FRIADENT® CERCON® Implant Abutments

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Zirconium Oxide Implant Abutments: A new era in tensile strength, light dynamics and biocompatibility

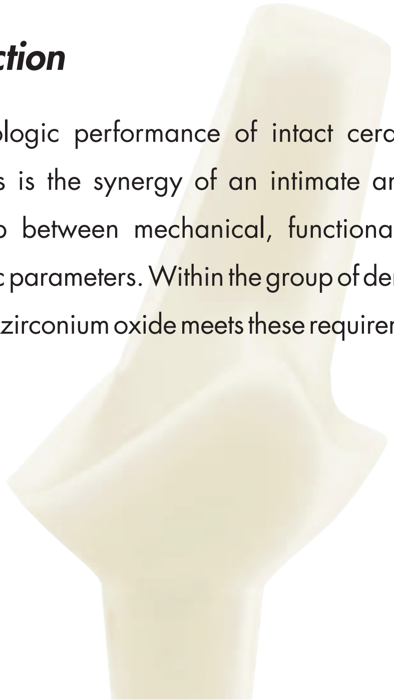
Summary

Today, custom implant abutments fabricated from titanium are considered a standard treatment option for implant-supported restorations. Improved materials, coupled with the increased demand by clinicians and patients for highly esthetic results, have contributed significantly to the development of a new generation of ceramic abutments. Full-ceramic FRIADENT® CERCON® abuments, fabricated from yttrium stabilized – zirconium oxide (Y-TZP), have been noted for their tooth-analog color, high loading strength, tissue tolerability and intra-sulcular design enhancement. The phenomenon of transformation toughening of zirconium oxide results in extremely high component stability, extraordinary bending and tensile strength, fracture and chemical resistance. The above noted properties allow zirconium oxide to ”self-repair” micro-crack initiation by stopping crack propagation.
To be a viable treatment choice ceramic restorations must cosmetically and functionally equal that of the natural dentition. The esthetic characterization of CERCON® implant abutments and its ceramic restorations implies the phenomenon of reflection and transmission of light.

FRIADENT® CERCON® abutments offer:

- Maximum mechanical stability
- Outstanding biocompatibility
- Accelerated and dense peri-implant soft tissue attachment
- Reduced plaque adhesion
- Light dynamic qualities comparable to natural teeth

Introduction



The physiologic performance of intact ceramic implant restorations is the synergy of an intimate and balanced relationship between mechanical, functional, biological and esthetic parameters. Within the group of dental ceramics CERCON® zirconium oxide meets these requirements ideally.

The outstanding biochemical, physical and light dynamic properties make CERCON® the material of choice for the production of prefabricated implant abutments. This scientific bulletin will detail its unique material and structure qualities.

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Dental Ceramic Classification

Ceramics are solid, mainly crystalline bodies emerging from high temperature burning (sintering). Based on their chemical composition, ceramics can be divided into the following groups:

Silicate Ceramics

Silicate ceramics, also known as glass ceramics, represent the oldest group of dental ceramics. The essential components of ceramics are their silicate carriers: clay, kaoline, feldspath and steatite. Aside the crystalline phases, a high percentage of glass phases usually develops when sintering. The availability of raw materials has made silicate ceramics less expensive than oxide ceramics. Originally, dental ceramics were predominantly silicates, and are still in use for veneer ceramics.

Oxide Ceramics

Oxide ceramics consist of pure metal oxides or a mixture of metal oxides. Oxide ceramics have no glass phases. They display a higher fracture toughness and tensile strength compared to silicate ceramics. Oxide ceramics stand out against increased wear, corrosion and temperature resistance. Dental restorations are increasingly fabricated from oxide ceramics.

Basic Characteristics of Oxide Ceramics

To be considered a true alternative, the mechanical and biological qualities of ceramic implant abutments must be equal to or better than those of widely used titanium abutments. These requirements can only be met by high-performance and biocompatible oxide ceramics.

Oxide ceramics are equal to metals from a mechanical standpoint, but biologically stronger. However, one exception is the high brittleness of ceramics, and the potential to crack. Until now, the use of full ceramic implant abutments for implant restoration has been limited due to this feature.

