OSSEOINDUCTION BY CALCIUM PHOSPHATE BONE SUBSTITUTE MATERIALS IS A FUNCTION OF CHEMICAL COMPOSITION AND STRUCTURE

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Introduction

Oseosductive materials promote rapid bone formation as they stimulate bone formation in the near vicinity of host bone by conductive mechanisms and also further away from osseous tissue by inducing the differentiation of bone precursor cells [1]. Hydroxyapatite (HA) is a well-known synthetic biomaterial for bone replacement and has a similar structure to bone mineral. Bone mineral contains trace level elements such as Sodium, Potassium, Fluorine, and Silicon (Si). Silicon is known to play an important role in skeletal development and quality of bone apposition. Since incorporation of Silicon into the calcium phosphate structure has been shown to enhance the bioactivity, silicon substituted calcium phosphate (SiCaP) ceramic has been utilized as an osteoconductive material for bone formation. However, the osseoinductive capacities of this biomaterial have not been assessed. A previous study carried out by Hing et al showed that bioactivity of hydroxyapatite bone substitute materials was enhanced by increasing level of microporosity within the implant struts [2]. The aim of this study was to test the hypothesis that SiCaP as a biocompatible bone graft substitute promotes osseoinduction that can be enhanced using materials with high microporosity.

Method

Four bone graft materials, each in the form of granules and blocks were supplied by ApaTech Ltd: (a) 20% microporous SiCaP (Actifuse), (b) 30-35% microporous SiCaP, (c) 11-13% SiCaP and (d) HA (Apapore80) were supplied by ApaTech Ltd. Twenty four plugs of bone substitute materials were implanted into the saccosplius muscle of four skeletally mature female sheep. Implants in the form of blocks were inserted directly into the muscle bed. In order to contain the implants at the surgical site, granules were packed into a cylindrical stainless steel mesh. Following this the granules were immersed in autologous blood. The mesh together with the granules were removed from the tube and then implanted into the muscle. In one group of the animals each animal carried four implants of granular materials and in another group each animal carried eight implants of which four were blocks and four granular plugs. Animals were euthanized at week 12. After sacrifice, implants surrounded by a layer of muscle were removed and fixed for histology. Thin sections of ~70 µm thick were prepared by ultramicrotomy in a proximal distal direction. Image analysis and histomorphometry was carried out on thin sections to assess bone formation within the implants. Percentage of bone area, soft tissue area and the area occupied by the test material were calculated. In addition, percentage of the amount of bone attached to the calcium phosphate surfaces was measured. Scanning Electron Microscopy (SEM) and EDAX were also carried out to evaluate the quality of bone formation, and elements remaining within the implants.

Results

Image analysis and SEM results from samples collected at 12 weeks showed bone formation within the pores of both granules and blocks of SiCaP and HA implants. More bone formation and contact was observed in SiCaP implants when compared with the HA implants where the amount of bone formed was minimal. There was more bone formation and bone attachment when SiCaP implants with the higher microporosity were compared with the HA implant (Fig 1 and 2). Further, increased amount of bone formation was observed between implants of the same chemical composition but with different microporosity. Implants with higher microporosity showed higher levels of bone formation and attachment. Bone area and attachment was observed to be greater for blocks of implants, specifically in 30-30% microporous SiCaP implant blocks (Fig 2). Bone attachment was observed more frequently inside the pores. Additionally in the SiCaP implants bone rich in silicon and osteocyte like cells could be seen in pores less than 20 µm in diameter. Bone cells could be identified within very small pores (Fig 1). Correspondingly in adjacent areas Si levels were reduced within the bone substitute material.

Discussion

The results of this study show that SiCaP promotes bone ingrowth. Ectopic bone formation was observed in all four groups of synthetic materials. We report that SiCaP is more osseoinductive than HA. Additionally, osseoinductivity can be promoted by increasing microporosity. Therefore our hypothesis is confirmed.

References:

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