CHAPTER 1

INTRODUCTION

Bioceramics

The precise definitions of "biomaterial" and "bioceramic" were stated in the National Institutes of Health (USA) Consensus Development Conference on the Clinical Applications of Biomaterials Development as the following definitions :

A BIOMATERIAL is any substance, other than a drug, or combination of substances, synthetic or natural in origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replaces any tissue, organ or function of the body.

A BIOCERAMIC is defined as a ceramic used as a biomaterial. All materials elicit a response from living tissues. Four different categories of behaviour were summarized (Hench, 1989).

1. If the ceramic is toxic, the surrounding tissue dies.
2. If the ceramic is nontoxic and it dissolves, the surrounding tissue replaces it.

3. If the ceramic is nontoxic and biologically inert, a fibrous tissue capsule of various thickness forms.
4. If the ceramic is nontoxic and biologically active, an interfacial bond is formed.

Thus, useful bioceramics can be classified into three main categories depending on their interaction with the surrounding environment. The three classes are :

1. Bio-Inert : This type of material maintains its physical and mechanical properties through the entire life of the clinical implant.
2. Bio-Resorbable : This type of material is gradually absorbed or dissolved and ultimately replaced by the surrounding living tissue. It serves as a template which aids in the construction of damaged or diseased tissue.
3. Surface-Active : This type of material develops chemical bonds with the surrounding tissues and helps in the process of attachment of the clinical implant to the surrounding tissue. These materials may or may not be bio-resorbable.

Ceramic materials as orthopedic implants are recently receiving a great deal of attention. Since the oxide ceramics are fully oxidized solids, they do not elicit metallic ions that could cause physiological imbalances. The potential of ceramic materials as permanently implantable skeletal prosthetic devices has been well

outlined (Hulbert et al., 1970). Since that time, there has been a tremendous explosion of activity in the area of bioceramic materials, some of which will be addressed briefly in subsequent discussions. Bioactive ceramics, which form strong bonds (there is still a great deal of uncertainty about the nature of these bonds) with natural bones, have expanded the horizons of ceramics in biomedical base applications.

Bio-Resorbable and Bio-Active Ceramics

The concepts of bio-resorbable ceramics and bio-active ceramics have played a very important role in establishing ceramics as a viable and important implant material. In certain applications like replacement of traumatized bones, it is extremely useful to have a material that is bio-resorbable. This type of material can be used for permanently implantable skeletal prostheses as well as a porous device for controlled drug release into the body. Ducheyne (1987) proposed that materials that elicited the formation of normal tissues on their surfaces and could establish a contiguous interface capable of supporting the loads that normally occur at the site of implantation would have optimal biocompatibility. It is also observed that a number of bio-active ceramics are also bio-resorbable to some extent. Thus, it will be best to treat the two together under one category.

The use of a combination of bio-resorbable materials and particulates of non-resorbable materials could provide physicians with an effective implant material. Plaster of Paris has been used to fill bone defects since the latter part of 19th century (Peltier, 1969). Recently, the bio-resorbable plaster has been used as a formable, biodegradable scaffold or binder to hold the particles of nonresorbable, calcium based ceramics such as calcium phosphates, which stimulate bone formation. Along with the calcium phosphate ceramic powders, materials like demineralized freeze dried bone or alumina powders can also be used. The plaster is resorbed after a few weeks of implantation and is replaced by fibrovascular connective tissues, capsules, and new bone, which holds the nonresorbable particles and incorporates them into the host bone. It has also been suggested that Plaster of Paris can be used to deliver other materials such as active pharmacons for controlled drug release devices.

There are several ceramic materials that can be termed bio-active. Excellent examples of such materials are glasses belonging to the Na_2O - CaO - SiO_2 - P_2O_5 system ; Beta tricalcium phosphate (β - $Ca_3(PO_4)_2$) commonly known as TCP ; hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) commonly known as HA; Ceravital, a glass-ceramic in the glass system Na_2O - K_2O - MgO - CaO - SiO_2 - P_2O_5 ; and A-W glass ceramic which contains oxyapatite ($Ca_{10}(PO_4)_6O_2$) and wollastonite (CaO · SiO_2 crystals). All these materials

have been known to produce a strong and direct bond with bone tissue. The nature of the "bond" is still the subject of intense debate and continuing research.

Though the bio-active glasses based on the $SiO_2 - Na_2O - CaO - P_2O_5$ system have good bonding to bones, clinical use has been very limited. The extreme brittleness of the material in its bulk form has prevented its use in any form of load bearing application. However, this material can be used to coat metal implants. Tricalcium phosphate (TCP) in particulate form is used as bone graft substitute and is designed to resorb over time. Hydroxyapatite (HA), in spite of its brittle nature, has experienced the widest clinical use due to its chemical similarity with bone mineral and its ability to form a strong bond with natural bones.

HA, the bio-active material is intermediate between bio-resorbable and surface-active material. Resorption or biodegradation of calcium phosphate ceramics is caused by physiochemical dissolution, which depends on the solubility product of the material and local pH of its environment ; physical disintegration into small particles due to preferential chemical attack of grain boundaries ; and biological factors, such as phagocytosis which causes a decrease in local pH concentrations.

Hydroxyapatite Products

Because of its interesting properties, HA products were produced in many countries and have different tradenames. Two types of HA commercial products were shown below :

1.1 Synthesized Products

. Calcitite (Calcitek, Inc. : U.S.A.)

. Periograf, Alveograf, and Durapatite (Cook-Waite : U.S.A.)

. Ossograf (Coors : U.S.A.)

