EN

AMANNGIRRBACH

CLINICAL GUIDE III
SCIENTIFIC COMPENDIUM

zolid

DNA GENERATION

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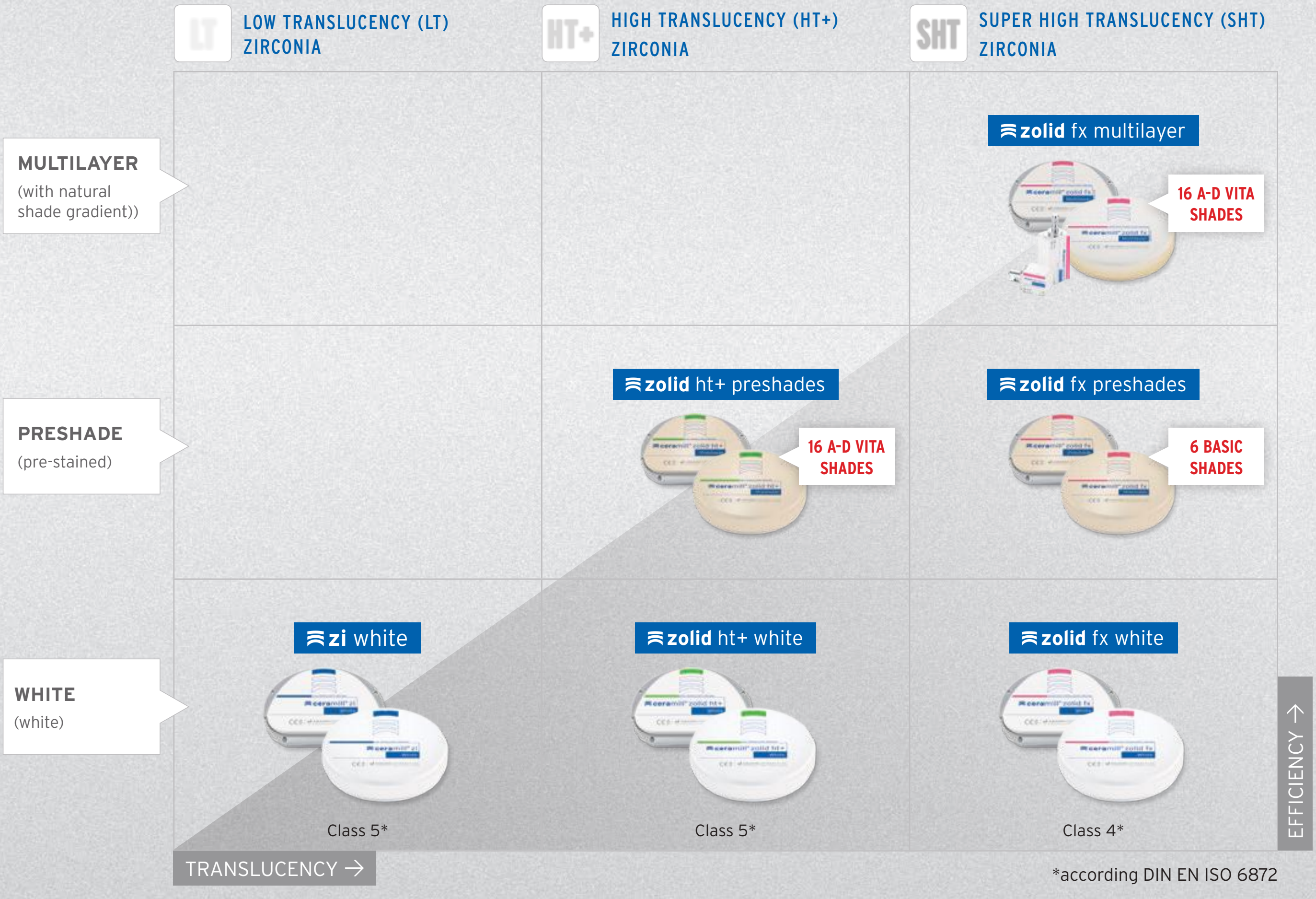
ZOLID ZIRCONIA – MUCH MORE THAN JUST A WHITE DISC

With Zolid, Amann Girrbach provides a comprehensive all-ceramic system for high-quality and esthetic zirconia restorations. Complete integration into the CAD/CAM workflow ensures maximum process reliability and continuously high quality.

This material is backed by a decade of experience in the development and in-house production of zirconia for restorations. Amann Girrbach laid the foundation stone 10 years ago with the Ceramill ZI blanks for copy milling. Since then, more than 10 million units have been produced from Amann Girrbach zirconia blanks worldwide. The extremely high quality is reflected in the virtually negligible complaint rate of < 0.1 % (Risk Management Report Amann Girrbach 2017). The excellent material properties of Zolid products are also reflected in several studies that underline the clinical evidence for the products.

Today, Amann Girrbach offers its customers a variety of different blanks for CAD/CAM production with the „Zolid All-Ceramic System". Thanks to the broad portfolio restorations are created that are individually adapted to each patient situation and can hardly be surpassed in terms of durability and esthetics.



	LOW TRANSLUCENCY (LT) ZIRCONIA	HIGH TRANSLUCENCY (HT+) ZIRCONIA	SUPER HIGH TRANSLUCENCY (SHT) ZIRCONIA
MULTILAYER (with natural shade gradient))			**zolid** fx multilayer 16 A-D VITA SHADES
PRESHADE (pre-stained)		**zolid** ht+ preshades 16 A-D VITA SHADES	**zolid** fx preshades 6 BASIC SHADES
WHITE (white)	**zi** white Class 5*	**zolid** ht+ white Class 5*	**zolid** fx white Class 4*

*according DIN EN ISO 6872

ZOLID ZIRCONIA – DENTAL DREAMS ARE MADE OF THIS

Zirconia (ZrO_2) forms the ideal basis for all-ceramic restorations as this material has outstanding properties that can hardly be matched by any other material.

MECHANICAL PROPERTIES

Compared to other ceramic materials, ZrO_2 is the absolute leader in terms of mechanical properties. Its strength of up to 1,200 MPa is significantly higher than that of commercially available lithium disilicate (500 MPa) or feldspar ceramics (160 MPa). Furthermore, zirconia also offers excellent fracture toughness and excellent ageing resistance.

OPTICAL PROPERTIES

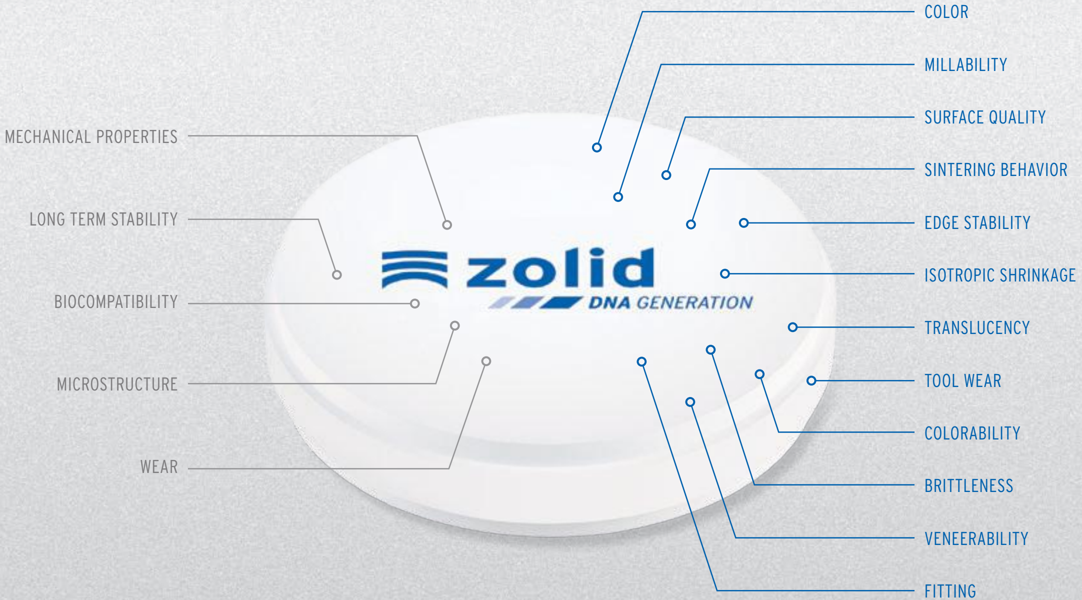
Its white, tooth-like basic color makes zirconia the perfect basis for highly esthetic, all-ceramic restorations. The translucency of ZrO_2 has been increased tremendously by new generations of raw materials, which are characterized by an increased cubic phase content. In terms of natural esthetics, the new zirconia materials are in no way inferior to glass ceramics such as lithium disilicates.

BIOCOMPATIBILITY

In addition to its excellent mechanical and optical properties, zirconia is extremely biocompatible. This is proven, among other things, by the hardly measurable chemical solubility. This property makes zirconia a genuine alternative to metallic materials, one which is particularly suitable for allergy patients.

ZOLID PROCESS ENGINEERING – ZIRCONIUM OXIDE AT THE HIGHEST LEVEL

Zolid blanks are manufactured 100 percent in-house at the Amann Girrbach headquarters in Austria. Only the best raw materials are processed there to blanks under the strictest controls and according to defined, certified processes. This is the only way to ensure that all material parameters are perfectly matched to the needs of dentistry. The in-house development and production of the Zolid blanks allows Amann Girrbach to have considerably greater influence on all material-relevant parameters.



TOSOH INSIDE

■ safety-relevant properties (partially normative)
■ application-oriented properties, additionally checked by Amann Girrbach (not normative)

STUDIES

The chapter "Studies" of the Scientific Compendium shows the current status of the most important external studies, which underline the clinical evidence of Zolid products. The results of the studies reflect the excellent properties of the blanks from Amann Girrbach and provide additional scientific certainty.