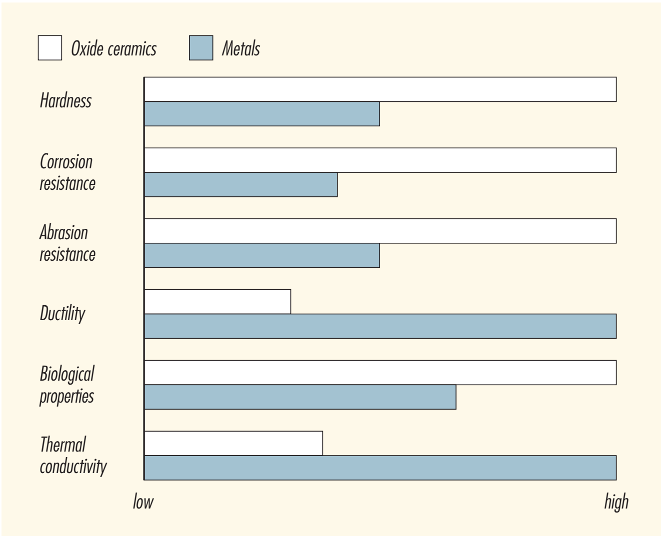


Table 2: Characteristics of oxide ceramics versus metals

	Silicate Ceramics	**Oxide Ceramics**
Type	Porcelain, mullit, veneer ceramics	Zirconium oxide, Aluminium oxide
Strength	Low	High
Hardness	Similar to enamel	Higher than enamel
Density	Low	Medium to high
Glass phase	High	None
Color	Light	White/neutral
Translucence	High	Medium

Table 1: Classification of dental ceramics

Zirconium Oxide

The name zirconium oxide, implemented in our habitual language, represents a simple form of the chemically correct name zirconium dioxide. The German chemist M. H. Klaproth discovered zirconium dioxide 1789 by heating zirconium rocks. The name zircon is derived from the Persian word "zargon" which means "gold color." The main material used for the extraction of zirconium dioxide, is the mineral zircon ($ZrSiO_4$). Zircon is found in volcanic rocks (granites, syenites and gneisses). The majority of zircon is mined in Australia, the United States, India and South Africa. Zirconium oxide is gained by melting coke with lime and zircon. A highly purified raw product must be used to develop high performance ceramics. For this reason, a special synthesis method was developed to obtain highly pure zirconium oxide.

Crystal Condition of Zirconium Oxide

Zirconium oxide has "self-repairing" properties, preventing crack propagation. Polymorphism is the reason for this unique ceramic phenomenon: Under high mechanical tension, tetragonal zirconium crystals transform into monoclinic crystals. This leads to a volume expansion of three to five per cent, permitting pseudo-elastic reactions. However, fine micro-cracks can develop in the surrounding matrix. Micro crack propagation resulting from high material tension is inhibited and stopped by transformation toughening. This leads to extremely high bending and tensile strength.[19]

Pure zirconium oxide is existent in three crystal conditions, even if the chemical composition is identical. This material characteristic is called polymorphism. At temperatures exceeding 2300° C, zirconium oxide is found as cubic crystal phase and changes into a tetragonal crystal phase when it cools down. Zirconium oxide transforms into a monoclinic phase at temperatures below 1200° C. The transformation from tetragonal to monoclinic is completed with a volume increase of approximately three to five percent. These volume changes would lead to very high inner structure tensions and component fracture. For this reason additives are necessary to completely or partially stabilize the high temperature phases (cubic or tetragonal) down to room temperature. This reduces compression stress within the structure to a controlled level and prevents component destruction while cooling-off.[23]

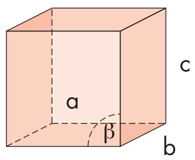
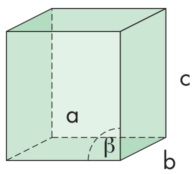
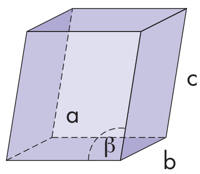
Crystal Phase	Crystal Grid Data		Density (g/cm^3)
Cubic >2300 °C	a = 5.124 Å b = 5.124 Å c = 5.124 Å β = 90 °		6.090
Tetragonal <2300 °C > 1200 °C	a = 5.124 Å b = 5.124 Å c = 5.177 Å β = 90 °		6.100
Monoclinic <1200 °C	a = 5.124 Å b = 5.177 Å c = 5.304 Å β = 98.4 °		5.830

Table 3: Crystal phases of zirconium oxide[21]

