Bioengineering Tissue for Organ Repair, Regeneration, and Renewal

Dismemberment was the main method of controlling organ disease, pain, and deformity by earlier surgeons. Disease organs and body parts had to be removed to control progression and pain. Advancement in knowledge and the development of sterile techniques, disinfection, antibiotics, anesthesia, and surgical techniques obviated the need for organ ablation and paved way for elective reconstruction. With immunotherapy, replacement of many organs through allogeneic transplant became feasible. Refinement in surgical technique has allowed elaborate repair and reconstruction of diseased parts. All surgical specialties have reconstructive domains. Presently the future appears to focus on regeneration and renewal of tissues and organs.

Sushruta, an Indian surgeon, was the first to be credited to attempt at surgical repair in 6th century BC.[1] Techniques of reconstruction have gradually developed to include complex reconstruction, such as cranio-facial reconstruction, sex re-assignment surgeries, and various tissue transfers. Graft materials have been used to replace skin, urethra, vascular structures, and other tissues, with varying results. These include xenografts, allografts, homografts, and artificial grafts. Rejection limits xeno and allogeneic grafting, while non-availability is the obvious constraint to homografting.

Tissues and organs can now be replaced with lab-generated counterparts through tissue engineering (TE). Cells can be provoked to organize and form functional tissues using biodegradable scaffold. TE involves getting source cells (from patient, cadaver, or stem cell) and extracellular matrix scaffold molded as desired. The cells are cultured and seeded into the scaffold. To accelerate growth and to help support the cells, growth factors, cytokines, or physical stimulation may be added. When the construct tissue is implanted into the patient, the seeded cells will proliferate, and replace the matrix following scaffold degradation and desorption.

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The extracellular matrix should be a material that can assimilate into the body with tissue regeneration. Natural biodegradable substances or synthetic degradable polymers such as polyglycolide, polylactide, polyethylene polytetrafluoroethylene, and terephthalate are used as matrix.[2] Naturally occurring matrix materials include collagen, fibronectin, hyaluronan, chitosan, glycosaminoglycan hydroxyapatites, and alginate.

Extracellular matrix bioengineering and the creation and utilization of surfaces, materials, and devices at the molecular level through nano biotechnology have greatly enhanced the development of TE.[3,4]

Autologous seed cell sources include multipotent stromal cells, epidermal stem cell, periosteum-derived cells, and neural stem cell. Stem cell can be banked for future use from autologous umbilical blood and other perinatal tissues (amniotic fluid); however, bone marrow mesenchyme stem cell and adipose-derived stem cell have the capacity to develop into diverse specialized cell lines.[5]

This multidisciplinary approach by scientists, engineers, and surgeons has resulted in construction of biological substitutes that are being applied in replacement of diseased tissue and organs.

TE is a rapidly expanding discipline. It has established role in skin and mucus membrane replacement, bone and cartilage regeneration, and head and neck reconstruction. The prospect is expanding daily. Bio-artificial organs can now be grown using autologous cell and an appropriate scaffold. Urinary bladders have been grown using this technique.[6] There are attempts to grow solid organ such as the liver, kidney, lungs, heart, and lymph nodes.

Tissue-engineered implants can grow, remodel, and respond to injury.[7] TE obviates the need for anti-rejection drugs and offers a unique opportunity in pediatric surgery because an implant will not outgrow the child recipient.

We have journeyed from diseased organ ablation to replacement and repair, and now to regeneration and even renewal. Regenerative medicine and TE hold promise and have remarkable potential for advancing opportunity for repair and replacement of damaged tissues and organs.

Engineering organs may help alleviate the severe organ shortage being experienced worldwide. This demand may continue to rise due to aging population. Bioengineered organs are free from immunological reaction, but the biotechnology is still expensive. All ethical issues must be considered especially when autologous stem cells are generated through cloning.

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