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Ion Substitution of Bioceramics: The Role of Ions

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Bone mineral is a natural ceramic, known as hydroxyapatite (HAp). However, it is not stoichiometric, but poorly crystallized, and multi-ion substituted. The formula of HAp can be described as $Ca_{10}(PO_4)_6(OH)_2$. All ions, calcium, phosphate, and hydroxide ions, in the crystal structure can be substituted by different cations and inions [1]. Calcium ion can be replaced by mono- or bivalent cations, such as strontium, magnesium, sodium ions. Phosphate ion can be substituted by multivalent inions, such as silicate and carbonate ions. Hydroxide can be substituted by monovalent inions, such as fluoride and chloride ions. These ion substitutions can not only change the composition, but also adjust the crystal structure. Researchers have found bivalent ions could decrease the crystallinity and inhibit the crystal growth of HAp [2,3]. Multivalent inions could also decrease its crystallinity, and influence the crystal size [4]. Most of substituted HAp, except fluoride substituted HAp, their solubility is increased because of its destabilizing effect on the crystal structure. However, the attraction of these ion substitutions is not only due to the influence on the structure and crystal growth. The most interesting thing which attracts more and more attention is their positive biological, even pharmaceutical effects. For example, strontium ranelate has been acted as a medication for osteoporosis because of the action of strontium ion. Fluoride ion is used to prevent teeth caries, and strengthen teeth. Calcium ion is good for bone health. These ions have shown their contributions on human life. Recently, Sr, Mg, Zn, Mn, Li, Cu, F, Si et al ions have attracted more and more attentions, because of positive effects on bone repair and regeneration. Sr ion has been shown its stimulation to osteoblast activity, bone strength, and bone growth [5-7]. Li ion could enhance the proliferation and cementogenic differentiation of human periodontal ligament-derived cells [8]. Zn ion can not only inhibit colonization of bacteria, but increase the activity of osteoblasts [9,10]. Si ion is not just to increase bone bonding and ingrowth [11,12]. It has a stimulation of angiogenesis [13]. Cu is known as its toxicity. However, Cu ion has been proven to accelerate and guide angiogenesis and wound healing without the expense of inductive proteins [14]. it's possible to reduce the use of regular drugs and proteins in hard tissue repair and regeneration when inorganic ions are introduced according to present studies. Compared to proteins, ions are easier to be incorporated into bioceramics, as powder, bulk, coating and injectable forms. Ions could be regarded as specific drugs when their pharmaceutical effect can be proven in in vitro and in vivo experiments. At present biomaterialists have started to focus on their biological effects in a certain concentration. But the important thing is to figure out their therapeutic dosages from different bioceramics and in vivo models. A systematic and local delivery should also been taken carefully.

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