Validation of Minimally Invasive Articular Cartilage Sparing Technique For Olecranon Osteotomy

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Short title: Olecranon osteotomy technique validation

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Abstract

Background: The authors present a cadaveric validation of a minimally invasive articular cartilage preserving olecranon osteotomy technique for use in the operative management of distal humeral fractures.

Methods: Twenty-four elbows in six male and six female formaldehyde embalmed cadavers were dissected. With the cadaver placed in a lateral decubitus position, a posterior sub-periosteal dissection was performed to the medial and lateral aspects of the olecranon at the level of the joint and Mini Hohmann retractors were inserted into each side of the ulnohumeral joint. The medial (M) and the lateral (L) points where the retractors touch the articular surface were marked with a fine marker pen (Crown point) and a line drawn between the two points. The midpoint formed the apex of the chevron osteotomy. An osteotomy was performed and analysis of the osteotomy relative to the ulnar bare area (UBA) was undertaken.

Results: The distal boundary of the UBA can be reliably found at a distance of 4.8±0.4 mm (females) and 5.4±0.8 mm (males) distal to the Crown point using this technique.

Conclusion: Identifying the Crown of the olecranon articular surface is a reliable and accurate technique which identifies the ulnar bare area reproducibly for the safe performance of a cartilage sparing, and minimally invasive, olecranon osteotomy for the surgical management of distal humeral fractures.

Keywords: Olecranon Osteotomy, intra-articular distal humerus fractures, articular cartilage preservation, ORIF distal humerus.

Introduction

In 1952, Cassebaum first described a technique to perform an olecranon osteotomy [1]. Open reduction and internal fixation (ORIF) of complex intra-articular distal humeral fractures is a technically demanding operation [2,3]. A prerequisite for the accurate restoration of the distal humeral articular surface is reconstruction of the medial and lateral columns with adequate visualisation of the articular surface [2,3]. Despite the number of surgical approaches described for addressing distal humeral fractures (paratricipital, triceps splitting, triceps sparing and triceps reflecting), [4,5,6,7] the trans-olecranon osteotomy approach provides the widest exposure to both columns and to the articular surface of the distal humerus [3,4].

In order to minimize damage to the cartilage-covered articular surface, the olecranon osteotomy should exit within the "ulnar bare area" (UBA). However, the anatomic location of the UBA is subject to variation based upon patient size and gender. Previous anatomic studies have attempted to describe it's location, including a range of 25-30mm from the ulnar tip [8], 22mm distal to the triceps insertion [9], or a mean angle of 20^{o} to the coronal plane [9], but obviously these measurements can be difficult to accurately recreate intra-operatively and without extensive soft tissue dissection. This risks disruption of the local blood supply and, therefore, increases the risk of non-union following fixation [2,3].

This study validates a technique of olecranon osteotomy for surgical management of distal humeral fractures, that aims to preserve articular cartilage by performing the osteotomy such that it reliably exits through the olecranon bare area.

Method

Specimens:

Twenty-four elbows in 12 formaldehyde embalmed cadavers were utilized, any that had bony deformities affecting elbow joint morphology were excluded from selection. Six female and six male cadavers (average age 81.2 and 87.3 years respectively) were dissected: all elbow joints were intact.

Surgical technique:

With the patient placed in a lateral decubitus position, a posterior approach to the elbow is performed. The elbow is maintained in 90º of flexion, with the ulna perpendicular to the floor. A midline longitudinal incision across the elbow is created, with a curve towards the lateral side, avoiding the ulnar nerve medially. Sub-periosteal dissection is performed to the medial and lateral aspects of the olecranon at the level of the joint. No further dissection is carried out once a small opening on both sides of the joint capsule is achieved. Mini Hohmann retractors are inserted into each side of the ulnohumeral joint, then are separated (Figure 1a).

The UBA divides the trochlea notch into two articular segments, and is known to lie at the highest point of the arc formed by the olecranon articular surface [9]. However, because the highest point could be considered a reference point relative to the floor, and the positioning of the elbow would affect this reference, we propose this point is referred to as the 'Crown', as in architecture where the highest point (keystone) of an arch is called the 'Crown' (Appendix 1).

