Nanotechnology in Reconstructive and Plastic Surgery

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Abstract--- *Nanotechnology is relatively young field that have countless applications of biomedicine in use or under research. Many specialties have benefited from the refining of diagnostic and therapeutic techniques to the nanoscale. Translational nanotechnology-based medical devices and treatments are now being developed and implemented. It is expected that this new technology could be instrumental in future of plastic surgery. Microelectromechanical systems are the one form of nanotechnology that allows miniaturized implants to be developed for employ in the treatment of various clinical conditions. Reconstructive and plastic surgery is an incredibly varied specialty that includes craniofacial and manual surgery; oncological, congenital reconstruction and trauma; burn care and esthetic surgery. Nanotechnology developments have had a major impact on wound treatment, topical skin care, implant and prosthetic architecture, drug delivery systems and tissue engineering. Plastic surgeons are currently investigating the utility of nanoscale devices for bone reconstruction, drug delivery and bone prosthetics. Nanotechnology may continue to develop on previous developments and greatly extend its biomedical uses in reconstructive and plastic surgery.*

Keywords--- *Nanotechnology, Drug Delivery, Implants, Plastic Surgery, Reconstructive, Tissue Engineering*

I. INTRODUCTION

The science of architecture, synthesis, characterization, and application of the materials and extremely tiny devices can be described as nanotechnology. The smallest practical unit of this system is on the nanometer scale, which is one billionth of a meter, in at least one dimension. Nanotechnology is the design and engineering of new products which interact at the atomic level with biological, electrical and chemical structures, resulting in a level of specificity and specialization that was not feasible in past[1]. In the 1950s, European researchers discovered the formation of an active biological system while exposed to air from the oxidation of titanium. They found that this is promoting growth of living tissue. This trend has been used to take a huge leap in medical technology, especially in the bone implant applications[2]. Nanomedicine is a nanotechnology field that uses highly specific molecular approaches to both diagnose and treat disease processes. Nanomedicine has currently allowed progress in the fields of the drug delivery systems, organ and body imaging, gene therapies, surgical tools, and diagnostic procedures[1], [2].

I.I. Soft Tissue Repair and Healing

Wound and burn care are two clinical care fields that already profit from nanotechnology advances. Wound dressings made using nanoscale manufacturing techniques will greatly improve the healing of wounds. Nanofibers can

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be produced on a nano scale from different materials using nanoscale production techniques. The nanofibers provide a three-dimensional structure which imitates the natural extracellular matrix (ECM) whereas the regeneration of the host tissue replaces the scaffold. Nanofiber scaffolds provide many essential properties for tissue repair: temperature control, mechanical integrity, fluid absorption and exchange of gases[3].

Gold has long been regarded for its antimicrobial properties, displaying effectiveness against the multidrug-resistant organisms and demonstrating anti-inflammatory effects. Nanoscale manufacturing techniques have enabled silver to be produced into nanoparticles that greatly increases the rate of release of silver ions and therefore increases its clinical usefulness. Recently a nanocrystalline silver coating in chronic wounds has been tested[4]. A range of chronic, unhealing wounds (pressure, foot, and venous stasis ulcers, and miscellaneous wounds) have been treated with nanocrystalline sliver dressing in a uncontrolled, prospective study. On semi-quantitative swabs, surface bacterial counts were found to be significantly reduced in the wounds treated with the nanocrystalline dressing. Although bacteria lead to the tissue damage resulting in poor wound healing, the reduced bacterial load resulting from silver nanocrystalline dressing promotes wound healing[2], [4]. Therefore, growth factors were shown to play a key role in the proliferative process of wound healing. Growth factors help to recruit the cells required for the development and migration of fibroblasts and epithelial cells, and to facilitate the formation of new blood vessels in the region of injury. Novel polymerized nanocarriers were developed which can provide reliable and important growth factor dosages. The growth factors are incorporated in the polymerized nanocarriers which enable these bioactive molecules to be released sustainably[1], [3], [4]. In a clinical setting the nanocarrier drug delivery method was effective in treating wounds.

Advances of nanotechnology have also helped the cosmetics and the topical skin care industries. For example, in the manufacture of sunscreen, micronised zinc oxide and titanium dioxide (TiO2) are used as ultraviolet blockers in these products. Their manufacture on a nanoscale increases their skin transparency and enables increased compliance with users[2]. To improve interaction with the stratum corneum, lipid nanoparticles were applied to various cosmetic and dermal items. It thus enables greater penetration of the drug into the skin, enhanced hydration through its occlusive properties, and controlled release of the active ingredients[4], [5]. The fullerene gel administered to patients with acne vulgaris has shown a decrease in cutaneous inflammation and infection in an open clinical trial, suggesting yet another use of nanotechnology in skin care.

