CHARACTERISTICS OF HYDROXYAPATITE: A REVIEW

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Abstract : *Hydroxyapatite is part of the group of ceramic materials called "apatite".. It has the theoretical chemical formula (Ca10 (PO4) 6 (OH) 2). Hydroxyapatite may have a hexagonal crystallographic structure (on bones and teeth) or a monoclinic one (on dental enamel). It can be of natural or synthetic origin. In medical applications, hydroxyapatite is encountered in various forms such as solid ceramic blocks, porous blocks, granules and sintered powders in a compact or porous state.*
Keywords : *Hydroxyapatite, Natural hydroxyapatite, Synthetic hydroxyapatite, Bovine bone,*

1. INTRODUCTION

Hydroxyapatite is encountered in natural or prepared form, industrial or in a laboratory [30].
In the first case, it is contained in biological materials such as corals, egg shells, ostrich eggshells or bone tissue [9], [15], [14]. Thus, the mass of bone tissue is composed, in varying proportions, (in particular) of three main components [22], [8], [25], [1], [7], [11], [31] (Fig.1):

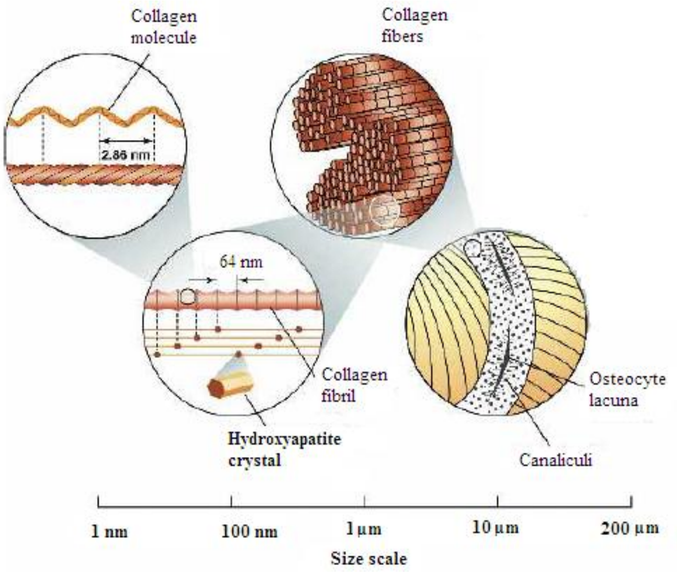

Figure 1: The complex and hierarchical structure of cortical bone, after [1]

1. From an organic matrix (~ 20-22%) consisting essentially of type I collagen fibers and of basic substance. Collagen fibers are in a proportion of (90-96)%, of the organic matrix and are organized into bundles.

2. A mineral phase, in a proportion of about 69%. It is mainly formed from microscopic crystals of calcium phosphates, consisting mainly of hydroxyapatite (HAp). It has the chemical formula ($Ca_{10}(P_{O4})_6(OH)_2$). Hydroxyapatite crystals may belong to the hexagonal spatial crystalline group (on bones and teeth) and monoclinic (on dental enamel) and are anchored on collagen fibers. The hydroxyapatite-collagen assembly gives bone tissue density and resistance. The mineral phase also includes dicalcium phosphate (Ca2P2O7), tricalcium phosphate (TCP, Ca3 (PO4) 2), some amorphous phases of calcium phosphate etc.;

3. Of water, about 9%, in a variable percentage depending on the age of the bone tissue.

In the second case, artificial hydroxyapatite has a natural origin, especially bovine bones [4], [28], [9], [24], [15], [14] or synthetic. Artificial hydroxyapatite is a bioceramic material that is part of the group called "apatite" and chemically described with the general formula $M_{10}(XO_4)_6Z_2$. In the formula, M^{2+} is a metal, XO_4^{3-} and Z are

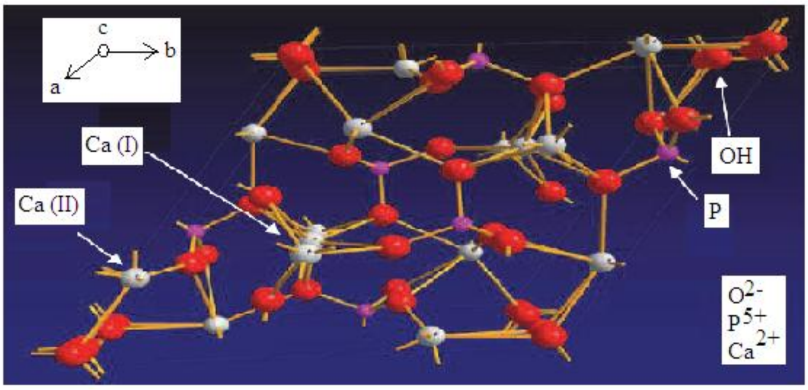

Figure 2: Crystalline structure of hydroxyapatite, after [22]

anions, and the elements or radicals M, X and Z give the name of each apatite. For the case where M is represented by calcium (Ca^{2+}) in a ratio of 39,84 % of apatite mass, X is phosphorus (P^{5+}), 18, 52 % and Z is the hydroxyl radical (OH-), 3,38 % the "apatite" compound is called stoichiometric hydroxyapatite. It is defined by the ratio Ca/P = 1,67 [22], [12]. In the hexagonal crystallographic structure, hydroxyapatite is represented in figure 2.

