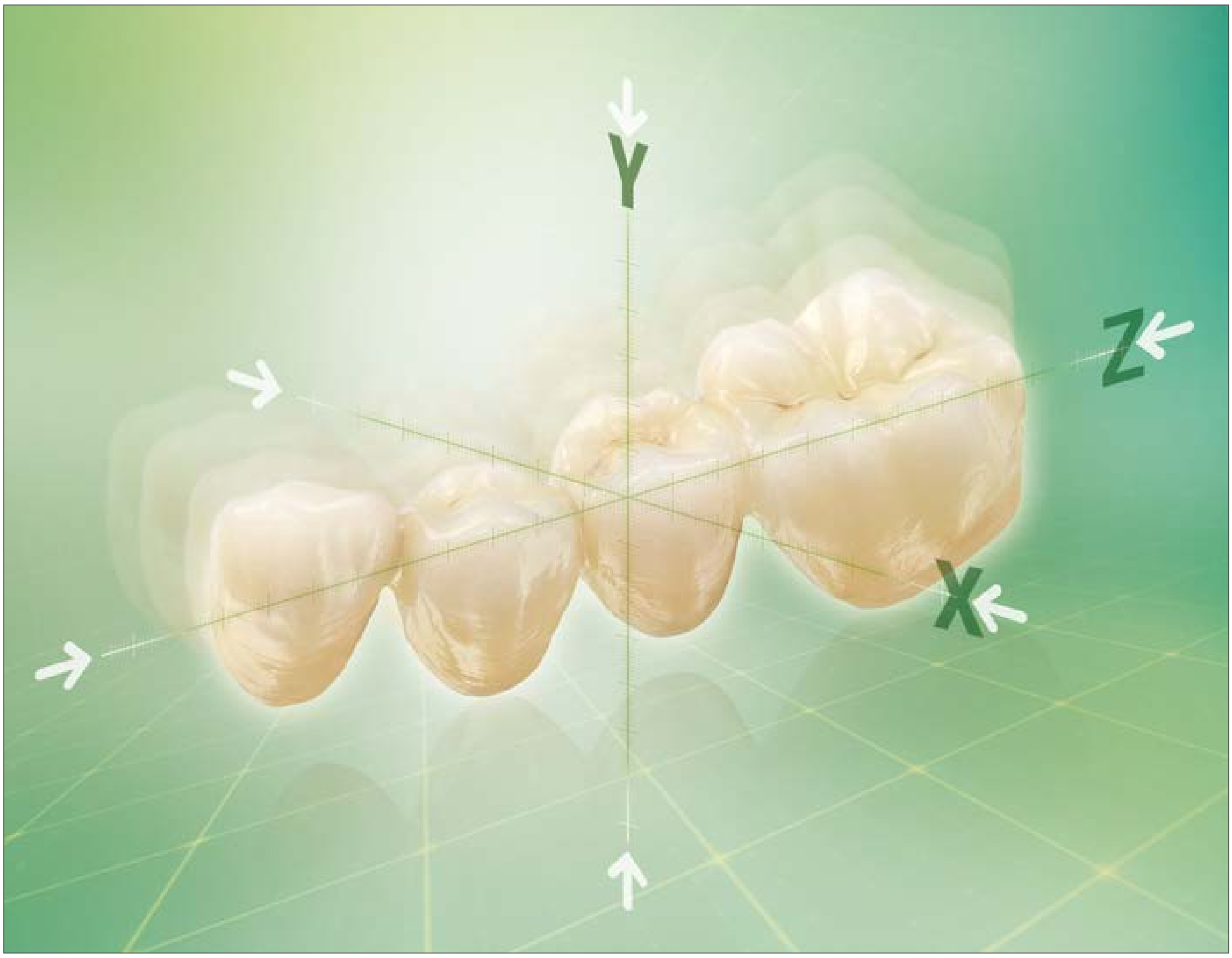
VITA YZ® SOLUTIONS

Technical and scientific documentation



VITA shade determination | VITA shade communication | VITA shade reproduction | VITA shade control

Date of issue 2025-05

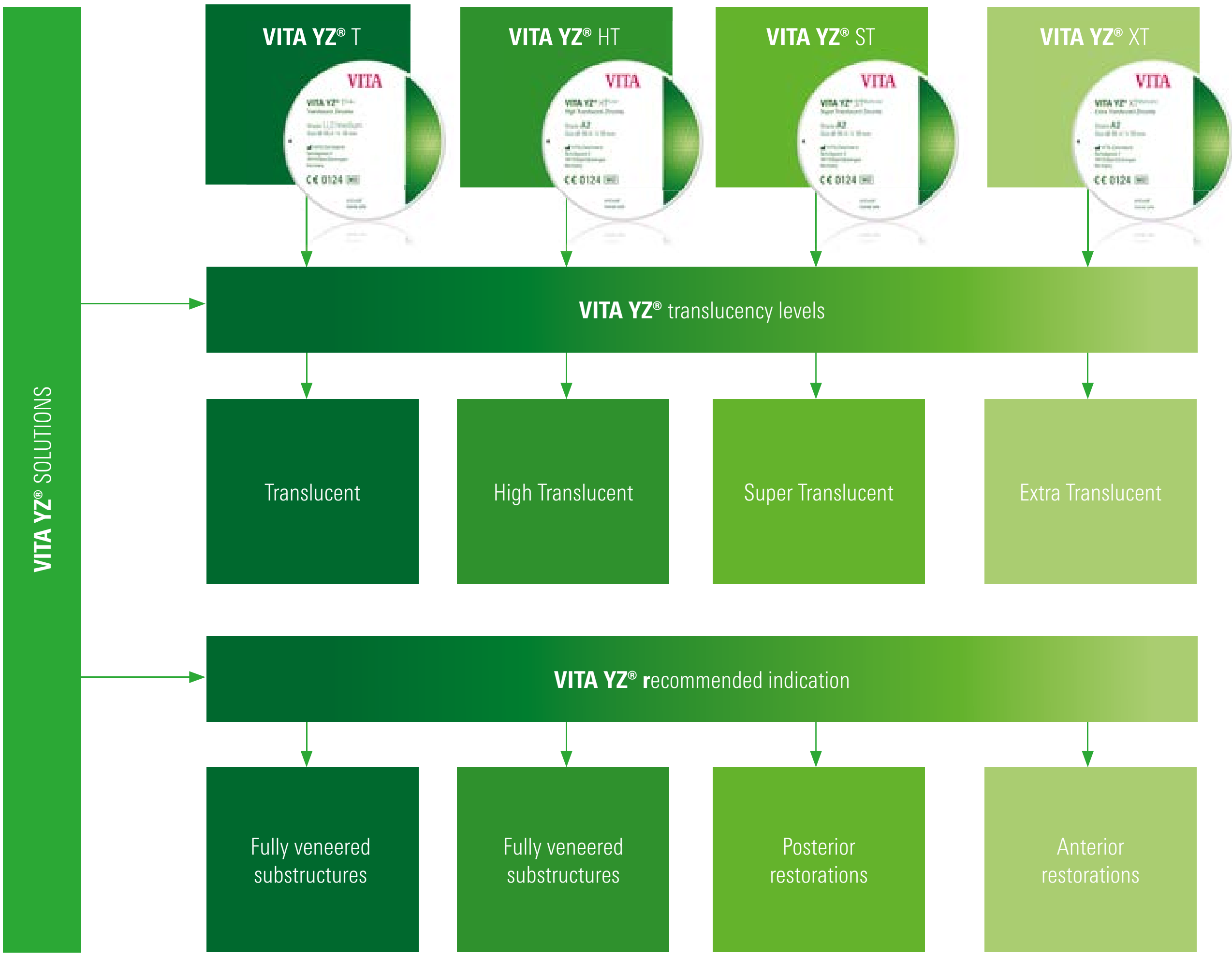
VITA – perfect match.

VITA

1. Introduction

Today there is a very wide range of CAD/CAM materials for use in practices and laboratories. An important milestone in dental material development was the use of zirconia (ZrO_2) at the beginning of the millennium. It enabled the fabrication of multi-unit, all-ceramic bridges for the first time.
VITA Zahnfabrik is one of the pioneers in this field and has been offering zirconia blanks for CAD/CAM fabrication of all-ceramic dental restorations since 2002 (originally introduced under the designation of VITA In-Ceram YZ).

Today the range of materials includes four translucency levels (T, HT, ST and XT for monolithic, partially and fully veneered bridges).



3-point flexural strength of VITA YZ T within the scope of quality testing

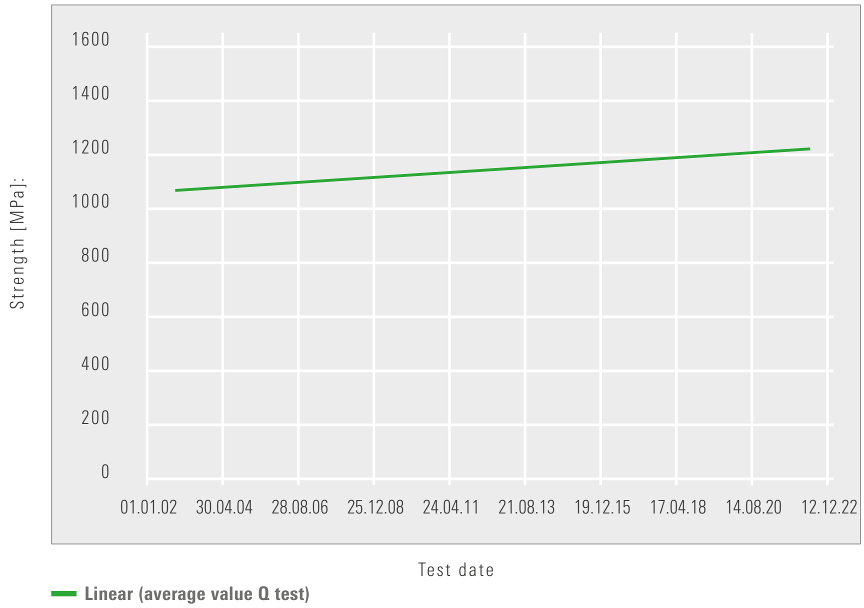


Figure 1: Flexural strength values from 2002 to 2022; determined within the scope of internal quality tests, source: Internal study, VITA R&D, (Gödiker, 12/2022, [1] see p. 35)

VITA Zahnfabrik is committed to very high quality standards. This includes the goal of continuously improving materials and processes.
One example is the improvement of mechanical properties of VITA YZ T, such as the 3-point flexural strength (see Fig. 1). This documentation provides an overview of the most important technical and scientific data of VITA YZ SOLUTIONS.