FRIADENT® CERCON®

In medicine and dentistry, zirconium oxide is used primarily because of its chemical stability, high mechanical loading, outstanding biocompatibility[2] and unique esthetic qualities. By adding oxides (e. g. magnesium oxide, calcium oxide or yttrium oxide), new zirconium oxide ceramics were developed for different applications. The most significant dental application is the polycrystalline stabilization of zirconium dioxide with yttrium oxide (Y-TZP). In comparison to other stabilizing oxides, this is the finest-grained most, densely packed and mechanically highest-grade structure. Transformation toughening and the resulting pseudo-elastic

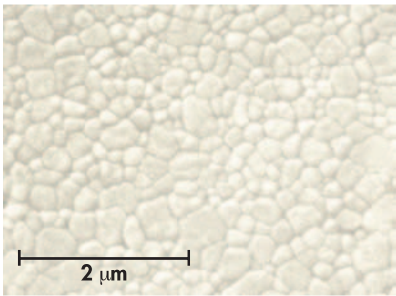
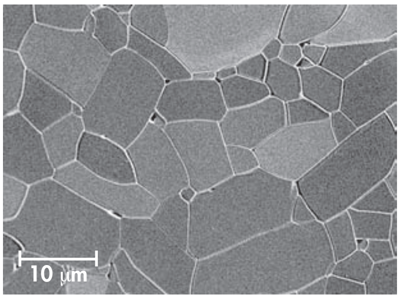
	 **CERCON®: (Y-TZP) zirconium oxide[22]**	 **Aluminium oxide[22]**
Optical characteristics		
Color	White to dentin color	Ivory
Refractive index	2.15 – 2.18	1.64
Structure characteristics		
Density	6.05 g/cm^3	3.9 g/cm^3
Open porosity	0 %	0 %
Middle crystallite	0.2 – 0,5 µm	5 – 10 µm
Cubic crystals	< 20 %	–
Tetragonal crystals	Predominantly	–
Monoclinic crystals	2 – 3 %	–
Chemical composition		
	> 92 % ZrO_2	99.7 % Al_2O_3
	5 % Y_2O_3	0.3 % miscellaneous
	< 3 % remaining constituents	
Mechanical characteristics		
Vickers hardness	1300	1800
Compression strength	2200 MPa	2800 MPa
Fracture toughness	900 MPa	340 MPa
Bending strength (K_{IC})	6 MPa √m	3 MPa √m
Coefficient of elasticity	210 GPa	380 GPa
Weibullmodul (m)	20	10
Thermal characteristics		
Coefficient of expansion	$10.5 \times 10^{-6}\ K^{-1}$	$8.5 \times 10^{-6}\ K^{-1}$

Table 4: Characteristics of zirconium oxide (FRIADENT® CERCON®) versus aluminium oxide

reaction is at its maximum if five volume percent yttrium oxide is added. These fundamental properties are made use of for the FRIADENT® CERCON® abutment and optimized in a specific manufacturing process.

Zirconium oxide surpasses the high loading characteristics of aluminium oxide. This allows an anatomical preparation of the implant abutment without impairing its function. A reduction in stability can be prevented by prepping FRIADENT® CERCON® abutments with water coolant[18].
CERCON® is two and a half times more resistant to breakage and tear compared to aluminium oxide. This means that approx. double force has to be exerted on the component before it fractures.

