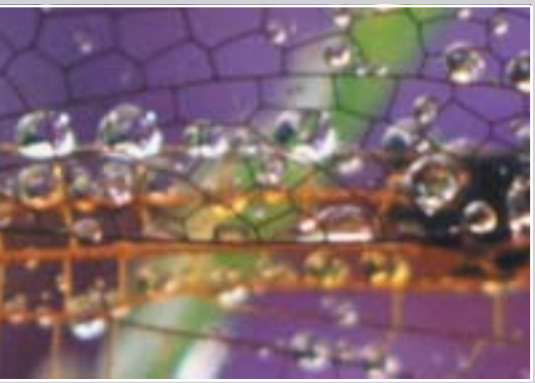
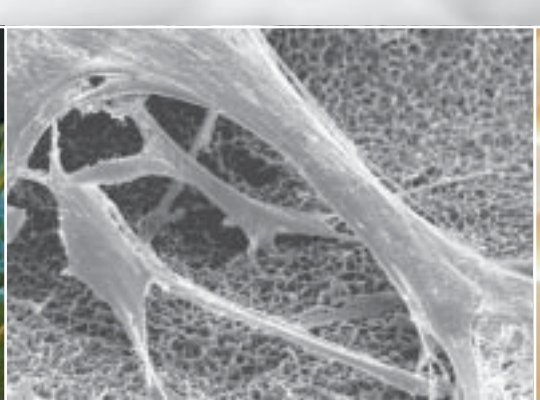
FRIADENT® plus

DENTSPLY
FRIADENT





DENTSPLY Friadent's quest for knowledge involves the constant pursuit of perfection through innovation. In the healthcare field this pursuit requires a harmonious bond between biology and technology. The ideal product design evolves from the analysis of nature's biological microsystems and the development of new technology.

Nature's evolution serves as the perfect model for our unique products. Taking the time to understand nature's processes and biological principles opens a world of new synergies. By applying these synergies to biology and technology, we can broaden the footprints of evolution to support today and tomorrow's healthcare needs.

Osseo-attractive –
The implant surface design of the future

Interaction between biology and technology is the key to future innovations

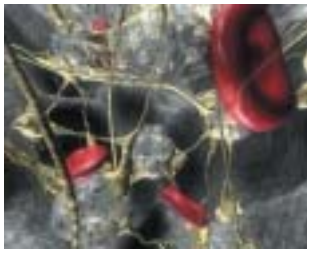
An ideal implant surface actively supports the bone's natural healing process, while ensuring a stable interface between implant and bone in a relatively short period of time. With its scientific partners, DENTSPLY Friadent has decoded the secret of osseointegration. Learning this complex process has provided us with the understanding to develop our new implant surface.

The first steps are critical for success

The prerequisite for successful bone healing is the attachment of osteogenetic cells on the implant surface. This can only be accomplished if there is sufficient blood supply between local bone and osteoblasts, known as contact osteogenesis.

Contact osteogenesis can be subdivided into three stages:

- Osteoconduction
- De novo bone formation
- Bone remodeling



Osteoconduction (Stage 1)
In the first stage of bone healing, bone-inducing cells (osteoblasts) migrate over a temporary fibrin network (connective tissue) to the implant surface. The three-dimensional (3-D) implant surface determines cell attachment quantity and time.

De novo bone formation (Stage 2)
Bone specific, extracellular matrix (collagen) attaches itself to the implant surface and mineralizes. In this stage, implant surface micromorphology determines cell attachment and subsequent bone formation.

Bone remodeling (Stage 3)
Following the first two stages, widespread cellular activity at the implant-bone interface leads to the formation of trabecular structures along the collagen fibers and thus the ingrowth of new bone. A stable and strong attachment between implant and bone is dependent on cell attachment, proliferation and differentiation during Stages 1 and 2.

Analysis of the bone healing process has shown a direct correlation between the implant surface topography and a successful, fast and stable healing phase. An ideal implant surface design will stimulate a biological reaction between the implant and bone, which in turn, could allow for early implant functional loading. The latest studies have shown that 3-D surface morphology is of greater significance than surface roughness[1].