With the application of pressure on the Hohmann retractors (Figure 1a), the tips of the retractors lie at the Crown of the olecranon articular surface, regardless of the position of the ulna relative to the floor. The midpoint (Point A - Figure 1b) forms the apex of the chevron osteotomy and is marked before being drilled with a suitable small diameter drill or K-wire. A distance of 3mm to 4mm is measured distal to this line, in the midline of the ulna and marked with a transverse line. This defines the base of the osteotomy. The chevron is then formed in the standard fashion with a sagittal saw forming a triangle with the previously marked distal transverse line as its base, and drill hole as its apex (Figure 2a). A chevron osteotomy, as described by AO, is preferred over a transverse osteotomy as this improves the surface area of the osteotomy and, therefore, promotes union [9]. This 'apex proximal' chevron osteotomy maximises the preserved attachment of the triceps aponeurosis and therefore blood supply to the mobilised bone fragments to aid healing. Using this method, the osteotomy would lie within the limits of the UBA (Figure 2b). The osteotomy is recommended to be completed with an osteotome to preserve articular cartilage length, as is commonly accepted practice, to minimise iatrogenic damage.

The chevron osteotomy is most frequently described as an "apex-proximal osteotomy", however it is our senior author's normal practice to perform an "apex-distal chevron osteotomy". This technique, described by the AO foundation [10] as the "reverse chevron osteotomy", is intended to preserve more bone and soft tissue attachment to the proximal osteotomised fragment, with the intended benefit of maximising healing potential. In addition, it has the further advantage of improving visualization of the anterior distal humerus. It should be highlighted, however, that this minimal-access technique for finding the UBA can be used with either a proximally or distally based chevron osteotomy, at the discretion of the surgeon.

Analysis

Our surgical technique was the result of an anatomical study, used to assess the accuracy of a minimal access surgical technique in identifying the UBA. It allowed precise positioning of the osteotomy, whilst avoiding unnecessary damage to the adjacent articular cartilage and soft tissues.

The elbows were ~~then~~ prepared via a posterior approach to the elbow as previously described. After placement of the Hohmann retractors, the medial (M) and the lateral (L) points where the retractors touch the articular surface were marked with a fine marker pen (0.5mm tip).

The retractors were then removed, the capsule excised and the elbow disarticulated. The soft tissues were subperiosteally dissected, in order to expose clear osseous margins at the proximal ulnar metaphysis. A full dissection of the ulnar border of the ulna was also carried out to expose the length of the ulna up to the styloid process. The medial and lateral points where the Hohmann retractors touched the olecranon, were connected with a straight line along the articular surface. The point where this line crosses the midline of the olecranon articular surface is the Crown (C) and the corresponding point on the dorsal surface is the apex of the chevron (A), in an apex-proximal osteotomy. The line P demarcates the proximal extent of the UBA and D, the distal extent. These borders, between cartilage-covered and cartilage-devoid surfaces, are clearly visible under direct vision. The tip of the olecranon process (F) and the tip of the proximal ulna (T) were investigated as important anatomical landmarks (Figure 1b and Table 1).

All dissections and measurements were performed by a single investigator at the Anatomy Laboratory at Keele University Medical School, Staffordshire, according to local ethical regulations. For error analysis, a second, blinded investigator, independently marked and measured the same cadaveric elbows following removal of primary investigators marks.

Statistical analysis:

All raw data were categorised with Microsoft Excel® software and were further statistically analysed with SPSS® software. The significance level for all statistical analysis was 95% ($p<0.05$) (Table 2). Measurement errors were determined by a number of participants repeating each measurement for one cadaveric sample a number of times. In this manner, we were able to determine inter and intra-operator errors. A sample of these errors is given in Table 3, it gives clinical context to the measurements in Table 2. For example, the error of measurement for PC is so large it makes it infeasible in practice. Whereas, for those remaining the errors of measurement are acceptable and within the bounds of clinical error, this makes them clinically useful.

Statistical analysis was carried out on all collected data. Anatomical points only identifiable following wide dissection of the elbow joint, or release of the triceps insertion, are excluded from this paper to avoid over complication, given they are not of surgical relevance. The full list of all points studied for the paper are detailed in Table 1 which demonstrates all landmark and distance abbreviations measured.

