SurfLink®

SUPERIOR SURFLINK® CHARACTERISTICS

ENHANCED CLINICAL PERFORMANCE

1. HYDROPHILICITY
2. OSTEOCONDUCTIVITY
3. BIOMECHANICAL FIXATION
4. CHEMICAL BONDING
5. STABILITY IN A PHYSIOLOGICAL ENVIRONMENT

NBM
Nano Bridging Molecules

THE BIOMIMETIC SURFACE TREATMENT SURFLINK®
➔WHERE TRUE OSSEOINTEGRATION BECOMES A REALITY

SurfLink® surface treatment by NBMolecules® produces a monolayer of permanently bound multi-phosphonate molecules on the surface of an implant. This novel phosphonate rich surface mimics one of the main constituents of bone, hydroxyapatite, providing a favourable environment for cell colonisation.

From a clinical perspective, the biomimetic surface treatment SurfLink® will:

- **Increase hydrophilicity of the implant surface**
- **Favour bone cell adhesion and cell colonisation**
- **Enable early bone formation on the implant surface**
- **Yield considerably greater bone-to-implant contact**
- **Enhance early and long-term biomechanical fixation**
- **Remain stable on the implant surface in physiological environment**
- **Promise long-term implant stability and true osseointegration**

Over the past decades, advances in refining the surface properties of titanium dental implants have dramatically reduced implant failure rate. The use of biomimetic agents has substantially increased our understanding of what takes place at the bone-to-implant interface. As a result, biocompatibility of implants has improved. Osseointegration and subsequent implant stability have been furthered.

Biomimetic coatings, such as bioceramics (hydroxyapatite, and other calcium phosphate phases), have been placed on the implant market. Such surface coatings have presented some advantages, but have also produced certain integrity problems (dissolution, delamination, particle release) increasing implant failure rate. The SurfLink® surface treatment, which permanently modifies the surface chemistry of implants, was developed to overcome the shortcomings of coatings.

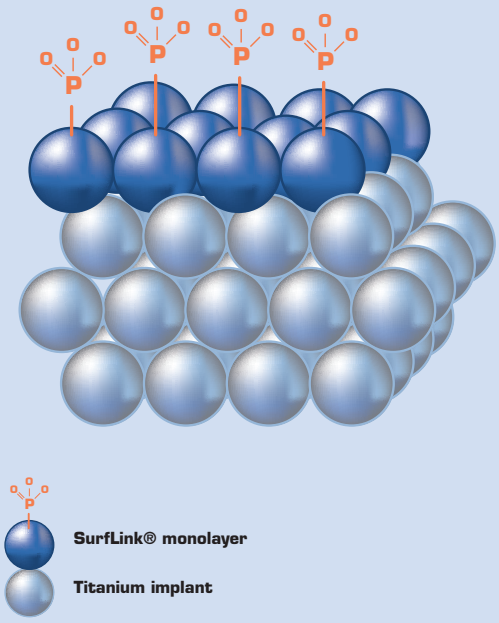

Figure 1 Schematic drawing illustrating the biomimetic SurfLink® monolayer permanently bound to the titanium dental implant with phosphate-like groups presented to the implant environment.

SUPERIOR SURFLINK® CHARACTERISTICS
➔HYDROPHILICITY

ENHANCED CLINICAL PERFORMANCE
➔FASTER OSSEOINTEGRATION, SUGGESTING EARLIER LOADING OF THE IMPLANT

SurfLink® treated implants are hydrophilic (i.e. have a strong affinity for water, Figure 2A and 3). The same untreated implants (control) are hydrophobic (i.e. have no affinity for water, Figure 2B).

Hydrophilic surfaces have been shown to attract biological fluids (e.g. water, ions and blood) as well as favouring protein adsorption immediately after implantation.[1] This will enable quicker cell adhesion and colonisation resulting in faster bone matrix formation and osseointegration.

