wjpmr, 2023,9(11), 90-94

SJIF Impact Factor: 5.922

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH
www.wjpmr.com

Review Article
ISSN 2455-3301
WJPMR

EFFECT OF ULTRA-VIOLET PHOTOFUNCTIONALIZATION ON DENTAL IMPLANTS – A REVIEW

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Article Received on 28/08/2023 **Article Revised on 18/09/2023** **Article Accepted on 08/10/2023**

ABSTRACT

Replacement of missing teeth using dental implant is a common clinical procedure for the restoration of edentulism. Numerous methods have been used to promote osseointegration for successful implant therapy. Photofunctionalization is defined as the phenomenon of titanium surface modification after intense UV treatment, including the change in the physicochemical properties and the improvement in biological features. The titanium surface is modified by UV radiation which gives a positive surface energy and hydrophilicity to the titanium dental implant surface thus promoting osseointegration.

KEYWORDS: *Dental implant, Photofunctionalization, UV radiation, Titanium, Osseointegration.*

INTRODUCTION

Ultraviolet (UV)-light-induced superhydrophilicity of titanium dioxide (TiO2) was discovered in 1997. UV photofunctionalization is defined as the phenomenon of titanium surface modification after intense UV treatment, including the change in the physicochemical properties and the improvement in biological features[1]. Photofunctionalization is found to be superior to other surface modifications of titanium, but do not increase, osseointegration[2].

Titanium has excellent mechanical properties apart from a low specific weight and a good corrosion resistance due to the dense oxide layer. This oxide layer (mainly TiO2) is an essential precondition for successful osseointegration[3]

This literature review is on effect of ultra-violet photofunctionalization on dental implants and its effect on oral implantology.

TITANIUM IMPLANTS

Since the introduction of titanium alloys in implantology, there has been a marked increase in the use of dental implants to replace lost teeth in patients.

Titanium is a chemical element with the symbol Ti and atomic number 22. Titanium is used in alloys to fabricate dental implants considering its highly acceptable mechanical properties, low density (4.5 g/cm3) and good bone-contact biocompatibility.[13] It is used as a refractory metal because of its relatively high melting point (1,668 °C or 3,034 °F).

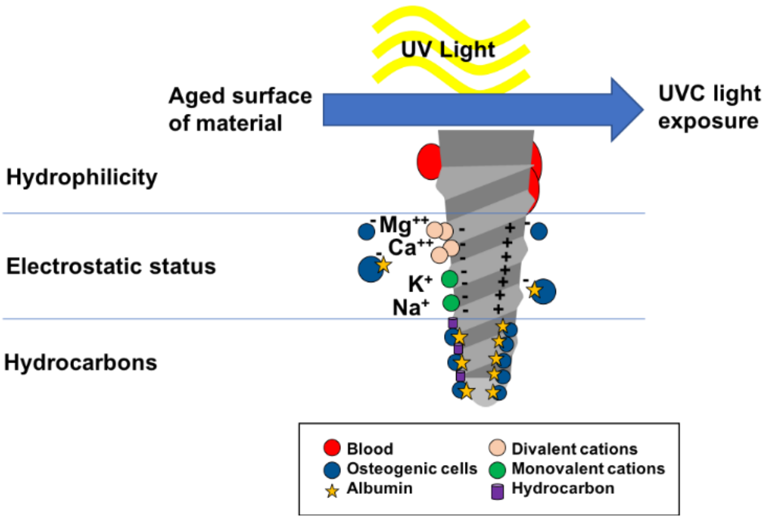
Currently, six different types of titanium are available as implant biomaterials. Among them, four are grades of commercially pure titanium (CPTi) (Grade I, Grade II, Grade III, and Grade IV), which is 98–99.6% pure titanium, and two are titanium alloys (Ti-6Al-4V and Ti-6Al-4V—Extra Low Interstitial alloys).[17] These grades are different in resistance to corrosion, strength, and ductility The main alloy used is called commercially pure titanium, cpTi.[13]

