Complex distal humerus trauma
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CHAPTER 6

Loss of Anterior Translation of the Distal Humerus Surface is associated with Decreased Elbow Flexion
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Abstract

Purpose: The normal anterior translation of the articular surface of the distal humerus with respect to the humeral diaphysis facilitates elbow flexion. We hypothesize that there is a correlation between anterior translation of the distal humeral articular surface and flexion after open reduction and internal fixation (ORIF) of a fracture of the distal humerus.

Methods: Two independent observers evaluated 141 lateral radiographs of patients more than 6 months after fracture of the distal humerus and 155 lateral radiographs of patients without injury of the distal humerus. The distance between the most anterior point of the distal humerus articular surface, perpendicular to the humeral shaft, from the anterior border of the distal part of the humeral diaphysis, was measured on lateral radiographs as a percentage of the width of the humeral shaft.

Results: The technique of measuring anterior translation of the distal humeral articular surface had good intra- and interobserver reliability. The most anterior point of the distal humeral articular surface lies an average of 11.7 mm (range, 6.8 to 17.0 mm) in front of the most anterior border of the humeral shaft in normal distal humeri, which represents 62% of the humeral shaft diameter (range, 33% to 91%). There was a limited but significant correlation between flexion and anterior translation as a percentage of the humeral shaft diameter in distal humeri after fracture that was maintained in multivariable statistical models.

Conclusions: Using a reproducible technique for measuring anterior translation of the distal humerus, there was a correlation between anterior translation of the distal humeral articular surface and elbow flexion after ORIF. Although the weakness of the correlation emphasizes that limitation of elbow flexion after ORIF of a distal humerus fracture is multifactorial, reduced anterior translation of the distal humeral articular surface might be a contributing factor.

Type of study/level of evidence: Prognostic IV.

Key words: Distal humerus; elbow motion; open reduction internal fixation
Background
Anterior translation of the trochlea with respect to the humeral shaft provides clearance for the coronoid process and space for the anterior arm and forearm musculature as the elbow flexes. This, combined with the coronoid and radial fossae to accommodate the coronoid process and the radial head, respectively, allows maximal flexion. This anterior translation evolved during the transition from quadruped to biped as the need for stability was supplanted by the need for flexion. A straight distal humerus offers more stability in extension, whereas an anteriorly translated distal humerus offers more stability in flexion.

The anterior translation of the trochlea with respect to the humeral diaphysis has been described quantitatively by various authors, most often as an angle between 30° and 45°, as well as the observation that the axis of rotation of the trochlea is in line with the anterior cortex of the humeral diaphysis on a lateral radiograph. Measurements of anterior translation and angulation in the literature are estimates. In the treatment of patients with stiff elbows after fracture of the distal humerus, we have found that loss of anterior translation of the trochlea with respect to the humeral shaft seems to limit the amount of flexion that can be restored after capsulectomy, even when the coronoid fossa has been deepened and the tip of the coronoid has been excised (fig. 1). We therefore hypothesized that loss of anterior translation of the distal humerus would correlate with elbow flexion after open reduction and internal fixation (ORIF) of the distal humerus.

FIGURE 1. A Lateral radiograph of a healed fracture of the right distal humerus and substantial loss of anterior translation of the distal humerus articular surface in a 75-year-old man. His final flexion 35 months after surgery was 105°, with an arc of flexion and extension of 80°. His humeral shaft width is 2.1 cm, and anterior translation is 0.1 cm. B Lateral radiograph of a healed fracture of the distal humerus in a 62-year-old woman. Her final flexion after 14 months was 120°, with an arc of flexion and extension of 90°. Her humeral shaft width is 1.7 cm, and the most anterior part of the distal humeral articular surface lies 1.1 cm in front of the anterior humeral line.
Materials and Methods
From 7 prior investigations, we derived a convenience sample of skeletally mature patients who had fractured their distal humerus and were treated with open reduction and internal plate and screw fixation. Institutional review board permission was obtained. We used lateral radiographs obtained on the day of the research-specific physical examination, when the patients were called back for an x-ray, including measurement of active flexion using a goniometer, a minimum of 6 months after final surgery. Patients with heterotopic ossification or oblique radiographs were excluded, leaving us with 141 subjects. On a lateral radiograph, the centers of 3 concentric circles are formed by the projection of the edges of the condyles, the ulnar groove at the back of the medial epicondyle, and the medial lip of the trochlea. Obliquity was defined according to agreement between 2 observers as a sidewise anterior-posterior translation of the spheres, where the overlap no longer resembled a circle. Superior or inferior malalignment did not influence anterior translation.

Articular stepoff was measured on the anteroposterior radiographs. We also documented the number of subsequent surgeries, the number of plates used for internal fixation, and the approach used for ORIF.

