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ceramic implants

international magazine of ceramic implant technology

1st EDITION

research
From titanium to zirconia implants

industry
The DWOS Synergy™ workflow in implantology

technology
Shifting of dental implants through ISO standards

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Dr Michael Gahlert

Munich/Basel
ITI Fellow
Focus on implantology and periodontology

Ceramic implants—game changer in dental implantology

Dear colleagues,

A specialist magazine exclusively concentrating on ceramic implants is a highly welcomed medium of information for all dentists working in the field of implantology. Ceramic implants have been the focus of the implantological community for a long time now and have reached full clinical approval by undergoing the same developmental stages as did titanium implants before.

From 2018 on, this brand new supplement on ceramic implants will be published twice a year presenting its subject matter as a highly complex and mani-faceted topic. By doing so, it offers practitioners a unique opportunity to exchange information based on the latest clinical and scientific findings. Against this backdrop, the fascination emanated by the "White Gold" will certainly not come up short. Being a long-term user myself I can confirm that ceramic implants do indeed polarize, and yet they also bring great pleasure to dentists and patients alike, thanks to their excellent clinical results and aesthetics.

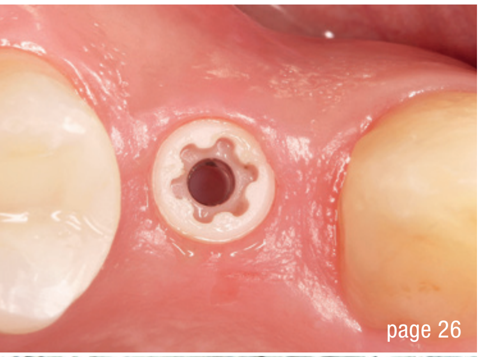
It will be very exciting to see how this topic will officially and academically be approached by the big scientific associations in the future. After an initial phase of extreme reluctance, more and more initiatives are brought forward to create scientific data around the progressive development of ceramic implants and to communicate and present those results at scientific congresses. It's merely a matter of time before the first consensus recommendation based on evidence-driven data will be formulated for practitioners. However, in addition to those affirmative developments, inconsistent quality standards of systems currently available on the market are a significant problem: The production of micro-rough zirconia surfaces as well as ceramic implants is a rather complex venture, putting high demands on the expertise and know-how of industry partners.

Ceramic implants are the last link in the chain of zirconium dioxide, a material that has so far positively influenced conservative and prosthodontic dentistry by making it largely metal-free. As a biological and metal-free alternative to titanium is now also available for the field of oral surgery, various groups of patients can henceforth be reached that previously rejected dental implants due to the ever-present titanium.

If one believes the recent IDS 2017 market analyses, ceramic implants are broadly considered as implantology's "game changer". They will most likely take centre stage in scientific discussions at future congresses, gain further global popularity as a research topic in academic circles and increase their present market penetration of currently 0.2 per cent in 2016 to 2 per cent in 2020, and even 8 per cent in 2025.

With this in mind, I wish all of those responsible for this present edition every success in implementing and establishing this topic, and I am convinced that this initiative will be successful in its contribution to further reduce communication deficits about ceramic implants.

Sincerely,
Dr Michael Gahlert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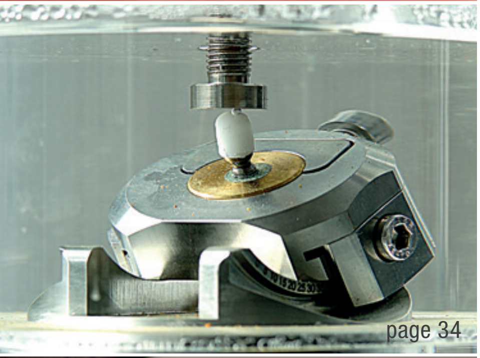
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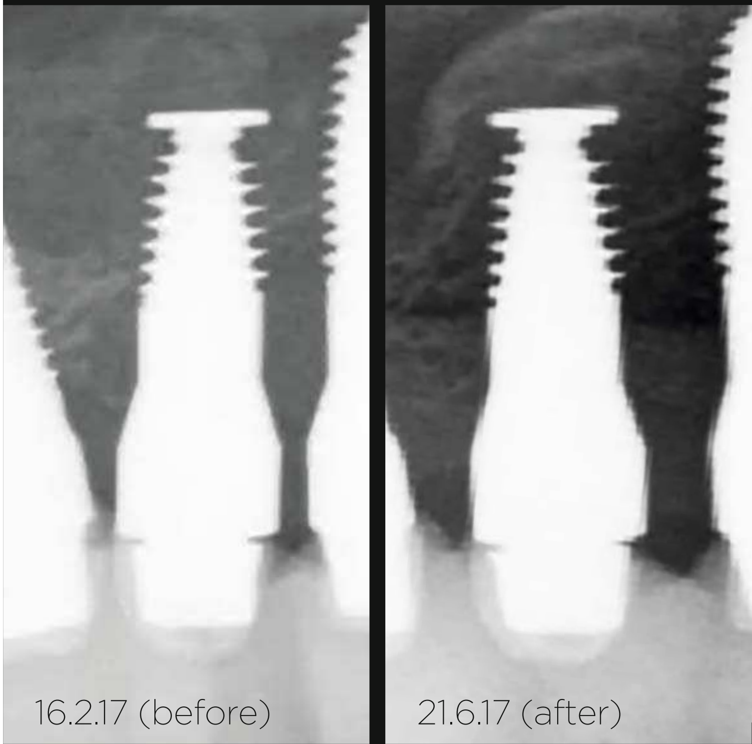
Ceramic is easier. But different.



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From titanium to zirconia implants

Dr Sofia Karapataki, Greece

Zirconium is a metal with the atomic number 40. Zirconium dioxide (ZrO_2) or Zirconia is a ceramic material without any metal properties. It is electrochemically inert causing no galvanising or electro current disturbance effects at an inter- and intracellular level. It is the most bioinert and biocompatible material currently available in the market, with no detected allergies or intolerances. The material exhibits lower surface free energy that leads to hydrophilic reduced plaque (biofilm) accumulation, so, less inflammation is expected leading to superior soft tissue health.

Zirconia fulfils highly desirable aesthetic results: healthy, pink and beautiful tissue can be created around an implant, with no tissue translucency. Its high aesthetics resembles natural tooth. Unlike titanium, it may stimulate bone growth in the long-term with ultimate osseointegration for both bone and gum. In addition to the white colour, a low modulus of elasticity and thermal conductivity have made zirconia implants a very attractive alternative to titanium in implant dentistry.[1–4]

With its interesting microstructural properties, zirconia is the material of choice for the "new generation" of implants. Hashim et al. (2016) made a systematic review and evaluated the clinical success and survival rates of zirconia ceramic implants after at least one year of functioning.[5] They concluded that in spite of the unavailability of sufficient long-term evidence to justify using zirconia oral implants, zirconia ceramics could potentially be the alternative to titanium for a non-metallic implant solution. This is also shown in the review made by Cionca et al. (2017), that through *in vitro* and *in vivo* studies, zirconia has managed to earn its place as a valuable alternative to titanium.[6]

Mechanical and physical properties

Zirconia though, is a totally different material than titanium. The thorough knowledge of implantology using titanium is not so easy to be transferred to zirconia, simply due to different physical and mechanical properties of the materials. Knowledge of the potentials of the material is the key of success and the only chance to minimise failures. Zirconia (ZrO_2) is a highly biocompatible material, but it needs to osseointegrate and withstand masticatory force without fracturing. A good product needs to be fabricated that would fulfil all the necessary requirements in order to be successfully implanted.

ZrO_2 is stable at room temperature at a monoclinic phase. Doped by yttrium oxide, when it cools down from 1,173 °C, a tetragonal phase stable at room temperature (metastable) is produced. This is the material used for implants. It is of major importance for the implant to be kept in the tetragonal phase to keep its mechanical and physical properties over time. It is well established that the stability of this phase is affected by several compositional parameters, including grain-size, processing conditions and quality control.

Purity or rather contamination with impurities, density and porosity of the final product as well as pre-sintering and sintering process and time are also some of these parameters. Environment or conditions (loading-temperature-humidity) in which the product will be used (it makes a difference whether zirconia is produced for a hip prosthesis or for dental implants) are to be kept in mind. And last but not least, handling of the material is of outmost importance.[7,8] Lughi et al. (2010) suggested engineering guidelines for the use of zirconia as dental material.[9]

Producing zirconia implants

There are two ways of producing zirconia implants: through moulding and through milling of prefabricated rods. The first method produces implants with specific shape and specific low roughness on their surface. Milling of the rods on the other hand, is done either on partially or fully sintered zirconia. The fabrication of an implant through soft machining of partially sintered ZrO_2