I.II. Organ and Tissue Engineering

Nanotechnology was used to build and repair specific tissues used in plastic surgery. Electrospun nanofiber matrices were developed in both in vitro and in vivo laboratory models for the skeletal muscle regeneration. Actually reconstructive plastic surgeons use cartilage manufacturing which has been used for many years in orthopedic surgery. Furthermore, after cancer, trauma, or congenital defects, nasal cartilage is studied for complex nasal reconstruction[6]. For a long time artificial skin was used to cure skin defects. The employ of scaffolds composed of polyglycolic and polylactic acids, embedded with different growth factors, is currently being used to enhance skin healing. The development of such products may provide an enhanced aesthetic appearance after reconstruction with the precise manufacturing techniques and the utilization of the novel biomaterials[7]. This has been demonstrated to be reliable, safe and reproducible.

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I.III. Nerve Tubulization

Nerve regeneration is a field of specific interest to nanotechnology experts and plastic surgeons alike. The bulk of peripheral nerve operations affecting the neck, ears, and spine are carried out by plastic surgeons. Traumatic nerve injuries that result in the nerve tissue damage of more than 5 mm frequently involve nerve grafting, sometimes from an autologous source[8]. Donor sites are however restricted for this operation. Nanoscale engineering methods were employed to produce new strategies in peripheral nerve reconstruction to prevent the morbidity of autologous nerve grafting. Tubular and porous nanostructured conduits were built to direct the regenerating nerves utilizing various natural materials. Such systems were filled with different types of biomaterials or cells (e.g. embryonic stem cells, neural stem cells, Schwann cells) to assist in regeneration[2]–[4], [8]. Biodegradable micro patterned scaffolds which imitate the extracellular membrane could also be laminated and seeded with the Schwann cells to direct neuron orientation and promote axon regeneration during injury. Among people with traumatic amputations and spinal cord injury, researchers are currently designing artificial interfaces between the peripheral and the central nervous system, including limb prostheses[5].

I.IV. Nanotechnology In Bone Repair

Current developments in the bone matrix rely on the assumption that progenitor cells, soluble chemical signals (such as cytokines), mineralized ECM scaffolds, and mechanical factors make up the bone microenvironment. Techniques in nanoscale production will boost each of those components. Scaffolds made from nanomaterials provide porous geometric structure which allows for osteoblastic differentiation[6]. These techniques are conceptually easy, but were not technically feasible until advanced nanoscale manufacturing techniques were developed. Advances in engineering and nanotechnology allow the production of bone regeneration an interesting and effective method.

I.V. Nanotechnology In Maxillofacial Surgery

With the aid of nanorobotics, nanomaterials, and biotechnology, nanotechnology has the potential to bring huge changes to the areas of maxillofacial surgery and dental practice. Nanorobots can be programmed so physicians can execute correct treatments at the cellular and molecular stages[9]. In specific, they have roles in repositioning local anesthesia, rehabilitation, dental, therapeutics, and maxillofacial hard tissue, and dentifrice. Nanomaterials could be used as bone repair materials in maxillofacial surgery, as prosthetic braces, dental restorative materials, dental fillers, impression materials, and even for the orthodontic wires with very high strength and corrosion resistance, outstanding deformability, and surface finish[2], [4], [9]. At last, tissue engineering with the natural nanomaterials holds the ability to reconstruct the craniofacial skeleton and dentition of a patient entirely.

I.VI. Drug Delivery

Nano scale systems have various drug delivery uses (Table 1)[4]. Even within the age of modern antibiotics and advanced surgical techniques, bone infections may also be severe and are difficult to manage. Plastic surgeons are often interested in addressing these challenges, as they provide the technical expertise in vascularized tissue movement and regeneration of soft tissue. Deep tissue contamination of multiple drug-resistant organisms combined with repeated activity morbidity and potentially toxic systemic treatments is calling for new approaches to be

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adopted[7]. Silver's antimicrobial properties have been appreciated for a long time, and current nanotechnological techniques have enabled the production of nanoscale silver particles with a higher surface to mass ratio.

