Triceps on, alignment off? A comparison of total elbow arthroplasty component positioning with a triceps-on and a triceps-off approach

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ABSTRACT

INTRODUCTION This retrospective review investigates whether the triceps-on approach obtains alignment of total elbow arthroplasty implants equivalent to a triceps-off approach.

METHODS The last 30 consecutive total elbow arthroplasties performed by the senior author were reviewed to identify the approach used and pathology treated. Initially, a triceps split and reflection approach was used, then a triceps-preserving approach. Two blinded reviewers measured the component alignment in standardised radiographs. Pearson's correlation coefficient was calculated to investigate inter/intra-observer error. The two groups were compared using an unpaired Student t-test.

RESULTS There were 13 elbows in the triceps-off group and 17 in the triceps-on group. Pearson's coefficient was 0.75 for interobserver error, 0.89 for intra-observer error. There was no statistical difference between the achieved alignment. All ulna components were flexed with a mean angle deviation of 4.5 degrees in the triceps-off group and 5.7 degrees in the triceps on. Two (15%) ulna components in the triceps-off group were placed in over 5 degrees of flexion, compared with seven (44%) in the triceps-on group.

CONCLUSION These results demonstrate no statistical difference in the achieved alignment between the two groups. Surgeons should beware of the tendency to place the ulna component in a flexed position, especially in the triceps-on approach.

KEYWORDS

Elbow – Arthroplasty – Approach – Triceps – Component alignment – Triceps-on – Triceps-off

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Introduction

Multiple approaches to the elbow have been advocated, with an ideal approach allowing good exposure to properly position the implants while preserving triceps function, achieving a good range of motion and having a low complication rate. The triceps-preserving approach or 'triceps-on' approach has the perceived advantage of maintaining the triceps envelope, which reduces the risk of extensor mechanism failure and should allow earlier mobilisation.¹ The criticism of this approach is that the exposure generated is poorer,² which could make component alignment difficult.^{3,4}

This study aims to investigate whether the triceps-on approach can achieve implant alignment equivalent to a triceps-off approach in a single surgeon series. The null hypothesis was that there is no statistical difference between the alignments of the two groups.

Materials and methods

A review was undertaken of the last 30 consecutive total elbow arthroplasties (TEA) performed by the senior author to identify the approach used and pathology treated. Until April 2014, the senior author used a triceps-off (split and reflection) approach originally described by David Stanley.⁵ This approach combines a split of the triceps with 25% medially and 75% laterally, with the lateral triceps being reflected sub-periosteally off the olecranon. The medial triceps is reflected medially beneath the ulnar nerve to protect it and, during repair, the nerve is brought back into its original position. Repair of the triceps is through transosseous sutures through the olecranon. After April 2014, the senior author changed to a triceps-on approach, originally described by Alonso-Llames,⁶ to treat supracondylar fractures in children (Fig 1). It has since been modified for TEA. The triceps is elevated on each side off the

Figure 1 The Alonso-Llames triceps sparing approach (courtesy of 3D4Medical).

intermuscular septum and posterior humerus and brought further distally with two para-olecranon incisions. The ulna nerve can be mobilised with a cuff of triceps fascia and capsule to allow closure at the end of the procedure

and bring the nerve back into a stable position.¹ Variations of this approach have been described and have been summarised by the authors in a review article.⁷ We believe this technique to provide the best exposure for total elbow arthroplasty while preserving the extensor mechanism and allowing visualisation of the ulna nerve.

Of the 30 elbows reviewed, there were 13 with a triceps-off approach and 17 with a triceps-on approach. All TEAs were performed using the Coonrad–Morey prosthesis (Zimmer Inc., Warsaw, Indiana, USA). Standardised antero-posterior (AP) and lateral x-rays were obtained for all patients as part of routine follow-up. These radiographs included the entire prosthesis in one film with the elbow in 90 degrees of flexion and neutral rotation for the lateral radiograph and maximal extension and supination for the AP radiograph. Any grossly rotated films were returned for further views. Lenoir and colleagues described a standardised technique for measuring the alignment of total elbow prostheses (Fig 2).⁸ This study used computed tomography, but the measurements were taken from a single two-dimensional slice and therefore should be reproducible using standard radiographs. The three-dimensional imaging did allow the authors to correct for implant position and therefore measure centre of rotation, which we were unable to do using simple radiographs. Two blinded reviewers measured the angles of humeral and ulna components in relation to the central canal alignment in both AP and lateral views. One reviewer repeated the measurements after a time lapse of one month.

