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Nanotechnology in Medical Therapeutics and Tissue Engineering

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Abstract: *Nanotechnology has developed to satisfy information technology industry requirements. Nanotechnology research has then grown to go into countless areas. The new technology has driven the development of different medical advancements including drug delivery systems, contrast agents for cancer treatment, diagnostic instruments, and tissue regeneration. In the beauty industry, nanotechnology has been implemented including the skincare market, dermal medicines, bleaching protocols. Minimal invasive approaches to surgical treatment by nanotechnological techniques created new horizons in plastic surgery. The use of nanotechnology has more widely affected the area of plastic and reconstructive surgery than have other medical sciences. Throughout various plastic and reconstructive surgery procedures, the results of nanotechnology could be detected, ranging through the use of nanomaterials throughout implantable materials to wound repair, wound healing and wound dressing, particularly in tissue engineering and regeneration. In the fields of tissue engineering and the regeneration the most exciting and fast advances are. The possibility of imitating physiological tissue to regenerate tissues and organs is a cutting-edge improvement. Successful and effective results obtained in these topics are actively creating new development opportunities.*

Keywords: *Drug delivery, Medical Therapeutics, Nanotechnology, Nanomedicine, Plastic Surgery, Regeneration, Tissue Engineering*

I. INTRODUCTION

Nanotechnology is the manipulation of matter one billion times smaller than one meter in size. With the naked human eye or optical microscopes, observation of atoms and molecules in such a small scale could not be seen, and could only be visualized by specific imaging devices that allow nanosized visualization[1]. Once high-tech imaging devices were developed and the concept of the "nano" size had become a topic for discussion, the National Nanotechnology Initiative provided a clear definition of the nanoscale measurements of matter: 1–1.00 nm. The field in plastic and reconstructive surgery is potentially that which profits most from nanotechnology[2]. To recognize its applications in medical diagnostics, therapeutics, and tissue engineering, recognizing the evolution of nanotechnology into nanomedicine and the features of nanomaterials are essential.

I.I. Nanotechnology Development Into Nanomedicine

Nanomedicine is one of the fields of medicine researched most thoroughly. As nanotechnology research developed, new methods and materials were developed; this led to the expansion of nanotechnology applications into all fields of science, like medicine, engineering, and materials science. Increasing use of nanotechnology in people's daily lives has

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prompted concerns about the safety of nanomaterial use for the environment[3]. This developed the nanotechnology research foundations, and introduced the admission of new regulations into the field of nanotechnology. Nanotechnology is one of the major interests of the existing research, from medicine to electronics, in all scientific fields. The concern of the medical field in nanotechnology has significantly increased particularly after the millennium period, and a new field, nanomedicine, has been developed. Nanomedicine explores all of nanotechnology's medical aspects, such as drug delivery and cell repair[4]. Nanotechnology advances are transforming the future of therapeutics, particularly in drug delivery and imaging. Nanotechnology has increasingly been used in the medical field, to the point that it is named after a particular discipline. Nanotechnology's application to the medicine is called nanomedicine. There is a wide range of uses in this area including nanoimaging, nanomaterials, nanosensors, and nanobiology. Nanotechnology is also used in medicine for a wide range of medical and clinical uses, such as drug delivery, tumor detection, cancer imaging and analytical tools. Nanosized materials actually have a variety of applications[5], [6]. Nanotubes, nanoparticles, nanorods, nanopillars, nanodots, nanopores, and many more nanomaterials were discovered and found to be effective in the field of medicine.

Nanofibers were among the first nanomaterials to see common use in a wide range of products, from buildings to aeronautics. The use of nanofiber has grown very rapidly, without understanding the possible side-effects to safety. It was later discovered that nanofibers inhalation via the air led to a spectrum of occupational lung diseases, particularly lung fibrosis. Nanoparticles have also been proven to cause inflammation to grow, and to increase skin aging. Following these, there were many studies to prove the harmful effects of nanotechnology[4], [6]. Despite these findings on the negative health effects of nanotechnologically generated compounds, treatment of these products received special attention and care. Nanotechnology consumer legislation became even more severe and stricter. Plastic and reconstructive surgery is a specialty for the restoring of images[1]–[3]. To understand the impact of the nanotechnology on plastic and reconstructive surgery, understanding the nanomaterials used in therapy, the use of nanotechnology in drug delivery mechanisms, diagnostics, and the use of nanotechnology in tissue engineering is crucial.

