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Electrospun composite PLLA/Oyster shell scaffold enhances proliferation and osteogenic differentiation of stem cells

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ABSTRACT

In bone tissue engineering, bioceramics are of the most widely used materials for treatment of bone defects clinically. The composites of bioceramic/polymer fibrous scaffolds have been designed and developed to fulfill the mechanical and biological requirements of the damaged tissue. In the present study, oyster shell (OS) as a bioceramic in combination with the biodegradable and biocompatible poly (L-lactide) has been used to prepare a new tissue-engineered composite. The morphology, porosity, water contact angle and mechanical properties of scaffolds were investigated. Mesenchymal stem cells were also cultured on fabricated scaffolds to evaluate their potential to support cell proliferation and osteogenic differentiation. The SEM results indicated that the electrospun scaffolds were nanostructured and the OS were oriented along the fiber axis. The tensile strength and also the increased surface hydrophilicity of scaffolds after plasma treatment were suitable for tissue engineering applications. MTT assay demonstrated that the fabricated scaffolds were capable of supporting stem cell attachment and proliferation. Biomineralization measurements demonstrated the enhanced osteogenic differentiation of stem cells on composite PLLA/OS scaffolds. Taken together, these scaffolds were shown to hold promising potential for the treatment of bone defects in vivo.

1. Introduction

Despite recent advances in medical approaches, the number of defects and diseases of bone tissue has been increased due to reduced average life expectancy of people, increasing population growth, environmental pollution and mechanical stresses of life. According to the phenomenon of population aging, the prevention and treatment is very important, and the scientist are searching for new approaches for more efficient repair and reconstruction of bone tissue damages [1]. There are conventional methods usually used for bone repair: The first and gold standard is “Autograft” in which the surgeon harvest the bone tissue from a healthy site of the body and transplant it in the bone lesion. The second method is allograft in which the transplant tissue is separated from unrelated individuals. In the first method, a second operation should be performed on the patient, but in the latter, immunology and transplant rejection issues may occur because people do not have the same antigens [2].

Because of the problems associated with the current bone treatment techniques, the researchers have tried to produce artificial scaffolds made from synthetic biocompatible and biodegradable polymers for bone repair procedures. The most important characteristics considered for the selection of a scaffolding material, are its compatibility with the human body environment, porosity, and the lack of immunological response [3]. Polymers do have valuable properties such as low cost, low weight and high chemical resistance, flexibility and easy scalability. Combining biodegradable polymers such as poly (caprolactone) (PCL), poly (L-lactide) (PLLA), with the bioceramics and calcium minerals, enable better control of structures macroscopically and microscopically to achieve a desired shape for the use of orthopedics. In addition, biodegradable polymers can be used to reduce the brittleness of ceramics and in the same time, keeping their bone regenerating properties [4]. Biodegradable polymers in combination with bioceramic materials have been shown highly promising in the field of bone tissue engineering [5–8].

Among the methods used for production of nanofibres, electrospinning is the most common and efficient one because of the ease of

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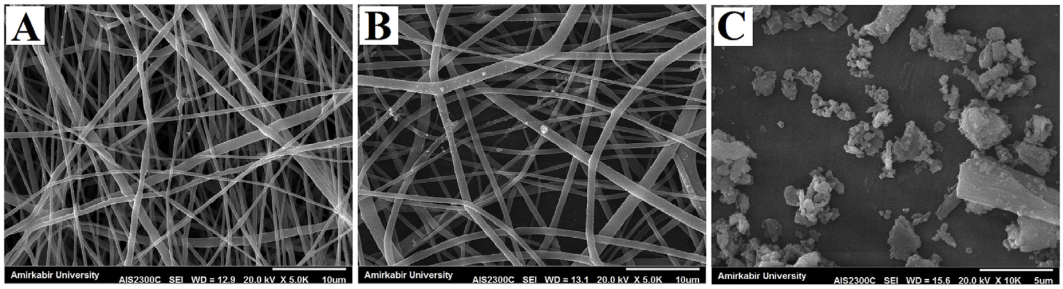

Fig. 1. SEM micrograph of electrospun scaffolds: A) PLLA B) PLLA/OS and C) OS.

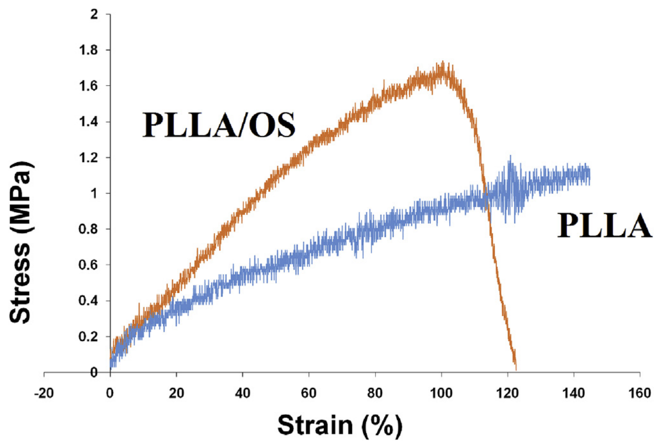

Fig. 2. Mechanical properties of fabricated electrospun PLLA and PLLA/OS scaffolds.

the process and the possibility to use for the most polymers. The main advantage of the process is that in contrast to other methods, the produced nanofibers are usually smooth and continuous. Electrospun nanofibers have the invaluable potential of mimicking the extracellular matrix (ECM) of the most native tissues in the human body. This property has been used by several researchers for the fabrication of tissue-engineered scaffolds for an efficient treatment of various tissue damages [9–13].

