Efficacy and Clinical Utilization of UV Activated Implant

Ⅵ. UV Activation implant! Means of overcoming the limitations of surface processing

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Ⅵ. UV Activation implant! Means of overcoming the limitations of surface processing

There is increase in the demands for implant with availability of health insurance for implant for those over the age of 65 years and continuing aging of the population. Accordingly, implant surface processing technologies to increase the implant success rate is further advancing with the relative reduction on the concerns for implant synostosis in comparison to the past. Sandblasted with large grit and Acid Etched (SLA) format is the most generalized surface processing format being applied to almost all implants, which has been evaluated as having achieved enhancement of mechanical surface area and optimized biological stability. However, it has the disadvantage of the occurrence of biological aging phenomenon that interferes with synostosis due to the attachment of organic matters such as hydrocarbon in the air onto the implant surface with the passage of time. In order to improve such disadvantages, superviolet (UV) Activation implant using UV photo-catalysis technology is being introduced recently. It appears to be effective since it can generate super-hydrophilic surface, increase the level of synostosis to induce better embedding of implant even in a diverse range of difficult cases through UV Activation. Therefore, I would like to review the characteristics and clinical applicability of UV implant as a means of overcoming the limit of surface processing.

1. Biologic Aging that interferes with the synostosis between the implant and bones

Unlike Resorbable Blasting Media (RBM) surface processing that widens the mechanical implant surface area by spraying hydroxyapatite powder onto the implant surface, Sandblasted with large grit and Acid Etched (SLA) surface processing that widens the surface area mechanically through pressurized spraying of Alumina (Al2O3) and increased biological affinity through etching process with strong acid at high temperature provides condition for promotion of osteogenesis by forming TiO_2 oxidation membrane on the implant surface.

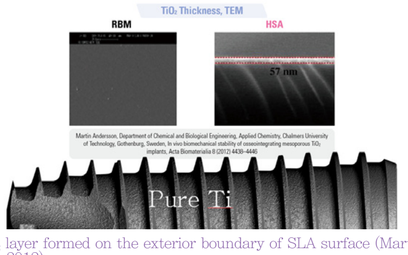


Fig.1 TiO_2 layer formed on the exterior boundary of SLA surface (Martin Andersson et al. 2012)

Fig.1 illustrates that TiO_2 membrane is formed on the exterior layer of the SLA surface processed implant. According to research result, hydrocarbon in the air covers approximately 60~75% of the entire surface area of the implant after about 1 months of embedding, thereby resulting in biological aging phenomenon that interferes with the synostosis between the implant and bones.

2. Characteristics of UV implant due to the effects of UV photo-catalysis

Due to the aforementioned biological aging phenomenon, the existing implant displays hydrophobicity on the surface due to organic matters such as hydrocarbon, etc., thereby resulting in degradation of the ability to pull osteogenesis factors. UV Activated implant, on the other hand, removes such organic matters to expose the TiO2 layer on the implant surface to convert the surface property to super-hydrophilic and increasing biocompatibility (Fig.2)

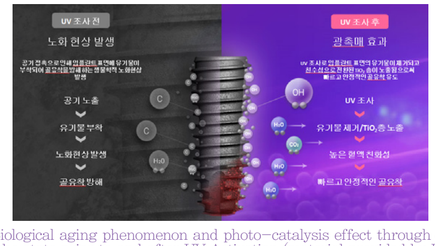


Fig.2 Biological aging phenomenon and photo-catalysis effect through comparison of the state prior to and after UV Activation (material provided by DIO)

1) Removal of organic matters

Without UV Activation, approximately 60~75% of the implant surface is covered with hydrocarbon. 10 minutes after UV Activated, the coverage is dropped significantly to about 20%. At this time, as illustrated in Fig. 3, the extent of coverage is not lowered any further even if UV Activation time is increased (Takahiro Ogawa et al. 2014).

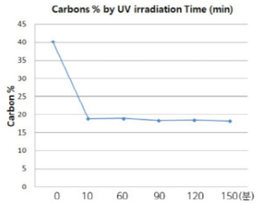


Fig.3 Reduction in hydrocarbon ratio through UV Activation (material provided by DIO)

UV Activation on the TiO_2 membrane on the SLA treated implant surface generates activated oxygen. Since this activated oxygen is highly oxidative, it binds with that organic hydrocarbon attached onto the surface and evaporates as CO2 to leave clean implant surface.

