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Research of Bioactive Bioceramics

by

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Abstract

It is important to improve the quality of life (QOL) for individuals to fulfil their lives in society. For this, it is important to realise the role of advanced medical treatment in improving QOL in the medical engineering field. The material studies on bioactive artificial bone, which requires artificial bone to be replaced with neonatal bone by absorption, regenerating the bone, which is not yet possible, have been unsuccessful in raising patients' QOL. In this study, the sintering of tricalcium phosphate ($Ca_3(PO_4)_2$) and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) as bioactive bioceramics was investigated to discover new advanced biomaterials. Tricalcium phosphate and hydroxyapatite materials, which have excellent properties, require the development of their manufacturing processes to produce the structure that can be optimally controlled and are becoming increasingly important for excellent bioceramics.

Keywords: Bioceramics, Hydroxyapatite, Tricalcium phosphate, Sintered body, Sintering

1. Introduction

It is important to improve the quality of life (QOL) for individuals to fulfil their happy life in the society. For this, it is also important to realise the role of advanced medical treatment to fulfil QOL in the medical engineering field. The artificial bone fabricated in fine ceramics is one of the foremost biomaterials. Aluminium oxide (Al_2O_3) and zirconium oxide (ZrO_2), etc. are the important bioceramics for implant materials such as artificial roots and artificial joints using the organism inactivation property. Furthermore, tricalcium phosphate ($Ca_3(PO_4)_2$) and hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) are two useful bioceramics which are similar to the mineral composition of bone and tooth. These two kinds of ceramics were developed in Germany in 1971 and U. S.-Japan in 1974-1975, respectively. These bioceramics were the origin of the development in bioceramics. Then, bulks and powders of these compositions were clinically applied over wide areas such as in artificial bone, artificial nose cartilage and bone filler, etc. In this study, bioceramics with excellent bioactivity are depicted based on content of both a special issue of "Ceramics Supporting Tissue Engineering" in the Ceramic Society Japan as a planning and editing chair in 2004-2005 and content of the research in Cambridge Centre for Medical Materials, University of Cambridge, U. K. as sabbatical year's of visiting professor position in 2005-2006.

2. Bioceramics

Bioceramics can be classified largely into three divisions; chemically stable bio-inert ceramics, bioactive ceramics which combines with bones directly, and bio-absorbable ceramics which undergoes decomposition and absorption in perspective of the chemical reactivity in vivo[1)-5)]. Especially, bioactive ceramics have attracted many clinical industries for its ability to self-regenerate bones on contact, as well as to restore support or function of the bone. At the present, the major bioactive materials used in the orthopaedic clinic are inorganic glass, glass ceramics, and sintered body. Particularly, the sintered bodies of tricalcium phosphate and hydroxyapatite are important biomaterials because their sintered body has excellent biocompatibility and mechanical biocompatibility. Therefore, the commercial products, which have been optimized via modifying composition, structure, and shape, are mainly on the market.

3. Bioactivity bioceramics research

The scaffold for cell differentiation and multiplication fulfils the important role in order to reproduce the organization of the bone. Particularly, crystallized materials such as a

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tricalcium phosphate and hydroxyapatite are more widely researched than materials such as glass or glass ceramics. The preparation and characterization of these powders and sintered bodies has been carried out by W. Bonfield *et al.*[6)-10)]. Generally, tricalcium phosphate and hydroxyapatite are abbreviated to TCP and HAp, respectively. HAp is often used as an artificial aggregate of the non-absorption nature, since it is a bioactivity material difficult to absorb in *vivo*. As one of the important techniques which controls absorbability or absorption rate in *vivo* of the bioactivity bioceramics, the trial which controls composition, structure or stoma of the sintered body advanced has been made. As former example, it is possible that the proportion of α and β phases in TCP can be controlled by adding magnesium content for required application[11)]. Clinically applied porous HAp and TCP bodies are sintered which appropriately controlls porosity and pore size. Furthermore, the research on composite materials which contain organic and inorganic components is carried out. Various researches as an organic-inorganic composite have been reported. Especially, the research on the composite material using high density polyethylene and collagen is attractive in biomaterial researching field. In this study, it is possible to get the dense sintered body of single phase at 1573 K for 2 hours in an air atmosphere. The sintering result used the commercial hexagonal HAp powder with particle size of micron order level is shown in Fig. 1. The sintered bodies were prepared by pressureless sintering at 1573 K for