1.1 Chemical composition

Components [Wt%]	**VITA YZ** T	**VITA YZ** HT	**VITA YZ** ST	**VITA YZ** XT
ZrO_2	90 – 95	90 – 95	88 – 93	86 – 91
Y_2O_3	4 – 6	4 – 6	6 – 8	8 – 10
HfO_2	1 – 3	1 – 3	1 – 3	1 – 3
Al_2O_3	0 – 1	0 – 1	0 – 1	0 – 1
Pigments	0 – 1	0 – 1	0 – 1	0 – 1

1.2 Physical/mechanical properties

Components [unit]	**VITA YZ** T	**VITA YZ** HT	**VITA YZ** ST	**VITA YZ** XT
CTE [1)] [10^{-6}/K]	10.5	10.5	10.3	10.0
Chemical solubility [1)] [µg/cm^2]	< 20	< 20	< 20	< 20
Sintering density [2)] [g/cm^3]	6.05	6.08	6.05	6.03
3-point flexural strength [1)] [MPa]	1350	1350	1200	850
Fracture toughness [3)] (CNB method) [MPa $m^{0.5}$]	4.5	4.5	3.5	2.5
Modulus of elasticity [4)] [GPa]	210	210	210	210
Hardness [5)] [HV 10]	12	12	13	13
Weibull modulus [1)]	14	14	13	11

[1)] Determination according to DIN EN ISO 6872:2015
[2)] Determination according to DIN EN 623-2:1993
[3)] Determination according to ISO 24370:2005
[4)] Determination according to DIN EN 843-2:2007
[5)] Determination according to DIN EN 843-4:2005

1.3 Manufacturing and quality standards

Today, there are a large number of companies that offer zirconia blanks. So many practices and laboratories ask the question: "Is all zirconia the same?" Although many blanks do not reveal any significant optical or haptic differences at first sight, substantial differences become obvious when taking a closer look at the material quality and properties.

VITA Zahnfabrik has continuously optimized the manufacturing processes for VITA quality zirconia and uses high process standards and strict test criteria. Only top-quality materials are processed in the production of VITA YZ. To ensure the high quality, standard measurements of particle size distribution, flowability and sintering behavior are carried out on each new raw material batch, in addition to detailed quality controls, to ensure the reliability.

Dilatometer measurements of various zirconia granules in the range of the presintering temperature

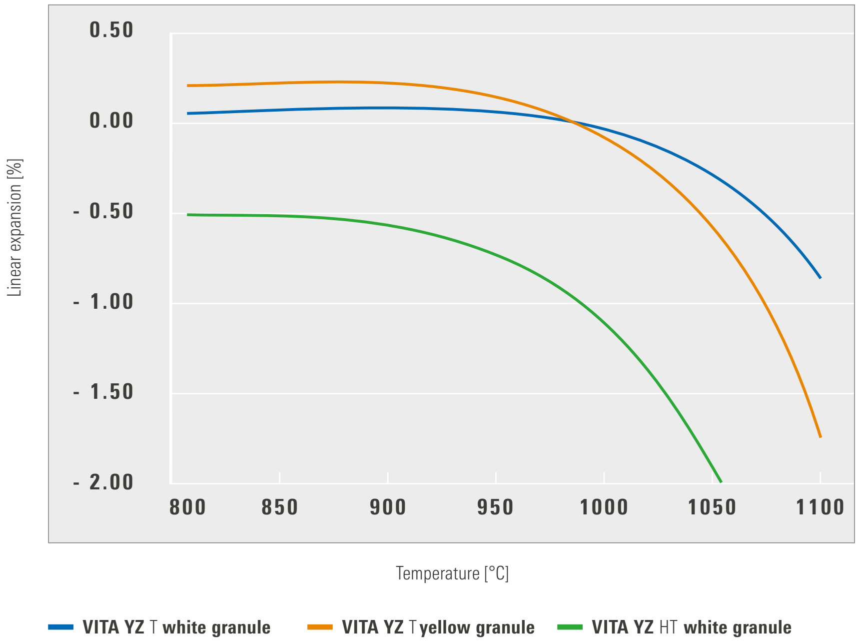


Figure 2: Study of the sintering behavior of various VITA YZ granules
Source: Internal study, VITA R&D (Gödiker, 11/2014 [1] see p. 35)

The target of VITA Zahnfabrik's high quality standards is to enable users in laboratories and practices to achieve reproducible results, independent of the material type in use. Granules made of non-colored (e.g., VITA YZ HT White) and industrial pre-colored zirconia (e.g., VITA YZ HT Color) exhibit, for example, different sintering properties which are influenced by adding colorants.

VITA focuses on modern procedures and measuring techniques (see Fig. 2) to be able to determine the differences in a precise manner. The granules are optimized in an industrial process (e.g., by material-specific presintering) so that the various types do not differ in their machinability and sintering properties, when they are used in practices and laboratories.

1.4 Control of the sintering behavior

To control or adjust the sintering behavior of zirconia in a way that enables practices and laboratories to achieve accurate and reproducible sintering results, is a key challenge for each manufacturer. For example, essential parameters are the quality of the raw material and the control of the moulding and presintering process.

Step 1: Pressing process, uniaxial, two-sided

Step 2: Pressing process, isostatic

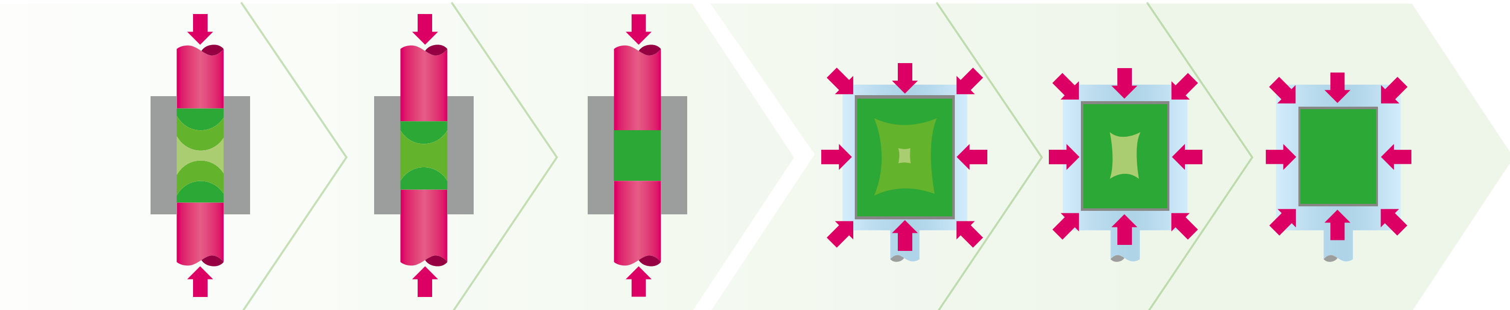


Figure 3: Schematic view of the pressing process for VITA YZ SOLUTIONS blanks

First, the basic shape of the zirconia blanks of VITA Zahnfabrik is achieved in a uniaxial pressing process and then the blanks are repressed isostatically in a high pressure container. The homogeneous density that is achieved is an essential precondition for homogeneous sintering behavior. The presintering process - that is, the industrial firing process - is precisely adjusted to the respective batch and blank geometry.

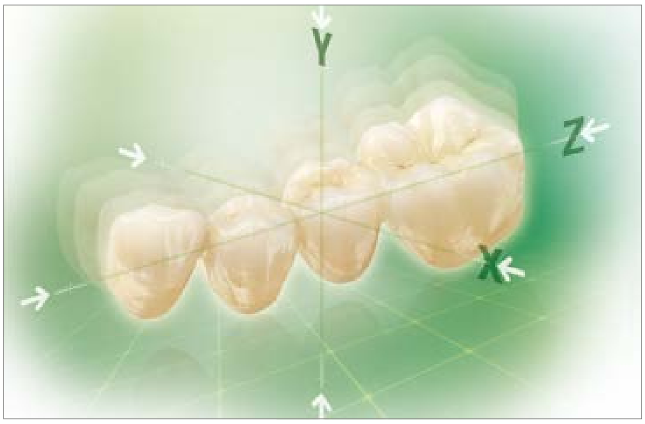


Figure 4: Example of sintering shrinkage (X-,Y-,Z-dimension)

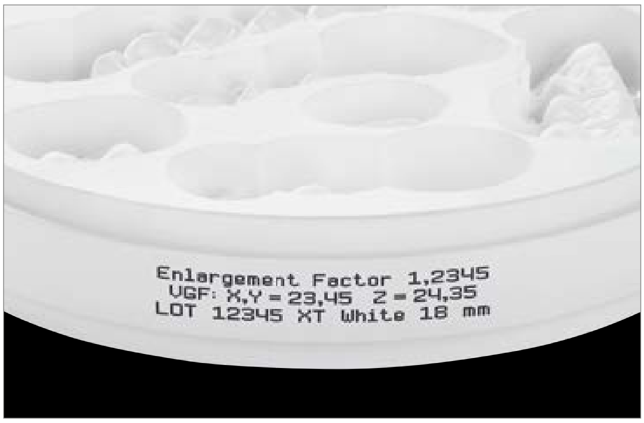


Figure 5: Example of enlargement factors indicated on blanks

Another essential step in accessing accurate sintering results is the precise determination of the enlargement factor. VITA Zahnfabrik determines this factor in all three spatial dimensions (X-, Y-, Z-dimension) for each production batch and integrates the information in the print on the blank (as a bar code or plain text). Some manufacturers, however, only indicate average values. Exact determination of sintering shrinkage and the precision of fit of the densely sintered dental object is particularly essential for multi-unit bridge constructions.

Figure 6: Example of sintering shrinkage of zirconia by approx. 20 %

Figure7: Example of test fit with model made of metal

The final quality inspection at VITA is carried out using a pass or fail of the test fit. For this purpose, a bridge structure with a maximum size indicated for the respective material is fabricated (CAD/CAM fabrication) using the enlargement factor determined for each batch; the structure is densely sintered and the fit is checked (see 2.8) on a standardized steel model (see Fig. 7).

1.5 Material and structural quality

The structural quality is an important factor for the high load capacity of zirconia restorations. It is primarily ensured by the material quality and a manufacturing process tailored to the raw material. If process steps, such as moulding, debinding and presintering are matched with one another, a homogeneous and pore-free structure is achieved. As a result, users in practices and laboratories will receive a high-quality blank. If this is not ensured, defects may occur in the structure, which may affect the long-term stability in clinical use.