High biocompatibility of calcium-based bioceramics and their similar chemical composition to the mineral portion of bone has caused these materials to have many applications in the human body [14]. Oyster shells (OS), due to their wide availability, low cost and natural biological origin exhibit very attractive properties for use in regenerative medicine. OS is fully composed from about 96% CaCO3 and other minerals in very small amounts. OS contains Crystal structure and composition similar to human bone so its application as the raw material for bone tissue engineering is promising [15]. In this study, we propose a composite scaffold for bone damages treatment derived from OS powder and PLLA. The core idea of this study is that if the composite

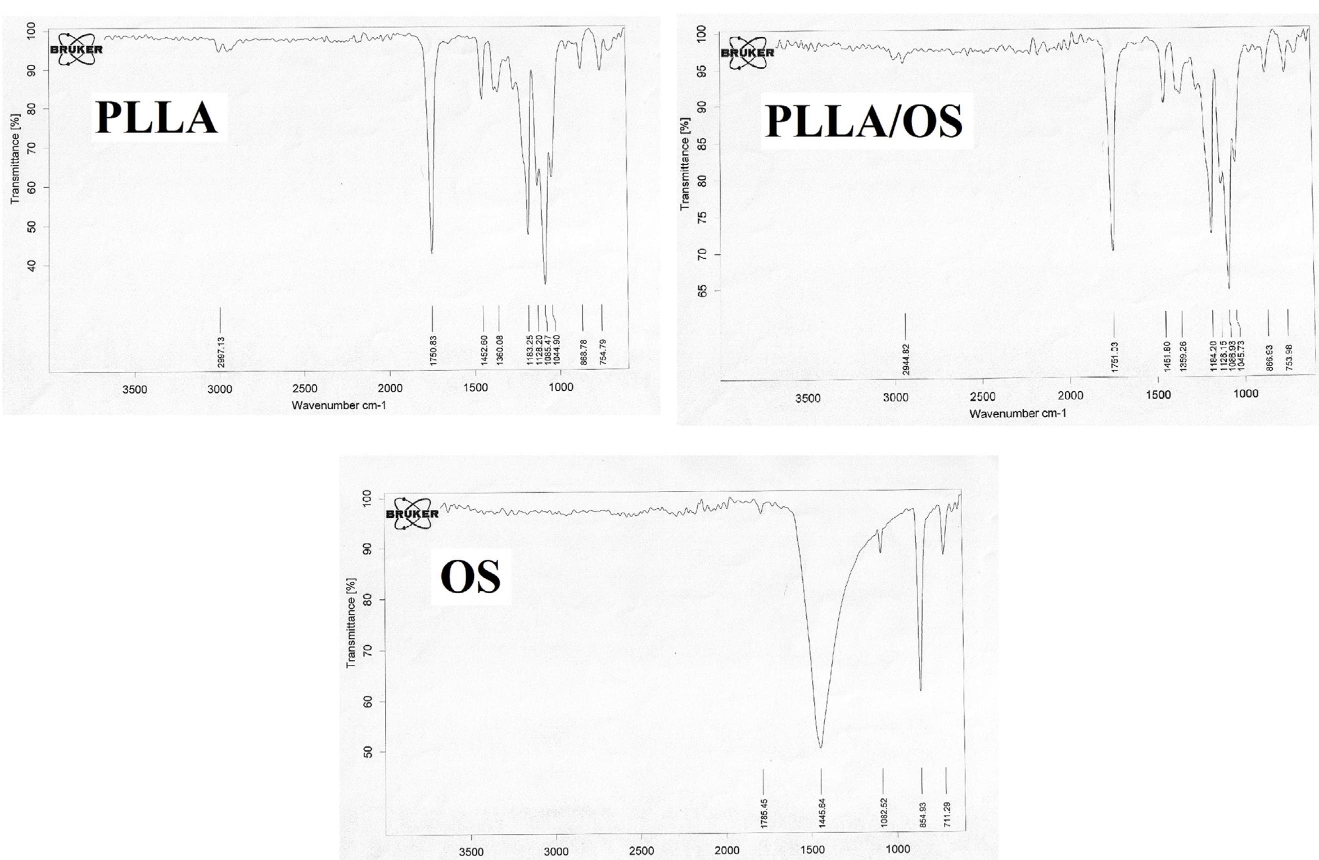

Fig. 3. FTIR spectra of A) PLLA B) PLLA/OS and C) OS.