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A Next-Generation Pin-On-Plate Tribometer for Use in Arthroplasty Material Performance Research

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Abstract : Introduction: In-vitro testing of arthroplasty materials is of paramount importance when ensuring that they can withstand the performance requirements encountered in-vivo. One common machine used for in-vitro testing is a pin-on-plate tribometer, an early stage screening device that generates data on the wear characteristics of arthroplasty bearing materials. These devices test vertically loaded rotating cylindrical pins acting against reciprocating plates, representing the bearing surfaces. In this study, a pin-on-plate machine has been developed that provides several improvements over current technology, thereby progressing arthroplasty bearing research. Historically, pin-on-plate tribometers have been used to investigate the performance of arthroplasty bearing materials under conditions commonly encountered during a standard gait cycle; nominal operating pressures of 2-6 MPa and an operating frequency of 1 Hz are typical. There has been increased interest in using pin-on-plate machines to test more representative in-vivo conditions, due to the drive to test 'beyond compliance', as well as their testing speed and economic advantages over hip simulators. Current pin-on-plate machines do not accommodate the increased performance requirements associated with more extreme kinematic conditions, therefore a next-generation pin-on-plate tribometer has been developed to bridge the gap between current technology and future research requirements. Methodology: The design was driven by several physiologically relevant requirements. Firstly, an increased loading capacity was essential to replicate the peak pressures that occur in the natural hip joint during running and chair-rising, as well as increasing the understanding of wear rates in obese patients. Secondly, the introduction of mid-cycle load variation was of paramount importance, as this allows for an approximation of the loads present in a gait cycle to be applied and to test the fatigue properties of materials. Finally, the rig must be validated against previous-generation pin-on-plate and arthroplasty wear data. Results: The resulting machine is a twelve station device that is split into three sets of four stations, providing an increased testing capacity compared to most current pin-on-plate tribometers. The loading of the pins is generated using a pneumatic system, which can produce contact pressures of up to 201 MPa on a 3.2 mm^2 round pin face. This greatly exceeds currently achievable contact pressures in literature and opens new research avenues such as testing rim wear of mal-positioned hip implants. Additionally, the contact pressure of each set can be changed independently of the others, allowing multiple loading conditions to be tested simultaneously. Using pneumatics also allows the applied pressure to be switched ON/OFF mid-cycle, another feature not currently reported elsewhere, which allows for investigation into intermittent loading and material fatigue. The device is currently undergoing a series of validation tests using Ultra-High-Molecular-Weight-Polyethylene pins and 316L Stainless Steel Plates (polished to a $Ra < 0.05$ µm). The operating pressures will be between 2-6 MPa, operating at 1 Hz, allowing for validation of the machine against results reported previously in the literature. The successful production of this next-generation pin-on-plate tribometer will, following its validation, unlock multiple previously unavailable research avenues.

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