1.6 Study of the microstructure

a) Materials and methods

SEM image analysis of the structure of densely sintered samples made of VITA YZ T and a competitor's zirconia after polishing and thermal etching.

b) Source

Internal study, VITA R&D, (Gödiker, 11/2014, [1] see p. 35)

c) Result

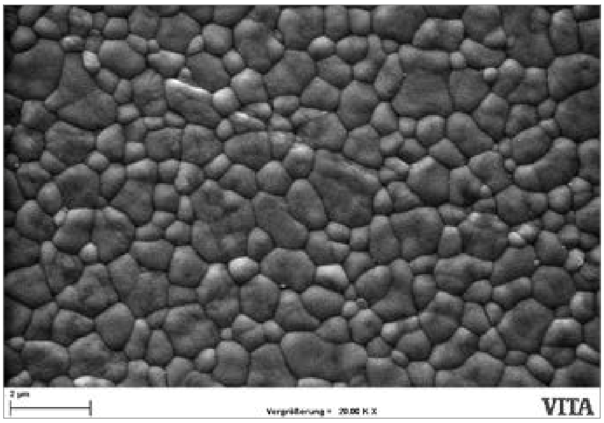


Figure 8: VITA YZ T at 20,000x magnification

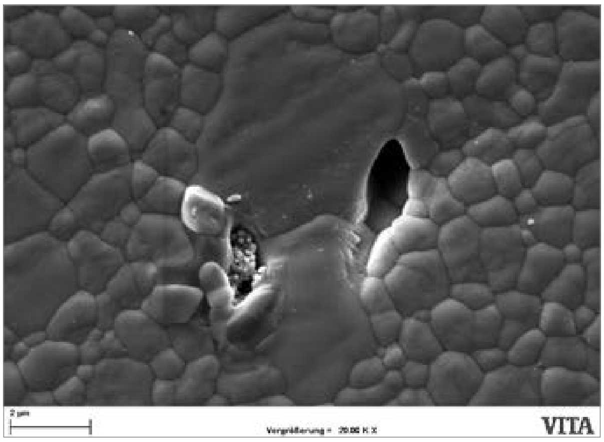


Figure 9: Competitor's zirconia at 20,000x magnification

d) Conclusion

Based on particularly high quality standards, VITA YZ features a homogeneous microstructure without pores or defects (see Fig. 8). The sintered microstructure features an average particle size of approx. 500 nm. Contamination and structural defects can sometimes be found (see Fig. 9) in low-quality zirconia blanks (often low price products). Some defects, however, can only be detected at high magnification. Depending on the size and position in the structure, the defects may deteriorate the mechanical properties.

1.7 Microstructure of different translucency types

a) Materials and methods

SEM image analysis of the structure of densely sintered samples made of VITA YZ T, HT, ST and XT after dense sintering in accordance with the manufacturer's instructions. The analysis was carried out after polishing and thermal etching.

b) Source

Internal study, VITA R&D, (Gödiker, 03/2017, [1] see p. 35)

c) Result

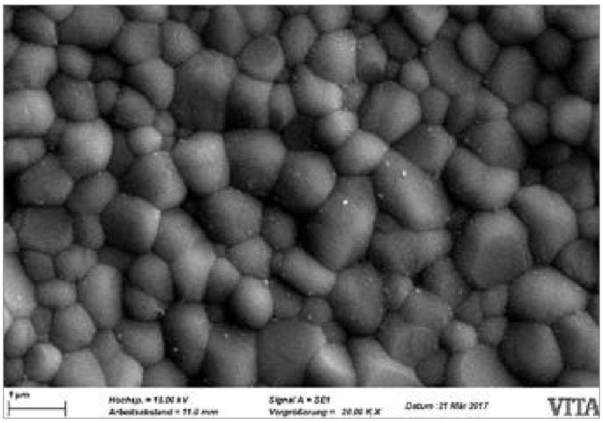


Figure 10: VITA YZ T at 20,000x magnification

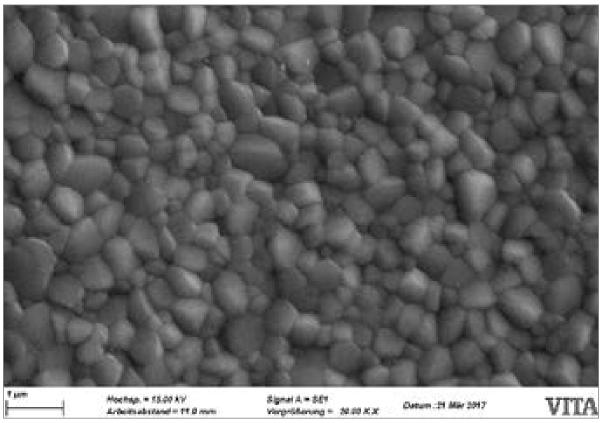


Figure 11: VITA YZ HT at 20,000x magnification

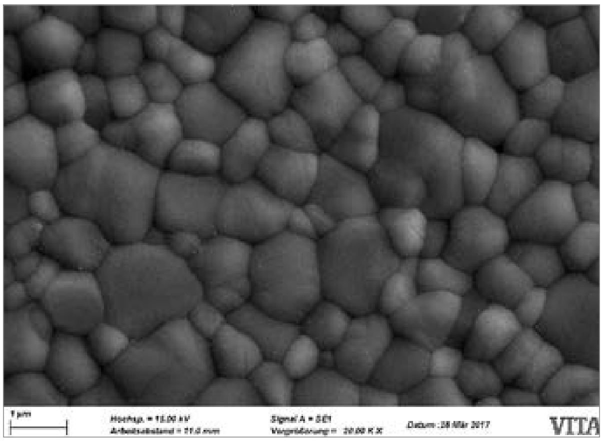


Figure 12: VITA YZ ST at 20,000x magnification

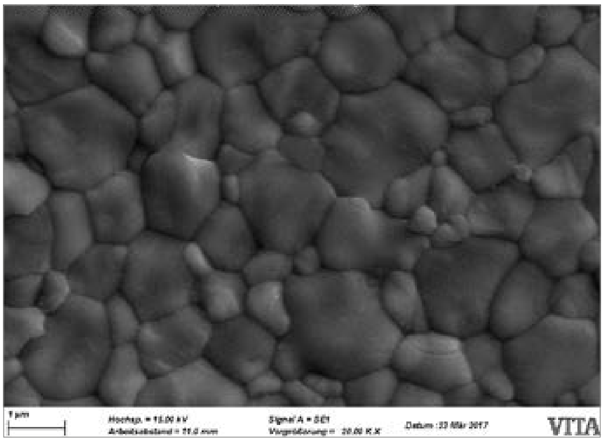
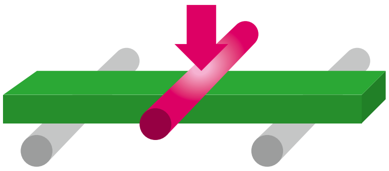


Figure 13: VITA YZ XT at 20,000x magnification

d) Conclusion

The particle sizes (and with them the proportion of particle boundaries) have a direct influence on the light refraction, and as a result, the translucency of the different materials. The larger the particles, the smaller the number of boundaries where the light is refracted. The comparatively translucent appearance of materials, such as VITA YZ T (particle size ~ 1.0 µm), can be attributed to that. The chemical composition, in particular the yttrium oxide content and aluminium oxide (Al_2O_3) enrichment at the grain boundaries, influence the light refraction properties. With a wt% of approx. 0.25, VITA YZ T has a considerably higher Al_2O_3) proportion than the other three VITA YZ types, and features a particle size of approx. 0.5 µm.
Consequently, this type appears comparatively opaque.



2. Physical/mechanical properties (in vitro)

2.1 3-point flexural strength of VITA YZ

a) Materials and methods

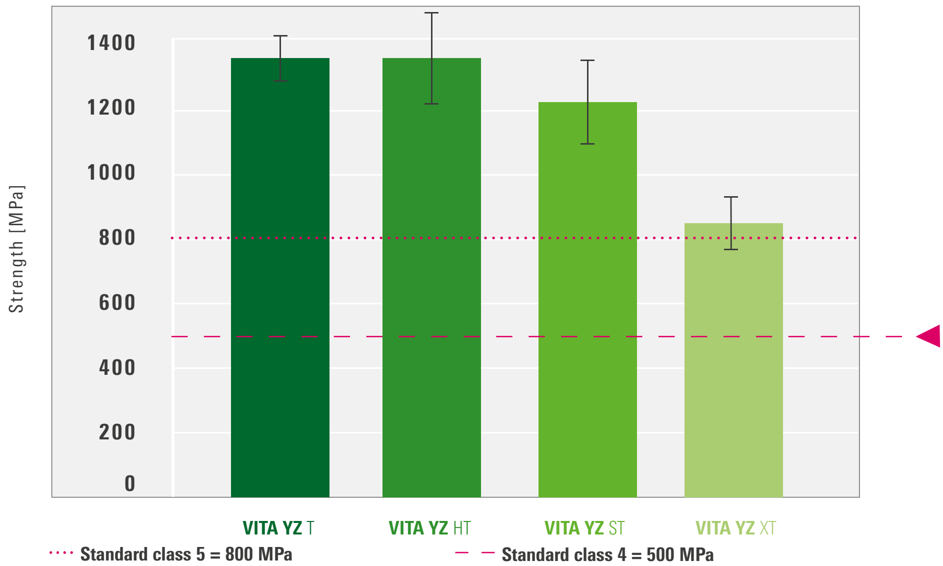
A diamond saw was used to prepare cuboid specimens from the VITA zirconia blanks. Then the specimens were milled manually using SiC paper (grain size P1200). Additionally, a 45% chamfer was added to each of the two edges on the side exposed to tensile stress. After sintering according to the manufacturer's instructions, the specimens featured final dimensions of 20.0 x 4.0 x 1.2 mm^3. Thirty six specimens of each material were loaded to fracture (using a universal testing machine) and the average 3-point flexural strength was determined.

b) Source

Internal study, VITA R&D, 3-point flexural strength of the different VITA YZ materials according to DIN EN ISO 6872:2015 + Amd.1:2018, (Gödiker, 08/2022), [1] see p. 35

c) Result

3-point flexural strength of the different VITA YZ materials

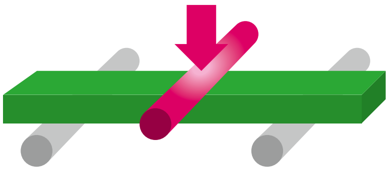


Standard class 4[1]: ≥ 500 MPa
monolithic crowns or crown substructures
monolithic bridges or bridge substructures with three units or less
Standard class 5[1]: ≥ 800 MPa
monolithic bridges or bridge substructures with four units or more

1) According to DIN EN ISO 6872:2015 + Amd.1:2018

d) Conclusion

In this test series, VITA YZ T and VITA YZ HT achieved average strength values of 1,350 MPa, while VITA YZ ST achieved values of 1,200 MPa. These values are above the standard requirement for indications of class 5; all three materials can be used for bridge constructions with four or more units.
In this test setup, VITA YZ XT achieved an average value of 850 MPa. Due to the lower fracture toughness (see point 2.5), the recommendation for indications corresponds to class 4.



