Efficacy and Clinical Utilization of UV Activated Implant

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Ⅰ. Efficacy of UV Activated Implant

Since the development of implants the technology for processing the implant surface has been researched and developed continuously in the methods of not only increasing the physical surface area but also biological stability of the implant. However, it was discerned that biological aging phenomenon, which hinders the usion of the bone and the implant occurs over time through the adhesion of organic matters such as hydrocarbon, etc. in the air onto the implant surface. Accordingly, ultraviolet (UV) ray activating implant method using photo-catalysis technology, that is used widely in general industries, has been researched continuously since several years ago in order to solve such problem.

In consideration of our society in recent years with increase in the demands and increase in more challenging implant surgeries due to rapid aging of the population, it is undeniable that general dental clinicians would find it very interesting and intriguing that with UV activated implants, it is not only possible to shorten synostosis period but also increase synostosis between the implant and the bones, which can also be used in difficult cases including those with inadequate bone density or immediate loading after tooth extraction, etc.

This paper is aimed at examining the clinical utilization of UV Activated implant, beginning with theoretical considerations of the UV Activated implant, as a means of overcoming the limitations of surface processing of implants.

1. Implant surface processing and biological aging phenomenon

Unlike the esorbable Blasting Media (RBM) surface processing in the format of physically increasing the surface area of implant through pressurized spraying of hydroxyapatite powder onto pure titanium surface of the implant, Sandblasted with Large grit and Acid etched (SLA) processing in which the surface area of the implant is increased by pressurized spraying of alumina powder along with etching of the surface with strong high temperature acid will turn the implant surface into a state that can promote osteogenesis through formation of TiO_2, that is, oxide film on the surface.

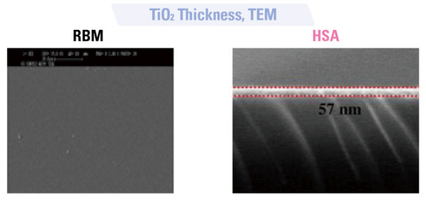
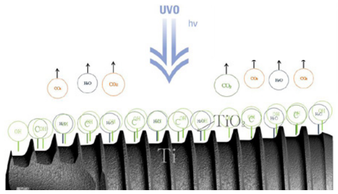


Fig.1 Martin Andersson, Department of Chemical and Biological Engineering, Applied Chemistry, Chalmers University of Technology, Gothenburg, Sweden, In vivo biomechanical stability of osseointegrating mesoporous TiO_2 implants, Acta Biomaterialia 8 (2012) 4438-4446

When the RBM surface processing in the left image is compared with the SLA (HSA) surface processing in the right image of Fig. 1, it can be seen that the SLA surface processed titanium on the right is in the state with formation of TiO_2 film on the surface. However, even the implant that has undergone such surface processing will experience occurrence of biological aging phenomenon (Biologic Aging) that hinders synostosis of the implant and the bones due to the adhesion of organic substances in the air such as hydrocarbon in about a month time. Through research on such phenomenon, Professor Ogawa of UCLA, USA has been proving that it is possible to solve the biological aging phenomenon on the implant surface through mercury UV ray Activation since several years ago. It was demonstrated that organic substances such as hydrocarbon is removed from the UV Activated implant surface, thereby resulting in the improvement of bio-affinity through exposure of the TiO_2 film on the implant surface.

2. Principle of photo-catalysis of UV implant

First, principle of photo-catalysis that removes organic substances such as hydrocarbon from the implant surface and converts the property of implant surface from hydrophobic to hydrophilic through UV Activation will be examined.



Radical Reaction

$O_3 + h\nu(\lambda < 310nm) \rightarrow O_2 + O(^1D)$
$O(^1D) + H_2O \rightarrow 2OH$
$2OH + C + O_2 + H_2O \rightarrow 2OH + CO_2 + H_2O$

Fig.2 Radical Reaction that manifests when titanium surface is UV Activated(Source: DIO R&D Institute)

When the implant surface is UV Activated, ozone occurs. However, ozone is immediately disintegrated and disappears at the UV wavelength of less than 310nm and there is no ozone related hazard. When TiO_2 film on the SLA processed implant surface is UV Activated, electron (e-) and proton (h+) pair is released to combine with oxygen (O2) and water (H2O) in the air, respectively, to generate 2 types of activated oxygen made up of superoxide anion (O2-) and hydroxyl radical (· OH). Since these activated oxygen has strong oxidizing power, it binds with C atom of organic substances such as hydrocarbon adhered to the implant surface before evaporating as CO2, thereby resulting in clean implant surface. In this process, the electrical property of the implant surface converts from negative to positive charge with the implant surface becoming hydrophilic and immediately absorbing moisture that comes in contact.

