Association of a Large Lateral Extension of the Acromion with Rotator Cuff Tears

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Background: Factors predisposing to tearing of the rotator cuff are poorly understood. We have observed that the acromion of patients with a rotator cuff tear very often appears large on anteroposterior radiographs or during surgery. The purpose of this study was to quantify the lateral extension of the acromion in patients with a full-thickness rotator cuff tear and in patients with an intact rotator cuff.

Methods: The lateral extension of the acromion was assessed on true anteroposterior radiographs made with the arm in neutral rotation. The distance from the glenoid plane to the lateral border of the acromion was divided by the distance from the glenoid plane to the lateral aspect of the humeral head to calculate the acromion index. This index was determined in a group of 102 patients (average age, 65.0 years) with a proven full-thickness rotator cuff tear, in an age and gender-matched group of forty-seven patients (average age, 63.7 years) with osteoarthritis of the shoulder and an intact rotator cuff, and in an age and gender-matched control group of seventy volunteers (average age, 64.4 years) with an intact rotator cuff as demonstrated by ultrasonography.

Results: The average acromion index (and standard deviation) was 0.73 ± 0.06 in the shoulders with a full-thickness tear, 0.60 ± 0.08 in those with osteoarthritis and an intact rotator cuff, and 0.64 ± 0.06 in the asymptomatic, normal shoulders with an intact rotator cuff. The difference between the index in the shoulders with a full-thickness supraspinatus tear and the index in those with an intact rotator cuff was highly significant ($p < 0.0001$).

Conclusions: A large lateral extension of the acromion appears to be associated with full-thickness tearing of the rotator cuff.

Level of Evidence: Diagnostic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Impingement syndrome and rotator cuff tears have been related to the morphology of the acromion[1-7]. Bigliani et al.[3] analyzed the shape of the acromion on lateral radiographs and found a higher prevalence of rotator cuff tears in patients with a hooked (type-III) acromion than in individuals with a curved (type-II) or a flat (type-I) acromion. Aoki et al.[1] found that patients with impingement syndrome had a flatter slope of the acromion on lateral radiographs than did asymptomatic individuals. Banas et al.[2] measured the angle between the undersurface of the acromion and the glenoid (the lateral acromion angle) on oblique coronal magnetic resonance images and found a significantly lower angle in patients with rotator cuff disease than in patients with an intact rotator cuff ($p < 0.0001$). Zuckerman et al.[7] performed a morphometric study on a large number of cadaver shoulders and found a significantly greater anterior projection of the acromion and a lower acromial tilt in specimens with a rotator cuff tear than in those with an intact rotator cuff ($p < 0.001$).

We have observed that the acromion of patients with a rotator cuff tear very often appears large during surgery or on true anteroposterior radiographs. The lateral extension of the acromion and its relationship to rotator cuff tears, however, have not to our knowledge been studied. The purpose of our investigation was therefore to quantify the lateral extension of the acromion in patients with a surgically documented rotator cuff tear and in individuals with an intact rotator cuff.

Materials and Methods

Definition and Measurement of Acromion Index

The lateral extension of the acromion was measured on standardized true anteroposterior radiographs made with the arm in neutral rotation. The measurement technique consisted of drawing three parallel lines and measuring the distances between those lines. The first line connected the superior and inferior osseous margins of the glenoid cavity and represented the plane of the glenoid surface. The second line was drawn tangen-