Arthritis was rated according to the classification of Broberg and Morrey, as follows: grade 0 (a normal joint), grade 1 (slight joint-space narrowing with minimum osteophyte formation), grade 2 (moderate joint-space narrowing with moderate osteophyte formation), or grade 3 (severe degenerative change with gross destruction of the joint).

Patients with fracture of the distal humerus
The average age of the 141 patients (69 men and 72 women) who had ORIF of a fracture of the distal humerus was 50 years (range, 18 to 98 years). The average interval between surgery and evaluation was 70 months (range, 6 months to 30 years). Sixty-nine patients had a single surgery, the index surgery for ORIF; 44 patients had 1 additional surgery; 23 patients had more than 1 additional surgery; and the number of additional surgeries was not documented in 5 patients. Forty-one patients showed signs of arthritis. Twenty-nine patients had grade 1 arthritis, 8 patients had grade 2 arthritis, and 4 patients had grade 3 arthritis. In 46 patients, only screws or wires were used for fixation; in 40 patients, 1 plate was used; in 45 patients, 2 plates were used; in 9 patients, 3 plates were used; and in 1 patient, 4 plates were used. The average maximum articular step or gap on the immediate postoperative radiographs was 0.54 mm (range, 0 to 9 mm). A medial approach was used in 6 patients; a lateral approach in 34 patients; and a posterior approach in 98 patients. The approach involved splitting the triceps in 3 patients, elevating or working around either side of it in 27 patients, and mobilizing it with an olecranon osteotomy in 68 patients. In 3 patients, the approach was not documented.

Patients without fracture of the distal humerus
As a measure of the normal anterior translation of the trochlea with respect to the shaft of the humerus, we also measured 155 lateral radiographs from patients
without trauma of the distal humerus. The average age was 45 years (range, 18 to 85 years). There were 40 men and 37 women. The fracture group and the normal group were comparable in terms of age and gender (Student's t-test \( p = .09 \), and chi-square test \( p = .50 \)). These 155 patients represented a random sample from a list of consecutive patients with radiographs taken to evaluate fracture of the radial head or lateral elbow pain over a 2-year period. Oblique radiographs were excluded.

**Measurements**

We measured anterior translation, rather than anterior angulation, because this method proved more reproducible than measuring angulation in a pilot study of 50 radiographs. There are no specific landmarks on the distal humerus to guide measurement of angulation. The measurements were performed using software (IMPAX ES DS3000; Agfa-Gevaerts N.V., Mortsel, Belgium).

Anterior translation was measured as the distance from the most anterior point of the distal humerus articular surface on a lateral radiograph, perpendicular to the anterior humeral line. The anterior humeral line is a line drawn along the distal anterior cortex of the distal part of the humeral diaphysis on a true lateral elbow radiograph. The humeral shaft width was measured (in millimeters) where the anterior humeral line cuts through the epiphysis (fig. 2). The measurements of anterior translation were expressed as a percentage of the humeral shaft width in order to scale them to overall bone size.

**Statistical analysis**

In order to evaluate the reliability of the measurement techniques, 2 observers performed all measurements, and the inter-observer reliability was calculated. To evaluate intra-observer reliability, each measurer repeated the measurement at least 1 week after the first measurement. The Pearson product-moment correlation coefficient \( r \) was used to measure the level of intra- and interobserver reliability.

The relationship between anterior translation of the articular surface of the distal humerus and elbow flexion was studied using a Pearson product-moment correlation coefficient \( r \), as well. Anterior translation as a percentage of the humeral shaft width was used to correct for variation in general elbow size between subjects. The \( r \) values are assigned to subdivisions as follows: slight agreement or correlation, 0.00–0.20; fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80; and almost perfect agreement or a strong correlation, \( \geq 0.81 \) \(^{11}\). Two-tailed values of \( p < .05 \) were regarded as statistically significant.

The relationship between arthritis and range of motion was evaluated using the Spearman correlation \( \rho \). The \( r \) values are assigned to subdivisions in the same order as above. The relationship between surgical approach and range of motion was evaluated using a 1-way analysis of variance. Two-tailed values of \( p < .05 \) were regarded as statistically significant.

Multiple linear regression analysis was used to analyze the ability of the explanatory variables (anterior translation, age, number of subsequent surgeries, number of plates, arthritis, time between day of surgery and follow-up, articular
stepoff, and surgical approach) to account for variation in the response variable (range of motion), in order to address any confounding between the explanatory variables. Instead of entering all the potential explanatory variables into the backward stepwise models, we chose to enter only those variables that were either significant (p < .05) or nearly significant (p < .1) in the univariate analysis.

FIGURE 2. A lateral radiograph of a healthy elbow demonstrates the reference points for the measurements. Line ‘a’ represents the anterior humeral line, line ‘b’ measures the humeral shaft width, and line ‘c’ represents the anterior translation of the distal humeral articular surface.

