Synthesis of Bioceramic Material- Hydroxyapatite

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Introduction

Hydroxyapatite (Hap) is a naturally occurring form of the mineral calcium apatite that grows in hexagonal crystals — calcium, phosphorous, and oxygen. Hydroxyapatite is the end-member hydroxyl of the complex apatite group. Pure hydroxyapatite has the color white. Thermodynamically, under physiological conditions such as temperature, pH and body fluid composition, HAp is the most stable compound for calcium phosphate. It forms much of the structure of the human bone, it develops enamel of the teeth. Hydroxyapatite, with formula $Ca_{10}(PO_4)_6(OH)_2$, is a mineral type of calcium phosphate. It is one of the few materials known as bioactive, meaning that when used in orthopedic, dental and maxillofacial applications, it can promote bone growth and osseointegration [1-2]. Hydroxyapatite is extremely inertial, biocompatible and osteoconductive. Pure HAp is a stoichiometric apatite phase with a Ca / P molar ratio of 1.67 and is the most stable calcium phosphate salt at normal temperatures and between 4 and 12 pH. [3] Hydroxyapatite is practically non-degradable, with resorption levels of only 5% to 15% per annum[4]. Nevertheless, it is worth noting that due to its brittleness, the application of pure HAp is minimal. Hydroxylapatite is a biomineral of considerable importance: Carbonated calcium-deficient hydroxyapatite is the primary mineral consisting of dental enamel and dentin. A modified type of hydroxyapatite, known as bone mineral, is up to 50 percent by length, and 70 percent by weight of human bone. Researchers have shown great interest in hydroxyapatite (HAp) materials because they are widely used as biomedical materials, including use as bone fillers, bone tissue engineering scaffolds, bioactive coatings, soft tissue repairs, drug / protein / gene loading and delivery systems (and column chromatography for rapid biomolecular fractionation). Additionally, HAp materials are potential candidates for use in products for cell targeting, fluorescence marking, imaging and diagnosis etc. Additionally, HAp is also used as a model compound to simulate the process of biomineralisation. HAp is one of the bioceramics illustrating the vast amount of regenerative graft material available on the market.

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HAp is very closely associated with the composition of the bony apatite. This is one of the bone's inorganic constituents. It is bounded in the organic matrix and it occurs in the regular bone with other mineral trace elements [5]. This is gaining growing significance in regenerative science because of the existence of the HAp.

Properties of HAP

The physicochemical and morphological properties of HAP depend on the method of origin / preparation [6]. With high porosity and more surface area, synthetic hydroxyapatite exhibited low crystallinity. HAP obtained from animal bone by calcination at 800 ° C, on the other hand, has the highest crystallinity [6]. Hydroxyapatite has the ability to form chemical bonds with the hard tissues around it [7-8] with HAP interface layer forming [9]. The identical physical and chemical characteristics of bone-based natural hydroxyapatite make it biocompatible [9]. However, it has been reported that the mechanical properties of HA are small, particularly for macroporosity scaffolds, therefore an increase in mechanical stability is needed. As a result, work was conducted to determine HA doped actions with a variety of reinforcing agents.

Preparation of Hydroxyapatite (HAP)

Methods widely used to prepare HAP primarily include hydrothermal method, method of precipitation, solvothermal method, method of spontaneous combustion, method of microemulsion, method of ultrasonic synthesis, method of bionic process and process of solid state reaction, namely wet method and method of drying. Among them, three key methods used by scientific research work in recent years are the most commonly used, the lowest cost and the best detailed properties obtained with HAP: hydrothermal process, solvent thermal process and precipitation method. Apart from the given methods Hap can also be prepared from fish bones [10].

Hydrothermal method

Hydrothermal method refers to the use of high temperature and high pressure aqueous solution as a reaction medium, in high temperature and autoclave by regulating the temperature of the solution within the autoclave to create convection in a super- saturated state in order to dissolve

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the insoluble in atmospheric conditions or to react to the recrystallization of the lysate of the substance.

Solvothermal method: Solvothermal method is developed using hydrothermal method, refers to a closed system such as autoclave, using organic or non-aqueous solvent as a solvent, at a certain temperature and solution pressure, a form of synthesis that the original mixture reacts to. Now sol-gel process is commonly used in place of solvothermal process. The original theory is to hydrolyze metal alcoxide or inorganic salt, polymerize the solvent, dry and roast the gel, and eventually obtain inorganic matter. This process emerged in the 1960s as an inorganic material preparation tool, and was widely used. In recent years, however, HAP's preparation by sol-gel method has only emerged. This process uses the reaction of calcium citrate or calcium acetate to phosphoric acid to obtain sol, and under some conditions, the sol is aged into gel. The gel is dried at low temperatures and calcined under vacuum at hightemperatures to obtain hydroxyapatite by nanometer [11].