3. Changes in the properties of the implant surface after UV Activation

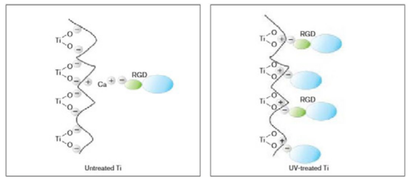


Fig.3 (Left) Mutual static electricity action between the ion and protein (green) and cell (blue) displayed on TiO_2 film without UV Activation. Ordinary TiO_2 film surface has negative charge. Since protein and cell also has negative charge, protein and cell can bind with the TiO_2 film surface only if there is presence of divalent cation such as Ca_2+. (Right) Direct mutual static electricity action with cell (blue) on the UV Activated TiO_2 film. Since the UV Activated TiO_2 film surface has positive charge, it can bind directly with protein or cell with negative charge.(Ultraviolet Photo functionalization of Titanium Implants/ Takahio Ogawa, 2014)

When the implant surface is UV Activated, the implant surface becomes hydrophilic and will be able to absorb blood more quickly. In addition, the electrical property of the surface converts from 'negative' to 'positive' to draw in nutrients such as protein or minerals, etc. that forms bones with 'negative' charge towards the implant surface. Such phenomenon enables quick and stable synostosis to increase the implant success rate even in difficult cases with poor bone conditions or tooth extraction case, etc.

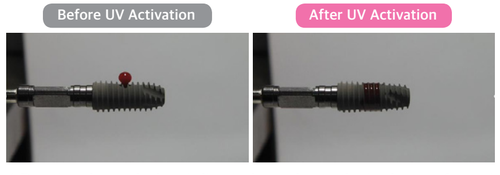


Fig.4 Reaction observed when iodine is dropped onto the implant surface prior o and after UV Activation
(Source: DIO R&D Institute)

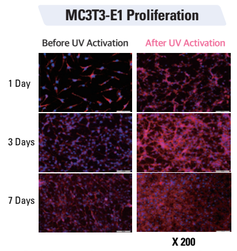
In the left image of Fig. 4, iodine was dropped onto the implant surface prior to UV Activation while iodine was dropped after UV Activation in the right image. While iodine remains on the implant surface in water drop shape in the left image, it can be seen that iodine is absorbed into the surface as soon as it is dropped in the right image.

Fig.5 Reaction when the implant is immersed in real blood prior to and after the UV Activation (Source: DIO R&D Institute)

As it can be seen in the Fig. 5 on the experiment of immersing 2 implants, one with UV Activation and the other without UV Activation, into blood collected from a male in 30' s, while the implant without UV Activation repels the blood in the surrounding due to the hydrophobicity of the implant surface, UV Activated implant surface pulls in the blood in the surrounding due to its hydrophilicity.

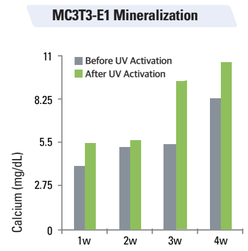
In Vitro Test-Cell proliferation experiment prior to and after UV Activation (College of Dentistry of Kyunghee University)

Cell proliferation experiment was executed by utilizing MC3T3-E1 cell line (mouse osteoblast cells) for the control group with SLA surface processed titanium disk with diameter of 10mm and the experimental group with SLA surface processed titanium disk with diameter of 10mm, which has been UV Activated.



Rapid increase in cell growth rate after 3 days on the UV Activated disk

Fig.6 MC3T3-E1 Proliferation prior to and after UV Activation



UV displayed rapid increase in the ability to generate bones within 2~3 weeks

Fig.7 MC3T3-E1 Mineralization prior to and after UV Activation

As it can be seen in the Fig. 6 above, there was rapid increase in cell proliferation on the UV Activated Titanium Disk from the 3rd day after the commencement of the experiment in comparison to the control group without UV Activation. Based on the result of increase in the proliferation of osteoblast cells on the UV Activated Titanium Disk in comparison to Disk without UV Activation, it can be discerned that UV Activation has marked effect on osteoblast cells.
Based on the results of experiment on osseo-mineralization by using SLA surface processed titanium disk with the same cell line, it can be confirmed that while the SLA surface processed titanium disk displayed increase in osseo-mineralization rate after 3 weeks, UV Activated titanium disk displayed rapid increase in the osseo-mineralization rate 2 weeks after the commencement of the experiment.

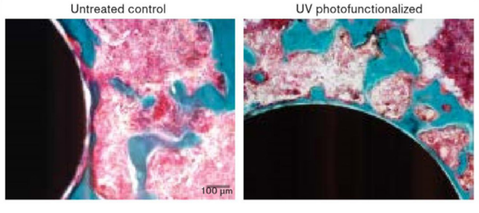


Fig.8 Evidence of increased peri-implant bone generation promoted by UV functionalization. These histologic images show peri-implant tissue at 2 weeks postimplantation in a rat femur model with and without UV treatment (Goldner trichrome)