2) Super-hydrophilicity

Although the implant surface after more than 1 month of surface processing becomes hydrophobic, it becomes super-hydrophilic after more than 10 minutes of UV Activation (Fig.4-1, 4-2). In the process, the surface property changes from negative charge to positive charge. Therefore, once moisture comes in contact with the surface, it is absorbed immediately into the surface (Fig. 5-1). Even tat the time of embedding implant, it gets wetted quickly by blood (Fig. 5-2) to enhance adsorption of protein related to osteogenesis. Since osteogenesis ingredients of protein and minerals, etc. have negative charge, they are drawn to the implant surface with positive charge, which will induce quick, stable and sturdy synostosis (Takahiro Ogawa et al. 2014).

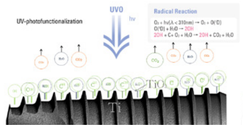


Fig.4-1 Reaction shown when the implant surface is UV Activated

Fig.4-2 Implant surface that converted from being hydrophobic to super-hydrophilic surface (material provided by DIO)

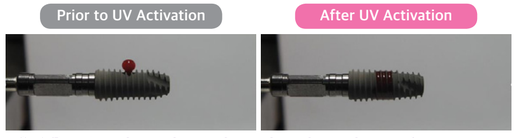


Fig.5-1 Reaction when iodine is dropped on the implant surface prior to and after UV Activation (material provided by DIO)

When iodine is dropped on implant surface, it stays in water droplet shape prior to UV Activation. However, after UV Activation, it is absorbed into the surface immediately after being dropped.

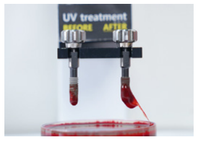
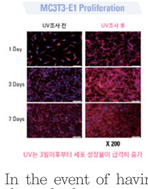


Fig.5-2 Reaction when the implant is immersed in blood prior to and after UV Activation (material provided by DIO)

When the implant is immersed in blood prior to and after UV Activation, the hydrophobic surface prior to UV Activation pushes surrounding blood out. However, after UV Activation, it turns into hydrophilic surface and draws in the surrounding blood.

3) Proliferation of osteocytes

[In Vitro Test] Cell proliferation experiment prior to and after UV Activation conducted at the Dental College of Kyunghee University. Cell proliferation experiment was conducted by using titanium disk Ø10mm only with SLA surface processing (control group) and MC3T3-E1 cell line (mouse osteoblast cells) Activated with UV for 10 minutes (experimental group). As illustrated in Fig. 6-1, UV Activated disk displayed rapid increase in the cell growth rate from the 3rd day after the commencement of experiment in comparison to the control group. In addition, as illustrated in Fig. 6-2, although the control group displayed rapid increase in the osteogenesis capability from the 3rd to the 4th week of the experiment, the group Activated with UV displayed almost 2-fold increase in the osteogenesis capability from the 2nd to the 3rd week. It can therefore be determined that UV Activation can achieve high level of effects in removing organic matters and create hydrophilic surface to elevate the osteocyte proliferation and osteogenesis capabilities.



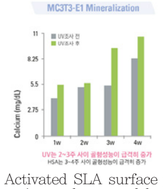


Fig.6-1 Cell proliferation experiment prior to and after UV Activation

Fig.6-2 Osteogenesis capability experiment prior to and after UV Activation (Dental College of Kyunghee University)

4) Ideal Bone to Implant Contact (BIC) rate

In the event of having Activated SLA surface processed implant with UV ray through the test on experimental rat model at the UCLA in the USA, there was 72% BIC in the 2nd week, which was 2.5 time higher than that of the group without UV Activation. In addition, BIC rates for the Activated and non-Activated groups on the 4th week were 98.2% and 53%, respectively, thereby illustrating approximately 2-fold difference in the BIC rates. It was observed that UV Activation can accelerate the synostosis process and increase the level of synostosis by maintain integration between better bones and implant (Fig. 7-1) (Takahiro Ogawa et al. 2014).