Precipitation method

Precipitation method is under certain pH and temperature conditions, make the appropriate molar ratio of calcium salt and phosphate solution mixture, stir continuously, and make the calcium and phosphate ions precipitate colloid HAP in alkaline conditions, Then prepare the HAP with well-crystallized and ultrafine particles by drying the precursor precipitate and calcinate it to 900 ~ 1200oC. HAP preparation is the most simple process. Many nano-hydroxyapatite preparation methods are now derived from precipitation process. Due to its advantages of simple technology, low reaction temperature, low cost, easy process, small product particles and high purity, this method is widely used to prepare medical hydroxyapatite powders [12].

With its particularity, HAP material plays an irreplaceable role in the repair and replacement of medical bone products. Therefore, it has wide prospects for research and application in the materials and biomedicine sector. Hydroxyapatite work and its composite materials have made significant progress, and have also been used in clinics.

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Applications of Hydroxyapatite (HAp)

HAp content has the potential for bone and tooth repair applications, drug delivery systems, cell tracking, imaging, and diagnostics. HAp is also used for rapid protein, nucleic acid and antibody fractionation. Since of its excellent osteo inductive properties, synthetic HAP has been commonly used as implant material for bone replacements [13]. Certain HAP uses include femoral plugs in complete hip replacement and HAP coating for cementless fastening on metal parts. In the engineering of bone tissue, HAP-enhanced surface properties can be used to increase cell response and proliferation to induce mineralisation. Hydroxyapatite has been used in biomedical fields of diversity, such as bone cement matrices, controlled release of drugs, tooth paste additives, dental implants etc [14].

Application of Hap for hard and soft tissue repairs

HAp is considered an excellent candidate for hard tissue repair due to its resemblance to the inorganic portion of human bone and teeth, and has been commonly used in orthopedics and dentistry for almost 40 years. HAp bioceramics are typically used in (1) powders or granules for filling bone and tooth defects; (2) particles as components of tooth pastes and bone cements; (3) small and unloaded implants such as in the middle ear; (4) porous scaffolds serving as temporary substrates for cell growth and new bone formation in non-load-bearing sites; (5) biocompatible and bioactive metal implant coatings for dental implants and hip joint prothesis where charging properties are required; or (6) bioactive step and mechanical reinforcement in a polymer-bioactive ceramic composite [15]. Additionally, HAp nanoparticles were widely used as the bioactive portion in the manufacture of biocomposite bone grafts and as a matrix for bone tissue engineering [16]. HAp nanocrystals have also recently been recognized as an essential bioactive component in helping cartilage regeneration [17]. Due to their excellent biocompatibility with soft tissue like skin, muscle, and gums, HAp materials have also attracted attention in soft tissue regeneration.

Application of Hap as bone tissue engineering scaffolds

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HAp is considered a potential material as a scaffold for bone tissue engineering applications, which act as an excellent temporary substratum for cell growth, proliferation, differentiation and eventual regeneration of bone tissue after in vivo implantation.

Application of Hap as drug/gene/protein carriers

Due to their excellent biocompatibility, easily tunable physical – chemical properties (e.g., scale, morphology, porous structure, and surface composition), low toxicity, low production costs, excellent storage stability, resistance to microbial degradation, and pH-dependent dissolution, etc., HAp materials may serve as carriers for drug / protein delivery and gene therapy [18].

Future aspects of HAp

In hard and soft tissue repair, bone tissue engineering, drug / gene / protein delivery, chromatography, imaging, and diagnosis, HAp materials are commonly used. HAp materials performance in applications depends upon their chemical compositions and structures. There are, however, so many open questions and problems that need to be examined further. HAp's future trends for biomedical applications can lie in the following aspects:

1. HAp's physical, chemical, and biological properties
2. Development of biomaterials based on HAp, with controllable degradation rate
3. One of the most important goals and obstacles for potential HAp applications is the development of HAp-based nanoparticles with the incorporation of diagnostic and therapeutic capability
4. The manufacture of HAp materials with excellent osteoinductive properties is a significant future development due to the potential applications for large-scale bone defect regeneration or reconstruction of damaged bone tissue using bone tissue engineering technique.

Conclusions

Because of its biodegradability, biocompatibility and bioactivity, hydroxyapatite is proved to be a significant resource for biomedical applications. HAP is an effective biomaterial for both dental and medical applications. HAP nanoparticles are more useful than traditional sized HAP bulk ceramics based on the HAP nanoparticles 'high surface-to-volume ratio, reactivity and

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biomimetic morphology for applications such as composite fillers, repair materials for damaged enamel and drug carriers. It can be concluded that, given numerous methods that have elaborated the HAP synthesis that are used as bone scaffolds and in dentistry, there is still a huge demand for developing a easy, effective and green method for HAP development.

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