Masterclass in Clinical Practice

Dental Implants

with

Dr Vladimir S. Todorovic[3]
Dr Andre W. van Zyl[4]

Implant Surfaces- Current status for success

[3] Vladimir S Todorovic, PhD
Research Associate, School of Dental Medicine, University of Belgrade, Serbia
Private practice, Belgrade, Serbia

[4] Andre W. van Zyl
(BChD) (Stell) MChD (OMP) (Stell)
Private Practice, Hermanus, South Africa

Introduction

The original dental implants developed in the 1960's was turned or machined titanium like any normal screw.

The bone to implant contact (BIC) is determined by how much of the implant outside surface is in direct contact with the surrounding bone and for this reason this surface area has been increased and enhanced over the years to increase implant success. The increased surface area and enhancements may have the following benefits:

1. Increased primary stability during placement of the implant by having increased roughness to engage the bone with higher mechanical interlocking.
2. The roughness increases the surface area for more bone-implant contact for better osseointegration.
3. Better biocompatibility by creating a more friendly surface for the cells to populate to form bone on the implant surface.
4. Improved, shortened healing times by incorporating growth factors onto the implant surface that accelerate bone growth.
5. Lowered risk of infection by incorporating antibiotic agents onto implant surface.
6. Increased wettability may increase protein adherence to the implant surface for quicker and more successful integration.
7. The above factors will lead to better short and long-term success of implant treatment.

Dental implants have become a standard method for replacing lost teeth. This innovative approach began in the 1960s when orthopaedic surgeon Per-Ingvar Brånemark found that bone can grow around and attach to titanium implants. This process, known as "osseointegration" marked the beginning of a new era in dentistry.

A brief history of surface modifications in dental implants

When an implant is placed, it achieves primary stability due to its geometry, which is then followed by the secondary stability as osseointegration takes place. This process takes 6-8 weeks for most implants. The surface area of an implant has an important role in the primary and secondary stability. The implant surface also has a role in the initial biological response after placement and plays an important role in the long-term stability due to enhanced integration. By increasing the surface area through texturing, it increases the bone to implant contact (BIC). The surface enhancement creates a dark matt surface compared to the shiny smooth surface of machined implants (Fig. 1).

Figure 2 shows a micro-focus CT 3D image of a machined Straumann® implant (specially produced for this project by the company) and next to it is a Straumann® BL SLA® implant showing a much rougher surface due to grit-blasting and acid etching.

Figure 3 shows a micro-focus CT image of a Straumann® machined implant merged with a new generation Straumann® SLA® surface implant to show the difference in the surfaces up close.

Figure 1: On the left the implant shows a shiny machined platform, compared to the grit-blasted and acid etched surface on the right which has a matt appearance.

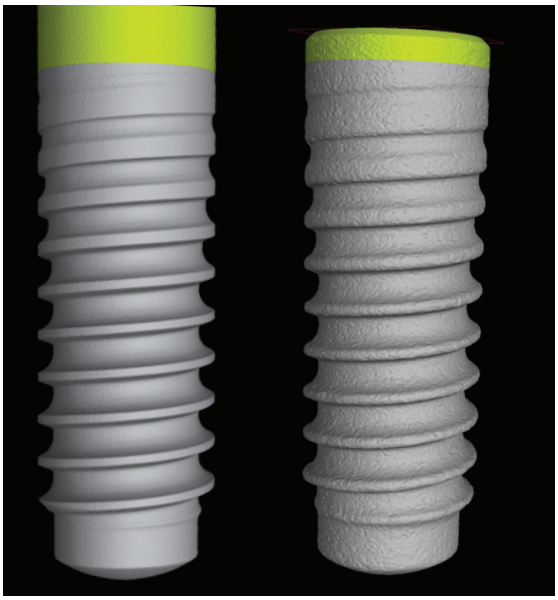

Figure 2: On the left a micro-focus CT 3D scan of a machined Straumann® implant and on the right the commercially available Straumann® implant with the SLA® surface showing a much rougher surface.

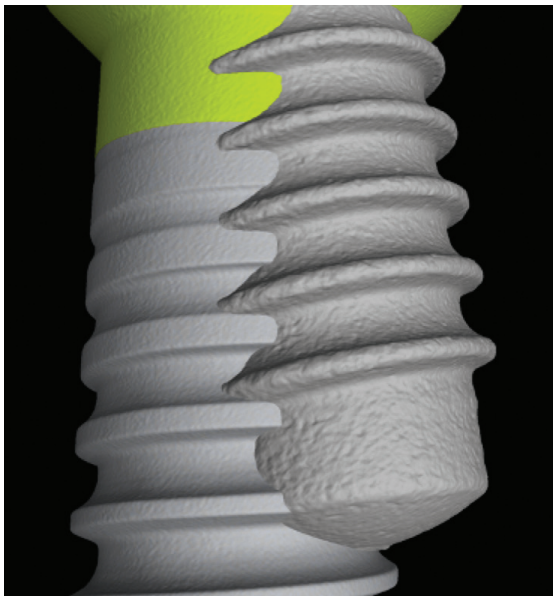

Figure 3: Direct comparison of machined versus SLA® surface with SLA® on the right.