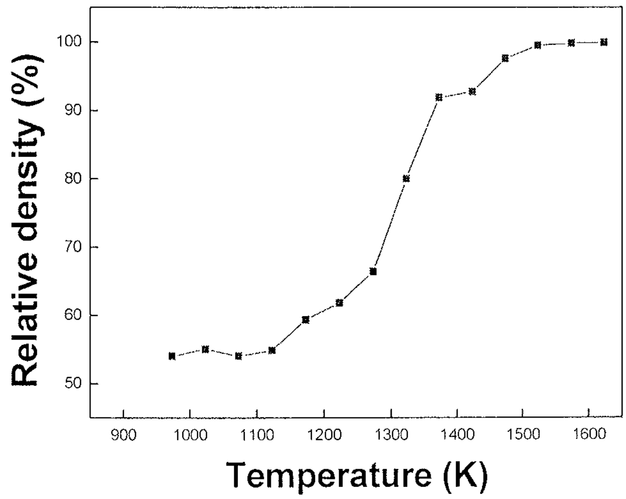

Fig. 1 Temperature dependence on relative density of the hydroxyapatite sintered bodies.

1 hour in air using isostatic pressed compact under 200 MPa for 3 minutes. Base on the result of powder X-ray diffraction (XRD) pattern of the HAp sintered body, the sintered composites exhibited diffraction peaks consisting of only monolithic HAp. Also, the bioactivity β type TCP sintered body which is an excellent bioabsorbable materials for the burial to defective part of bone is fabricated by presssureless sintering at 1273 K for 1 hour in air using cold isostatic pressed compact under 200 MPa for 3 minutes. In addition, α type TCP which is more bioabsorbable than β type TCP is also carried out except for the cases in which the time to absorption is sufficiently long that it decomposes. The result of XRD patterns of the TCP sintered bodies, the TCP is transformed from α phase to β phase at about 1273 K. In recent study, the result of examining the controlled effect of the relative density (porosity) of the HAp sintered body with addition of TiN is shown Fig. 2. It is possible to control the density of the Hap sintered body by TiN content and sintering

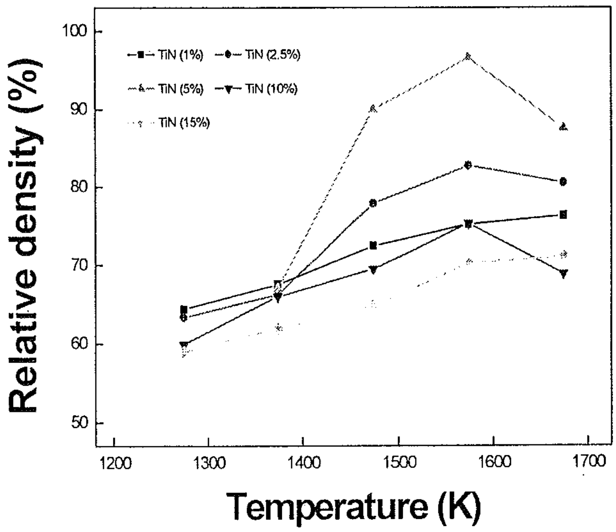

Fig. 2 Temperature dependence on relative density of the hydroxyapatite sintered bodies.

temperature. Furthermore, tetracalcium phosphate (TTCP) is similar to the mineral composition of HAp and TCP. To date, there have been few reports regarding the properties of TTCP. The near future, the sinterability and physical properties of TTCP as a bioceramics will be investigated in order to determine its new advanced biomaterials.

4. Summary

The material study on bioactivic artificial bone, , which requires artificial bone to be replaced with neonatal bone by absorption, regenerating the bone, which is not yet possible, have been unsuccessful in raising patients' QOL. The scaffold for cell differentiation and multiplication fulfils the important role in order to reproduce the organization of the bone. Particularly, crystallized materials such as a tricalcium phosphate and hydroxyapatite are more widely researched than materials such as glass or glass ceramics. In this study, the sintering of hydroxyapatite, HAp ($Ca_{10}(PO_4)_6(OH)_2$) and tricalcium phosphate, TCP ($Ca_3(PO_4)_2$) as a bioactive bioceramics were investigated to determine their new advanced biomaterials. The HAp and TCP materials, which have excellent properties, require the development of their manufacturing processes to produce the structure that can be optimally controlled, are becoming increasingly important for excellent bioceramics.

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