New Paradigms in Implant Micro-Geometry

Dr. Peter Gehrke, Germany

The successful osseointegration of dental implants depends on the types of implant-to-bone interactions that occurs at the point of contact. Dental implant surfaces play a key role in these interactions. The initial migration of cells, their adherence, and their proliferation and differentiation directly affects how bone forms, as well as the quality of the bone. The FRIADENT® CELLplus implant surface (DENTSPLY Friadent, Mannheim, Germany) possesses a homogenous surface morphology which positively influences cell attachment and improves bone apposition to implants. BioPoreStructuring (BPS, an etching process derived from the semi-conductor and pharmaceutical industries) is used to create CELLplus, according to Peter Gehrke, Dr. med. dent. (Prosthodontist, and Global Marketing Director, DENTSPLY Friadent). According to Dr. Gehrke, "CELLplus represents the further development of the first microretentive grit blasted/acid-etched titanium oxide surface introduced 15 years ago by Friadent." He adds that CELLplus represents the "latest developments in microdesign and production opening new, innovative technologies, which until now were unavailable in implant dentistry. Friadent fulfilled the requirements for dental implants arising from the latest scientific knowledge on surface morphology."

Dr. med. dent. Peter Gehrke

The CELLplus Surface Design The Friadent CELLplus surface is created through an automated process called BPS, which includes both semiconductor-microchip thermal etching and highly-purified water treatment technology modeled after that used in the pharmaceutical industry. The CELLplus surface is a textured, micro-retentive titanium surface achieved by grit-blasting and specific innovative high-temperature acid-etching. The blasting material provides a defined macro-structure, while small micro-pores are created by etching with mineral acids.
Friadent BPS was developed in close cooperation with leading companies in the field of etching technology and computer chip manufacturing. This fully automated, high-temperature etching technique allows for precise setting and maintenance of all process parameters. BPS was enhanced through a series of complex experiments in order to ensure the homogenous microstructure of the implant surface. Consequently, a precise and consistent surface texture is achieved. All of the process steps are carried out under clean room conditions.

How CELLplus Works The characteristics of FRIADENT® CELLplus are unique. Typically, dental implant systems demonstrate bone growing from the bone to the implant surface. With CELLplus, bone grows not only from the bone to the implant surface but essentially from the implant surface back to the bone. Dr. Gehrke explains that any endosseous healing compartment will display distance and contact osteogenesis.

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Osteogenesis at the implant interface represents the balance of these two distinctly different phenomena by which bone can become juxtaposed with an implant surface. In distance-osteogenesis the osteogenic cells line the old bone surface, and the extracellular matrix establishes the implant surface contact. The blood supply to these cells is between the cells and the implant, and bone is laid down on the old bone surface. "The implant surface," Dr. Gehrke continues, "will always be partially obscured from the bone by intervening cells and the general connective tissue extracellular matrix." In the case of contact osteogenesis, the cells have first been recruited to the implant surface, as shown with the FRIADENT® CELLplus surface. "The blood supply is between the cells and the old bone," Dr. Gehrke notes. New bone formation is laid down directly on the implant surface. The developing bone matrix can directly interlock within the surface morphology. Animal studies have shown large numbers of direct contacts of osteogenesis starting from the CELLplus surface with the bone growth, not only in soft bone but also in cortical bone.[1–3]

According to Dr. Gehrke, the enhancement of the implant surface affects the cells and the integration of the implant because during initial bone healing, FRIADENT® CELLplus enhances the early cell activity and therefore the apposition of new bone, resulting in an excellent secondary stability within a few weeks. The 3-dimensional architecture of CELLplus represents the ideal morphology for instant cell attachment as well as progressed cell migration, proliferation and differentiation, and the aftereffect of accelerated osseointegration. Very early on, the micropores allow for secure retention of cell extensions (filopodia).