FLEXURAL STRENGTH, FRACTURE TOUGHNESS AND TRANSLUCENCY OF CUBIC/TETRAGONAL ZIRCONIA MATERIALS

Material:	Ceramill Zolid FX
Keywords:	Flexural strength, fracture toughness, translucency, zirconium oxide, lithium disilicate
Location:	Munich, Germany
Authors:	P. Zadeh, N. Lümkemann, B. Sener, M. Eichberger, B. Stawarczyk
Published in:	The Journal of Prosthetic Dentistry, 2018
Original paper:	Flexural strength, fracture toughness and translucency of cubic/tetragonal zirconia materials

OBJECTIVE OF THE STUDY

Comparison of the mechanical and optical properties of cubic/tetragonal zirconium oxides with lithium disilicate ceramics

MATERIALS AND METHOD

Six different zirconium oxides (Ceramill Zolid FX, Amann Girrbach; CopraSmile, Whitepeaks Dental Solutions; DD cubeX^2, Dental Direkt; NOVAZIR MaxT, Novadent Dentaltechnik; Priti multidisc ZrO_2, Pritidenta; StarCeram Z-Smile, H.C. Stark) were investigated together with a lithium disilicate ceramic (IPS e.max Press LT A2, Ivoclar Vivadent AG) as control group. The 4-point flexural strength (N = 105/n = 15) and the fracture toughness (N = 105/n = 15) (DIN EN ISO 6872) were measured in each case. Furthermore, the translucency (N = 70/n = 10) was investigated using an ultraviolet spectrometer. In addition, a grain size analysis (N = 6/n = 1) of the zirconium oxides was conducted with a scanning electron microscope. Statistical evaluation was performed using the Kolmogorov-Smirnov test, a multifactorial analysis, a one-way ANOVA, followed by post-hoc-Scheffé, Kruskal-Wallis and Mann-Whitney U tests. In addition, a Weibull analysis was performed using the maximum likelihood method at a confidence interval of 95 % ($\alpha = 0.05$).

RESULTS

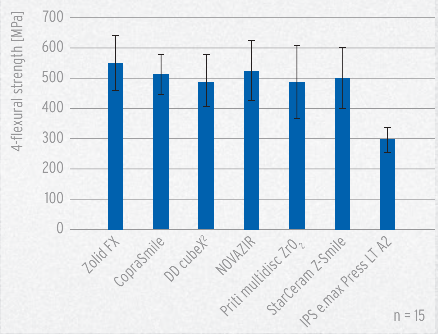


Fig. 1 Mean values 4-flexural strength

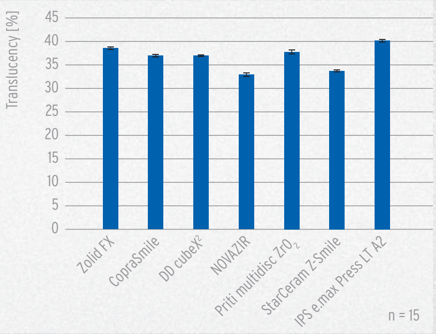


Fig. 2 Mean values for translucency

SUMMARY AND CONCLUSION

Ceramill Zolid FX achieves the highest average flexural strength (557 ± 88 MPa) of all tested materials (see Fig. 1). With a Weibull module of 6.9, the material proves to be one of the three most reliable materials in the investigations. In terms of optical properties, Ceramill Zolid FX achieves the highest translucency (38.3 ± 0.3 %) of the investigated zirconium oxides (see Fig. 2). Only lithium disilicate ceramic achieved higher measured values (40.4 ± 0.4 %). The fracture toughness test shows that Ceramill Zolid FX demonstrates a higher fracture toughness with an average value of 3.56 ± 0.47 MPa*√m than the tested lithium disilicate ceramic (2.10 ± 0.14 MPa*√m). Ceramill Zolid FX thus achieves higher mechanical properties than the lithium disilicate ceramic tested and exhibits the highest flexural strength and translucency of all zirconium oxides tested.

FOUR-POINT FLEXURAL STRENGTH OF FIVE DIFFERENT CUBIC/TETRAGONAL ZIRCONIA MATERIALS

Material:	Ceramill Zolid HT+ Preshade A4, Ceramill Zolid FX
Keywords:	4-point flexural strength
Location:	Munich, Germany
Authors:	B. Stawarczyk
Published in:	Study sponsored by Amann Girrbach at the LMU University Munich, April 2018
Original paper:	Four-point flexural strength of five different cubic/tetragonal zirconia materials

OBJECTIVE OF THE STUDY

Comparison of the 4-point flexural strength of different zirconia materials

MATERIALS AND METHOD

Five different zirconium oxides of the 4th generation were tested with flexural strengths of Class 5 (> 800 MPa, DIN ISO 6872) (Argen Z HT+, Argen; Ceramill Zolid HT+, Amann Girrbach; DD cubeX2 HS, Dental Direkt; IPS e.max ZirCAD/MT BL, Ivoclar Vivadent; NexxZr+, Sagemax). In addition, a pre-stained 4th generation zirconium oxide (Ceramill Zolid HT+ Preshade A4, Amann Girrbach) and an unstained third generation zirconium oxide with a flexural strength of Class 4 (> 500 MPa, DIN ISO 6872) (Ceramill Zolid FF, Amann Girrbach) were tested. For each material, 15 specimens were milled for the 4-point flexural test (Ceramill Motion 2, Amann Girrbach). The flexural bending test was conducted with a universal testing machine until the specimen fractured. The test series were evaluated using descriptive statistics with the Kruskal-Wallis test and the Mann-Whitney test.

RESULTS

Zirconia generation	Zirconia	Mean ± SD	MIN/Median/MAX	Weibull modulus
4.	Argen Z HT+	757 ± 129^{cd}	535/740/948	6.6
	Ceramill Zolid HT+	801 ± 129^{cd}	606/759/1006	7.0
	DD cubeX2 HS	593 ± 107^{ab}	263/609/724	4.3
	IPS e.max ZirCAD/MT BL	631 ± 108^{abc}	425/623/835	6.3
	NexxZr+	521 ± 81^{a}	369/514/702	7.3
	Ceramill Zolid HT+ PS A4	698 ± 69^{bcd}	581/696/826	11.7
3.	Ceramill Zolid FX	510 ± 100	279/503/643	5.1

Tab. 1 Flexural strength [MPa] of the zirconium oxides

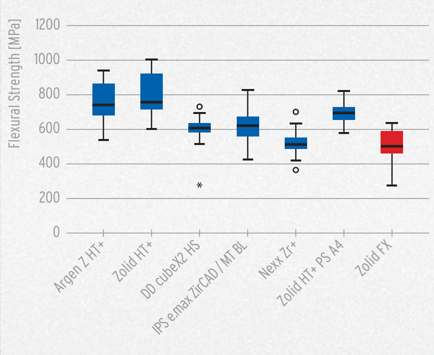


Fig. 1 Box plot flexural strengths

SUMMARY AND CONCLUSION

Ceramill Zolid HT+ achieves the highest flexural strength (801 ± 129 MPa) on average compared to the other measured zirconium oxide materials. The pre-stained Ceramill Zolid HT+ Preshade A4 material achieves the third highest flexural strength of 698 ± 129 MPa. The Class 4 Ceramill Zolid FX material achieves lower flexural strengths than the Class 5 materials, but with (510 ± 100 MPa) lies within the normative required range for Class 4. The highest Weibull module of 11.7 is achieved by Ceramill Zolid HT+ Preshade A4. As a result, the material shows the highest reliability. In general, it should be noted that the determination of the flexural strength always depends on the specimen preparation and the respective evaluation method. This can lead to deviations from the manufacturer's data.

COMPARISON OF FOUR MONOLITHIC ZIRCONIA MATERIALS WITH CONVENTIONAL ONES: CONTRAST RATIO, GRAIN SIZE, FOUR-POINT FLEXURAL STRENGTH AND TWO-BODY WEAR

Material:	Ceramill ZI, Ceramill Zolid
Keywords:	Monolithic zirconium oxide, flexural strength, ageing, wear
Location:	Munich, Germany
Authors:	B. Stawarczyk, K. Frevert, A. Ender, M. Roos, B. Sener, T. Wimmer
Published in:	Journal of the mechanical behavior of biomedical materials 59, 2016,128-138
Original paper:	Comparison of four monolithic zirconia materials with conventional ones: Contrast ratio, grain size, four-point flexural strength and two-body wear

OBJECTIVE OF THE STUDY

Investigation of the mechanical and optical properties of monolithic zirconium oxide compared to conventional zirconium oxide.

MATERIALS AND METHOD

Four different monolithic zirconium oxide materials (Zenostar (ZS), Wieland-Dental; DD Bio ZX^2 highly translucent (DD), Dental Direkt; Ceramill Zolid (CZ), Amann Girrbach; InCoris TZI (IC), Sirona) were examined for their optical and mechanical properties compared to a conventional zirconium oxide (Ceramill ZI (CZI), Amann Girrbach). For the optical properties, the contrast values of the zirconium oxides (n = 15/zirconium oxide) were measured using a spectrometer according to ISO 2471. In addition, the grain sizes of the zirconium oxides were measured with a scanning electron microscope using the specimens for the contrast values. For the mechanical properties, a 4-point flexural strength test according to ISO 13356 was conducted with a universal testing machine for three different groups (N = 45/n = 15). The specimens of the first group were hydrothermally aged in an autoclave at 134 °C for 5 h at 2.3 bar pressure. The second group (n = 15) was aged in a chewing simulator at 100 N for 1.2 million cycles under thermocyclic load (5 °C/55 °C). The third group was not subjected to ageing. Twelve specimens each for the four monolithic zirconium oxides were produced for the wear analysis. The specimens were divided into two groups of six samples (polished, glazed). The conventional zirconium oxide was veneered with ceramic and acted as a control group. Wear simulation was performed versus antagonists made of tooth enamel in a masticatory simulator under thermocyclic (5 °C/55 °C) load at 50 N. The statistical evaluation of the investigations was based on a 2-/1-way ANOVA with post-hoc Scheffé, Kruskal-Wallis-H, Mann-Whitney-U, Spearman-Rho, Weibull statistics and linear mixed models ($p < 0.05$).

