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Review

The influence of topography on tissue engineering perspective

Negar Mansouri [a], SamiraBagheri [b,*]

[a] Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Nanotechnology & Catalysis Research Centre (NANOCAT), IPS Building, University of Malaya, 50603 Kuala Lumpur, Malaysia

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ABSTRACT

The actual in vivo tissue scaffold offers a three-dimensional (3D) structural support along with a nano-textured surfaces consist of a fibrous network in order to deliver cell adhesion and signaling. A scaffold is required, until the tissue is entirely regenerated or restored, to act as a temporary ingrowth template for cell proliferation and extracellular matrix (ECM) deposition. This review depicts some of the most significant three dimensional structure materials used as scaffolds in various tissue engineering application fields currently being employed to mimic in vivo features. Accordingly, some of the researchers' attempts have envisioned utilizing graphene for the fabrication of porous and flexible 3D scaffolds. The main focus of this paper is to evaluate the topographical and topological optimization of scaffolds for tissue engineering applications in order to improve scaffolds' mechanical performances.

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1. Introduction

Recently, tissue loss replacement has revealed high potency to take the place of surgical treatment approaches which contain a large section of healthcare systems. At present, there exist several therapeutic strategies to cure or replace tissue shortage such as artificial or prosthesis body parts, mechanical devices, drug therapy, biological prepared tissues, transplantations, surgical reconstruction and autologous transplant. Ultimately, though, major damage to a tissue or organ can neither be repaired nor long-term restoration affects in a really acceptable level by these methods. Even though, these old-styled ways and means of tissue therapy have survived countless patients and influenced toward better life quality, they are subjected to some disadvantages like rare resources, high susceptibility to infection, high possibility of immune system refusal, and uncertain long-term dealings

* Corresponding author.
E-mail address: samira_bagheri@edu.um.my (SamiraBagheri).

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with patients. Additionally, the problems become more acute for pediatric as the implantable organ may not grow simultaneously with the child growth trend.

Tissue engineering is evolving as a major optimal alternative or integral solution, whereby tissue and organ incapacitation is treated by embedding natural, synthetic, or semisynthetic tissue and organ mimics. Tissue engineering field is defined as a multidisciplinary science field in which principles and strategies of engineering, biological and medical sciences are integrated en route for acquisition of fundamental knowledge related to the development of biological replacements to renovate, preserve, or progress function of damaged tissue/organ [1]. Researchers have found out numerous prospective applications of tissue engineering including neonatal tissue loss, congenital abnormalities such as esophageal atresia, bladder exstrophy and congenital diaphragmatic hernia [2]. It has observed an abundant amount of improvements in fetal diagnostics which contribute toward fabrication of missing tissue or organ for surgical exchange during childbirth. Primary experiments of tissue engineered organs have concentrated on skin regeneration as an alternative for burned skin. Later, considerable outcomes consist of tissue-engineered bone, blood vessels, liver, muscle, and even nerve conduits have been reported. On account of the medical and therapeutic potential, there is substantial academic and commercial interest in this technology [3].

1.1. Tissue engineering

Tissue/organ shortage or damage triggered by any kinds of injuries is considered as one of the most disastrous and pricey concerns dealing with human healthcare. Tissue engineering is the interdisciplinary study of obviating the organ shortage problems with intention of biological alternatives which can assist in recovering or augmenting function of injured tissue. Many scholars have concentrated on enforceable tissue growth for cardiothoracic surgical treatment such as heart valves, veins, myocardium, throat, and trachea. Tissue engineering knowledge involves principles and approaches related to engineering, life science, material and chemical science in the direction of improvement of biological replacements with high potential to reinstate, preserve, or cure tissue/organ malfunction. This general idea of tissue engineering was engaged in 1993 to situate a mouse tumor cells in the abdominal cavity of a pig whereas the cells were not rejected by the immune system. In 1975, a pilot study has been investigated to ameliorate glucose control in diabetes by putting pancreatic islet cells in semipermeable membranes. Tissue engineering attempts have been accepted for all tissue and organ types since 2001. Tissue engineering objective encompasses repairing organ's function via the distribution of living tissue which have a duty to actuate the creation of new, physiologic and operational tissue involved the collective endeavors of biological scientists, engineers, material scientists, geneticist and clinicians [4].

