ORIGINAL RESEARCH PAPER

Engineering

BASIC CHARACTERISTICS OF SCAFFOLDS SUITABLE FOR USE IN TISSUE ENGINEERING

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ABSTRACT

The term tissue engineering scaffold means that the main role of the biomaterial component is to serve as a temporary 3D support structure for living cells. In recent years, scaffolds have been designed to be more than just a structure of inert material. They are designed to create a biologically responsive environment that leads to the creation of a newly created tissue. In the tissue engineering´s area, patient safety is the top priority for all applications. For this reason, scaffolding must ultimately be degraded and in addition, degradation products must be biocompatible. In this review, we highlight the basic characteristics of the scaffolds suitable for use in tissue engineering.

INTRODUCTION

Already in 2008, Chan and Leong in their study describe four major scaffolding approaches for tissue engineering have evolved.

Nowadays, many scaffolds made from different biomaterials and manufactured by various manufacturing techniques are used. These scaffolds are made for the regeneration of various tissues and organs in the body. Key features in the design or usability determinations scaffolds for tissue engineering, regardless of tissue type, was described in Dr. O'Brien's, 2011, where he focused on all these points as: biocompatibility, biodegradability, mechanical properties, scaffolding architecture and manufacturing technology.

Extracellular matrix as a model for scaffolding

Most cells in human tissues are dependent on the anchor. It is a solid matrix called extracellular matrix (ECM). This matrix is characteristic for each type of tissue. The main role of ECM is to provide structural support and physical environment for cells. Thus, cells can be attached, grown and respond to signals. ECM provides the tissue with mechanical properties such as stiffness and elasticity. These properties are actually the properties of the tissue. ECM also acts as a reservoir of growth factors. Finally, ECM provides a degradable physical environment that allows remodelling and neovascularization in response to physiological, developmental and pathological challenges tissue processes, such as: homeostasis, morphogenesis and wound healing, singly. In tissue engineering, scaffold plays an important role mainly as a substrate that can mimic the native ECM. It has been shown that the behaviour of the cells depends on the tissue properties of the scaffold.

SCAFFOLD PROPERTIES

Creating the scaffold with the required properties such as mechanical strength and chemical surface properties controls tissue regeneration. These properties can be modified and adapted by appropriate choice of material, scaffolding components, and designing techniques. It is also important that the chosen method of treatment does not have a negative impact on scaffold in terms of biocompatibility and biodegradability. Scaffold should be able to degrade accurately by following a certain timeframe that allows the growth of new tissue as well as compensation of scaffold. Scaffolding should have two main functions, namely:

1. Enable and control cell growth through scaffold prior to implantation.
2. Move cell migration directly into the defect.

Scaffolding should also have the chemical properties of the surface that promotes cell attachment and proliferation. Porous structures are essential for the adhesion, transport of nutrients and metabolism products, formation of tissue and sufficient blood supply of new tissue.

Regarding the mechanical properties of the scaffolds they are fixed geometry of the scaffold, inherent properties of bulk materials and production techniques. For example, polymers with higher crystallinity, under normal conditions have a higher tensile strength. If the crystallinity of the polymer chains is reduced due to processing, the resultant scaffold strength is reduced and the lifetime of the scaffold is also reduced. Another important aspect of construction of scaffolds is the inclusion of bioactive DNA molecules, proteins and extracellular matrix´s peptides. If bioactive molecules are involved, the production technique that is activated by these relevant molecules can´t be used because it will affect the adhesion of cells distributing signals, and drugs. Cell migration, proliferation, and differentiation can be greatly enhanced through local distribution of drug, which improves tissue regeneration.

Suitable cells, scaffolds and biochemical or physical factors are basic unit for tissue engineering. These units must work from tissue engineering to the cellular process itself.

When selecting scaffolding technology, the required and expected material properties, as well as the scaffolding function, must be taken into account. And we must also take into consideration the time and cost of producing viable scaffolds for treatment of a particular patient. Each manufacturing technique has its advantages and disadvantages, so choosing a suitable method depends on the requirements for a specific type of tissue.

Scaffold must be of such material that the cells of each type of tissue can settle on it and begin to grow. There are various materials that can meet these criteria. These are usually associated with one or two subgroups based on their physical properties:

- hydrophilic materials - have the ability to absorb water in the aquatic environment.
- less hydrophilic materials - hydrophobic - may contain water in a continuous micro or macro porous structure. They usually require a surface design to ensure biological activity and enable cellular interaction.

For capture cells on the surface of the scaffold, is usually sufficient spontaneous adsorption of proteins from serum in the culture medium. Such porous materials are typically made of relatively hydrophobic and solid polymers. This material has the ability to be sucked in the aquatic environment. Porous structures can be formed using a variety of techniques, such as, for example, salt leaching, emulsification, freeze drying and electrospinning.

Figure 1: Fibrous gird,

Source: https://issuu.com/gsdharvard/docs/material performance/74

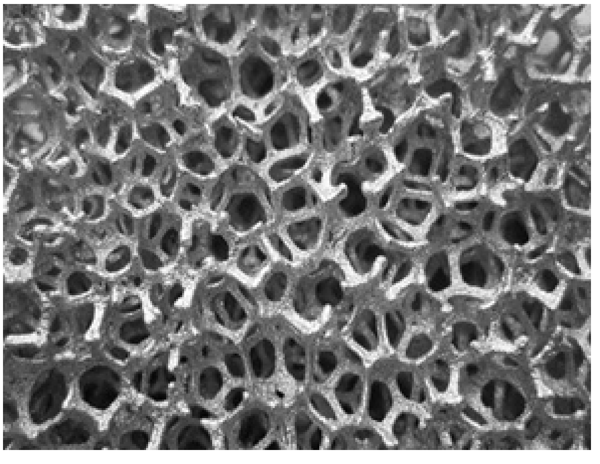

Figure 2: Porous structure of Ni-Cr-Mo-Nb open-cell foam,

Source: https://www.researchgate.net/publication/320566948_Open-cell_superalloy_foams_via_the_combined_ electrolytic-suspension_route/figures?lo=1

