MUSCULOSKELETAL SURGERY (2019) 103:155–160
https://doi.org/10.1007/s12306-018-0556-6

ORIGINAL ARTICLE

Tension band wiring versus locking plate fixation for simple, two-part Mayo 2A olecranon fractures: a comparison of post-operative outcomes, complications, reoperations and economics

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Received: 5 April 2018 / Accepted: 6 July 2018 / Published online: 13 July 2018
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Abstract

Purpose Simple displaced transverse olecranon fractures are traditionally managed operatively with a tension band wire device (TBW). We compared clinical outcomes, morbidity and the cost of treatment of TBW versus pre-countered low-profile locking plates for the treatment of Mayo 2A fractures.

Patient and methods All olecranon fractures admitted to our unit between 2008 and 2014 were identified ($n=129$). Patient notes and radiographs were studied from presentation to final follow-up. Patient outcomes were recorded using the QuickDASH (Disabilities of Arm, Shoulder and Hand) score. Patient demographics and nature of complications were recorded as were the rate and nature of any repeat operation.

Results Eighty-nine patients had Mayo 2A fractures (69%). Sixty-four underwent TBW ($n=48$) or locking plate fixation ($n=16$). The mean ages of both groups were similar at 57 (15–93) and 60 (22–80), respectively. In the TBW group, the mean post-injury QuickDASH was 12.9, compared with 15.0 for the locking plate group. There was no statistically significant difference between the outcomes for either group. Nineteen of the 48 TBW patients had complications (39.6%). Sixteen of the 48 TBW patients had reoperations (33.3%). In particular, we would highlight that 13 (27.1%) of patients treated with TBW underwent subsequent removal of metalwork for hardware irritation. There were no complications and or reoperations in the 16 patients who received locking plate fixation. Both complication and reoperation rates were statistically significantly different. Despite being initially more expensive, when the cost of reoperation for TBW group was included, locking plates were found to be on average £236.33 less per patient than for TBW.

Conclusions We suggest that locking plates are superior to TBW concerning post-operative morbidity, reoperation rate and cost for Mayo 2A fractures in contrast to previous articles.

Level of evidence Therapeutic study, III.

Keywords Olecranon fracture · Tension band wiring · Locking plates · Comparison

Introduction

Olecranon fractures are common and account for 10% of upper extremity injuries [1]. Simple displaced transverse fractures account for approximately 85% of all adult olecranon fractures. These are classified as Mayo-type 2A injuries [2], displaced but stable fracture patterns with no comminution or joint incongruity. These fractures are traditionally managed operatively with open reduction and internal fixation using a tension band wire device (TBW) as described by Weber and Vasey [3].

Although recognised as the gold standard for simple olecranon fractures, there is a recognised morbidity associated with successful TBW management. The main complication relates to post-treatment prominent, irritant hardware and subsequent future removal of metalwork from the elbow [1, 4–8]. Recent studies show TBW hardware irritation rates of 30–90% and removal rates of 2–90% [4–8]. Rarer complications include anterior interosseous nerve palsy and impaired

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forearm rotation from prominent anterior cortex wires [9, 10].

Open reduction internal fixation with a plate is advocated in the presence of comminution or fracture dislocation. In recent years, the development of locking plates with fixed angle screw constructs has made this the implant of choice for the more complicated fractures over previous non-locking and tension band plates. It is the consensus that a TBW device will not adequately control these more challenging injuries [11].

Locking plates provide superior fixation and resistance against screw pull out in osteoporotic bone and comminuted metaphyseal fractures [12] and may be used for simple olecranon fracture patterns especially in the elderly when bone stock is poor.

Several studies have compared outcomes, complications and costs between TBW and plating for a range of both simple and complex olecranon fractures. Patient cohorts tend to include a variety of fracture patterns and are analysed as a group [1, 5, 6]. Both treatments are consistently shown to give good or excellent function and outcome in the majority of cases with no statistical differences between the methods of fixation. Rates of implant removal are higher in the TBW cohorts, and plate fixation is shown to be more expensive [1, 4–6].