RESULTS

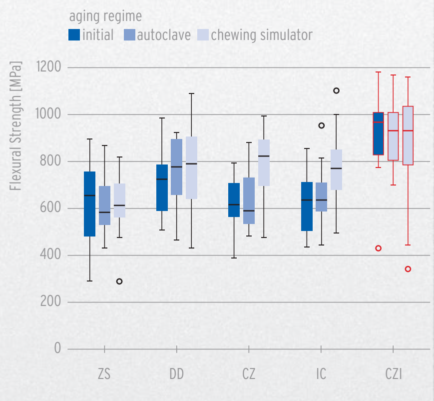


Fig. 1 Box plot with flexural strengths of the tested zirconium oxide groups

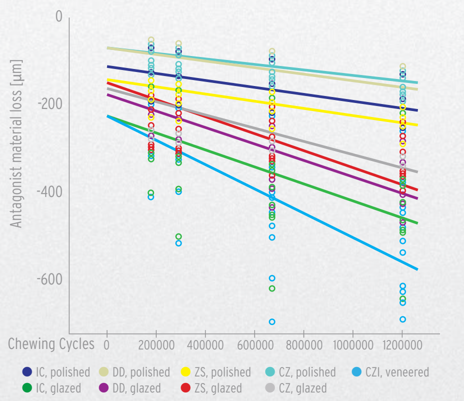


Fig. 2 Scatter diagram with mass loss on the antagonist side of the tested zirconium oxide groups

SUMMARY AND CONCLUSION

The monolithic zirconium oxides achieved lower contrast values than conventional zirconium oxide. No correlation between the contrast values and the grain size could be observed. The flexural strengths determined (see Fig. 1) show that the monolithic zirconium oxides have lower flexural strengths than conventional zirconium oxide. The ageing of the materials has no significant influence on the flexural strength. For Ceramill Zolid, the flexural strength increases after hydrothermal ageing and demonstrates the highest flexural strengths after mechanical ageing compared to the remaining three monolithic zirconium oxide materials. Furthermore, Ceramill Zolid achieves the highest Weibull modules in all three groups of monolithic materials. There are no significant differences within the flexural strengths for the non-aged and hydrothermally aged monolithic zirconium oxides. The wear tests (see Fig. 2) show that conventional zirconium oxide achieves the highest material and antagonist wear. The monolithic zirconium oxides, on the other hand, show significantly lower wear, with the polished specimens showing the lowest wear compared to the glazed samples. There was no correlation between surface roughness and wear.

OPTICAL AND MECHANICAL PROPERTIES OF NEWLY DEVELOPED MONOLITHIC MULTILAYER ZIRCONIA

Material:	Ceramill Zolid FX Multilayer
Keywords:	Monolithic multilayer zirconium oxide, mechanical properties, translucency
Location:	Mansoura, Egypt
Authors:	S. Elsaka
Published in:	The Journal of Prosthodontics 2017 Dec 14
Original paper:	Optical and Mechanical Properties of Newly Developed Monolithic Multilayer Zirconia

OBJECTIVE OF THE STUDY

Evaluation of the optical and mechanical properties of a monolithic multilayer zirconium oxide and comparison with two further monolithic, monochrome pre-stained zirconium oxides.

MATERIALS AND METHOD

The multilayer zirconium oxide of Amann Girrbach (Ceramill Zolid FX Multilayer Shade 0/B1, CZF, Class 4 ISO 6872), the monolithic zirconium oxide of Zirkonzahn (Prettau Anterior Shade T0, PA, Class 4 ISO 6872) and a monolithic zirconium oxide of Wieland (Zenostar Translucent Shade T0, ZT, Class 5 ISO 6872) were investigated. To determine the optical properties, the translucency parameter TP and the contrast ratio CR were determined using a spectrophotometer (n = 30/material). The following parameters were determined for the mechanical properties: 3-point flexural strength and fracture toughness (SEVNB method) according to ISO 6872 (n = 30/material), Vickers hardness HV1 and the brittleness index (n = 30/material). The microstructure of the materials (n = 10/material) was examined with scanning electron microscope images. The statistical evaluation of the test series was based on a one-way ANOVA and a Tukey´s test. The significance level was set at $p < 0.05$. In addition, a Weibull analysis was performed with the measured values from the strength test.

RESULTS

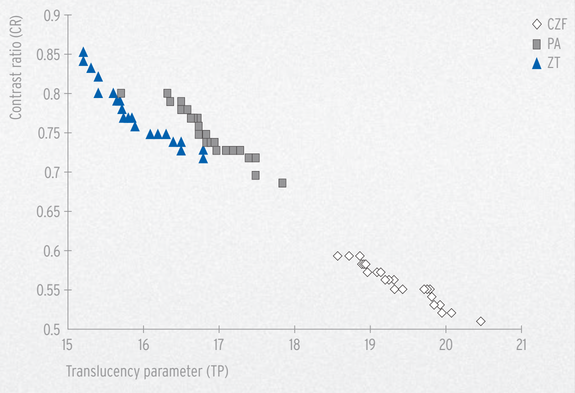


Fig. 1 Relationship between TP and CR of CAD/CAM-manufactured, monolithic zirconium oxide materials

Materials	Flexural strength (MPa)	Characteristic strength (σ_0) (MPa)	Weibull Modulus (m)	Fracture toughness (MPa $m^{0.5}$)
CZF	676 (49,75)^{B}	698	14.46	3.7 (0.27)^{B}
PA	595.5 (51.19)^{C}	594	12.07	1.72 (0.12)^{C}
ZT	960.1 (70.22)^{A}	995	15.84	4.7 (0.34)^{A}

Materials	Hardness (GPa)	Brittleness index (µ$m^{-1/2}$)	Translucency parameter (TP)	Contrast ratio (CR)
CZF	11.36 (0.61)^{A}	3.08 (0.21)^{A}	19.41 (0.49)^{A}	0.56 (0.02)^{C}
PA	5.41 (0.26)^{C}	3.15 (0.29)^{A}	16.83 (0.41)^{B}	0.74 (0.03)^{B}
ZT	7.09 (0.40)^{B}	1.52 (0.14)^{B}	15.88 (0.45)^{C}	0.76 (0.03)^{A}

Fig. 2 Mean values and statistical analysis of the measured values (mean values with different index letters are statistically significant)

SUMMARY AND CONCLUSION

The Ceramill Zolid FX Multilayer material achieves the significantly highest translucency and the lowest contrast ratio compared to the tested zirconium oxide materials. Within the comparable material Class 4, Ceramill Zolid FX Multilayer achieves significantly higher flexural strength, fracture toughness and a higher Weibull modulus than Prettau Anterior. Only Zenostar Translucent from the non-comparable material Class 5 achieves significantly higher flexural strengths, fracture toughness and a higher Weibull modulus than the Class 4 materials. In summary, the Ceramill Zolid FX Multilayer achieved the highest translucency of all materials and the highest mechanical properties within the Class 4 materials.

EVALUATION OF FLEXURAL STRENGTH OF HIPPED AND PRESINTERED ZIRCONIA USING DIFFERENT ESTIMATION METHODS OF WEIBULL STATISTICS

Material:	Ceramill ZI
Keywords:	3-point flexural strength, zirconium oxide, Weibull module, Weibull statistics
Location:	Zurich, Switzerland
Authors:	B. Stawarczyk, M. Özcan, A. Trottmann, C. Hämmerle, M. Roos
Published in:	Journal of the mechanical behavior of biomedical materials 10 (2012) 227-234
Original paper:	Evaluation of flexural strength of hipped and presintered zirconia using different estimation methods of Weibull statistics

OBJECTIVE OF THE STUDY

Determination of the 3-point flexural strength and the Weibull parameters of nine different zirconium oxide ceramics using different statistical methods.

MATERIALS AND METHOD

The zirconium oxide samples ZENO ZR (ZE), Wieland; GC ZR Disc CIP (GC), GC Europe; Ceramill ZI (CZ), Amann Girrbach; Copran YZ (CY), White Peak; InCoris ZI F0.5 (IC), Sirona Dental; Vita In-Ceram YZ (VI), Vita Zahnfabrik; Cercon ZR (CC), DeguDent; LAVA Zirkon (LZ), 3M Espe) were prepared in the white state and sintered according to manufacturer specifications. The control group was formed by a HIP zirconium oxide (DC-zirconium, DCS). The specimens were tested in a universal testing machine according to ISO 6872 to determine the 3-point flexural strength. The statistical analysis was performed using the normal (Levene test, one-way ANOVA, Scheffé test) and Weibull distribution, calculated by different evaluation methods.

RESULTS

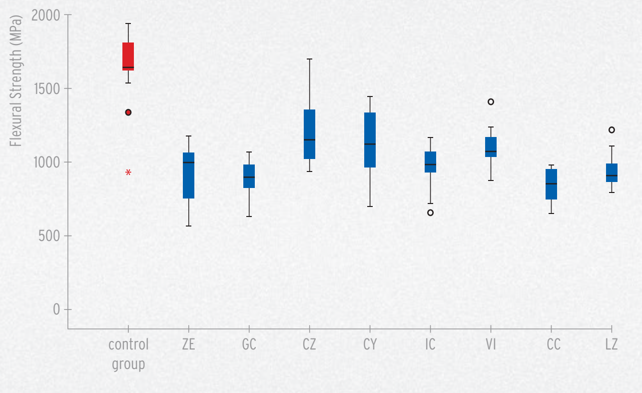


Fig. Box plot of the 3-point flexural strength of all tested zirconium oxide groups

SUMMARY AND CONCLUSION

The HIP zirconium oxide material (control group) achieves the significantly highest flexural strengths compared to the other zirconium oxides tested. Ceramill ZI (CZ) achieves the highest average flexural strengths among the remaining seven zirconium oxides.

THE EFFECT OF ZIRCONIA SINTERING TEMPERATURE ON FLEXURAL STRENGTH, GRAIN SIZE, AND CONTRAST RATIO

Material:	Ceramill ZI
Keywords:	Zirconium oxide, flexural strength, translucency, grain size, sintering temperature
Location:	Zurich, Switzerland
Authors:	B. Stawarczyk, M. Özcan, L. Hallmann, A. Ender, A. Mehl, C. Hämmerle
Published in:	Clinical Oral Investigations, 2013 Jan;17(1):269-74
Original paper:	The effect of zirconia sintering temperature on flexural strength, grain size, and contrast ratio

OBJECTIVE OF THE STUDY

Determination of the effect of the sintering temperature on the flexural strength, contrast ratio and grain size of zirconium oxide.

