Fixation of Glenoid Components in Reversed Total Shoulder Replacement

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Introduction: The ‘Reversed’ shoulder joint was conceived to better treat those patients who suffer from irreparable rotator cuff tears with associated rheumatoid arthritis, who would only be likely to achieve very limited gains with an anatomical design. Despite early high complication rates, recent designs of reversed anatomy shoulders have demonstrated acceptable survival and restoration of function for the majority of patients [1-3]. Some complications reported in the literature include loosening of the glenoid prosthesis, indicating failure to achieve sufficient fixation of the un-cemented implant, this being required so as to promote osseo-integration of the hydroxyapatite coating. A greater appreciation of the behaviour of different designs and surgical conditions is required.

Materials and Methods: An experimental study presented by Harman et al. [4] was reproduced in an earlier study by our group giving very good correlation between their experimental data and our Finite Element (FE) predictions. The experiment was reproduced again using FE, but with a more extensive range of prostheses than previously tested. These designs were the Delta III (Depuy), RSP Neutral (Encore), RSP Reduced (Encore), Bayley-Walker (Stanmore Implants), Anatomica (Zimmer) and Verso (Biomet), as shown in Figure 1. FE models of these six different reversed glenoid prostheses were developed from CAD data and physical inspection using the software packages MENTAT (MSC software) and AMIRA (Mercury Software). Meshes of the prostheses consisted of 20-30 thousand linear tetrahedral elements.

The prostheses were positioned relative to a block of polyurethane within the FE software and a ‘virtual’ surgery was performed, essentially implanting the prostheses within the material. The maximum number of potential screws were used in all cases, with the maximum length of screw used. Final models consisted of 60-70 thousand linear tetrahedra. Interfaces between the polyurethane and implant were modelled as a contact surface, with a coefficient of friction of 0.4. The screw interfaces were rigid, assuming a good initial fixation of the thread. The capability to resist combined horizontal and vertical loading was assessed based upon the relative motion between the implant and bone at the interface, termed micromotion.

Results: Lateralisation of the glenohumeral centre of rotation was found to correlate with higher interface micro-motions. A direct comparison of the six different designs (Fig 2) showed that in all implants fixed to the polyurethane using a combination of screws generated peak micromotions below the threshold believed to induce fibrous tissue formation and/or loosening. The Bayley-Walker implant generated the highest peak micromotion at 240 μm, followed by the Anatomica (82 μm), RSP Neutral (80 μm), RSP Reduced (75 μm), Delta (55 μm) and Verso (50 μm). The use of either four screws (Delta and RSP designs) versus two screws (Anatomica and Verso) did not appear to make a significant impact upon interface micromotions.

Discussion: With the continued success of the concept of reversed anatomy shoulder prostheses to treat dysfunctional rotator cuff with associated rheumatoid arthritis, it is important that techniques exist to provide effective screening of new devices before they are introduced to the market. This Finite Element study suggests that while many designs on the market provide a natural resistance to high interface micromotions due to inherent design, some adjustments can be made to improve clinical outcomes. However, it should be highlighted that the use of a homogeneous bone material, such as is presented here, is not representative of the real situation. Anchorage of screws to the denser cortical material is envisaged to alter the mechanical environment significantly. The next phase of this work is to use a heterogeneous material distribution within the bone material, as derived from CT. The presence of variable material quality through the bone, particularly when conditions of rheumatoid arthritis are simulated, will further clarify the influence of design upon interface strength and stability.