The aim of this study was to compare patients treated surgically with either TBW or locking plate fixation for Mayo 2A fractures of the olecranon. Patient-reported outcomes were compared for both groups as were the nature and rate of pre-defined surgical complications. A cost analysis for each group would show the cost per patient of each treatment. We aimed to see whether one treatment was superior in the management of these simple olecranon fractures. Our null hypothesis was that there would be no difference between either form of treatment with regard to patient outcome, complication rate or financial cost.

Materials and methods

All olecranon fractures treated at our institution over 6 years between June 2008 and June 2014 were identified retrospectively using our hospital trauma database. Two senior orthopaedic registrars (US resident equivalent) reviewed all pre-operative radiographs using the NHS Scotland Picture Archiving and Communications System (PACS) national archive search function to record injuries as per the Mayo classification [2]. These were cross-checked by each other to reduce error. Any disagreement in radiograph Mayo classification between these two registrar observers was discussed with the senior study consultant author and resolved allowing classification of all patients into one of six Mayo injury patterns. All Mayo 2A fractures were therefore identified for inclusion into the study.

Using the Trakcare (InterSystems Corporation, Cambridge, MA) and Bluespier (Droitwich, UK) healthcare information systems, the authors accessed patient medical notes detailing inpatient orthopaedic assessment, operative notes and subsequent fracture clinic follow-up correspondence. Past medical history, comorbidities and correspondence from primary care doctors were also recorded from these systems.

Patient demographics and mechanism of injury were identified. Exclusion criteria included open fractures, previous ipsilateral elbow fracture and concomitant ipsilateral upper limb injury, and patients who underwent open reduction with fixation techniques other than TBW and anatomically contoured locking plates.

All patients either underwent TBW or locking plate fixation by one of a group of eight surgeons in our unit (four orthopaedic consultants and four orthopaedic registrars under consultant supervision). The choice of implant was surgeon dependant. The duration of procedure was recorded from the anaesthetic charts.

The tension band constructs were held using two parallel 1.6-mm Kirschner wires passed antegrade across the fracture no further than 10 mm through the anterior cortex. A uniform construct of a 1.0-mm (size 18 American wire gauge) stainless steel wire was used as the tension band with two knots in all cases.

The locking plates were all proximal ulna Stryker VariAx Elbow Locking Plates (Kalamazoo, MI, USA). Fixation was uniform between cases, with all including an intramedullary screw across the fracture from the most proximal screw hole passing distally, perpendicular to the fracture line.

Post-operative follow-up protocol was identical in both groups. Patients were fit for discharge after passing physiotherapy assessment. They were at 2 weeks post-operatively for wound review, elbow radiographs and initiation of active range of motion if placed in a temporary plaster slab. Patients were then seen at 6 weeks for repeating radiographs and referral to physiotherapy if needed. Final follow was at 3 months post-surgery where patients were discharged unless otherwise indicated.

To calculate patient outcomes, a validated scoring system, the QuickDASH (Disabilities of Arm, Shoulder and Hand), (Institute for Work & Health, Toronto, ON, Canada) [13] patient-reported outcome measure was used to determine functional outcome post-treatment. This was recorded by telephone consultation with the cohort patients and calculated by the authors at the time of the study after the final outpatient discharge.

Surgical complications were categorised by the authors as incidence of infection, hardware irritation, non-union and failure of fixation. These were elicited and recorded by

retrospective medical notes, primary care correspondence and radiograph review. Reoperations were recorded by retrospective medical note, radiograph and operation note review.

Treatment costs per patient were ascertained by looking at duration of procedures, index and secondary operations and implant type. The cost was then derived by calculation of a timed theatre slot both in both trauma and elective scenarios and accepted implant cost from our trauma provider in December 2014.

Statistics

The Mann–Whitney rank sum test was used to detect any significant differences in the functional outcomes, complications and reoperation rates between the two groups. Statistical significance was set at a p value of 0.05. Statistical analysis was performed with IBM SPSS Statistics 23 (IBM, Chicago, Illinois, USA).