2.2 Comparison of 3-point flexural strength

a) Materials and methods

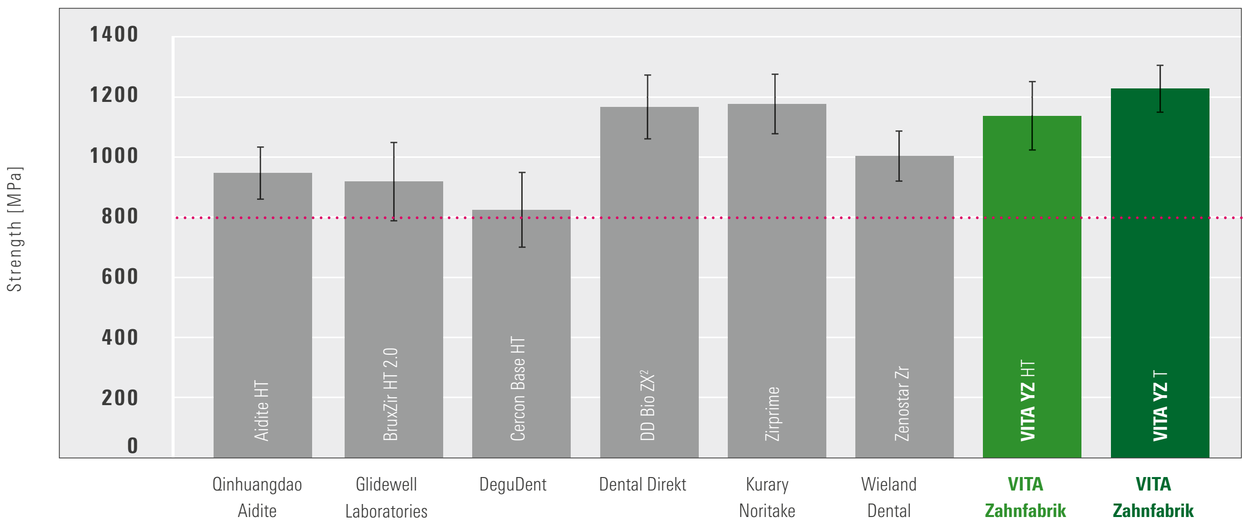
A diamond saw was used to prepare cuboid specimens from the VITA zirconia blanks. Then the specimens were milled manually using SiC paper (grain size P1200). Additionally, a 45% chamfer was added to each of the two edges on the side exposed to tensile stress. After sintering according to the manufacturers' instructions, the specimens featured final dimensions of 20.0 x 4.0 x 1.2 mm^3. Ten specimens of each material were loaded to fracture (using a universal testing machine) and the average 3-point flexural strength was determined.

b) Source

Internal study, VITA R&D, (Gödiker, 01/2014, [1] see p. 35)

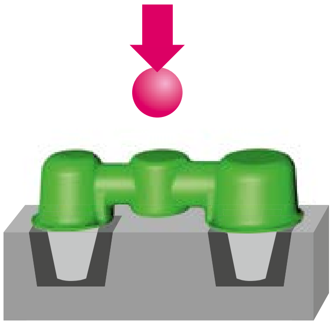
c) Result

Comparison of 3-point flexural strength



d) Conclusion

All zirconia materials examined in this test produced values above the standard requirement (> 800 MPa) for class 5. Compared to the competition, the strength values determined for VITA YZ SOLUTIONS were at a very high level. Determined strength differences may be a result of various materials that are not presintered equally, which can make sample preparation more difficult. To examine this, the dry green strength (= strength of the specimens in the presintered stage) of the materials was also examined. It ranged from 40 to 90 MPa, which suggests differences in the processing characteristics.



2.3 Static fracture load of different connector cross-sections

a) Materials and methods

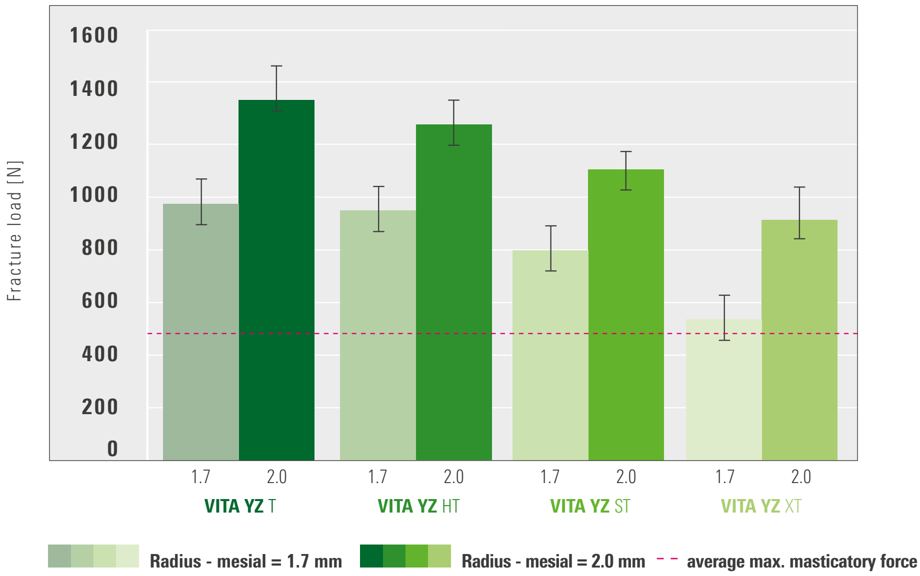
Stylized three-unit posterior bridges made of VITA YZ T, HT, ST and XT were fabricated using a CAM system, and densely sintered according to the manufacturer's instructions.
The thinner "mesial" connector had a radius of 1.7 mm (~ 9.0 mm^2 cross-sectional area), the thicker "distal" a radius of 2.0 mm (~ 12.0 mm^2).
The bridges with an increased connector cross-section had radii of 2.0 mm ("mesial") and 2.3 m ("distal"). All abutments had a uniform wall thickness of 0.5 mm. All bridges were bonded to steel stumps using zinc-phosphate cement. For each material, six bridges with small connector cross-sections and six with increased connector cross-sections were loaded to fracture using a universal testing machine.

b) Source

Internal study, VITA R&D, (Kolb, 08/2017, [1] see p. 35)

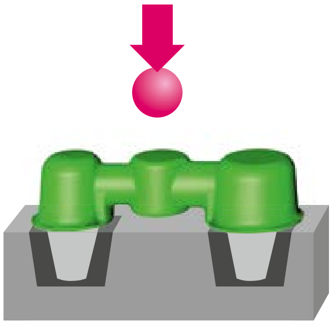
c) Result

Fracture load - VITA YZ bridges with different connector cross-sections



d) Conclusion

All average values measured in this test, including the bridges with smaller connector cross-sections, were above the average maximum masticatory force with a value of approx. 490 N [5]. Fracture always occurred in the "gingival" area of the thinner ("mesial") connector under tensile stress, analogous to the 3-point bending test.
The slight increase in the connector cross-section results in a considerably increased fracture load. It is therefore recommended to make the most of the available space when designing the connectors, in order to achieve a design with high load capacity. Based on this series of tests, a connector cross-section of at least 12 mm^2 in the molar area is recommended for VITA YZ XT (see Design recommendations - Working Instructions 10446M/1).



2.4 Static fracture load before and after hydrothermal aging

a) Materials and methods

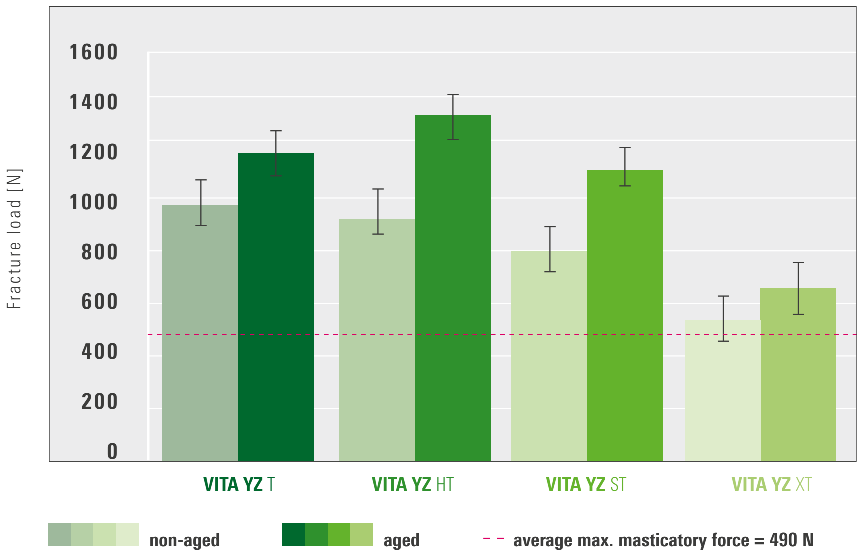
In this test setup, the clinical use of the material is simulated using material aging to test the stability in the oral environment. Stylized three-unit posterior bridges made of VITA YZ T, HT, ST and XT were fabricated using a CAM system, and densely sintered according to the manufacturer's instructions. The thinner "mesial" connector had a radius of 1.7 mm (~ 9.0 mm^2 cross-sectional area), the thicker "distal" a radius of 2.0 mm (~ 12.0 mm^2). All abutments had a uniform wall thickness of 0.5 mm. Half of the samples of each material were aged in steam in an autoclave at 134 °C for 72 hours. All bridges were bonded to steel stumps using zinc-phosphate cement. For each material, six aged and six non-aged bridges were loaded to fracture using a universal testing machine.

b) Source

Internal study, VITA R&D, (Kolb, 08/2017, [1] see p. 35)

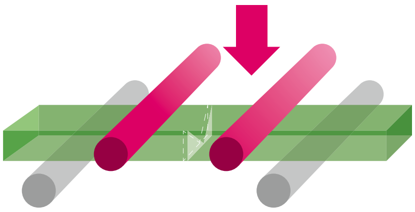
c) Result

Fracture load - VITA YZ bridges before and after aging



d) Conclusion

For both simulated aging and non-aged samples, mean values were reached that were above the maximum expected masticatory force [5], which suggests good long-term stability in the oral environment. The phenomenon of higher fracture loads after hydrothermal aging will be examined in future tests.



2.5 Fracture toughness

a) Materials and methods

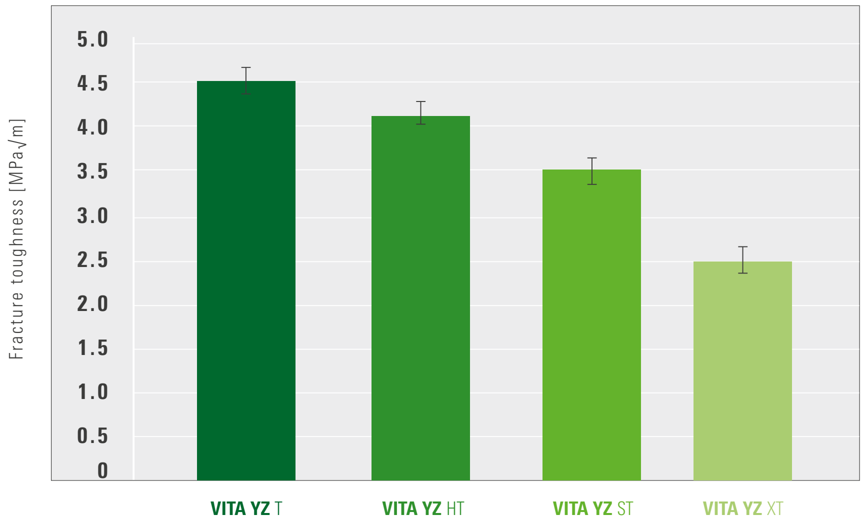
According to DIN EN ISO 6872:2015, the SENBV method should be used to measure the fracture toughness of fine-grained materials with grain sizes of less than 1 µm. Based on this, the fracture toughness test was carried out using the chevron-notched beam method according to ISO 24370 (Fine ceramics [advanced ceramics, advanced technical ceramics] – Test method for fracture toughness of monolithic ceramics at room temperature by chevron-notched beam [CNB] method). For this purpose, defined notches were prepared on bending specimens (3 x 4 x 30 mm^3) using a diamond saw (see sketch on the left) and then the specimens were loaded to fracture using a universal testing machine. Five specimens per series were tested.

b) Source

Internal study, VITA R&D, (Gödiker, 07/2017, [1] see p. 35)

c) Result

Fracture toughness of VITA YZ measured with the CNB method according to ISO 24370



d) Conclusion

The test shows a connection between chemical composition and mechanical resistance. Analogous to the increase in the yttrium oxide content (see Table 1.1 Chemical composition), the crack toughness of the
different types decreases continuously. This is also reflected in the fracture load or the flexural strength of the materials. Current studies [12] put the main focus on influencing factors and the test methods for fracture toughness.

