

Plasma spraying for medical application

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INTRODUCTION: For endosseous implant fixation in bone, such as in case of artificial hip and knee joints, two methods are currently applied. The older and more frequent method uses bone cement. Primary fixation of the endoprosthesis is secured by in-situ polymerisation immediately after the implantation.

The second method is the cementless implantation technology. Primary fixation is achieved by mechanical press-fit of the implant into the minimal excavation, well adapted to the geometric configuration of the endoprosthesis.

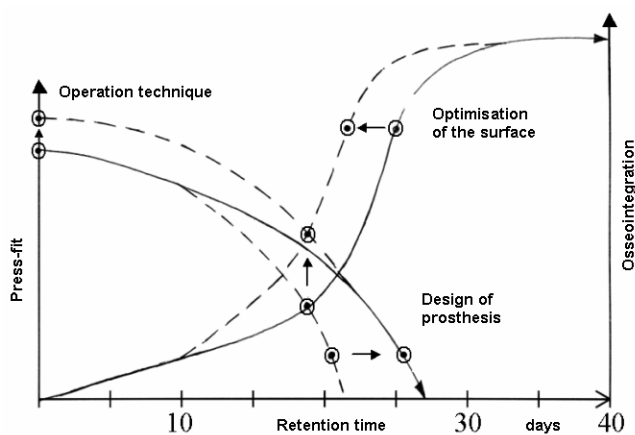


Fig. 1. The change from mechanical (press-fit) to physiological fixation (bony-ingrowth) of a cementless implanted prosthesis as a function of the retention time [1].

The initial degree of press-fit depends on the design of the implant as well as on the performance of the implantation (Fig.1). The long-term stability of the implant is only ensured if the host bone directly interlocks with the surface of the implant. This bony-ingrowth must be as fast as possible, because the press-fit-fixation becomes increasingly loose after insertion. Therefore, an optimisation of the implant surface in contact to the host bone is required in order to force the osseointegration.

SURFACE MORPHOLOGY: In the past, a variety of surface modifications have been in clinical use. Osseointegration was shown to be fastest and most effective for rough surfaces with open structure that varied between 50 to 400 μm [2]. Vacuum Plasma Sprayed (VPS) Titanium coatings are an optimised way to achieve a surface topography and morphology in this preferred 3-dimensional range (Fig. 2). The bone cells anchor directly to Ti due to the presence of a self-protecting TiO_2 passive layer, which is responsible for the biocompatibility of this metal. The individual surface configuration of each type of implant can be engineered within a wide range of roughness to meet the particular requirements for bone bonding at the site of implantation. Responsible

is a careful adaption of the spray powder particle size distribution to the spray parameter. Implants into the less stable spongiosa require a higher roughness compared with the value of a surface in contact to the corticalis.

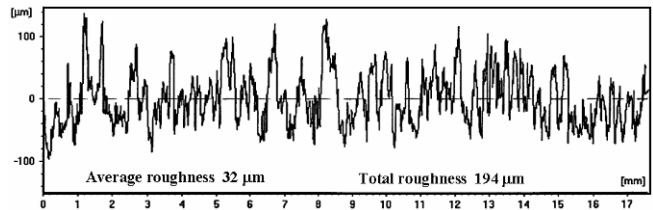


Fig. 1. Height profile of a VPS-sprayed titanium coating, recorded with a mechanical stylus profilometer. The thickness of the titanium coating is 350 μm , the surface roughness can be described by the parameters $R_a = 32 \mu\text{m}$ and $R_t = 194 \mu\text{m}$.

BIOACTIVITY: Materials that enable an interfacial chemical bond between the implant and the bone tissue due to a specific biological response are called bioactive [3]. Due to its similarity to the mineral phase of natural hard tissue, artificial hydroxyapatite (HA) is considered as a bioactive material.

The idea of using the plasma-sprayed process for the production of HA coatings on endoprosthesis was first described in Japan [4]. In contrast to uncoated metal samples, the implants with HA surface developed in a short time a strong connection between implant and bone tissue. In 1985 the first experience of producing HA coating by the VPS technology was gained [5]. High crystallinity and phase-purity was achieved thanks to a subtle balance between the HA-spray powder and the VPS parameters. The coatings are characterised by a dense and crack-free structure and therefore less prone to penetration of and chemical attack by human liquids.

CONCLUSION: The combination of Ti with HA offers an interesting option for a rough surface with osseointegrative approach. The adhesive strength of the ceramic and therefore brittle HA is improved by the ductile Ti undercoat and partially overcomes the discontinuity in mechanical properties at the bone / implant interface. This combination also distributes the mechanical forces across an extended interface along the rough and significant ductile VPS-sprayed Ti structure down to the stiff metal implant.

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