The Effect Of The Humeral Tray Component Positioning for Onlay Reverse Shoulder Arthroplasty Designs

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Introduction:
Reverse Shoulder Arthroplasty (RSA) is effective in treating pain and loss of function for patients with cuff tear arthropathy (1). Over the years, its indications have expanded to include irreparable rotator cuff tears, complex proximal humerus fractures, and revision arthroplasty (4). Even if post-operative clinical and biomechanical results show great promise (1, 3), concerns still exists on the lack of external rotation and scapula notches due to impingement (1). Recent reverse shoulder prosthetic systems have introduced a concept of universal humeral stem component platform that has an onlay humeral tray which articulates with the chosen glenosphere. Even if several studies have investigated how humeral retroversion affects RSA, there are no studies to report how the positioning of the onlay humeral tray can affect the biomechanics of RSA.

Methods:
The Newcastle Shoulder Model (2, 3) was used to investigate the biomechanical effect of the humeral tray positioning in the Biomet Comprehensive® reverse prosthesis. The model includes 6 rigid bodies (thorax, clavicle, scapula, humerus, ulna nad radius) and 31 muscles of the upper extremity. The humeral component was fixed in 20 degrees of retroversion and five tray offsets positions were tested: no offset, and 5mm offset in the anterior, posterior, medial, and lateral positions, respectively (Figure 1). Impingement was evaluated for abduction, scapular plane elevation, forward flexion, and external/internal rotation with elbow at the side (adduction) and at 90° of shoulder abduction. Muscle lengths and moment arms (elevating and rotational) were also calculated for the deltoid, the infra-spinatus, the teres minor and the sub-scapularis.

Results:
Inferior impingement was always observed between the humeral cup and the inferior scapular pillar and it was not affected by the humeral tray positioning. However, superior impingement results showed less bony contact between humerus and acromion/coracoid during abduction, scapular plane elevation, and rotation when the tray was placed lateral or posterior (Figure 2). The sub-scapularis rotational moment arm was increased with a posterior offset (Figure 3A), while infra-spinatus and teres minor rotational moment arms were increased with an anterior offset (Figure 3B). No significant effect was observed for the deltoid elevating moment arm. There were only very small changes in length tested.

Discussion:
Humeral tray offset may not have as large impact on RSA function as other fixation or design factors (e.g inferior glenoid placement, size of sphere, oblique glenoid osteotomy), but it should be considered since it can affect the overall function of the prosthesis. Position the humeral tray with a lateral offset.
decreases superior impingement, but posterior offset offers a better biomechanical advantage for patients needing RSA because it decreases superior impingement and increases rotational moment arm of the inferior part of the sub-scapularis and of the anterior deltoid. Positioning the humeral tray anteriorly has the advantage of improving external rotation by increasing the rotational moment arm of the inferior part of the infra-spinatus and teres minor, and of the posterior deltoid.

**Significance:**
The results of this study may be helpful for surgeons dealing with specific pathologic anatomy in patients who are indicated for RSA.

**Figure 1**

**Humeral tray positions tested:**
- No offset reference position in superior view (Top).
- Lateral and medial offset in coronal view (two bottom left figures)
- Anterior and posterior offset in sagittal view (two bottom right figures).
The red and green arrow showed the direction of the offset applied relative to the referent no offset position.
Free-impingement range of motion relative to the humeral tray offset position for:

A. humeral abduction,
B. humeral scapular plane elevation,
C. humeral forward flexion.
Rotational moment arm of the subscapularis during internal rotation with arm abducted.

- No offset
- Anterior offset
- Lateral offset
- Medial offset
- Posterior offset

Rotational moment arm of the teres minor during external rotation with arm abducted.

- No offset
- Anterior offset
- Lateral offset
- Medial offset
- Posterior offset

Rotational moment arm of the teres minor during rotation with arm abducted (A) and with arm in adduction (B), relative to the humeral tray offset position.