Can Downward Inclination of the Glenoid Component Balance Supraspinatus Deficiency?
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Introduction: Anatomic total shoulder arthroplasty is an accepted treatment for degenerative pathologies of the glenohumeral joint with functional rotator cuff muscles. However, degenerative changes in the supraspinatus tendon, leading eventually to transmural tear, are common. It has been shown that a deficient supraspinatus muscle induces an increased upward migration of the humeral head during abduction, which induces more eccentric loading of the glenoid implant (rocking-horse phenomenon), and precludes the long-term survival of the glenoid component. Since the superior inclination of the glenoid has been associated to humeral head migration [1], it has been suggested that a downward inclination of the glenoid implant might balance a deficient supraspinatus muscle by recentering the loading on the glenoid. This hypothesis has been verified in a cadaver study [2], and a fatigue experimental study has reported an improved glenoid fixation with downward inclination [3]. In spite of the above studies, the consequences on the joint force and the associated cement stress around the glenoid implant are still unknown. Therefore, the goal of this study was to evaluate further the potential advantage of a downward inclination of the glenoid implant when the supraspinatus muscle is deficient.

Materials and Methods: A 3D finite element model of the glenohumeral joint based on CT and dissection data of a normal shoulder was used for this analysis. Six muscles were considered: the anterior, middle, and posterior deltoid, the supraspinatus, subscapularis and infraspinatus combined with teres minor. The stability of the glenohumeral joint was achieved by the articular surfaces and the wrapping of the muscles around the humeral head, allowing for the natural translation of the humeral head relative to the glenoid. Active abduction was simulated in the plane of the scapula, from 0 to 150 degrees. The muscle activation was controlled by a feedback algorithm, assuming constant muscle force ratio derived from EMG and PCSA [4]. The rotation of the scapula was reproduced with a scapulo-humeral rhythm of 2:1. The arm weight was set to 37.5 N (5% of the bodyweight) and an additional weight of 10N (1 Kg) was placed in the hand. The Aequalis anatomic prosthesis was inserted in the shoulder model according to manufacturer recommendations. A uniform cement mantel of 0.5 mm around the glenoid implant was considered. The polyethylene glenoid implant and the cement were assumed elastic, while metal parts were rigid. The glenoid bone was characterized by an inhomogeneous elastic modulus derived from CT data. Three cases were compared: healthy muscles without glenoid inclination (A), deficient supraspinatus without glenoid inclination (B), deficient supraspinatus with glenoid inclination (C). The inclination of the glenoid (10 degrees) was achieved by an asymmetric inferior resection of the glenoid bone (fig. 1). The effect of glenoid inclination was evaluated through the following quantities: the glenohumeral joint force, the middle deltoid force, the upward migration of the humeral head, the location of the contact point center and the tensile stress within the glenoid cement.

Results: In case (A), the maximal glenohumeral contact force reached 980N (130% of the body weight) at nearly 90 degrees of abduction. This force increased to 1050N in case (B), but decreased to 940N in case (C). The maximal force within the middle deltoid was 300N in case (A), 380 in case (B) and 350N in case (C). The maximal upward migration of the humeral head (relative to its perfect centering in the glenoid) was 1.7mm in case (A) and 2 mm in case (B). In case (C), the humeral head was about 4mm below. The most eccentric location of the contact point was 5.5mm above the glenoid axis in case (A), 7.4mm in case (B) and 6.8mm in case (C). Within the cement mantel, the maximal tensile stress occurred at 60 degrees of abduction. It was 8.7 MPa in case (A), 10.2 MPa in case (B) and 13.0 MPa in case (C).

Discussion: A deficiency of the supraspinatus muscle, when associated to anatomic total shoulder arthroplasty, increases the upward migration of the humeral head, producing more eccentric glenoid loading. A downward inclination of the glenoid component can balance this deleterious effect. This mechanism was reproduced by the present biomechanical model, which also provided the resulting glenohumeral joint force and the cement stress around the glenoid component. Although an inclination of 10 degrees of the glenoid could partly balance the supraspinatus deficiency, limiting the increase of eccentric loading, this potential advantage was however counterbalanced by a drastic increase of the cement stress. This stress increase was caused by the partial removal of the subchondral bone support in the inferior part of the glenoid, resulting in a softer bone support and causing higher deformation and stress within the cement mantel. To conclude, we suggest that a downward inclination of the glenoid implant should not reject the subchondral bone support.


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