CELLplus vs. Other Implants

Dr. Gehrke states, "What sets this surface apart from some of the other surfaces that are commercially available today is that the growth-activating microstructure of CELLplus shows ideal wettability qualities that allows for increased cell attachment within the first minutes of fluid and tissue contact." Proactive cell adhesion enhances the spread and maturation of cells, along with rapid differentiation of osteoblasts and accelerated bone formation. However, before any of the initial bone formation can take place, the attaching cells must be able to span distances 100 times their size. The properties and surface structure of the FRIADENT® CELLplus surface make bridging such gaps possible. The accelerated attraction of the osteoblasts that attach to the CELLplus surface creates extraordinary bone formation in the early stages of osseointegration (5–25 days after implant placement).

Several studies have compared the CELLplus surface to other surfaces, determining that this surface provides a better and/or a faster osseointegration than other surfaces commercially available.[1–3,5,6] Dr. Gehrke states, "An important study is probably the one that we conducted on osteoblast interactions on different micro-structured implant surfaces."[2] This was a comparative study of combined cell attachment, migration, proliferation and differentiation together performed by Dr. Rachel Sammons and coworkers at the University of Birmingham. This in vitro study on the comparison of FRIADENT® CELLplus with six different commercially-available implant surfaces included two basic methods:

1. The suspension method, which compared cell attachment and the spreading of osteoblasts to different implant surfaces placed in a suspension of rat cavarial osteoblasts for 30 minutes in 4 experiments. The cells were classified by SEM into four stages of attachment.
2. The organ-culture pocket method, which compared cell migration, proliferation, and differentiation in a study model that simulates the sequences of osseointegration.

In this second model, implants were placed in infusion tubings, which had been cut lengthwise (exposed section 2 mm). The different implant surfaces were covered with rat cavarial bone fragments and then placed and sutured in nylon pocket and incubated for 2 or 4 weeks. In comparison to the six different surface modalities, cell spreading with CELLplus progressed more rapidly to the later stages. A significantly higher percentage of fully spread cells and more extensive cell sheets with firmer attachment to the CELLplus micropores were found. Consequently, CELLplus has proven faster osteoblast differentiation and extracellular matrix formation with the result of en-

hanced bone formation at the implant interface.

CELLplus and Compromised Alveolar Bone

Even in situations involving poor bone quality, superior structure integrity and stronger bone maturation on the implant surface provide clinically higher secondary stability. In vivo examinations of the new surface show improved bone density and intimate bone-to-implant contact.[3] The FRIADENT® CELLplus surface demonstrates a significant increase in bone formation and accelerated osseointegration within the key healing period of 3 days to 8 weeks. Thus, Dr. Gehrke notes, the Friadent CELLplus surface yields faster rehabilitation of the maxilla and mandible.

Dr. Gehrke explains, "There are promising results from Michael Weinländer, University of Vienna, showing that there is better bone quality and better bone formation."[5] This observation is confirmed by studies of Arthur Novaes, University of Sao Paulo; for example, if there is, clinically, more bone at the implant interface, it is probably more stable in offering secondary stability.[1]

CELLplus and Wettability

FRIADENT® CELLplus has ideal wettability qualities that allow for increased cell attachment within the first minutes of fluid and tissue contact.[7,8] Initially, CELLplus is lipophilic, which favors the connection of proteins and the formation of a temporary fibrin network. Bone-inducing cells (osteoblasts) quickly adhere to the implant surface via this fibrin scaffold. Biomolecules, such as lipids and proteins, cause a dynamic change in the surface wettability to hydrophilic. It is at this point that optimal blood supply between local bone and bone cells on the surface of the implant is achieved.

"Hypothesizing along these lines," Dr. Gehrke explains, "what we have done is modified the surface to increase the fibrin connection to it."

Potential for Peri-implantitis

Considering the principles of biological width, we have designed a double zone at the crestal part of CELLplus implants. At the top crestal section of 0.4 millimeters, the implants are machined, followed by a solely acid-etched zone of 1.1 mm and 1.6 mm, respectively. Below this double crestal zone, CELLplus implants have a grit-blasted and acid-etched endosseous microstructure.

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