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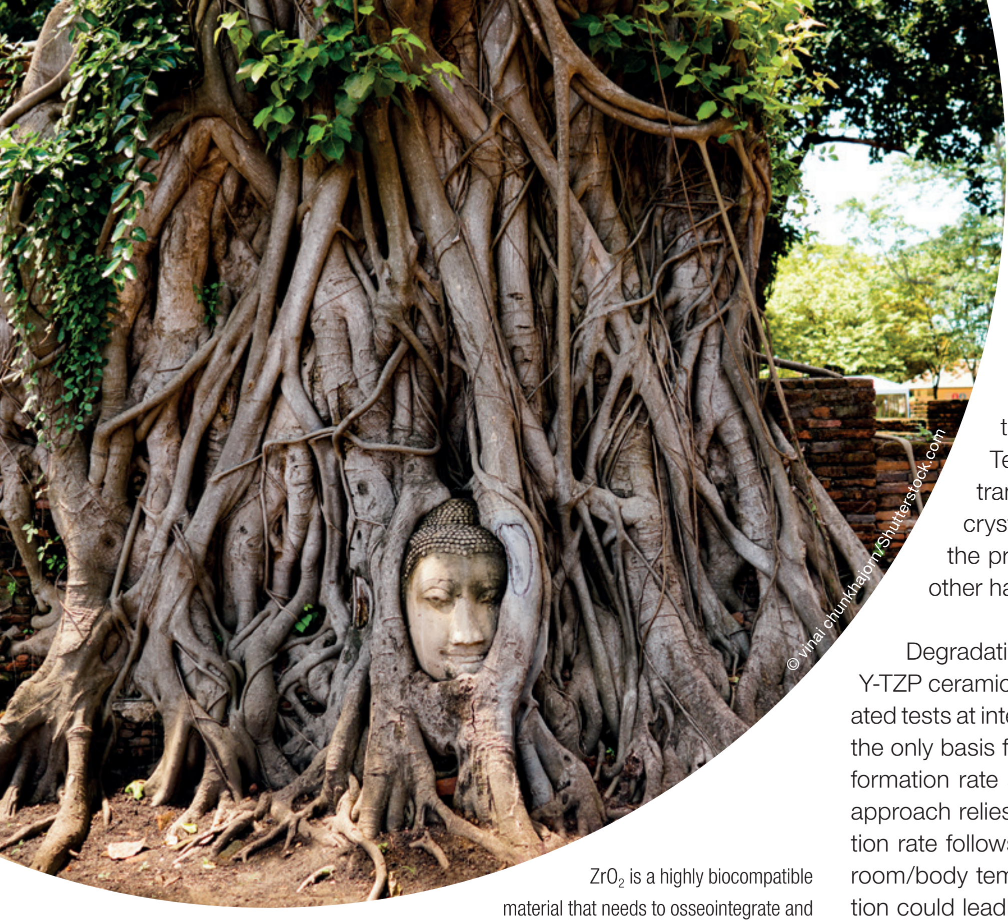

ZrO_2 is a highly biocompatible material that needs to osseointegrate and withstand masticatory force without fracturing.

provides the advantage of easier milling than the fully sintered ZrO_2. It requires less milling time and causes less wear of the cutting tools.[10, 11]

In hard machining of fully sintered ZrO_2, no sintering shrinkage is expected and there is no need for a sintering oven. However, microcracks maybe introduced.[10] Since diamond zirconia is known as the toughest material existing, only diamond tools are used for cutting sintered zirconia. The grinding of the fully sintered ZrO_2 causes a certain degree of transformation (from tetragonal to monoclinic phase) in the surface of this material.[12] When comparing the final surface of the soft machined ZrO_2 to the hard machined ZrO_2, it is expected that the former will have a more consistent final state, given that it is left intact (no sandblasting or grinding) after the final sintering.[13]

The implants that are produced need to be roughened in order to be osseointegrated. Question arises what is the optimal roughness and surface that is produced after it, in order for zirconia implants to be successfully osseointegrated in any of the aforementioned production methods. It seems that the rougher the body, the better the odds for osseointegration.[14] This though should not be the goal for the head of the implant in case that it is visible in the mouth—it could favour bacteria colonisation. The best method to achieve the optimal roughness as well as the moment that this should be realised with respect to the material's properties is also not established. Finally, depending on the procedure, the roughened surface needs to be totally clean, free of all foreign bodies.

Ageing of titanium vs zirconia

Ageing of titanium implants is a not widely known phenomenon and starts four weeks after their production which decreases dramatically the osseointegration potential.[15–18] Ageing of zirconia (Low Temperature Degradation LTD, i.e. the slow transformation of the metastable tetragonal crystals to the stable monoclinic structure in the presence of water or water vapour) on the other hand is quite well investigated.

Degradation rates at room or body temperature of Y-TZP ceramics are currently not available, and accelerated tests at intermediate temperature (100 to 300 °C) are the only basis for extrapolating an estimate of the transformation rate and, hence, of the product lifetime. This approach relies on the assumption that the transformation rate follows the same Arrhenius-like trend down to room/body temperature. Unfortunately, such extrapolation could lead to a significant error in estimating room/body temperature lifetimes.[9] Still this is the method that is used in researches. Monzavi M. et al. (2017) examined 36 zirconia implants of four different brands and found that the effect of ageing was minimal in all systems.[19] They suggested though that *in vivo* studies are needed to investigate the effect of mastication force on the extent of LTD and the influence of surface changes such as delamination of the grains on surrounding hard- and soft-tissue.

Still a certain degree of transformation from tetragonal to monoclinic phase can actually improve the mechanical properties of Y-TZP. Under stress, i.e. at the tip of a crack, the Y-TZP undergoes a phase transformation from tetragonal to monoclinic phase. This phase transformation results in a 3 to 4 per cent volumetric expansion inducing a compressive stress in the area of the crack and theoretically prevents crack propagation.[1] An implant which exhibits phase transformation in case of microcracks and high forces is desirable. Still it is not sure whether the already existing microcracks that are produced (for instance, during handling) during mastication or parafunctional activities, don't propagate, leading to a possible fracture.

One- vs two-piece zirconia implants

Zirconia appears in two varieties, one- and two-piece implants. One-piece implants offer the absence of a microgap between implant and abutment which seems to be of benefit. The surgical placement of the implant, though may not always meet the prosthodontic requirements and angled abutments in order to correct misalignment, is not common. Secondary corrections of the shape by grinding must be avoided, as this severely affects the fracture strength of zirconia.[20] Protection by use of splints is also required, though not always possible. So, two-piece implants were designed. Designing a zirconia implant should be based on material properties and should simplify surgical and prosthetic steps for the doctor. Size limitations should be considered, in order to produce an implant that is not prone to fractures. A clinical study by Gahlert et al. (2012) showed a marked tendency of one-piece implants with a narrow diameter (3.25 mm) to fracture, with a percentage that reached 92 per cent of the fractured implants.[21] Threads and shape of implants should be designed according to the needs, always with respect to material.

Size and shape precautions should also be applied to the implant head in order to avoid the risk of creating microcracks during implantation. The implant head if positioned at the gingival level or even higher, could eliminate the need for a second surgery, as well as to bypass the bacterial growth in the gap between implant and abutment. The decision of choosing between a one- and a two-piece implant could be influenced by the design of the implant, the available space to be installed, and the prosthetic rehabilitation that follows.

Implant-abutment connection

Connection of the abutment with the implant is performed by three ways: either by screwing, cementing, or even as a combination of both. When screwing, the material of the abutment and the connecting screw is of crucial importance for the implant to be intact. As a consequence from titanium knowledge, screwing an abutment made from the same material as the implant was a "natural" step. Screwing though zirconia inside a zirconia, unlike titanium, cannot result in a tight connection, because of the stiffness of the material. This loosening could possibly result in fracture and if this happens to the implant, it could jeopardise everything. In case of abutment failure, one should estimate the convenience of removing the abutment screw.

A recent *in vitro* study by Preis et al. (2016) comes to strengthen the aforementioned performance of different implant-abutment connections, was investigated in six groups of different two-piece zirconia implant systems.[22] In group 1, the abutments were cemented to an alumina-toughened zirconia implant. In group 2, the abutments were screwed with a carbon fibre reinforced polymer screw on an alumina-toughened zirconia implant. In the remaining four groups, the abutments were screwed with titanium screws on tetragonal zirconia polycrystalline implants. A standard screw-retained titanium implant served as the control. The bonded zirconia system and the titanium reference survived without any failures. Screw-retained zirconia systems showed fractures of abutments and/or implants,