2. MEDICAL REQUIREMENTS

The hydroxyapatite biomaterial can be synthesized by several routes or technological processes [12], [24], [3], [5], [10]: hydrothermal methods, sol-gel process, reactions in solid state, chemical co-precipitation etc.

In medical applications, synthetic hydroxyapatite is encountered in various forms [25], [12], [27], [29], [26]: solid ceramic blocks, porous blocks, granules and sintered powders in a compact or porous state formed of very fine particles with dimensions between (1-5) μm and generally angular shapes (Fig.3).

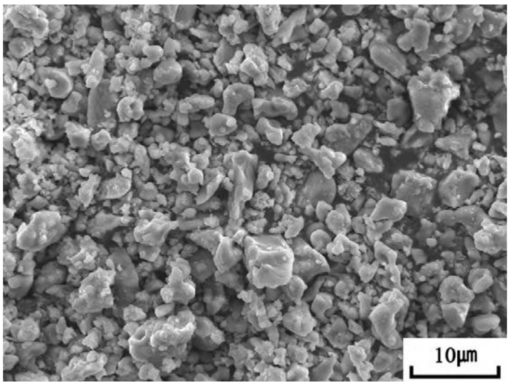

Figure 3: SEM image of HAP powder., after [13]

Table :1 Different physical and mechanical properties of synthetic HAP in comparison to natural bone; after [13]

Properties	Natural bone	Synthetic HAP
Density (g/cc)	1.8–2.1	3.1
Elastic modulus (GPa)	3–20	73–117
Compressive yield strength (MPa)	130–180	600
Fracture toughness (MPam1/2)	3–6	0.7

Because of the chemical and structural similarity with the bone mineral phase [14], [25], [11], [4], [17], [2], [6], [16], [20] hydroxyapatite is characterized by excellent biocompatibility (hard and soft tissue), bioctivity (the ability to form direct chemical bonds with live bone tissue [11]), non-toxicity, bioresorbable (variable rate and extent) [21], etc. in relation to the human body and by an excellent ability to stimulate bone regeneration and bone proliferation. As a result, hydroxyapatite has significant medical applications such as [8], [12], [19], [18]: dental implants, maxillofacial reconstruction, spinal surgery (spinal fusion), orthopedic coating (plasma spray), implantable drug delivery systems and bone fillers. Natural and synthetic hydroxyapatite differ in physical structure, crystal size and porosity. However, they are similar in chemical terms and in biological properties [28]. In medical applications subject to intense and cyclical demands, hydroxyapatite does not have the necessary mechanical strength [17], [12]. In this aspect, it is pointed out the decrease of breaking strength, of dense hydroxyapatite with increased porosity [18]. For this reason, the use of hydroxyapatite is restricted in these medical applications [17].

At the present, clinical and experimental research aims at improving the physical and mechanical properties of hydroxyapatite without affecting it’s biological properties. To this purpose, it is mentioned [12]:

- method of synthesis;
- the sintering method;
- biphasic hydroxyapatite;
- dopants in the crystalline structure.

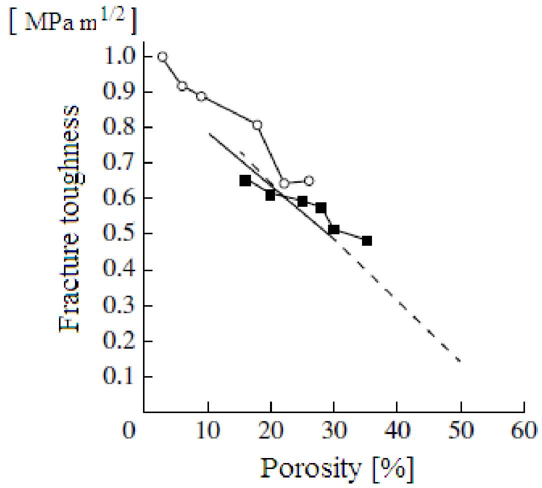

Figure ; 4 Fracture toughness as a function of porosity for dense HA ceramics, after [18]

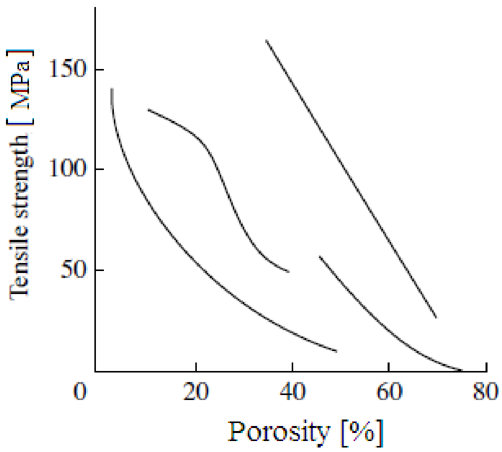

Figure ; 5 Tensile strength as a function of porosity for HA ceramics after [18]

3. CONCLUSION

Hydroxyapatite plays an important role in the medical applications of biomaterials. It can be obtained from biological materials or synthesis procedures. It has an assemblage of biological properties such as: excellent biocompatibility for hard and soft tissue, bioctivity, non-toxicity, bioresorbable, etc. In case of intense and cyclic mechanical stress, hydroxyapatite does not have the necessary mechanical strength. However, mechanical and physical properties can be improved.

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