CHAPTER I
INTRODUCTION

1.1 Background

The edentulous posterior maxilla is anatomically characterized by thin cortical bone at both the ridge crest and sinus floor and low density cancellous bone in the remainder. Implant placement in the maxilla can be difficult for many reasons, including inadequate posterior alveolus, increased pneumatization of maxillary sinus, and close approximation of sinus to marginal bone (Figure 1a). Because of the available bone is particularly important in implant dentistry, maxillary sinus bone graft augmentation has become one of the most common surgical procedures for increasing bone volume for implant placement in the posterior atrophic edentulous maxilla as shown in Figure 1b (Fanuscu, Vu, et al., 2004).

![Figure 1.1 Cone Beam Computerized Tomography image of inadequate posterior alveolus for implant placement (a) and sinus bone graft augmentation for increasing bone volume for implant (b) (Courtesy by Dr. Wichit Tharanon, Advanced Dental Technology Center, 2006).](image-url)

Maxillary sinus floor elevation was initially described by Tatum at an Alabama implant conference in 1976 and subsequently published by Boyne in 1980 (Tatum, 1976; Boyne & James, 1980). Many sinus bone graft augmentation techniques were developed using various filling materials. Clinically, a complex structure consisting of bone with the varying stiffness can be found around implants placed in the posterior maxilla with grafted sinus as a result of graft composite and maturation process (Papa, et al., 2005). Numerous
research projects have been published to evaluate the prognosis of implants under different grafting materials (Papa, Cortese et al., 2005; Xu, Shimizu et al., 2005; Bianchi, Dolci, et al., 2005).

A complex structure of bone around the implants placed in the posterior maxilla with grafted sinus consists of crestal cortical bone, cancellous bone, sinus floor cortical bone and graft bone (Figure 1.2a, b). The long-term implant treatment results of dental implants depend on maintenance of bone support and the stability of marginal bone levels and maintenance of osseointegration are of the fundamental importance for successful implant therapy (Borchers & Reichart, 2006; Brunski, 1999; Brunski, et al., 2000). Many variables may have an influence on the outcome of the sinus graft procedure in combination with implant treatment. The factors for the success or failure of a dental implant have been focused on the biomechanical aspect (Bianchi, Dolci, et al., 2005). Biomechanical complications are primary related to implant prognosis leading to implant success or failure (Taylor, Agar, et al., 2000).

![Figure 1.2 A complex structure of bone around the implants placed in the posterior maxilla with grafted sinus](image)

Van Steenberghe made a clear distinction between success and prognosis of an implant (van Steenberghe, 1997). Success is regarded at a certain timepoint, while prognosis compares the bone stability around implants, e.g. if an implant has lost half of its bone height it still may be functional (successful). However, if the bone continues to be
lost its prognosis is questionable. Biological failure may also be associated with excessive marginal bone loss, although the implant may remain clinically stable. Therefore the prognosis prediction of implant is plays an important role in long-term treatment result.

Load transferring to surrounding bone is a key factor for the success or failure of a dental implant (Geng, Tan, et al., 2001). Conceptually, when considering the overall of load transferring in peri-implant tissue, it is important to understanding the mechanics of load transfers at the interface along osseointegrated implant. The remodeling processes in living bone are the mechanisms by which bone tissue adapts its overall structure to changes in its mechanical load environment. The biologists assign to the word “optimum” in that nature could have accomplished this biological adaptation in a better way (Cowin, 2001).

Because of the absence of a periodontal ligament in dental implants, chewing force are directly transmitted from the rigid implant material to the surrounding bone, causing relatively high cervical stress concentrations. Previous clinical studies have shown that bone loss around implants is associated with unfavorable loading conditions (Jensen, Shulman, et al., 1998; Cehreli, Akkocaoglu, et al., 2007; Turkyilmaz, & McGlumphy, 2008). The distribution of forces in peri-implant bone has been investigated by finite element analyses in several studies (Fanuscu, Vu, et al., 2004; Geng, Tan et al., 2001; Acka & Cehreli, 2006). It has been demonstrated in various finite-element model studies that, when dental implants are loaded, the highest stress concentrations are located in the crestal, cortical part of the bone around the neck of the implant (Meijer, 1992; van Rossen, 1991). Several previous studies suggested that the peak stress should be avoided or reduced (.Borchers & Reichart, 1983; Esposito, Hirsch, et al.,1998; Abu-Hammad, Osama , et al., 2007).