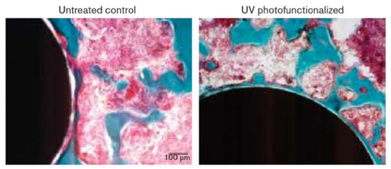


Fig.8 Evidence of increased peri-implant bone generation promoted by UV functionalization. These histologic images show peri-implant tissue at 2 weeks post implantation in a rat femur model with and without UV treatment (Goldner trichrome)

[In Vivo Test] Dental BIC experiment prior to and after UV Activation conducted at the College of Kyunghee University. It is an animal experiment on BIC using the implant only with SLA surface processing (control group) and implant with 10 minutes of UV Activation (experimental group). 2 SLA processed implant and UV Activated implant were embedded in left and right shinbones, respectively, in each of the 3 New Zealand white rabbit. BIC at the 2nd and the 4th week of experiment were compared. As illustrated in the Fig. 7-2, BIC of the UV Activated implant was 60%, which is substantially higher than that of the UV non-Activated implant at 38% in the 2nd week. Measurements taken in the 4th week were 79% and 62%, respective, thereby showing higher BIC for the experimental group in comparison to that of the control group.

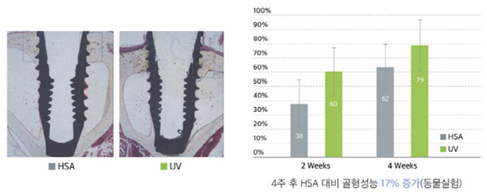


Fig.7-2 BIC experiment prior to and after UV Activation (Dental College of Kyunghee University)

3. Clinical utilization of UV implant

1) Immediate embedding of implant after tooth extraction

Unlike the normal cases, the case of embedding implant immediately after tooth extraction has the advantage of anticipation of osteogenesis capability of the extracted tooth. However, there are cases with difficulties in obtaining fixation at the initial stage due to lower bone contact ratio because of the lack of bone at the time of embedding. Under the experiment, embedding implant immediately after tooth extraction displayed bone contact ratio that is 1/3 of the ordinary cases. However, UV Activated implant displayed synostosis strength that is similar to the ordinary cases, thereby demonstrating healing effects that are 2~3 folds higher than the implant without UV Activation (Akiyoshi Funato et al. 2013).

2) Short implant for maxillomandibular moral section

Although short implant can be used in the cases of being close to the nerve alveolaris inferior in the mandibular moral region and in the case of little residual bone in the maxillary sinus for the purposes of minimal invasiveness and to lower the possibility of complication after the surgery, there is the weakness of having limits in the synostosis capabilities with the implant due to reduction in the surface area. However, as the results of research, it was found that the short implant Activated with UV displayed synostosis strength equivalent to that of ordinary implant with length of more than 10mm not Activated with UV at 4 and 8 weeks after the surgery (Akiyoshi Funato et al. 2013).

3) Inflammation around the implant

No. of patients undergoing treatment due to implant complications is gradually increasing with inflammation around the implant account for large proportion of such complications. When the bone absorption rates 90 and 180 days after the embedding of implant are measured in the experiment using dogs, the bone absorption rate around the implant was lower for the UV Activated implant (Fig. 8-1). Moreover, when viewed from histological perspective, the UV Activation implant displayed no bone absorption at the top and the interface between the bone and the implant was maintained. On the other hand, implant not Activated with UV displayed bone attachment failure or partial destruction at the interface between the bone and the implant (Fig. 8-2). It is anticipated that UV Activated implant can suppress the progress of inflammation around the implant (Katsuhiko Kimoto et al. 2016).

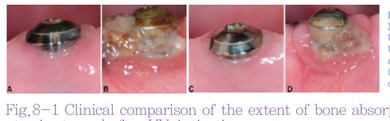


Fig.6 Intraoral photographs. A, Non-UV group after 90 days, (B) UV group after 90 days, (C) non-UV group after 180 days (90 days after dental floss application), and (D) UV group after 180 days (90 days after dental floss application).

