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UV Photo-Functionalised Implants – Does It Really Work?

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Abstract

Achieving predictable osseointegration remains challenging in compromised bone. Ultraviolet (UV) photo-functionalisation of titanium dental implants has emerged as a promising strategy to enhance early bone–implant interactions. This case series evaluated the clinical performance of UV-treated implants placed in sites with reduced bone quality and healing capacity. Photofunctionalisation was performed immediately prior to implant placement to modify the surface physicochemical properties of titanium. Clinical outcomes, including implant stability, healing progression, and early osseointegration, were assessed during follow-up. UV-treated implants demonstrated rapid establishment of secondary stability, shortened healing times, and favourable bone–implant contact despite challenging local conditions. No implant failures were recorded during the observation period. These findings indicate that UV photofunctionalisation may enhance early osseointegration and improve treatment predictability in compromised bone. This technique represents a simple, chairside adjunct that may broaden the clinical indications for implant therapy in patients with limited bone quality.

Keywords

UV Photo-Functionalised Implants; UV-photofunctionalisation procedure; Super-hydrophilicity; Electrostatic charge; Antibacterial.

Introduction

A smile is the prettiest thing you can wear. A beautiful smile goes a long way to making a good impression. However, when a tooth or teeth are lost, the effect can be catastrophic. The loss of teeth greatly affects the self-confidence in individuals and can result in significant disabilities that disrupts the social activities and psychological well-being on the individual. Some individuals go as far as completely avoiding any social interactions to avoid embarrassment, which tend to lead to isolation and depression over a long period [1-3].

Figure 1: The top image shows the patient with a missing upper right central incisor. The patient came in with a lack of confidence to smile in a social setting, and had requested a permanent alternative to replace his missing tooth. The bottom image shows the patient with his upper right central incisor replaced with an implant-retained dental crown.

Historically, missing dentition is treated with removable or fixed prostheses, such as dentures or dental bridges. However, how many times have we heard of the patients' dissatisfaction with dentures? Patients complain of the poor retention, the poor stability, the pain and discomfort, and most of all, the fear of the denture falling off in front of other people. How many times have we heard a patient say they keep getting food stuck under their bridges?

Figure 2: The image is from the movie "Mrs Doubtfire, 1993". The image shows how a denture may lose its retention during a social setting.

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Figure 3: The top image shows the patient as first presentation. The patient presented with maxillary and mandibular full dentures. The chief complaint was the loss in confidence to smile and eat. The bottom image showed the patient with fixed implant-retained bridges for his maxillary and mandibular arches.

As the dental industry advances, the need to replace dentition with a more natural replacement has led us to dental implants [1]. Dental implant therapy is a reliable treatment option to replace dentition in partially or fully edentulous patients, and have shown to have success rates of more than 95% over ten years [4].

History of Implants

Brånemark first described the process of osseointegration in 1971 [5]. Osseointegration is the osseous bonding process of the host bone to the titanium implant surface [6].

This resembles the physiological processes as such in direct fracture healing, involving cellular and plasmatic homeostasis, leading to fibrin polymerisation, and then blood clot formation. This serves as a scaffold for neo-angiogenesis, extracellular matrix attachment, and the introduction of bone-forming progenitor cells [6]. New bone is formed by contact osteogenesis or distant osteogenesis. Distance osteogenesis occurs by osteoblast migration to the surface of the surgical cavity, where it differentiates to form new bone. Contact osteogenesis occurs by osteogenic cells migrating directly onto the implant surface and differentiate here [6].

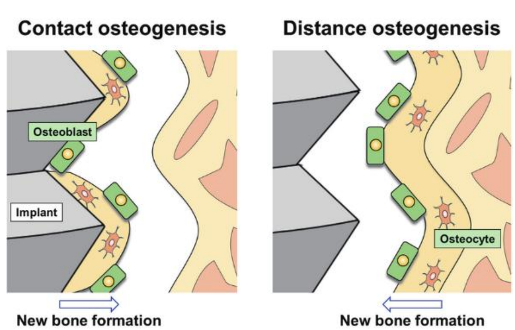

Figure 4: The comparison of contact osteogenesis vs distance osteogenesis. Picture courtesy of Kondo et al. 2024.