Results

A total of 129 patients were treated at our unit over the 6-year period between 2008 and 2014. The interobserver agreement ratio was 0.93 between the two registrars. Of these 129 patients, 89 (69%) had Mayo 2A olecranon fractures.

There were four Mayo 1A and one Mayo 1B stable fractures. Twenty-two comminuted Mayo 2B fractures were identified. Of the unstable fracture patterns, nine Mayo 3A and four Mayo 3B were identified in this series.

Of the 89 Mayo 2A fractures, 25 cases were excluded for conservative treatment or non-locking plate construct fixation leaving 64 patients included.

Forty-eight patients (75%) were treated with tension band wire fixation as described. Sixteen patients (25%) were treated with locking plate fixation using the Stryker VariAx Elbow Locking Plates.

Post-treatment cohort study follow-up

The mean TBW follow-up post-index procedure was 42 months (28–78).

The mean locking plate follow-up post-index procedure was 32 months (28–54).

All patients attended at the final outpatient appointment at 3 months with the remainder of the quoted follow-up period related to surveillance retrospectively of patient notes and radiographs from our above regional and national healthcare information systems. All reoperations for fixation failure or infection occurred during first 3 months post-operatively, and all ongoing complications or repeat procedures were identified between discharge from outpatient clinic and the time of this study.

Table 1 Demographics of the two cohorts

	Tension band wiring	Locking plate fixation
Number of patients	48	16
Mean age (range)	57 (15–93)	60 (22–80)
Male	20	4
Female	28	12
Mechanism of injury		
High energy	4	3
Low energy	44	13
Smoker	13	4
Diabetes mellitus	4	1
Associated injuries		
Non-upper limb polytrauma	3	0

Table 2 The rate and nature of complications in each cohort

Complications	Tension band wiring n (%)	Locking plate fixation n (%)
Deep infection	1 (2.1%)	0 (0%)
Non-union	1 (2.1%)	0 (0%)
Metalwork irritation	15 (31.3%)	0 (0%)
Fixation failure	2 (4.2%)	0 (0%)

Patient demographics

Table 1 summarises the demographics of the two cohorts included.

Patient outcomes

For the tension band wire cohort, the mean QuickDASH was 12.9 post-injury.

For the locking plate fixation cohort, the mean QuickDASH was 15.0 post-injury.

There was no statistically significant difference in the final patient-reported outcome measures when comparing the two cohorts ($p = 0.312$).

Surgical complications

Post-operative complications were noted in 19 of the 48 patients who underwent tension band wire fixation (39.6%). Table 2 summarises the rate and nature of complications. This included one deep infection (2.1%), one non-union (2.1%), 15 cases of metalwork irritation

(31.3%) and two cases of fixation failure (4.2%). There were no post-operative complications noted in the locking plate fixation cohort.

The three TBW fixation constructs that resulted in fixation failure and non-union were analysed separately. The two failed fixations that were subsequently revised were of standard technique with no evidence of inadequate fixation. The non-union case had a noticeable fracture gap on intraoperative screening despite a normal TBW construct, and this was eventually managed conservatively with no repeat intervention and an acceptable outcome score.

There was a statistically significant difference between the incidence of 19 complications in the TBW cohort versus 0 in the locking plate group ($p = 0.003$).

Reoperations

Clinical notes were examined to determine the rate of reoperation and reason for intervention in each case. Table 3 summarises the rate and nature of reoperations in each cohort. In the tension band wiring group, there were 16 patients (33.3%) that required further surgery.

Thirteen patients (27.1%) underwent elective removal of metalwork for ongoing implant irritation. Two patients (4.2%) had their TBW construct revised due to failure of the fixation and loss of reduction. These were both revised to locking plates and were subsequently not included in the locking plate cohort. One TBW patient underwent a wound washout and re-closure for wound sepsis. In the locking plate group, there were no reoperations.

