Effect of Ring Material and Diameter on Orthopedic Implant Stability: External Fixation in Femur Bone

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Abstract

Axial stiffness is the most important factor in stability. It is known that any changes in the diameter of any components of the frame will either increase or decrease the axial stiffness of the fixation. The model of implant and bone will be variety as the variables changes. Current studies states that ring stability are one of the most important factors in ensuring fractured bones to have a successful re-union. In circular external fixation, the stability of the pin-bone interaction is influenced by the stability of the fixation frame where the major component is the rings. The objective is to study the finite element analysis (FEA) of the external fixator assembled in human diaphysis under compression force with different materials of the exoskeleton which are stainless steel, titanium alloy, magnesium alloy and carbon fiber. The results obtained show the mechanical strength of each material where it will be used to compare the value of von-Mises stress, stiffness and total deformation to acquire the best suitable ring diameter and material. Based on the result, as the diameter of the ring increases, the stiffness of the ring will be decreased.

Keywords: External Fixation, Stiffness, Structural Analysis.

1. Introduction

Human body contains 206 bones that can be divided into two categories which are axial skeleton and appendicular skeleton. Femur bone is the most important part of leg for human to walk but most of bone fracture will occur at femur bone especially for older people. Fracture happens when the bone cannot withstand the external impact or stress exerted upon them [1]. Fracture can be divided into two types which are open fracture or closed fracture. Open fractured usually happens when a high-force blow hits the thigh bone that caused by a collision with an object for example, a car accident. In order to heal the fractured site, an external fixator is used because it can create a mechanical environment to help heal the bone fractures typically by the secondary bone healing in suitable patients [2]. External fixator is known as an exoskeleton applied to a broken endoskeleton where any changes in exoskeleton effects the endoskeleton [3]. It is used to maximize the stability of a broken bone where pins and screws are attached to the frame outside the skin. The advantage of using this kind of fixation are that it makes less interruption of blood supply to fracture fragments, decrease the length of surgery where sometimes surgeon left the fixation at patient until fracture is fully healed and decreasing the blood loss [4]. As a result, stability can be conceived as the sum of distribution from both endo- and exoskeleton. However, fixation failure can lead to a few complications that will be experienced by the patient such as pin loosening that can directly increase pain. Therefore it will lead to the usage of excessive pain medication and delayed in the mobilization. According to Pommer et al, [5] the early occurrence of pin loosening is due to mechanical reason where the main reason of the failure of the implant is the stability. Each of the components of the system is directly influence the stability of external fixator. Frame is one of the components that directly influence the stability where the ring properties give a huge impact towards it [6]. According to Zhang and Oyadiji [7], the stiffness of circular fixator effect by the properties of the rings. In order to prevent these circumstances, a newly designed external fixator has been introduced by Hospital Universiti Kebangsaan Malaysia (HUKM) and Universiti Malaysia Perlis (Unimap) as a universal fixator for bone fracture treatments was used for this study. Investigation for identifying and measuring strength or weakness of the performance of fixator is needed before apply to human body. Therefore, in order to prevent failure of the implant, the understanding of the effect of ring diameter on the mechanical performance of the external fixator is paramount to avoid. Thus, delay the process of osseointegration and bone remodelling.

2. Materials and Methods

Figure 1(a) shows the fixator that was designed in SolidWork and all the finite element analysis were conducted by using ANSYS Workbench. The bone is attached to four half pins and two half ring to give support to the bone. The rings have the diameter of 150 mm, 180 mm, 200 mm and 240 mm where these diameters are the standard size of existing rings in clinical use where a constant standard radial thickness of 12 mm and axial thickness of 5 mm were applied. The half pins used are also the standard size half pins where they have the diameter of 4 mm and it is attached 2

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