Validation of the lesser sigmoid notch of the ulna as a reference point for accurate placement of a prosthesis for the head of the radius

A CADAVER STUDY

We undertook a study on eight arms from fresh cadavers to define the clinical usefulness of the lesser sigmoid notch as a landmark when reconstructing the length of the neck of the radius in replacement of the head with a prosthesis. The head was resected and its height measured, along with several control measurements. This was compared with in situ measurements from the stump of the neck to the proximal edge of the lesser sigmoid notch of the ulna. All the measurements were performed three times by three observers acting independently.

The results were highly reproducible with intra- and interclass correlations of > 0.99. The mean difference between the measurement on the excised head and the distance from the stump of the neck and the lesser sigmoid notch was -0.02 mm (-1.24 to +0.97). This difference was not statistically significant (p = 0.78).

The proximal edge of the lesser sigmoid notch provides a reliable landmark for positioning a replacement of the radial head and may have clinical application.

Comminuted fractures of the head of the radius should be reconstructed. However, consideration must be given to the type of fracture, the size of the fragments involved and the presence of associated ligamentous or bony lesions. Another option is to replace the head with a prosthesis which has given promising results when used for fractures which were too comminuted to reconstruct. A problem which can occur with such replacement is the inability to restore accurately the anatomical length of the head and neck because of the lack of appropriate instrumentation and anatomical landmarks. Biomechanical studies have shown that the length of the neck of the radius is an important influence on the kinematics of the elbow and on radiocapitellar intra-articular pressure. Failure to restore the length of the resected bone of the radiocapitellar joint may lead to axial and valgus instability at the elbow. In contrast, overlengthening with a replacement may result in excessive pressure on the articular cartilage of the capitellum, producing early degenerative changes. No intra-operative bony landmarks have been described as being useful for determining the appropriate height of the prosthesis. The head itself may not provide a suitable reference if it has been severely comminuted or previously resected. Our aim therefore was to determine if the centre of the proximal edge of the lesser sigmoid notch on the ulna could be used as a reliable and reproducible bony landmark to ensure accurate restoration of the length of the neck of the radius.

Materials and Methods

We used non-paired arms disarticulated at the scapulothoracic joint from eight cadavers, frozen until required. The limbs came from four men and four women with a mean age of 77 years (60 to 90).

Before testing, the specimens were thawed overnight. The arms were positioned with the dorsum of the hand facing upwards and the forearm placed in neutral rotation with the elbow flexed at 90°.

A lateral approach to the elbow was used to gain access to the radiohumeral joint. An anterolateral incision was then made in the capsule with division of the annular ligament. The ulna was secured to the humerus with the elbow at 90° of flexion by a metal pin 4 mm in diameter traversing the olecranon and trochlea. A Hoffman-type external fixator (Stryker, Geneva, Switzerland) was used to sta-
to-distal direction. A pin was then drilled into the radius parallel to the distal ulnar pin, and perpendicular to a line formed between the distal ulnar and radial pins. All pins were measured at a standardised distance from the top of the pins and the relative positions recorded, before resection of the head of the radius. The linking bar of the external fixator was removed after resection and the distances between the pins were measured using a hand-held electronic digital calliper (Mitoyo, Kagawa, Japan) accurate to 0.05 mm. Since resection of the head did not alter the orientation or relative position of the external fixation pins and there was no proximal translation of the radius in these unloaded conditions when the external fixator was removed in the pilot study, we kept the external fixator secured in situ during the remainder of the study.

A Kirschner (K)-wire 1.25 mm in diameter was drilled into the proximal ulna and another into the proximal radius. The latter was bent through a right angle to act as a marker where it crossed the corresponding ulnar wire. The distance between the top of the ulnar wire and the crossing radial wire was measured using the electronic calliper and recorded and annotated as convergence 1. This measurement was repeated after resection of the head and annotated as convergence 2 to identify any convergence of the radius and ulna caused by this resection (Fig. 1). All the measurements throughout the experiment were performed independently by three observers (RPvR, FvG, WdW) who repeated them three times.

Additional measurements were undertaken to validate the method, particularly to quantify the proximal migration of the radius relative to the humerus and ulna after resection of the head. Radiohumeral translation was measured by drilling a hole in the proximal radius with a 0.75 mm K-wire distal to the anticipated resection of the head. A second hole was drilled in the lateral epicondyle. The distance between these two holes was measured before and after resection of the head and annotated radiohumeral 1 and radiohumeral 2, respectively (Fig. 2). The difference was defined as the radiohumeral translation.

The ulnar side of the head and the lesser sigmoid notch of the ulna were marked at the proximal radioulnar joint, with the forearm in neutral forearm rotation, by drilling a 0.75 mm K-wire from the lateral side through it in a medial direction and into the lesser sigmoid notch. The radioulnar translation which followed subsequent resection of the head was calculated from the change in the distance between the K-wire which was retained in the ulna at the lesser sigmoid notch and the edge of the resection on the stump of the neck after the radius (radioulnar 1) and the corresponding measurement on the radial head, from the drill hole in the radial head to the edge of the resection (radioulnar 2). Calculations were normalised to account for the width of the sawblade.