2.6 Reliability/Weibull modulus

a) Materials and methods

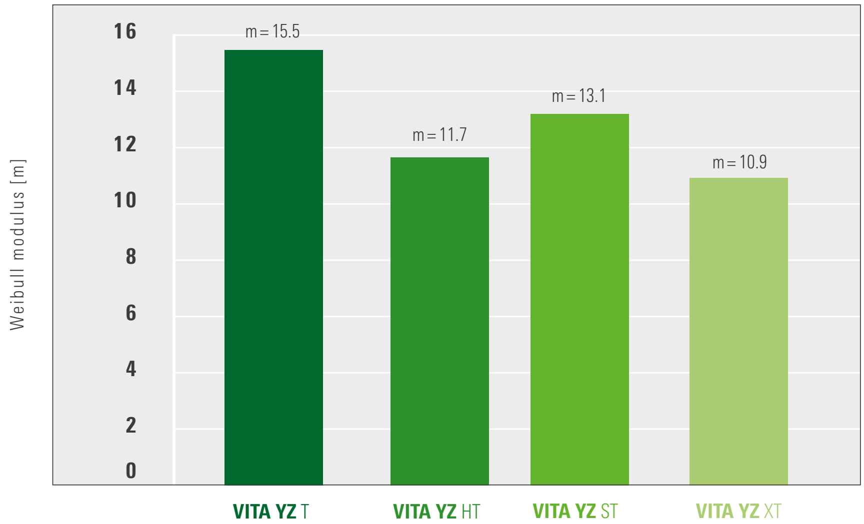
"Using a theory developed by Weibull, which is based on the concept of failure of the weakest link, the strength distribution of ceramic materials can be described effectively in mathematical terms. [. . .] if the distribution parameters are known, there is a clear correlation between the load and the probability of fracture." [2] The Weibull modulus of VITA YZ T, HT, ST and XT was determined based on the 3-point flexural strength values of 30 samples of each material.

b) Source

Internal study, VITA R&D, (Gödiker, 08/2017, [1] see p. 35)

c) Result

Weibull modulus of the different VITA YZ materials



d) Conclusion

In this test, excellent values were determined for the different VITA YZ materials with average values of the Weibull modulus from just under 11 to 16. The low deviation in the values measured is an indicator of high reliability and constant material quality. If only minor deviations from the average value (with respect to the determined minimum values) are measured, it can be expected that the material ensures reliable use within its respective recommended indication range.

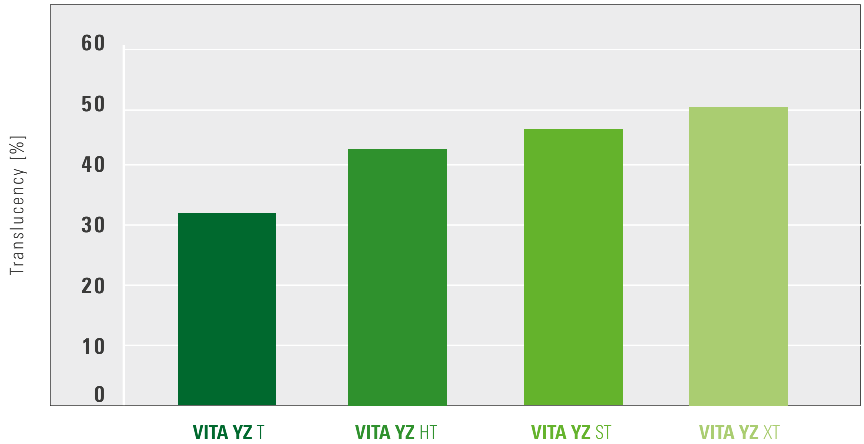
2.7 Translucency

a) Materials and methods
A photospectrometer was used to measure the translucency. The material samples used had a wall thickness of 1.0 mm and were polished to high gloss on both sides. The measured value is the average of five samples per series.

b) Source
External study, Tosoh Corporation, (Technical Report, 08/2017, [10] see p. 35)

c) Result

Translucency of the different VITA YZ materials



Average values with regard to the determined translucency		
VITA YZ T	32 %	
VITA YZ HT	42 %	
VITA YZ ST	46 %	
VITA YZ XT	50 %	

d) Conclusion
The values determined in this test can only be compared within the scope of this test setup since measured values depend on the sample thickness, the measuring device and the apertures used. Since the transmission is also influenced by the shade, a direct comparison with glass ceramics is difficult.
However, the measured values for VITA YZ XT are at a similar level.

2.8 Fit after the sintering process

a) Materials and methods

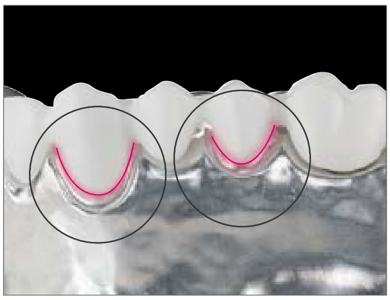
Various restorations are fabricated based on a digital model (CAD design). The corresponding control model was then milled from aluminum using a CNC machine. While taking the corresponding sintering shrinkage into account, the individual restorations were also fabricated (enlarged) using the same machine. This way, possible measurement inaccuracies that may result from a scanning process should be eliminated. Finally, the fit of the sintered structures was examined visually and haptically using a control model, and virtually by overlapping the digital structure with the real structure using wrap software.
This documentation shows the example of a 14-unit VITA YZ T bridge restoration.

b) Source

Internal study, VITA R&D, (Gödiker, 10/2014, [1] see p. 35)

c) Result

Figure 14a/b/c: a) model; b) milled, multi-unit VITA YZ structure; c) wrap software with overlapping structures (from left to right)



VITA YZ T

Competitor's ZrO_2

Figure 15/16: Visual fit check after sintering process using a control model for VITA YZ T/competitors

d) Conclusion

Using measurement equipment, the enlargement factor of each VITA YZ SOLUTIONS production batch is exactly determined in all three spatial dimensions so that excellent fit is also achieved for multi-unit VITA YZ bridge structures. All tolerances measured in this study are within the size of the cement gap (50 µm). In comparison, the competitor's zirconia examined in this test already shows a poor fit during the visual inspection (see Fig. 16).

2.9 Examining CAM machinability using crown/substructure geometries

a) Materials and methods

Various restorations made of VITA YZ T and a competitor's zirconia were fabricated to check the CAM machinability and the reproducibility of the virtually designed marginal areas. Then the restorations were examined under the light microscope with regard to the edge stability. Since colorants may influence the sintering behavior and the raw fracture strength of the respective material, the machinability of pre-colored blanks was particularly analyzed.

b) Source

Internal study, VITA R&D, (Gödiker, 01/2014, [1] see p. 35)

c) Result

Figure 17: VITA YZ T (pre-colored material)

Figure 18: Competitor's zirconia (pre-colored material)

d) Conclusion

Based on a crown substructure, this test shows that the use of VITA YZ T enables the fabrication of extremely exact, precision-fit restorations, thanks to the high edge stability (see Fig. 17). In comparison, the competitor's material exhibits marginal fractures in some areas after the CAM process (see Fig. 18). VITA Zahnfabrik ensures that the raw breaking strength of the "white" product (presintered blank free of binders) for non- and and pre-colored VITA YZ material types is at a similar level to enable users in practices and laboratories to achieve reproducible results, independent of the material type in use.

2.10 Test of CAM machinability using "merlon" geometry

a) Materials and methods

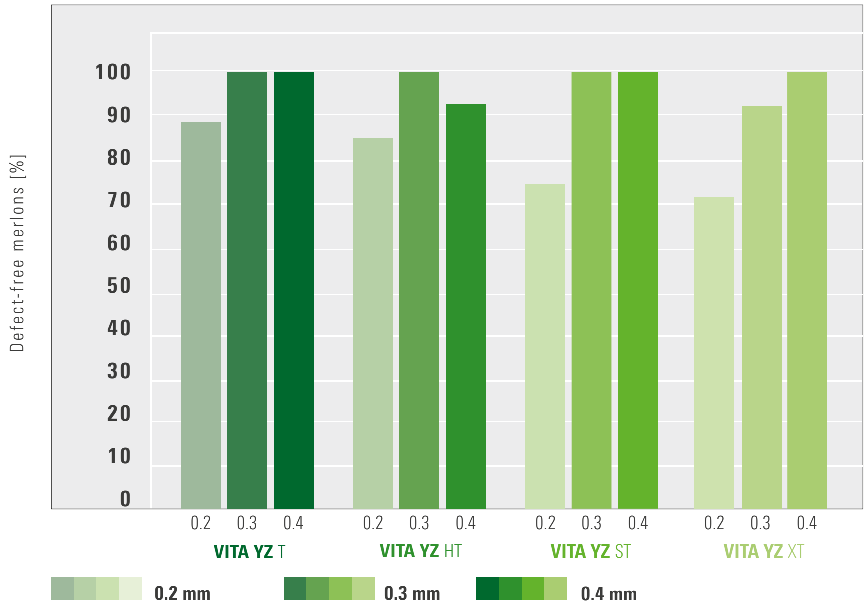
For enhanced evaluation of the CAM machinability and the reproducibility of the virtually designed margin areas of the different VITA YZ types (T, HT, ST, XT), seven "merlons" (specimen geometry with four merlons, see left figure) with wall thicknesses of 0.2 mm or 0.3 mm or 0.4 mm were produced using a CAD/CAM system (see Fig. 19). The same milling strategy was used for all specimens. Finally, the specimen geometries (in the three wall thicknesses) were visually examined and the merlons of the respective specimens checked for defects. The result chart shows the success rate of the merlons per specimen geometry for each material type and wall thickness.

b) Source

Internal study, VITA R&D, (Gödiker, 08/2017, [1] see p. 35)

c) Result

CAM machinability of the different VITA materials



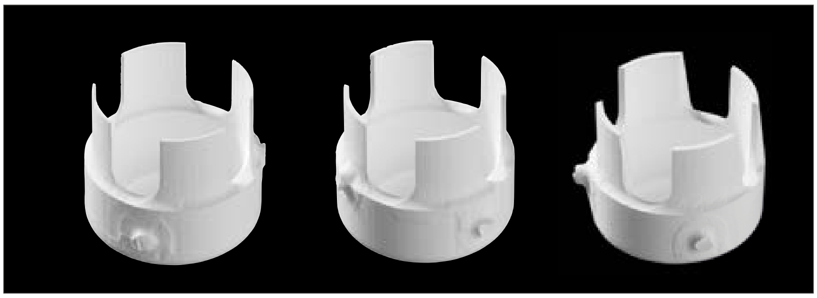
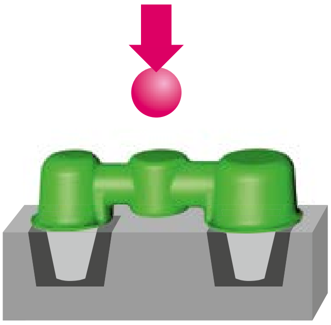


Figure 19: "Merlon" geometries made of VITA YZ with wall thicknesses of 0.2 mm, 0.3 mm and 0.4 mm (from left to right))

d) Conclusion

This test shows that the use of all VITA YZ SOLUTION types enables the fabrication of extremely exact, precision-fit restorations, thanks to the high edge stability (see Fig. 19). However, with lower inherent strength, the survival rate decreases for particularly thin-walled geometries (see 0.2 mm), and the probability of a defect after CAM processing increases as a result.