Recently, several techniques have been developed to introduce a degree of porosity in titanium alloy (Ryan, Pandit, et al., 2008; Schiefer, Bram, et al., 2009; Warnke, Douglas, et al., 2009) which has led to the rapid development of various different dental implant designs. To reduce high bone stresses at the crestal bone around implant neck, several attempts have been made to transfer the chewing stresses by porous structure of titanium implant (Jo, Lee, et al., 2007; van Rossen, 1991). As an important computer tool, the finite
element method is particularly convenient for evaluating and improving implant design without the risk and expense of real implantation (Cook, Weinstein, et al., 1982).

1.2 Statement of the Problem

Dental implants placed in the posterior maxilla have lower success rates compared to implants placed in other oral regions (Jensen, Shulman, et al., 1998). Although marginal bone loss around implants is reported as a complication when it progresses uncontrolled, resorption does not always lead to implant loss, but may be the result of biomechanical adaptation to loading. Considering graft stiffness, the previous studies show that grafting materials is a one of the load-bearing capacity or adaptability factor to loading implant placed in maxillary sinus graft (Papa, Cortese, et al., 2005; Xu, Shimizu, et al., 2005). However, the contribution of the grafted bone in establishing and maintaining implant stability is not yet well known. It is not known in such cases whether the grafted or residual bone secured the implant and whether porous implants reduce bone stresses.

1.3 Rationale

The ability to predict the biomechanical response of bone around implants is important for a stable and predictable treatment result. The biomechanical performance of bone surrounding implant placed in maxillary sinus grafted can be investigated by using advanced engineering tools such as computer aided design (CAD) system, medical image processing and finite element method. Because the components in an osseointegrated implant placed in maxillary sinus grafted are extremely complex geometrically, the use of optimal load sharing concept in load bearing capacity of complex system aid to predict the prognosis of implant placed in maxillary sinus graft.

From the biomechanical point of view, the phenomenon of highest stress concentrations in cortical bone around implant can be explained by the fact that most materials applied in dental implantology have high Young’s modulus. The porous structure helps to reduce the maximum stress at cortical bone and the porous structure implant should be design. To create the porous structure in the implant is a novel method to fabricate the implant with low Young’s modulus instead of changing the material properties.
1.4 Hypothesis

1. The effects of the two investigated clinical factors (MBL progression and grafted bone quality) will produce the optimal load sharing in the complex system of implant placed in maxillary sinus grafted.

2. The advantages of applying the porous structure design into the complex system of implant placed in maxillary sinus grafted will reduce the stress concentration of the cortical bone.

1.5 Objective of the study

The factors performing prognosis and long-term treatment result of implant placed in maxillary sinus graft are faced with the important clinical situations and implant implant design including the quality of graft maturation, the progression of marginal bone loss and the variation of porous implant designs. The research aims at better described for biomechanical performance of implant place in maxillary grafted sinus. Therefore the specific objectives of the study are to:

1.5.1 To evaluate the influence of MBL and graft stiffness on biomechanical performance in surrounding bone of implant placed in maxillary sinus graft

1.5.2 To find the optimal load sharing in different clinical situations due to marginal bone level and graft stiffness based on possible clinically simulating models.

1.5.3 To find a proper specific design (pore size, porosity) of porous structural implant based on the specific porous structure (bitruncated cubic honeycomb)

1.5.4 To evaluate the effects of honeycomb porous structure titanium implant on bone stresses at crestal bone and load transferring to surrounding bone in the complex system of implant placed in maxillary sinus graft.
1.6 Scope and limitation of the study

The scope of the study is defined by the following conditions:

1.6.1 The geometrical assessment results were based on the computer model, which may be different from the living bone tissue.

1.6.1 The magnitude and direction of loading were taken from the literature to evaluate mechanical performance by means of a finite element method.

1.6.3 The mechanical testing of human subjects are beyond the scope of the study.

1.7 Organization of the dissertation

Chapter I highlights the clinical situations and states the problems of the stability of implant placed in maxillary sinus graft.

Chapter II gives the background of this research by way of literature review for the biomechanical aspect of osseointegration implant placed in maxillary sinus grafted and the porous structural titanium implant.

Chapter III presents the influence of graft quality and marginal bone loss for the stability of implant placed in maxillary sinus graft in which the overall clinical scenarios.

Chapter IV describes the biomechanical study for the porous structured implant design by means of a finite element study.

Chapter V presents the biomechanical performance of complex structure of implant placed in maxillary sinus graft base on the porous structure implant design.

Chapter VII wraps up the dissertation by discussing the conclusions and suggestion for the further study.
References