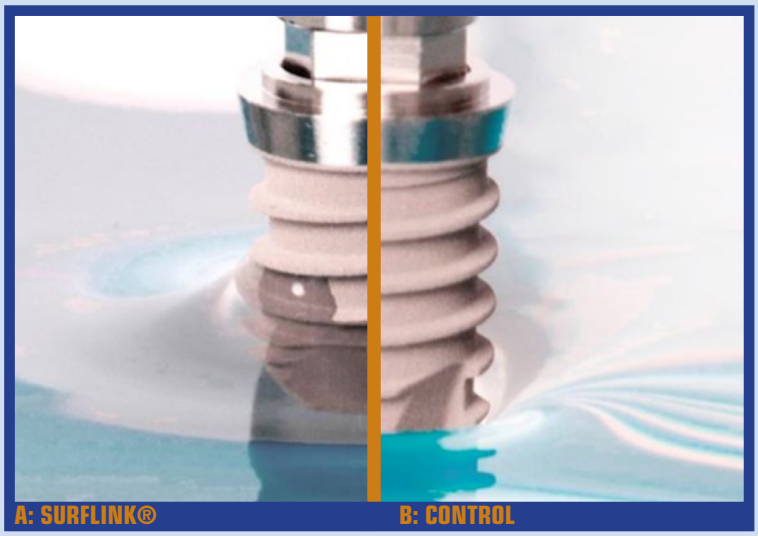

Figure 2 Water affinity experiments with a sterile SurfLink® treated implant (A) and a sterile untreated control implant (B).
Note: *the water is 'climbing up' the SurfLink® treated implant (A), whilst the untreated control implant 'pushes away' the water (B).*

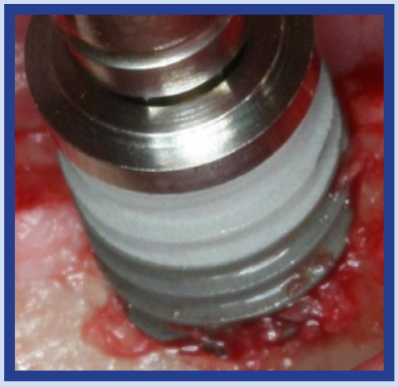

Figure 3 Clinical image taken during the placement of a sterile SurfLink® treated implant.
Note: *the biological fluids are seen to be 'climbing up' the implant.*

SUPERIOR SURFLINK® CHARACTERISTICS
➔OSTEOCONDUCTIVITY

ENHANCED CLINICAL PERFORMANCE
➔FASTER OSSEOINTEGRATION, SUGGESTING EARLIER LOADING OF THE IMPLANT

The surface of SurfLink® treated implants is osteoconductive (Figure 4A). The surface of the same untreated implants (control) does not appear to be osteoconductive (Figure 4B).

OSTEOCONDUCTIVITY: contact points originating from the old original trabecular bone are formed on both SurfLink® treated and control implants at 2 and 8 weeks healing in sheep. However, with SurfLink® treated implants newly formed bone quickly spreads out from these contact points to cover the implant surface, resulting in greater bone matrix formation on the implant surface and faster osseointegration of the implant (Figure 5). Thus in a clinical situation, enhanced early implant stability can be expected.

