THE EFFECT OF GEOMETRY OF PROSTHESIS ON THE STABILITY OF HIP JOINT ARTHROPLASTY USING FINITE ELEMENT METHOD

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To my beloved husband, Mohamad Shukri, my mother, Ramlah Abdul Rahman and my family

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ABSTRACT

Lack of stability is known as one of the principal factors contributing to the loosening of hip prosthesis. Initial stability of the hip prosthesis is related to the magnitude of relative displacement at the femoral bone-prosthesis interface. The present study investigated the effect of prosthesis geometry on the initial stability. In addition, the effect of hole and fin as additional features of prosthesis was also investigated. Three-dimensional (3D) finite element model of femur and prosthesis was constructed based on Computed Tomography (CT) dataset of a Malaysian male patient. Simulations of normal walking condition were performed on the models to investigate the relative displacement between the bone and prosthesis interface. The simulation results showed that rectangular hip prosthesis contributed to the reduction of relative motion at the proximal and distal ends of the prosthesis. For the prosthesis with additional hole as a feature on the proximal region of prosthesis, the result showed that it increased the magnitude of relative displacement at the proximal region on the medial side. For the effect of fin, it was observed that the relative displacement was lower than 40 µm along the lateral and medial sides.

ABSTRAK

Kekurangan kestabilan adalah salah satu faktor utama yang menyumbang kepada kegagalan pembedahan pinggul tulang. Kestabilan pertama bagi implan adalah berkait rapat dengan magnitud pergerakan relatif di antara dua permukaan iaitu permukaan tulang dan permukaan implan. Tujuan projek ini dijalankan adalah untuk menyiasat kesan geometri implan ke atas kestabilan pertama. Selain itu, kesan lubang dan sirip sebagai ciri tambahan pada implan juga turut dikaji. Model tiga dimensi (3D) femur dan implan dibina berdasarkan setdata Tomografi Berkomputer yang diperoleh dari seorang pesakit lelaki Malaysia. Simulasi berdasarkan beban berjalan secara biasa dijalankan untuk mengkaji pergerakan relatif di antara permukaan tulang dan implan. Keputusan dari simulasi menunjukkan bahawa implan yang berbentuk segiempat dapat merendahkan pergerakan relatif di bahagian proksimal dan bawah implan. Bagi implan yang mempunyai ciri lubang pada bahagian proksimal implan, keputusan menunjukan bahawa ia telah meningkatkan pergerakan relatif pada kawasan proksimal bagi bahagian tengah. Untuk kesan sirip, diperhatikan bahawa pergerakan relatif lebih rendah daripada 40μm pada bahagian tengah dan belakang.

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A	-	Area
E	-	Young Modulus
L	-	Length
σ	-	Stress
δ	-	Displacement/deflection

CHAPTER 1

INTRODUCTION

1.1 Problem Definition

Hip arthroplasty is a procedure to replace the damaged bone on the hip joint with an implant called hip prosthesis. However, there are several important issues in determining the longevity of the hip prosthesis such as stress distribution in the femoral bone and the stability of the hip prosthesis. Many authors have agreed that one of the factors contributing to the long-term longevity of the hip arthroplasty is the stability of the hip prosthesis (Chae *et al.*, 2006, Pancanti *et al.*, 2003, and Viceconti *et al.*, 2006). Unlike cemented prosthesis, the stability of cementless prosthesis depends on the rate of bone growth to the prosthesis surface. There are two types of stability; initial stability and secondary stability. Initial stability refers to the amount of relative motion at the bone-prosthesis surface induced by the physiological loading before biological process. While, secondary stability is the relative motion at the bone-prosthesis surface once the biological process is completed (Viceconti *et al.*, 2006 and Orlick *et al*., 2003).

There are many factors influencing the initial stability such as geometry and material properties of prosthesis, quality of the bone, and the human activity. Different approaches have been used in evaluating the stability of either *in vitro* study or *in vivo* study. These approaches are important to determine the long-term fixation of hip prosthesis and the success of the hip arthroplasty. Many previous studies have analysed and investigated the effect of cross section on the hip prosthesis. However, they were more interested to investigate the stress distribution on the prosthesis surface compared to its stability (Joshi *et al.*, 2000, Bennet and Goswami, 2007, Sabatini *et al.*, 2008, and Chen *et al.*, 2009).

Therefore, the focus of this study is to analyse and determine the relative motion on the cementless prosthesis by investigating the effect of geometry of prosthesis. In addition, the effect of hole and fin as an additional feature on the proximal region of prosthesis was also investigated in this study. In this study, a finite element analysis was performed to evaluate the relative motion at the bone-prosthesis interface for normal walking condition. Three-dimensional solid model of femur bone constructed from the CT dataset was obtained from a male patient. Then, the prosthesis was designed based on the morphological data extracted from femoral bone constructed earlier.

1.3 Objectives

The objective of this study is to design hip prosthesis for total hip joint arthroplasty based on morphological data of a patient. In addition, a finite element procedure was established in order to assess the initial stability. The initial stability was determine based on the value of relative displacement at the bone-prosthesis interface. Finally, another objective of this study is to investigate the effect of geometry of prosthesis and additional features on the initial stability.

1.4 Scope

The computed tomography (CT) dataset was obtained form a male patient. Then, the three-dimensional model of femoral bone was constructed based on this dataset. After that, the morphological data of bone were obtained in order to construct the hip prosthesis. The design of prosthesis was focused on cementless and collarless hip prosthesis. The parametric studies were to investigate the effect of geometry of prosthesis and additional feature on the initial stability. There were two types of feature, which are hole and fin. As for loading condition, normal walking condition was chosen as the loading case.

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