There was a statistically significant difference between the incidence of 16 reoperations in the TBW cohort versus 0 in the locking plate group ($p = 0.008$).

Table 3 The rate and nature of reoperations in each cohort

Reoperations	Tension band wiring *n* (%)	Locking plate fixation *n* (%)
Washout	1 (2.1%)	0 (0%)
Non-union	0 (0%)	0 (0%)
Metalwork removal	13 (27.1%)	0 (0%)
Fixation revision	2 (4.2%)	0 (0%)

Economics

Theatre running costs were obtained from the divisional accounts department. These costs include the direct costs such as staffing and sundries, along with indirect estate costs such as maintenance and lighting.

The surgical duration and type of implant used were recorded from review of operation and anaesthetic notes. In our health board, a TBW construct costs £7.00 for 2 Kirschner wires and one 18-gauge steel wire and the Stryker locking plate and screws costs £244.10 both from our trauma provider.

The mean surgery time for both cohorts showed no statistical difference. Patient set-up, anaesthetic and surgical approaches were identical for both groups. Non-implant operating theatre costs were therefore equivalent.

A 30-min day surgery removal of metalwork, washout or similar case under general anaesthesia at our institution costs £1420 in December 2014. This was an accepted cost, derived from Greater Glasgow and Clyde Health Board divisional accounts department.

When the cost of reoperation for TBW surgery was included in the overall cost of surgery, locking plates were found to be on average £177 less per patient than for TBW, despite the initial increased implant cost associated with locking plates. Table 4 details cost breakdown.

Discussion

In current clinical practice within the UK, tension band wire fixation is the most widely used technique for displaced, non-comminuted olecranon fractures. However, several studies have reported comparable clinical outcomes between tension band wiring and plate fixation when comparing a range of variable fracture patterns.

Tarallo et al. [5] compared TBW fixation with the Acumed (Hillsboro, OR, USA) congruent elbow plate either used in a locking or non-locking capacity for both Mayo 2A and 2B fractures. Good outcomes were shown in both with no difference in complications analysing the Mayo 2A subgroup (21 TBW vs 10 Plate fixation); however, when grouping both fracture patterns a statistically significant increase in hardware removal was seen in the TBW group.

Delsole et al. [6] compared 23 TBW fixation constructs versus 25 cases using the Synthes DePuy (West Palm Beach, FL, USA) one-third tubular hook plate. Both devices were used for Mayo-type 1, 2 and 3 fractures by the authors. The largest

Table 4 Implant cost breakdown

Implant	Implant cost	Total cost for implants	Reoperation costs	Total cost for cohort	Cost per patient
48 TBW	£7.00	48 × 7 = £336	16 × £1420 = £22,720	£23,056	£480.33
16 Locking plates	£244.00	16 × 244 = £3904	£0	£3904	£244.00

subgroup contained Mayo 2A fractures (18 TBW vs 15 Hook plate). Grouping all fractures showed that good outcomes were achieved in both constructs; however, there was a statistically significant increased time to union in the hook plate group.

Schliemann et al. [4] compared the clinical and radiological outcomes in 13 TBW fixation constructs versus 13 Synthes DePuy (West Palm Beach, FL, USA) Olecranon Locking compression plates in Mayo 2A fractures. Outcomes were good with no difference between the cohorts. Twelve patients required TBW removal versus 6 in the locking plate group. This was the first study to look at Mayo 2A fractures in isolation and compare clinical and radiological outcomes of TBW versus locking plates. They concluded in favour of TBW due to similar results but increased costs in the locking plate group. It is noted that the locking plate group patients were approximately 10 years older than the TBW group with poorer bone quality being a suggested reason.

Claessen et al. [8] published a large retrospective study involving 392 olecranon fractures treated with plate or TBW open reduction internal fixation for the purpose of predicting reoperation and implant removal. Mayo 2A and 2B fractures and a variety of different implants were grouped in their analysis that showed 99 reoperations (25%). This cohort was then studied to show a statistically significance increase in both reoperation and request for reoperation in younger patients and those of female sex. Subsequent bivariate analysis showed no difference between fracture types and TBW versus plating when comparing reoperation and implant removal rates.