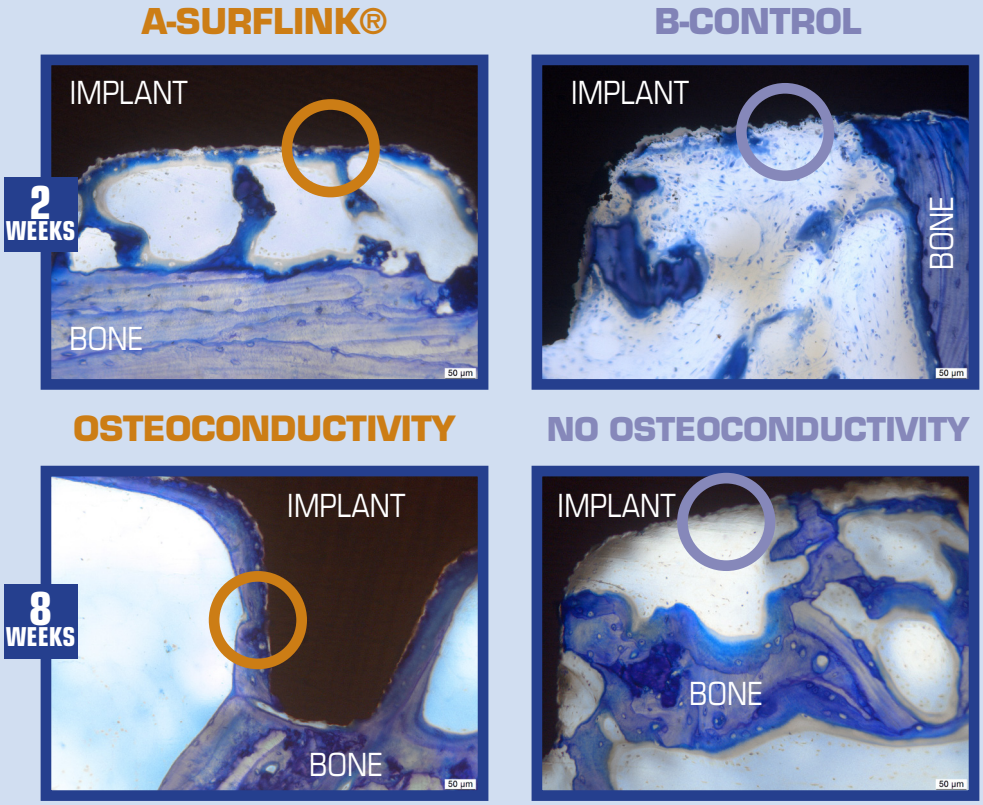

Figure 4 High magnification of histology slides of osteoconductive SurfLink® treated implants (A) and non osteoconductive untreated control implants (B) after 2 and 8 weeks healing in sheep.

Figure 5 Process of bone formation on a SurfLink® treated implant.

SUPERIOR SURFLINK® CHARACTERISTICS
➔BIOMECHANICAL FIXATION

ENHANCED CLINICAL PERFORMANCE
➔FASTER OSSEOINTEGRATION, SUGGESTING EARLIER LOADING OF THE IMPLANT.

SurfLink® treated and untreated control implants were placed in the pelvis of sheep (Table 1). Following sacrifice at 2, 8 and 52 weeks, the implants were assessed for osseointegration by biomechanical (torque and stiffness) and histological testing (new/old bone and bone to implant contact, BIC).

TABLE 1: SHEEP PELVIS ANIMAL STUDY.

	2 weeks	8 weeks	52 weeks
Sheep	8	8	8
SurfLink® treated implants*	12+12	12+12	12+12
Untreated implants (control)*	12+12	12+12	12+12

All implants used have SLA type roughened surface with or without SurfLink® surface treatment.
*12 implants used for biomechanical analysis and 12 implants used for histological analysis.

TABLE 2 : PAIR-WISE 'SURFLINK® VS. CONTROL' IMPLANTS INTRA-ANIMAL COMPARISON IN SHEEP PELVIS STUDY.

	2 weeks	8 weeks	52 weeks
Torque	+32%	+10%	+ 5%
New/Old bone surrounding implant	+43%	+13%	- 6%
Stiffness	+37%	- 2%	+21%
Trabecular type Bone to Implant contact (BIC)	+ 3%	+ 3%	+39%

From the pair-wise analysis of implants from the same animal, faster osseointegration of SurfLink® implants is indicated by the increase in torque (+32%), new/old bone (+43%) and stiffness (+37%) in comparison to untreated control implants (Table 2). Notably, the increased implant fixation at early time points suggests earlier loading of the implant in a clinical situation (Figure 6).

