Design and Development of Metal Nanoparticle Incorporated Scaffolds from Biomaterial for Tissue Engineering Applications

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Abstract

Biomaterials find wide applications in biomedical field especially in wound healing, tissue engineering and drug delivery. They are corrosion and wear resistant, durable, non-toxic along with having excellent mechanical strength. Biomimic materials can be employed in place of heart valves or arteries. Polyester, polypropylene, Chitosan, Nanocellulose, Polyglycolic acid etc. are a few polymers that are extensively employed in medical field. This review offers an overview of current research in scaffolds from biomaterials, their fabrication, challenges and importance in the biomedical field.

Keywords

Tissue engineering; Scaffolds; Hydrogels; Biodegradable nanomaterials

1. Introduction

Modern science uses a wide range of biomaterials for the treatment of various diseases. Over the past two decades, the research interest in biodegradable polymers has rapidly increased and thousands of publications and patents dealing with their preparation and characterization have been reported [1]. The biodegradable polymers, allow for a broad variation of their structure and properties, and thus, enable optimization for diverse applications. Resorbable medical sutures, drug-delivery and encapsulation, resorbable and transparent films for wound dressing, or films designed for agricultural applications should be mentioned as representative examples. With advancements in tissue engineering, it has become necessary to develop polymers that meet more demanding requirements [2]. In the design of biodegradable biomaterials, many important properties must be considered. These materials must (1) not evoke a sustained inflammatory response (2) exhibit a degradation time in correlation with their application (3) excellent mechanical properties for their specified use (4) expel non-toxic degradation products that can be readily resorbed or excreted and (5) include appropriate permeability and processability for designed usage. These properties are greatly affected by a number of features of degradable polymeric biomaterials [3].

Proteins and amino acid-derived polymers have been utilized as biomaterials in sutures, scaffolds and drug delivery devices. While amide bonds are hydrolytically stable, the body possesses a wide-array of proteases that can rapidly degrade proteins. Collagen has been extensively researched for various medical applications due to its biocompatibility, mechanical strength and enzymatic degradability [4]. Due to collagen’s fibrous nature, it is largely used in tissue engineering scaffold, specifically in load bearing applications. In order to improve collagen’s potential as a biomaterial, it has often been modified or combined with other degradable polymers. It is mainly done in the form of polymeric blends.

2. Chitosan as a biodegradable natural polymer for tissue engineering

Metal nanoparticles can be effectively synthesized from the self-assembly of star block copolymers containing biodegradable natural polymers like chitosan. By incorporating metal nanoparticles in scaffolds from biomaterial, antibacterial activity can be enhanced. Metal nanoparticles have catalytic properties also, which trigger their degradation rate. Due to their small size, they can easily penetrate through cell membranes causing damage to the building blocks and inhibit the ATP production. Nanoparticle incorporated scaffolds are more efficient than nanoparticle attached on the surface of the biomaterial [5].

The most reliable technique for the preparation of scaffold includes the use of electro spinning method (**Figure 1**). Due to the number of reaction sites, surface to volume ratio, and porosity, polymer nanofibres are better used in the fabrication of scaffolds. Developing a scaffold from biomaterial, mainly chitosan grafted with other biodegradable polymers such as polyglycolic acid, polycaprolactone, polylactic acid, polyethylene glycol with the incorporation of metal nanoparticles coated with collagen, can effectively improve their mechanical properties, antibacterial properties and the hydrophilic nature of the scaffold. Chitosan is also known for its wound healing by regenerating new tissues, better transmission of oxygen, increased blood coagulation rate and preventing microorganisms. The drawback of chitosan when employed in such applications include its poor solubility and it can be overcome by incorporating hydrophobic moieties in its structure [6].

3. Nanoparticle embedded hydrogels for tissue engineering

Hydrogels embedded with nanoparticles is a new approach in the tissue engineering applications. Polyvinylcaprolactam polymer is a better choice due to its biocompatibility and lower critical solution temperature nearly around the human body temperature. Apart from these properties, it has high water content and porosity resembling a living tissue. Due to lack of mechanical strength, its application as a drug delivery vehicle has some limitations. Highly stretchable hydrogels can be prepared by incorporating inorganic materials such as SiO_2, clay etc. as fillers.