1__*SEM (3000 x) of FRIADENT® plus surface structure. Bimodular topography with micropores (0.5–1µm) in macropits[1].*

2__*Percentages of cells at stage 4 on FRIADENT® plus in comparison to other implant surfaces.[1] Cell attachment classification after Rajaraman et al.*

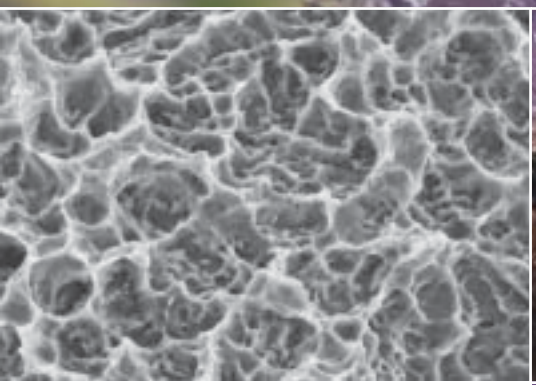
3__*Initial contact and anchorage of osteoblast via small extensions (filopodia) on FRIADENT® plus[1].*

Ultimate biocompatibility

When studied more closely, most of nature's truest wonders exhibit multi-functional abilities. The wings of an insect are a perfect example of interaction between macro and microdesign, and more specifically, wettability.

This interaction also plays an important role on implant surfaces. The wettability of FRIADENT® plus is designed to enhance the osteoconduction stage. The primary cell attachment of the microstructure is activated during this stage.

<u>The plus:</u> Excellent wettability properties for utmost biocompatibility.



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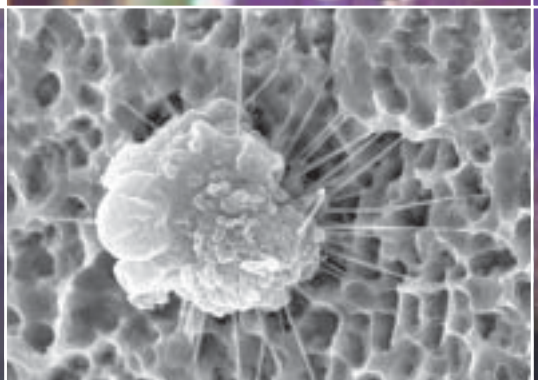

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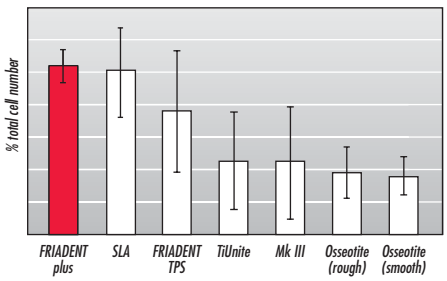
Average percentage of cells at stage 4 on implant surfaces



FRIADENT® plus –
The surface technology of tomorrow, today

Combining the following key implant surface factors accelerates the osseointegration process[2]:

- Surface macro- and micromorphology
- Biocompatibility
- Wettability
- Chemical composition

Additionally, they ensure improved bone quality at the implant interface and an optimal implant loading capacity.

Complex conditions place high demands on product design and technology of implant surfaces.

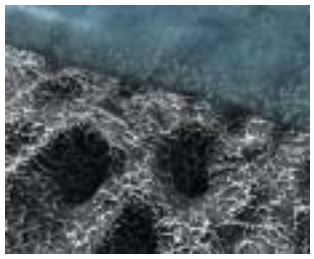
DENTSPLY Friadent pioneered the first microretentive grit-blasted/acid-etched titanium oxide surface 15 years ago. Today, the superiority of this surface design still stands true. Our latest developments in microdesign and production have opened new, innovative technologies, which until now were unavailable.

We are introducing yet another first: the FRIADENT® plus surface. The highly specialized production process used to manufacture this surface is unmatched and new to implant dentistry.

The 3-D bimodular microstructure of the FRIADENT® plus surface is created in two steps:

FRIADENT® plus
Primary Microstructure

Surface macroroughness is achieved by grit-blasting the endosseous section of the implant.



FRIADENT® plus
Secondary Microstructure

After grit-blasting, the implants go through a unique thermal etching process: FRIADENT® **B**io**P**ore**S**tructuring. The growth activating microporosity and surface morphology needed for osseointegration is achieved during this step. The specific acid used by DENTSPLY Friadent for this process creates the ideal physical, chemical and biological properties needed to attract bone-inducing cells to the implant surface.

This cutting edge technology guarantees superior surface quality, never before achieved.

With FRIADENT® plus, DENTSPLY Friadent has developed a growth activating microstructure that contributes to all osseointegration stages, while ensuring a stable bone-to-implant contact in a short time period.