The pore size of fibrous (Figure 1) or spongious (Figure 2) materials should be in the range of several microns to allow free migration of cells inside the scaffold. This micro porosity is an advantage for enabling fast and efficient delivery of nutrients and growth factors by passive diffusion regardless of the size of the structure and its geometry. However, these properties disturb the biocompatibility of the porous grid. Porous scaffolds can be improved with modified biopolymers to improve bio-functionality. This bioactivity is usually presented on scaffolds with little time control and can´t be designed for the specific needs of resident (tissue stem) cells. For this reason, many scientists have started to deal with the development of scaffolding with better control of their structural properties. Within such an approach, given the scaffold architecture can better replicate the natural cell environment and provide cells more relevant incentives to support regeneration or ex vivo tissue formation.

The second subgroup of materials for the scaffold is characterized hydrophilic properties, cross-linked polymer chains to facilitate the rapid hydration and swelling in a physiological environment. Scaffolds made of such materials are known as hydrogels and are prepared by covalent or physical crosslinking (molecular splicing, ionic bonds or hydrophobic forces) hydrophilic polymers, polysaccharides, polypeptides or proteins. There are several non-toxic crosslinking methods that enable solidification of the hydrogel solution in the presence of living cells and the creation of a 3D scaffold with a homogeneous cell distribution. The porosity of the hydrogel should be in units of nanometres', which prevents free movement of the cells within the scaffold in the absence of active cell remodelling. Because many types of cells are dependent on the anchor and require a certain degree of mobility, basic structure of the hydrogel it must be designed to contain binding to cells and proteolytic sensitive segments in order to allow active remodelling. These properties allow the encapsulation of the cells into the modified surrounding material by their natural biochemical nature.

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CONCLUSIONS

The role of tissue engineering is the development of biological replacements for the repair, replacement or regeneration of defective tissues. Key components of the tissues are cells, scaffolds, and growth stimulating signals. Generally, they are referred to as a triad of tissue engineering. Scientists are confronted with a large range of choices for choosing scaffolds for tissue engineering. This article reminds the basis characteristics of the scaffolds used in the tissue engineering.

REFERENCES:

[1] Chan, B. P and Leong, K. W. (2008), "Scaffolding in tissue engineering: general approaches and tissue-specific considerations." Eur Spine J, 17(4), 467-479.
[2] O´Brien, F. J. (2011), "Biomaterials scaffolds for tissue engineering", Materialstoday, 14(3), 88-95.
[3] Badylak S. F. (2004) "Xenogeneic extracellular matrix as a scaffold for tissue reconstruction." Transpl Immunol, 12(3–4), 367–377.
[4] Piez, K. A. (1997) "History of extracellular matrix: a personal view." Matrix Biol., 16(3), 85–92.
[5] Robert, L. (2001) "Matrix biology: past, present and future." Pathol Biol (Paris), 49(4), 279–283.
[6] Schönherr, E., Hausser, H. J. (2000) "Extracellular matrix and cytokines: a functional unit." Dev Immunol., 7(2–4), 89–101.
[7] Ghasemi-Mobarakeh, L., Prabhakaran, M. P. et al. (2015) "Structural properties of scaffolds: Crucial parameters towards stem cells differentiation", World J Stem Cells, 7(4), 728–744.
[8] Prabhakaran, M.P., Venugopal, J., Ghasemi-Mobarakeh, L., Kai, D., Jin, G., Ramakrishna, S. (2012) "Stem cells and nanostructures for advanced tissue regeneration." Biomedical applications of polymeric nanofibers. BERLIN: SPRINGER, 21–62.
[9] Li, Y., Rodrigues, J., Tomás, H. (2012) "Injectable and biodegradable hydrogels: gelation, biodegradation and biomedical applications." Chem Soc Rev, 41,2193–2221.
[10] Grayson, W. L., Martens, T. P., Eng, G. M., Radisic, M., Vunjak-Novakovic, G. (2009) "Biomimetic approach to tissue engineering Proceedings of the Seminars in cell and developmental biology." Amsterdam: ELSEVIER, 665–673.
[11] Material Performance: Fibrous Tectonics & Architectural Morphology, studio report, (2016), Harvard University Graduate School of Design, Fall 2013 - 2015. Instructor: Achim Menges. Published on Jul 22,
[12] Smorygo, O., Mikutski, V. et al. (2017) "Open-cell superalloy foams via the combined electrolytic-suspension route", Conference: Euro PM Congress & Exhibition, 1-5 October, At: Milan, Italy,
[13] Karp, J. M., Langer, R. (2007) "Development and therapeutic applications of advanced biomaterials." Curr Opin Biotechnol., 18(5), 454–459.
[14] Langer, R., Tirrell, D.A. (2004) "Designing materials for biology and medicine". Nature, 428(6982), 487–492.
[15] Vijayavenkataraman, S., Shuo, Z., Fuh, J. Y. H., Lu, W. F. (2017) "Design of Three-Dimensional Scaffolds with Tunable Matrix Stiffness for Directing Stem Cell Lineage Specification", An In Silico Study. Bioengineering (Basel). 4(3), 27
[16] Diomede, F., D'Aurora, M., Gugliandolo, A., Merciaro, I., Orsini, T., Gatta, V., Piattelli, A., Trubiani, O., Mazzon, E. (2018) "Biofunctionalized Scaffold in Bone Tissue Repair". Int J Mol Sci, 19(4).