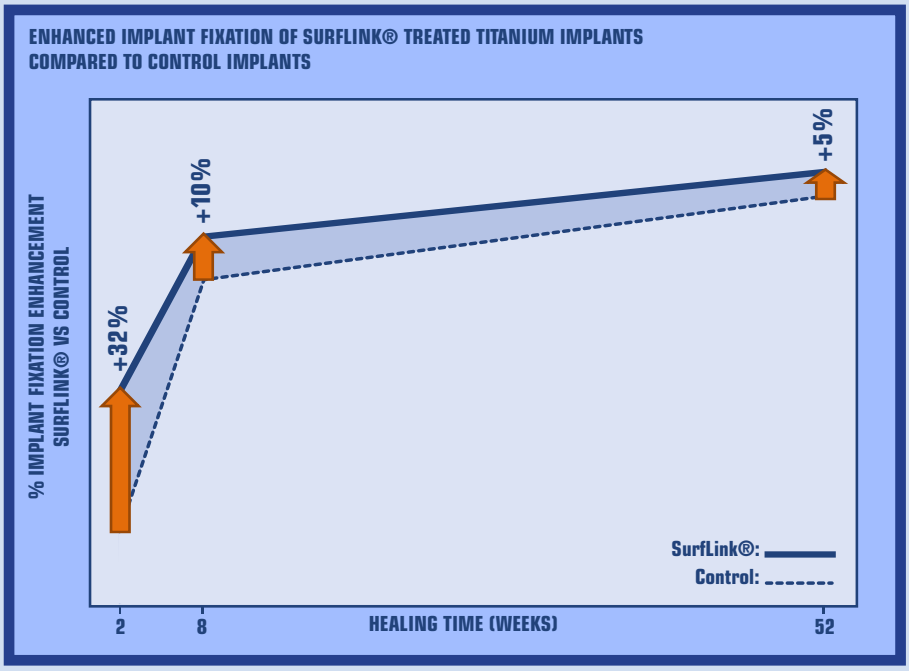

Figure 6 Schematic illustration of the percentage implant fixation enhancement, SurfLink® treated implant (blue line) versus an untreated control implant (dashed blue line).

SUPERIOR SURFLINK® CHARACTERISTICS
➔CHEMICAL BONDING

ENHANCED CLINICAL PERFORMANCE
➔INCREASED IMPLANT FIXATION, LEADING TO ENHANCED LONG-TERM IMPLANT STABILITY

SurfLink® provides a chemical connection between bone and the implant surface, in addition to the mechanical interlocking due to the implant's roughened topography (Figure 7A). This results in increased implant stability in comparison to control implants, which rely on mechanical interlocking alone (Figure 7B).

The permanently attached SurfLink® molecules on the implant surface attract ions, leading to increased protein adsorption and cell adhesion. In an animal study at 52 weeks (Table 2, see section 3 Biomechanical fixation) trabecular bone in contact (BIC) with the implant surface was 39% higher, accounting for the increase in stiffness (+21%) when compared to control implants. As a result, after torque testing a fracture within the bone was observed, rather than at the bone to implant interface as it was observed with control implants.

Increased implant fixation could result in a better load transfer on implants, particularly with smaller diameter implants.