***4**__FRIADENT® implants assembled for the computerized thermal etching process.*

***5**__SEM (500 x) of FRIADENT® plus surface structure. Homogenous pits similar in length and depth produced by grit-blasting[1].*

***6**__SEM (3000 x) of FRIADENT® plus surface structure.*
Higher magnifiation shows micropores of 0.5–1 µm diameter and 3–5 µm in depth[1].

Optimal osseointegration

An animal's ability to adapt to its environment is crucial in nature. For example, the unique microstructure of the shark's skin reduces flow resistance during swimming.

The FRIADENT® plus 3-D microstructure ensures uniform initial cell spreading. The FRIADENT® plus macrodesign, in tandem with its surface topography, ensures outstanding insertion properties, resulting in stable bone-to-implant contact.

<u>The plus:</u> Unique 3-D microdesign for optimized osseointegration.

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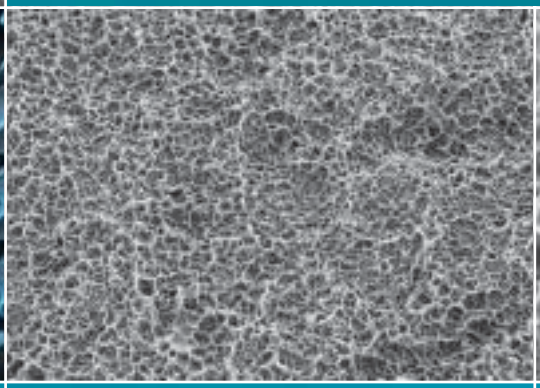

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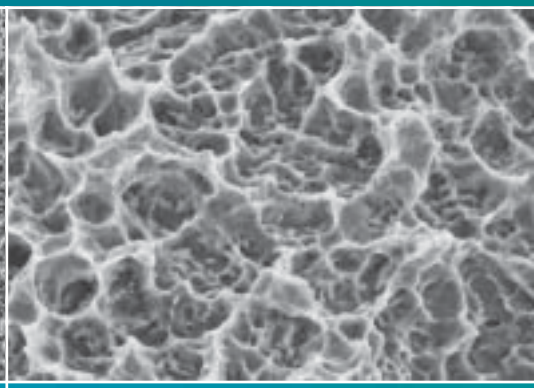

FRIADENT® plus –
The next generation implant surface

We utilized nature's pure form as a starting point for our implant's surface design. Therefore, the surface is able to support the biological process of peri-implant bone healing (the interaction between surface morphology and osteogenesis that leads to osseointegration).

This concept becomes reality with the advent of the FRIADENT® plus implant surface.

FRIADENT® plus is the next generation implant surface, with many new and unique benefits.

The plus:
Growth activating microstructure for rapid fibrin formation.

FRIADENT® plus has ideal wettability qualities that allow for increased cell attachment within the first minutes of fluid and tissue contact. Initially, FRIADENT® plus is lipophilic which favors the connection of proteins and the subsequent formation of a temporary fibrin network. The extension of this fibrin clot formation on FRIADENT® plus is significantly higher compared to other titanium surfaces[4].

The plus:
Dense fibrin network for rapid cell adhesion.

Via this extened fibrin network, bone-inducing cells (osteoblasts) quickly adhere to the implant surface.
The layer of proteins causes a dynamic shift 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[3].

The plus:
Accelerated bone apposition for increased primary stability.

In the homogeneous FRIADENT® plus microstructure (0.5 – 1.0 µm), the thread-like cytoplasmic extensions (filopodia) of osteoblasts provide retention with true multifocal contacts.

Proactive cell adhesion enhances the spreading and maturation of cells, along with rapid differentiation of osteoblasts and accelerated bone formation.
A prerequisite for this initial bone activation is rapid cell spreading and bridging. Only the FRIADENT® plus surface has documented long-distance (100-times cell size) cell bridging capabilities[1].