2.11 Influence of CAM processing on the load capacity

a) Materials and methods

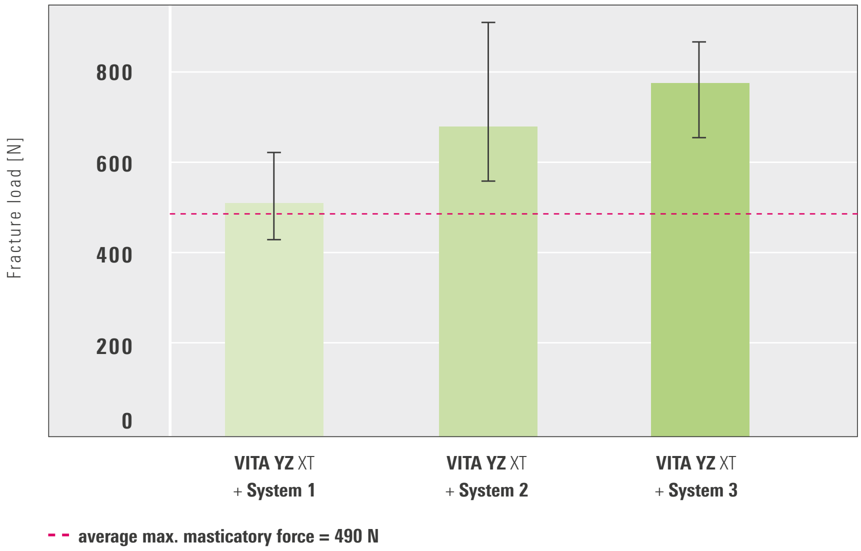
To examine the influence of CAM processing (e.g., by using various milling strategies) on the load capacity of bridges, stylized posterior bridges made of VITA YZ XT were milled using three different CAD/CAM systems and densely sintered, according to the manufacturers' instructions. The thinner "mesial" connector had a radius of 1.7 mm (~ 9.0 mm^2 cross-sectional area), the thicker "distal" a radius of 2.0 mm (~ 12.0 mm^2). The abutment copings featured a uniform wall thickness of 0.5 mm. All bridges were bonded to steel stumps using zinc-phosphate cement. For each CAD/CAM system used, six bridges were loaded to failure using a universal testing machine.

b) Source

Internal study, VITA R&D, (Kolb, 11/2017, [1] see p. 35)

c) Result

Fracture load after CAM fabrication with various systems



d) Conclusion

The result of this test shows that the CAD/CAM system used for the fabrication can have a significant influence on the fracture load of a bridge restoration. For example, both the parameters of the software (turning speed, feed rate, infeed) and the milling tools (type, condition) or the milling machine, can influence the surface quality of the restoration and its load capacity. The respective manufacturers' specifications (material and system manufacturer) must therefore be strictly observed for durable restorations. Recommendations on processing of VITA YZ are available at: www.vita-zahnfabrik.com

2.12 Sintering behavior

2.12.1 Influence of the sintering temperature

a) Materials and methods

The influence of the sintering temperature on the particle size was studied by Piconi [4]. If the temperature is too low, the structure cannot be completely densely sintered. If the temperatures are too high, the material reveals a tendency to grain growth. Such temperature deviations have an optical and mechanical influence on the final result. Insufficiently sintered materials appear to be opaque. Excessively sintered materials appear to be translucent, but generally have reduced mechanical properties.
Samples made of VITA YZ HT and XT were fired at maximum temperatures of 1370 °C, 1450 °C, 1530 °C and 1600 °C for the purpose of direct comparison. The respective temperature was kept for two hours. The structures were then analyzed using a scanning electron microscope (SEM).

b) Source

Internal study, VITA R&D, (Kolb, 10/2017, [1] see p. 35)

c) Result

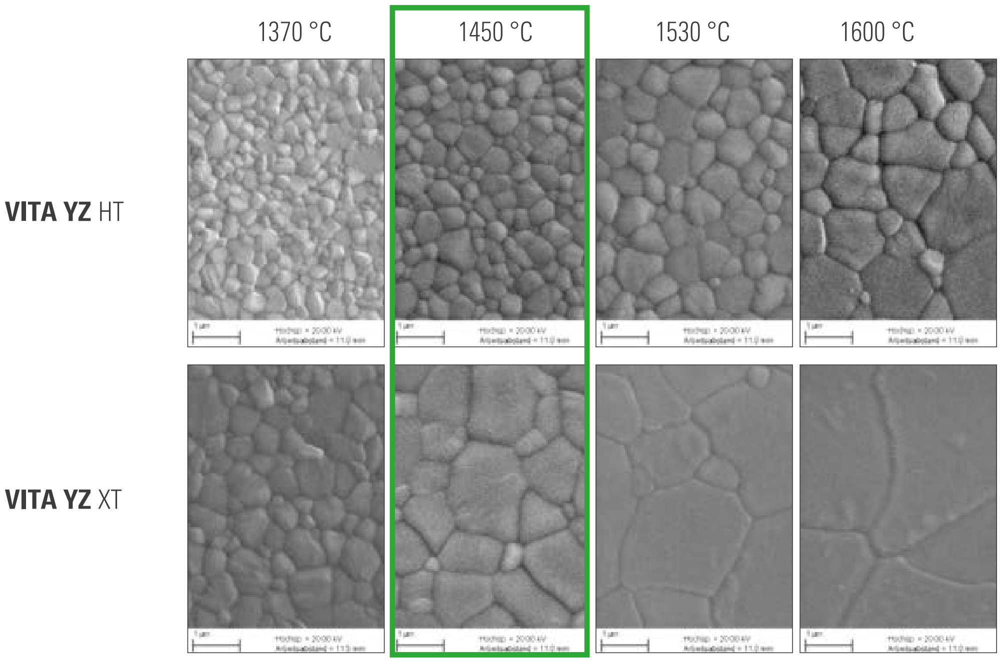


Figure 20: VITA YZ structure at various temperatures, magnification 20,000x

d) Conclusion

The ideal sintering temperature for VITA YZ HT and XT is 1450 °C, according to the manufacturer's recommendations. With this temperature, ideal optical and mechanical properties can be achieved for the named VITA YZ types. If VITA YZ is sintered at a higher temperature (e.g., at 1600 °C), clearly visible grain growth occurs. Although this increases the translucency of the material, it also deteriorates its mechanical properties. In the case of VITA YZ XT, the temperature increase leads to a reduction in strength of approx. 100 MPa. It can also be assumed that the enormous grain growth will have a negative impact on the long-term load capacity as well.

2.12.2 Influence of the high speed sintering method

a) Materials and methods

Restorations made of VITA YZ T and HT can be densely sintered with the VITA ZYRCOMAT 6000 MS within 80 minutes. Appropriate heating and cooling parameters are used to enable this. However, a high speed sintering method, should not affect the structural quality, mechanical properties and the fit. In the following series of tests, material samples made of VITA YZ T were sintered using a conventional and a speed technique. Then the structure was examined in the SEM and analyzed in various other tests.

b) Source

Internal study, VITA R&D, (Gödiker, 10/2011, [1] see p. 35)

c) Result

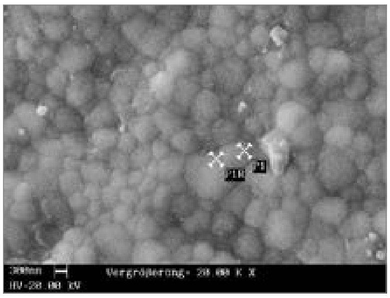


Figure 21a: Structure of **VITA YZ** T, conventionally sintered, magnification 20,000x

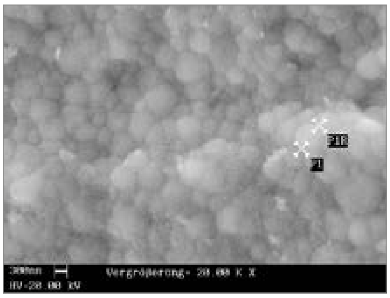


Figure 21b: Structure of **VITA YZ** T, high speed sintered, magnification 20,000x

Characteristic values/data of VITA YZ	**Conventional sintering process**	**High speed sintering process**
Sintered density [g/cm^3]	6.06	6.07
3-point flexural strength [MPa]	1,200	1,278
Crystal structure	tetragonal	tetragonal
Particle size [nm]	500	500
Fit of bridges	Excellent	Excellent

d) Conclusion

Equally good results can be achieved for VITA YZ T and VITA YZ HT with both conventional sintering (17 °C/min, 2 h holding time) and high speed sintering, with regard to structure, mechanical properties and fit. With the more translucent types VITA YZ ST and XT, a significant increase in opacity can be observed after high speed sintering with increasing yttrium content, which is why this sintering process cannot be recommended, particularly for esthetic reasons.

2.13 Manual adjustments/surface treatment

2.13.1 Influence of systems of milling tools for ceramic

a) Materials and methods

Within the scope of the study, the influence of milling tools and sandblasting on the VITA YZ T substructure material were examined. A total of 158 milling tools from 12 different manufacturers were used. A special test system was developed for these tests to ensure a standardized milling process. The material samples were examined under the SEM following surface treatment (milling tools or sandblasting).

b) Source

Einfluss Keramikschleifersysteme, Quintessenz Zahntechnik 2009 ([6], see p. 35)

c) Result

Figures 22 – 24: VITA YZ surfaces polished, adjusted with milling tools and sandblasted (from left to right), magnification 5,000x in each case

d) Conclusion

Different tools and methods cause different degrees of damage to zirconia surfaces (see Figs. 22 - 24). It is recommended to finish the dental object in the presintered stage (always from coarse to fine). Ideally, in the last step, the surfaces should be polished to minimize any defects on the surface. The sandblasting process by comparison, produces a rugged surface. The resulting defects might deteriorate the mechanical properties and cause stress in the bonding area towards the veneering ceramic.