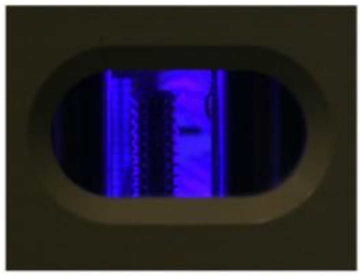
For both of the main alloys used to make implantable devices, namely commercially pure titanium, cpTi, and Ti-6A1-4V, the surfaces are mainly composed of the oxide TiO2.[15]

This oxide layer is 4–6 nm thick and also contains hydroxyl groups in addition to the oxide. The exact composition of the surface is important in promoting the adhesion of osteoblasts and the oxide layer tends to have favourable biological properties.[13] The oxide coating also has the effect of passivating the metal, so that corrosion is inhibited and the release of titanium ions is minimized.[16]

The surface of titanium (to be exact, titanium dioxide) has been considered chemically stable over time. However, recent studies uncovered important surface properties significantly that have changed with time.[4] With time it is seen to have an increase in the percentage of carbon element.[5]

UV RADIATION





UV radiation is a non-ionizing radiation that is generated by the sun, electric arcs and mercury lamps. Recent publications in the dental implant literature have indicated that treating dental implant titanium dioxide surfaces with ultraviolet radiation (UV) 200-400 nanometers (nm) increase bone to implant contact after the usual healing time.[6]

The UVA (wavelength range from 320 to 400 nm) and UVC (wavelength range from 200 to 280 nm) irradiation is found to produce hydrophilicity and nano-scale modification of the titanium surface.[18]

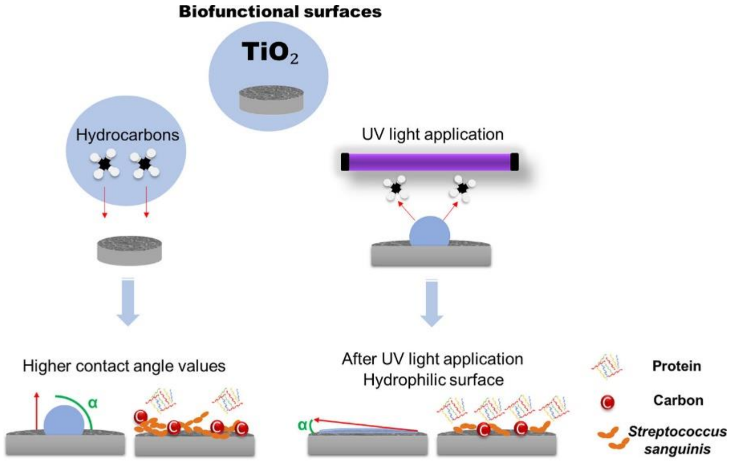
However, the vital mechanism behind excellent osseointegration might be because of carbon removal from the titanium surface by UVC.[7]

While time exposures of 12 minutes to 48 hours have been used to surface treat implants, it may be that as little as 16 seconds may be the minimum effective exposure time. Nonetheless, the most appropriate UV time exposure is to be determined.[9,10]

PHOTOFUNCTIONALIZATION

The effects of UV-treated titanium surfaces include increased adsorption of proteins, increased osteogenic cell attachment, increased retention of cells, facilitated cell spread, increased cell proliferation and enhanced osteoblastic differentitation.[7]

When TiO2 surfaces containing crystalline structures are exposed to UV light, a photocatalytic activity can be produced which will promote antimicrobial function.