As illustrated in the Fig. 8 above, while the UV Activated implant displays distinct difference in the osteogenesis process, areas around the implant without UV Activated have partial and localized osteogenesis. On the other hand, it can be confirmed that osteogenesis was induced extensively in the areas around the UV Activated implant without the intervention of soft tissues. In the biodynamic test with experimental mouse model, UV Activated implant had BIC of 72% 2 weeks after the loading of the implant, which is 2.5 times higher than the control group without UV Activation. BIC increased to 98.2% 4 weeks later, which is approximately 2 times higher than that of the control group at 53%. Through these results, it can be discerned that UV photo activation not only accelerates the synostosis process but also increases the quantity of osteogenesis. (Ultraviolet Photo functionalization of Titanium Implants/ Takahio Ogawa, 2014)

4. Success rate, healing time and stability of UV Activated implant

In 2014, Professors Akiyoshi Eunato, Masahiro Yamada and Takahiro Ogawa, etc. analyzed 95 patients who underwent 222 cases ordinary implant procedure and 70 patients who underwent 168 cases of UV Activated implant procedure over a period of 2.5 years. More than 90% of the implant procedures in both groups were difficult case that required stepwise or simultaneous surgeries.

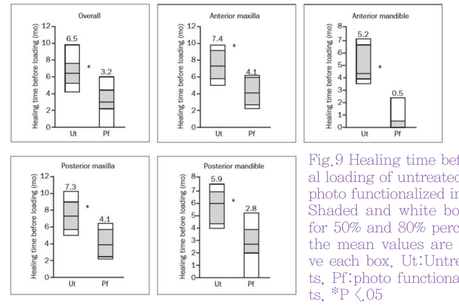


Fig.9 Healing time before functional loading of untreated and photo functionalized implants. Shaded and white boxes account for 50% and 80% percentile, while the mean values are denoted above each box. Ut:Untreated implants, Pf:photo functionalized implants, *P <.05

As the results of the research, loading of photo activated implant displayed high success rate of 97.6 % with 3.2 months needed for healing up to the time of loading, which is a substantial reduction in comparison to 6.5 months for the control group, as illustrated in the Fig. 9 above.

Table1 ISQ Change and Increase for Photofunctionalized Implants

Primary stability range	Implants	ISQ		
		At placement (ISQi)	At loading	Increase/m
ISQi < 40	3	37.7 ± 2.3	63.0 ± 7.5**	4.6 ± 0.4
ISQi 40–49	8	47.6 ± 1.8	73.8 ± 8.6***	8.7 ± 4.1
ISQi 50–59	13	56.1 ± 2.7	66.8 ± 8.7***	2.6 ± 2.4
ISQi 60–69	18	66.5 ± 2.6	70.5 ± 12.4^{NS}	NA
ISQi 60–64	4	62.8 ± 1.5	74.0 ± 7.2*	2.0 ± 1.5
ISQi 65–69	14	67.6 ± 1.5	69.5 ± 13.5^{NS}	NA
ISQi 70–79	33	76.1 ± 1.9	72.4 ± 11.5^{NS}	NA
ISQi ≥ 80	24	82.7 ± 1.9	80.4 ± 6.1^{NS}	NA

ISQi 60–69 was subdivided into ISQi 60–64 and 65–59 groups to precisely determine threshold of significant change in ISQ at loading.
Statistically significant differences between time points; *P < .05; **P < .01; ***P < .001; NS: not significant.
ISQi: initial ISQ at implant placement; NA: not applicable.

The increase in the ISQ value of photo activated implant was in the range of 2.0~8.7 every month, which is higher than the increase in the ISQ value of control group in the range of -1.8~2.8 stated in literatures.

Table 2 Implant Data

	Overall implant length			Implant diameter		Complex cases	
	Mean (mm)	≤ 10 mm (%)	≥ 13 mm (%)	Mean (mm)	≥ 5 mm (%)	Implant length (mm)	Implant diameter (mm)
Untreated implants (n = 222)	12.04 ± 1.69	56 (25.2)	109 (49.1)	4.71 ± 0.75	123 (55.4)	12.20 ± 1.65	4.64 ± 0.73
Photofunctionalized implants (n = 168)	11.76 ± 1.69^{NS}	63 (37.5)	72 (42.9)	4.51 ± 0.71**	66 (39.3)	11.71 ± 1.30*	4.50 ± 0.76^{NS}

Statistically significant differences between untreated and photofunctionalized groups: *P < .05, **P < .01, NS: not significant.

The photo activated group used implant with length of less than 10mm more extensively and the diameter of the implant used was smaller in comparison to that of the control group on the average. In conclusion, in spite of the use of the implant with shorter length and smaller diameter more often, it was possible to use quicker loading protocol without having to decrease the success rate through photo activation. This is associated with the speed of increase in the stability of the photo activated implant. This result suggests that photo activation can provide new and realistic method for further advancement of implant procedure. (Success Rate, Healing Time, and Implant Stability of Photo functionalized Dental Implants / Akiyoshi Eunato, Masahiro Yamada, Takahiro Ogawa, 2014)