The mechanical and biological properties of a novel biodegradable polycaprolactone-magnesium porous scaffold for bone tissue engineering

K.H.M. Wong[1], K.W.K. Yeung[1], P.K. Chu[2], K.D.K. Luk[1] and K.M.C. Cheung[1]
1Department of Orthopaedics and Traumatology, The University of Hong Kong, Pokfulam, Hong Kong, China
2Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong, China

Introduction

Bone tissue engineering offers an alternative solution to the traditional methods of bone replacement including allografts and autografts. Tissue grafting has been used since 1660s[1]. However, there are concerns of tissue shortage and transmission of disease. Therefore, the use of scaffold is the most common technique and good approach to regenerate diseased or damaged bone tissue. Polycaprolactone (PCL) is one of the suitable candidates to be used as the scaffold material since it has a low degradation rate when compared with other polymers. However, the low mechanical strength and intrinsic hydrophobic properties of polymers may inhibit its use[2]. Hence, our group has recently fabricated a biodegradable polymeric-metallic scaffold made of PCL and magnesium (Mg) to solve the problems[3]. This study aims to investigate the mechanical and biological properties of the newly developed scaffold.

Materials and Methods

PCL-Mg scaffold with 29% 45μm and 150μm Mg beads were prepared by salt leaching method, respectively. The surface morphologies of the scaffolds were examined by scanning electron microscopy (SEM).

To test the mechanical properties of the PCL-Mg scaffolds, compression test was conducted by using the Material Testing System (MTS) machine.

The biocompatibility of the PCL-Mg scaffolds were tested by culturing green fluorescent protein osteoblasts (GFPOB). In addition, a 7-day immersion test in DMEM medium was conducted to test the bioactivity of the scaffolds. The scaffolds were examined by SEM and energy-dispersive X-ray spectroscopy (EDX) after immersion.

Results

From the compression test, both the PCL-Mg scaffolds with the 2 particle sizes exhibited higher compressive moduli than the pure PCL scaffold (Figure 1). The average compressive modulus of 150μm Mg scaffold was found to be approximately 1.5MPa, which was 3-fold higher than the pure PCL scaffold. For the 45μm Mg scaffold, the average compressive modulus was found to be even 6-fold higher. Cells tolerated very well on the PCL-Mg scaffolds as shown in Figure 3a after 3 days of cell culture. In addition, after 7-day of DMEM immersion, a large area of calcium (Ca) and phosphate (P) was detected on the PCL-Mg scaffold (Figure 3b) but not on the pure PCL scaffold.

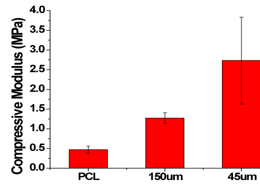

Figure 1. Compressive moduli of the PCL and PCL-Mg scaffolds. 3-fold and 6-fold higher of moduli were found on the PCL-Mg scaffolds than the pure PCL scaffold.

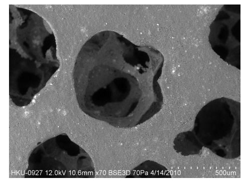

Figure 2. Surface morphology of the PCL-Mg scaffold. The total calculated porosity was approximately 70% with the pore sizes ranged from 200μm to 400μm.

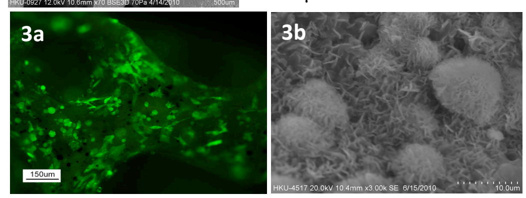

Figure 3a. Microscopic view of GFP mouse osteoblasts cultured on PCL-Mg scaffold for 3 days. Cells grow well on the scaffold. Figure 3b. Ca & P were viewed and detected under SEM and EDX, respectively.

Discussion and Conclusions

PCL is a biodegradable polymer with slow degradation rate that has been used in drug delivery and tissue engineering[4]. However, similar to most other polymers, lack of cell adhesion and interaction and low mechanical properties may inhibit its use in bone tissue applications[5]. Hence, modification is needed. Magnesium as an incorporating material is a biodegradable metal which possess higher mechanical properties when compared with polymers. Furthermore, it is an essential mineral to cells[6]. The results suggested that the compressive modulus has been increased to at least 3-fold higher. In addition, calcium phosphate was detected after 7-day DMEM immersion, which was not found on the pure PCL scaffold. The result proved that the PCL-Mg scaffold is bioactive which is favorable for cell growth and hence allow bone apposition. Moreover, the amount of magnesium incorporated was 29%, which can be varied according to different applications.

To conclude, the newly developed PCL-Mg scaffold is able to improve both the mechanical and hydrophobicity of PCL polymer scaffold. However, other test include the mechanical test during degradation is still needed.

References: 1. Hollister S et al. Nat Mater. 4, 518-24, 1997 2. Roether et al. Biomaterials 23, 3871-78, 2002. 3. U.S. Non-Provisional Application No. 12/836,326 filed 14 July 2010. 4. Corden TJ et al. Biomaterials 21, 713-24, 2000. 5. Puppi D et al. Progress in Polymer Science 35, 403-40, 2010. 6. Saris L et al. Clin Chim Acta 294, 1-26, 2000

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