Shapiro-Wilk testing demonstrated statistical difference between male and female anatomical landmarks, and therefore gender grouping was maintained throughout evaluation of the results (Table 2).

From the statistical analysis of the data collected, the distal boundary of the UBA can be reliably found at a distance of CD=4.8±0.4 mm (for females) and CD=5.4±0.8 mm (for males) distal to the Crown point. This is illustrated graphically in Figure 3 which plots the measured distances from the Crown (C) to the distal boundary of the UBA (D) for the male and female cadaveric subjects. The error bars signify the error of measurement as would be seen in clinical use (±0.5mm). Also shown are the averages for male and female CD values (5.4mm and 4.8mm respectively). The lower limits where 90% of the sample populations reside are shown for both males and females (3.8mm and 3.5mm respectively): for the sample as a whole this would be 3.6mm.

Discussion

An olecranon osteotomy for the management of distal humeral fractures [1] should exit within the ulnar bare area (UBA), to avoid unnecessary articular cartilage damage. The UBA lies between 25mm and 30mm from the proximal ulnar tip but the position is variable based on factors including gender and size of the proximal ulna. Published literature on identifying the

UBA is relatively sparse. Wang AA et al. [8] has described the dimensions of the UBA and proposed a relationship between the length of the ulna, from the tip of the proximal ulnar metaphysis to the ulnar styloid. Ao et al [9] have described an 'oblique' osteotomy based on their cadaveric study, also aiming to contain the osteotomy within the UBA. In this paper, the bare area was found to remain relatively consistent between specimens, and they proposed an osteotomy apex with a mean distance of 22mm from the triceps insertion, with a mean angle of 20^o to the vertical plane. However, such measurements are difficult to reproduce in the clinical setting, and we believe this is the first paper to describe a surgical technique for accurate placement of the olecranon osteotomy within the UBA.

Identification of the UBA is achieved either by estimation of its distance from the proximal ulnar tip at operation, or by direct visualisation. Although prospective measurement of CT scans and calibrated radiographs of the bony anatomy can assist in the intra-operative identification of the bare area, the overlying triceps tendon and aponeurosis can make accurate intra-operative measurement difficult.

This study has confirmed that a minimally invasive technique, using readily available mini-Hohmann retractors, to identify the bare area of the olecranon is accurate and potentially more clinically applicable than the other methods described above. It reliably identifies the UBA whilst avoiding extensive stripping of the triceps insertion (for exposure of the proximal ulnar tip) or wide dissection of elbow joint, allowing quicker surgical access with less soft tissue injury from dissection.

This technique is reproducible and although the retractors can slightly overlap when inserted, the line between the medial and lateral points accurately identifies the Crown of the olecranon articular surface.

To our knowledge the published literature provides limited surgical relevance. The study by Wang AA et al. [8] has shown similar dimensions of the ulnar bare area, but this is the first study to identify a reliable and reproducible surgical landmark, the Crown, which aids the completion of an olecranon osteotomy that preserves articular cartilage. Their use of the length of the ulna between the tip of the proximal ulnar metaphysis and the ulnar styloid were not borne out in our study as it was evident that this distance did not show normal distribution in our sample and therefore would be unreliable for comparison.

Limitations

The cadavers were not of young age; it is not known whether the size of the ulnar bare area alters with age and this requires investigation. Additionally, the fact that few of the initial landmarks did not present normal distribution may be due to the sample size.

Conclusions

This new method of identifying the Crown of the olecranon articular surface is reliable and accurate and helps identify the ulnar bare area reproducibly for the safe performance of a cartilage sparing olecranon osteotomy.

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Declarations of interest: None

References:

[1] Cassebaum WH. Operative treatment of T & Y fractures of the lower end of the humerus. *Am J Surg. 1952*;83:265–270.

[2] Wong AS, Baratz ME. Elbow fractures: distal humerus. *J Hand Surg Am. 2009 Ja*n;34(1):176-90.

[3] Galano GJ, Ahmad CS, Levine WN. Current treatment strategies for bicolumnar distal humerus fractures. *J Am Acad Orthop Surg. 2010 Jan*;18(1):20-30.

