CHAPTER 1
INTRODUCTION

Motivation , Objective and Scope

1.1 Motivation

Surgical implants to repair or augment parts of the skeleton (bone, teeth, joints) can be produced from a number of materials, among which ceramics play an important role. There are two types of these bioceramics : bioactive ceramics and bioinert ones. Calcium phosphate bioceramics are bioactive ceramics that have at least a surface structure resembling that of the mineral phase of the skeleton. Thus, bioactive ceramics bond to bone in a natural way. This property render them very attractive for surgical application. Unfortunately, mechanically they are very weak, especially in tension, the consequence being that clinical application of bulk bioactive ceramics is limited to be sited in the human body where no tensile forces are present.

Tetracalcium phosphate (TTCP) is one of calcium phosphate compounds that is suitable for dental application, for example, as composition of self-setting cement, sealer/filler in endodontic procedures and etc. At present, high purity tetracalcium phosphate suitable for dental application is expensive due to the cost of high purity chemical used as the starting materials.

In Thailand, cattle are not only used for agrarian but also for food. In the past, cattle bone was useless but now it is used as raw material to prepare fertilizer. Cattle bone is available in Thailand at low cost and it is expected to be a cheap source of calcium phosphate.

A successful preparation of hydroxyapatite (HA) from cattle bone was reported by Lorprayoon (1989) and also the preparation of dicalcium phosphate dihydrate (DCPD) from cattle bone reported by Jinawath and

Trakarnvichit (1995) render the possibility to prepare tetracalcium phosphate (TTCP) from cattle bone. Therefore a research project entitled "Preparation of Tetracalcium phosphate from cattle bone" is proposed.

Among the hydraulic calcium phosphate compounds, tetracalcium phosphate is a common one and becomes a popular material for study.

1.2 Objective :

The objective of this research was to prepare tetracalcium phosphate from cattle bone, characterize the prepared tetracalcium phosphate and use it as a starting material to prepare a self-setting calcium phosphate cement which can be used as remineralizers of caries lesions in dental enamel and as dental or bone cements.

1.3 Scope :

The preparation of tetracalcium phosphate from cattle bone was based on the heat treatment of mixtures of dicalcium phosphate dihydrate with $CaCO_3$ and of calcium pyrophosphate ($Ca_2P_2O_7$) with $CaCO_3$ in air under a specific range of composition and temperature.

The obtained TTCP was mixed with DCPD to prepare a self-setting cement.

The sequence of the experiment was : precipitation of DCPD from the bone ash solution (as described by Jinawath,1995), characterization of DCPD obtained and preparation of TTCP from synthesized DCPD, characterization of prepared TTCP, preparation of self-setting cement from TTCP and DCPD and property testing.

In order to improve setting and mechanical properties, a study was conducted on the hardening of calcium phosphate cement containing the equimolar mixture of TTCP and DCPD in aqueous H_3PO_4 solution. The effect of HA as seed, surface area of TTCP as reactant, curing time, and

powder/liquid ratio on the strength and setting time of hardened cement were investigated.

1.4 Literature Survey

The beginning of the application of calcium phosphate material as bone substitute or bone graft may be traced back to Albee (1920) who reported that a "Triple calcium phosphate" compound used in a bony defect promoted osteogenesis or new bone formation. The modern era of calcium phosphate based bioceramics started 30–40 years ago (1960) with the first successful publication by Levitt et al. in Journal of Biomedical Materials Research. They stated that although apatites had undergone intensive investigation for many years, lack of effective methods of forming apatite powders into solid shaped had prevented the study of potential uses of calcium phosphate bioceramics.

Levitt et al. (1969) and Monroe et al. (1971) reported a method for the preparation of calcium phosphate ceramic, principally mineral calcium-fluor-apatite, $Ca_{10}(PO_4)_6F_2$, and suggested the possible use of this apatite ceramic for dental and medical implant materials. In 1971, Hench et al.(1971) developed a calcium-and-phosphate-containing glass ceramic, referred to as Bioglass, and showed that it "Chemically" bonded with the host bone through a calcium phosphate-rich layer. Clarke et al. (1973) reported the method of preparing a tricalcium phosphate ceramic and suggested its use as a bone graft material.

Levin et al.(1974) reported the first dental application of a tricalcium phosphate ceramic in periodontal defects in dogs. Hubbard (1974), presented the preparation of several calcium phosphate ceramics from reagent materials and explored their possible uses as orthopedic implants. At the same time, Roy and Linnehan (1974) reported a method of preparing an apatite material from a reef-building coral species by hydrothermal transformation of the calcium carbonate in the coral, based on the

replaniform concept developed by White et al.(1972).

Calcium phosphate bioceramics have gained a distinct place in the biomaterials research field because it can be judged by the large number of publications and presentations. For example, more than 100 presentations at the World Biomaterials Conference in Kyoto, held in 1988, were related to calcium phosphate.

It is interesting to note that while most scientific publications deal with animal and clinical testing, and less than one third with technical experimental results, patents deal almost exclusively with preparation methods, technical innovations, and construction of specific implants. The intensive patent filings emphasize the high expectations that the medical community has calcium phosphate biomaterials, and therefore we believe that clinical applications will be even more important in future than they are already.

At the Present time, there are several commercial companies in the United States and in Europe marketing calcium- and phosphate-containing bioactive glass ceramics and calcium phosphate ceramics (Table 1.1).

Table 1.1 Calcium phosphate materials in current use (LeGeros, 1988)

(A) Calcium phosphate ceramics :

1. Calcium hydroxylapatite , $Ca_{10}(PO_4)_6(OH)_2$, HA

[Commercial products : Calcitite (Calcitek,Inc.); Periograf , Alveograf , Durapatite(Cook-Waite) ; Ossograf(Coors) ; Ortho-Matrix ; Allotropat(Heyl,Germany) ; Bioapatite(France)]

2. Beta-tricalcium phosphate , $Ca_3(PO_4)_2$, β-TCP

[Commercial products : Synthograf , Augmen(Miter,Inc.,distributed by Johnson&Johnson)]

3. Biphasic calcium phosphates (mixture of HA and β-TCP)

[Prepared by compacting and sintering some commercially available "Tricalcium phosphate" or precipitated "apatites"]

[Commercial products : Triosit(Zimmer) , approximately 60 HA/40 β-TCP]

(B) Calcium phosphate materials from natural products :

1. Coralline HA : coral (Porites) hydrothermally converted to HA

[Commercial products : Interpore 200 (Interpore)]

2. Bio-oss (from sintered bovinc bone)

(C) Glass ceramics

[Commercial products : Bioglass (American Biomaterials Corporation) , Ceravital (Germany)]

Ciesla and Rudnicki (1987, 1989) investigated temperature range to obtain a roentgenographically pure preparation of tetracalcium phosphate by means of a reaction in solid phase and transformations of tetracalcium phosphate occuring while heated in air within temperature range 400 to 1500°C.

Hamanishi et al. (1996) proposed that the clinical application of the TTCP-DCPD cement paste could be as an injectable finely packable

substitute for the defects in the cancellous bone caused by comminuted fracture or surgical curretage of benign bone tumors extending even to the subchondral region. TTCP-DCPD self-setting apatite cement has favorable characteristics as a drug carrier, because it hardens isothermally at almost neutral pH, which enables the cement to contain several drugs without denaturation, and because the crystallinity of the cement and subsequent rate of drug release is controllable by changing the crystallinity of the seed apatite. Thus, TTCP-DCPD self-setting apatite cement is promising bone-conducting substitute as either a paste, granules, or hardened blocks for several pathologic conditions in bone.