In each case the head and neck of the radius were excised by division of the neck perpendicular to the long axis of the radius at a random position distal to the head using a
The length of the resected head was measured from the edge of the resection to the ulnar side of the x-axis on the head (Fig. 3). This was compared with the distance between the stump of the neck and the centre of the proximal edge of the lesser sigmoid notch. A correction was added to allow for the thickness of the saw blade, and the estimated length of the neck of the resected head was calculated.

All the radioulnar measurements were performed first, before the actual height of the resected head was determined. The independence of the three observers was ensured by concealing the window of the electronic calliper from each other. Care was taken not to bias the observers’ measurements by alternating observers between repetitions and measurements.

Statistical analysis. The results of all three observers were used in the analysis and the reliability between observers was determined by calculating the interclass correlation coefficient. Repeated-measures analysis of variance (ANOVA) was applied to the results of each experiment and the F-ratio determined. The level of significance was set at \( p \leq 0.05 \) for all statistical analysis.

Means and ranges were calculated for repeated measures per observer and per specimen for all measurements taken. The data were further analyzed to show the differences between corresponding measurements. After normalizing the measurements of the head for the thickness of the oscillating saw blade (0.75 mm), paired two-tailed Student's t-tests were done to compare all paired measurements. Finally, the correlation coefficient between the height of the resected head and the estimated length of the neck measured from the stump of the neck to the proximal edge of the lesser sigmoid notch was calculated.

Results

All the measurements were highly reproducible and reliable, with inter- and intraclass correlation coefficients of \( > 0.99 \) for all. The F-ratio in the repeated-measures ANOVA showed no significant differences in any of the measurements for all three observers and repetitions (\( p > 0.9 \)).

The absolute mean results of the measurements are shown in Table I. The mean difference between the measured height of the resected head after correction for the width of the saw blade, and the estimated length of the head measured as the distance between the stump of the neck and the proximal edge of the lesser sigmoid notch was -0.02 mm (-1.24 to +0.97). The paired, two-tailed t-test did not show any significant difference between these measurements (\( p = 0.78 \)) and a very strong correlation was found between them (\( r^2 = 0.98 \)).

Similar agreement was found between the other pre- and post-resection measurements. Some convergence of the radius did occur (\( p < 0.05 \)) but this did not result in significant radiohumeral (\( p = 0.71 \)) or radioulnar longitudinal translation (\( p = 0.38 \)).

Discussion

Biomechanical and clinical studies have shown the importance of accurate restoration of the length of the neck of the radius. Unihumer radiokinematics and radiocapitellar forces have been shown to be disturbed if the length of the neck is not reproduced within 2.5 mm of the native length. The diameter of prostheses for the head as well as the orientation of the head have also been shown to play a role in radiohumeral contact and load transmission. Erosion of the capitellum, a decreased range of movement, and pain in the elbow may result from a mismatch between the anatomical size of the head and that of the selected prosthetic replacement, necessitating removal of the prosthesis in some cases.

There are currently no dedicated instruments available in clinical practice to determine the length of the prosthesis required in replacement of the radial head, so a trial prosthesis is inserted to assess the necessary diameter of the stem and the height of the prosthesis. All parameters may be reconstructed if a modular design of prosthesis is used. The proximal border of the trial prosthesis should be flush with the proximal edge of the lesser sigmoid notch when...
the forearm is placed in neutral rotation. If it lies more prominently it is possible to adjust the length, by resecting more neck.

Depending on the design of the prosthesis it may also be possible to lengthen the neck by cementing the definitive implant slightly proud. In some designs it may also be possible to extend the prosthesis or use a larger size.

In a recent study the coronoid process was suggested as a radiological reference for positioning a replacement of the head of the radius. The authors concluded that the prosthetic radial head should be approximately level with the lateral edge of the lesser sigmoid notch. We accept that our model had no associated damage to the interosseous membrane or the ligaments at the elbow. In our experimental model the dimensions of the radial head were accountable. Several other anatomical studies have recently been published on the dimensions of the proximal radius but none has commented on the anatomical landmarks to be used when reconstructing the head.

In our experimental model the dimensions of the radial head were available for measurement. This is not always the case in a trauma setting. Using the lesser sigmoid notch as a reference, we found no significant difference and a strong correlation between the estimated length of the head and neck, and the actual dimensions of the resected radial head.

We accept that our model had no associated damage to the interosseous membrane or the ligaments at the elbow. We conclude that in isolated comminuted fractures of the head of the radius warranting its replacement, the proximal edge of the lesser sigmoid notch can be used confidently as a landmark to reconstruct the height of the radius.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Table I. Mean (range) results of the measurements in mm for each specimen

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† LSN, lesser sigmoid notch

References