SEM investigation of implant surface characteristics

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Implants have become an essential part of restorative dentistry. Their success and long-term prognosis mainly depend on design, accurate manufacturing of their surface structure, bone quality, clinical skill and individual risk factors. Titanium implants have been used in dentistry with great success for more than 50 years and various surface modifications have been made to improve osseointegration. An ideal implant requires high levels of surface cleanliness in order to minimise the risk of foreign body reactions. Different implant systems have different surface properties, leading to different cell adhesion results.

Objective

Contaminants from the manufacturing or packaging process can cause an uncontrolled foreign body reaction resulting in the formation of high amounts of connective tissue, which leads to insufficient osseointegration. Against this background, the authors examined the surface characteristics of a new implant prior to its clinical use in their private practice. The implant was analysed using scanning electron microscope imaging (SEM) and energy-dispersive X-ray spectroscopy (EDX) in order to determine the elemental composition of potential impurities.

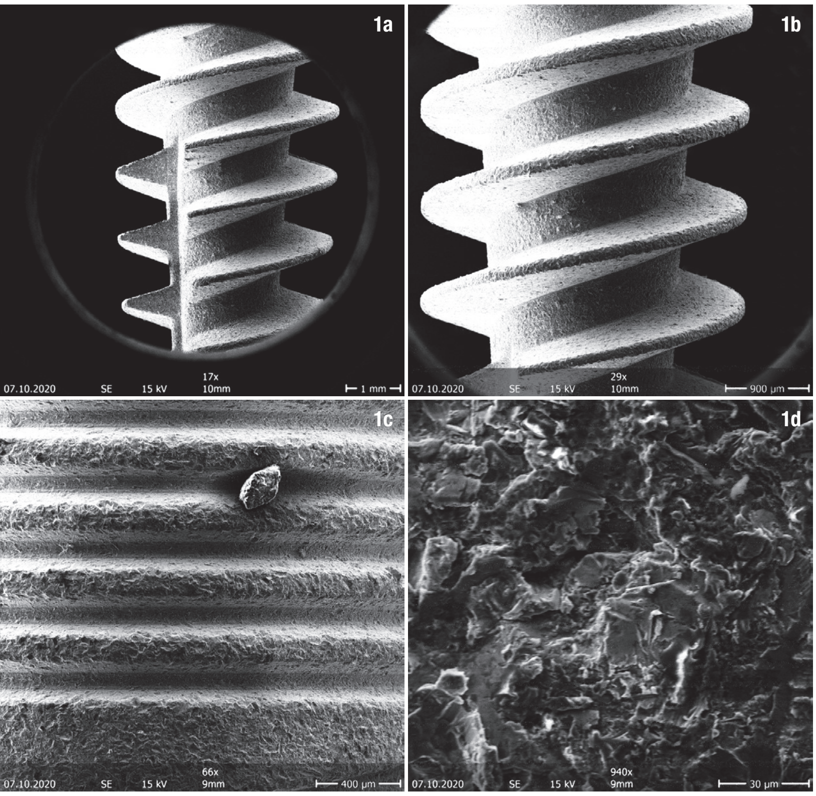

Fig. 1: Overview **(a)**, detailed view of spirals and inhomogeneous rough surface **(b)**, roughness of the surface with organic deposition is clearly visible **(c)**, rough surface **(d)**.

Material

The investigated implant was a DSI RBM Premium Line implant (Dental Solutions Israel) made of titanium alloy Ti-6Al-4V ELI, in accordance with ASTM-F136-02. It has a spiral thread design with twin cutting grooves. The coronal micro-threads are designed to increase bone–implant contact and, in turn, long-term stability in the crestal area. The micro-rings on the implant neck are designed to minimise shear forces in the crestal zone and peri-implant bone loss. This tapered implant features a 2.42 mm internal hex connection, one abutment platform for all implant diameters (3.5–5.0 mm) and an increased fixture-abutment contact area. The apex is rounded and features self-tapping threads for optimal surgical flexibility.

Implant surface

The investigated implant has a resorbable blast media (RBM) surface. During manufacturing, this surface is treated with high-speed particle blasting, using the resorbable bioceramic beta-tricalcium phosphate (β-TCP). The surface is cleaned and etched from calcium particles with a low concentrated organic acid. This process does not change the titanium surface pattern and produces a uniform surface with homogenous pore diameters and a greater bone-to-implant contact value (BIC). β-TCP, a resorbable material often used in synthetic bone grafts, dissolves during the healing process. The surface roughness value (Ra) is between 2.5 to 3.0 µm. The micro-pits in the surface measure 1–3 µm.