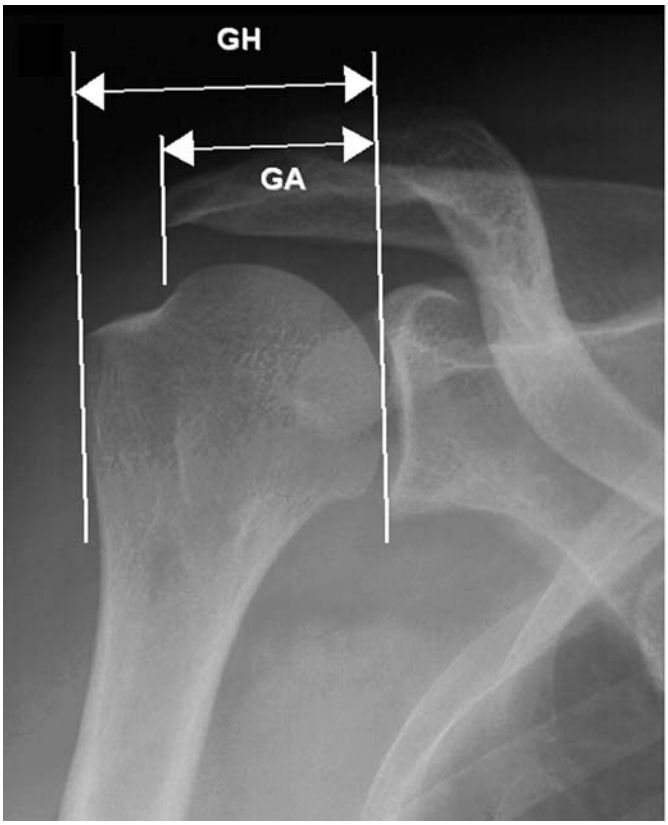

Fig. 1

The lateral extension of the acromion was quantified by measuring the acromion index on true anteroposterior radiographs. The acromion index (AI) was calculated by dividing the distance from the glenoid plane to the acromion (GA) by the distance from the glenoid plane to the lateral aspect of the humeral head (GH). The larger the lateral extension of the acromion, the higher the acromion index.

tial to the lateral border of the acromion, and the third line was drawn tangential to the most lateral part of the proximal part of the humerus. The distance from the glenoid to the acromion was divided by the distance from the glenoid to the lateral aspect of the humeral head, and the resulting value was called the *acromion index* (Fig. 1). A high acromion index corresponded to a large lateral extension of the acromion. Using a ratio rather than absolute values allowed us to avoid magnification errors on radiographic images and to compare individuals of different sizes.

Evaluation of the Measurement Technique

Because distances measured on a radiograph are influenced by the position of the patient in relation to the x-ray cassette and by the direction of the x-ray beam[8], a preliminary study was undertaken in order to assess the reliability of the measurement method. Five fresh-frozen cadaveric shoulder specimens consisting of the entire scapula, the proximal third of the humerus, the joint capsule, and the tendons of the rotator cuff were thawed twenty-four hours before examination. The scapula was fixed in a vise with the scapular blade and the glenoid surface oriented in a vertical plane. The humeral head was manually centered in the glenoid cavity, with the articular surface in neu-

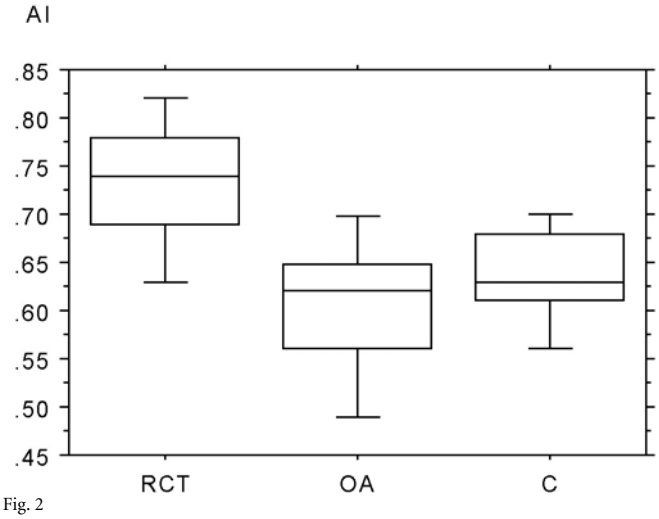

Fig. 2

Box plot showing the acromion index in the patients with a full-thickness rotator cuff tear (RCT), the patients with osteoarthritis and an intact rotator cuff (OA), and the control group of asymptomatic volunteers with an intact rotator cuff (C). The differences in the index between the patients with a full-thickness rotator cuff tear and the two groups of individuals with an intact rotator cuff were significant ($p < 0.0001$).