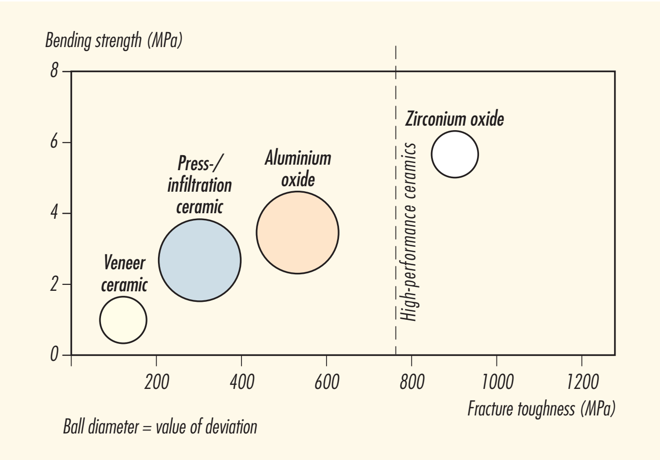


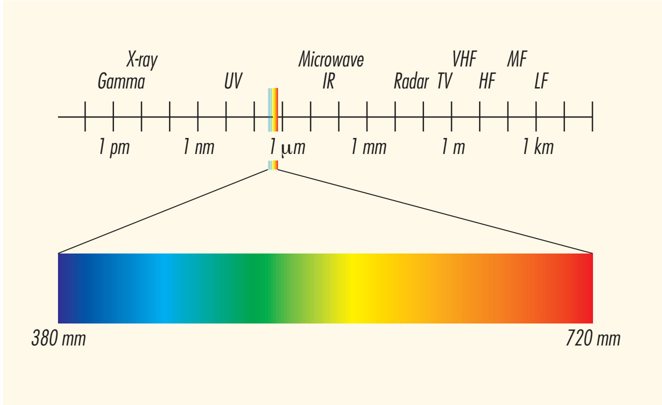
Table 5: Ceramics in dentistry – material characteristics

Light and Color Perception

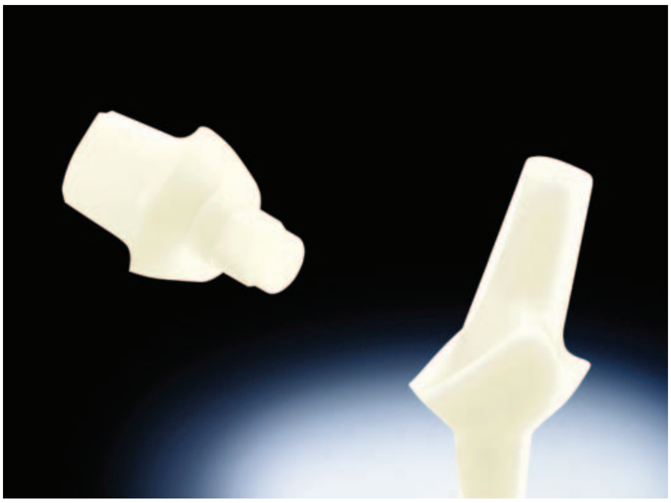
Tooth design, long-term success of a restoration and color conformity of natural and replaced teeth are the prerequisites of a highly esthetic restoration. To achieve this, both the dentist and the dental technician must take into account the esthetic aspect of the natural teeth and the material used.

What is Light?

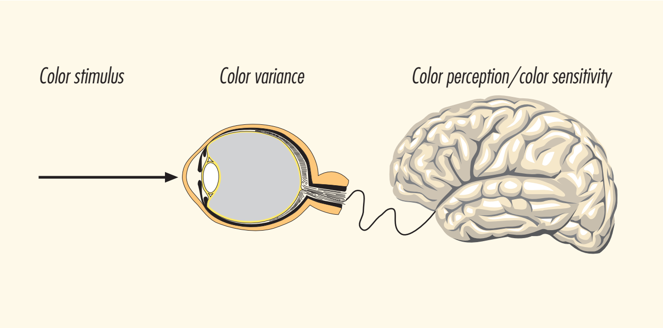
Light is an electromagnetic radiation that can be perceived by the unaided human eye. It can therefore be described like all other types of radiation, by its wavelength.



The different effects that electromagnetic waves have are dependent on their wavelength.
Visually, perceivable light is only a small portion of the electromagnetic wave spectrum. It goes from the short-waved gamma ray (located on the left side of the spectrum) to the ultraviolet and infrared wave, to the long waved radio and broadcast wave located on the right side of the spectrum. The light visible to man is in the area of 380 to 720 nm. Different wavelengths set the color impression with this spectrum. For example, the blue appears at about 400 nm, the green at about 550 nm and the red at about 700 nm. The light seems colorless when the complete light spectrum is reflected back evenly. The light appears colored, when the various wave parts are reflected back at different intensities.



FRIADENT® CERCON® abutments for FRIALIT®/XiVE® and ANKYLOS®



Color Perception

In general, color perception or color sensitivity, originates in the human brain. There are three important stages in this process.

Color Stimulus

Color stimulus is produced if the retina generates a color variance from a light source.

Color Variance

Stimulating the light receptors in the retina, results in visual actions that are transmitted to the brain via the optic nerve.

Color Perception/Color Sensitivity

The third step takes place in the brain. The visual actions are received at the vision center via the optic nerves, where they trigger a color perception.

