UNIVERSITI TEKNOLOGI MARA

EXPERIMENTAL INVESTIGATION ON THE EFFECT OF BIOFLUIDS PROPERTIES ON THE TRIBOLOGY OF TOTAL JOINT REPLACEMENT (TJR)

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ABSTRACT

The procedure known as total knee replacement (TKR) is now routinely performed on those who suffer from degenerative joint disease. Researchers continue to be concerned about the limited-service life of implants despite the constantly rising number of treatments Nevertheless, polyethylene (PE) liners, which are frequently used as implant materials, can gradually deteriorate, producing particles that induce inflammation and potentially result in implant malfunction. This study examines a dual strategy to improve the lifetime of TKR. First and foremost, we investigate the potential substitution of PE liners with poly lactic acid (PLA) implants. PLA exhibits enhanced biocompatibility and has the potential to mitigate the formation of wear debris. Furthermore, we present an innovative approach to lubrication by utilising plant-derived oils (canola, castor, and sunflower seed) in conjunction with hyaluronic acid (HA) modifiers. The present lubrication methodology emulates the characteristics of synovial fluid, which serves as the inherent lubricant within our joints. The tribological behaviour of the bio lubricants has received particular concern, as reductions in friction and wear have been crucial to the development of modern knee implants. Therefore, this research aims to assess the viability of employing the polymer PLA to substitute cartilage in TKR procedures that employ vegetable oils as lubricants. This study utilised a response surface methodology (RSM) with a Box-Behnken design (BBD) to enhance the lubricants composition. The present study employed a statistical approach to comprehensively examine the impact of lubricants composition and concentration of HA modifier on the tribological properties. The RSM analysis effectively evaluated the data and determined the most appropriate formulation. The potential of using a polymer as a cartilage replacement was studied using a three-level, three-factor BBD to examine the interactions between the essential factors of load (45 kg to 90 kg), speed (60 rpm, 210 rpm, and 360 rpm), and concentration (0 ml, 5 ml, and 10 ml) of bio-lubricants. After the completion of the optimization procedure, experimental validation was performed via a pin-on-disk tribometer. The coefficient of friction (COF) and wear rate of each oil-HA combination were measured using this tribometer. With an adjusted R^2 of 0.77 and an R^2 of 0.91, the analysis of variance shows that the experimental data were successfully interpreted by optimization using RSM. In comparison to other lubricants, castor oil exhibits the lowest surface roughness, measuring at 1.0754 µm. In summary, this research investigates the potential of PLA implants and plant-based oil lubrication with HA to improve the efficacy and durability of TKR This research has identified castor oil mixed with HA as a highly promising lubricant formulation with remarkable tribological properties, using RSM optimisation and tribometer testing. The aforementioned phenomenon possesses the capacity to yield prolonged implant lifespans and improved patient outcomes.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Osteoarthritis is a joint condition that results in bone-on-bone grinding, functional disability, and discomfort due to cartilage degradation in the shoulder, hip, and knee (Katz, Arant, and Loeser 2021). It is a chronic, progressive illness that causes the breakdown of joint cartilage. It can be extremely painful and result in a loss of movement and function. Total knee replacement (TKR) is a highly effective therapy for degenerative joint disease, with good to outstanding long-term outcomes, and over one million knee replacements are done each year across the world (Jan Philippe Kretzer et al. 2014). TKR can fail over time, with a mean revision rate of 6% after five years according to a recent study of global joint registries (Koley, Saha, and Ghosh 2015). TKR failure is highly complicated, however the primary causes may be mechanical or biological.

The major biological process leading to implant failure has been identified as chronic inflammation following the production of wear particles due to wear rubbing surfaces (Fazal, Haseeb, and Masjuki 2013). Several researchers concentrated on the wear of rubbing surfaces under varied operating circumstances [5][6]. However, little is known about the interfacial lubrication mechanisms in knee replacements, although such information can aid to decrease wear and, as a result, eventually increase implant longevity. Ultra-high molecular weight polyethylene (UHMWPE) is a frequently employed material for the bearing surface in TKR surgery (V. Sharma et al. 2023). Although UHMWPE exhibits favorable wear resistance, it is not impervious to damage. Over time, the friction that occurs during movement might lead to the generation of wear particles in the UHMWPE. Microscopic particles play a significant role in the process of aseptic loosening, which is widely recognized as the primary factor contributing to the long-term failure of TKR. The constraints associated with UHMWPE in TKR, including the production of wear particles and the resulting aseptic loosening, serve as a driving force for investigating alternate bearing materials. The objective of this study is to examine the viability of utilizing polylactic acid (PLA) as a