Website address:

https://www.gesundheitsindustrie-bw.de/en/article/dossier/implants-of-the-future-bioactive-corrosion-resistant-and-antibacterial

Implants of the future: bioactive, corrosion-resistant and antibacterial

People's life expectancy is increasing due to constantly improving medical treatment. One result of this is the greater wear of joints, which then need to be replaced with implants. Increased life expectancy means that the implants remain in the body for much longer and therefore need to be longer lasting. The revision rate of implant materials used in clinical practice is still as much as 10 per cent, particularly in the case of hip and knee joint implants (formation of wear particles, corrosion products). It is therefore necessary to develop new implant materials that help increase the life span of implants and reduce material failure.

The cement-free Metha® Short Hip Stem prosthesis with Plasmapore® μ-CaP coating of the entire proximal surface supports rapid secondary fixation. μ-CaP is applied on the microporous titanium Plasmapore® surface. It has an osteoconductive effect and accelerates contact between the bone and the prosthesis stem.
© B. Braun Melsungen AG

The manufacture of implants and the use of new materials are a great challenge for science and industry given that a broad range of different factors affects the life span of implants. The biocompatibility of the implant material is one key element in the endeavour to improve implants. Biocompatibility refers to the behaviour of biomaterials, for example how materials interact with the body, whether they elicit an immune response or how well they integrate with a particular cell type. Another important factor is the behaviour of a material under high strain. Material failure can lead to cracks between the coating and the basic material as a result of imperfect undercoating, and this in turn means that body fluid may come into contact with the basic material. The basic material corrodes, thus necessitating the removal of the implant.

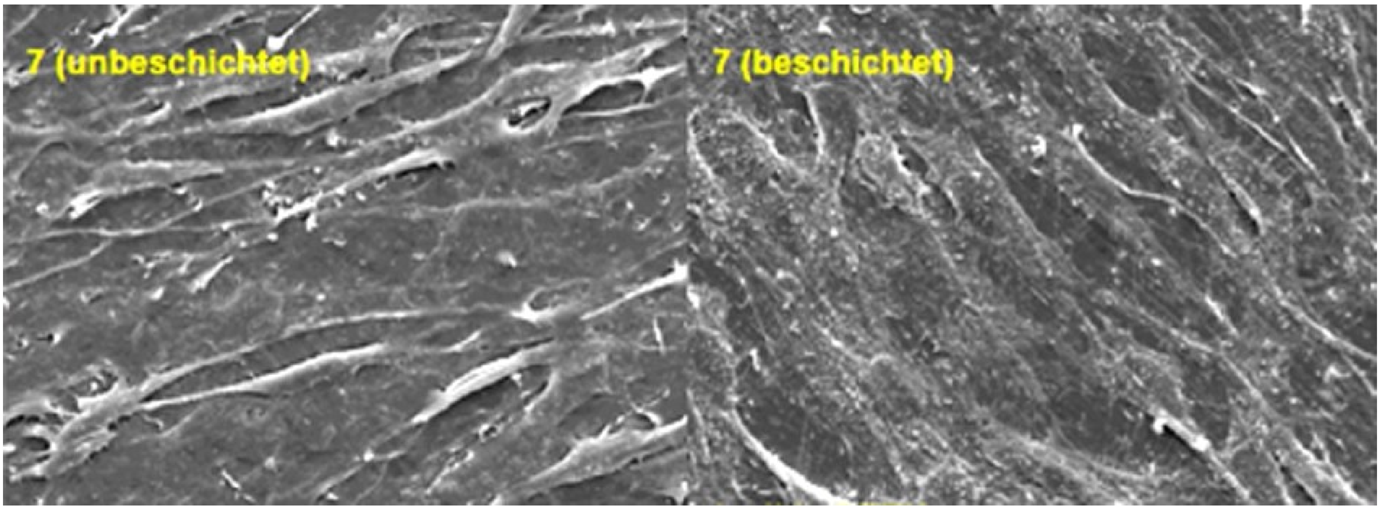
In addition, due to increasing life expectancy, implants tend to remain in the body much longer than before, which might be another reason why the implant needs to be removed prematurely. All this can lead to complications and require follow-up treatments for the patient, which put a high cost burden on the health system. Researchers around the world are therefore working on the development of different materials. All materials have numerous advantages, but also certain disadvantages. From rustproof stainless steel to complex titanium alloys, the majority of the problems that arise are often due to imperfect surface hardness or insufficient resistance to wear.