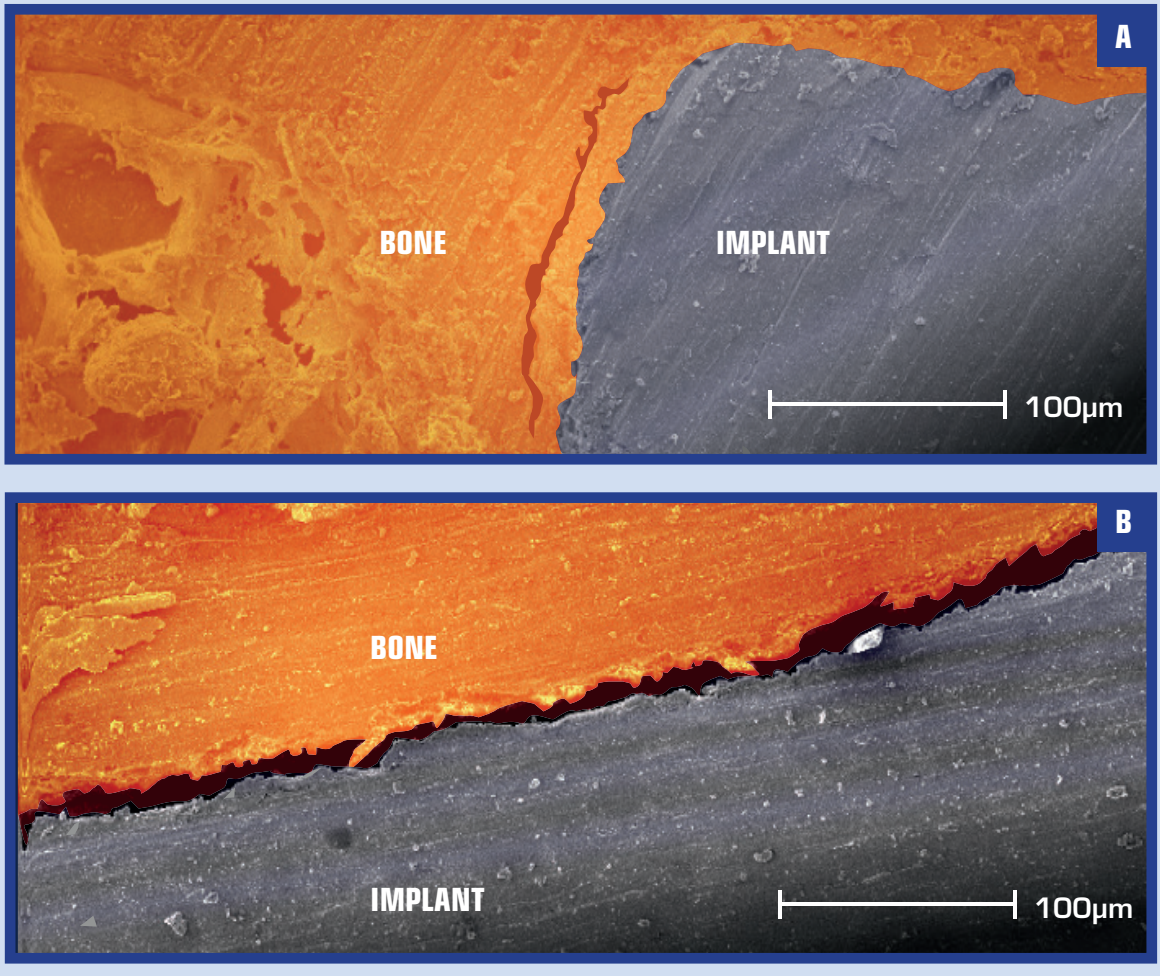

Figure 7 Illustration of sections of implants retrieved after 52 weeks showing fracture within bone on the SurfLink® treated implant (A) rather than at the bone to implant interface, as observed with the control implant (B).