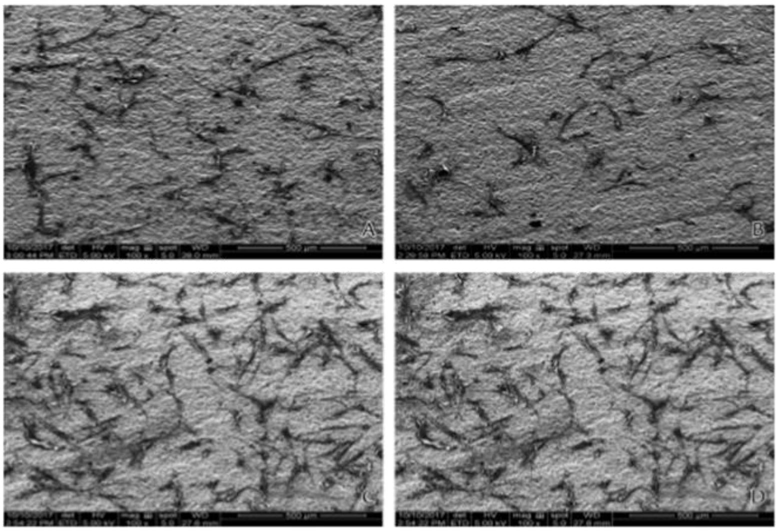
The mechanism of the photocatalytic activity comprise of the generation of reactive oxygen species OH, $O2^-$ and H2O2, which are responsible for the outer membrane decomposition of microorganisms. Therefore, surface modifications and improvements of biological properties are relevant for the success of dental implant therapy.[19]

EFFECT OF UV PHOTOFUNCTIONALIZATION ON DENTAL IMPLANTS

Photofunctionalization was performed at chairside immediately before implantation by treating the implants with UV light for 15 minutes using a photo device (TheraBeam Affiny,Ushio).[8]

The increase in the cell growth indicates that the percentage improvement in terms of the bone implant contact should be clinically significant.[20]

Number of cells per cm2 counted on surface of titanium disks. A, SEM image of nascent specimen. B, SEM image of aged specimen. C, SEM image of UV-treated aged nascent specimen. D, SEM image of UV-treated and FGF2-mimed aged nascent specimen. Original magnification ×100. SEM, scanning electron microscope.



The study conducted by Hajime Minamikawa et al, demonstrated that photofunctionalization is effective in increasing the osteoconductivity of the Ti alloy. It was also found that the strength of bone implant integration for photofunctionalized machined implants was higher than that for non-photofunctionalized roughed implants[2].

The mechanisms behind the enhanced osseointegration of dental implants after photofunctionalization are due to improving hydrophilicity and eliminating hydrocarbon contamination on the implant surface.[12]

Because of carbon removal by photofunctionalization, the implants may have regained the highest level of innate osteoconductivity, which led to minimal inter-implant variation in osseointegration capability. The more frequent use of shorter and smaller diameter implants, the use of photofunctionalization allowed for a faster loading protocol without compromising the success rate[8].

Photofunctionalization converted Ti6Al4V surfaces from hydrophobic to superhydrophilic.[2]

The anatase TiO2-coated pure Ti surface attained photocatalytic hydrophilicity after UV illumination led to significant increases in cell attachment, cell spreading and cell proliferation on this surface. These in vitro effects seem to accelerate the early bone apposition to the implant surface[11].

No surgical complications were observed in relation to photofunctionalization, and surprisingly, the percentage of surgical complications was lower with the use of photofunctionalization, suggesting the practicality and safety of this technology[8].

The success rate for photofunctionalized implants is found to be 97.6%.[8]

CONCLUSION

The use of UV irradiation is a simple and inexpensive method that facilitates osseointegration in compromised regions, thereby allowing a faster loading protocol. Photofunctionalization converted Ti6Al4V surfaces from hydrophobic to superhydrophilic. Osteogenesis around photofunctionalized implants was more extensive than untreated controls, and there was enhanced attachment, spread, proliferation, and development of functional phenotypes of osteoblasts grown on photofunctionalized Ti alloy. More interestingly, the effect of photofunctionalization on increasing the strength of bone-implant integration was greater than that by surface roughening. Photofunctionalization can therefore be considered as a countermeasure to regenerate the lost hydrophilicity.

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