MATERIALS AND METHOD

Zirconium oxide specimens made of Ceramill ZI (Amann Girrbach) were investigated. For the 3-point flexural strength, the (N = 198; n = 22/group) specimens were prepared to their final dimensions with SIC abrasive paper before sintering. The samples were sintered at a heating rate of 8 °C/min at the following final sintering temperatures: 1,300 °C (group a), 1,350 °C (group b), 1,400 °C (group c); 1,450 °C (group d), 1,500 °C (group e), 1,550 °C (group f), 1,600 °C (group g), 1,650 °C (group h), 1,700 °C (group i), with a holding time of 120 min. The 3-point flexural strength was determined according to ISO 6872 using a universal test machine. The contrast ratio was measured using additional (N = 90, n = 10/group) specimens using a spectrometer according to ISO 2471. For grain size analysis, one specimen per group was polished (N = 9, n = 1) and sputter-coated with gold and then analyzed using a scanning electron microscope. The statistical analysis was performed using a one-way ANOVA with Scheffé and Weibull statistics ($p < 0.05$). In addition, the Pearson correlation coefficient between flexural strength/contrast ratio and sintering temperatures was calculated.

RESULTS

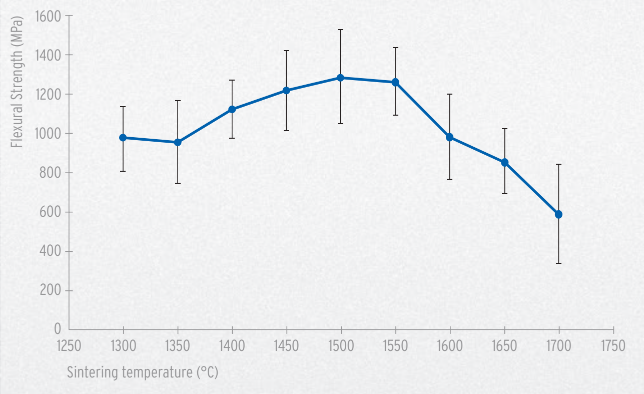


Fig. 1 Mean values of flexural strength as a function of different sintering temperatures

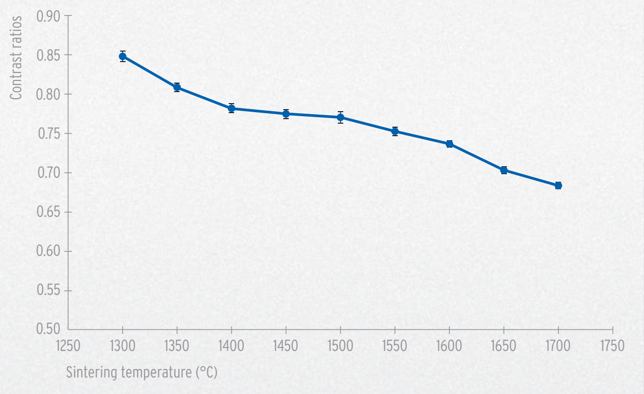


Fig. 2 Contrast ratios of zirconia after different sintering temperatures

SUMMARY AND CONCLUSION

The results show that the contrast ratio and the grain size increases with an increase in the sintering temperature, but the flexural strength decreases from a temperature of 1,550 °C (see Fig. 1). This is also reflected by defects within the microstructure at final sintering temperatures above 1,650 °C. With a sintering temperature of 1,450 °C, Ceramill ZI lies within the range in which the highest flexural strengths were achieved.

INFLUENCE OF SPECIMEN PREPARATION AND TEST METHODS ON THE FELUXURAL STRENGTH RESULTS OF MONOLITHIC ZIRCONIA MATERIALS

Material:	Ceramill Zolid
Keywords:	Monolithic zirconium oxide, specimen preparation, flexural strength, test methods
Location:	Munich, Germany
Authors:	B. Schatz, M. Strickstrock, M. Roos, D. Edelhoff, M. Eichberger, I.M. Zylla, B. Stawarczyk
Published in:	Materials, 2016; 9(3): 180
Original paper:	Influence of Specimen Preparation and Test Methods on the feluxural Strength Results of Monolithic Zirconia Materials

OBJECTIVE OF THE STUDY

The influence of different specimen preparations and test methods on the flexural strength of monolithic zirconium oxides is to be determined.

MATERIALS AND METHOD

Three different zirconium oxide materials for monolithic restorations were investigated: Ceramill Zolid (C) (Amann Girrbach), Zenostar Zr (Z) (Wieland Dental) and Bio zx^2 (D) (Dental Direkt). Dry polishing before and wet polishing after sintering were compared. This results in two main groups for which the flexural strengths were determined using three test methods (biaxial, 3-point, 4-point flexural strength) for each group. Each group consists of n = 40 specimens. The flexural strength tests were performed according to DIN EN ISO 6872 with a universal testing machine. A profile meter was used to measure the surface roughness following preparation. The influence of the specimen preparation on the surface of the specimen was analyzed with the aid of a scanning electron microscope. Statistical evaluation was performed using a 3-factorial ANOVA (factors: zirconium oxide, specimen preparation and test method) and a 1-factorial ANOVA (factors: test method, zirconium oxides combined with the other two factors). In addition, a 2-parameter Weibull distribution assumption was performed to determine reliability under the various test conditions.

RESULTS

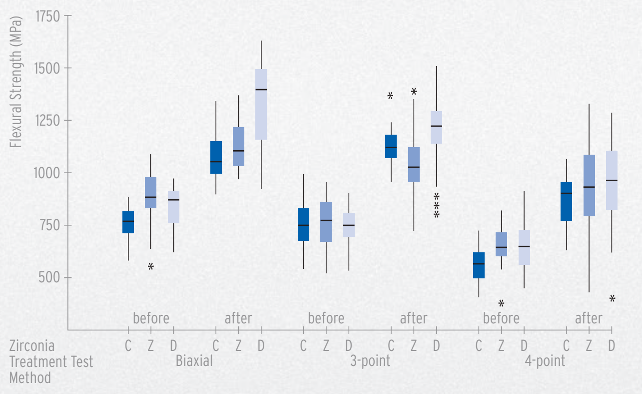


Fig. Influence of specimen preparation and test method on the flexural strength of different zirconium oxide materials

SUMMARY AND CONCLUSION

The investigation shows a dependence of the flexural strength on the respective test method. The highest values are obtained when measuring the biaxial flexural strength. This process is followed by measurements of the 3-point flexural strength and 4-point flexural strength, which generate the lowest values. The specimen preparation method has a significant influence on the flexural strength. This resulted in a higher surface roughness of the dry polished specimens. The measured flexural strength values of the different zirconium oxides are in the same value ranges within the groups and therefore show no effect of the material.

IN VITRO EVALUATION OF MARGINAL DISCREPANCY OF MONOLITHIC ZIRCONIA RESTORATIONS FABRICATED WITH DIFFERENT CAD-CAM SYSTEMS

Material:	Ceramill Zolid White
Keywords:	CAD/CAM system, marginal fit, zirconium oxide
Location:	Cairo, Egypt
Authors:	T. Hamza, R. Sherif
Published in:	The Journal of Prosthetic Dentistry, 2017 Jun;117(6):762-766
Original paper:	In vitro evaluation of marginal discrepancy of monolithic zirconia restorations fabricated with different CAD-CAM systems

OBJECTIVE OF THE STUDY

Investigation of the marginal fit of five different monolithic zirconium oxide restorations fabricated with different CAD/CAM systems.

MATERIALS AND METHOD

The model for the examination is an individually fabricated stump made of stainless steel that simulates a first premolar of the maxilla. 30 monolithic zirconium oxide crowns were fabricated, which are divided into the following five groups: Group TZI InCoris TZI (Sirona), milled with the MC XL milling machine (Sirona), Group CZ Ceramill Zolid White (Amann Girrbach), milled with Ceramill Motion 2 (Amann Girrbach), Group ZZ Zenostar zirconium oxide (Wieland), milled with Wieland dental milling machine (Wieland), group PZ Prettau zirconium oxide (Zirkonzahn), milled with milling machine M1 (Zirkonzahn) and group BZ Bruxzir solid zirconium oxide (Glidewell), milled with S1 dental milling machine (CNC machine, VHF). The marginal fit deviation was measured with a microscope at 100x magnification. The generated data have been statistically evaluated using a one-way ANOVA. In addition, post hoc tests and a Bonferroni correction ($\alpha = 0.05$) were performed.

RESULTS

					95% CI for Mean			
Surface	**N**	**Mean (µm)**	**±SD**	**±SE**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
TZI	24	39.3	2.3	0,.47	38.29	40.23	34.42	43.67
PZ	24	19.4	7.1	1.4	16.39	22.37	7.72	30.06
CZ	24	25.1	8.2	1.68	21.63	28.60	13.44	40.05
BZ	24	22.8	8.9	1.82	19.04	26.60	9.86	35.77
ZZ	24	27.3	11.4	2.32	22.45	32.05	9.95	43.60
Total	120	26.8	10.5	0.96	24.86	28.66	7.72	43.67

TZI	Incoris TZI
PZ	Prettau zirconia translucent zirconia
CZ	Ceramill Zolid translucent zirconia
BZ	Bruxzir solid zirconia
ZZ	Zenostar zirconia
CI	Confidence interval

Tab. 1 Results of descriptive statistics

SUMMARY AND CONCLUSION

The highest marginal deviation was achieved in the Sirona Group with InCoris TZI. The Bonferroni post hoc test shows that the Sirona Group differs significantly from all other groups tested. No significant differences were found within the 4 other groups (Amann Girrbach, Wieland, Zirkonzahn, Glidewell) (see Tab. 1). The tested Amann Girrbach CAD/CAM system with Ceramill Motion 2 produced clinically acceptable margin fits for the material Ceramill Zolid White. With an average value in marginal deviation of 25.1 ± 8.2 µm, the marginal fit lies significantly below the marginal fit stipulated by McLean and Fraunhofer[1] and their stipulated adhesive gap of less than 120 µm in order to achieve a clinically successful restoration.

