Polyethylene Wear in Anatomic and Reversed Shoulder Prostheses
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INTRODUCTION:
Polyethylene wear is a recurrent problem in joint arthroplasty. In addition to permanent deformation or complete destruction of the component, small debris particles are also associated to inflammation reaction of the surrounding bone, eventually leading to the failure of the bound between the implant and the host bone, and implant loosening.

In anatomic total shoulder arthroplasty, failure of the glenoid polyethylene component is the main cause of complication, often related to periprosthetic osteolysis and aseptic loosening [1]. Polyethylene wear of anatomic prostheses has been clinically observed on retrieved glenoid components. For reversed shoulder prostheses, polyethylene wear is usually related to the scapular notching. However, the surface wear of the humeral cup is still unknown. In reversed prosthesis, the glenohumeral force is lower and the contact area is higher than in anatomic prosthesis [2]. Consequently, the contact pressure should thus be much lower, but the volumetric wear might be as important in reversed prostheses as in anatomic prostheses.

The goal of this study was thus to estimate the volume of polyethylene wear of a reversed prosthesis, and compare it to an anatomic prosthesis, during one year of activities of daily living (ADL).

METHODS:
A numerical musculoskeletal model of the glenohumeral joint was used for this comparative study [2]. The model included the scapula, the humerus and 6 scapulo-humeral muscles: middle, anterior, and posterior deltoid, supraspinatus, infraspinatus and subscapularis combined with teres minor. Arm motion and joint stability was achieved by muscles, allowing for natural translation of the humeral head. The muscle activation patterns were derived from EMG data and controlled by a synchronization algorithm. Arm weight was 37.5 N (5% bodyweight). The reversed (RP) and anatomic (AP) Aequalis prostheses were positioned in the numerical model according to manufacturer recommendations. For the RP, the rotator cuff muscles were deactivated since this prosthesis is used when these muscles are partly or completely deficient. Linear wear was defined by $H = k p s$, where $k$ is the wear factor, $p$ the contact pressure and $s$ the sliding distance. Pressure and sliding were provided by the musculoskeletal model. The wear factor was pressure dependent, based on experimental relationships [3]. Eight levels of abduction were considered. Their daily frequency was estimated from in-vivo recorded data on healthy volunteers during activities of daily living (table 1) [4]. One year of use was simulated to predict the linear and volumetric wear. The volumetric wear was the difference of volume between the original and worn component.

<table>
<thead>
<tr>
<th>Abd. level</th>
<th>10°</th>
<th>30°</th>
<th>50°</th>
<th>70°</th>
<th>90°</th>
<th>110°</th>
<th>130°</th>
<th>150°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily freq.</td>
<td>13021</td>
<td>6790</td>
<td>5557</td>
<td>2678</td>
<td>633</td>
<td>153</td>
<td>34</td>
<td>37</td>
</tr>
</tbody>
</table>

Table 1. Daily frequency associated to each abduction level.

RESULTS:
With the AP, the contact pattern on the glenoid surface moved rapidly from the inferior to the superior side during the first 30 degrees of abduction, and then went back to the inferior side. It reached 20 MPa at 90° of abduction. With the RP, the contact pattern on the humeral cup surface remained at the inferior side. In overall, contact pressure was 20 times lower with the RP than with the AP (Fig 1).

One year of use produced a maximum linear wear of 0.2 mm with the AP, and 0.13 mm with the RP (Fig 2). The volumetric wear was 8.4 mm³ with the AP, but reached 44.6 mm³ with the RP.

DISCUSSION:
Polyethylene wear particles were found around humeral and glenoid components of AP removed after aseptic loosening associated to osteolysis [5, 6]. This loosening process might occur in the same way with RP if the amount of wear is comparable. Since this potential problem has not been reported yet, this study aimed to estimate and compare the polyethylene associated to an AP and a RP. Using a numerical musculoskeletal shoulder model, one year of simulated activities of daily living produced 5 times more volumetric wear with the RP than with the AP, which confirms a potential polyethylene wear problem with RP.

Within the limitations of numerical analyses, the musculoskeletal model provided a comparative analysis of the two prostheses in the same conditions. The motor and stabilizing function achieved by muscles allowed for the natural translation of the humeral head of the AP and the increased muscle moment arm of the RP. A variable wear factor was essential because of the large range of contact pressure involved. Although activities of daily living were only characterized by abduction cycles in the scapular plane, the in-vivo recorded shoulder kinematics provided a realistic estimate of the shoulder use. Since kinematics was measured on healthy volunteers, the patient activity was probably overestimated. The wear mechanism complexity was not fully reproduced here. Cold flow deformation and cross-shear was not accounted for, but would have of little effect on the simulated movements.

Polyethylene particles are a matter of concern with AP. Infiltration of these particles within the bone-implant interface can induce a progressive implant loosening. According to the present results, this problem should not be underestimated with RP. It might indeed be associated to the higher level of humeral stem loosening reported with RP. The long term survival of RP might be improved by using a highly cross-linked polyethylene, which has a better abrasion resistance but lower plastic resistance.

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REFERENCES: