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Strontium-containing mesoporous bioactive glass scaffolds with improved osteogenic/cementogenic differentiation of periodontal ligament cells for periodontal tissue engineering

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ABSTRACT

To achieve the ultimate goal of periodontal tissue engineering, it is of great importance to develop bioactive scaffolds which can stimulate the osteogenic/cementogenic differentiation of periodontal ligament cells (PDLCs) for the favorable regeneration of alveolar bone, root cementum and periodontal ligament. Strontium (Sr) and Sr-containing biomaterials have been found to induce osteoblast activity. However, there has been no systematic report about the interaction between Sr or Sr-containing biomaterials and PDLCs for periodontal tissue engineering. The aims of this study were to prepare Sr-containing mesoporous bioactive glass (Sr-MBG) scaffolds and investigate whether the addition of Sr could stimulate osteogenic/cementogenic differentiation of PDLCs in a tissue-engineering scaffold system. The composition, microstructure and mesopore properties (specific surface area, nanopore volume and nanopore distribution) of Sr-MBG scaffolds were characterized. The proliferation, alkaline phosphatase (ALP) activity and osteogenesis/cementogenesis-related gene expression (ALP, Runx2, Col I, OPN and CEMP1) of PDLCs on different kinds of Sr-MBG scaffolds were systematically investigated. The results show that Sr plays an important role in influencing the mesoporous structure of MBG scaffolds in which high contents of Sr decreased the well-ordered mesopores as well as their surface area/pore volume. Sr^{2+} ions could be released from Sr-MBG scaffolds in a controlled way. The incorporation of Sr into MBG scaffolds has significantly stimulated ALP activity and osteogenesis/cementogenesis-related gene expression of PDLCs. Furthermore, Sr-MBG scaffolds in a simulated body fluid environment still maintained excellent apatite-mineralization ability. The study suggests that the incorporation of Sr into MBG scaffolds is a viable way to stimulate the biological response of PDLCs. Sr-MBG scaffolds are a promising bioactive material for periodontal tissue-engineering applications.

1. Introduction

Periodontitis is an inflammatory disease that progressively invades the periodontium, including alveolar bone, periodontal ligament and root cementum [1]. A major cause for tooth loss, periodontitis affects around 15% of the adult population [2] and even up to 60% as reported in another study [3,4]. While conventional treatment for periodontitis aimed at removing the dental plaque and calculus is generally successful, the complete repair and regeneration of lost periodontal structures remains a significant challenge. For the past decade, although various treatment options for periodontitis have been developed, such as root surface conditioning [5,6], use of a variety of bone grafts [7,8], guided tissue regeneration (GTR) with space-maintaining barrier membranes [9,10], application of growth factors [11,12], etc., only a few of these approaches achieve predictable and optimal periodontal tissue regeneration [13], and only little new connective tissue attachment and cementogenesis can be expected.

The desire to develop more favourable treatment options to restore periodontal structure and regain the physiological function of the periodontium has inspired advanced research into periodontal tissue engineering, which involves the combination of cells with regenerative capacity and engineering biomaterial scaffolds with desirable biochemical property. Periodontal ligament cells (PDLCs) have been demonstrated to have the ability to differentiate into osteoblasts and cementoblasts in vitro [14] due to their unique localization and multilineage differentiation capacity [15]. However, limited sources of autologous PDLCs for patients with

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