DESIGN OF A REVERSE SHOULDER IMPLANT TO MEASURE SHOULDER STIFFNESS DURING IMPLANT COMPONENT POSITIONING

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Introduction

Dislocation of the shoulder joint is one of the more common complications after reverse total shoulder arthroplasty [1], which is often associated with malposition of the prosthetic components [2]. Therefore, achieving sufficient shoulder stability should not be neglected when positioning the implant components. One parameter for assessing shoulder stability can be shoulder stiffness. The aim of this work is to develop a reverse shoulder implant prototype that allows intraoperative measurement of shoulder stiffness while varying the position of the implant components. The measured stiffness could provide a quantitative statement regarding the optimal positioning of the implant components, which can be adjusted accordingly in the final reverse shoulder prosthesis.

Methods

To measure the stiffness of the shoulder joint, it is necessary to record the joint angles and the torques generated during movement. The changes in the rotation angles were measured using 3D hall sensors and magnets. The magnets were placed under the humerosocket, and the hall sensors were integrated into the glenosphere. The strength of the magnetic field was used to determine the position of the humerosocket in relation to the glenosphere. The accuracies of the angle measurements were tested using a test bench (*Figure 1*).

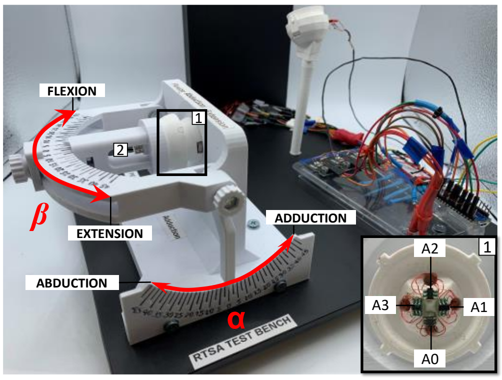

Figure 1: Test bench for 3-dimensional angular adjustment of the joint (alpha:adduction/abduction; beta:flexion/extension) Glenosphere with pyramidal arrangement of 4 hall sensors (A0-A3) 1 *.Three magnets under the humerosocket* 2 *.*

Three thin film pressure sensors were used to record forces at different points under the humerosocket. To obtain a force value from the sensor signal, the sensors were calibrated using a load cell. The variation of the implant components positions was integrated into the prototype implant through different constructive mechanisms to adjust the stiffness of the shoulder joint.

Results

In the range of ±45° flexion/extension combined with ±15° adduction/abduction, the joint position could be determined with sufficient accuracy (error e ≤ 5°). The areas near the combined maximum deflections of ±45° flexion/extension and ±45° adduction/abduction indicate the greatest deviation from the target angle (*Figure 2*). The force values of the thin film sensors enable the calculation of moments around two axes. As variable component position parameters, the tray offset, the neck-shaft angle and the humerus version were integrated into the implant prototype.

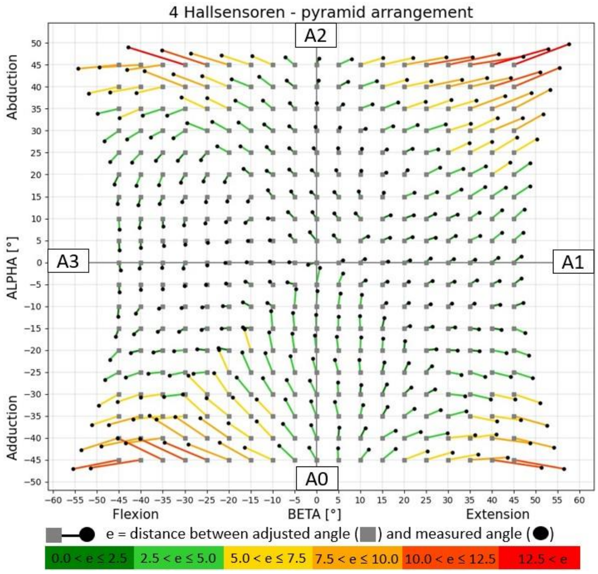

Figure 2: Angle measurements with four hall sensors

Discussion

Ideally, the accuracy of the angle measurements should only depend on the amount of deflection and not on the direction of deflection. The asymmetric behavior indicates a deviation from the correct positioning of the hall sensors. The application of a calibration matrix could compensate for the measurement errors and could demonstrate the potential of the new method for joint angle measurements. The accuracy of the torque measurements and the functionality of the mechanical arresting mechanisms must be investigated in further studies. Overall, the developed measurement method can help to avoid malpositioning of the implant components in reverse total shoulder arthroplasty.

References

1. Clark et al, J Shoulder and elbow surgery, 21:36-41 2012.
2. Randelli et al, J Musculoskeletal surgery, 98:15-18, 2014.