Literature Summary

Topic: Micro/nano Scale Implants

Kaylee Maya

Hybrid Biomaterials
Spring 2022

Throughout the years, the biomedical industry has advanced and continues to expand its possibilities. Although the biomedical industry is composed of a series of different inventions as well as techniques, one very new method of the biomedical industry is the use of nano/micro scale implantations. The human body is very complex in the sense that there are very small systems and very large systems, both holding extreme importance to the human body and its functions.

Due to the fact that the human body is very complex and has many functions, there are a series of different types of implantations used within the biomedical industry. The first source used for this literature summary helped understand the use of nano/micro scale implantations across the human body. For example, micro and nanotechnology have been used to affect the sub-micron scales. The sub-micron scales is also known as the cellular process prior to implantation. Although the sub-micron scale is extremely important to the process prior to implantation, the way the body reacts prior to the is also dependent on the type of implant and where it is being placed within the body. Some categories for implants are cardiovascular, neural, as well as orthopedic. Although there are only three categories listed, each of these categories largely expand in terms of the capabilities for implantation. For example, The need for cardiovascular implants within the United States is very high. This is due to poor American diets resulting in heart diseases as the number one killer within the country. It is estimated that about 82.6 million Americans have one or more types of heart disease. In order to create efficient cardiovascular implants in important to understand the link between the biomaterial surface and the blood-and-adjoining-tissues. If there is a better understanding of the two it helps eliminate poor outcomes and increases the clinical ability of the implant.

Although there are many ways to utilize implants on a nano/micro scale, researchers are still trying to combat the idea of implants being foreign within the body. Foreign objects in the body can be considered anything that has not been biologically created and put in your body in a certain position. Something as small as a piece of wood up to an implant can both be considered foreign to the body. The uniqueness of the device being on the micro/nanoscale helps eliminate the foreign aspect when dealing with implants. This can expand the capacity of what the biomolecular and cellular events were capable of prior to implants being able to be micro/nanoscale.

Contrary to the possibility of the body rejecting such implant due to its foreignness, the advantages outweigh the negatives in terms of micro/nano scale implantation. Some advantages according to the reference 1 are as followed. Sub-cellular size allows the body to have a high tissue uptake in addition to being able to minimize or completely reduce polymer usage, this increase biocompatibility and can be less toxic for the body.

Continuing on the note of nano/micro scale implantation, one key use of nano scale modifications in implantation can be seen in an orthopedic approach, more specifically for osseointegration processes. Based on an article from *Acta Biomaterialia* there was a specific study on this topic. This study was based on the technology at a nano-scale level for osteointegration processes. More specifically this paper was showing the advancements for titanium implant surfaces which can enhance the osteointegration process. Osteointegration is

comprised of ordinary medical methods as well as physiochemical methods that when combined can have a better biological approach for modification. These advancements can be made by utilizing bioactive materials in correspondence with the bioactivity of the implant materials. When they looked on a micro/nano scale for modification they saw that the functionalization of titanium of surfaces provided enhancement in the osteointegration processes. Yet when looking at the study as a whole the only negative to this study was that due to the fact that micro/nanoscale technological developments are not commercially available This is due to the fact that there is not enough clinical demand for such biomedical implants.

When looking at the human body is composed of a total of 206 bones. Some of these bones are large while others are small and cannot easily be fixed if broken or fractured. Thankfully through the large variety of biomedical implants, size does not challenge the biomedical field. This advancement within the biomedical industry is due to the micro/nanoscale implants, more specifically in this study the use of the functionalization of titanium surfaces on micro/nanoscale implants for osteointegration processes. This study looks specifically at mouth in terms of oral rehabilitation through the use of dental implants as well as orthopedic implants. The original world of implants, circa 1970's, utilized hexagonal and cylindrical designs as well as zirconia as the implant material. Since then, titanium has become the first choice in terms of implantation due to its versality of the surface in terms of morphological aspects, implant design and connections. Titanium in particular is used due to its resistance against corrosion yet its capability in terms of its strength a long term success.