[4]Mühldorfer-Fodor M, Bekler H, Wolfe VM, McKean J, Rosenwasser MP. Paratricipital-triceps splitting "two-window" approach for distal humerus fractures. *Tech Hand Up Extrem Surg. 2011 Sep;*15(3):156-61.

[5] Wilkinson JM, Stanley D. Posterior surgical approaches to the elbow: a comparative anatomic study. *J Shoulder Elbow Surg. 2001;*1:380 –382.

[6] Bryan RS, Morrey BF. Extensive posterior exposure of the elbow: a triceps-sparing approach. *Clin Orthop Relat Res. 1982;*166:188 –192.

[7] Alonso-Llames M. Bilaterotricipital approach to the elbow: Its application in the osteosynthesis of supracondylar fractures of the humerus in children. *Acta Orthop Scand. 1972;*43:479-490.

[8] Wang AA, Mara M, Hutchinson DT. The proximal ulna: An anatomic study with relevance to olecranon osteotomy and fracture fixation. *J Shoulder Elbow Surg. 2003 May-Jun;*12(3):293-6

[9] Ao R, Zhang X, Li D, Chen F, Zhou J, Yu B. The Bare Area of the Proximal Ulna: An Anatomic Study With Relevance to Chevron Osteotomy. *J Hand Surg Am. 2017 Jun;*42(6):471.e1-471.e6. doi: 10.1016/j.jhsa.2017.02.012. Epub 2017 Mar 30.

[10] AO Foundation. *Transolecranon approach. Alternative: Chevron osteotomy with the apex proximal (reversed chevron). Available at*: https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/distal-humerus/approach/transolecranon-approach#preparation-for-osteotomy. *Accessed 24 Oct,* 2020.

Instrument references

Digital Vernier Caliper. Quality Faithful Tools, Long reach, Galleon Boulevard, Crossways Business Park, Dartford, Kent, DA2 6QE, UK)

Microsoft Excel Software. (Excel, version 14.0.6112.5000, Microsoft Office Home and Student 2010, 2010 © Microsoft Corporation)

SPSS software (SPSS package, version 16.0, WinWrap Basic, Copyright 1993-2007, Polar engineering and consulting).

Figure legends:

Figure 1a: Intra-operative photograph demonstrating the position of two mini Hohmann retractors to identify the Crown of the olecranon articular surface.

Figure 1b: Landmarks of the olecranon. Antero-posterior and lateral views of a cadaveric proximal ulna and radius demonstrating relevant data points. The triceps aponeurosis attachment is preserved. Key: A = Apex of the chevron in an apex-proximal osteotomy, C = Crown, D = Distal point of the UBA, F = Tip of olecranon process, L = Lateral metaphyseal projection at the level of the Crown, M = Medial metaphyseal projection at the level of the Crown, P = Proximal point of the UBA, and T = Tip of the proximal ulna.

Figure 2a: Cadaveric image demonstrating the chevron olecranon osteotomy between the Crown line found with the described Hohmann technique and the presented 4mm critical distance. Key: L = Lateral metaphyseal projection at the level of the Crown, M = Medial metaphyseal projection at the level of the Crown.

Figure 2b: Cadaveric image demonstrating the completed osteotomy with reflection of the olecranon to reveal the articular exit of the osteotomy contained within the ulnar bare area.

Figure 3: A comparison of measured distances from the Crown (C) to the distal boundary of the UBA (D) for the male and female cadaveric subjects.

Supporting information:

Doc S1: Anatomical results – Validation of the Crown.

Table 1: Abbreviations of anatomical landmarks and distances

Landmarks	Distances
C: Crown, (found with Hohmann method)	**FT:** Proximal tip of the ulna to the tip of the olecranon process
P: Proximal point of the UBA, (midline – articular surface)	**PD:** The length of the UBA at its midline aspect
D: Distal point of the UBA, (midline – articular surface)	**PC:** Crown to the proximal margin of the UBA
L: Lateral metaphyseal projection at the level of the crown.	**CD:** Crown to the distal margin of the UBA
M: Medial metaphyseal projection at the level of the crown.	**ML:** Width of the proximal ulnar metaphysis at the level of the crown
A: Apex of the chevron in an apex-proximal osteotomy.	
F: Tip of olecranon process.	
T: Tip of proximal ulna.	

