DESIGN AND DEVELOPMENT OF A NOVEL BALL-ON-CUP TRIBOMETER FOR THE CHARACTERIZATION OF AN INGENIOUS TOTAL HIP PROSTHETIC LINER MADE OF UHMWPE AND ITS COMPOSITE

ABSTRACT

Total hip replacement (THR), regarded as the orthopaedic operation of the 20th century, uses ultra-high molecular weight polyethylene (UHMWPE) as the acetabular liner since 1960s. However, the life of a metal-on-plastic THR is often limited to 15-20 years, primarily due to excessive wear debris generation during its operation, leading to osteolysis and aseptic loosening of the prosthetic joint leaving behind a painful revision surgery. Presently worldwide research is dedicated in improving the life of a metal-on-plastic THR by the improvement of tribological characteristics of an UHMWPE acetabular liner.

The objective of present work is to develop UHMWPE and UHMWPE-MWCNT composite based acetabular liners and their preclinical evaluation as per international guidelines to compare their wear performance. An ingenious technique is proposed for the manufacturing of the acetabular liner using medical grade UHMWPE-GUR1050 polymer powder by a cold isostatic compaction against a mirror finished metallic surface, and it is followed by shape-constrained sintering. UHMWPE powder is processed with experimentally obtained optimum value of compaction pressure, sintering temperature and sintering duration to get products having the properties at par with hot isostatic processed (HIPped) products, viz., relative density of ~ 97% and Vickers hardness of ~ 5.0. Moreover, the newly developed acetabular liners are found to possess inborn plateau finished bearing surface with R_a <100 nm and a negative skewness of 1.156, altogether making it an ideal choice for any bearing applications.

UHMWPE-MWCNT nanocomposites with different concentrations of the filler are processed for enhancing the mechanical properties of virgin polymer to the maximum possible extent. Up to 0.25 wt.% of MWCNT is successfully dispersed and distributed homogeneously in UHMWPE by ultra-sonication and magnetic stirring to improve the hardness and compressive yield strength of UHMWPE by 77% and 43%, respectively, with 60% increase in tensile yield strength. After the confirmation of biocompatibility of UHMWPE-0.25MWCNT nanocomposites, it is used to manufacture acetabular liner with improved mechanical properties compared to the pure polymer.

A novel mechanism is designed as a modular attachment for a standard pin-on-disc machine to transform the same into a 'Ball-on-Cup' tribometer similar to an orbital bearing machine (OBM) hip simulator meeting the ISO-14242-3 recommendations. The novel 'Ball-on-Cup' tribometer is developed to study *in vitro* tribological characteristics of the newly developed UHMWPE and UHMWPE-0.25MWCNT acetabular liners against stainless steel (SS) femoral heads with ISO-14242-3 recommended kinetics at an accelerated frequency of 5 Hz. A 1:2 volumetric solution of 2% w/v high molecular weight Sodium Alginate and 0.75% w/v Gellan gum is used as a lubricant during wear simulation of the developed prosthesis for its rheological similarity with the synovial fluid.

In vivo condition of human hip joint is simulated with significant success using the novel 'Ball-on-Cup' tribometer, where Sodium Alginate/Gellan gum is used as a lubricant, generating spherical and sub-spherical shaped wear debris from the tested prosthesis under the action of adhesive and fatigue wear. These wear debris are found to be morphologically similar in comparison to those retrieved from the human body while using THA. The stable wear rate of ~20 mm^3/MC observed for non-crosslinked UHMWPE acetabular liner against SS femoral head is found to be at par with that of reported values by most of the laboratories worldwide for cross-linked UHMWPE liners, which is reduced further by ~ 55% after 0.25 wt.% of MWCNT reinforcement. Hence, it is concluded that UHMWPE and UHMWPE-MWCNT composite processed with the proposed ingenious technique may be considered as potential aspirants for the next generation acetabular liner in metal-on-polymer THR in order to increase its longevity.