Relationship Between Plastic Surgery and Nano-Medicine

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Abstract

One of the most diversified surgical subspecialties is plastic and reconstructive surgery. Grafts, flaps, free-tissue transfers, and replantation of diverse tissues ranging from nerve, vascular, bone, muscle, and skin are among the procedures used. The objective of plastic surgery is to restore the form and function of resected or damaged tissue while keeping or refining the aesthetic appearance and maintaining or refining the blood supply. The plastic surgeon can assist the patient to improve their quality of life by sticking to these standards. Surgical procedures in general are mostly focused on mechanical tissue healing, with biological activity receiving less consideration.

Keywords: Reconstructive surgery • Nano-medicine • Biomaterials • Replantation

Introduction

Despite great technological advancements and surgical method breakthroughs, there remain a variety of flaws and injuries that might benefit from stimulation of the underlying tissue biology to aid recovery. Interaction with other fields of study, such as bio- and nanomaterial's, might considerably assist reconstructive surgery. Nano-medicine is unusual in that the small size of the materials utilized allows researchers to have an impact on molecular targeting and repair [1]. The benefit of such materials is that the building blocks, due to their size and composition, can drive bodily healing at the cellular level. The goal is to create nano- and biomaterials with structures and compositions that can replace or repair missing or damaged native biologic structures in the human body.

Though the traditional tissue engineering paradigm includes polymeric scaffolds, co-cultured cells, growth factors, extracellular matrix components, and other bioactive molecules, all of which are integrated into a bioreactor, biomimetic materials have recently been introduced as a novel way to elicit tissue response without the use of a bioreactor [2]. The objective is to develop nano- and biomaterials with structures and compositions that can replace or repair native biologic structures in the human body that have been lost or damaged.

Though polymeric scaffolds, co-cultured cells, growth factors, extracellular matrix components, and other bioactive molecules are all used in the traditional tissue engineering paradigm, biomimetic materials have recently been introduced as a novel way to elicit tissue response without the use of a bioreactor [3]. A combined strategy that uses both mechanical reconstruction and biomimetic materials to restore injured tissues might be a huge step forward in the future of regenerative and restorative medicine. We will discuss particular instances in which these two domains might work together to address clinical problems for the benefit of patients in this paper. The combination of mechanical expertise in plastic surgery with the regenerative qualities of inherent biological processes via nano- and biomaterials has the potential to provide better surgical results than each area could accomplish on its own.

Mandibular reconstruction

Repairing abnormalities caused by oncologic excision or trauma sometimes necessitates mandibular reconstruction. Reconstruction methods vary depending on the location and size of the mandibular defect; generally, lesions less than 6 cm are usually restored with vascularized bone. Due to its length, compatibility with endosteal implants, and possibility for skin islands if soft-tissue restoration is required, the free fibula osteocutaneous flap is the workhorse donor source for mandibular repair. When compared to traditional free-hand procedures, the use of Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM) has been proven to enhance function, morphology, and accuracy for complicated segmental mandibular reconstruction [4,5].

Mechanical stability with exact bone replacement and osteointegration at the contact areas between the natural and rebuilt mandibles are two of the most significant aims in mandible restoration. CAD/CAM has improved the precision of exact bone replacement; however, it has little influence on osteogenesis or osteointegration other than more accurate bone to bone contact. In the case of mandibular restoration, a general approach to regenerative medicine entails physically healing the original defect and incorporating the graft through improved vascularization, with the final objective of restoring shape, function, and inherent biological activity.

Researchers have already begun investigating a nano-materials approach to bone regeneration in an attempt to mend big lesions in the jaw, but past research suggests that the bony matrix does not appear to use exogenous growth hormones adequately. Without nanotechnology, BMP2 (Bone Morphogenetic Protein-2) was used to help stimulate bone growth, but it resulted in devastating side effects such as cancer, spinal cord compression (due to soft tissue swelling), ectopic bone formation, increased bone resorption from overstimulation of osteoclast activation, and induction of adiopogenesis instead of the desired osteogenic process. By seeding a scaffold with polymeric nanoparticles to allow efficient vascularization and innervation, nanotechnology can provide a more sophisticated approach, guaranteeing that the regenerated bone is functional and connected with the original structure of the bone. For example, it is feasible to immobilize BMP-2 using a gold nano-array, allowing for a regulated release of BMP2 during the bone regeneration process while limiting negative effects. As a result, by seeding the scaffold with signalling components, we may be able to distribute these signalling molecules in a controlled geographical and temporal manner. This would provide plastic surgeons more control over the regeneration process, allowing them to assure proper vascularization and structure. Not only could chemical release be adjusted, but the implant could be designed so that distinct spatial portions of the implanted scaffold fulfil a specific biological purpose by releasing components tailored to the cellular response required in that location [6]. Elastin, type I collagen/hydroxyapatite, and type I collagen are some of the tissues that may be used to make the scaffold. The scaffold's components offer mechanical and chemical cues that encourage the body's cells to migrate to the healing site and differentiate into bone. The regenerated bone will be optimally integrated within the native tissue, allowing function and form to be significantly superior to current mandibular reconstruction treatment options, by optimizing vascularization and focusing on the biological mechanism in tissue repair, while also perfecting the shape of the scaffold to fit the natural contour of the patient.

