ACQUIRING DYNAMIC THREE-DIMENSIONAL HUMERAL DEFECT ANATOMY IN A REAL-TIME MINIMALLY INVASIVE ENVIRONMENT

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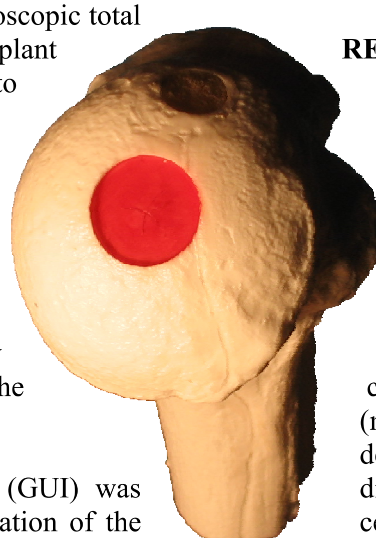
INTRODUCTION: A novel method for resurfacing localized articular cartilage damage in the shoulder joint has recently been developed by Arthrosurface (Franklin, MA). However, incorporation of this innovative implant requires an invasive surgical procedure to gain access to the glenoid and humeral surfaces of the joint. Because of the relatively small size of this implant, it is believed that this technology could be further used to create a minimally invasive total shoulder joint replacement system. In particular, the incorporation of a surgical navigation component within the existing design presents as a timely, achievable, and extremely beneficial progression for the first ever arthroscopic total joint replacement. To obtain optimal implant sizing and positioning, it is necessary to obtain the three dimensional geometry of the shoulder. The ability to obtain these geometries during surgery avoids expensive and time-consuming preoperative planning. The objective of this research was to define a method to recreate the anatomy of a humeral head defect in a dynamic real-time, minimally invasive environment, and to evaluate the accuracy of the reconstruction.

METHODS: A graphical user interface (GUI) was established in MatLab to allow for visualization of the surface geometry of the glenohumeral joint in real-time. A MicroScribe MLX (Immersion, San Jose, CA, USA) digital coordinate measuring machine (CMM) digitized the surface of the defect portion of the humeral head. Between 100 and 150 points were obtained by tracing the defect portion, and a surface fitting algorithm used these points to recreate the geometry of the surface. This surface reconstruction was used to identify optimal implant positioning, obtain implant specific measurements necessary for implant sizing, and visualize the geometry in a surgical environment.

To account for joint motion, a second CMM (MicroScribe G2L, Immersion, San Jose, CA, USA) was rigidly fixed to the humeral shaft. The coordinates from the second CMM transformed the coordinate system of the first CMM, so that the points and surfaces could be collected while the humerus was being moved.

To evaluate the accuracy of the defect, a simulated defect was created in a bone substitute as shown in the figure. A 5/8 inch (15.88 mm) end mill produced a precise couterbored defect of a known size and position (shown in red on figure). Two parameters were chosen to quantify the accuracy of the system: defect size and defect center position. The CMM that was used to trace the defect had a digitizing tip diameter of 1 mm, making the effective defect size 14.88 mm. 20 virtual models were recreated in MatLab from the bone model (N=20).



RESULTS: Points representing the surface defect were obtained in a dynamic real-time environment. These points were used to reconstruct a surface, which allowed visualization of the geometry, defect size, and defect position of the humerus.

Defect size accuracy was evaluated by comparing the diameters of the cylindrical defect. The effective true defect diameter was 14.88 mm. The calculated defect size was 14.95 ± 0.09 mm (mean ± SD). Position accuracy was determined by calculating the three dimensional distance from the true defect center to the calculated defect center. This distance, from the true defect center to the calculated center was 0.566 ± 0.267 mm.

CONCLUSIONS: This system produced a patient specific model of a humeral head defect with no pre-surgical preparation necessary. Existing implants for resurfacing the humeral head are manufactured in increments of 5mm diameters. Our sizing and positioning accuracy are well within an acceptable range for choosing an implant size and for a targeted position for navigation.

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