Results
Reliability of measurements
Intra-observer reliability was almost perfect for the 2 observers. The respective product–moment correlation coefficients were \( r = .810 \) and \( r = .965 \) for width of the humeral shaft and \( r = .859 \) and \( r = .956 \) for the anterior translation (p < .001). With respect to interobserver reliability, the average correlation between observer 1 and 2 was good for humeral width (\( r = .832 \)) and substantial for anterior translation (\( r = .777 \)) (p < .001).
Measurements and statistical analysis
The average humeral width in the control group was 19.2 mm (range, 14.6 to 26.1 mm). The average anterior translation in this group was 11.7 mm (range, 6.8 to 17.0 mm, SD, 4.95). This converts to an average translation as a percentage of the humeral shaft width of 62% (range, 33% to 91%, SD 11%).

The average humeral width in the fracture group was 20.1 mm (range, 15.1 to 29.0 mm). The average anterior translation in this group was 12.8 mm (range, 10 to 29.5, SD, 2.26). This converts to translation as a percentage of the humeral shaft width of 64% (range, 0% to 142%, SD 23%).

The small difference in anterior translation as a percentage of shaft width between the fractured and the nonfractured humeri was not significant (p = .292). The average active elbow flexion among fracture patients was 125° (range, 70° to 150°). There was fair correlation (r = .232 with p < .005) between flexion and anterior translation as a percentage of the humeral shaft width in the fracture group. Analyzed as a dichotomous variable, patients with less than 33% or less than 50% anterior translation had significantly less flexion than did patients with greater anterior translation (both p < .01).

Pearson correlation showed a slight correlation between age and flexion (r = −.168 with p < .05) in the fracture group. There also was a fair correlation between the number of subsequent surgeries and flexion (r = −.247 with p < .05), as well as a slight correlation between the number of plates used and the flexion-extension arc (r = −.176 with p < .05). We did not find significant correlations between range of motion and articular stepoff.

Spearman correlation showed a fair correlation between the amount of arthritis (according to the classification of Broberg and Morrey) and flexion and extension (ρ = −.304 with p < .05 and ρ = −.338 with p < .05, respectively). One-way analysis of variance showed no association between surgical approach and range of motion (all p > .05).

In bivariate analysis, there was a significant or near-significant association between flexion and anterior translation, age, number of subsequent surgeries, arthritis, and time between day of surgery and follow-up. The best logistic regression model included all explanatory variables and accounted for 21% of the variation in flexion (p < .001).

Discussion
Although slight obliquities in the lateral elbow radiographic projections and the relatively qualitative nature of the landmarks used to exclude oblique radiographs and select measurement points are likely to introduce both imprecision and observer variability, our measurement technique proved adequately reliable with 2 different observers. We can be sure that these are not “pure lateral” radiographs, as perfection is rare in radiography. The question of “How good is good enough?” is certainly open to debate.
Although the deformity after fracture is a combination of loss of translation and loss of angulation of the distal articular part of the humerus, we measured anterior translation rather than anterior angulation because this measurement was more reproducible. It is unclear how much of the variability in measurements of anterior translation (SD 11% and 23%) is due to the techniques of measurement and how much is due to anatomical variation. Despite these concerns, our finding that the anterior limit of the distal humeral articular surface extends an average of nearly two thirds of a shaft width anterior to the anterior humeral line appears accurate and will hopefully prove reproducible and useful.

The absence of a significant difference in anterior translation between fracture and non-fracture groups is likely a reflection of changes in anterior translation associated with ORIF. Both increased and decreased anterior translations were observed in the ORIF group (range, 0–142% translation, compared to 33–91% in the non-fracture group). The result is a substantial difference in the standard deviations but no difference in the means of these cohorts.

The correlation between anterior translation and elbow flexion was limited (fair) but significant. Several other factors, including age, number of subsequent surgeries, arthritis, and time between day of surgery and follow-up were maintained in the best fit multivariable model, suggesting that all are important independent factors determining final elbow flexion. The retrospective, convenience nature of our sample of patients, the variability in surgeries subsequent to the index surgery, and the inclusion of large numbers of patients with increased translation might have diluted the effect of loss of anterior translation on elbow flexion. In addition, there is likely a substantial variation in capsular stiffness that has a stronger influence on elbow flexion than do changes in bony alignment.

On the basis of these data, patients and surgeons seeking increased elbow flexion after ORIF of a fracture of the distal humerus can be aware that the ability to regain flexion might be restricted when the anterior translation of the distal humeral articular surface is lost due to residual deformity. Loss of anterior translation is common, particularly for complex articular fractures and fractures with substantial metaphyseal comminution. Even a well-performed capsulectomy might not restore flexion if this anterior translation has been lost.
References