LITERATURE

[1] J. Mc Lean und J. von Fraunhofer, „The estimation of cement film thickness by an vivo technique,“ Br Dent J , Nr. 131(3), pp. 107-11, 1971.

COMPARISON OF THE FIT ACCURACY OF ZIRCONIA-BASED PROTHESES GENERATED BY TWO CAD/CAM SYSTEMS

Material:	Ceramill Zolid FX
Keywords:	Zirconium oxide, accuracy of fit, CAD/CAM systems
Location:	Daegau, Republic of Korea
Authors:	S. Ha, J. Cho
Published in:	The Journal of Advanced Prosthodontics, 2016;8:439-48
Original paper:	Comparison of the fit accuracy of zirconia-based protheses generated by two CAD/CAM systems

OBJECTIVE OF THE STUDY

Evaluation of the internal and marginal fit of two CAD/CAM systems and evaluation of the effect of pressed ceramics on the fit of the construction.

MATERIALS AND METHOD

The first molar of a mandibular acrylic model was used as the model basis for the investigation. The tooth is prepared with a 1 mm circumferential groove and occlusally reduced by 2 mm, the convergence angle was 5°. This was used to create an abrasion-resistant master stump. 20 zirconium oxide constructions (10 x monolithic crowns, 10 x veneering caps) were each fabricated using the Ceramill CAD/CAM system (Ceramill Motion 2, Ceramill Zolid FX; Amann Girrbach) and the Zirkonzahn CAD/CAM system (Milling UNIT M5, Prettau; Zirkonzahn). The overall accuracy of fit was determined using the weight technique. The replication technique was used as a further method for examining the internal and marginal fit of defined areas of the crown. The statistical evaluation was performed with a Shapiro-Wilk test, a one-way ANOVA and a Levene´s test at a significance level of 0.05.

RESULTS

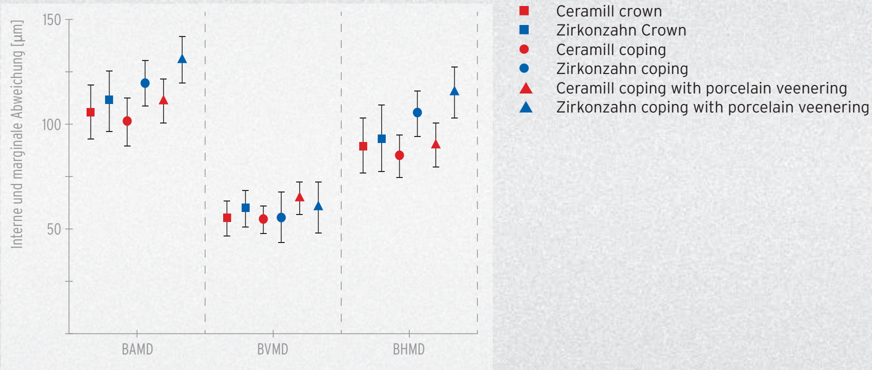


Fig. Margin deviation of the monolithic crowns, veneering caps and veneered copings (BAMD= buccal-absolute-margin deviation; BVMD= buccal-vertical-margin deviation; BHMD= buccal-horizontal-margin deviation)

SUMMARY AND CONCLUSION

The Ceramill CAD/CAM system with Ceramill Zolid FX achieves smaller marginal deviations than the zirconium tooth CAD/CAM system. The internal deviation is smaller with Zirkonzahn than with Ceramill, although this does not allow comparability due to differently defined cement gaps in the systems. Both systems achieve clinically acceptable marginal deviations.

EFFECT OF HYDROFLUORIC ACID CONCENTRATION AND ETCHING DURATION ON SELECT SURFACE ROUGHNESS PARAMETERS FOR ZIRCONIA

Material:	Ceramill ZI
Keywords:	Zirconium oxide, surface roughness, etching process, hydrofluoric acid
Location:	Lodz, Poland
Authors:	B. Smielak, L. Klimek
Published in:	The Journal of Prosthetic Dentistry, 2015 Jun;113(6):596-602
Original paper:	Effect of hydrofluoric acid concentration and etching duration on select surface roughness parameters for zirconia

OBJECTIVE OF THE STUDY

Determination of the effects of hydrofluoric acid (HF) on the surface roughness of zirconium oxide

MATERIALS AND METHOD

100 cylindrical discs (d = 9 mm; h = 5 mm) were made from Ceramill ZI (Amann Girrbach) material. These are divided into 3 groups with 30 test specimens each and a control group with 10 test specimens. The 3 groups are divided into a treatment with 40 % HF, 9.5 % HF and 5 % HF. These groups are divided into 10 test specimens for each etching time of 1, 5 and 10 minutes. The control group (n = 10) remained untreated and was polished with SIC abrasive paper. For evaluation purposes, the specimen surface was examined with a scanning electron microscope. Profilometric investigations were performed with a confocal laser scanning microscope and the roughness values Ra_{mean} and Rz_{mean} were determined for the etched and the unetched surface. The statistical evaluation was performed by a student T-test with a comparison of 2 groups (etched and control group) with each other. A test probability of $P< 0.05$ is considered significant and a test probability of $P < 0.01$ is considered statistically significant.

RESULTS

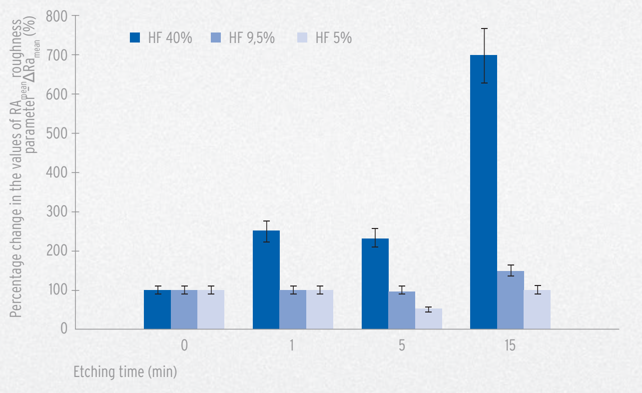


Fig. 1 Percentage change of the roughness parameter Ra_{mean} in relation to etching duration

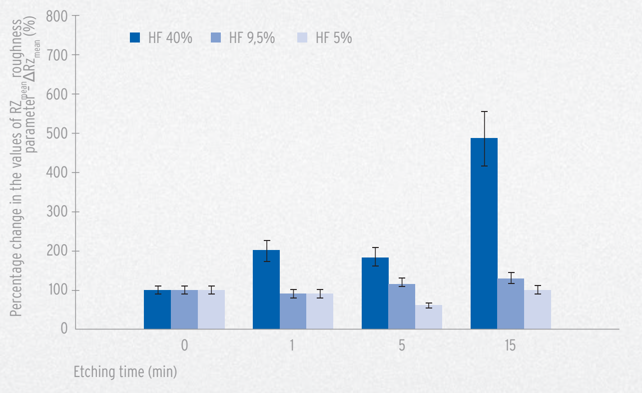


Fig. 2 Percentage change of the roughness parameter Rz_{mean} in relation to etching duration

SUMMARY AND CONCLUSION

The results show that an increasing etching time has a positive effect on the quality (increased Ra_{mean} and Rz_{mean} values) of the treated zirconium oxide surface (see Fig. 1 and Fig. 2). Furthermore, the concentration of the etching solution also influences the zirconium oxide surface. Here the higher concentrated (40 %) hydrofluoric acid achieves the best results. Statistically significant differences to the untreated surface are achieved. Etching with a 5 % hydrofluoric acid is not recommended as a method to increase the surface roughness of zirconium oxide.

BONDING VALUES OF TWO CONTEMPORARY CERAMIC INLAY MATERIALS TO DENTIN FOLLOWING SIMULATED AGING

Material:	Ceramill ZI
Keywords:	Ceramics, inlays, bonding strength, fixation techniques, acrylic cement
Location:	Abha, Saudi Arabia
Authors:	A. Khalil, K. Abdelaziz
Published in:	The Journal of Advanced Prosthodontics, 2015; 7: 446-53
Original paper:	Bonding values of two contemporary ceramic inlay materials to dentin following simulated aging

OBJECTIVE OF THE STUDY

Comparison of the bonding strength of CAD/CAM-manufactured feldspar ceramic and zirconium oxide-based inlays, bonded to dentine using etching and bonding techniques. Dual-curing and one-step systems of self-adhesive acrylic cements, before and after artificial ageing, are tested by means of continuous cyclic loading and thermocycling.

MATERIALS AND METHOD

The examination was based on occlusal cavities of 80 extracted teeth, which were treated in two groups with (n = 40) feldspar ceramic inlays ((FP) Vitablocs Trilux forte) on the one hand and (n = 40) zirconium oxide-based inlays ((ZR) Ceramill ZI) on the other. The two groups were divided into two subgroups with 20 samples each for the etch bond (RelyX Ultimate Clicker) and the self-adhesive (RelyX Unicem Aplicap) bonding technique. After bonding the inlays to the acrylic cements, 10 inlays of each subgroup are loaded with a vertical continuous load of 50 N over 240,000 cycles using a universal testing machine. The same specimens were then subjected to a thermocyclic load (5-55 °C) according to the ISO-TR 11405 standard for 3,500 cycles with a dwell time of 30 seconds. The remaining 10 specimens of the subgroup serve as a control group. In a next step, 3 mm thick specimens were separated from the restored teeth, which were then subjected to the bonding strength test. The statistical evaluation of the measurement series was performed with one-way ANOVA and Tukey´s comparisons ($\alpha = 0.05$) to show the significance of the determined differences. In addition, the fracture mode of the ceramic-cement-dentin bond was determined.