Burns and skin regeneration

Skin grafts-either Full-Thickness Skin Grafts (FTSG) or Split-Thickness Skin Grafts (STSG)-are one of the most common methods used by plastic surgeons to rebuild burns. Because skin grafts are harvested without a blood supply from the donor site, the recipient site's vasculature and capacity to undergo angiogenesis are crucial for graft survival. The epidermis and dermis are both included in FTSG, whereas the epidermis and different degrees of the dermis is included in STSG. Due to the requirement to seal the donor site first, FTSGs are restricted to tiny flaws. Even though auto-grafts are the gold standard for skin repair, they are not always possible to employ due to a scarcity of tissue for bigger lesions.

However, because the donor site is left with dermis components to mend subsequently, STSG can cover greater abnormalities [7-9]. Furthermore, as compared to FTSG, the STSG may endure greater contraction and color changes, making it a preferred treatment.

A potential area of study is the employment of diverse skin replacements and other biological components to overcome the limitations of auto-grafts. Recell®, a non-cultured autologous skin cell spray, has, for example, been used effectively as an adjuvant to skin grafting in the treatment of more severe burns or as a stand-alone therapy for donor-site wounds. All cell types (keratinocytes, papillary dermal fibroblasts, Langerhans cells, and melanocytes) are present in the suspension, which can help with speedier healing, regimentation, and scarring.

Cultured expanded cell lines of autologous keratinocytes have been used in several low-level tissue engineering endeavours. These can then be "re-applied" to the wound in a variety of ways. These approaches have the drawback of lacking dermis and adnexal tissues, being restricted in thickness and lacking structural stability. Early attempts to use bio-printing to make a skin substitute are ongoing, but they have many of the same flaws [9]. These procedures are archaic compared to present tissue engineering capabilities, and there is a significant expense connected with growing cells and using bioprinting technology. For example, whether enough cells can be quickly created to bio-print the requisite skin constructions is a big restriction. The advantage of employing nano-scale materials is the ability to mend wounds faster and more effectively by stimulating the body's natural regeneration mechanisms.

Synthetically derived polymers are being employed as commercially accessible skin replacements. Synthetically derived polymers are defined as materials that have been cultivated ex-vivo or produced from a source other than the patients themselves. Porcine and bovine collagen, shark chondroitin, cadaveric dermis, newborn foreskin, Cultured Autologous Epidermis (CAE) keratinocyte sheets or cell spray, and fibroblasts seeded onto a 3D hyaluronic acid derived scaffold or synthetic polymer membrane make up these skin replacements. Due to the incorporation of numerous skin replacements, these products have limitations such as inadequate vascularization, inability to integrate, scarring, and immunological rejection, even though they include natural components such as hyaluronic acid. Furthermore, they necessitate the patient's limited movement during therapy, which is not always feasible. Natural polymers, on the other hand, may perform better in the clinic because they are more biocompatible, have reduced immunogenicity, and may be resorbed overtime when the freshly deposited tissue is rebuilt [10].

Finally, prior research in nano-medicine resulted in the production of nano-scale films capable of sensing mechanical stimuli and forces operating on the skin. These films might be used to track and record the spatiotemporal mechanical qualities that are required for skin regeneration. Furthermore, the usage of a film might be utilized to detect the healing process during the regeneration process, allowing for individualized medication or surgical therapies. If the film detected that a patient was taking longer to cure a skin wound, for example, more pharmacological treatments may be injected to speed up the healing process. Nanowires, by chance, have a high degree of sensitivity, allowing them to provide the essential tunability for skin regeneration. The use of these films in plastic surgery would allow doctors to monitor the healing process in real-time, allowing them to fine-tune the healing process and obtain better results.

Conclusion

Even though plastic surgery has made significant progress, there are still many areas where it may be improved. Surgeons might be better able to restore function and achieve greater outcomes by utilizing nano-medicine methods. The capacity to create materials, implants and drug-eluting nanoparticles that can be promptly transferred to the clinic become a feasible aim in the future by combining the skills of tissue engineers, biologists, material scientists, and plastic surgeons. To better understand how to apply nano-medicine to the area of plastic surgery, further research in the pre-clinical domain is needed. Plastic surgeons will be able to modify and progress the discipline in the long run by collaborating with specialists from various fields.

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