4. Other biodegradable nanomaterials for tissue engineering

Nanoparticle incorporated nano polymeric films exhibit better therapeutic effects and represent better option for skin tissue engineering. Curcumin incorporated PVA composite film has been recently developed for wound dressing. Chitosan/gold films were also developed, which increase the antimicrobial property of the film.

A better understanding of the mechanism of cells is needed for the development of skin repair scaffolds [6]. The efficiency of the nanoparticle incorporated scaffolds depends on several factors such as size of nanoparticles, roughness of the scaffolds etc. [7]. The uncontrolled release of nanoparticles to the cells, diffusion of nanoparticles to other organs creating toxicity and a more active biocompatibility test are some other factors, which will improve the use of biomaterial scaffolds in tissue engineering.

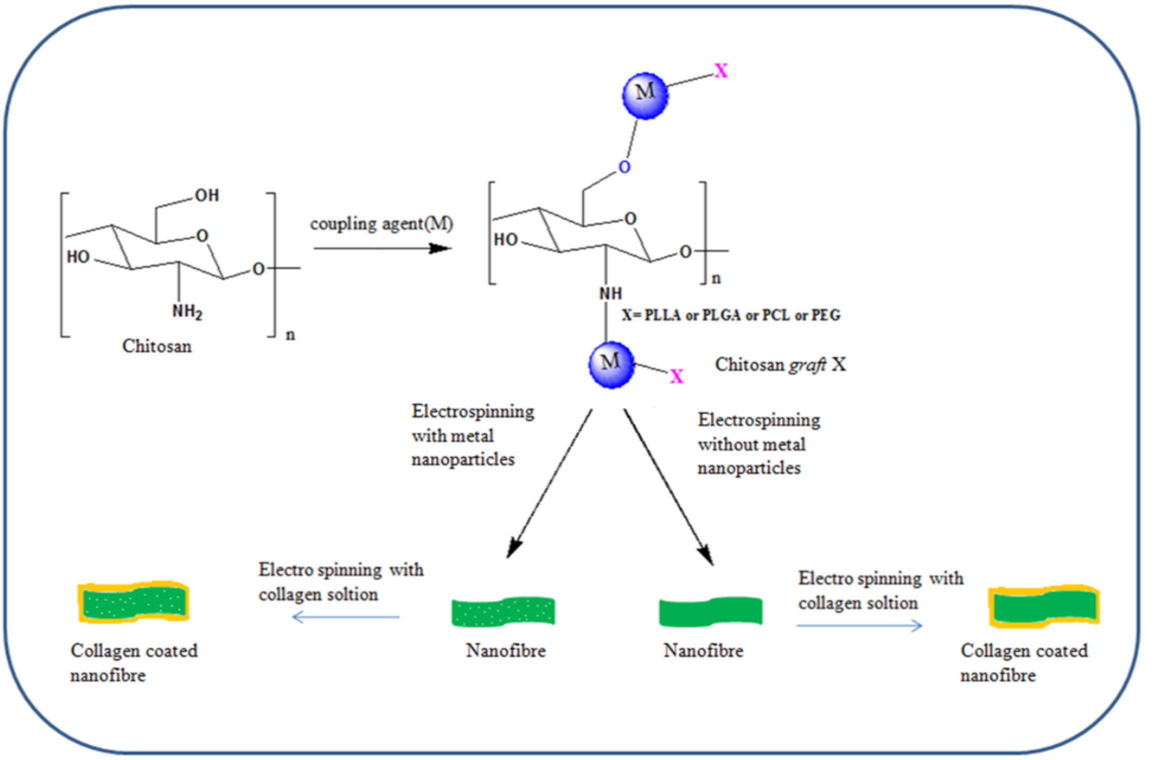

Figure 1: Schematic representation of the metal nano particle incorporated scaffolds

5. Outlook and future perspectives

Numerous advanced strategies were developed in preparing scaffolds in tissue engineering. Still several challenges have to be overcome before the scaffolds are clinically used and commercialized. The mechanical, structural and chemical properties have to be tuned for the use of scaffolds to increase the biodegradation rate and cell proliferation. The degradation rate of scaffolds used in tissue engineering depends entirely on composition, polymeric structure and method used in fabricating the scaffold. The incorporation of nanoparticles and crosslinking have an opposite effect on degradation that need to be optimized.

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