Introduction

Tissue loss, trauma or disease is a major socio-economic burden on world healthcare and leads to poor quality of life for the patient. Current treatment approaches for bone are mainly focused on alleviating pain and surgical intervention, replacing the damaged tissues by synthetic biomedical implants, which often fail as a result of not fully integrating with the host tissue. Complete integration or regeneration, can only be achieved when the implant mimics the natural tissue being replaced.

Tissue engineering (TE) is a field that has evolved over recent years to assist tissue loss by providing a living biofunctional tissue equivalent that is able to mimic the properties of the host tissue. An ideal strategy of a TE system is to place cells within the biomaterial scaffold designed to promote cell function and form new tissue. Within the TE concept, the scaffold plays an integral role, serving initially as a physiological support structure with the potential to influence cell processes, such as attachment migration, proliferation and differentiation. In it’s 3-D form, the scaffold provides the necessary support for cells, and it’s architecture defines the ultimate shape of the new tissue.

Current advances in material science and engineering have enabled the use of more sophisticated rational tissue engineering approaches that better mimic in vivo situation, where correct scaffold design, and material properties combined with the synergistic action of stem cells, biological and mechanical cues can be pursued to achieve the regeneration of tissues. In the body, tissues are organized into three-dimensional structures as functional organs and organ systems. To engineer functional tissues and organs successfully, the scaffolds have to be designed to facilitate cell distribution and guide tissue regeneration in the same way. The choice of material is influenced by mechanical properties and integration with surrounding host tissue.

A great range of biomaterials are used as bone substitutes, depending on their bioactivity. Examples include bioglasses and a range of calcium phosphate ceramic biomaterials such as hydroxyapatite (HA) or tricalcium phosphate (TCP). The ability to control porosity and solubility of some ceramic materials offers the possibility of using them as drug delivery systems for growth modulating factors, thus creating an optimal environment for cell growth and differentiation. In addition, new polymers for guided regeneration and the formation of natural and synthetic bone matrix substitutes are also evolving. An ideal biomaterial should have similar physical and bioactive properties to those of the tissue being replaced or repaired.

In tissue engineering (autologous or allogeneic) cell populations are usually expanded ex-vivo, and then seeded onto a scaffold that accommodates and guides the growth and proliferation of the cells in a three dimensional manner. Scaffolds can be fabricated from natural biomaterials, synthetic or semi-synthetic materials to provide the necessary support for cells to proliferate and maintain their differentiated function.

Scaffold systems

Many new approaches have arisen as a result of major advances in both the materials and stem cell technology, and these have opened up numerous challenging possibilities to assist the human body in achieving its own regenerative potential.

In the case of bone tissue engineering, the scaffolds should closely mimic the in vivo environment for bone growth. Scaffolds such as hydrogels and functionalized polymers and porous ceramics present excellent substrates for cell attachment. In addition, stem cell seeded systems, combine the capacity for cell self-renewal with the ability to initiate multiple differentiation cascades resulting in the regeneration of cells with specialized functions, within the 3D scaffold. Examples of such scaffolds include; biomimetic Carbonated Hydroxyapatite (CHA) and alginate composites for cell encapsulation and a porous β-metacalcium phosphate scaffold with osteoinductive and pro-angiogenic potential.

This presentation will review tissue engineering approaches primarily for bone formation, with emphasis on the integral role of the scaffold, it’s biomimetic design and ability to allow cell attachment, differentiation and subsequent integration with host tissue.