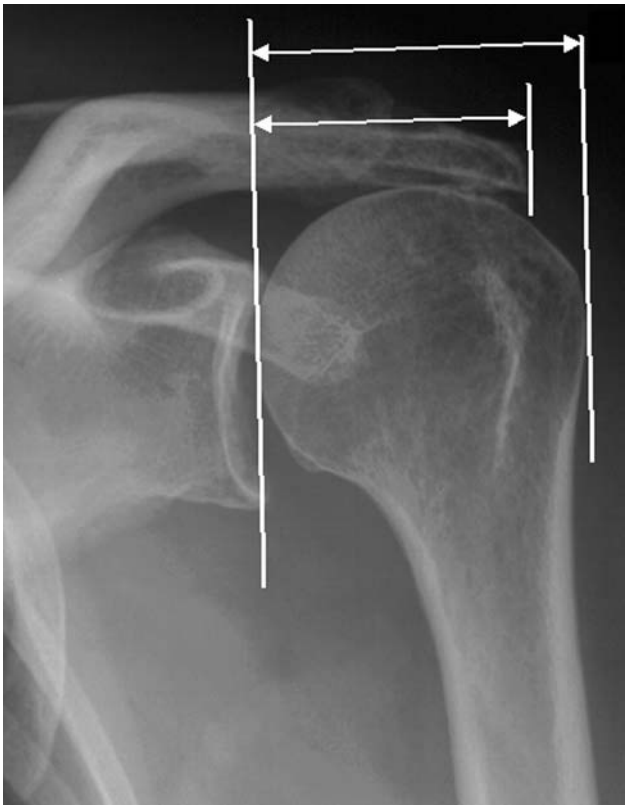

Fig. 3-A

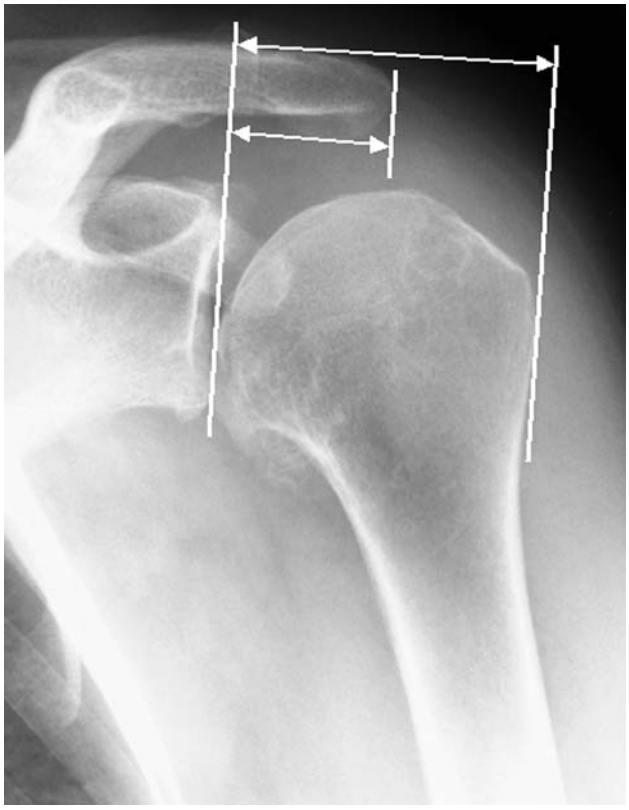

Fig. 3-B

Fig. 3-A True anteroposterior radiograph of a shoulder with a full-thickness rotator cuff tear and a large lateral extension of the acromion (an acromion index of 0.82). **Fig. 3-B** Radiograph of a shoulder with osteoarthritis and an intact rotator cuff. The acromion index was 0.50.

tral rotation and the humeral shaft in adduction. The c-arm of an image intensifier (Siemens, Erlangen, Germany) was inclined in such a way that the x-ray beam was tilted downward by 30° and directed to the center of the glenohumeral joint in order to obtain a true anteroposterior image of the shoulder specimen. This radiographic image was printed for further evaluation with use of a high-quality black-and-white printer. The humerus was then internally and externally rotated until the capsuloligamentous structures were tight, and radiographs were made in these two positions. These images served to assess the influence of humeral head rotation on the acromion index. To study the effect of scapular rotation on the acromion index, two other radiographs were made with the scapula successively rotated by +20° and then by −20° around a vertical axis while the humeral head was kept in neutral rotation. This resulted in slightly oblique anteroposterior radiographs of the glenohumeral joint.

Patient and Control Groups

Two groups of patients and an age and gender-matched control group of asymptomatic individuals were included in this study. The patients were selected from among individuals who had been treated with either a rotator cuff repair or a total shoulder replacement at our institution between 1995 and 2003. The primary inclusion criterion was the availability of a preoperative, true anteroposterior radiograph with the humerus in neutral or internal rotation. Patients with a history of trauma, inflammatory disease, or previous surgery on the acromion on the affected side were excluded. Patients with a collapse of the humeral head due to osteonecrosis and those with moderate-to-severe glenoid erosion (>15° of glenoid retroversion) were also excluded because such deformities directly affect the acromion index.

