Cochrane
Library

Cochrane Database of Systematic Reviews

Surgical interventions for treating fractures of the olecranon in adults (Review)

Matar HE, Ali AA, Buckley S, Garlick NI, Atkinson HD

Matar HE, Ali AA, Buckley S, Garlick NI, Atkinson HD.

Surgical interventions for treating fractures of the olecranon in adults.

Cochrane Database of Systematic Reviews 2014, Issue 11. Art. No.: CD010144.

DOI: 10.1002/14651858.CD010144.pub2.

www.cochranelibrary.com

TABLE OF CONTENTS

HEADER	1
ABSTRACT	1
PLAIN LANGUAGE SUMMARY	2
SUMMARY OF FINDINGS FOR THE MAIN COMPARISON	4
BACKGROUND	7
OBJECTIVES	8
METHODS	8
RESULTS	10
Figure 1.	11
Figure 2.	14
Figure 3.	15
DISCUSSION	18
AUTHORS' CONCLUSIONS	20
ACKNOWLEDGEMENTS	20
REFERENCES	20
CHARACTERISTICS OF STUDIES	23
DATA AND ANALYSES	36
Analysis 1.1. Comparison 1 Plate fixation versus tension band wiring, Outcome 1 Good clinical outcome (little pain or loss of elbow motion: Helm criteria) 16-86 weeks follow-up.	38
Analysis 1.2. Comparison 1 Plate fixation versus tension band wiring, Outcome 2 Adverse events.	39
Analysis 2.1. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 1 Functional assessment (Modified Murphy Scoring System).	39
Analysis 2.2. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 2 Murphy score (including function, pain, loss of movement, joint space): excellent or good result.	40
Analysis 2.3. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 3 Adverse events.	40
Analysis 2.4. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 4 Loss in flexion > 20°.	41
Analysis 3.1. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 1 Good clinical outcome: objective clinical improvement 6-24 months follow-up.	41
Analysis 3.2. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 2 Painless elbow joint.	42
Analysis 3.3. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 3 Normal range of movement.	42
Analysis 4.1. Comparison 4 Netz pins versus K-wires tension band wiring (TBW), Outcome 1 Adverse events (4-54 weeks follow-up).	43
Analysis 5.1. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 1 Mayo Elbow Performance Score 12-36 months follow-up.	43
Analysis 5.2. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 2 Postoperative complications.	44
Analysis 5.3. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 3 Operation time and blood loss.	44
Analysis 6.1. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 1 Disabilities of the Arm, Shoulder and Hand Score (DASH) (0-100: 100 = worst outcome) at 2-5 years.	45
Analysis 6.2. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 2 Mayo Elbow Performance Score (0-100: 100 = best outcome) at 2-5 years.	45
Analysis 6.3. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 3 Adverse events.	46
Analysis 6.4. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 4 Range of elbow motion.	46

Analysis 6.5. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome	
5 Participant dissatisfaction.	47
APPENDICES	47
CONTRIBUTIONS OF AUTHORS	50
DECLARATIONS OF INTEREST	50
DIFFERENCES BETWEEN PROTOCOL AND REVIEW	50
INDEX TERMS	50

Surgical interventions for treating fractures of the olecranon in adults

Hosam E Matar¹, Amjid A Ali², Simon Buckley², Nicholas I Garlick³, Henry D Atkinson⁴

¹Speciality Registrar, Trauma and Orthopaedics, Liverpool, UK. ²Department of Trauma and Orthopaedics, Northern General Hospital, Sheffield, UK. ³Department of Trauma and Orthopaedics, Royal Free Hospital, London, UK. ⁴Department of Trauma and Orthopaedics, North Middlesex University Hospital, London, UK

Contact address: Hosam E Matar, Speciality Registrar, Trauma and Orthopaedics, Mersey Rotation, Liverpool, UK. hematar@doctors.org.uk, hematar@hotmail.co.uk.

Editorial group: Cochrane Bone, Joint and Muscle Trauma Group.

Publication status and date: New, published in Issue 11, 2014.

Citation: Matar HE, Ali AA, Buckley S, Garlick NI, Atkinson HD. Surgical interventions for treating fractures of the olecranon in adults. *Cochrane Database of Systematic Reviews* 2014, Issue 11. Art. No.: CD010144. DOI: 10.1002/14651858.CD010144.pub2.

Copyright © 2014 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

ABSTRACT

Background

Fractures of the olecranon (the bony tip of the elbow) account for approximately 1% of all upper extremity fractures. Surgical intervention is often required to restore elbow function. Two key methods of surgery are tension band wire fixation and plate fixation.

Objectives

To assess the effects (benefits and harms) of different surgical interventions in the treatment of olecranon fractures in adults.

Search methods

We searched the Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (22 September 2014), the Cochrane Central Register of Controlled Trials (CENTRAL, 2014, Issue 8), MEDLINE (1946 to September week 2 2014), EMBASE (1980 to 19 September 2014), trial registers, conference proceedings and reference lists of articles.