As the biomechanics of both fixation constructs have become better understood, plate fixation has become more popular for simple fracture patterns. In a cadaveric model, Wilson et al. [14] published their results comparing compression at the fracture site during rest and simulated muscle activity. They concluded that pre-contoured plates provide significantly greater compression than tension bands in the treatment of transverse fractures of the olecranon, both over the whole fracture and specifically at the articular side of the fracture. Additionally, Hutchison et al. [15] studied the tension band principle on olecranon fracture models in a laboratory and failed to prove the theory that posterior tensile forces are converted to compressive at the articular fracture site, challenging popular convention. This issue is compounded by the increasing prevalence of elderly patients with osteoporotic bone, in which locking plates provides better fixation in poor quality bone stock.

Our study describes the largest retrospective series of Mayo 2A fractures in the literature with minimum 2-year follow-up to determine complication or reoperation, comparing 46 TBW against 16 locking plates. In our study, both cohorts recovered well with no difference between patient-reported outcomes. This mirrors the existing literature. In contrast to the literature, we have shown a significantly higher rate of both post-surgical complications and reoperations between the groups which is the headline of this study. The predominant reason for this is the development of post-treatment-irritant TBW hardware requiring elective removal at a later date. Previous studies report higher trends of rates of removal for TBW but lack significance. In our cohort of 16 locking plates, all patients recovered uneventfully.

Follow-up rates were similar at 42 versus 32 months. Although not strictly equal, due to the trend of locking plate fixation being more prevalent in the later years of the study to match national orthopaedic surgical trends, our follow-up periods are robust enough to conclude that the above statistically significant differences between complications and reoperations exist.

All TBW patients complaining of prominent metalwork did so at clinic review or general practitioner attendance during the first 12 months post-operatively and then progressed to hardware removal between 3 and 24 months.

The authors recognise the limitations of this study. Eight different surgeons of consultant (US attending equivalent) or registrar/resident grade performed the 64 procedures in our institution; however, case record analysis revealed that similar surgical techniques were employed. As the review was retrospective, treatment bias may exist with each surgeon tending to use their preferred device, particularly the trend of more TBW constructs in the earlier years of the study.

No locking plates in our study were subsequently removed. This is in contrast with the above studies that showed rates of 0–53% removal of olecranon plates [4–6]. One of the explanations may be that these included hook plates and more of the older first generation of locking plates with a larger profile. Another theory may have been the perceived increased difficulty of locking plate removal due to superior bone hold versus TBW removal; however, no patients in our locking plate group volunteered symptoms prompting removal.

One perceived criticism would be that patients went elsewhere with complications. In the post-discharge study period, all radiographs and medical notes were available on our national systems where one can identify any further symptoms or intervention of which we found no incidences, we are therefore confident that our findings are representative.

Previous literature concludes that plate fixation is more expensive, including Schliemann's paper that specifically looked at locking plates for Mayo 2A fractures [1, 4–6] and therefore as outcomes are equal, recommend TBW. Our cost analysis demonstrated that, when taking into account complication rates and the subsequent need for reoperation, locking plates were cheaper than TBW. After the implant costs, acute revision or future elective removal of metalwork costs were combined, the tension band group cost £480.33 per patient compared to £244.00.

The authors feel that this study is a pragmatic representation of olecranon fracture fixation practice in a busy district general hospital where consultants and registrars perform routine fracture fixation. We show statistically significant differences between the established TBW treatment versus locking plate fixation in terms of morbidity and reoperation.

We suggest that financial savings may be made to healthcare providers by choosing a more expensive initial implant due to the reduced incidence of further procedures. Although both treatments lead to good outcomes, the safety and convenience to patients may also be significantly lower with the use of locking plates for Mayo 2A fractures of the olecranon and we would recommend a prospective randomised study designed to look at complication rates and economic cost.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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