After these exclusions, the first group of patients consisted of 102 individuals (fifty men and fifty-two women with an average age of 65.0 years [range, forty-five to eighty-nine years]) with a surgically proven full-thickness rotator cuff tear involving at least the supraspinatus tendon and the second group consisted of forty-seven patients (nineteen men and twenty-eight women with an average age of 63.7 years [range, thirty-eight to eighty-eight years]) with primary osteoarthritis in whom the integrity of the rotator cuff was confirmed during total shoulder replacement.

The age and gender-matched control group consisted of seventy asymptomatic volunteers (thirty-two men and thirty-eight women with an average age of 64.4 years [range, fifty-four to seventy-five years]) in whom ultrasonography of the rotator cuff performed by an experienced musculoskeletal radiologist showed no signs of tendon degeneration or a tendon tear. These individuals were recruited for the purpose of this

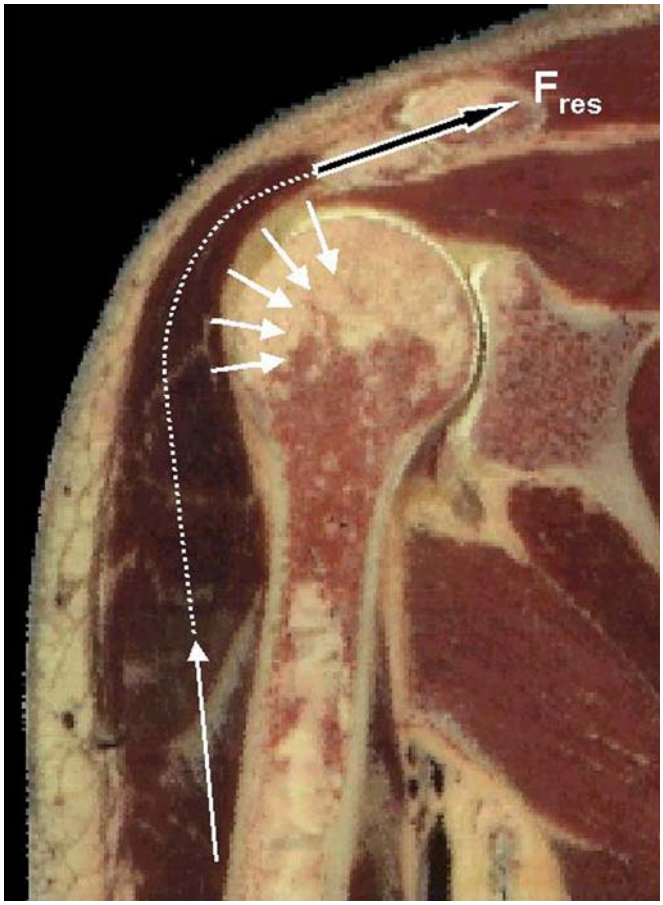

Fig. 4

Contraction of the middle portion of the deltoid muscle (represented by the interrupted line) pulls the arm upward (long arrow) and presses the humeral head against the glenoid cavity (short arrows). The orientation of the resultant deltoid force (F_{res}) depends on the orientation of the muscle fibers at their origin on the acromion.

study from among the employees at our institution or they were patients who had been admitted to our institution for the treatment of a spinal or lower-extremity disorder. Inclusion criteria were a normally functioning shoulder and no history of trauma or previous surgery. True anteroposterior radiographs with the arm in neutral rotation were made under fluoroscopic control. Informed consent was given prior to participation in this study.

The acromion index was determined, as described above, by two independent observers. Statistical analysis was performed with a repeated-measures analysis of variance with a significance level of 0.05.

Results

The preliminary study of the cadaver specimens showed that the acromion index depended on the position of the humeral head and the scapula relative to the x-ray beam. The acromion index increased by an average of 0.03 (maximum, 0.07) as the humeral head was turned from neutral to external rotation while the scapula was kept in the neutral position. However, the acromion index did not change when the humerus was rotated from neutral to internal rotation. Internal and external rotation of the scapula increased and decreased the acromion index by an average of 0.07 (maximum, 0.16) and 0.05 (maximum, 0.17), respectively. Therefore only true anteroposterior radiographs with the glenoid surface perpendicular to the film and the humerus in neutral or internal rotation were included in the main study.