2.13.2 Influence of sandblasting

a) Materials and methods

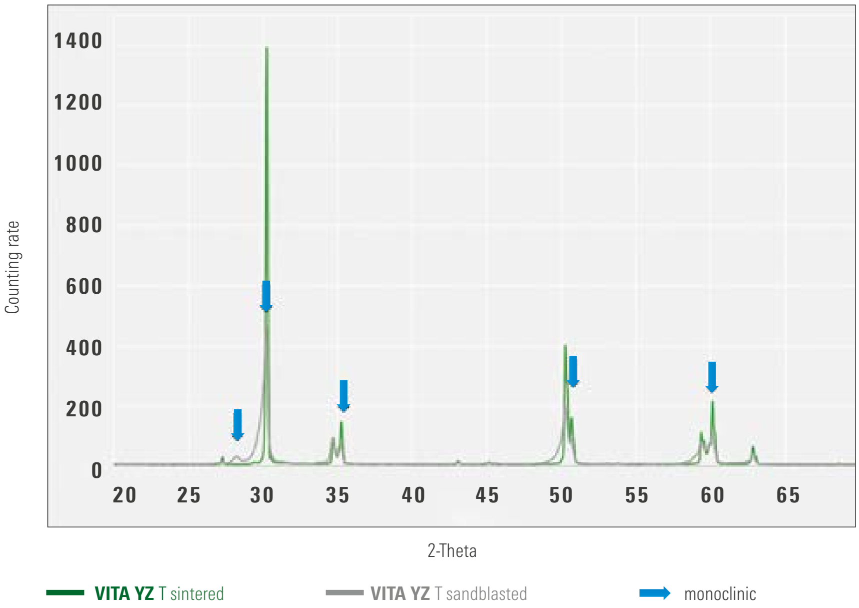
Identical specimens were prepared from VITA YZ T and sintered for this test. The specimens of the first series were not reworked. The surface of the specimens of the second series were treated in the sandblasting unit (50 µm corundum, 2 bar). Then the existing crystal structures were analyzed in the X-ray diffractometer. The peaks of the untreated specimens in the diagram below demonstrate that only tetragonal crystal structures can be detected on the surface. The additional peaks and widening of peaks after sandblasting are indicators of stress in the structure and monoclinic phase contents.

b) Source

Internal study, VITA R&D, (Gödiker, 12/2017 [1] see p. 35)

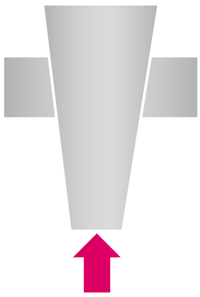
c) Result

Diffractometer measurement of VITA YZ before and after sandblasting



d) Conclusion

The tetragonal zirconia lattice is transformed into a monoclinic crystal structure by sandblasting. Positive material properties, such as fracture toughness and aging resistance attributed to tetragonal modification, can no longer be ensured in this case. In addition, the monoclinic phase features a different CTE, which may result in unfavorable stress in the bonding area in combination with the veneering ceramic. Assumed positive effects of sandblasting, such as increasing the surface roughness, cannot be proven after the CAM process. As a result, it is unlikely that sandblasting will improve the wettability with veneering ceramic. For these reasons, it is recommended not to sandblast the surfaces to be veneered. However, sandblasting of the inner surfaces to improve the adhesive bond is possible and useful.



2.14 Examining the quality of the adhesive bond

a) Materials and methods

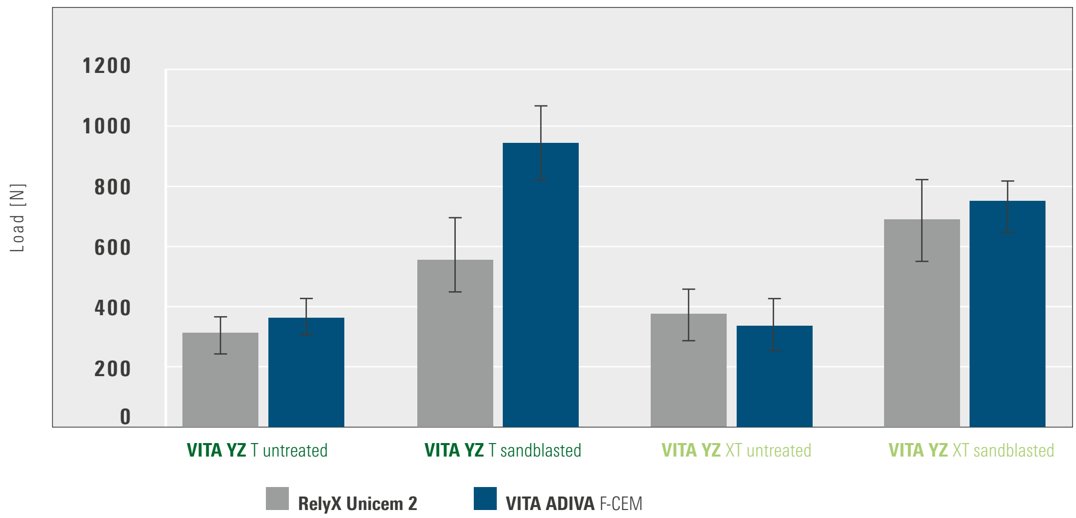
The compressive shear strength of two bonding composites to VITA YZ SOLUTIONS was tested. For this purpose, defined truncated cones made from VITA YZ T and XT were glued into discs of the identical material provided with a bore and then the cones were ejected by means of a universal testing machine or loaded to failure. The bonding composite RelyX™ Unicem 2 (3M ESPE) and VITA ADIVA F-CEM (VITA Zahnfabrik) were used for bonding. Some of the samples were bonded in the untreated condition and the other samples were preconditioned. The untreated samples showed the typical surface of machining (milling process). The other series of samples was sandblasted with 50 µm Al_2O_3 particles at a pressure of 2.0 bar.
A total of 10 specimens of each series were examined.

b) Source

Internal study, VITA R&D, (Gödiker, 10/2017, [1] see p. 35)

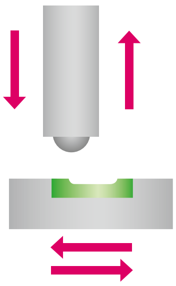
c) Result

Compressive shear strength - bonding composites to VITA YZ types



d) Conclusion

The test results show that there is a significant increase in the compressive shear strength to VITA YZ after preconditioning by sandblasting. Sandblasting of the inner surfaces of the crown at a pressure of 2.0 bar and using 50 µm Al_2O_3 particles is therefore recommended. No significant differences in the determined compressive shear strength to VITA YZ T and VITA YZ XT were found. Significantly higher compressive shear strength values were determined only for the sandblasted VITA YZ T samples in combination with VITA ADIVA F-CEM. Overall, however, there is no significant difference between the two bonding systems with regard to the adhesive bond to VITA YZ.



2.15 Abrasion behavior

Two-body abrasive wear

a) Materials and methods

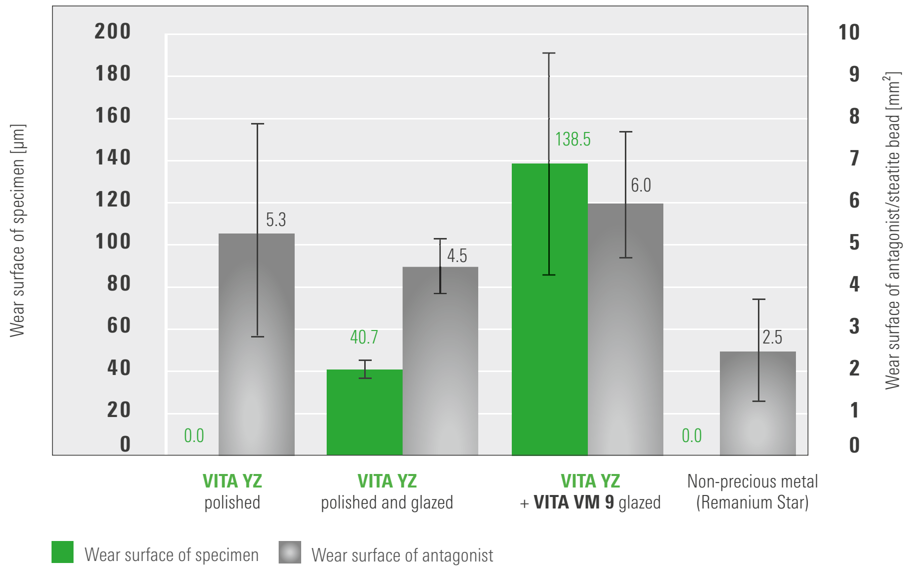
To determine the abrasion level of zirconia compared to a non-precious metal alloy (NPM), a pin-on-block wear test - in the chewing simulator (EGO, Regensburg) - was carried out using the following parameters: steatite beads as the antagonist, 50 N load force, 1.2×10^5 cycles, 1.6 Hz and 600 thermal cycles at 5 - 55 °C.
After completion of a chewing simulation, the substance removal was measured.
Eight specimens per series were examined.

b) Source

University of Regensburg, Report (Rosentritt, 09/2011, [3], see p. 35)

c) Result

Abrasion tests



d) Conclusion

Material removal could not be measured for zirconia samples polished to high gloss (see test results for VITA YZ mentioned above) or for non-precious metal. If a glaze layer is applied to the VITA YZ samples, material removal can be measured again.
The target of applying glaze material is to adjust the enamel-like abrasion behavior of dental zirconia restorations (see glazed VITA YZ samples). New in vivo studies indicate that no increased wear is expected on both the zirconia restoration and the antagonist, if appropriate surface quality is ensured.

Current in vitro studies with zirconia of different chemical compositions show similar results, depending on the surface treatment [11].

2.16 Biocompatibility

VITA YZ is tested and evaluated by independent institutes in accordance with the Standards Series ISO 10993 Biological Evaluation of Medical Devices. All material types of VITA YZ are deemed biocompatible. Based on detailed quality controls for each new batch, such as radioactivity measurements, constant biocompatibility is consistently guaranteed.

