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IN VIVO GLENOID LOADS - MEASURED WITH INSTRUMENTED IMPLANTS IN 6 PATIENTS

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INTRODUCTION

Realistic loads acting in the shoulder joint are essential for improving implant design and testing. Additionally this data can be used to advise patients and medical staff which motions can be performed in the rehabilitation process, and which should be avoided short time post operative. So far, joint loads were estimated using computer models or cadaver experiments with strongly varying results depending on the author and used model.
Recently an instrumented shoulder implant was developed, capable of measuring 3D forces and moments acting on the humerus [1]. However, most critical in shoulder arthroplasty is still the glenoid component, including the "rocking horse phenomenon". An eccentric load on the glenoid, leading to implant loosening and increased wear, causes this.
This phenomenon is also included in mechanical testing of glenoid implants [2]. However, the direction of the eccentricity of the shoulder load is unknown so far. Models calculated eccentricities for abduction motion [3,4], while most activities of daily living are connected with elevation in the sagittal plane
Using synchronous in vivo load measurement and motion capture with scapula tracking, the loads of the humerus can be transferred to the glenoid. Still, the eccentricity of the acting force cannot be measured directly. However, in a simplified model described by [5], the combination of the resultant force F_G and the bending moments M_X and M_Y acting in the glenoid plane can be a hint of an eccentric force shift. In this model positive values for M_X and M_Y indicate a force shift to anterior-inferior and negative values a shift to posterior-superior, respectively (Fig.1, top left).
Many activities of daily living involve an elevation of the arm in the sagittal plane. Therefore we analyzed this motion as far as the patients were capable to do it.

METHODS

To measure the loads in the glenohumeral joint, a BIOMET Biomodular shoulder hemi-prosthesis was equipped with 6 strain gages, a 9-channel telemetry, and a coil for inductive power supply [1]. Six patients wearing these implants ((3♂, 3 ♀; 63 - 81 years, 52-107kg Bodyweight (BW)) took part in this study performing elevation in the sagittal plane (E_{SAG}) at least five times up to their personal maximum angle. Motion capture (Optotrak®, Ontario, Canada) including scapula tracking was done synchronously to transform the measured humeral loads to the glenoid. The motion of the scapula was accessed with a scapula tracker and an acromion marker cluster [6]. The orientation between scapula and glenoid was determined from preoperative CT images. Load values were first transformed from the humerus coordinate system (COS) into the scapula COS. Then they were transformed into the glenoid COS. The X-axis points forwards, Y-axis superior in the glenoid plane, and the Z-axis laterally. Data from patient S3L with the left sided implant were mirrored to the right side. Forces are stated in % body weight (%BW), the moments in %BWm.
The data for each patient was averaged using a method described by Bergmann and Bender [7] to create typical load-time curves.

RESULTS AND DISCUSSION

All patients reaching values of E_{SAG} >90° showed negative values for M_X and M_Y, indicating a shift of the resultant force towards posterior-/superiore (See Fig.1, top left). Only S4R (Patient Nr.4, implant on the right side) reaching only 80° E_{SAG} had positive M_X and M_Y.
The absolute highest bending moments were measured at S3L with 0,45%BWm for M_X and 0,51%BWm for M_Y at E_{SAG}=120°, while S2R had only 0,05 %BWm (M_X) and 0,16 %BWm (M_Y), at a much higher elevation angle of 170°.
Looking at the resultant forces, the differences between the patients are not as big as in the moments. However, the very athletic S8R had by far the highest loads with 172,7%BW, while S5R showed only 52,3%BWm, which can be partially explained by the low E_{SAG} of only 80° and her very high bodyweight of 107kg.
The force direction in the frontal plane was pointing medial-inferior for all patients when reaching their individual E_{SAG} maximum. Again very individual force directions were seen among the patients. This could be a hint of individual humero-scapular motion pattern. Motion restrictions

CONCLUSIONS

These measurements gave first insights on glenoid loads measured with an instrumented shoulder implant and transformed to the glenoid via motion capture. However, to verify these findings, combined in vivo measurement and fluoroscopic capture could give an even deeper inside of scapular kinematic and load. These measurements are planned for the future.