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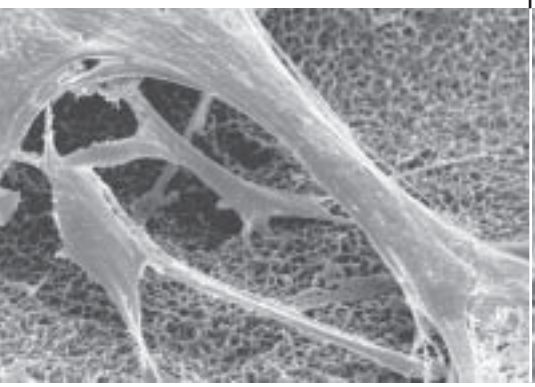
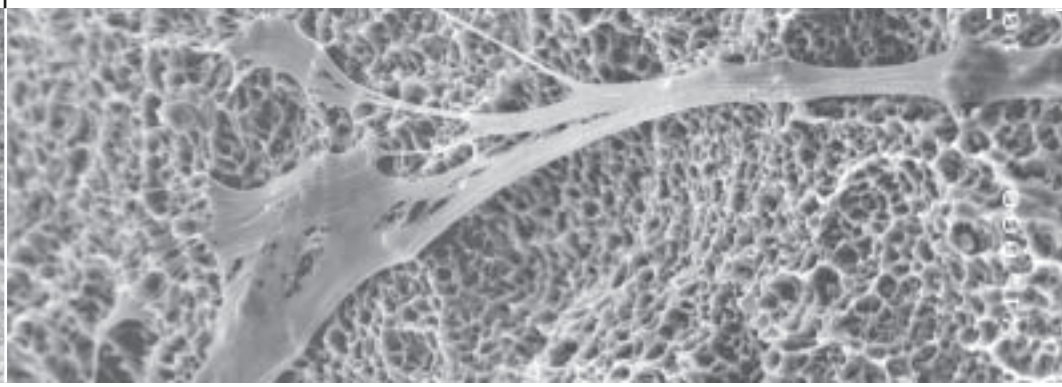




7__*SEM (20.000 x), Fibrin and red blood cells on FRIADENT® plus. Fibrin scaffold has a three-dimensional network, while titanium surface is visible in the background[4].*

8__*SEM (1000 x), Fibrin and red blood cells on FRIADENT® plus[4].*

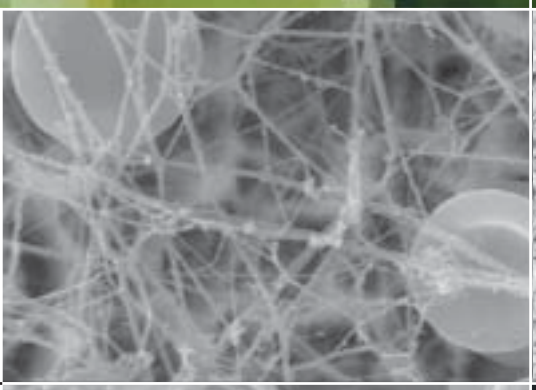
9__*Cell at stage 2: Filopodia span across surface pores, enter them to wrap around protruding ridges[1].*

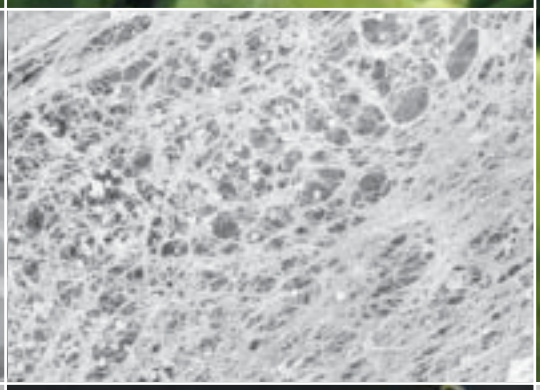
10__*Cell at stage 2: Extension of lamellipodia form close contact with FRIADENT® plus[1].*

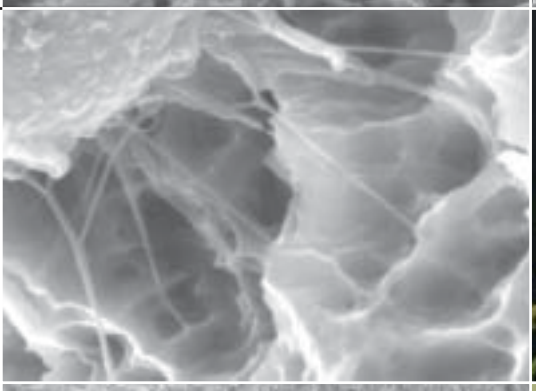
11__*Cells on FRIADENT® plus typically form widespread multifocal contacts, connecting each other, spanning surface pores and cavities over long distance. Cell chains consist of 3 to 6 cells, each approx. 30µm long[1].*