As dental implant treatment advance over the years, we ask ourselves, how can we improve the treatment, and how can we speed up the process?

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How is implant stability achieved?

Implant stability is achieved in two stages, i.e. primary and secondary stability. Primary stability is obtained at the time of implant placement, which mechanically obtained via friction between the implant fixture thread and the osseous bone, whilst the secondary stability starts 2 weeks post implant placement and is achieved biologically, i.e. by bone mineral deposition onto the implant surface [7].

The graph below was described by Raghavendra et al., which shows the gradual changes of the primary and the secondary stability of an implant placed in bone. The total stability is based on the amount of primary and secondary stability present, and it is shown that the lowest stability is at the 2 to 4 weeks post implant placement period [8].

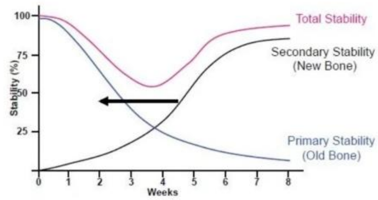

Figure 5: The graph by Raghavendra et al. showing the primary stability, secondary stability and the total stability by percentage against time (weeks). Picture courtesy from Raghavendra et al. 2005 [8].

If we were able to move the secondary stability curve towards the left, we inadvertently reduce the dip in total implant stability. Thus, research efforts have been focused in trying to speed up the secondary stability of dental implants.

Factors to accelerate secondary stability

Some of the methods that have been investigated to improve the secondary stability include:

1. Changing the local factors, e.g. by radiation, by changing the thickness of the titanium oxide layer, by corrosion, by subjection to an electric field, etc
2. Physical therapy, e.g. by vibration stimulation, etc
3. Drug therapy
4. Implant surface modification
5. Using different implant fixture and components materials. as well as the use of concentrated growth factors (CGF).

However, they have all shown limited applications or unsatisfactory outcomes [5]. The ultrasonic treatment has shown to damage to the implant surface, which affected the attachment of the human osteoblast-like cells onto the titanium surface [9]. The surface treatment processes like polished implant surfaces and plasma sprayed implant surfaces showed a decrease in alkaline phosphatase activities, which affected the growth and metabolic activity of the osteoblast-like cells [10,11]. Another surface treatment; clinically applied surface coatings, e.g. calcium phosphate, are designed to promote osteogenesis between the bone and the coating but the coating is prone to peeling and degradation from the titanium surface, leading to unsatisfactory outcomes to long-term osseointegration [12]. CGF has promising results with bone regeneration without the need for a secondary surgery, such as obtaining autograft bone from a separate site intra- or extra-orally, however, the lack of patients' cooperation to have blood drawn can be a hindrance [5].

UV photo-functionalisation

In this article, we discuss UV photo-functionalisation; which is the surface modification of the titanium implant surface by UV treatment. Titanium is originally a bio-inert material that does not interact directly with cells and biomolecules [13]. But with UV photo-functionalisation, this changes with the alteration of the physicochemical properties and biologic capabilities of the titanium [14,15,16].

UV-photofunctionalisation procedure

UV is a non-visible, high-frequency, short-wavelength light that is naturally radiated from the sun [17]. The procedure of UV photo-functionalisation is relatively straightforward, yet yields significant benefits. With the newer UV machines, this can even be done chairside. The host site is first prepared with the standard osteotomy procedures. Just prior to fixture placement, the fixture is taken out from its container with the handpiece fixture driver, and placed into the chairside UV machine, or in some machines, the container itself is placed into the machine. The UV photo-functionalisation process then starts depending on the preset time cycle of the UV machine used, e.g. as low as 16 seconds [18]. The treated titanium fixture is then directly placed into the osteotomy site, either with the handpiece or torque wrench.

Figure 6: Examples of chairside UV photo-functionalisation machines. Left – UV Activator by DIO. Right – Actilink Reborn by Plasmapp.

Figure 7: Visible UV light radiation on the titanium fixture with the Actilink Reborn by Plasmapp.

The UV photo-functionalisation of the titanium dental implants was described to move the graph curve, as described by Raghavendra et al. towards the left [8,19]. This can imply that UV photo-functionalisation

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can speed up the implant treatment process and reduce the chance of implant failure, by hastening the secondary stability.