I.II. Use of Nanomaterials In Medical Therapeutics

Understanding the nanodevices and nanomaterials used in the medical field is essential to understanding the nanotechnology's therapeutic applications. Nanopores are the simplest nanomaterials, originally produced by automotive sector, but have found great use within the medical sector[7]. In medicine, there was the possibility of creating sufficiently large nanopores to allow the distribution of nutrients and oxygen, but small enough to avoid complex immune and pathogen transmission; this is how the possible effects of such a substance on restoring health became understood. In this system, carbohydrates (like glucose), and hormones (like insulin), share gases (like oxygen and carbon dioxide), and are capable of moving via the nanopores; molecules that could cause disease (such as viruses, microbes, or immune complexes) are bigger and could not pass through nanopores[5], [6]. Hence this was known as a perfect way to facilitate certain healing approaches. Perhaps one of the best examples for the use of nanopores is the glucose mechanism. This system may be useful for neurodegenerative conditions, e.g. Parkinson's disease or Alzheimer's disease. To promote the release of neurotransmitters, new encapsulated cells, encapsulated neurons, and

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could be delivered to the brain induced by electrical stimulation[8].

It was discovered that nanopores are also useful in DNA experiments after the discovery of various nanopores applications as nanopores could be used to distinguish the different DNA nucleotide bases: pyrimidine and purine[8]. This discovery initiated the functional use of nanopores in DNA sequencing. In medical diagnosis, fluorescence has been used more and more. The use of fluorescent dyes is very difficult because it involves specific colors, molecules and lasers. Nanocrystals were developed and called the quantum dots, in order to overcome this issue. The molecule's color could be changed by adjusting the nanocrystal structure, or simply by changing the thickness[7]. This has created a clearer and more economical medical and testing approach. Quantum dots may be used in different fields such as cancer diagnosis, microarrays of DNA, and screening of medications. The growing use of nanotechnology in drug delivery has driven scientists to conduct studies on discovery of new nanosized materials to be used in systems for drug delivery. Nanoshells have been developed following the success of carbon fullerenes[4], [6], [8]. These gold-coated nanospheres might be ingested into the cancer patient's body and transported to the cancer site. Afterwards, after burning the bottle, an ultraviolet laser could be used to provide heat to expel the drug into the nanoshell. This approach offers a basis for target-specific cancer treatment.

Microparticles with the magnetic characteristics have increasingly been used in the separation of the cells or cell structures in cell studies. With nanotechnology developments it was questioned whether the nanoparticles could be used to remove infectious pathogens or certain toxins from blood. This was effective in animal models and is presently a promising research for treating renal patients with dialysis[5], [8]. Because of the large surface area by volume ratio and their nanosize, nanomagnets have been shown to be more effective than the hemoperfusion, and the potential of using nanotechnology to purify the blood, especially through direct removal of the sepsis infectious pathogens or the elimination of toxins in infections, are still under preclinical study. The most common nanomaterials that are used in nanomedicine are illustrated in Figure 1[9].

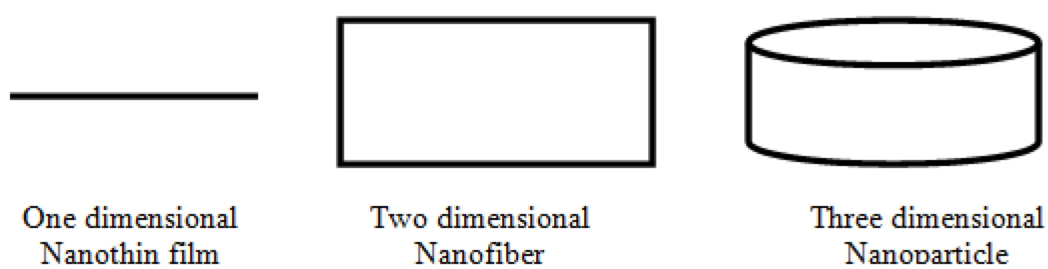

Figure 1: Most common materials used in nanomedicine

I.III. Nanotechnology In Diagnostics

When scientific advances advance, more efficient and effective forms of diagnosis for diseases are being followed. Diagnostics, particularly imaging, greatly influences the efficacy of the treatment Nanotechnology work is producing exciting tumor imaging advances. Powder formed nanoparticles, like magnesium oxide, are covered with the cancer cell antibodies, and when released, they identify the cancer tissue by moving to the cancer site. Subsequently conducted

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magnetic resonance imaging will allow for the exact anatomical position of the cancer tissue[10]. A similar use is made of cadmium selenide quantum dots. These particles are becoming fluorescent in ultraviolet light, which are used by doctors as a guide in cancer tissue removal. Numerous types of cancer are in the context of plastic surgery; thus an increase in the diagnosing and treating cancer has also created a profit for the plastic surgery industry. Genetic studies are also effectively applied to the nanotechnology. For instance, nanosized gold particles are used by labeling of DNA to establish the genetic sequence[11]. The nanopores may study intercellular structures, such as nucleic acids. For histology, nanotechnology is not only used in the intercellular structures; the similar technology might also detect microorganisms. The advancement of cancer screening using this technique has resulted in minimally invasive cancer diagnosis and surgery with improved cure time[9], [11].