Fig.8-1 Clinical comparison of the extent of bone absorption around the implant prior to and after UV Activation

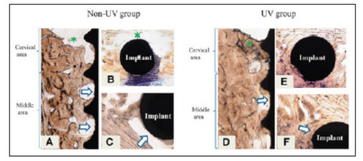


Fig.7 Light microscopic histological images (after 180 days). The grind samples were stained by methylene blue and examined under a light microscope. A, Cervical and middle areas of non-UV-irradiated implant at sagittal section. B, Cervical area of the non-UV-irradiated implant at horizontal section. C,Middleareas ofthe non-UV-irradiated implant at horizontal section. D, Cervical and middle areas of UV-irradiated implant at sagittal section. E, Cervical area of the UV-irradiated implant at horizontal section. F, Middle area of the UV-irradiated implant at horizontal section.

Fig.8-2 Histological comparison of the extent of bone absorption around the implant prior to and after UV Activation

4) Utilization in orthodontics

In research related to orthodontic mini-screw Activated with UV ray for 12 minutes, there were more cells attached to the UV Activated mini-screw as illustrated in Fig. 9-1. Moreover, as illustrated in Fig. 9-2, there was 30~40% lower detachment rate of mini-screw after 3 weeks in comparison to that without UV Activation (Takahiro Ogawa et al. 2015).

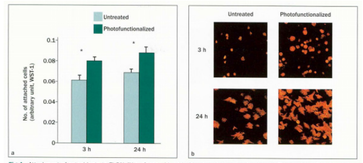


Fig.4 Attachment of osteoblasts to Ti-6Al-4V surfaces with and without photofunctionalization. (a) The number of attached cells after 3 and 24 hours of incubation, evaluated using the WST-1 colorimetric assay. The number of cells was evaluated as an amount of formazan product (arbitrary unit), which represents the total amount of metabolic activity of cells and is considered to be correlated with the amount of cells. *P < .05. (b) Low-magnification confocal microscopic images of osteoblasts cultured for 3 and 24 hours on untreated and photofunctionalized surfaces, corroborating the WST-1 result.

Fig.9-1 Comparison of the extent of cell attachment onto mini-screw for fixation prior to and after UV Activation

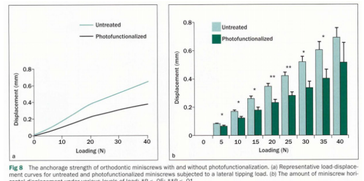


Fig.8 The anchorage strength of orthodontic miniscrews with and without photofunctionalization. (a) Representative load-displacement curves for untreated and photofunctionalized miniscrews subjected to a lateral tipping load. (b) The amount of miniscrew horizontal displacement under various levels of load. *P < .05, **P < .01.

Fig.9-2 Comparison of the fixation force of the mini-screw prior to and after UV Activation

5) Satisfaction of the patient through reduction in time required for healing

According to the experiment, implant Activated with UV for 15 minutes displayed increased hydrophilicity and better absorption of blood to achieve high rate of success at 97.6% in a diverse range of cases. On the average, time taken for loading was 3.2 months, which is marked reduction in comparison to 6.5 months for the implant not Activated with UV (Fig.10) (Akiyoshi Funato et al. 2013).

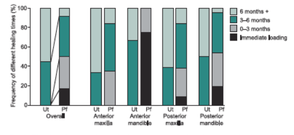


Fig.5 The distribution of specific healing times before functional loading of untreated and photofunctionalized implants. Ut: Untreated implants, Pf: photofunctionalized implants.

Fig.10 Distribution of healing period prior to loading prior to and after UV Activation

In actual clinical settings, the mechanical binding force by the existing bone is maintained after embedding of implant is generally maintained (Primary Stability) before the binding force gets weakened due to the absorption of existing bones. However, since the newly generated bones grow, the binding force between the implant and the bone increases again (Secondary Stability). At this time, there is a time slot called 'stability dip' at which the binding force between the implant and bones is the weakest. Clinically, this is determined to be at about the 3rd ~ 4th week after embedding of implant (Fig. 11). Therefore, if it is possible to increase the Secondary Stability through UV Activation, it would be possible to prevent implant failure and induce quicker binding of implant and bone by minimizing the duration of stability dip.

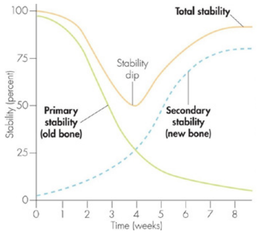


Fig.11 Stability in accordance with passage of time in ordinary implant