# HUMERAL HEAD RECONSTRUCTION: NEER VS. ANATOMICALLY BASED PROSTHESES

+*Büchler, P (A-Swiss National Science Fondation); **Farron, A; *Rakotomanana, L

+*Biomedical Engineering Laboratory & Orthopaedic Hospital, Lausanne, Switzerland. Biomedical Engineering Laboratory, Swiss Federal Institute of Technology, PSE A - Ecublens, 1015 Lausanne, Switzerland, ++41 21 693 83 51, Fax: ++41 21 693 83 30, Philippe.Buechler@epfl.ch

**Introduction**

In the design of the third generation of shoulder prosthesis, the tendency is to restore the patient normal anatomy [1]. The hypothesis for developing "anatomical" prostheses is that restoration of the original bone shape will optimally restore physiological motion, forces in surrounding muscles [2] and the centre of rotation [3]. If this is true, forces transmitted to the glenoid surface should be closer to the original forces, limiting the risks of glenoid degeneration. As far as we know, no biomechanical study has confirmed this hypothesis. Our goals were therefore to assess the benefits of the anatomical reconstruction of the humeral head on shoulder motion and contact pressure. A comprehensive model of the glenohumeral joint was developed to compare Neer vs. anatomically based humeral heads after hemiarthroplasty.

**Material and methods**

A 3D model of the glenohumeral joint, based on finite element method, was developed from CT-scan data of a cadaverous human shoulder without pathology. The model included the 3D geometry of humerus and scapula with inhomogeneous bone density distributions, the glenoid articular cartilage and the subscapularis, supra and infraspinatus rotator cuff muscles. Cartilage was assumed hyperelastic and incompressible. Muscles were 3D reconstructed from their humeral and scapular insertions. Sliding contacts were assumed between muscles and bones. Nonlinear passive behaviour of muscles was accounted for [4]. The design of the anatomical humeral head was based on the ellipsoid which best fitted the humeral head of the intact shoulder. Anatomical and Neer prostheses were numerically implanted with cement in the humerus. The stem and plane of osteotomy for the anatomical prosthesis were the same as for the Neer prosthesis. Internal (0° to 60°) and external (0° to 40°) rotations of the humerus were simulated. The neutral position was defined as that when the centre of the humeral articular surface faced the centre of the glenoid fossa. Rotations were achieved by a gradual displacement of scapular muscle extremity (infraspinatus for external rotation, subscapularis for internal rotation) whereas all other muscles were inserted to bones at both ends. Scapula was floating, maintained by flexible elements replacing stabilising muscles. The distal humerus section was stabilised by four vertical flexible elements to preclude any significant abduction motion. Perturbation of the boundary conditions were tested: no modification on the results (bone stress distribution and muscles forces) were observed.

**Results**

_Glenoid contact pressure_

At 60° internal rotation, the contact region for the intact shoulder and for the anatomical prosthesis was located in the central part of the glenoid surface. The Neer contact region was located in the superior part of the glenoid surface (Fig. 1).

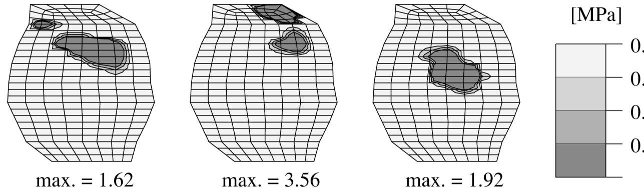


Figure 1: Glenoid contact pressure and location (60° internal rotation)

At 40° external rotation, the contact region was located similarly to that for internal rotation (superiorly for Neer; centrally for the anatomical cases). Values of contact pressure were highest for the Neer prosthesis (Table 1).

_Von Mises stress_

The von Mises stress distribution in the scapula bone was very dependent on the glenohumeral contact location. The peak values were located in the superior part of the bone with the Neer prosthesis. The von Mises peak values with the Neer prosthesis were 25% higher at 40° external rotation and 40% higher at 60° internal rotation. With the anatomical head, the stress distribution was similar to the normal case. A maximal discrepancy of about 15% was observed at 60° internal rotation between von Mises peak values. For the humeral bone, no significant differences in the stress distribution were observed between the two prostheses, except in the proximal region (in contact with the base of the head).

| | 40° external rotation | 60° internal rotation |
|---|---|---|
| Intact | 1.5 [MPa] | 1.6 [MPa] |
| Neer | +77% | +120% |
| Anatomical head | -5% | +19% |

Table 1: Contact pressure (variation from the intact case %)

_Muscular forces_

At 60° internal rotation, the force in the active muscles was 33% smaller with the Neer implant than for the two other cases (Fig. 2). At 40° external rotation, the active forces appeared to be similar for the three cases.

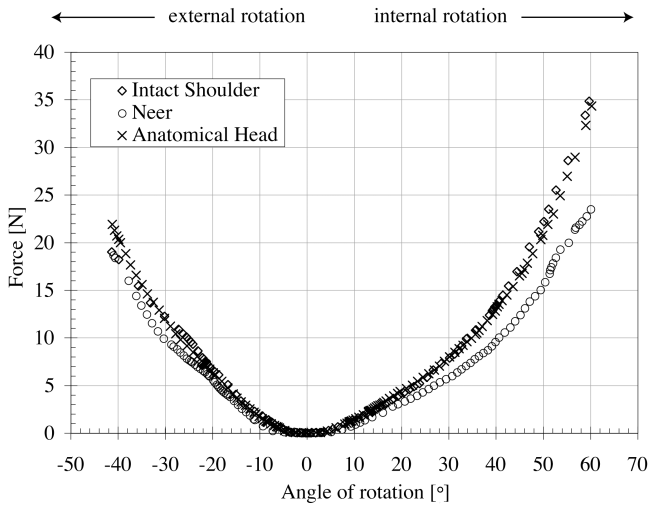


Figure 2: Force developed in the infraspinatus during external rotation (left) and in the subscapularis during internal rotation (right)

**Discussion**

The modern tendency of shoulder prosthesis design is toward the restoration of the patient normal anatomy. Our comprehensive 3D-computer model, developed to test this hypothesis, showed that anatomically based humeral heads induced bone stress, muscular forces and contact pressures, which were similar to the values calculated for the original humerus. This indicates that the restoration of the humeral head leads to more physiological motion (assessed by the location of contact pressure area) and bone stresses. However, at least two points should be clarified before considering application of this anatomical concept in Total Shoulder Arthroplasty. For an osteoarthritic joint with an exaggerated flattened humeral head, the design of an anatomical head should account for surrounding soft tissue atrophy. Also the influence of the anatomical head on prosthetic glenoid component anchorage may be important.

**References**

[1] Boileau et al. (1997) JBJS [Br] 79:857-65 [2] Flatow (1995) Semin Arthroplasty 6:233-44 [3] Pearl et al. (1999) JBJS [Am] 81:660:71 [4] Pioletti et al (1999) Med Eng Phys 21:95-100.

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**Othopaedic Hospital, Lausanne, Switzerland.