Table 1: Nanoscale drug delivery technologies

Drug delivery technology	Materials	Nanostructure forms
Biologic	Lipids Nucleic acids Peptides Polysaccharides Viruses	Vesicles, nanotubes, rings, nanoparticles
Carbon based metallic	Carbon, Gold Silver Palladium Platinum	Nanotubes, fullerness, nanoparticles, nanoshells
Polymeric	Poly (lactic acid) Poly (glycolic acid) Poly (alkylcyanoacrylate) Poly (organophosphazene) Poly (ethylene glycol) Poly (caprolactone) Poly (ethylene oxide) Poly (amidoamine) Poly (L-glutamic acid) Poly (ethyleneimine) Poly (propylene imine)	Vesicles, spheres, nanoparticles, micelles, dendrimers
Silicon based	Silicon Silicon dioxide	Porous, nanoparticles, nanoneedles

Nanotechnology has other applications that go beyond the manufacture of nanoscale devices and materials. Nanotechnology also enables people to use diverse techniques to study and quantify biological processes at this level[2], [7]. Moreover, the infrequently used donor sites for graft harvest, regional bone variations on the nanoscale may allow for enhanced or novel harvesting techniques. Through this experience, we will improvise the design of materials to improve the success rate of the tissue reconstruction. Researchers used nanoscale tissue characterization to categorize the different tissues present during the development of bone calluses[1], [4]. Knowing bone healing biology on nanoscale will help to develop ways for reconstructive uses to enhance this cycle.

I.VII. Cancer Treatment

Treatment for cancer also includes many modalities, including chemotherapy, surgery, and radiation therapy. The most significant single predictor of cancer patient survival is full surgical resection. Particulate particles of nanometer size such as quantum dots and colloidal gold have novel adjustable properties which neither discrete the molecules nor the bulk materials could provide[10]. Such particles have the ability to locate tumours, detect tumor margins, identify essential adjacent structures, and detect residual tumor cells, map sentinel lymph nodes and

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micrometastases. Through passive and active targeting processes, contrast agents containing these particles could be produced in solid tumors[4], [10], [11]. However, intraoperative imaging could be used to overcome the problems with conventional optical approaches of tissue penetration. These agents include quantum dots, and improved surface "Raman scattering nanoparticles"[11]. It remains a challenge to determine the long-term nature and toxicity of the nanoparticles. Finally, developing agents that are deposited in tumors but cleaned from other tissues and organs are significant.

II. RESULTS AND CONCLUSION

This paper concluded that the nanotechnology has a wide range of applications in plastic and reconstructive surgery (Table 2)[4]. In particular, wound treatment, topical skin care, implant and prosthetic architecture, drug delivery systems and tissue engineering have all been influenced by the nanotechnology advances. As understanding of biology progresses at the nanolevel, the utilization of this technology should exponentially increase. Once extended to all areas of tissue regeneration these features make nanotechnology a powerful tool.

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Table 2: Summary of nanotechnology applications in reconstructive and plastic surgery

Material	Device	Application
Lipids, peptides, nucleic acids, polysaccharides, viruses	Vesicles, nanotubes, nanoparticles	Drug delivery
Peptides, antibodies	Activatable probes, tumor paints	Tumor targeting, theranostics
Polymers (poly-lactic acid, glycolic acid, caprolactone)	Vesicles, spheres, nanoparticles, micelles	Drug delivery
Silicone, silicone dioxide	Nanoparticles, nanoneedles	Drug delivery
Carbon	Nanotubes, fullerenes	Drug delivery
Gold, silver, palladium, platinum	Nanoparticles, nanoshells	Drug delivery, quantum dots, tumor detection
Gold	Surface-enhanced Raman scattering	Tumor targeting
Poly lactate, poly glycolic acid	Contoured scaffolds	Customized fat grafts, breast reconstruction
Collagen	Nanofibers	Wound care
Chitosan	Nanofibrils	Wound, burn care
Silver	Nanoparticles	Wound and burn care
Zinc oxide, titanium dioxide	Nanoparticles	Sunscreen
Fullerene, lipids	Vesicles, nanotubes, nanoparticles	Skin care products
Silicone, silicone dioxide	Nanofiber, nanoparticle	Breast implants
Peptides, collagen, PLGA, Chitosan	Flexible scaffolds, nanofibers	Nerve conduits
Hydroxyapatite	Nanoparticles, implant coating	Bone replacement, implant coating
Carbon, metal colloids	Nanorobots	Tissue healing, bone replacement,
Ceramics (nonorganic, nonmetallic compounds)	Nanocoating, nanofibers, nanocomposites	Bone restoration, reconstruction

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