SUPERIOR SURFLINK® CHARACTERISTICS
➔STABILITY IN A PHYSIOLOGICAL ENVIRONMENT

ENHANCED CLINICAL PERFORMANCE
➔EXPECTED INCREASED SHORT AND LONGTERM IMPLANT STABILITY IN NORMAL AND COMPROMISED HEALING SITUATIONS

SurfLink® surface treatment is stable during osseointegration and inflammatory events as well as during remodelling.
The P-C bond in phosphonated molecules, such as SurfLink®, is resistant to chemical and enzymatic hydrolysis.[2]
An *in vitro* study showed that the SurfLink® molecule remains permanently bound to the surface of c.p. titanium Gr. 4 discs between pH 1 and 9 (Figure 8). The range tested covers physiologically relevant conditions which have been reported in the literature.[3-8] In particular SurfLink® is stable in acidic conditions, which occur during bone remodelling (e.g. as low as pH 3-4 in osteoclasts bone resorption[3,4]) or inflammatory events (as low as pH 5.5[6,7]). In comparison, hydroxyapatite becomes increasingly more unstable towards acidic conditions.[9,10]
In a clinical situation, SurfLink® will not leave the implant surface.

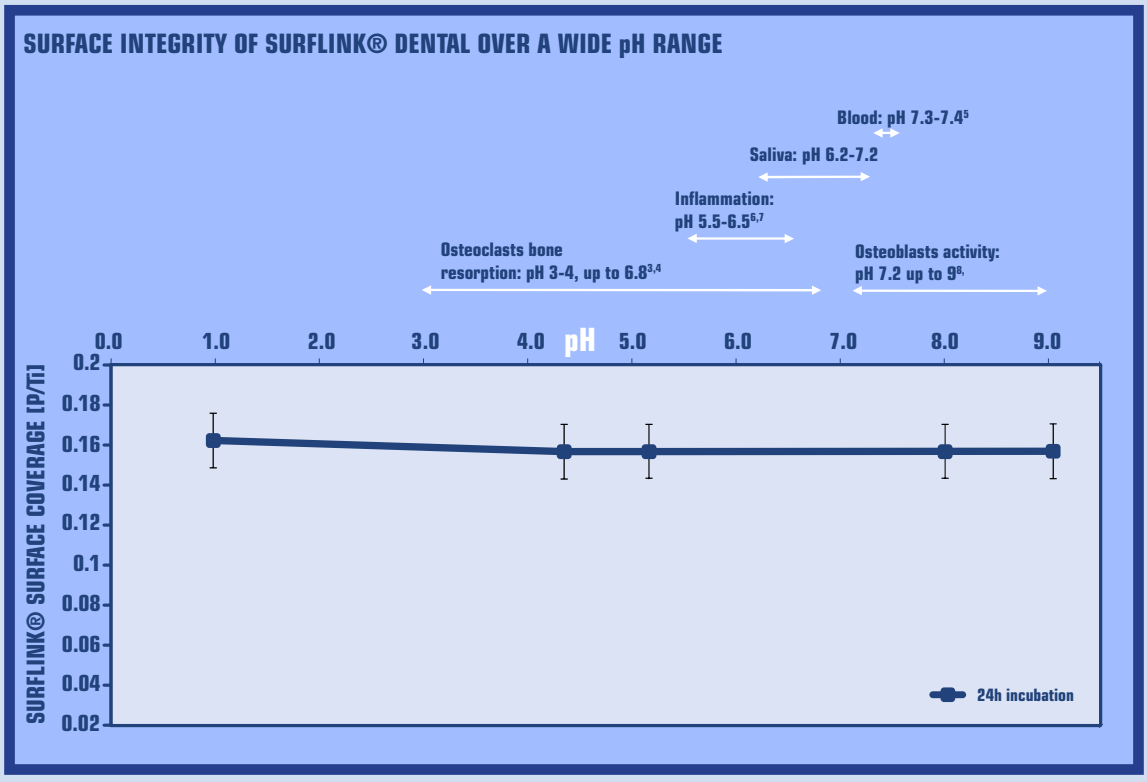

Figure 8 Phosphorous/Metals ('P'/'Metals') atomic concentration ratios measured by X-ray photoelectron spectroscopy (XPS) are plotted as a function of pH and incubation time.
Note: *no significant changes in surface composition were found. SurfLink® remains firmly bound to the implant surface between pH 1 and 9.*

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