3D printing of bone scaffolds with hybrid biomaterials

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Abstract
In this research, a novel hybrid material bone implant manufacturing through the integration of two materials using additive manufacturing (AM) technology is proposed. Biomimetic application can manufacture high strength biomechanical implants with optimised geometry and mass. The combination of polymers allows a significant leap in the development and production of a great diversity of components and applications of biomaterials. A novel hybrid scaffold with a poly lactic acid (PLA) matrix reinforced with carbohydrate particles (cHA) is analysed using digital surface software in the mass proportions of 100/0, 95/5, 90/10 and 80/20 for application in tissue and regenerative engineering, seeking a higher proposition strength of PLA. Filaments are used to fabricate scaffolds by 3D printing, using the fused deposition method. The frameworks are submitted to bioactivity tests, surface roughness evaluation, apparent porosity and mechanical analysis. Analysis of the microstructure of the composite particle evaluates the 3D surface luminance structure and the profile structure. Cross-sectional views of the specimens are extracted and analysed, and the surface roughness, waviness profile, and Gaussian filter of the structures are observed. In summary the structures are checked and analysed by SEM and EDS where possible, to observe the bioactive behaviour of the materials. The relationship between cHA content and roughness is shown to be proportional. The mechanical properties are shown to be affected by the reduced interaction between the PLA matrix and the cHA particles.

Keywords: tissue engineering; bone generation; PLA/cHA; 3D printing; hybrid manufacture

1. Introduction

Findings from population statistical research institutes point to a rising life expectancy in the world population. As humans age, the risk of compromising organs, tissues and the body as a whole increases. Tissue engineering seeks to use biomaterials to replace conventional transplants. A biomaterial is defined as any substance or combination of materials, other than drugs or synthetic natural materials, which can be used, for any period, to partially substitute for any tissue, organ or function of the body for the purpose of maintaining or improving the lifespan of an individual [1]. A fundamental requirement of a biomaterial used in clinical medicine is that it is biocompatible, that is, it can coexist with human tissue without causing any undesirable or inappropriate effects [2, 3]. Biomaterials can be classified into three main categories: bioinert, intolerant materials that are not capable of inducing any biological interfacial bond between the implant and the host tissue [4, 5]; bioactive, capable of interacting with body tissues, forming chemical or biological bonds and favouring the development of processes such as implant fixation, colonisation and tissue regeneration; and bioreabsorbable, materials that are gradually reabsorbed until they disappear entirely and are wholly replaced by new tissue in vivo. In general, biomaterials can be classified into: natural, from plants and animals; and synthetic, which can be sub-categorised into metals, synthetic polymers, ceramics and composites [6, 7].

Metal is a common materials used in the biomedical field for implants. Its high tensile strength and fatigue characteristics make it suitable for a variety of applications, such as dental implants, and joints such as knees and hips [8, 9]. However, metals have limitations