Engineering of Tissues: A Boon For Medical Science

Himanshu Trivedi[1], N D Gupta[2], Afshan Bey[3], Mahira Kirmani[1]

ABSTRACT

Disease or injury may lead to damage and degeneration of body tissues, which requires treatments to facilitate their repair, replacement or regeneration. Tissue engineering is a recent advancement in the field of medicine that has opened new avenues in the field of regeneration of lost body structures. It is a triad of scaffold, cells and growth factors which acts in unison to achieve desired results. The field of tissue engineering aims to regenerate damaged tissues, in place of replacing them, by developing biological substitutes that restore, maintain or improve tissue function.

Keywords: Tissue engineering, Regeneration, Growth factors

INTRODUCTION

From ages man has made attempts to replace the body parts with inanimate objects made by him to restore the functional and esthetic demands of general population. Current advancements in science and technology has opened up a new era for tissue engineering which uses body's own potential for regeneration of missing body parts. In dentistry it has led to the regeneration of missing teeth and supporting structures. Tissue engineering is a new frontier in treatment of various oral diseases proving it's worth with each passing day.

The term 'tissue engineering' was first given at a National Science Foundation workshop in 1988 to denote 'application of the principles and methods of engineering and life sciences towards the basic understanding of structure-function relationships in normal and pathologic mammalian tissues and the development of other biological options to restore or/and maintain or improve tissue function'. As stated by Langer and Vacanti[1], tissue engineering is the research field which combines the principles of engineering, and life and health sciences with the development of biological functional substitutes. The aim is to restore, protect (halt disease progression) or improve the function of the damaged tissue and/or organ.

Application of tissue engineering strategies[2,3] has three main variables by definition: (i) tridimensional porous supports or scaffolds,[4,5] (ii) cells, and (iii) bioactive agents, i.e. physical stimulus,[6] and/or growth factors (GFs).[7,8] Cells can be imparted and cultured onto a structure or scaffold capable of supporting three-dimensional tissue formation.[9] Growth factors can be used in the isolated form in injured tissue/organ, or in association with scaffolds and/or cells of different types (Differentiated and undifferentiated).[10,11]

SCAFFOLDS

The developing field of tissue engineering (TE) aims to regenerate damaged tissues by uniting cells from the body with highly porous scaffold biomaterials, which act as templates or framework for regeneration of tissues, to initiate and promote the growth of new tissue. Numerous scaffolds produced from a variety of biomaterials and manufactured using a various techniques have been used in attempts to regenerate different tissues and organs in the human body. Regardless of the tissue being targeted, a number of factors and determinants are important when designing and selecting scaffolds for use in tissue engineering.

A scaffold should be biocompatible so as to not induce any reaction in the recipient's body, biodegradable so that it is replaced by body's own cells and tissues with time, strong enough to maintain sufficient space, porous to facilitate the growth and inseeding of desired cell lineages and cost effective.

Typically, three groups of biomaterials, synthetic polymers, ceramics and natural polymers, are used in the fabrication of scaffolds or templates for tissue engineering. Each of these individual biomaterial groups has specific advantages and disadvantages so the use of composite scaffolds consists of different phases is becoming increasingly common. Specially for hard tissue regeneration, there has been widespread use of ceramic scaffolds, such as hydroxyapatite (HA) and tri-calcium phosphate (TCP). Ceramic scaffolds are typically characterized by high mechanical strength (Young's modulus), sunstantially low elasticity, and highly brittle surface. From a bone perspective, they exhibit excellent biocompatibility due to their chemical and structural resemblance to the inorganic phase of native bone. The interactions of bone cells with ceramics are very instrumental for bone regeneration as ceramics are known to promote osteoblast differentiation and proliferation.

Numerous synthetic polymers have been used to produce desired scaffolds including polystyrene, poly-l-lactic acid (PLLA), polyglycolic acid (PGA) and poly-dl-lactic-co-glycolic acid (PLGA). Although these materials have shown good clinical success as they can be fabricated with a remarkable architecture, and their degradation characteristics controlled by varying the amount of polymer itself or the composition of the individual polymer, they have drawbacks including the risk of failure due to reduced bioactivity. In addition, concerns exist about the degradation process of PLLA and PGA as they degrade by hydrolysis, producing carbon dioxide and thus lowering the local pH which can

[1]PG Student, [2]Professor and Chairperson, [3]Professor, Department of Periodontics and Public Health Dentistry, Dr Ziauddin Ahmad Dental College, AMU, India

Corresponding author: Dr Himanshu Trivedi, Department of Periodontics and Public Health Dentistry, Dr Ziauddin Ahmad Dental College, AMU. 202002

How to cite this article: Himanshu Trivedi, N D Gupta, Afshan Bey, Mahira Kirmani. Engineering of tissues: a boon for medical science. International Journal of Contemporary Medical Research 2016;3(5):1526-1528.

result in cell and tissue necrosis.

Biological materials such as collagen, various proteoglycans, alginate-based substrates, bone tissues and chitosan might have all been used in the production of scaffolds for tissue engineering. Unlike synthetic polymer-based scaffolds, natural polymers are biologically active and significantly promote excellent cell adhesion and growth. Furthermore, they are biodegradable too allowing host cells, over time, to produce their own extracellular matrix and replace the degraded scaffold. With all natural polymers, one major problem with using collagen as the main constituent of a scaffold for tissue engineering is that it has relatively bad mechanical properties. However the compressive and tensile mechanical properties of collagen can be improved through physical and chemical cross-linking methods.

Other tissues, such as bone for inference, have an intrinsic property to repair, remodel and regenerate as such. Therefore the task in the field of tissue engineering is to try and harness this innate regenerative capacity of bone. One way to do so might be to mould the scaffold in such a way that the scaffold itself provides regenerative signals to the cells which nagate the requirement for prolonged in vitro culture prior to implantation.