The SLA® surface is rougher due to the texturing from the large-grit sandblasting which gives it a macro-roughness, followed by acid etching which gives it a micro roughness. This surface was pioneered in 1998 and is followed by many manufacturers today. Over the past 2 decades, Straumann® engineered the hydrophilic SLActive® surface which provided accelerated early osseointegration. It starts off as the same process used in SLA® surfaces which is then processed as a highly hydrophilic surface. More recent research suggests that the nanostructures of this surface is partly responsible for the accelerated healing providing 50% more surface than SLA® and 100% more than machined surfaces. The SLActive® surface has also shown anti-inflammatory qualities that benefit the healing process.

When this type of surface is examined under even larger resolution and magnification such as nano-focus CT imaging (Fig. 4), the texturing shows extreme roughness not visible with the naked eye.

Another technique for increasing the surface area for better integration is to increase the thread depth of the implant. This does not necessarily mean a larger diameter implant, but the deeper threads increase the primary stability as well as

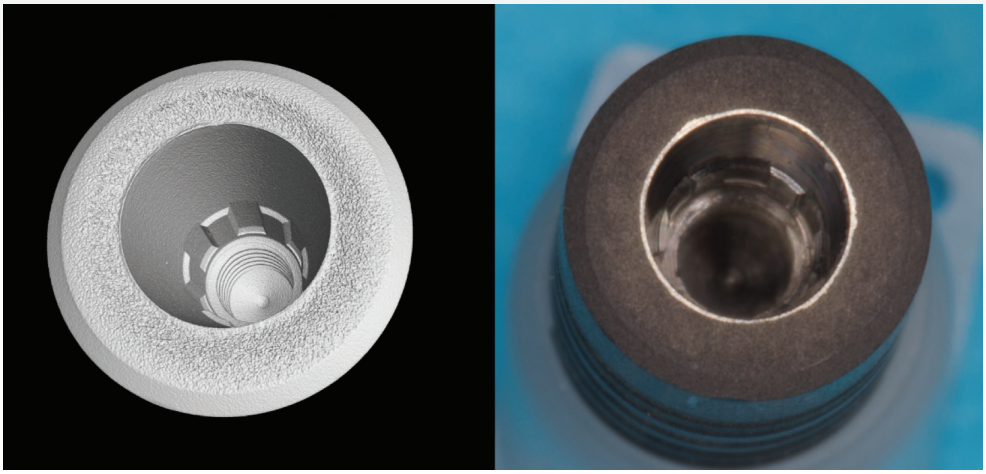

Figure 4 On the left a nano-focus CT 3D image of the Ankylos® implant platform and on the right a photograph of the platform showing the matt appearance of grit-blasted and acid etched treatment.

surface area. This has the advantage that shorter implants can be used in limited poorer quality bone areas such as posterior maxilla (Fig. 5 & 6).

Bone to implant contact – a tissue response.

It is important to understand the process of osseointegration to understand the reasons behind surface enhancements for better integration. Following implantation, peri-implant tissues experience a series of cellular and extracellular reactions at the bone-to-implant interface, ultimately resulting in the implant surface being surrounded by newly formed bone (1). Blood is the first tissue to make contact with the implant surface. Blood cells and inflammatory cells from the damaged vascular tissue infiltrate the tissue gap surrounding the implant. Platelet activation triggers the formation of a clot at the implant-tissue interface, which subsequently serves as a scaffold for osteoconduction, facilitating the migration of osteogenic cells. This osteogenic process is regulated by a variety of growth factors released by blood cells at the bone-to-implant interface and is characterized by two phases:[1] the formation of woven bone through an intramembranous pathway, and the development of lamellar bone on the spicules of woven bone.[2] Newly formed osteoid tissue eventually makes direct contact with the implant surface, facilitating osseointegration. The migration of active osteogenic and mesenchymal cells to the implant surface typically begins within 24 hours post-implantation.[3] The released cytokines play a critical role in signalling cell migration, adhesion, and proliferation, resulting in the deposition of bone proteins over the implant surface, creating a non-collagenous matrix scaffold that regulates cell adhesion and binds with minerals. The matrix formed is initially poorly mineralized bone tissue, and continuous deposition of calcium and phosphate occurs, further enhancing the integration of the implant with the surrounding bone.[4]

Contemporary strategies for enhancing dental implant surfaces

Over the last few decades, extensive research has been conducted on enhancing the surface characteristics of dental implants to improve osseointegration and reduce the risk of peri-implantitis. This involves various surface modification techniques — such as texturization described above, hydrophilization, coatings, and functionalization with molecules or nanoparticles.