The valgus/varus angles were calculated for each elbow by measuring the deviation of the prosthesis from the long axis of bone in the coronal plane using a picture archiving and communication system (InSight PACS, Insignia Medical Systems, Basingstoke, UK). Components that were in a valgus position in relation to the bone were given a positive angle and those with a varus position given a negative angle. Similarly, the flexion/extension angles were

Figure 2 AP and lateral measurements of the humeral and ulna prostheses using technique described by Lenoir and colleagues.

Figure 3 Indications for total elbow arthroplasty.

Table 1 Mean discrepancy from the anatomical axis.									
Triceps:	Humerus					Ulna			
	Valgus/varus (°)	95% CI	Flexion/extension (°)	95% CI		Valgus/varus (°)	95% CI	Flexion/extension (°)	95% CI
Off	1.5	0.9–2.1	2.4	1.9–2.9		2.7	2.2–3.2	4.5	3.3–5.7
On	1.8	1.3–2.3	2.0	1.6–2.4		3.4	2.5–4.3	5.7	4.1–7.3
T-test	0.547		0.080			0.121		0.555	

Table 2 Direction of displacement.								
Triceps:	Humerus				Ulna			
	Varus	Valgus	Flexion	Extension	Varus	Valgus	Flexion	Extension
Off (n = 13)	8 (62%)	5 (38%)	2 (15%)	11 (85%)	0 (0%)	13 (100%)	13 (100%)	0 (0%)
On (n = 17)	8 (50%)	8 (50%)	7 (44%)	9 (56%)	1 (6%)	15 (94%)	16 (100%)	0 (0%)

calculated, using the long axis of the bone in the sagittal plane, with components in flexion giving a positive angle and those in extension a negative angle. Measurements were taken to one decimal place, the maximum accuracy permitted by the software, and a mean of the two reviewers' measurements was taken. Pearson's correlation coefficient was used to measure the inter- and intra-observer reliability, with correlation deemed good to excellent above 0.75. Statistical analysis between the two groups was performed using an unpaired t-test, with significant results below 0.05. R² correlation for angle deviation was calculated against surgeon experience with a significance value set above 0.8.

Results

The diagnosis for each TEA is presented in Figure 3. The measured alignment is outlined in Table 1 and the directions of displacements are outlined in Table 2. There were no statistically significant differences for any of the alignment metrics when comparing the two groups.

Pearson's correlation coefficient between the reviewer one and reviewer two was 0.75 for the first set of measurements and 0.77 for the second. Pearson's correlation coefficient for the single reviewer at two time points was 0.89. This represents a strong or very strong correlation

between and within reviewers for angles measured, demonstrating a reproducible technique.⁹

Two (15%) ulna components in the triceps-off group were placed in greater than 5 degrees of flexion, in comparison with seven (44%) in the triceps-on group. One (6%) ulna component in the triceps-on group was greater than 5 degrees valgus. No other components were greater than 5 degrees from the desired position. There were no cortical penetrations.

Humeral alignment was evenly split between varus and valgus alignment. There was preponderance towards placing the implant in extension in the lateral plane which was less apparent in the triceps-on group, although this did not reach statistical significance. No implant was placed greater than 5 degrees from the anatomical axis of the bone.

When plotted against time, the amount of deviation from desired component alignment for all the planes did not change with surgeon experience ($R^2 < 0.2$ in all planes).

Discussion

The pathology for which the TEA was performed differed between the two groups, with a higher percentage undergoing the surgery for trauma in the triceps-on group. This would reflect the national trend in the indications for TEA.^{10,11} In the elderly trauma population, there are often good reasons for leaving the triceps attached, such as requiring upper extremities to assist with ambulatory demands. The triceps-on approach, however, is technically easier in the trauma population. This is due to the degree of bone loss in this group, as the fractured fragments of the distal humerus are excised and these fragments are usually much larger than the resection performed for elective patients with arthritis. There is also less stiffness present in the traumatic group with no pre-existing arthritis, allowing easier manipulation of the limb to gain access to the elbow.

This study has not shown a significant difference in component positioning between the two approaches. However, for both groups, the ulna component is always put in flexion and has the most deviation away from the ideal alignment. The ulna component is also nearly always put into valgus, but with less deviation from the ideal alignment. Surgeon experience with time in this series did not appear to affect the component alignment.