SEM analysis

The Zeiss DSM 940 scanning electron microscope and the X-ray spectroscopy system NORAN System SIX

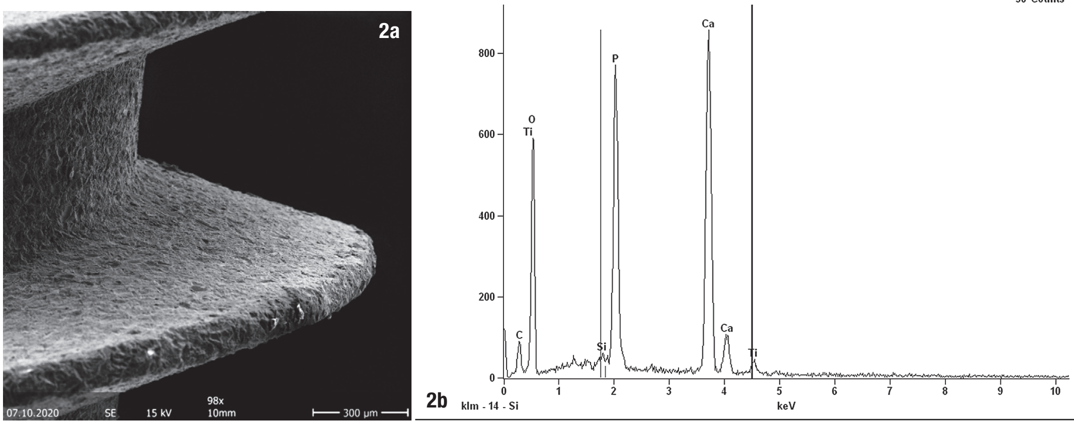

Fig. 2: View of coil with detached particle **(a)**, EDX analysis shows peaks for calcium and phosphorus, which originate from surface treatment; spot analysis **(b)**.

(Thermo Fisher Scientific) were used for analysis. Once unpacked and mounted on an SEM target, the sterile implant was immediately investigated without further coatings. It was observed that the spirals had regular intervals. The edges showed some inhomogeneities. A homogenous porous surface was clearly visible. Small contaminations were found (Fig. 1). The energy-dispersive X-ray spectroscopy detected peaks for calcium and phosphorus, which originate from surface treatment (Fig. 2). Apart from that, small organic carbon particles as well as a few small particles composed of aluminium were detected. Low amounts of silicon were focally detected.

Discussion

Today, implants can survive for a long time.[1] In a past study, the authors analysed eight sterile-packaged implants from different manufacturers.[2] They found that even implants in the low-budget segment can have good surface characteristics. The accurate topographic characterisation of dental implants is vital, as their surface microstructure affects osseointegration. The influence of Ra on growth of different cells has been extensively studied and it is known today that epithelial cells do not attach as strongly to acid-etched or sand-blasted surfaces as to smooth (polished, Ra <0.5 µm) surfaces, while fibroblasts adhere equally well to rough (such as machined) and smooth surfaces.[3–5] Other authors also suggest that metabolic activity (i.e. the production of osteocalcin, prostaglandin E2 [PGE2] and transforming growth factor-β1 [TGF-β1], or alkaline phosphatase activity) of osteoblast-like cells is significantly increased on rough (i.e. sand-blasted, etched or plasma-sprayed) surfaces. Inorganic materials, such as bio-reactive calcium phosphate or hydroxylapatite (HAp) coatings, have been applied extensively owing to their chemical similarity to bone minerals.[6,7]

Conclusion

Osseointegration of foreign materials always causes a persisting foreign body reaction with the activation of macrophages and resulting inflammatory processes.[8] These general pathological reactions need to be kept low in order to reduce peri-implantitis, potential pathological alterations, or implant loss. Unfortunately, many implants show contaminations in the form of metallic or inorganic particles, which originate from the manufacturing or packaging process.[9–12] These particles can cause implant failure. Reliable control mechanisms need to be put in place by manufacturers to ensure that only implants with minimum health risks for patients are sold. Additionally, irregularities in the shape or the structure of threads can support the deposition of unwanted particles.

Literature

about the authors

Dr Branislav Fatori has more than four decades of experience in implantology. In addition to his German doctoral degree, he holds a second doctoral degree from the University of Belgrade in Serbia. He was trained at internationally renowned clinics and has worked as a consultant for implant manufacturers.

Dr Inge Schmitz has worked at the Institute of Pathology of the Ruhr-University Bochum in Germany since 1990. Her main interests are implantology, stents, electron microscopy and osteology. She studied biology at the same University and completed her PhD at the University of Essen in Germany in 1989.

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