Overall, Through the use of ordinary techniques such as grit-blasting, acid-etching, and surface conditioning in combination with the morphological aspects allow for a premium titanium-based implant on a micro/nanoscale. The use of titanium alongside the modified techniques results in shortening the first phase of the osteointegration process. The first phase of the osteointegration process is comprised of blood platelet activation, protein adsorption, three-dimensional fibrin clot cross-linking, osteogenic cell migration as well as collagen deposition and finally the bone matrix forming. These methods are the leading way for nano modification in terms of biomedical implants. These methods in addition to helping modify implants on a micro/nano scale can be used for localized drug delivery processes. For example, nanostructured materials and drug carriers such as titanium- based nanotubes are arising within the biomedical field. The key to this study was not only looking at the nano/micro scale implantation using titanium-based materials but also the structural organization and chemical composition on these implants. It is necessary with these types of implants that they are able to mimic the natural bone structure as a soft tissue approach that ultimately heals the bone with time with respect to the bioactivity of the biomaterials on the implant itself.

In line with the previous source, the last source from the *Dental Implant Materials of 2019* continues on the note of nano/micro scale implants for enhanced osseointegration. This study reviews the new modification methods for titanium based, specifically for dental implants. As the previous paper mentioned, the utilization of large- grit, acid-etched processes for implantation. Prior research thought that the eukaryotic cells within the human body weren't capable of being susceptible to nanostructures for osteogenesis. Yet after recent research and clinical tests, it was seen that these titanium nano structured implants were showing over a 95%

survival rate. Although the survival rate of these types of implants were high, the recent research also suggests that the reasoning behind the eukaryotic cells being able to respond to these chemical morphological changes at a nanoscale was due to a series of items including the titanium dioxide. The other important factors of the nanostructured implants consist of peptide coatings, fluoride treatments, calcium- phosphorus applications and the use of ultraviolet photo functionalization.

Although there are many important factors to consider when looking at bone, the preparation for implant placement is just as crucial. Due to the aggravated bone, surgical trauma provokes bleeding and hemostasis, a common response to a break or aggravation of the body. Although this is a rather normal occurrence, through the use of surface modification of the titanium-based implants, it can lessen the hemostasis in addition to improving other initial responses in respect to the implant surface. Through chemical and physical modification of the nano structures, the implant will not only fix the injured area but also strengthen the quality of the healing process for the bone. In terms of longevity of the clinical studies supporting nano/micro scale titanium-based implants, there is more research that is necessary. In correspondence to the modifications made through implantation, there also must be some sort of correspondence between the implantation and the bone remodeling process. Due to the fact that this study is fairly new, it is highly possible to use these methods for implantation for accelerated bone healing yet until further research can be done in terms of bone remodeling alongside implantation on a nano scale, it can be used in clinical trial but not worldwide biomedically.

In conclusion, the use of nano/micro scale implantation is an astounding advancement within the biomedical field. As seen within the review, nano/micro scale implantation is not limited by category but by other naturally occurring processes and functions within the human body. Specifically, the use of nano/micro scale implantation for enhanced osseointegration will continue to be researched and studied until it can be utilized on a large commercial scale. For now, the process of bone remodeling must be studied in depth in relation to nano/micro scale implantation in order for there to be any type of advancement to the biomedical industry on a commercial scale. Hopefully in the soon to be future nano/micro scale implantation will be used globally in the hopes of providing a less invasive and high risk option for those in need.

References:

Ammar Arsiwala, Preshita Desai, Vandana Patravale, Recent advances in micro/nanoscale biomedical implants, Journal of Controlled Release, Volume 189, 2014, Pages 25-45, ISSN0168-3659

Souza JC., Sordi MB, Kanazawa M, et al. Nano-scale modification of titanium implant surfaces to enhance osseointegration. Acta biomaterialia. 2019;94:112-131. doi:10.1016/j.actbio.2019.05.045

Yeo, I.-S.L. Modifications of Dental Implant Surfaces at the Micro- and Nano-Level for Enhanced Osseointegration. *Materials* **2020**, *13*, 89. https://doi.org/10.3390/ma13010089