CELLS

The source of cells used in tissue engineering can be autologous (from the patient), allogenic (from some other human donor), or xenogenic (from a different species donor).[12] Autologous cells have been proved to be a potential source for use in tissue engineering owing to the low association with immune complications. Autologous cells though are not cost effective and batch controlled for universal clinical usage.[13] In contrast, allogenic cells offer advantages over autologous cells in terms of uniformity, standardization of procedure, quality control and cost effectiveness.[13]

Cell sources can be further be classified into mature (non-stem) cells, adult stem cells (somatic stem cells), embryonic stem cells (ESCs), and totipotent stem cells or zygotes.[14] The utility and applicability of mature cells is restricted because of its poor proliferative and differentiating capacity. Adult stem cells are stem cells found at specific sites or tissue compartments and play a vital role in maintaining the integrity of tissues like skin, bone and blood.[15] They are undifferentiated cells that can be processed to differentiate into specific tissue types. Traditionally, adult stem cells were believed to produce a smaller number of cells restricted to a particular germ layer origin; however, some evidence now indicates that adult stem cells isolated from diverse tissues have greater plasticity than previously thought. Several researchers have attributed this obvious plasticity of adult stem cells to developmental signals-mediated differentiation.

GROWTH FACTORS

Growth factors are proteins that may act locally or systemically to affect the growth and function of cells in several ways. They may act in an autocrine manner, where the cells that produce them are also affected by them; or more commonly, in a paracrine manner, such that the production of a growth factor by one cell type affects the function of a different cell type. These factors may control the growth of cells and hence the number of cells available to produce a tissue. They may also control the metabolism of a particular cell type: for example, the rate of production of an extracellular matrix component such as collagen.[16] Several growth factors such as platelet derived growth factor, nerve growth factor, fibroblast growth factor, insulin derived growth factor as single agents or in combinations, have been examined for their regenerative potential in animal models and in the clinic.[17]

CONCLUSION

Clinical application of tissue engineering ranges from the regeneration of craniofacial structures to skin and cardiac tissues. Present studies are focusing on the development of a best possible scaffolds and cell delivery systems that have properties and surgical practicality appropriate for successful clinical outcomes. It appears that well defined discriminating preclinical models followed by well framed clinical trials are needed to further investigate the true potential of these and other candidate factors.

REFERENCES

1. Langer R, Vacanti J. Tissue engineering. Science 1993; 260:920–926.
2. Vinatier C, Mrugala D, Jorgensen C, Guicheux J, Noel D. Cartilage engineering: a crucial combination of cells, biomaterials and biofactors. Trends Biotechnol. 2009;27:307–314.
3. Rush SM. Trinity evolution: mesenchymal stem cell allografting in foot and ankle surgery. Foot Ankle Spec. 2010;3:140–143.
4. Ducheyne P, Mauck RL, Smith DH. Biomaterials in the repair of sports injuries. Nat. Mater. 2012;11:652–654.
5. Yan LP, Oliveira JM, Oliveira AL, Caridade SG, Mano JF, Reis RL. Macro/microporous silk fibroin scaffolds with potential for articular cartilage and meniscus tissue engineering applications. Acta Biomater. 2012;8:289–301.
6. Balash P, Kang RW, Schwenke T, Cole BJ, Wimmer MA. Osteochondral tissue cell viability is affected by total impulse during impaction grafting. Cartilage. 2010;1:270–275.
7. El-Amin SF, Hogan MV, Allen AA, Hinds J, Laurencin CT. The indications and use of bone morphogenetic proteins in foot, ankle, and tibia surgery. Foot Ankle Clin. 2010;15:543–551.
8. Engebretsen L, et al. IOC consensus paper on the use of platelet-rich plasma in sports medicine. Br. J. Sports Med. 2010;44:1072–1081.
9. Furth ME, Atala A, Van Dyke ME. Smart biomaterials design for tissue engineering and regenerative medicine. Biomaterials. 2007;28:5068–5073.
10. Dhollander AA, DeNeve F, Almqvist KF, Verdonk R, Lambrecht S, Elewaut D, Verbruggen G, Verdonk PC. Autologous matrix-induced chondrogenesis combined with platelet-rich plasma gel: technical description and a five pilot patients report. Knee Surg. Sports Traumatol. Arthrosc. 2011;19:536–542.
11. Kreuz PC, Muller S, Freymann U, Erggelet C, Niemeyer P, Kaps C, Hirschmuller A. Repair of focal cartilage defects with scaffold-assisted autologous chondrocyte grafts: clinical and biomechanical results 48 months

after transplantation. Am. J. Sports Med. 2011;39: 1697–1705.
12. Naughton GK. From lab bench to market: critical issues in tissue engineering. Ann N Y Acad Sci. 2002; 961:372-385.
13. Knight MA, Evans GR. Tissue engineering: progress and challenges. Plast Reconstr Surg. 2004;114:26E-37E.
14. Stock UA, Vacanti JP. Tissue engineering: current state and prospects. Annu Rev Med 2001; 52:443-451.
15. Vats A, Tolley NS, Polak JM, Buttery LD. Stem cells: sources and applications. Clin Otolaryngol. 2002; 27:227-232.
16. Anitua E, Troya M, Orive G. An Autologous Platelet Rich Plasma Stimulates Periodontal Ligament Regeneration. J Periodontol. 2013;84:1556-66.
17. Cochran DL, Wozney JM. Biological mediators for periodontal regeneration. Periodontal 2000. 1999;19: 40-58.

Source of Support: Nil; **Conflict of Interest:** None

Submitted: 27-03-2016; **Published online**: 30-04-2016