I.IV. Nanotechnology Use In Tissue Engineering

Tissue engineering is an evolving field covering both medical and engineering tests. As the general population's life expectancy increases, so does the number of patients suffering from the degenerative diseases. The volume and effect of trauma events is also growing with the advancement of technology. This led to a search for the tissue regeneration, in order to replace the damage. Cartilage, muscle, and heart tissues have limited ability for regeneration[7], [10]; thus, reconstruction is now recognized as the only option for curing the degenerative, pathological or traumatic disorders of these tissues completely. Nevertheless, the field of tissue engineering is not restricted to tissues with limited ability for regeneration; skin and bone are two examples of tissue that can regenerate but are still in the interest of tissue engineering community. This is due to bone loss could not be entirely replaced by human body in different conditions[2], [4], [8]. These tissue styles are therefore extensively studied in the field of tissue engineering.

In developed countries, the modern lifestyle and the increased use of the processed, carbohydrate-rich foods result in the obesity. The resulting effect of an increased life expectancy has been created by developments in therapeutics and medicine as well as improvements in living conditions. Those two causes, obesity and increased life expectancy, result in an increase in the damage to cartilage, especially in weight-bearing joints. Cartilage regeneration is minimal in the human body[12]. It results in the net impact of cartilage degradation leading to loss of pain and mobility. In the previous decades, cartilage tissue engineering has also been developed to look for a permanent treatment for the cartilage degeneration caused by the trauma and disease. In cartilage tissue engineering, there are four components that are vital: extracellular matrix, cell source, scaffold, and bioreactors (Fig. 2)[9].

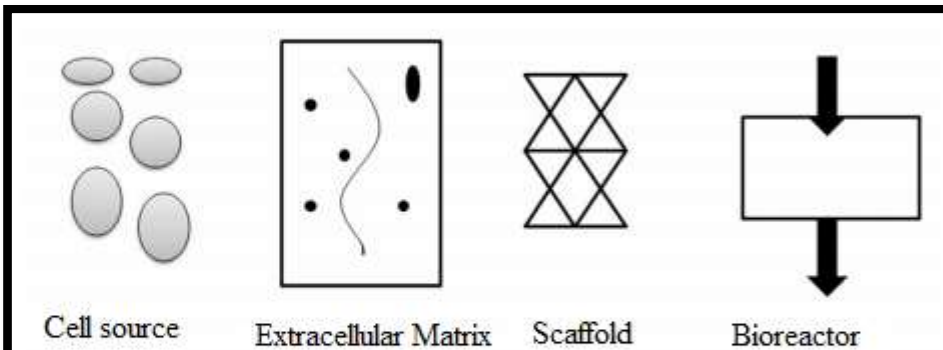

Figure 2: Requirements for Tissue Regeneration

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In cartilage tissue engineering, nanotechnology is increasingly being used in development of specific scaffolds for the extracellular matrix formation, adhesion, cell regeneration and cell differentiation. Among all methods for engineering nanoscaled cartilage scaffolds, electrospinning is the most effective technique. A charged polymer fluid is poured in this technique onto a surface loaded with opposite charge[12]. Fibre diameter and topology of scaffolds can be precisely regulated. It is also possible to control the solution properties such as conductivity and viscosity, as well as the parameters needing accuracy, such as needle tip size, and general variables such as air humidity and temperature. By using the electrospinning process fiber diameters could be precisely managed to be as thin as few nanometers[13]. This system works by creating high electrical gradient field between the spinneret and collector unit. The created electrical force is transferred to the solution containing the polymer to counteract the charges contained in the solution, contributing to the evaporation of the solvents. The solvent left behind after the process of evaporation begins to lengthen towards the collector. To achieve different fibre alignments, the collector device could be rotated[12], [13]. This approach is both efficient and cost effective. This method is very successful in achieving the structural shapes of several tissues, like the dermal tissue; thus, it is one of the most important methods in nanomedicine development of scaffolds.

Cartilage has an avascular structure which results in very limited capacity for regeneration. This is because the tissue has poor cellularity and limited blood supply. Rheumatoid arthritis and Osteoarthritis are the two most prevalent conditions which lead to cartilage destruction[14]. Apart from these conditions, the cartilage structure frequently induces damage of congenital anomalies, cancer, trauma and multiple degenerative diseases. Both symptoms are being treated progressively at present to enhance the range of motion and reduce the discomfort. The cartilage is very essential for people's movement, because it is the material at the ends of the bones that protects the joints[13]. Loading and trauma may cause cartilage damage, with the long-term effects. As the cartilage's regeneration the capacity is relatively low, a regenerative strategy was found to be necessary for the complete treatment and cure of degenerative cartilage conditions. The regeneration of chondrocytes in exact morphology is one of the crucial issues in cartilage engineering. The cartilage is organized in weight-bearing joints in layers where the superficial layer's chondrocyte morphology is different compared with that of the deep layer[12], [14]. This is one of the key drawbacks of artificial cartilage regeneration which cannot be resolved.

