INTRA-OPERATIVE 3D LASER SCANNING AND BEST FIT ALIGNMENT FOR COMPUTER ASSISTED ORTHOPAEDIC SURGERY

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Over the last decade Computer Assisted Orthopaedic Surgery (CAOS) has emerged particularly in the area of minimally invasive Unicompartmental Knee Replacement (UKR) surgery. Image registration is an important aspect in all computer assisted surgeries which is a process of developing a spatial relationship between pre-operative data, such as Computerised Tomography (CT) scans or Magnetic Resonance Imaging (MRI) scans and the physical patient in the operation theatre. It allows the surgeon to visualise the 3D pre-operative scan data in-relation to the patient's anatomy in the operating theatre.

Current image registration techniques for CAOS in minimally invasive UKR are achieved by digitising points on the articulating surface of the knee joint using a navigated probe. By using these digitised points a rigid body is formed which is then fitted to the pre-operative scan data using a best fit type minimisation. However, this manual digitisation approach is time consuming and often takes 15-20 minutes and is therefore costly. The rationale for this study was to develop a new, quick, cost effective, contactless shape acquisition technique which could produce an accurate rigid body model in theatre from the ends of the exposed bones using 3D scans taken intra-operatively by a Laser Displacement Sensor.

Bespoke and automated 3D laser scanning techniques based on DAVID-Laserscanner have been developed and were used to scan surface geometry of the knee joint in 10 cadaveric legs. The Medial compartments of 9 joints had undergone a UKR procedure post donation but the lateral compartments were unaffected. The 9 legs were CT scanned and then segmented using Mimics 12.01 to generate 3D models of the medial compartments. The 10 legs were also MRI scanned using a 3D FLASH technique to produce 3D models of the lateral articular cartilage. All the samples were then 3D Laser scanned using a tailored plane-less technique and customized positioner assemblies. The CT and MRI generated 3D models were then registered with the corresponding 3D Laser scans in the Geomagic Qualify® package using manual surface registration. This is a type of surface (point based registration or free-form surface matching) registration which works closely on Iterative closest point (ICP) algorithm. Once the models were registered, a best fit alignment was performed between two datasets. Results indicate average best fit alignment errors and standard deviations ranging from 0.2 mm to 0.9 mm with errors normally distributed. Most of the errors could be attributed to calibration errors, segmentation errors and post-processing systematic errors.

We have demonstrated the feasibility of using a novel laser scanning technique where by acquiring multiple scans of the tibio-femoral joint in theatre, complete 3D models of the geometry and surface texture can be developed which can be registered with the pre-operative scan. The overall time for scanning, post-processing and the registration requires less than 5 minutes and is a non-invasive, cost-efficient approach. This study has provided proof of concept for a new automated registration technique with the potential for providing a quantitative assessment of the articular cartilage integrity during lower limb arthroplasty.