UNIVERSITI TEKNOLOGI MARA

DESIGN AND DEVELOPMENT OF HIGH FLEXION TOTAL KNEE REPLACEMENT (TKR) USING FINITE ELEMENT ANALYSIS (FEA)

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ABSTRACT

The human knee is a heavily loaded joint that must support the body's weight to do active daily movements. Total knee replacement (TKR) is a surgical procedure replacing the knee joint with artificial material to restore the functionality of the knee joint. According to the 2019 Malaysian National Health and Morbidity Survey, 30.4% were overweight, and 19.7% were obese, which increased the demand for TKR in Malaysia. Every country has experienced an upsurge in TKR surgeries in the past few years, and this is predicted to rise, with 3.48 million TKR procedures performed by 2030. Nevertheless, the problem emerges after surgery when patients cannot do daily activities such as squatting, kneeling, and sitting-on-feet because they cannot flex beyond certain angles when performing these tasks. The study aims to determine the high flexion TKR design, construct finite element analysis on the assembly of TKR, and compare the finite element analysis results with the experimental compression testing. The design selection process was introduced, and design modifications were carried out by designing three different surfaces on the tibial insert. FEA was performed on the three modified designs with varying contact surfaces, such as small, medium, and large contact areas. Four angle flexions of 0°, 90°, 135°, and 165° with a distinct net force based on the percentage of body weight were implemented on the TKR. The final modified TKR design was fabricated using additive manufacturing. Also, customised jigs were developed to hold the fabricated TKR in the Shimadzu Servopulser testing machine. During the compression testing, the load was applied to the femoral until it reached 326.18 N at a speed of 0.5 mm/min. The outcome of FEA, including total deformation, von Mises stress, and contact pressure on TKR, was observed and compared to find the final modified TKR design. The result of FEA shows that the inclination surface on the tibial insert has total deformation of 0.207 mm, 0.223 mm, 0.775 mm, and 0.814 mm, which lessens the deformation by 28.32%, 42.29%, 16.03%, and 20.05%, at the angle flexion of 0°, 90°, 135°, and 165° respectively, compared to unmodified tibial insert. Simulation results showed good agreement with the experiment, where the percentage difference between them is 14.46%. In conclusion, the modification of the high flexion TKR design was completed by having the results of FEA reduced in total deformation, von Mises stress, and contact pressure, as well as consistency in stiffness and deformation between simulation and experiment.

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CHAPTER 1
INTRODUCTION

This chapter includes an overview of the overall research. A brief of the research background regarding the study purpose and research gap is introduced. The problem statement, research questions, and research objectives are explicitly identified. Lastly, the limitations and significance of the study are mentioned in detail.

1.1 Research Background

The human knee is the most stressed and heavily loaded joint as it needs to support the entire human body's weight to do active daily movements such as walking, sitting, running, and kneeling [1]. However, injury and pain from the knee joint are uncertain and unpredictable because of accidents, sickness, or ageing. Total knee replacement (TKR) is a surgical procedure replacing the knee joint with artificial material. The replaced artificial knee joint is called a prosthesis. This surgery and post-treatment are necessary for patients to relieve pain and restore knee joint functionality and durability [2]. Figure 1.1 shows a knee prosthesis consisting of a femoral component, tibial insert, and tibial component [3].

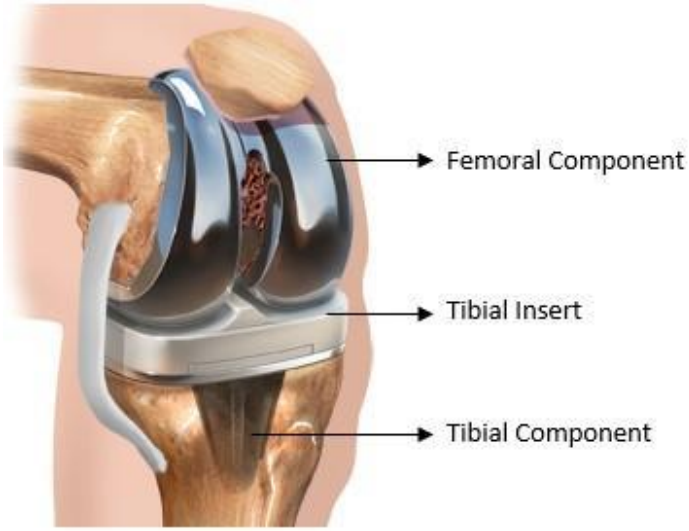

Figure 1.1 Knee Prosthesis [3]

Every country has experienced an upsurge in TKR surgeries in the past few