CHAPTER 1

INTRODUCTION

1.1 Overview

Due to increasing demands for superior esthetics combined with biocompatibility and mechanical performance to withstand the conditions in the oral cavity, dental porcelains have widespread usage as restorative materials in dentistry [1-3]. They contain varying amounts of crystalline ingredients such as silica (SiO_2), feldspar (K_2O-Al_2O_3-$6SiO_2$), and alumina (Al_2O_3) and have been used for denture teeth since 1790 [2]. These crystalline constituents are held together in glass, which is clear and has a liquid like structure [3]. In general, three types of dental porcelain-based ceramics are classified according to fusion temperature, i.e. high-fusing, medium-fusing and low-fusing [4]. Today the major use is for many applications such as inlays, individual jacket crowns, veneering metal crowns and bridgework (Fig. 1.1) [5]. Ceramics for dental restorations are attractive to dentists and patients because they are chemically very stable and provide excellent esthetics which does not deteriorate with time, low thermal conductivity, abrasion resistance and biocompatibility. However, they exhibit very low tensile strength (usually between 20 and 60 MPa) and very low ductility and toughness values, typical of brittle solids, finishing difficulties and poor thermal expansion matching [6-8].

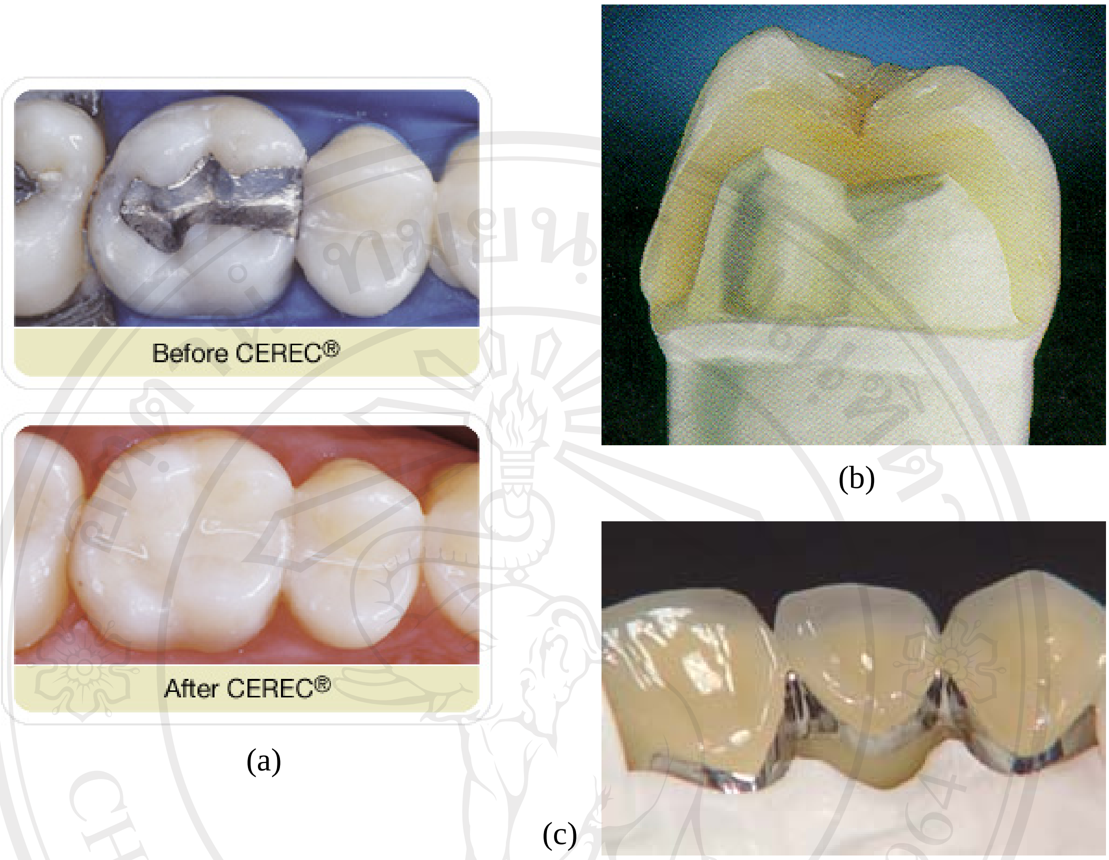

Fig. 1.1 Applications of dental porcelain-based ceramics: (a) inlay, (b) all ceramic jacket crown and (c) veneering metal bridgework [5].

One problematic aspect of ceramics in general and of dental applications in particular is their low flexural strength and fracture toughness (Fig. 1.2) [9]. Several methods have been developed to overcome these issues such as ion exchange, thermal tempering or reinforcing with alumina [3,8,11]. These techniques required high sintering temperature or prolong sintering time [12]. One of the effective ways to solve these issues is to employ a nanocomposite approach. Nanocomposite materials have generated profound interest because of the new physical of nanostructures and many potential applications based on improved superior mechanical properties like hardness, fracture strength, and fracture toughness [13-18]. Ceramic nanocomposites

Fig. 1.2 Cracks of dental porcelain-based ceramics in clinical applications [8].

are a class of structural ceramics which first came to prominence between 1988 and 1991 with the publication of a series of papers by Niihara group [14-16] describing their processing, microstructure and properties. Excellent properties were reported for a number of systems, but the combination which has attracted most attention consists of alumina reinforced with SiC nanoparticles [17,18]. Although composite structures are not new for dental porcelains, the design of specific composition and microstructure using ceramic nanocomposite concept is a novel idea for the dental porcelain-based system. The majority of dental porcelains used in restoration are feldspathic-based glass-ceramics whose microstructure consists of dispersed leucite crystals in a glass matrix [19]. Thus, in this work, it may be possible to fabricate a material that produces a novel microstructure which has been designed for a specific purpose of dental applications, e.g. to enhance mechanical strength.

Such material can be fabricated by reinforcing the parent phase with a high-modulus, high strength and/or high ductility second constituent in the form of fibers, platelets or particulates [20]. Oxide additives, such as Al_2O_3, TiO_2, Fe_2O_3 and ZnO have been successful employed to reinforce glass and glass-matrix composites for the several years with extensive applications in ceramic matrices [21,22]. The enhancement of fracture toughness, in relation to the un-reinforced matrix, is due to a complex of matrix/reinforcement interactions, which causes cracks to deviate or branch, with certain fracture energy absorption. Crystalline phase-reinforced ceramics, in which matrix/reinforcement interactions cause the maximum energy absorption, show excellent bending strength and fracture toughness [10,22].

1.2 Objectives

In this work, attention is given to the fabrication and characterization of the crystalline phase reinforced ceramic nanocomposites. The major part of the thesis is devoted to the fabrication and characterization of four porcelain-based systems; i.e. Al_2O_3-, (Al_2O_3-M_xO_y)-, TiO_2-, and (TiO_2-Fe_2O_3)-reinforced porcelain ceramic nanocomposites. These materials have been examined in terms of the concept of processing-structure-property relationships. The correlation between chemical composition, microstructural development and mechanical properties of these materials is established and compared.