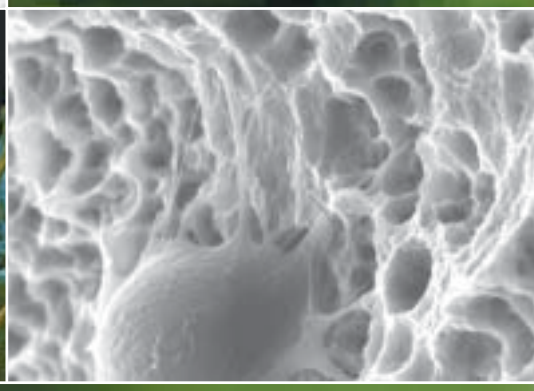
12__*Composite SEM image showing bridging cells on FRIADENT® plus surface. Original magnification x1000; bar = 10µm[1].*

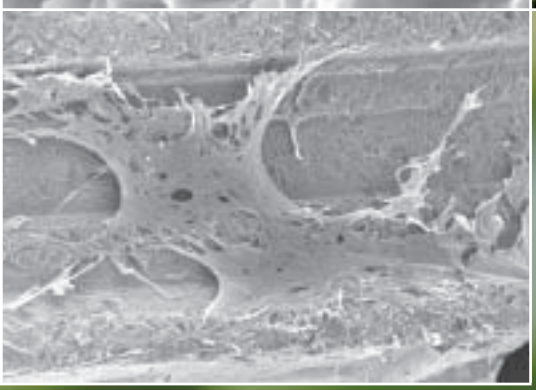
13__*Cells traversing threads of FRIADENT® implant. Possible span distance 120 to 350 µm[1].*











Increased cell attachment

Biology has many different solutions for achieving a secure hold. For example, barnacles anchor themselves to hard surfaces with barb-like antennae to guarantee their reproduction and growth.

Cells differ from barnacles in that they have limited attachment capabilities to foreign surfaces. Implant surface cell attachment must be supported by surface topography. The surface microroughness of FRIADENT® plus is tailored to the needs of bone-inducing cells allowing for rapid attachment.

<u>The plus:</u> Increased cell adhesion for accelerated bone development.

FRIADENT® plus –
The next generation implant surface

The plus:
Homogenous bone-to-implant contact for increased stability

The accelerated recruitment of osteoblasts on the FRIADENT® plus surface leads to intensive bone formation in the early stages of osseointegration (5 to 25 days)[5]. Even in poor bone quality, superior structure integrity and stronger bone maturation on the implant surface provide clinically high secondary stability.

The plus:
High removal torque for increased treatment safety

FRIADENT plus grit-blasted and high temperature acid-etched implants display higher removal torque values compared to solely acid-etched implants and anodic oxidized texture implants.[5] These high removal torque values after a loading period of five months may be interpreted as an increase of bone integration and primary and secondary implant stability.

Thus, the FRIADENT® plus surface yields safer rehabilitation of the maxilla and mandible.

The plus:
Optimized osseointegration for predictable treatment success

Comparative in vivo examinations of the FRIADENT® plus surface confirm an improved bone density at the interface and a higher bone-to-implant contact (BIC). The FRIADENT® plus demonstrates a significant increase in bone formation within the key healing period of 3 days to 8 weeks[6].

In human histologies of unloaded XiVE® plus implants, a high bone-to-implant contact after 45 days in good bone quality with a rate of 99.5%, respectively 10 weeks in weak bone with a rate of 68.5% could be demonstrated[7]. So far, similar values were reported only for human biopsies of early or immediately loaded implants with a five to nine month healing period[8].

With these results, a "plus" of osseointegration is evident for FRIADENT® plus implants. The FRIADENT® plus surface offers the potential for early functional implant loading and more predictable treatment success.

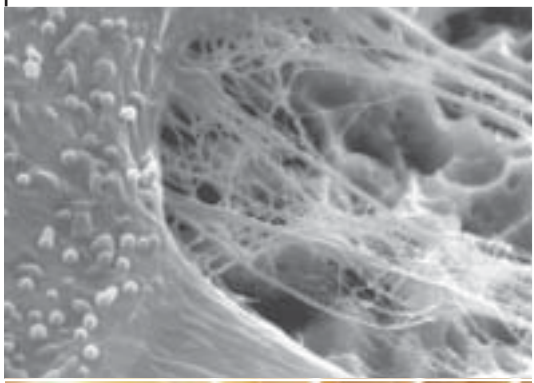
***14**__Extracellular matrix on FRIADENT® plus surface[1].*