CERCON® Light Dynamics

The ideal synergy of mechanical, functional, biological and esthetic features contributes significantly to the esthetic result of a ceramic implant restoration. In order to represent a truly alternative treatment option, ceramic restorations must have the same cosmetic and functional characteristics as the natural dentition. Teeth optimally combine hardness, strength, durability, and light dynamics.[20]

Opalescence is an optical characteristic of ceramics and refers to the ability to transfer a specific range of light (red-orange shades) as well as to reflect the other wavelengths (blue-violet shades).

- Perception of a yellowish shade: long-wave transmission of light (red-orange)
- Perception of a bluish shade: short-wave bending of light (blue components)

Translucence is the stage between the appearance of complete opacity (such as ivory) and complete transparency (such as glass).

Conventional titanium abutments can produce a bluish metallic shimmer at the restoration margin especially in cases of thin soft tissue. This results in a significant loss of esthetic quality and may contribute to an unsatisfactory treatment outcome, particularly for patients with a high smile line.

With the introduction of FRIADENT® CERCON® ceramic abutments new horizons open up in esthetic implant dentistry.

Customized FRIADENT® CERCON® implant abutment in region 21; screw access was sealed with temporary cement.

Full-ceramic crown in situ

Clinical case: Dr. H.-C. Lauer, Frankfurt/Germany

Medical and Dental Characteristics

Biocompatibility

The use of zirconium oxide (yttrium-oxide-stabilized zirconium oxide) has been successfully proven since 1969 in implantology. It is increasingly used in the field of dental medicine. The degradation behavior of zirconium oxide has been tested under physiological conditions since its introduction to medical use.[2,3] Fatigue and loading tests[5] confirm its suitability even after 50 years of clinical use. Numerous studies[1-3] document the biological safety of zirconium. No toxic effects occur at the interface of zirconium oxide with bone or soft tissue. Tests of the mutagenic effects (chromosome aberration test) and carcinogenic effects (Ames test) yield the same positive results. [2]

Influence of Abutment Material on Bacterial Adhesion and Plaque Reduction

An intact implant restoration requires the effective maintenance of the peri-implant margins, including low plaque adhesion to the implant abutment.[6] Inadequate soft tissue attachment may lead to bacterial penetration, resulting in peri-implantitis and progressive loss of hard and soft tissues.[4]

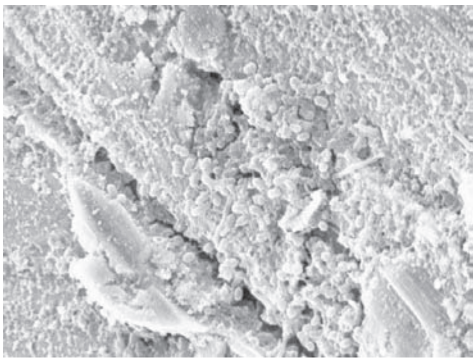
An implant abutment material must therefore meet the following requirements:

- Reduced plaque adhesion
- Dense attachment of gingiva
- Optimum plaque removal

Reduced Plaque Adhesion with CERCON®

Recent studies by Rimondini et al.[17] and Scarano et al.[16] confirm a 40% reduction in bacterial adhesion on CERCON® compared to titanium with comparable roughness. Consequently, CERCON® actively contributes to peri-implant tissue protection.The degree of adhesion between bacteria and abutment depends on the abutment's and bacteria's free surface energy, the roughness of the surface, and the saliva's[14] ionic conductivity. Most infections in the oral cavity are due to the initial adhesion of bacterial colonization. It starts from surface irregularities, such as grooves or abrasive defects, and extends gradually over the entire abutment. In the sub-peri-implant region bacteria are inaccessible to mechanical removal. This allows bacteria to attach strongly to the abutment.[6] The adhesion of bacteria directly correlates to the roughness and the number of surface defects.[8-15] Abutments with low roughness values show a significant reduction in plaque adhesion and plaque growth.[10]

Poortinga et al.[7] demonstrated the significant influence of energy on bacterial adhesion, besides surface roughness. Bacteria absorbing and passing electrons from the fluid substrate adhere in stronger and greater numbers compared to bacteria only receiving electrons. These results prove that the electron transfer between bacteria and their substrate also influences the adhesion and thus plaque formation.



Bacteria adhesion to titanium (cocci layer and filamentous microorganism)

Reduced bacteria adhesion to CERCON®

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22. DeguDent GmbH Hanau

23. Brevier Technische Keramik Verband der Keramischen Industrie e.V.

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