Regeneration of the cartilage is accomplished in tissue engineering through many stages. The first stage is to cultivate the stem cells. Despite this, the cells are implanted onto a 3D scaffold constructed from biomaterial. It is necessary to choose the scaffold as this structure would provide a 3D matrix for the tissue growth, mimic the biomechanical properties of the extracellular matrix, and enable cell adhesion. Bioreactors are then used to provide optimum medium for growth[9], [13].

The skin is the human body's shield, which serves as a protective layer against natural hazards. The skin may undergo multiple bleeding attacks as a result of its work, such as ulcers, burns, wounds or lacerations. The skin consists of two strata: dermis and epidermis[12], [13], [15]. All structures have varying pathways and durations of recovery. In a large majority of cases of trauma, skin heals of scarring tissue. Work in nanotechnology has provided ability to regenerate the skin and recover the anatomical appearance[15]. Scaffold formation is important for skin regeneration, close to all fields of tissue engineering. Scaffolds need to contain other features as they need to be biocompatible, and

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that after application an adverse reaction will not be regenerated; they need to activate cell attachment to allow replication, and scaffolds need to replicate the tissue's extracellular matrix that is required to be regenerated as much as possible. Some of the important characteristics needed for an efficient scaffold to be present are outlined in Fig. 3[9].

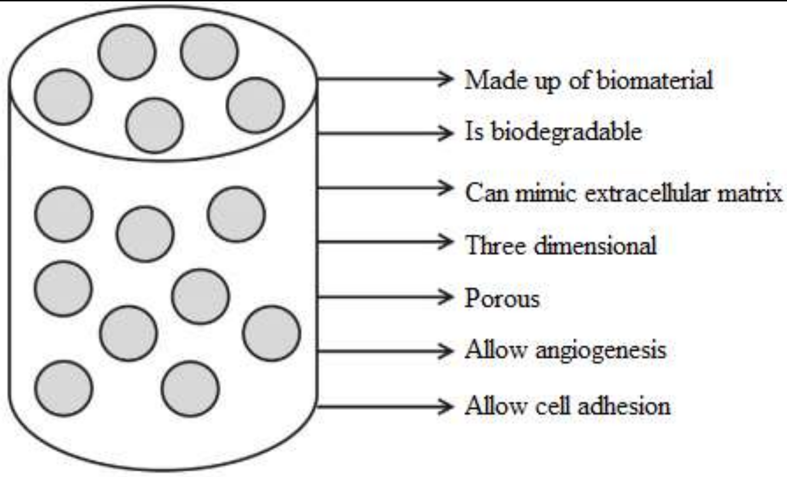

Figure 3: Important Properties of Scaffolds

The tissue-engineering technique has allowed engineered heart muscle to be produced in vitro with sufficient properties and contractility. In addition, heart valves have been developed using nanomaterials which have a critical role in the blood circulation[12]. In general, nanomaterial injections have been found to be beneficial in restoring heart valve function which is not working properly. The use of nanofibre-based scaffolds, using electrospinning method, is a viable strategy for myocardial tissue regeneration[15]. The choice of the content to be used is a critical question. In the regeneration of cardiomyocytes many materials and substances have been studied. The efficiency could be improved by two approaches in the regeneration of tissue-engineered heart valves. Nanoparticles are used widely in the distribution of medicines as stated[13], [14]. The other approach is to use nanoparticles for pathways of drug delivery to reduce the production of embolus or thrombuses after cardiac surgery.

II. CONCLUSION

Nanomedicine includes certain areas of the medical field, such as regulation, repair and tracking, using nanoscaled structures and tools, of a certain or particular human system at the cellular and molecular level. The use of nanotechnology to restore and track human health is very exciting, especially in the fields of imaging, diagnostics, drug delivery and tissue engineering. All these subjects are of great interest to plastic surgery, particularly in cancer treatment and tissue engineering. The advent of nanotechnology has completely changed the diagnosis and treatment of cancer, which is also the cornerstone of the regenerative part of the field. Drug delivery, genetic testing, preventing diseases are all important to the industry. The incorporation of nanotechnology into the world of tissue engineering has created new prospects in the field of regeneration. Some goods are already on the market, while numerous innovations and concepts are still being checked and accepted. With these nanotechnological advances, tissue regeneration became one of science's most extensive research areas and new inventions and innovations are extremely promising for achieving

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successful organ and tissue regenerations.

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