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2017

document version

Publisher's PDF, also known as Version of record

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citation for published version (APA)

Tastepe, C. S. (2017). *Osteoinductive Treatment Methods for Implant Surfaces Exposed to Peri-implantitis*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

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Chapter 8

General Discussion and Summary

The challenge of peri-implantitis treatment has gained broad interest, especially in the last decade. Dental clinicians have seen an increase in the incidence of peri-implantitis. If left unaddressed, peri-implantitis has negative consequences for both the patient and the dentist, ultimately leading to the loss of the implant. Researchers have been conducting investigations and discussing the available knowledge to determine the best treatment option for peri-implantitis. However, in spite of the fact that the implant surface plays a significant role, the ideal implant surface treatment has yet to be established [1].

Although some available surface treatment methods have been shown to be successful in achieving efficient removal of the biofilm and may even improve clinical parameters such as BOP, PPD, and GI, the peri-implantitis defect does not totally recover and fill with new bone that is in direct contact with the implant surface [2]. This incomplete recovery may mean that the applied surface treatment method is lacking an important property. We hypothesized that the lacking property is the incapability of the treatment to restore the impaired osteoconductivity of the surface. Therefore the aim of this thesis was: *To develop an implant surface treatment method which will efficiently clean the biofilm and modify the surface (rejuvenate the infection-exposed-implant surface) by making it more biocompatible and osteoconductive.*

The air powder abrasive method was shown to be very effective in biofilm removal. However, the drawback of this method was the risk associated with residual powder particles that were left on the titanium surface post-application. These residues were thought to impair the bone healing process. However, this phenomenon could be turned into an opportunity by using osteoconductive powders as the cleaning powder, whereby the residue would not impair the process. Moreover, it could actually even improve it. The treated surface could transform into a more biocompatible surface with the osteoconductive powders impacted on it. However, the new powder should also efficiently clean the biofilm without damaging the surface structure of the titanium surface.

Chapter 3 of this thesis tested the cleaning efficiency and surface modification effect of the air powder abrasive method with osteoconductive powders. For this aim, we applied an *in situ* biofilm model (48 hour intraorally produced) on SLA (sand blasted large grit acid etched) surface titanium discs, which have an identical surface microstructure to dental implants. It was shown that osteoconductive powders, namely HA and TCP, could efficiently clean the intraoral biofilm coated SLA surface titanium discs. It was also shown that the powder properties, particle size, and powder hardness influenced the cleaning efficiency. Furthermore, the powders did not damage the SLA surface structure of the titanium. The most important finding of this study was the fact that CaP particles were found to be spread randomly on the surface. The chemical content of the surface also changed, showing concentrations of Ca and P elements.

These results led us to a second step, where we improved the method by applying different powders and settings for different aims such as cleaning and surface modification. The ideal settings should not only be efficient but also be safe to be able to apply it intraorally in future clinical use. Therefore, in **chapter 4**, different settings with an advanced device were checked on a clinically relevant model. This time, dental implants that were lost due to peri-implantitis were used as specimens. The method was tested on calcified biofilm residues and real dental implants. HA powder was found to be an efficient

biofilm cleaner and BioCaP acted as a good surface modifier under the chosen settings. The surface morphology and chemical content met our expectations.

The goal of the surface modification was to make the surface more biocompatible and facilitate the attachment and the proliferation of the bone cells. In **Chapter 5**, it is shown that this goal was also achieved. The cell attachment, cell viability, and proliferation were improved on the treated titanium surface comparing to the untreated surface. Therefore, the *in vitro* cell response toward the titanium surface was also improved.

Following the promising *in vitro* results, an *in vivo* test should tell whether it was possible to reach our ultimate goal of re-osseointegration post-treatment. The surface treatment method was applied on ligature induced peri-implantitis defects in a dog model. For the *in vivo* application, we improved the treatment by incorporating growth factor BMP-2 into the BioCaP powder to make it osteoinductive[3]. **Chapter 6** histologically shows that, following surgical peri-implantitis treatment with HA and BioCaP powder abrasive treatment, it is possible to achieve significant re-osseointegration and bone fill.

Subgingival air powder abrasive treatment has been used to treat peri-implant mucositis and as preventive care for peri-implantitis, as a non-surgical treatment method. However, the influencing parameters and the cleaning effect's dimensions had never been studied. **Chapter 7** gives an insight on which parameters (such as powder flow, pressure or application movement, etc.) play the biggest role on the cleaning effect of the subgingival air powder abrasive application and how to get the most effective clinical use of air polishing. We concluded that air powder abrasive treatment should be applied at high pressure, with deep insertion of the nozzle and sufficient water flow. A certain amount of powder flow (0.09 gr /sec) is needed but beyond that point higher powder flow does not have a beneficial effect. We also learned that the nozzle must be moved over the implant surface to obtain the optimum cleaning effect.

Throughout this research, we have experienced several lessons and challenges. First and foremost, implant surface biocompatibility and its sensitivity to external factors were challenges. It is very easy to deteriorate the biocompatibility but extremely difficult to reestablish it. The disturbance of material properties, which is caused by infection, has costly consequences. Therefore, the ability to obtain the desired biological response following the peri-implantitis treatment is strongly related to the implant's properties. On the other hand, although minerals like CaP are very beneficial for generating an osteogenic cell response on the implant surface, the thickness of the layer, the physical properties of the powder, the application method may change the cell response dramatically. Regarding technical parameters, the compatibility of the device with the chosen powder is another crucial point. The biggest challenge we faced was having an ideal model for testing the mechanical removal of the biofilm. Since the aim was to not only kill bacteria but also remove the biofilm, the strength of the attachment of the biofilm was as important as the microbiological properties. However, good microbiological properties did not always mean strong attachment for *in vitro* biofilm models. A compromise was inevitable. Consequently, the *in vitro* results obtained were confirmed by *in vivo* experiments.

In conclusion, this thesis validates a new implant surface treatment method that has been shown to be effective *in vitro* and *in vivo*. Future research directions should involve the design and implementation of an improved air powder abrasive device that allows for sterile application of the method. Furthermore, a safer clinical application method can be established with the help of a “rubber dam-like” device to protect the surrounding tissues. We speculate that this method can be translated successfully to clinical use when the above mentioned requirements are met.

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