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REFERENCES

[1] Westerhoff P. et al., 2009, Medical Engineering & Physics, 31(2), pp. 207-13.
[2] Anglin C. et al., 2000, Journal of Shoulder and Elbow Surgery, 9(4), pp. 323–31
[3] Soslowsky J., 1992, Journal of Orthopaedic Research, 10(4), pp. 524–34
[4] Terrier A. et al., 2009, 55th ORS Meeting, Poster-No. 1926.
[5] Kutzner I., 56th ORS Meeting, Poster-No. 2056.
[6] van Andel C.,et al., 2009, Gait & Posture, 29(1), pp. 123-8.
[7] Bender & Bergmann, Computer methods in biomechanics and biomedical engineering, Sept. 2011, pp. 37–41

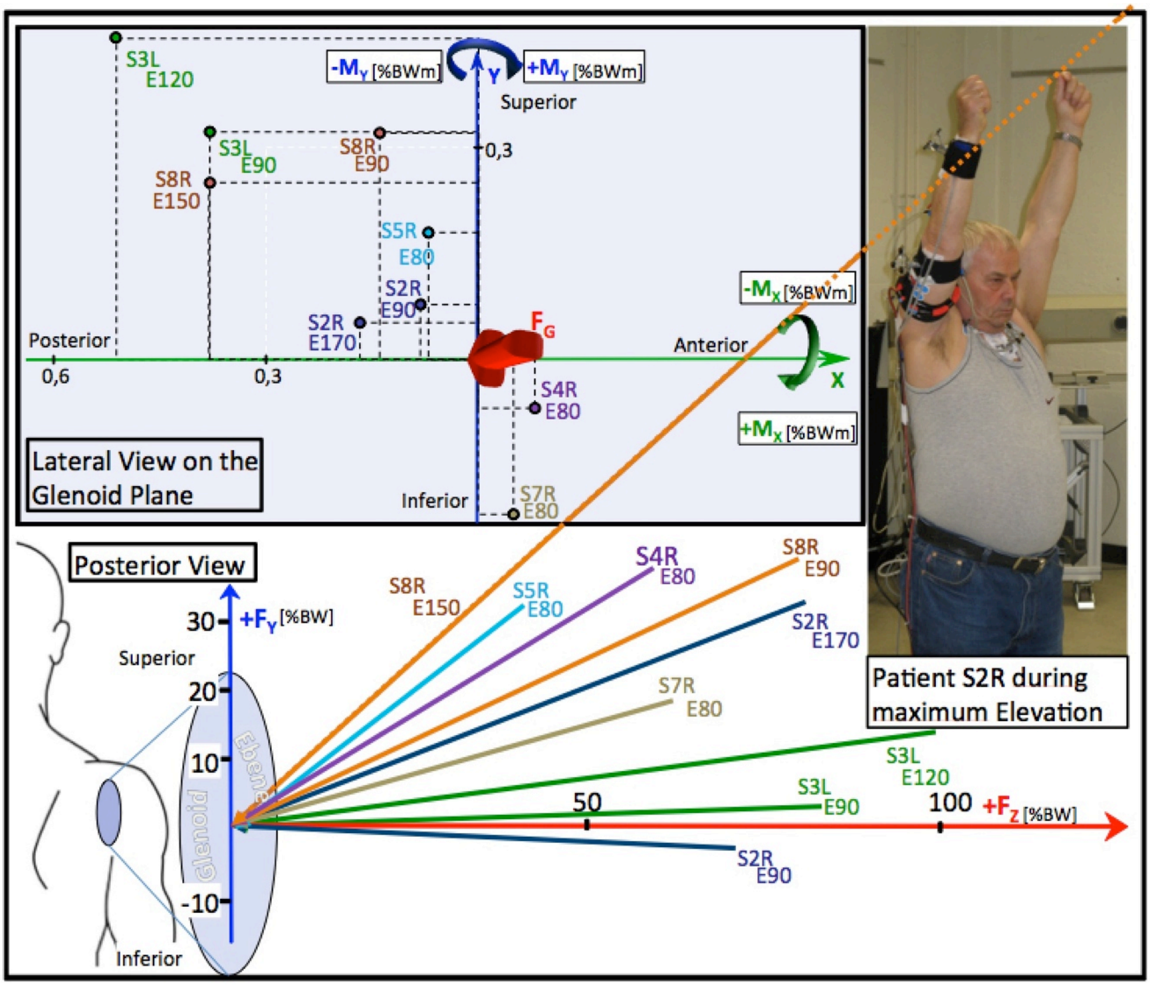

Figure 1: top: Bending moments in the glenoid plane: $+M_Y$ indicates eccentricity of the resultant force in anterior direction, $-M_Y$ indicates eccentricity to posterior; $+M_X$ indicates eccentricity to inferior; $-M_X$ indicates eccentricity to superior; E90= Elevation 90°
Bottom: direction and magnitude oft he resultant force in the frontal plane
Top right: Patient S2R during maximum elevation