

# THE RELATIONSHIP BETWEEN GLENOID INCLINATION AND IN-VIVO GLENOHUMERAL JOINT MOTION DURING SHOULDER ABDUCTION

Jennifer L Bishop<sup>1</sup>, Stephanie K Kline<sup>1</sup>, Kristopher J Aalderink<sup>2</sup>, and Michael J Bey<sup>1</sup>

<sup>1</sup>Henry Ford Hospital, Bone and Joint Center, Detroit, MI, USA

<sup>2</sup>Henry Ford Hospital, Department of Orthopaedic Surgery, Detroit, MI, USA  
jbishop2@hfhs.org

## INTRODUCTION

Rotator cuff injuries are common, leading to pain, loss of function, and medical expense. The etiology of rotator cuff injuries is not well understood, but cadaveric studies have shown that glenoid inclination (i.e., the extent to which the glenoid is tipped superiorly relative to the scapula) may be associated with rotator cuff tears and superior translation of the humerus (Konrad et al., 2006; Wong et al., 2003). However, the relationship between glenoid inclination and superior translation of the humerus has not been determined under in-vivo conditions. The objectives of this study were to: 1) compare glenoid inclination between the repaired and contralateral shoulders of patients undergoing unilateral rotator cuff repair, and 2) quantify the relationship between glenoid inclination and in-vivo superior translation of the humerus relative to the scapula. We hypothesized that glenoid inclination would be greater in the repaired shoulder and that there would be a significant association between glenoid inclination and superior translation of the humerus during shoulder abduction.

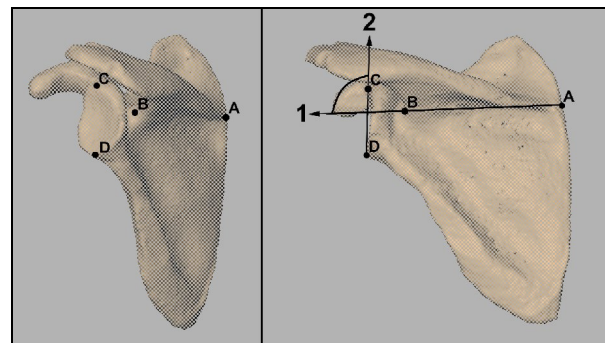
## METHODS AND PROCEDURES

Following IRB approval, 21 subjects (14 male; age:  $63 \pm 11.4$ ) were enrolled. Each subject underwent arthroscopic surgery to repair an isolated supraspinatus tendon tear 3-4 months prior to this study. The contralateral shoulder of each subject was asymptomatic.

Subjects were positioned with their shoulder centered in a biplane x-ray system (Tashman and Anderst, 2003). X-ray images were acquired at 60 Hz while subjects abducted

their shoulder in the frontal plane from full adduction to  $\sim 120^\circ$  of abduction. Three trials from each shoulder were recorded.

Following testing, bilateral CT images of the humerus and scapula were acquired. The humerus and scapula were segmented and reconstructed into 3D bone models. Using these models, glenoid inclination was measured using landmarks reported by Hughes and colleagues (2003) (Figure 1).



**Figure 1.** Glenoid inclination is the angle between lines 1 and 2. Line 1 connects (A) the scapular spine's intersection with the medial border, and (B) the spinoglenoid notch. Line 2 connects (C) superior most and (D) inferior most points on the glenoid rim.

The 3D positions of the humerus and scapula were measured from the biplane x-ray images using an accurate ( $\pm 0.4$  mm,  $\pm 0.5^\circ$ ) model-based tracking technique (Bey et al., 2006). Superior/inferior (S/I) translation of the humeral head center (HHC) relative to the scapula was quantified in terms of: S/I translation range (HHC RANGE), S/I translation from the adducted starting position to full abduction (HHC ABD), and maximum superior translation relative to the adducted starting position (HHC MAX).

As an alternative measure of joint motion, glenohumeral joint contact patterns were calculated using a technique that combined joint motion measured from the biplane x-ray images with the CT based bone models (Anderst and Tashman, 2003). The contact center location was determined by calculating the centroid of the closest 200 mm<sup>2</sup> region of contact between the articulating surfaces of the humerus and glenoid. The 3D coordinates of this contact center location were expressed relative to the scapula. S/I translation of the contact center (CC) was quantified in terms of: S/I translation range (CC RANGE), S/I translation from the adducted starting position to full abduction (CC ABD), and maximum superior translation relative to the adducted starting position (CC MAX).

A paired t-test assessed the effect of shoulder condition (repaired vs. contralateral) on glenoid inclination. The association between glenoid inclination and the six measures of glenohumeral joint translation was assessed for only the contralateral shoulder with linear regression and a correlation coefficient. Significance was set at  $p < 0.05$ .

## RESULTS

Glenoid inclination was an average of  $1.6 \pm 3.3^\circ$  lower in the repaired shoulder than in the contralateral shoulder ( $p = 0.04$ ). The study failed to detect any statistically significant association between glenoid inclination and the six measures of joint translation (Table 1).

S/I Translation Outcome Measure	Correlation Coefficient (r)	P value
HHC RANGE	-0.25	0.30
HHC ABD	-0.25	0.30
HHC MAX	0.02	0.95
CC RANGE	-0.10	0.67
CC ABD	-0.22	0.37
CC MAX	-0.16	0.50

**Table 1.** Correlation and regression results between glenoid inclination and kinematics.

## DISCUSSION

Previous research has reported that rotator cuff tears are associated with greater glenoid inclination (Hughes et al., 2003; Tetrault et al, 2004). In contrast, the current study indicates that glenoid inclination of the repaired shoulder is *lower* than the contralateral shoulder. It is possible that this discrepancy is due, in part, to differences in measurement technique. In fact, Kandemir and colleagues (2006) found a significant difference between 2D and 3D measurements of this angle.

Previous cadaver studies showed a decrease in superior translation as glenoid inclination decreased (Wong et al., 2003; Konrad et al., 2006). Contrary to these findings, the current study failed to detect any statistically significant association between glenoid inclination and the six measures of superior humeral translation. One potential explanation for this discrepancy is that previous research was based on cadaveric studies that cannot accurately simulate in-vivo muscle and joint forces. Moreover, it seems overly simplistic to expect that glenohumeral joint motion is influenced by a single anatomic factor such as glenoid inclination. In summary, this study failed to support the theory that glenoid inclination is the primary etiologic factor responsible for superior humeral translation and the development of rotator cuff tears.

## REFERENCES

- Anderst, WJ and Tashman, S (2003). *J Biomech*, 36:1291-9.
- Bey MJ et al. (2006). *J Biomech Eng* 128:604-9.
- Hughes RE et al. (2003). *CORR*, 407:86-91.
- Kandemir U et al. (2006). *JBJS*, 88-B:1105-9.
- Konrad GG et al. (2006). *Clin Biomech*, 21:942-9.
- Tashman, S and Anderst, WJ (2003). *J Biomech Eng* 125:238-45.
- Tetrault P et al. (2004). *JOR* 22(1):202-7.
- Wong et al (2003). *JSES* 12(4):360-4.