The average acromion index (and standard deviation) was 0.73 ± 0.06 in the patients with a full-thickness rotator cuff tear, 0.60 ± 0.08 in the patients with osteoarthritis, and 0.64 ± 0.06 in the control group (Figs. 2, 3-A, and 3-B). The differences in the index between the patients with a full-thickness rotator cuff tear and the two groups of individuals with an intact rotator cuff were significant ($p < 0.0001$). With the numbers studied, the difference in the index between the patients with osteoarthritis and the control group was not significant, and there was no correlation between the acromion index and age or sex. The interobserver correlation was excellent (coefficient of correlation, 0.87). The mean and maximum differences between the measurements of the two observers were 0.00 ± 0.03 and 0.08, respectively.

Discussion

The pathogenesis of rotator cuff tears is probably multifactorial. In 1931, Codman and Akerson[9] thought that changes in the integrity of the rotator cuff tendons were due to age and constitutional conditions or overuse but trauma produces the tendon rupture in most instances. In 1939, Lindblom[10] found histological evidence of degenerative changes of the tendinous tissue in older persons. He also described decreased vascularization at the tendon insertion, especially at the supraspinatus insertion. In 1949, Armstrong[11] suggested that the supraspinatus syndrome (described as a painful arc) results from compression of the bursa and the tendons of the rotator cuff under the acromion, especially under its anterior part. This theory was later supported by Neer[4], who stated that rotator cuff lesions resulted from compression, or impingement, of the soft tissues that pass in the fixed space between the humeral head and the coracoacromial arch. Since then, several authors have investigated the morphology of the acromion and its relationship to rotator cuff disease[1-3,5-7,12,13]. The lateral extension of the acromion, however, has not been previously investigated, to our knowledge. In the present study, patients with a full-thickness rotator cuff tear had a significantly larger lateral extension of the acromion than did individuals without cuff disease.

The role of acromial morphology in the pathogenesis of rotator cuff disease remains controversial. Many of the above-mentioned authors suggested that a hooked (type-III) acromion, a flatter slope of the acromion, or a decreased lateral acromion angle may reduce the subacromial space and consequently increase the pressure on the rotator cuff tendons, predisposing them to degeneration. Others believe that the shape of the acromion is the result, rather than the cause, of rotator cuff disease[14-16].