RESULTS

Mean bond strength				
Ceramic Material	**Etch-and-Bond cement (EB**		**Self-adhesive cement (SA)**	
	Non-aged	**Aged**	**Non-aged**	**Aged**
Feldspar-based ceramic (FP)	6.33 ± 1.80^{a}	5.74 ± 1.71^{a}	5.55 ± 1.46a	5.23 ± 1.09^{a}
Zirconia based ceramic (ZR)	5.77 ± 0.96^{a}	5.10 ± 0.97^{a}	4.62 ± 1.59^{a}	4.41 ± 1.12^{a}

FP = Feldspar-based ceramic,
ZR = Zirconia-based ceramic,
EB = Etch-and-Bond cement,
SA = Self-adhesive cement

Same superscript letters indicate no significant difference classes of thest specimens (Tukey'scomparisons, P > .05)

Tab. 1 Bonding strength values [MPa] of different ceramic inlays to dentine

SUMMARY AND CONCLUSION

No significant differences in bonding strength were observed between the Vitablocs Trilux forte inlays and the Ceramill ZI inlays (see Tab. 1). The different acrylic cements also showed no significant differences for the two ceramics used. Simulated ageing by means of continuous loading and thermocycling also did not lead to significant differences in the bonding strength of the different groups.

CLINICAL EVALUATION OF 1,132 ZIRCONIA-BASED SINGLE CROWNS: A RETROSPECTIVE COHORT STUDY FROM THE AIOP CLINICAL RESEARCH GROUP

Material:	Ceramill ZI
Keywords:	Zirconium oxide, ceramic veneered single crowns, success rate, survival rate
Location:	Bologna, Italy
Authors:	C. Monaco, M. Caldari, R. Scotti
Published in:	The International Journal of Prosthodontics, 2013 Sep-Oct ;26(5): 435-42
Original paper:	Clinical evaluation of 1,132 zirconia-based single crowns: a retrospective cohort study from the AIOP clinical research group

OBJECTIVE OF THE STUDY

Determination of the clinical results (1-5 years) of zirconium oxide-based single-tooth crowns. The main risk factors leading to zirconium oxide failure are to be determined from the results.

MATERIALS AND METHOD

398 patients with 1,132 zirconium oxide-based single-tooth crowns, both tooth and implant supported, were included in the study between January 2005 and July 2010. Of the restorations, 343 (30.3 %) were in the anterior region and 789 (69.7 %) in the posterior region. 16 different types of zirconium oxide were used for the zirconium oxide frames (for group classification see Tab. 1, Group 2 Ceramill ZI, Amann Girrbach). Tooth preparation was performed by tangential or chamfer preparation. Patients were examined on the basis of the AIOP guideline. To establish a link between parafunctions and mechanical failure of the restorations, patients with bruxism (n = 125, subgroup) were included in the study. For statistical evaluation, a cumulative survival rate (CSR) was determined in which chipping fractures of the ceramic veneer (grades 1-2) or debonding are not considered as failures. In addition, a cumulative success rate (SR) was calculated in which chipping fractures (grades 2-3) and debonding or secondary caries (level 3) are considered to be failures. Furthermore, the Mantel-Haenszel odds ratio (OR) in relation to the parafunction of all restorations was calculated.

RESULTS

Group (no. of restorations)	No. of restorations (zirconia brand)
Group 1 (1 to 20)	3 Everest ZS (KaVo) 9 Zirconia dioxide Cara (Heraeus) 19 Biotech (Biotech) 19 New Ancorvis zirconia (New Ancorvis) 17 Echo (Sweden & Martina) 14 Kéramo zirconia (Kéramo)) 11 e.max. ZirCad (Ivoclar Vivadent)
Group 2 (21 to 50)	32 Byroziram (Cyrtina) 31 Zircodent (Orodent) 27 Ceramill ZI (Amann Girrbach) 30 BB Bio Z (Dental Direkt) 21 Diazir (Diadem) 21 Zenostar (Wieland Dental)
Group 3 (51 to 100)	74 ICE (Zirkonzahn)
Group 4 (101 to 500)	180 NobelProcera zirconia (Nobel Biocare)
Group 5 (>500)	624 Lava (3M ESPE)
Total	1,132

Tab. 1 Zirconium oxide groups 1-5

	Anterior failed		Posterior failed		Total failed	
Groups	**CSR (%)**	**SR (%)**	**CSR (%)**	**SR (%)**	**CSR (%)**	**SR (%)**
All groups (n = 1,132; 100%)	2 (99.4)	13 (96.2)	19 (97.6)	52 (93.4)	21 (98.1)	65 (94.3)
Group 5: LAVA (anterior = 178, posterior = 446, n = 624, 55.1%)	0 (100)	3 (98.3)	10 (97.7)	23 (94.8)	10 (98.4)	26 (95.8)
Group 3: ICE (anterior = 9, posterior = 65, n = 74, 6.5%)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
Group 2: Byroziram Cyrtina (32), Zircodent (31), Ceramill ZI (27), DD Bio Z (30), Diazir (21), Zenostar (21) (anterior = 51, posterior = 111, n = 162, 14.3%)	0 (100)	7 (86.3)	0 (100)	9 (91.9)	0 (100)	16 (90.1)
Group 1: Biotech (19), New Ancorvis (19), Echo (17), ZirCad (11), Cara (9), Kéramo (14), Everest (3) (anterior = 30, posterior = 62, n = 92, 8.2%)	0 (100)	0 (100)	3 (95.2)	7 (88.7)	3 (96.7)	7 (92.4)

CSR = cumulative survival rate; SR = cumulative success rate.

Tab. 2 Survival rate CSR and success rates (SR) of zirconium oxide-based restorations

SUMMARY AND CONCLUSION

The cumulative survival rate for all constructions was 98.1 %, with a cumulative success rate of 94.3 % (see Tab. 2). A correlation between parafunctions and mechanical failure was observed in patients with severe parafunctions. Ceramic veneered zirconium oxide single-tooth crowns with tangential and chamfer preparation thus show good clinical results over a period of up to five years. Technical failure could only be observed sporadically and was primarily limited to patients with parafunctions. Group 2, which included Ceramill ZI, demonstrated a survival rate of 100 % and a success rate of 91.9 %.

MONOLITHIC ZIRCONIA RECONSTRUCTIONS SUPPORTED BY TEETH AND IMPLANTS: 1-3-YEAR RESULTS OF A CASE SERIES

Material:	Ceramill Zolid/in vivo
Keywords:	Monolithic zirconium oxide, tooth and implant supported, esthetics, marginal fit, survival rate
Location:	Berne, Switzerland
Authors:	A. Worni, J. Katsoulis, L. Kolgeci, M. Worni, R. Mericske-Stern
Published in:	Quintessence International, 2017;48(6):459-467
Original paper:	Monolithic zirconia reconstructions supported by teeth and implants: 1-3-year results of a case series.

OBJECTIVE OF THE STUDY

Assessment and evaluation of the performance/success of tooth and implant-supported, monolithic zirconium oxide restorations.

MATERIALS AND METHOD

Tooth- and implant-supported monolithic single crowns (SCs) and fixed restorations (FDPs) made of zirconium oxide (Ceramill Zolid, Amann Girrbach) were included. The insertion of the implants and the subsequent prosthetic restoration were performed in the same clinical environment. A technician performed all laboratory work with the same CAD/CAM workflow (DentalDesigner, Ceramill Motion 2). The technical results, esthetics (shade matching), marginal fit, anatomical form and biological aspects were documented. Adjusted criteria of the United States Public Health Service (USPHS) and periodontal parameters were used for the clinical evaluation by two independent investigators. Descriptive statistics and non-parametric tests were used for statistical comparisons.

RESULTS

Forty patients (17 men, 23 women, average age 59.1 ± 14.7 years) with 109 reconstructions (74 SCs, 35 FDPs) supported by 38 implants and 71 teeth, with a total of 238 monolithic zirconium oxide units (of which 62 were pontics and 18 cantilevers) were included in the clinical assessment. The median follow-up was 23.8 months (12 to 36 months). No technical failures were observed. The overall survival rate of the restorations was 99.6 % (tooth-supported: 100 %; implant-supported: 98.4 %) due to the loss of an implant. The recorded periodontal/peri-implant parameters indicate healthy soft tissue, caries was not observed. The records obtained from the USPHS revealed good clinical results.

SUMMARY AND CONCLUSION

The short-term results of the present study indicate that monolithic zirconium oxide restorations (Ceramill Zolid, Amann Girrbach), both tooth and implant supported, particularly in the posterior region, may be a satisfactory treatment option. Survival rates are very high within the first 23.8 months (99.6 %) and must be followed up in long-term studies.

SCIENTIFIC FACTS

SCIENTIFIC FACTS

BIOCOMPATIBILITY

In medicine, biocompatible materials are described as being in direct contact with living tissues and having no negative influence on their metabolism.

Biocompatibility plays a particularly important role in implant dentistry. As dental implants are in direct contact with the surrounding tissue for a long period of time, they must not lead to any immune responses. A biological test of the biocompatibility of a dental medical device provides information on the reactions that can be expected by the patient upon contact with this product.

A biological assessment of a medical device ensures that the resulting risk potential is acceptable for the patient upon contact with this product. The certification of the biocompatibility of medical materials and devices complies with the ISO 10993 1-12 series of standards and is an important step on the way to CE labeling of a medical device.

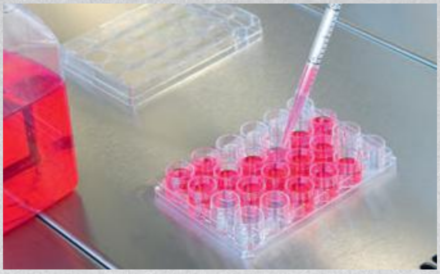


Fig. Cell nutrition with culture medium

CYTOTOXICITY

Testing for cytotoxicity is an important part of the biological assessment of medical devices according to ISO 10993-5 and is performed as in vitro cytotoxicity.

In the cell toxicity test performed on mouse fibroblast cells (L 929) according to the standard guidelines, the product can be tested for potential cell growth inhibiting properties. The material is then classified according to the requirements for biological tolerability.

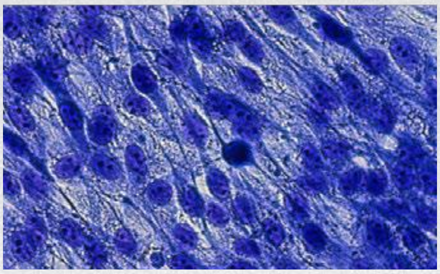


Fig. Richardson staining for the analysis of vital cells

CHEMICAL SOLUBILITY

By testing the chemical solubility, the dissolution of a material in the patient‘s mouth can be simulated (accelerated procedure). For this purpose, the material is brought into contact with a highly aggressive, acidic substance.