1.1.1. Tissue engineering current state

Tissue engineering, which makes use of mimicking the nature, has the capabilities to encounter the transplantation troubles. Numbers of issues in cell technology have noticeable effects in satisfactory level of engineered tissue such as cell source, manipulation of cell function, actual usage of stem cell technology, fabrication and design technology of tissue, engineering of immune reception [5].

There have been found some drawbacks for methods utilizing implantation of foreign body organs including high chances of infection and fracture, immune problems and migration overtime. Besides, methods including tissue replacement have pointed out to biologic alterations due to the maladaptive interaction of the substituted tissue in its new place. As an illustration, redirecting urine into the colon may cause fatal colon cancers after some years. Tissue engineered esophageal tubes made of skin tissue probably result in skin tumors. Although tissue engineering still needs some enhancements and developments in terms of material and chemical engineering, but it has attracted researchers' interest for its prospective applications. Regrettably, some inevitable difficulties and limitations exist for tissue transplantation and artificial organs which makes these therapeutic methods defective treatment solutions. These difficulties can be listed as below:

i) Shortcoming of available donors due to the high difference between amount of patients demanding transplants and offered organs
ii) Immunosuppression problems of transplantation receivers
iii) High risks of infection, tumor growth, and annoying side effects
iv) Donor site morbidity.

Due to the above problems, tissue engineered products was revealed to exchange unhealthy tissue with alive tissue designed and fabricated exclusively for each patient [6].

1.1.2. Tissue engineering scaffolds

Various scientists are trying to investigate capable chemical and physical configurations of long-lasting/biodegradable biomaterials leading to fabrication of novel tissue-engineered products. These biomaterials can be made of natural, synthetic or hybrid materials meanwhile the compatibility of them with living organs is an essential necessity in vitro/vivo. As a result, design specifications of biomaterials are a controversial tissue engineering issue which ought to be surveyed in molecular chemical level. The first evidence of successful investigation in tissue engineering field was recorded for bone grafts in Amsterdam. After 225 years, "scaffold" notion was demonstrated as a porous template for damaged tissue regeneration [7].

Tissue engineering has been introduced as a potential substitution method to cure absence or failure of a tissue or organ with no constraints of current approaches. This technique includes the cell growth out of small biopsy and consequently culture the cell in impermanent porous 3D scaffold to create the new organ or tissue. Designed and expanded cells adjoin to the scaffold in all dimensions, proliferate and discharge their own extracellular matrices followed by exchanging the biodegrading scaffold. Theoretically, in order to grow new and practical living tissues there should be some fundamental components available as so called the ingredients containing living cells, matrix or scaffold and signaling molecules. Cell sources can be classified into three main resources including autologous, allogeneic, and xenogeneic. Effectual proliferation and differentiation characteristics of cells as well as their cell-to-cell interaction and biomolecular production assist tissue engineering field drastically. Perfect tissue engineering donor cells are those having ease of access with easy expansion without permanently changing the phenotype or function and have the minimum immunologic feedback. Scaffolds, which can be natural or synthetic, assist as templates for cell growth. Scaffold design procedures has confronted with consequential challenges along with some specific criteria in tissue engineering field which are listed in the Table 1. Several tissue engineered 3D porous scaffolds were made from different types of biodegradable

Table 1
Scaffold design requirements.

Design criteria	Description
Excellent surface adhesion	Encourage cell growth, and provide the preservation of differentiated cell functions
Biocompatibility	Do not induce in-vivo inflammation or toxicity
Biodegradable	Should be removed gradually after cultivation, degradable into non-toxic products
Highly porous	Offer adequate space to ensure efficient cell adhesion and distribution as well as extracellular matrix regeneration to facilitate homogeneous tissue formation