Table 2: A comparison of Left and Right sided measurements for each gender (measurements in mm).

			FT (mm)	ML (mm)	TP (mm)	TD (mm)	PD (mm)	CP (mm)	CD (mm)
Female	Mean		24.2	20.1	16.0	21.4	5.4	0.6	4.8
	SD		1.4	1.6	1.0	1.1	0.8	0.5	0.8
	Mean L		24.6	19.9	16.3	21.5	5.4	0.7	4.9
	Mean R		23.9	20.3	15.8	21.3	5.4	0.4	5.1
	Difference according to R-L side	p	0.4	0.7	0.5	0.8	0.9	0.3	0.4
	Combined Shapiro-Wilk	p	0.9	0.4	0.9	0.2	1.0	0.4	0.5
Male	Mean		29.2	25.2	16.8	23.8	7.0	1.6	5.4
	SD		1.5	1.8	1.2	2.0	1.4	1.0	1.5
	Mean L		29.3	25.2	17.2	24.4	7.2	1.9	5.3
	Mean R		29.0	25.3	16.4	23.2	6.8	1.2	5.6
	Difference according to R-L side	p	0.7	1.0	0.3	0.3	0.5	0.2	0.8
	Combined Shaprio-Wilk	p	0.95	0.54	0.22	0.46	0.24	0.52	0.14
Difference between male and female		p	0.000	0.000	**0.098**	0.001	0.002	**0.07**	**0.23**

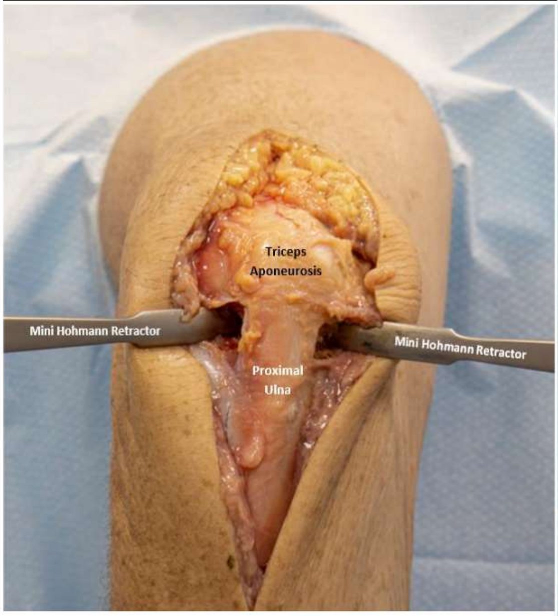
Table 3: A comparison of measurement errors (in mm)

	Average	Standard Deviation	95%CI	%error
FT	34.5	1.22	0.96	3%
PD	5.3	0.53	0.42	8%
PC	1.2	0.47	0.38	31%

Measurement error

This table illustrates the potential for error in measurement. PC had the greatest percentage error at 31%, this corresponded to a total error of approximately 0.3mm, which is not clinically relevant given a maximum accuracy of 0.5mm for a measuring tape with 1mm increments. A high percentage error is not surprising given it is the shortest of the measured distance.

Figure 1a: Intra-operative photograph demonstrating the position of two mini Hohmann retractors to identify the Crown of the olecranon articular surface.	**Figure 1b**: Landmarks of the olecranon. Antero-posterior and lateral views of a cadaveric proximal ulna and radius demonstrating relevant data points. The triceps aponeurosis attachment is preserved. Key: A = Apex of the chevron in an apex-proximal osteotomy, C = Crown, D = Distal point of the UBA, F = Tip of olecranon process, L = Lateral metaphyseal projection at the level of the Crown, M = Medial metaphyseal projection at the level of the Crown, P = Proximal point of the UBA, and T = Tip of the proximal ulna.