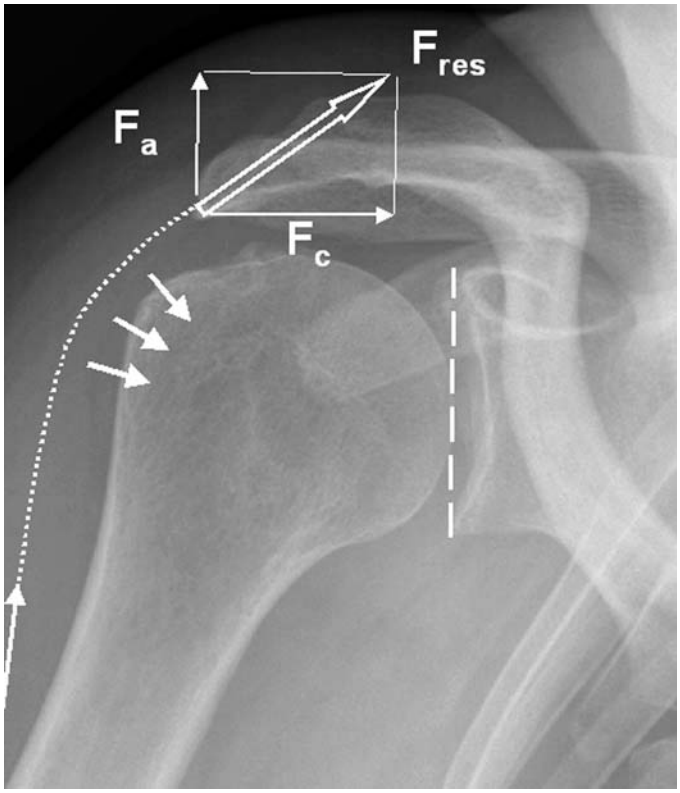

Fig. 5-A

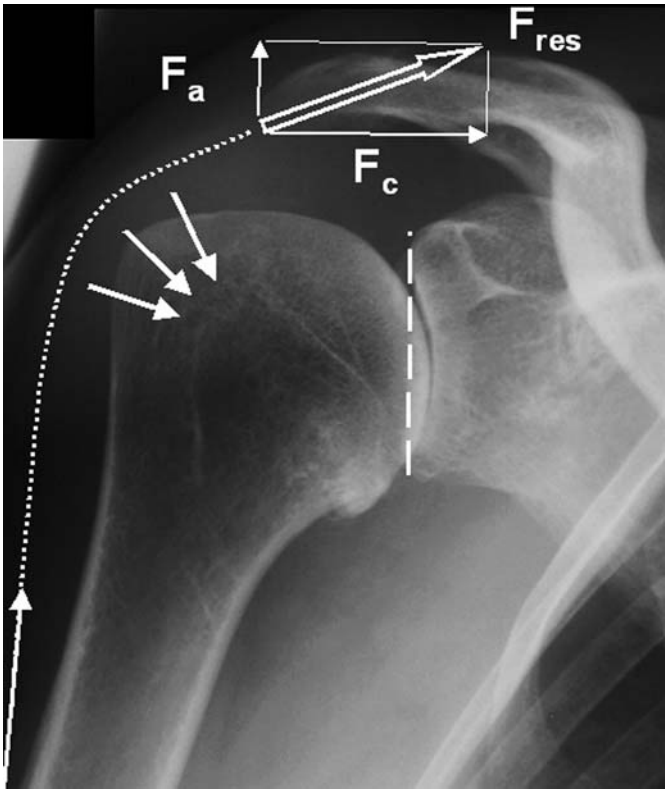

Fig. 5-B

Fig. 5-A Schematic representation of the forces exerted by the middle deltoid on the proximal part of the humerus (see Fig. 4 for an explanation). A large lateral extension of the acromion is associated with a high ascending force component (F_a) (parallel to the glenoid plane) **Fig. 5-B** A small lateral extension of the acromion is associated with a high compressive force component (F_c) (perpendicular to the glenoid plane).

We hypothesized that a large lateral extension of the acromion predisposes the supraspinatus tendon to degeneration. Theoretically, the lateral extension of the acromion influences the orientation of the resultant deltoid muscle force vector: the muscle fibers of the middle deltoid originate from the acromion and wind around the humeral head before inserting on the humeral shaft. Contraction of this muscle during active abduction pulls the humeral shaft upward and presses the humeral head against the glenoid cavity (Fig. 4). The orientation of the resultant force vector depends on the orientation of the deltoid muscle fibers at their origin on the acromion. The larger the lateral extension of the acromion, the higher the ascending force component (Fig. 5-A). The smaller the lateral extension of the acromion, the higher the compressive force component for a given deltoid muscle force (Fig. 5-B). One could speculate that a high ascending force component favors subacromial impingement and degenerative changes of the supraspinatus tendon, whereas a high compressive force component favors degenerative changes of the glenohumeral joint. Joint-space narrowing decreases the distance from the glenoid plane to the most lateral aspect of the proximal part of the humerus and therefore increases the acromion index. It is therefore possible that the mean acromion index of patients susceptible to the development of osteoarthritis is even smaller than the value of 0.60 measured in this study.

We did not differentiate between concentric shoulders and shoulders with a decreased acromiohumeral distance due to a massive rotator cuff tear. Superior migration of the humeral head may be associated with a small lateral displacement of the humeral head as a result of the concavity of the glenoid. A lateral shift increases the distance from the glenoid plane to the lateral aspect of the proximal part of the humerus but does not affect the distance between the glenoid and the lateral border of the acromion. Therefore, one can assume that the acromion index decreases when the acromiohumeral distance decreases. Exclusion of eccentric shoulders from the group with a rotator cuff tear would probably increase the mean acromion index and therefore increase the difference between the groups with the torn and intact rotator cuffs.

The previously described morphologic parameters of the acromion, such as the acromial type, the lateral acromion angle, or the acromial slope, were not assessed in this study. One could, however, imagine that there is a correlation between the lateral acromion angle defined by Banas et al.[2] and the acromion index described in this paper. Both parameters use the glenoid plane as a reference. We concluded that a large lateral extension of the acromion seems to be associated with degenerative rotator cuff tears. Additional studies are necessary to confirm that this aspect of the acromion is a cause rather than a consequence of rotator cuff tears. ■

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