***15**__Bone formation rate of FRIADENT® plus compared to TPS[5].*

***16**__Histology (10 x): Bone contact along FRIADENT® plus surface in thread region[5].*

***17**__Histomorphometric picture of bone-to-implant contact of FRIADENT® plus surface[6].*

***18**__Cut-out of one thread of a XiVE® plus implant (20 fold extension). Arrows indicate homogenous bone line (red) between theads[7].*



FRIADENT® plus –
for a plus of osseointegration

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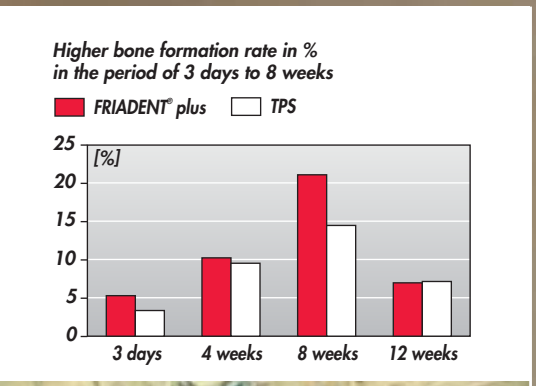

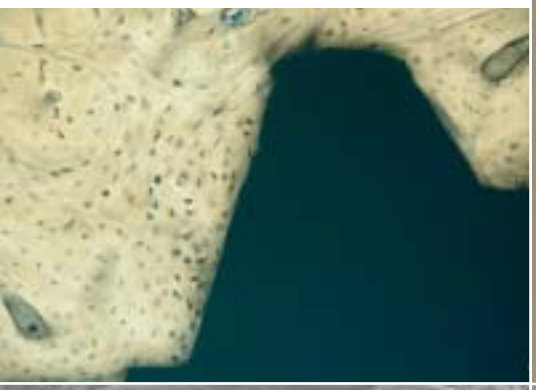

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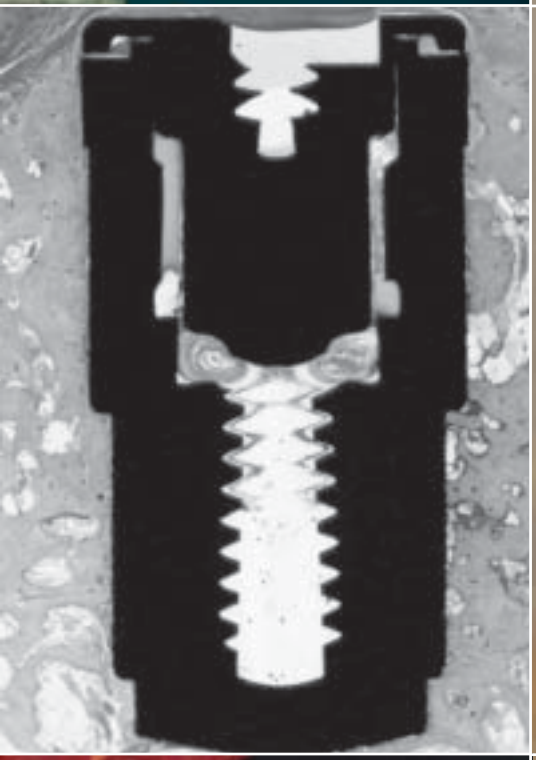

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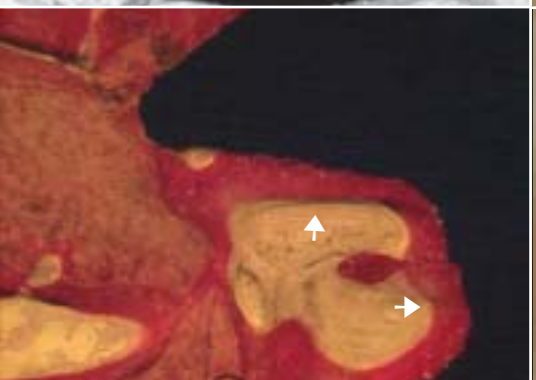

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Enhanced bone quality

Many biological constructions stand out because of their amazing stability. At the same time, they are lightweight and functional. For example, the stable, lightweight construction of the Nautilus makes swimming in great depths possible while protecting the organism from enormous water pressure.

Stable implant-bone apposition and ideal 3-D structuring of remodeling bone are essential for implant osseointegration. This aids in the absorption of occlusal forces ensuring undisturbed healing. The plus surface also allows for functional implant loading during the early peri-implant stage.

The plus: Enhanced bone quality for predictable long-term success.

Literature

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