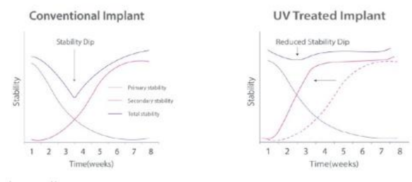

Figure 7: Left graph shows the primary, secondary and total stability against time for conventional implants. Right graph shows the altered secondary and total stability in UV photo-functionalised implants. Note the difference in stability dip. Figure courtesy of Funato et al. 2013 [19].

Effect of UV Photo-functionalisation on Implant properties

How does UV photo-functionalisation alter the physicochemical and biologic properties of the titanium implants? The three phenomenon that will be discussed in this article is super-hydrophilicity, electrostatic charge, and antibacterial properties.

Super-hydrophilicity

Regardless of surface topography, titanium implants are the lose their hydrophilicity and become hydrophobic or hydrorepellant over time. The extend of wettability is commonly assessed by measuring the contact angle of water [7]. The categories of the contact angle are: superhydrophilic 0° < θ < 10°, hydrophilic 10° < θ < 30°, hydrophobic 30° < θ < 90°, and hydrorepellant θ > 90°.8 UV photo-functionalisation has been described to not only rejuvenate the hydrophilicity of dental implants but can actually induce super-hydrophilicity, which promotes faster osseointegration, and thus leading to an increase in bone-implant contact (BIC) ratio [20,21].

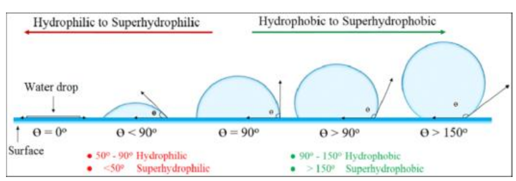

Figure 8: Ranges of contact angles of water. Photo courtesy of Sawase et al. 2008 [16].

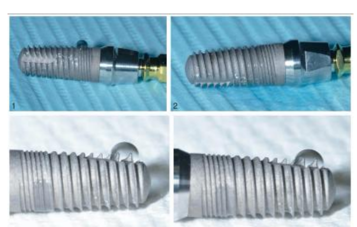

Figure 9: Image 1 shows a water bead that does not spread and remains in a spherical shape. Image 2 shows the spreading of the water bead, which is close to 0 degrees, after the titanium implant has undergone UV photo-functionalisation. Images 3 and 4 shows the non-UV-treated dental implants and how the water bead remained in the hemi-spherical shape even after 5 minutes. Figure courtesy of Funato et al. 2013 [19].

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Electrostatic charge

UV photo-functionalisation alters the electrostatic state of the titanium dioxide, by the reduction of Ti4+ to Ti3+. This causes the superficial layer of TiO2 energy to become more electropositive, making it a direct attractant for cells. This leads to an increase in protein adsorption, increase in osteoblast migration, increase in osteoblast affinity, increase in osteoblast spread, increase in osteoblast proliferation, and increase in osteoblast differentiation [22,23]. The ability to increase osteoblastic proliferation without decreasing osteoblast differentiation translates to an approximate two-fold increase in bone volume around the UV-treated titanium implant surfaces, while also speed up the magnitude of osseointegration by 2.5 to 3-folds 2 weeks post implant placement [22,24].

Puisys et al. described that the BIC ratio at the end of the bone remodelling phase after implant placement to be about 60-70% under a light microscope [20], Funato et al. claimed that UV photo-functionalisation of titanium implants lead to rapid and complete establishment of osseointegration with nearly 100% BIC in animal models [7].

In comparison to non-UV-treated implant surfaces, the bone morphology around the UV-treated titanium implants is observed to change significantly, which allow for more rapid and stable osseointegration.

New bone formation occurred extensively on UV-treated implants with virtually no intervention by soft tissue, maximising bone–implant contact up to nearly 100% 4 weeks after implant placement [22,25].

