The biomechanical effects of acromial fracture angulation in reverse total shoulder arthroplasty

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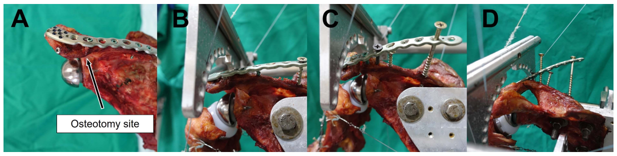
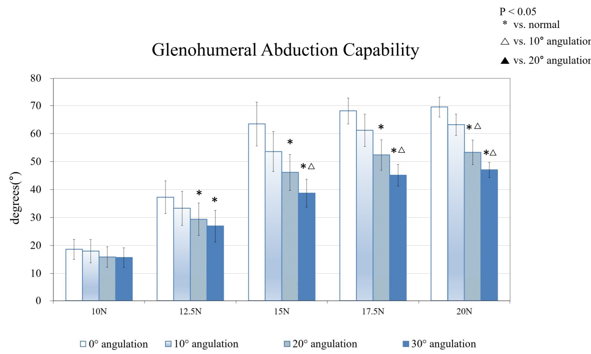
INTRODUCTION: The incidence of acromion and scapular spine fracture after reverse shoulder arthroplasty (RSA) has been reported to range from 0.8 to 15.8%. Clinical outcomes have shown that recovery of shoulder function after acromial fracture with RSA are inferior to that achieved before the fracture. Although conservative treatment and surgical intervention in acromial fractures improved functional outcomes compared with the preoperative status, patients without fracture after RSA had better clinical outcomes. The biomechanical changes and treatment guidelines on acromial fracture after RSA are still not well understood. The purpose of our study was to analyze the biomechanical changes with respect to acromial fracture angulation in RSA.

METHODS: RSA was performed in nine fresh frozen cadaveric shoulders. The tendon insertions of the subscapularis, teres minor, and anterior, middle, and posterior deltoid were sutured to implement physiological loading of shoulder muscles. An acromial osteotomy was performed on the plane extending from the glenoid surface to simulate an acromion fracture. Four conditions of acromial fracture inferior angulation were evaluated (0°, 10°, 20°, and 30° angulation). The middle deltoid muscle loading origin position was adjusted based on the position of each acromial fracture. The impingement free angle and capability of the deltoid to produce movement in the abduction and forward flexion planes were measured. The length of the anterior, middle and posterior deltoid was also analyzed for each acromial fracture angulation.

RESULTS: The impingement free abduction angle decreased as the acromial fracture angulation increased. There was no significant difference in the abduction impingement angle between 0° (61.8° ± 2.9°) and 10° angulation (55.9° ± 2.8°); however, the abduction impingement angle of 20° (49.3° ± 2.9°) significantly decreased from 0° and 30° angulation (44.2° ± 4.6°), and 30° angulation significantly differed from 0° and 10° ($P<0.01$, respectively). On forward flexion, 10° (75.6° ± 2.7°), 20° (67.9° ± 3.2°), and 30° angulation (59.8° ± 4.0°) had significantly decreased impingement free angle than 0° (84.2° ± 4.3°; $P<0.01$, respectively), and 30° angulation was significantly decreased than 10°. On analysis of the glenohumeral abduction capability, 0° significantly differed (at 12.5, 15.0, 17.5 and 20.0N) from 20° and 30°. For forward flexion capability, 30° angulation showed a significantly smaller value than 0° (15N vs 20N, respectively). As acromial fracture angulation increased, the middle and posterior deltoid muscles of 10°, 20°, and 30° became shorter than those of 0°, however no significant change was found in the anterior deltoid length.

DISCUSSION AND CONCLUSION: The most important finding of this study was that acromial fractures occurring after RSA significantly affect impingement free range of motion, abduction capability and length of the middle and posterior deltoid. Specifically, the range of motion deteriorates in proportion to the degree of angulation. Acromial fractures of 30° angulation negatively affect abduction capability. Moreover, the length of the middle and posterior deltoid significantly shortened proportionally with acromial fracture angulation. Osteotomy performed in the current experiment was at the location corresponding to Levy type IIB, and the result was relatively poor in conservative treatment for type IIB in their clinical series. Our findings suggest that surgical anatomical restoration should be considered because the impingement free angle in forward flexion and abduction is significantly reduced when the angulation of the fracture site is more than 20° in type IIB fracture. Considering that the one of the biomechanical rationale for RSA is distalization, our study found that the more severe the angulation in acromial fractures, the more severe the degradation in range of motion and abduction capability. This supports one of the reasons for the poorer the functional outcomes of postoperative acromial fracture. In our experiment, although the angulation of the acromial fracture was relatively tilted toward the posterior side, a significant decrease was observed in the impingement free angle on forward flexion. According to the results of several clinical studies, even after surgical treatment for acromial fracture, the range of motion and shoulder function did not recover completely, and painful acromial nonunions were observed. Although clinical outcomes and fracture healing are difficult to predict, these findings show that there is an advantage in removing structural barriers that can block the range of motion when bony alignment is restored by surgical fixation for angulated acromion fractures. In acromial fractures at the plane of glenoid surface, 10° inferior angulation of the acromion did not interfere with abduction and abduction capability. However, 20° and 30° of inferior angulation caused prominent impingement in abduction and forward flexion, and reduced abduction capability. In addition, there was a significant difference between 20° and 30°, suggesting that not only the location of the acromion fracture after RSA but also the degree of angulation are important factors for shoulder biomechanics.


A
B
C
D
Osteotomy site


P < 0.05
* vs. normal
△ vs. 10° angulation
▲ vs. 20° angulation
Glenohumeral Abduction Capability
degrees(°)
10N
12.5N
15N
17.5N
20N
0° angulation
10° angulation
20° angulation
30° angulation