Popular materials with some disadvantages

Besides ceramics and plastics such as polyhydroxybutyric acid (PHB), titanium is one of the key materials used for implants. This is mainly due to its excellent biocompatibility. However, implants with greater flexibility and elasticity are difficult to produce with titanium due to its brittle and inflexible properties, and because it is a metal that corrodes easily, which can lead to an implant quickly becoming non-functional and needing to be changed prematurely. In order to remedy this situation, industrial and scientific partners are looking for new materials suitable for implants. For example, a flexible silicon elastomer implant is being used in the field of hand surgery for treating rheumatoid, degenerative arthritis of the thumb saddle joint.

The biofunctionalisation of surfaces is currently one of the major priorities in the development of new implants. Titanium implants are roughened in order to improve the mechanical anchoring in the bone. Metal and plastics implants are coated with growth factors or other drugs in order to improve the implants' integration into the surrounding tissue and/or prevent inflammatory reactions. Implant research also predominantly focuses on the investigation of processes that occur at the interface between the material and the body tissue. Implants can restore a mechanical function, but can also promote the growth of natural body structures by serving as placeholder, giving off growth factors and dissolving after successful healing (see article entitled "Synthetic tendons made from bicomponent fibres"). In addition, medical technology is increasingly using nature as a model, for example by using carbonate-containing compounds for developing spinal implants (see article entitled "Orthobion GmbH: biomaterials for spinal implants").

Increasing biocompatibility with nanoparticles



Scanning electron microscopy: The photo on the right shows a clearly structured cell surface achieved with a special surface coating that facilitates osseointegration. The cells do not display a spindle-shaped morphology.

Nanobiotechnology links biology with nanotechnology, i.e. with the production and investigation of structures and materials in the nanoscale range. Nanobiotechnology is also used for implant research. Nanostructured implant surfaces are assumed to improve the interaction between the implant and the surrounding cells/tissues. Nanoparticles made of high-strength materials with specific gliding properties can improve the life span of an implant by preventing the abrasion of particles. In addition to the specific structuring of surfaces in the nanometer range, which leads to improved cell adhesion and proliferation, osteoinduction is another important factor. Osteoinduction is the ability of a material to induce the formation of new bone. The formation of new bone leads to a direct structural connection between the implant surface and the bone material.

In order to prevent an implant from being rejected by the human body, nanobiotechnology is focusing on methods that enable implants to release active substances, rather than requiring patients who have been given an implant to take medicines. This can be achieved by treating the implant surface with inert gas ions which leads the formation of a layer of nanobubbles immediately beneath the implant surface. These bubbles can be filled with drugs that are subsequently released in the body over a certain period of time. The size of the bubbles determines the dose of the drug and the duration over which it is released.

Looking for antibacterial materials

Biomaterials of the future need to be resistant to wear and corrosion as well as having antibacterial properties to prevent infections that need to be treated and that might cause enormous stress to the patient. The functionalisation of implant surfaces using nanobiotechnology methods also plays a major role. Silver has excellent antibacterial properties. Silver particles attached to the surface of implants continuously release silver ions which inhibit enzymes of the bacterial energy metabolism. This leads to the death of the bacteria, and the rate of infection can be reduced.

Implants of the future need to be able to meet a broad range of requirements. The sole aim is no longer just the replacement of a defective body function, implants are also required to promote the body's regenerative power and dissolve when no longer needed, prevent inflammatory reactions and remain in the body throughout a person's life. A lot of research is still necessary before implants that are able to meet all these requirements can be developed.

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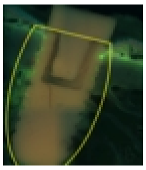

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