconia/triceram..
With increasing thickness of the veneering porcelain, a statistically significant reduction of bond strength was found.

## References

[1] Hsueh, C.H.; Kelly, J.R.; simple solutions of multilayered discs, subjected to biaxial moment loading; Dental Materials 2009, S. 506-513]

## Acknowledgement

This study was financially supported by the “Forschungsgemeinschaft Dental”. Special thanks to Dentaurum (Ispringen), Wieland Dental & Technik GmbH (Pforzheim) and Dekema (Freilassing).

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