Selection criteria

Randomised controlled trials (RCT) and quasi-RCTs that compared different surgical interventions for the treatment of olecranon fractures in adults.

Data collection and analysis

Two review authors independently performed study selection, risk of bias assessment and data extraction. The primary outcomes of this review were function, pain and adverse events.

Main results

We included six small trials involving 244 adults with olecranon fractures. Of these, four were RCTs and two were quasi-RCTs; both of which were at high risk of selection bias. All six trials were at high risk of performance bias, reflecting lack of blinding, and four trials were at high risk of detection bias. The quality of the evidence for most outcomes was generally very low because of limitations in study design and implementation, and either imprecision of the results or inadequate outcome measures. Thus, we are very uncertain about the estimates of effect.

One trial (41 participants) comparing plate fixation with standard tension band wiring provided very low quality evidence at 16 to 86 weeks' follow-up of a better clinical outcome after plate fixation (good outcome (little pain or loss of elbow motion): 19/22 versus 9/19, risk ratio (RR) 1.82 favouring plate fixation, 95% confidence interval (CI) 1.10 to 3.01). There was very low quality evidence of less symptomatic prominent metalwork after plate fixation (1/22 versus 8/19; RR 0.11, 95% CI 0.01 to 0.79). The results for other adverse effects (infection and delayed or non-union) were inconclusive. Evidence is pending from a newly (September 2014) completed trial (67 participants) making the same comparison.

Four trials compared four different modified techniques of tension band wiring (i.e. additional intramedullary screw fixation, biodegradable pins, Netz pins and cable pin system) versus standard tension band wiring. There was very low quality evidence of little difference at six to 14 months in function assessed by a non-validated scoring tool from the addition of an intramedullary screw. However, there were fewer cases of metalwork prominence in the intramedullary screw group (1/15 versus 8/15; RR 2.00, 95% CI 1.15 to 3.49; one trial; 30 participants). There was very low quality evidence from one trial (25 participants) of little difference in subjectively or objectively assessed good outcome at a mean of 20 months between tension band wiring with biodegradable implants versus metal implants. There were no adverse events, either non-union or sinus or fluid accumulation, reported. All 10 participants in the metalwork group had an extra operation to remove their metalwork at one year. One trial, which did not report on function or pain, provided very low quality evidence of lower rates of metalwork for any reason or for symptoms after Netz pin tension band wiring compared with standard tension band wiring (11/21 with Netz pin versus 17/25 with standard tension band wiring; RR 0.77, 95% CI 0.47 to 1.26; 46 participants); this evidence also supports the possibility of higher rates of metalwork removal for Netz pins. Two intra-operative complications occurred in the Netz pin group. The fourth trial, which compared the cable pin system with standard procedure, found low quality evidence that cable pin improved functional outcome at a mean of 21 months (Mayo Elbow Performance Score (MEPS), range 0 to 100: best outcome: mean difference (MD) 7.89 favouring cable pin, 95% CI 3.14 to 12.64; one trial; 62 participants). It also found low quality evidence of fewer postoperative complications in the cable pin group (1/30 with cable pin system versus 7/32 standard tension band wiring; RR 0.15, 95% CI 0.02 to 1.17), although the evidence did not rule out the converse.

One trial provided very low quality evidence of similar patient-reported function using the Disabilities of the Arm, Shoulder and Hand questionnaire (0 to 100: worst function) at two or more years after fixation using a novel olecranon memory connector (OMC) compared with locking plate fixation (MD -0.70 favouring OMC, 95% CI -4.20 to 2.80; 40 participants). The only adverse event was a superficial infection in the locking plate group.

Authors' conclusions

There is insufficient evidence to draw robust conclusions on the relative effects of the surgical interventions evaluated by the included trials. Further evidence, including patient-reported data, on the relative effects of plate versus tension band wiring is already pending from one recently completed RCT. Further RCTs, using good quality methods and reporting validated patient-reported measures of function, pain and activities of daily living at set follow-ups, are needed, including checking positive findings such as those relating to the use of an intramedullary screw and the cable pin system. Such trials should also include the systematic assessment of complications, further treatment including routine removal of metalwork and use of resources.

PLAIN LANGUAGE SUMMARY

Surgical interventions for treating fractures of the olecranon (an elbow bone) in adults

Surgical treatment of olecranon fracture

The bony tip of the elbow is called the olecranon. It is shaped to allow bending and straightening of the arm at the elbow. The olecranon sits directly under the skin of the elbow, which makes it vulnerable to injury and fracture (break) following a fall. When this happens, people are sometimes unable to straighten their arms. Treating this fracture usually involves an operation to re-position the broken parts of the bone and then fix them in place using wires, pins, plates, screws and other devices.

Description of the studies included in the review

We searched the medical literature until September 2014 and found six trials, involving 244 adults with olecranon fractures. Each trial tested a different comparison. Tension band wiring, which is a commonly used technique for fixing these fractures, was the 'control' intervention in five trials.

