# A computational model of a reverse shoulder joint prosthesis

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**INTRODUCTION:**

The reverse shoulder prosthesis is designed to provide a salvage solution for the end-of-stage cuff tear arthropathy patients who have poor biomechanical function. The reverse shoulder medializes the natural anatomical gleno-humeral center of rotation, thus changing the biomechanics of the shoulder. The change of the center of rotation increases the lever arm for the remaining deltoid muscle bundle, theoretically resulting in an increase of range of motion and reduced muscle forces. However, the increased moment arm also causes a larger contraction range of the deltoids for a given angular movement of the joint and this can potentially challenge the deltoid by bringing it out of its ideal fiber length range. This paper aims to investigate the interplay between design parameters of a reverse prosthesis by means of an advanced computer model. The model comprises a total of nine independent parameters of which two are investigated in this paper.

**MATERIALS AND METHODS:**

A model of the DELTA XTEND (DePuy, Warsaw, IN) system was developed using the AnyBody Modeling System (AnyBody Technology A/S, Aalborg, Denmark, Damsgaard et al, 2006). The model is based on the public domain AnyScript Model Repository (www.anybody.aau.dk/repository) and comprises an arm and shoulder complex with morphology according to Van der Helm (1994) and Van der Helm et al (1992). The anthropometrical dimensions of the model roughly correspond to a 50th percentile European male. The model was based on anatomical parameters by Van Der Helm et al (1992) and Van der Helm (1994). The muscles of the model are based on a three-element Hill model including length-strength and length-velocity relationships and the passive-elastic behavior.

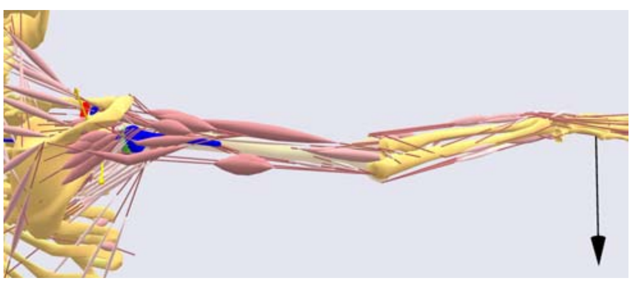

*Figure 1. The reverse prosthesis model.*

The reverse prosthesis forms a spherical joint between two parts:

1. The glenosphere is attached to a flat surface created on the glenoid fossa by the surgeon. In this process the surgeon has the opportunity to adjust the inferior/superior and lateral/medial offset of the glenosphere. These are the two parameters investigated in this paper. Furthermore, the inclination angle of the glenosphere in the scapular plane is adjustable. The computer model implements these placement parameters as well as a variable radius of the glenosphere.
2. The scapular part of the prosthesis has a shaft for insertion into the humerus at a version angle selected by the surgeon and a head that forms an angle with the shaft. The model offers several other parameters summarized in Table 1.

Obviously, a systematic investigation of a nine-parameter design space using in-vivo models is neither ethically nor realistically possible, and investigation is therefore only possible with either in-vitro or computer models. Here we shall systematically vary the inferiorization and lateralization of the glenosphere on the scapular part of the prosthesis and investigate the influence on necessary muscle active state to perform a movement.

| *Parameter* | *Description* | *Default value* |
|---|---|---|
| Radius | The glenosphere (GS) radius | 0.019 m |
| GlenosphereInf | Inferior offset of the GS | 0.005 m |
| GlenosphereLat | Lateral offset of the GS | 0.0 m |
| GlenosphereInclination | Inclination of the GS | -15 deg |
| HumeralSpacer | Length | 0.009 m |
| CupDepth | Determines trade-off between stability and mobility | 0.008 m |
| StemRetroversion | Retroversion of the stem on the Humerus regarding to the elbow axis | 0 deg |
| EpiphysisRetroversion | Retroversion of the epiphysis regarding to the stem | 0 deg |
| NeckShaftAngle | Angle between the epiphysis and the stem of the humeral prosthesis [Deg]. | 155 deg |

*Table 1. Design and implantation parameters in the model.*

**RESULTS**:

Figure 2 shows the necessary muscle active state to obtain 90 degree abduction with 45 degree elbow flexion against gravity and an inferior load of 10 N acting on the hand. The posture is shown in Fig. 1.

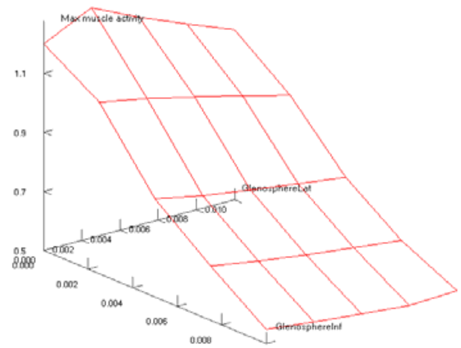


*Figure 2. Dependency of muscle active state in the posture of Fig. 1 on inferiorization and lateralization of the glenosphere.*

**DISCUSSION**:

The result (Fig. 2) shows as expected that the combination of abduction and rotation moment is challenging; many of the combinations of the two parameters lead to muscle active states over 1, meaning that a person with average muscle strength is unable to attain this posture in the absence of rotator cuff muscles. However, there are also several combinations that lead to muscle activations of only about 0.5 indicating that the performance of the implant depends significantly on these parameters.

Further work includes simulation of impingement and systematic studies involving all the parameters of the prosthesis.

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