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Real-Time, In Vivo Measurement of Contact Pressures at a Knee Arthroplasty

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There is a need to measure contact pressures at the femoral component and tibia plate of a knee arthroplasty implant to determine the wear and tear of the polyethylene (PE) insert of the implant. Today, most pressure monitoring systems for knee arthroplasty implants are either limited to in vitro or intraoperative use, or cannot measure contact pressures at the polyethylene surface. Here, we are developing a wireless passive sensor system for measuring the contact pressure at the knee arthroplasty in vivo. The sensor system is made of a pressure-sensitive magnetic layer embedded under the top surface of a PE insert used for mapping the contact pressures with the femoral components. The pressure-sensing layer consists of a grid of pressure and stress sensitive magnetoelastic thin strips that alter their magnetic properties with applied force. Measurements are taken at pressure points located at the crossings of the grid. The magnetization of each sensing strip is remotely measured by using an AC magnetic field to excite the material to generate higher-frequency fields, which are then detected through external detection coils. The responses of these sensing strips are fed into an algorithm to determine the pressure loadings at all pressure points, which allows for real-time, in vivo determination of pressure profiles on the PE insert. By using an array of magnetoelastic sensing strips, we have demonstrated the remote detection of pressure across a surface. The 2nd order harmonic amplitude of a 30 mm$\times$1.5mm magnetoelastic strip decreased linearly with increasing pressure. For this sensing strip, the rate of decrease was about 0.1 (normalized to unstressed signal level) per 200 kPa. An algorithm was also developed to determine the pressures at all pressure points from the responses of the sensing strips. Experimental results have shown that the algorithm can accurately map the pressure profile of a 3$\times$3 sensing strip array. Further works include developing a fabrication process for safely embedding the sensing strips into a PE insert, and modifying the algorithm for a larger sensing strip array.

An Intelligent Bone Spinal Disc Implant for Asian Population

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There is a high level of patient appeal and physician acceptance of motion preservation as the future treatment of symptomatic and painful degenerative disc disease. However, spinal artificial disc replacement is still in its infancy. We have been designing, developing and evaluating motor articulated implants for use in bone-spinal disc surgery for Asian population. Apart from the generally smaller built of Asian compared to the American and European, the motor articulated implant should make provisions for the difference in eastern and western lifestyles. In the eastern world, we generally sit on a lower platform. Frequent activities like squatting result in a different stress-strain profile on the lower spine of an Asian compared to that of the Westerner. Preserving the motion of flexion bending in human lumbar spine is important. The motion preservation characteristics have to be maintained without compromising device durability, bone-device interfaces and corrective intervention. A systematic approach was adapted in designing the implant. Physical size of the implant should replicate the actual Intravertebral Disc (IVD). Implant should be able to fit into vertebral body. This is aid by shaping the spine vertebral body to accommodate the implant. A motor articulated implant must have suitable spaces for the implementation of sensors to detect forces and motors to control the motion of the prototype. The device must be able to receive real-time sensory inputs which can then modulate the implant orientation in bending accordingly. A prototype of the implant device has been fabricated to study its motion preservation capabilities. The prototype comprises of a parallel manipulator mechanism where the top plate is linked to the base plate by independent kinematic chains. The mechanical structure is made of Aluminium 6061. The mechanical parts were also put through the chemical process of anodizing for a good finishing surface. In the prototype device, we used three DC micromotors (Faulhaber) for actuation. Due to the small dimension, fibre optics pressure sensors were used. Three customized sensors were developed, calibrated and deployed on the upper plate. A PIC32 microprocessor was used to compute the compliance motion of the prototype when subjected to forces during flexion bending motion. The computer simulation of the kinematics of the parallel mechanism demonstrated the implant's flexion bending capabilities. We are conducting biomechanical experiments with this prototype implant deployed between L3–L5 of an artificial spinal column. The prototype device should achieve motion preservation capabilities comparable to the existing implants. More computer simulation will also be conducted to improve the mechanical design and control mechanisms of the proposed disc implant.

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