The solubility of dental materials is determined according to DIN EN ISO 6872. To do this, specimens with a specific surface area are weighed, stored in 4 % acetic acid at 80 °C, then rinsed, dried and weighed again. The solubility related to the surface is determined from the weight difference.

Fig. Determining chemical solubility with a balance

MATERIAL CLASSES & GENERATIONS ZIRCONIUM OXIDE

Dental ceramics are divided into so-called classes for fixed dentures depending on the intended clinical application with the required mechanical and chemical properties according to the DIN EN ISO 6872 standard. The flexural strength of the material is the decisive criterion of the 5 classes.

The highest class, Class 5, requires a flexural strength of > 800 MPa and thus represents the largest clinical indication option for monolithic or veneered dentures consisting of more than 4 elements.

Class 4 with the required > 500 MPa only allows 3-part ceramic dentures including molar restorations. Due to the generally high strength properties of zirconium oxide materials, most types and generations fall within the range of these two classes. The development of zirconium oxide as a material in dentistry has resulted in different generations, some of which differ significantly in their properties. Due to minor changes in the chemical composition, in particular the content of aluminum oxide and yttrium oxide, the translucency values as well as the strength properties were influenced significantly. As a rule, the flexural strength decreases with increasing translucency due to the phase modification of the structure. Zirconium oxides of the 1st and 2nd generation (Ceramill ZI and Zolid) correspond to the highest Class 5 and differ fundamentally by the reduction of the aluminum content, which resulted in increased translucency without loss of strength.

In addition, the 3rd generation (Zolid FX) was significantly increased in terms of translucency by modifying the yttrium content and the associated cubic phase fractions within the structure. This aspect is of particular interest for monolithic restorations in the anterior tooth region. However, this modification causes a loss of strength, which is why the 3rd generation only corresponds to Class 4.

In order to finally have a material available on the market which shows no loss of strength and nonetheless demonstrates increased optical properties, the 4th generation (Ceramill Zolid HT+) was developed, where the translucency value lies between the 2nd and 3rd generation and still meets the mechanical properties of Class 5. Due to this division into classes and generations, it is very important to clearly emphasize these differences in comparative studies.

Fig. Maximum indication width (class 5) using the example of a 14-unit zirconia restoration

FLEXURAL STRENGTH/WEIBULL STATISTICS

Flexural strength describes the behavior of a dental material such as ceramics with respect to single loading up to fracture. It thus represents a parameter for the limit of a body‘s elastic load-bearing capacity under flexural stress. Flexural strength is the most important parameter for estimating the strength and dimensioning of workpieces.

The flexural strength test and the minimum requirements for dental ceramics are specified in DIN EN ISO 6872 or the Weibull statistics according to ISO 20501, whereby DIN EN ISO 6872 distinguishes between 3-point and 4-point flexural strength and biaxial strength. To compare strength values measured in megapascal [MPa], the test method used, the specimen dimension and the preparation method (as fired or ground) must be specified.

The strength value of ceramics is usually given as Weibull strength (failure value at 63.21 %). The Weibull modulus m is a statistical value here for the variation of the strength values of the ceramic material and is given as a measure of the reliability of the fracture behavior of ceramics.

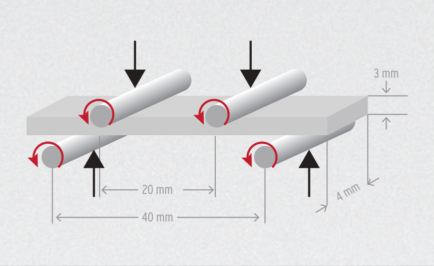


Fig. 4-point bending arrangement for ceramic testing

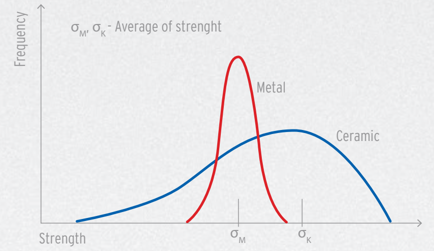


Fig. Qualitative comparison of the strength distribution of metal and ceramic batches

E-MODULUS

The modulus of elasticity is a material parameter that describes the relationship between the elongation and the stress during the deformation of a solid body. The value of the modulus of elasticity is greater the more resistance a material exhibits against its deformation. A material with a high modulus of elasticity (e.g. zirconium oxide) possesses high rigidity, a component made of a material with a low modulus of elasticity (e.g. acrylics) is more flexible and therefore more elastic.

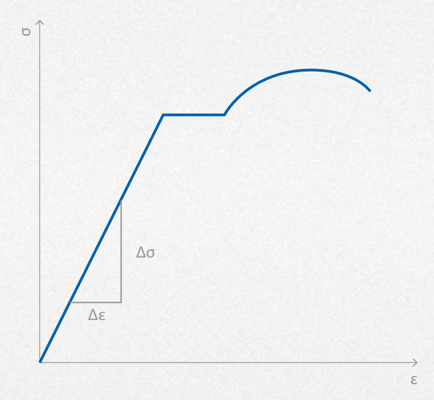


Fig. Force-displacement diagram with Hooke‘s linear line

FRACTURE LOAD

For certain tests, the fracture load in Newton [N] is determined instead of the flexural strength. This is particularly useful for comparative load tests, e.g. on dental crowns and bridges, as the strength cannot be clearly determined here due to the undefined geometries and cross-sectional areas. The maximum determined fracture load is the value at which the component fails.

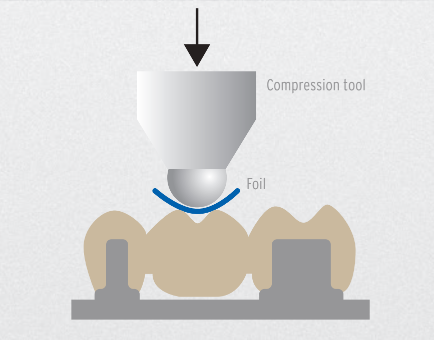


Fig. Fracture load of 3-unit bridge

FRACTURE TOUGHNESS

Fracture toughness describes the resistance of a component to the propagation of fractures. The fracture toughness parameter is the critical stress intensity factor KIc, its unit is [MPa√m]. Crack or fracture toughness indicates the exact stress that causes brittle fracture under static loading. Fracture toughness can be determined using various methods and is only partially regulated by standards.

Again, the specification of the method used is important for the comparability of the values as well as for the determination of the flexural strength. A distinction is made between the methods IF, IS, SEVNB and CNB. Not every method is ideally suited for every type of material and must therefore be carefully defined prior to material testing. The dental standard ISO 6872 specifies the SEVNB (Single Edge V-Notched Beam) procedure according to ISO 23146 for determining the fracture toughness of dental ceramics.

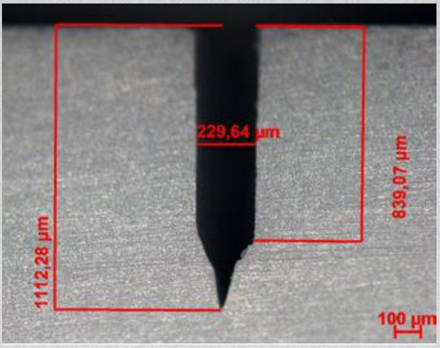


Fig. Notch for fracture toughness test according to SEVNB method

MECHANICAL AGEING / MASTICATORY SIMULATION

Masticatory simulators are used for mechanical and preclinical testing and are intended to simulate the mechanical and thermal stresses on dentures in the oral cavity. Various simulation parameters are available for this purpose. Masticatory simulation with freely adjustable thermocyclic-mechanical load changes (e.g. 5 °C/55 °C, 37 °C; 10-700 N; 1-5 Hz), as well as force curves and max. chewing load are freely controllable in combination with sliding movements (vertical and horizontal load).

This simulation ensures the corresponding fatigue behavior of the materials tested by cyclically changing force loads. Fractures, cracks, chipping and abrasion can be the result. Both standardized test specimens and restorations using natural teeth as a basis are used. Natural teeth as well as steatite or steel balls are used as antagonists. The test specimens are typically exposed to a masticatory simulation of 1.2 million cycles at a chewing force of e.g. 50-100 N and a simultaneous thermal alternating load between 5 °C and 55 °C. This simulates a wearing period of 5 years.

The test is terminated within the cycle time after the breaking load has been reached and a fracture has occurred. If no damage occurs which requires terminating the test, the specimens are initially tested after simulation to determine the remaining breaking load. This allows drawing conclusions as to whether pre-damage due to fatigue behavior has occurred.

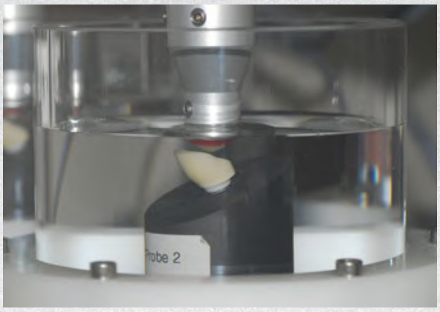


Fig. Masticatory simulation with a ceramic crown in artificial saliva

HYDROTHERMAL AGEING

Hydrothermal ageing of zirconium oxide in particular describes the damage to the ceramic structure caused by water absorption (hydrolysis) and can lead to a significant phase transition from the tetragonal to the monoclinic crystal structure, which subsequently leads to a degradation of the mechanical properties.

This is also referred to as „low temperature degradation“ (LTD). This ageing can be simulated in an autoclave by subjecting the material to hydrothermal treatment at 134 °C, 0.2 MPa, min. 5 h. The tests for hydrothermal ageing are specified in ISO 13356. Under hydrothermal ageing, ZrO_2 ceramics exhibit the known transformation behavior, which is characterized by linear layer growth of a transformed zone from the surface into the material (see Fig.). Newer generations of zirconium oxide with increased yttrium content and stabilization of the cubic phase at room temperature show significantly lower or no transformation effects.