UV photo-functionalisation also induced contact osteogenesis, whereby osteogenic cells migrate directly onto the implant surface and differentiate here, so that new bone formation is observed on the titanium implant interface, and de novo bone is observed to be adjacent to the circumference of the titanium implant surface [7]. Bone formation in non-UV-treated implants, on the other hand, consisted mainly of bone formation by distant osteogenesis, whereby bone started from the implant preparation cavity, leaving the implant interface almost bone-free.

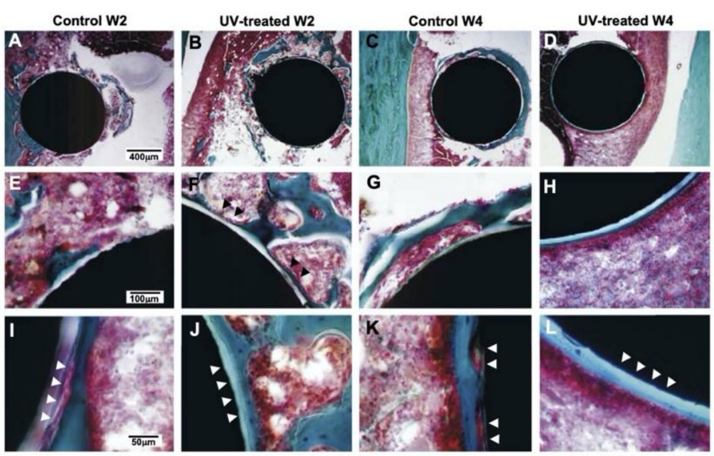

Figure 10: The figure shows the difference in peri-implant bone generation histologically. It compares non-UV-treated and UV-treatment titanium implants 2 weeks and 4 weeks post implant placement. In the UV-treated samples, it was evident that there was vigorous bone formation around the UV-treated implant surfaces that also prevented soft tissue interposition between bone and implant surfaces. Photo courtesy of Aita et al. 2009 [26].

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Antibacterial

Compared to orthopaedic implants that are normally completely submerged in sterile tissue, dental implants are placed trans-mucosally, i.e. the upper portion of the dental implant is exposed to the oral cavity, exposing it to over 600 different bacterial species [27].

Bacterial contamination is a concern during dental implant placements. When bacteria adhere to the titanium surface, peri-prosthetic biofilm layers made up of proteins and polysaccharides that are highly resistant to antimicrobial therapy are formed. This can lead to localized infections or even systemic infections [28]. If bacterial adhesion occurs before tissue repair, the body's host defence cannot prevent surface colonization, biofilm formation and bacterial adhesion [29].

Dental implants are the most susceptible to these in the first 6 hours of implant placement [30] When the titanium implant is treated with UV photo-functionalisation just prior to placement, the reduction in bacterial attachment and biofilm formation on the titanium surface can be sustained for up to 16 hours [30]. This prolonged protective property against bacterial contamination, in combination with the enhancement of osteoblastic cell attachment and proliferation, not only greatly promote implant osseointegration but shows the ability to reduce the risk of implant loss due to bacterial adhesion [11,17,31,32].

UV photo-functionalisation effect is not limited to the implant fixture surfaces only. The junction between the implant abutment to fixture connections may also harvest pathogenic bacteria that could lead to peri-implant infections. Therefore, the use of UV treatment on implant abutments can reduce the bacterial adhesion in this location and, hence, help improve the implant survival rate over time [15].

Summary and Conclusion

UV photo-functionalisation is a simple procedure and is low in cost and has been proven effective on all types of titanium surfaces. There has been a study that has investigated whether the increase of the BIC ratio from UV photo-functionalisation could overcome the limitations for shorter implants [16]. If possible, the use of shorter implants can result in less invasive implant surgeries, less surgical complications, less morbidity, and less cost for patients. For example, the use of shorter implants can avoid the necessity of the pre-implantation surgery, such as sinus floor elevation or bone augmentation to avoid vital structures. UV photo-functionalisation has also been seen to improve the biocompatibility of biological bone substitutes and barrier membranes. The possibilities from UV photo-functionalisation should be explored further to investigate its capabilities.

We have to also keep in mind that UV photo-functionalisation expediates the initial stability of dental implants, however, it does not improve the overall stability once osseointegration is fully achieved.

Acknowledgements

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