3. VITA VM 9 veneering material

3.1 Physical/mechanical properties

VITA VM 9	Unit of measure	Value
Coefficient of thermal expansion (20 - 500°C)	$10^{-6} \cdot K^{-1}$	8.8 – 9.2
Softening point	°C	670
Transformation temperature (TG)	°C	600
Chemical solubility (ISO 6872)	$\mu g/cm^2$	9.9
Average particle size	µm (d_{50})	18
3-point flexural strength (ISO 6872)	MPa	102
Vickers hardness (Transpa Dentine)	HV1	670

Determination according to DIN EN ISO 6872

3.2 Chemical composition

Components	Wt%
SiO_2	60 – 64
Al_2O_3	13 – 15
Na_2O	4 – 6
K_2O	7 – 10
CaO	1 – 2
ZrO_2	0 – 1
B_2O_3	3 – 5

3.3 Coefficient of thermal expansion

a) Materials and methods

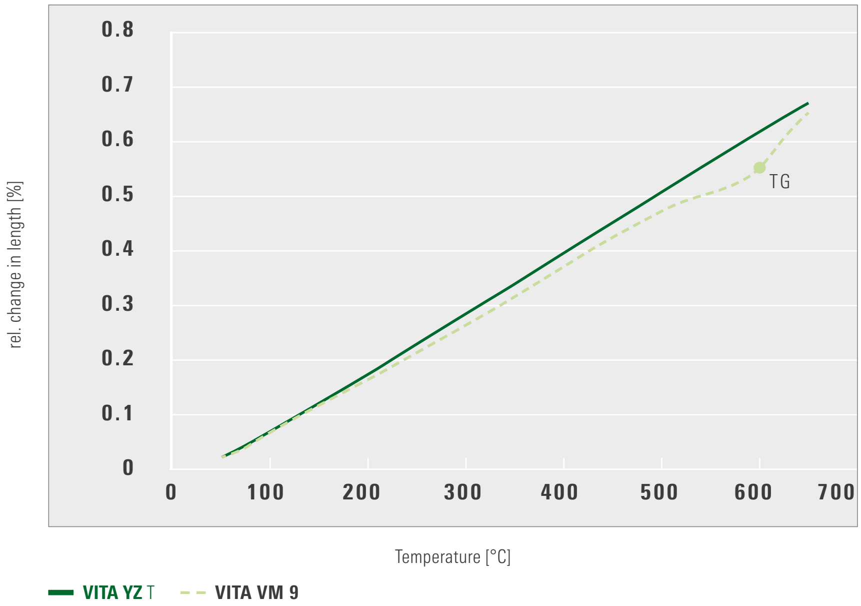
In a direct comparison, specimens made of VITA YZ T and VITA VM 9 were measured in the dilatometer (Netzsch). The specimens were heated up to the softening temperature with a heating rate of 5 °C/min. The coefficient of thermal expansion (CTE) for the respective material is obtained from the measured, relative change in length up to a defined temperature (500 °C).

b) Source

Internal study, VITA R&D, (Gödiker, 10/2009, [1] see p. 35)

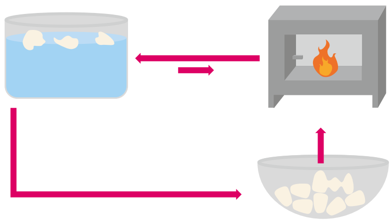
c) Result

Thermal expansion of VITA YZ T and VITA VM 9



d) Conclusion

VITA YZ T has a CTE of approx. $10.5 \cdot 10^{-6} \cdot K^{-1}$. To ensure optimal stress ratios, the CTE of VITA VM 9 veneering material is slightly lower at approx. $9.2 \cdot 10^{-6} \cdot K^{-1}$. This is to ensure that long-term reliable bonding between the veneer and the substructure can be achieved. When using this measurement method, the determined glass transition temperature (TG) of the veneering material is approx. 600 °C.



3.4 Thermal shock resistance

a) Materials and methods

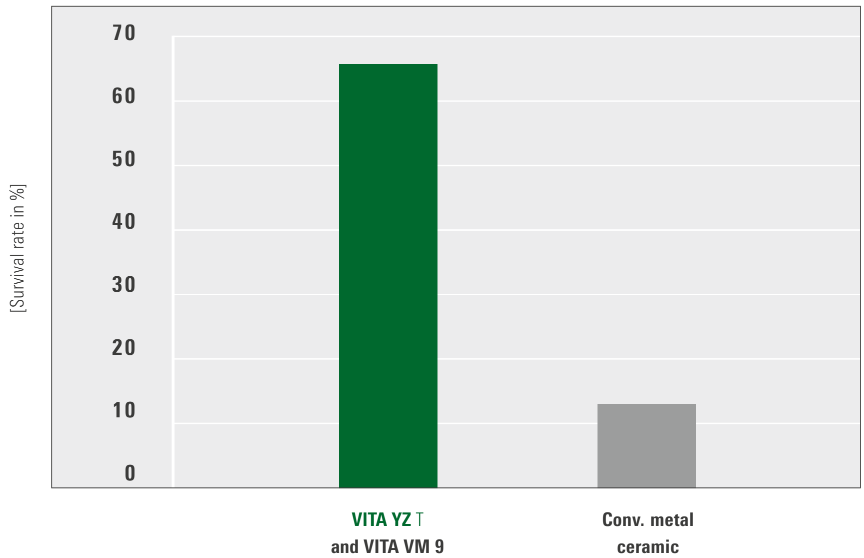
The thermal shock resistance (TSR) test is a proven internal test procedure of VITA used to evaluate the interaction of substructure material and veneering material, or of the residual stress in the overall system.
For this test, six crowns and a three-unit substructure made of VITA YZ T were fabricated according to the manufacturers' working instructions and later, veneered with VITA VM 9. In the next step, the restorations were heated to 105 °C in a furnace and the temperature was maintained for 30 minutes. Finally the restorations were quenched in ice water and checked for crack formation and flaking of the ceramic. Undamaged restorations were subsequently heated to the next temperature level (120 °C) in steps of 15 °C until the maximum temperature of 165 °C was reached.

b) Source

Internal study, VITA R&D, (Gödiker, 10/2009 [1] see p. 35)

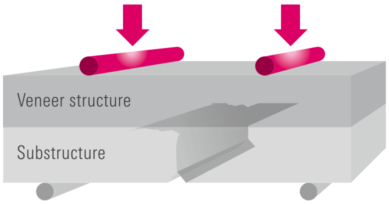
c) Result

Thermal shock resistance



d) Conclusion

The higher the survival rate of the restorations used in this test, the lower the risk of crack formation or flaking of the veneering material based on long-term experience in daily use in practices/laboratories. In combination with VITA VM 9, VITA YZ T demonstrates a clearly higher survival rate than veneered metal ceramic in this test setup. The values determined for VITA YZ in combination with VITA VM 9 were compared with the average results of metal ceramic studies (various VMK generations in combination with various metal alloys) of the past years.



3.5 Bond quality of VITA YZ T and VITA VM 9

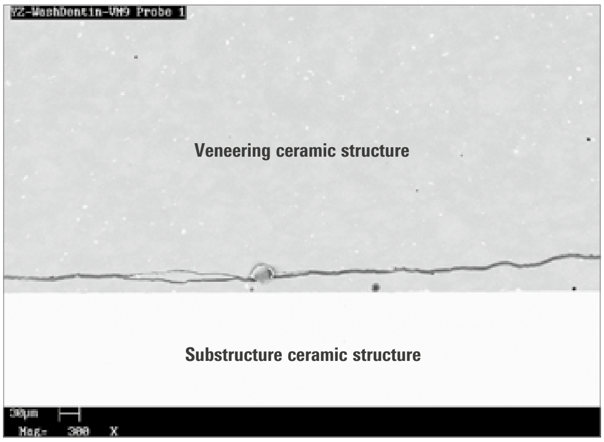
a) Materials and methods

Bond tests are test methods to evaluate the bond quality (i.e., the load capacity of the bond of the substructure material to the veneering material.) The "Schwickerath test" (see ISO 9693), for example, is used as a 3-point bending test for metal ceramic. There is no ISO standard test for all-ceramic systems. In the test setup used in this study, a 4-point bending test was carried out to generate a crack in the bonding area to determine the energy released during crack propagation (see energy release rate). This method (established by Charalambides et al. [7]) is used, for example, by NASA (National Aeronautics and Space Administration) for paint coatings on the outer wall of rockets.

b) Source

Haftverbundmechanismen in dentalen Schichtsystemen (Tholey, 2007, [8] see p. 35)

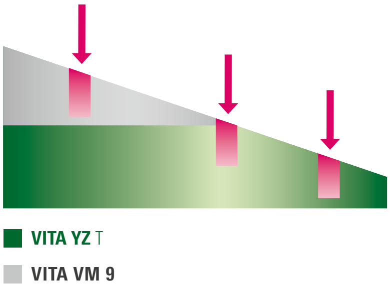
c) Result



Figures 25 : VITA YZ T veneered with **VITA VM 9**, crack path in the veneer, magnification 300x

d) Conclusion

The bond of VITA YZ T to VITA VM 9 is regarded as excellent in the test series, since crack formation did not occur at all in the bonding area, but rather the cracks progressed through the layer of veneering material (see SEM picture; light gray substructure and dark gray veneering structure). Consequently, no measurable (energy) value of the actual bond can be determined.



3.6 Bonding area between VITA YZ T and VITA VM 9

a) Materials and methods

To examine the bonding area between VITA YZ T and VITA VM 9 closely, the VITA YZ T specimens were veneered with VITA VM 9 and subsequently sawed into wedges. Then the specimens were treated with VITA CERAMICS ETCH (hydrofluoric acid gel, 5 %) for 20 seconds and the surfaces were examined under a scanning electron microscope (SEM).

b) Source

SEM observations of porcelain YTZP interface (Tholey, 2009, [10] see p. 35)

c) Result

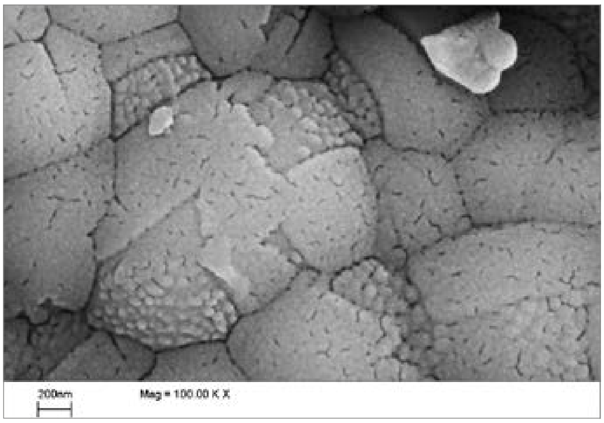


Figure 26: VITA YZ T structure after veneering, magnification 100,000x

d) Conclusion

The veneering process (application of ceramic and firing) changes the crystalline structure of the VITA YZ T substructure in the bonding area so that a new crystal structure is formed. The SEM picture shows this new surface (magnification 100,000x). The results indicate that this new structure bonds perfectly to the VITA VM 9 veneering material structure and a high-strength bond between substructure and veneer is achieved.

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   VITA Zahnfabrik H. Rauter GmbH & Co. KG
   Ressort Forschung und Entwicklung
   Spitalgasse 3
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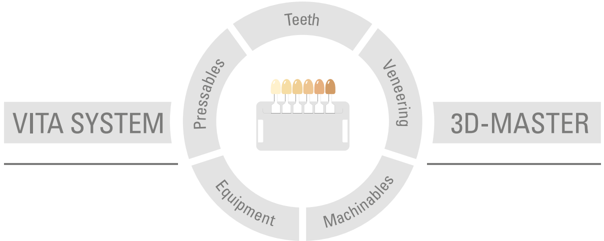

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