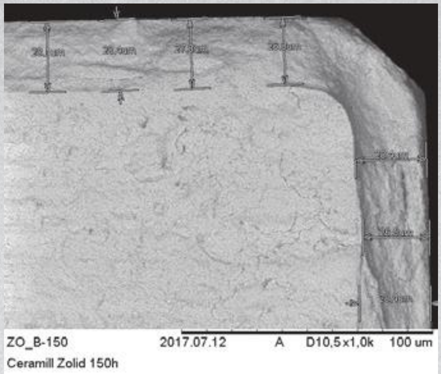


Fig. Magnified image of the marginal layer on zirconium oxide after hydrothermal ageing

HARDNESS

The hardness of a material is the resistance of a material to permanent deformation by penetration of a harder test specimen. The hardness test measures either the depth of a penetration body (Rockwell) or the size achieved (Vickers, Knoop, Brinell).

Metallic and ceramic dental materials are usually tested by the Vickers method (HV) according to ISO 6507, in which a pyramid-shaped diamond is used. The choice of the most suitable hardness testing method depends on the structure and homogeneity of the material. In the case of a heterogeneous structure, a larger impression is therefore required than for a homogeneous material to obtain a representative assessment of the respective hardness of the material. Values are therefore only comparable if the same method was used for the same load and test time as a basis (e.g. HV10).

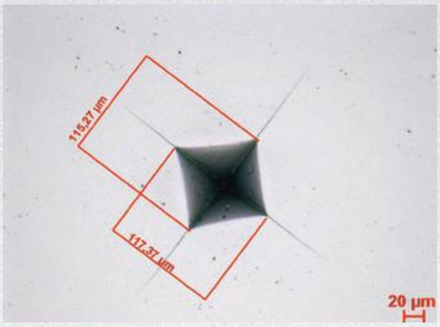


Fig. Measurement of a Vickers indentation for hardness determination

ABRASION

The loss of hard tooth substance in the human dentition is a natural sign of wear and tear and depends on food consistency and individual chewing strength. The hard substance of the tooth is reduced due to friction. This can be intensified by pathological processes such as functional disorders, e.g. bruxism (nocturnal grinding), as well as the effects of acids.

Among other things, dental restorative materials are tested for abrasion resistance in masticatory simulators. This type of simulation using cyclic loads with lateral movements and the possibility of using different antagonist materials has proven itself in numerous studies. Volumetric measurements for abrasion values and roughness measurements (R_a and R_{max} values) serve as typical measurement variables. The mean roughness value R_a is a statement about the smoothness of a surface after substance removal.

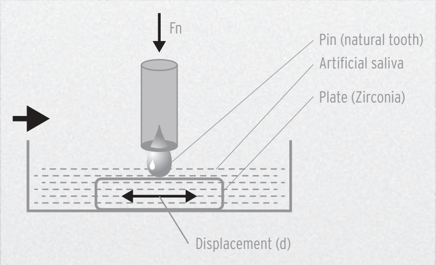


Fig. Test setup for abrasion measurement (pin on disc method)

BONDING STRENGTH

Basically, one can distinguish between two types of bonding options for dental restorations. The bond between the fixed denture on the remaining dentition and the bond between two restorative materials such as metal-ceramic or the bond of veneer acrylics to the frame material. The adhesive tensile strength and bonding strength of dental materials and adhesives are regulated in ISO/TS 11405 and represent important parameters in the evaluation of the performance of adhesives in the field of reconstructive dentistry. This standard provides information on various test methods for quality testing the bond between restorative dental materials and dental hard substance, i.e. enamel and dentine.

The Schwickerath test as stipulated in DIN EN ISO 9693 is used for testing the bonding strength between dental materials such as alloys and veneer ceramics. Here, platelets with fused ceramic are subjected to a bending test to check the load-bearing capacity of the composite for tensile/compressive stress. DIN EN ISO 10477, in turn, regulates the testing and requirements for the bonding of crown and bridge acrylics by pressure-shear strength testing.

The adhesive strength of the veneer ceramics in all-ceramic systems can basically be tested both by compression bending tests and by the Schmitz-Schulmeyer shearing test. With regard to the technical reproducibility and comparability of the bonding strength of all-ceramic systems, the modified shearing test according to Schmitz-Schulmeyer is preferable.

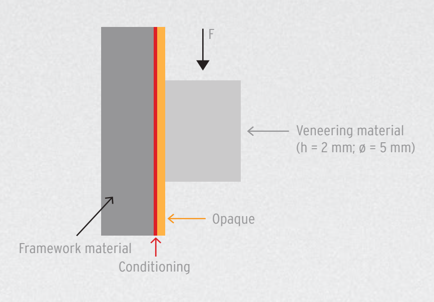


Fig. Test setup to determine the bond strength

MARGINAL GAP ANALYSIS

Regardless of the material and fabrication process of the fixed denture, good accuracy of fit and an excellent marginal seal are decisive for long-term success. A poor marginal seal leads to increased plaque accumulation. The micro-gap increases the risk of caries and can lead to periodontal problems and even bone loss. Both increase the risk of loss of the restoration.

The marginal gap is the distance from the preparation border to the crown margin of the restoration. The crown margin terminology according to Holmes is the most uniform definition of marginal gaps. The stipulations for acceptable marginal gaps in studies range from 20 µm – 200 µm for the measured gap width. In CAD/CAM all-ceramic restorations, the internal marginal fit and the marginal seal are, among others, the decisive factors for their longevity. A marginal seal of 50 µm is considered clinically acceptable and has established itself as a standard. In general, however, there is no clear limit for the marginal gap as this is also not regulated by standards. Zirconium oxide restorations should have at least an equivalent fit compared to other all-ceramic systems and the classic metal frames.

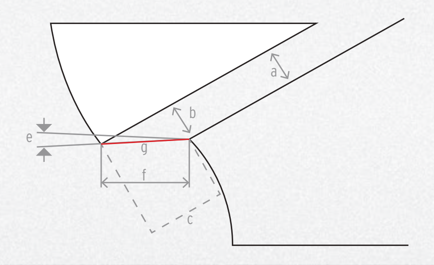


Fig. Parameters of the crown margin terminology according to Holmes at the marginal gap between crown (white) and preparation margin (grey)

TRANSLUCENCY / CONTRAST VALUE

The partial light transparency of a material is referred to as translucency. Opacity is a measure of the impermeability of substances to light (attenuation) and is the inverse of translucency.

The ability of matter to allow light waves to pass unhindered (transmission) is referred to as transparency. Due to their microstructure, zirconium oxide materials exhibit certain translucencies which are significantly influenced by factors such as impurities or microdefects (pores). However, desired alloy components such as aluminum oxide, yttrium oxide and its distribution in the microstructure also lead to significant changes in translucency. All these influencing factors lead to the scattering and absorption of light and can in part be deliberately controlled or influenced. To determine and compare the translucency of materials, the contrast ratio is determined. The CR value, also called contrast ratio, indicates the ratio of the light reflection of a specimen on a black background to the light reflection on a white background and serves as a measure for the translucency of the material. The lower this value is, the higher the translucency of the material.

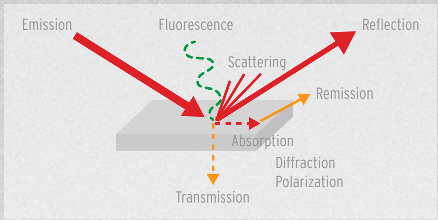


Fig. Light scattering effects on translucent ceramic materials

STRUCTURE/GRAIN SIZES

Similar to dental (precious metal) alloys, a homogeneous and fine-grained structure in ceramic materials guarantees just as high strength and good resistance to ageing (corrosion in alloys). The method for determining the grain sizes of zirconium oxide is governed by ISO 13356. For partially stabilized zirconium oxide with 3 mol yttrium, the critical grain size was fixed at 600 nm, i.e. for larger grains the tetragonal-monoclinic phase transformation is no longer reversible and thus the mechanism of transformation amplification is no longer given.

However, this only applies to 3Y-TZP 1st and 2nd generation zirconium oxides (Ceramill ZI and Zolid) without so-called cubic phase components. The grain sizes of these new generations with increased yttrium content and increased translucency are considerably larger in some cases due to the cubic stabilized phase. This combination of size and isotropic behavior of the light of these crystal phases makes the zirconium oxide appear significantly more translucent. Due to the lack of or reduced possibility of transformation amplification, the strength properties lie below those of the first generations, however, the new types of highly esthetic zirconium oxide in part offer significantly improved ageing resistance despite increased average grain size.

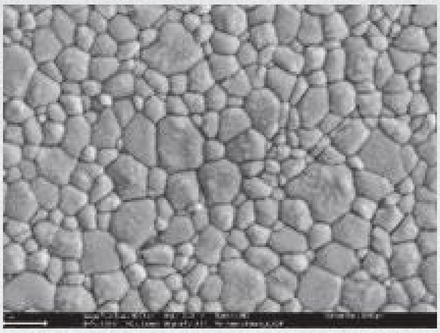


Fig. Scanning electron microscopic image of a 4th generation zirconium oxide structure

CONFIDENCE INTERVAL/P-VALUE

The confidence interval is preferably used for a statistical evaluation if the unknown parameters of the overall population are to be deduced from a known sample. A 95 % confidence interval is often used in dental studies. This means that the measured values lie within this interval with a 95 % probability if the tests are repeated under the same conditions. The smaller the number of samples selected, the wider the 95 % confidence interval.

The so-called p-value/α-value, which is usually assumed to be <0.05 in dental studies, is associated with the confidence interval. In principle means that the probability of the result being random is < 5 %. In this case, the result would be statistically significant for a p-value <0.05. On the other hand, if the p-value is >0.05, the result is not statistically significant.

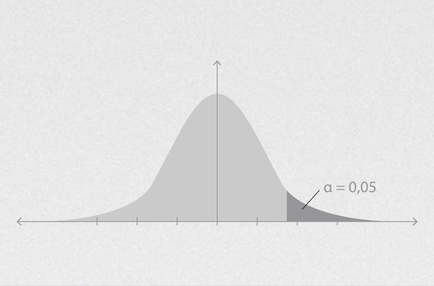


Fig. Probability distribution with 95 % confidence interval (light grey) for an α value α = 0.05 (dark grey)

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