The difficulty in ulna component positioning has been suggested to be due to an absence of anatomical landmarks on the ulna and the insufficiency of aiming devices. To help with this issue, one study has suggested that the flat spot of the dorsal surface of the ulna can assist surgeons to correctly orientate the ulna component within the ulna.¹² This is easily visible during a triceps-preserving approach and even when the sigmoid notch anatomy is distorted. Alternatively, a drill bit and guide wire starting at the tip of the olecranon to find the ulna canal has been suggested.⁵ Specific jigs referencing the posterior humerus and ulna aspect of the ulna have been used to aid alignment.⁴ This achieved a mean alignment of the humeral

implant of 0.3 degrees of valgus and 0.7 of extension compared with the targeted angle. The ulna components were 0.3 degrees of valgus and 8.6 of flexion compared with the angle targeted. This amount of flexion was not thought to be clinically significant by the authors, but is higher than in our study.

The main reason for the ulna component being placed in flexion is considered by our team to be due to insufficient bone resection from the olecranon tip. Our technique has now changed to identify the insertion point of the triceps on the olecranon tip and use this as a guide for cutting a box out of the articular surface of the ulna. This allows a 'straight shot' down the canal while preserving the insertional fibres of the triceps. This can be seen in Figure 4, which demonstrates the anatomical location of the cut. Despite our extended olecranon resection a significant proportion of the bone is left behind, as seen in Figure 5, and no intraoperative or immediate postoperative fractures have been observed. This technique is now routinely used as a result of these findings.

Figure 4 The olecranon cut preserving the triceps insertion. (A) The triceps tendon. (B) The olecranon cut.

Figure 5 Postoperative radiograph demonstrating extended olecranon resection.

Malalignment of the humeral component into valgus or varus is known to increase the load on the humeral component compared with optimal alignment in cadaveric studies.¹⁵ Placing the ulna implant in a flexed position can lead to stress risers, fracture and early implant failure.⁵ A further study in an unlinked TEA noted a significantly increased likelihood of revision with varus or valgus malposition of either component by more than 5 degrees.¹⁴ Flexion or extension malposition in this study did not seem to correlate with worse outcomes. Another study showed more accurate varus or valgus alignment of both components was suggested to be associated with less pain and with improved function (assessed by the Mayo Elbow Performance Score), although the differences were not statistically significant.⁸ Futai *et al.*¹⁵ reported mean humeral component valgus alignment of 4 degrees and ulnar valgus of 5.9 degrees, both higher than in our study. They found that increased malalignment led to edge loading of the articular surface and thereby potential early polyethylene wear and loosening. One of the key techniques that allowed us to achieve more accurate alignment of the humeral component was the exposure of the distal humerus. After disarticulation, the distal humerus is completely denuded of all soft-tissue attachments to allow delivery through the surgical wound and excellent visualisation of the axis and the intramedullary canal of the bone (Fig 6). Again, this is a technique that is made easier in the trauma setting due to the excision of larger bone fragments. Our results show that no humeral component was placed in greater than 5 degrees malalignment from the ideal. There were also no statistically significant differences in alignment between the two groups. Although the humeral alignment in the sagittal plane came closest to achieving significance it is not thought that the degree of difference between the groups is clinically

Figure 6 Distal humeral dissection in the triceps-on approach. (A) the ulnar nerve. (B) the distal humerus as seen after initial dissection and cut.

significant as it is less than the previously defined 5 degrees of malalignment.¹⁴

We have been unable to assess component malrotation or the axis of rotation in this study based on the imaging available. As a retrospective review, and given our patient population in this study, it was not thought to be appropriate to bring patients back for further investigations such as computed tomography. Further work is under way to assess these aspects of component positioning involving cadaveric work. A power calculation was not performed for this study and, owing to the small numbers involved, it is likely to be underpowered to detect small differences in the alignment of the components between the two groups. The relatively narrow indications and the small group of patients requiring this type of intervention make it difficult to generate big data and therefore design robust trials by which to test theories about the effect of the surgical approach used. In our institution, the triceps-off approach is no longer performed and therefore the comparative group here is essentially an historic one. As far as the

authors are aware, however, this is the largest study comparing the triceps-on and the triceps-off approaches for total elbow arthroplasty to date.

Conclusion

Multiple studies have shown the triceps-on approach to maximise elbow extension strength, allow earlier postoperative mobilisation and have a lesser rate of triceps failure.^{1,16,17} This study does not demonstrate a difference in component positioning using the triceps-on approach. However, surgeons should be aware of the tendency to place the ulna component into flexion and valgus regardless of what approach is used.

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