Drug-releasing dental implant surfaces, commonly referred to as "smart surfaces," represent a promising technology that combines various surface modification processes with drug delivery systems. These surfaces have multifunctional properties, enabling them to perform multiple biological functions. Techniques such as micro-/nano-topography and coated surfaces are integrated with pharmacological agents, including antibiotics and analgesics, to facilitate local drug delivery at the healing interface of dental implants. This approach aims to provide antibacterial effects, accelerate bone formation, and reduce inflammation.[5] Research has demonstrated that the application of calcium phosphates, bisphosphonates, and bone morphogenetic proteins (BMPs) at the dental implant interface significantly enhances osseointegration without causing adverse effects such as cytotoxicity.[6] Additionally, antibiotic-loaded

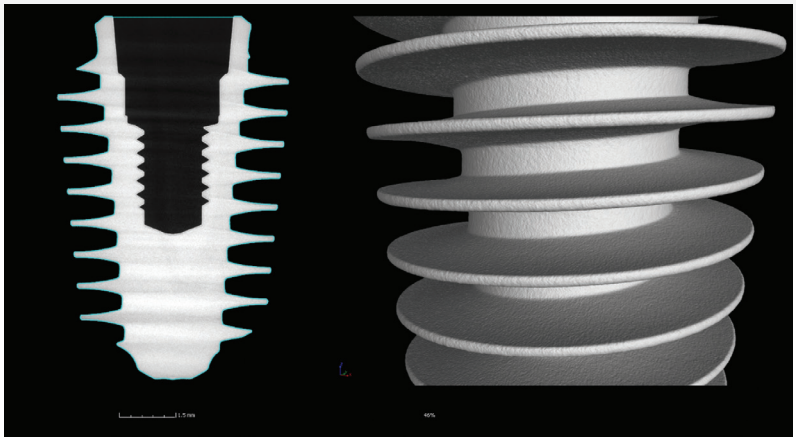

Figure 5: Deep threads of a Megagen® Implant as seen on micro-focus CT image on the left and the micro-focus CT 3D image on the right.

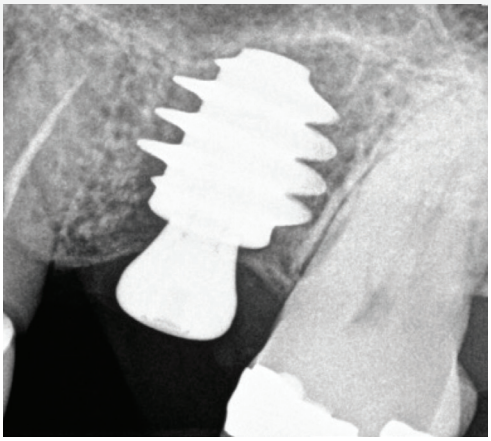

Figure 6: Radiograph of a 7mm Megagen® implant underneath the maxillary sinus. Deep threads giving enough surface area for integration enabling the short implant instead of sinus floor elevation with a conventional implant.

surfaces have proven highly effective in preventing bacterial contamination. These modified surfaces have the potential to reduce the rate of early implant loss and foster a more favourable environment for osseointegration, especially in medically compromised patients who experience altered healing.

However, the development of these pharmacological devices has a long way to go before they are approved for commercial use, as they must meet strict safety requirements. Currently, dental implants equipped with drug delivery systems and advanced coatings are not available on the market. However, promising results from ongoing research may lead to revolutionary advances in dentistry and implant therapy in the near future.[7]

Conclusion

Surface enhancements to increase surface area such as grit-blasting and acid etching has increased the success rates of short implants and thereby increasing the options for short implants instead of bone augmentation for longer implant placement.

It will be a while before we see incorporation of growth factors and anti-bacterial agents onto implant surfaces as the norm.

Innovative geometry changes have also helped to make short implants a viable option in limited bone volume situations.

We can expect more developments in the years ahead to improve success rates of dental implants.

References

1. Babu RA, Ogle O. Tissue response: biomaterials, dental implants, and compromised osseous tissue. Dent Clin North Am. 2015;59(2):305-15.

2. Berglundh T, Abrahamsson I, Lang NP, Lindhe J. De novo alveolar bone formation adjacent to endosseous implants. Clin Oral Implants Res. 2003;14(3):251-62.

3. Meyer U, Joos U, Mythili J, Stamm T, Hohoff A, Fillies T, et al. Ultrastructural characterization of the implant/bone interface of immediately loaded dental implants. Biomaterials. 2004;25(10):1959-67.

4. Murai K, Takeshita F, Ayukawa Y, Kiyoshima T, Suetsugu T, Tanaka T. Light and electron microscopic studies of bone-titanium interface in the tibiae of young and mature rats. J Biomed Mater Res. 1996;30(4):523-33.

5. Kunrath MF, Garaicoa-Pazmino C, Giraldo-Osorno PM, Haj Mustafa A, Dahlin C, Larsson L, et al. Implant surface modifications and their impact on osseointegration and peri-implant diseases through epigenetic changes: A scoping review. J Periodontal Res. 2024;59(6):1095-114.

6. Alenezi A, Chrcanovic B, Wennerberg A. Effects of Local Drug and Chemical Compound Delivery on Bone Regeneration Around Dental Implants in Animal Models: A Systematic Review and Meta-Analysis. Int J Oral Maxillofac Implants. 2018;33(1):e1-e18.

7. Kunrath MF, Shah FA, Dahlin C. Bench-to-bedside: Feasibility of nano-engineered and drug-delivery biomaterials for bone-anchored implants and periodontal applications. Mater Today Bio. 2023;18:100540.