. Ortho - Matrix and Allotropat (Heyl : Germany)

. Bioapatite (France)

. Apaceram and Apato (Japan)

1.2 Natural Products

. Coralline HA : Coral (Porites) hydrothermally converted to HA

[Commercial products : Interpore 200 (Interpore)]

. Bio-oss (from sintered bovine bone)

The HA product that Chulalongkorn University was interested in is the one prepared from cattle bone. Cattle bone product was used in two ways, direct and chemically treated. Because synthetic HA was expensive due to its manufacturing techniques either by precipitation from aqueous solutions or hydrothermal treatments. So this research aimed

at cattle bone product as a substitute. HA originated from cattle bone, namely natural cattle bone (MP) and chemically treated cattle bone (TP) were under comparative study in terms of biocompatibility, mechanical suitability, and cost (Lorprayoon, 1989). *In vivo* test showed that all HA products from cattle bone had good biocompatibility in animal experiment and clinical trials (Itiravivong, 1992.)

Objectives and Scopes of this Research

In this research, dissolution behaviour of two kinds of HA derived from cattle bone ash was studied under simulated physiological condition. Characteristic change such as Ca and P released at different time of incubation, bulk density, porosity were determind, phase present in the bulk and microstructure of HA were observed. The *in vitro* study data could be related to the bone growth enhancement and bone bonding because apatite dissolution might promote enhanced bone bonding (Maxian, Zawadsky, and Dunn, 1993). Thus *in vitro* study in dissolution behaviour of HA from cattle bone ash is necessary and important. The following flow chart shows the scope of this thesis.

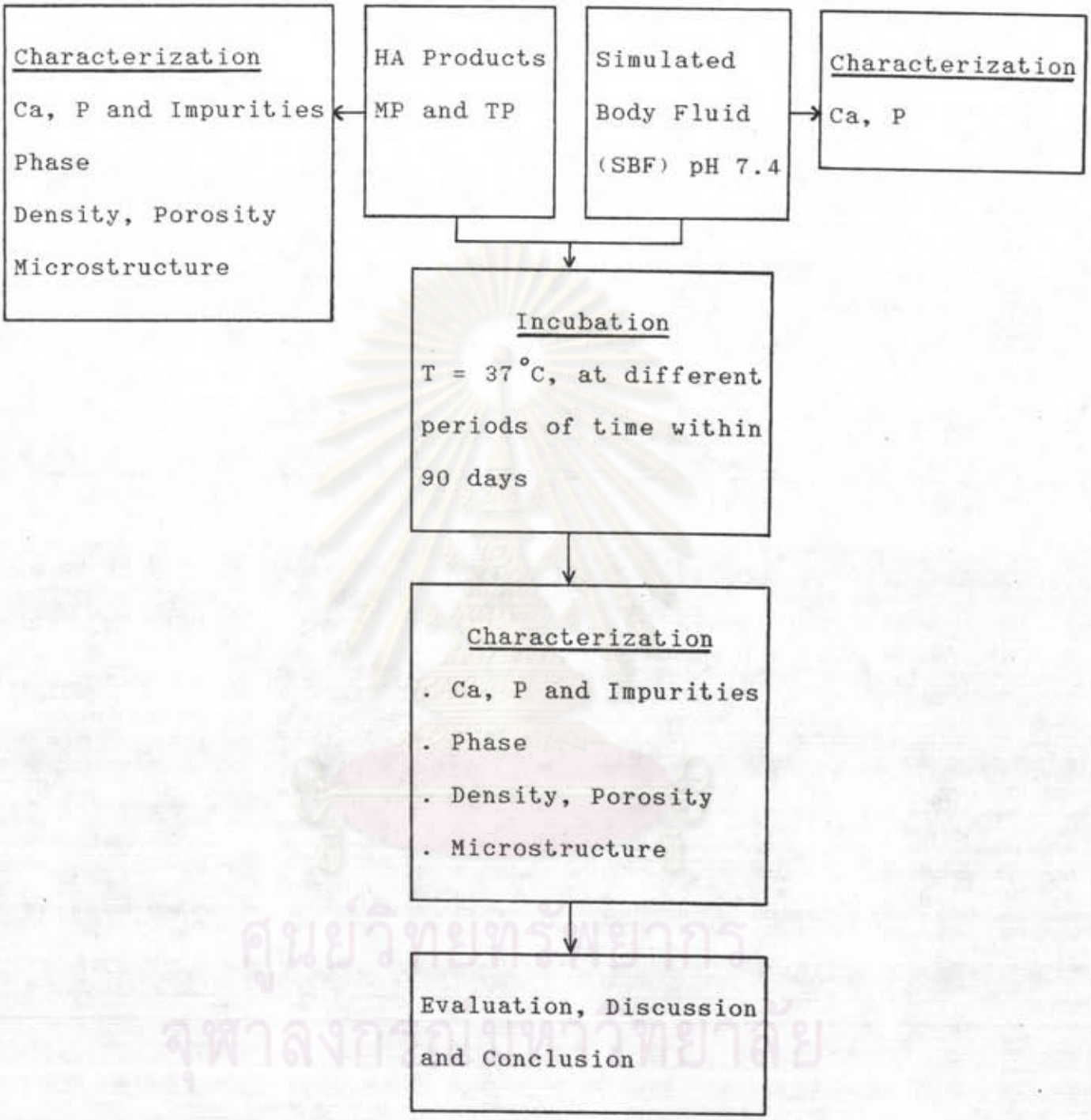

Fig. 1.1 Flow chart of thesis work