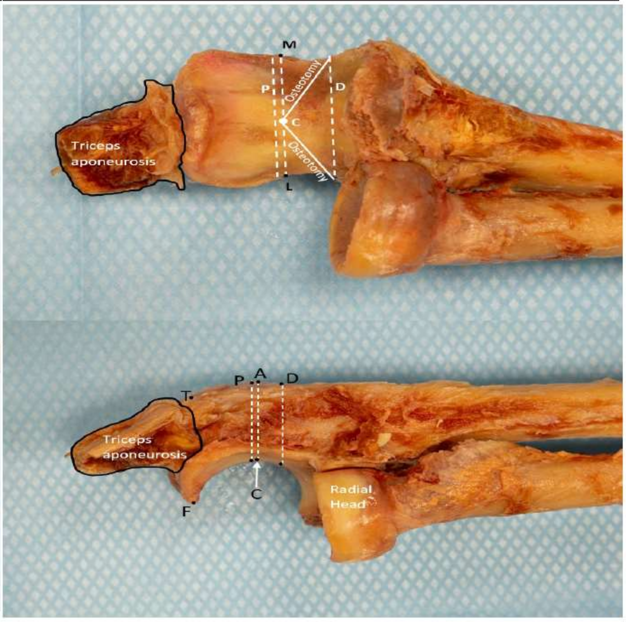
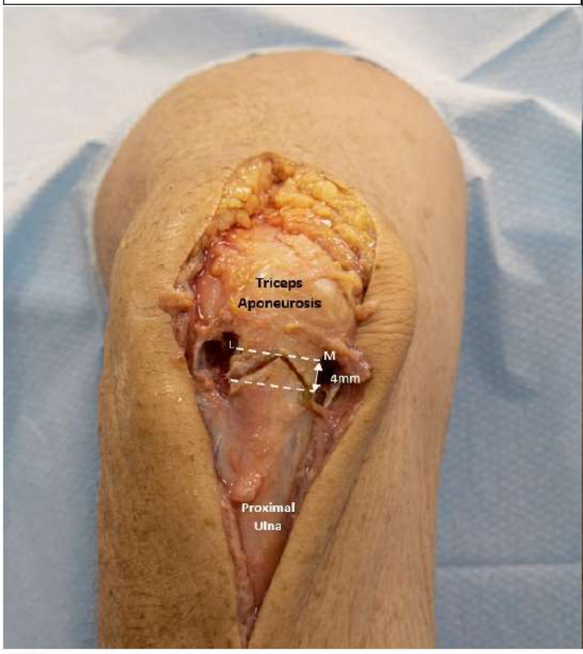


Figure 2a: Cadaveric image demonstrating the chevron olecranon osteotomy between the Crown line found with the described Hohmann technique and the presented 4mm critical distance.
Key: L = Lateral metaphyseal projection at the level of the Crown, M = Medial metaphyseal projection at the level of the Crown.



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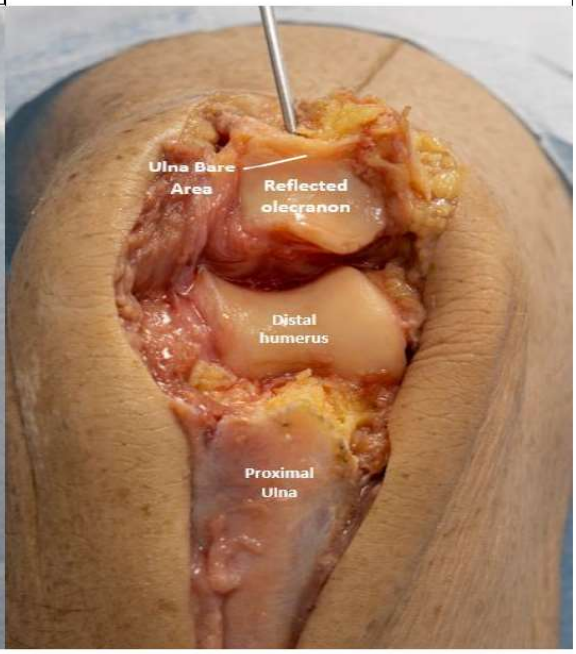

Figure 3: A comparison of the measured distances from the Crown (C) to the distal boundary of the UBA (D) for the Male and Female cadaveric subjects.