Quality of the evidence

All six trials were small and had weaknesses that could affect the reliability of their results. We judged the overall quality of the evidence available for each comparison as either low or very low.

Summary of the evidence

One trial compared the use of plate fixation with tension band wiring. It found that more people had pain-free elbow motion after plate fixation and fewer people had discomfort from metalwork prominence, which is a well-known problem with wire fixation where the metal wiring on the surface of the bone just under the skin causes pain, discomfort and other problems.

Four trials compared different ways of wiring the fracture. Two trials found very little clear evidence of any differences between them. One trial found that adding an intramedullary screw (this is a screw that was inserted through the bone and along the central bone canal) to standard tension band wiring reduced the risk of the metalwork under the skin being prominent. Another trial found that the cable pin system improved function and resulted in fewer complications compared with standard tension band wiring.

Finally, one trial compared a new method of fixation using a titanium-nickel device that once implanted takes the shape of the olecranon with locking plate fixation. It found no clear evidence of differences between the techniques in patient-reported function and complications (the only complication was a superficial infection).

Conclusions

Currently, there is not enough evidence to determine the best treatment for these fractures with confidence. Further high quality research is needed, which is likely to have an important impact on our confidence in the estimates of the effects and will likely change the estimates.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON *[Explanation]*

Plate fixation compared with tension band wiring for treating olecranon fractures in adults						
Patient or population: adults with olecranon fractures Settings: hospital Intervention: plate fixation (using 1/3 tubular plates) Comparison: tension band wiring fixation						
Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk ¹	Corresponding risk				
	Tension band wiring	Plate fixation				
Functional assessment (e.g. via patient-reported outcome measures of elbow function)	see Comments	see Comments	-	-	-	Not reported. 1 on-going trial (67 participants) testing this comparison will be reporting DASH (Disabilities of the Arm, Shoulder and Hand) scores at 1 year (NCT01391936)
Good clinical outcome (little pain or loss of elbow motion: Helm criteria) Follow-up: mean 28.5 weeks, range 16-86 weeks	Study population		RR 1.82 (1.10 to 3.01)	41 participants (1 study)	⊕○○○ very low ²	Results were rated 'good' if there was no more than slight or occasional pain, loss of movement was less than 15° at the elbow and no revision surgery for operative failure
	474 per 1000	863 per 1000 (522 to 1427 (all 1000))				

Pain	see Comments	see Comments	-	41 participants (1 study)	-	Separate pain data were not available; these should be in the 1 ongoing trial (67 participants) testing this comparison (NCT01391936)
Adverse events - overall	see Comments	see Comments	-	41 participants (1 study)	-	Incomplete reporting and discrepancies in the reporting of infection meant that numbers of participants with ≥ 1 adverse events data could not be reported here
Adverse events - symptomatic metal prominence Follow-up: mean 28.5 weeks, range 16-86 weeks	Study population		RR 0.11 (0.01 to 0.79)	41 participants (1 study)	$\oplus\circ\circ\circ$ very low³	Metalwork prominence is a well-known problem of tension band wiring. Symptoms were local discomfort or pain over the implant. There was no record of implant removal surgery in either group
	421 per 1000	46 per 1000 (5 to 333)				
Adverse events - delayed or non-union Follow-up: 6 months	Study population		RR 0.17 [0.01 to 3.41]	41 participants (1 study)	$\oplus\circ\circ\circ$ very low³	Surgical treated (debridement) infection preceded both cases in the tension band wiring group
	106 per 1000	18 per 1000 (1 to 362)				
Adverse events - heterotopic ossification (bone formation) Follow-up: mean 28.	Study population		RR 0.29 [0.01 to 6.72]	41 participants (1 study)	$\oplus\circ\circ\circ$ very low³	The single participant with heterotopic ossification in the tension band wiring group de-

5 weeks, range 16-86 weeks			veloped ulnar neuropathy
	53 per 1000	16 per 1000 (1 to 357)	

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: confidence interval; **RR:** risk ratio.

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

1. The basis of the assumed risk is that for control group (tension band wiring) in the study population.
2. The evidence was downgraded 2 levels for limitations in design and implementation (including lack of blinding and spread of timing of outcome measurement) and 1 level for indirectness (the Herm criteria were not validated and could be considered surrogate to functional outcome).
3. The evidence was downgraded 2 levels for limitations in design and implementation (including lack of blinding and spread of timing of outcome measurement) and 1 level for imprecision.

BACKGROUND

Description of the condition

At the elbow, the proximal (or upper) ends of the two forearm bones (the radius and ulna) and the distal (lower) end of the humerus (the upper arm bone) come together. The olecranon, which is the name for the proximal part of the ulna, forms the bony point or 'tip' of the elbow when the elbow is bent. The top side of the olecranon and the lower end of the humerus are shaped such that they act as a hinge joint, which allows bending (flexion) and straightening out (extension) of the arm at the elbow. The upper and posterior surface of the olecranon forms the insertion site for the triceps muscle, which is the main muscle used for straightening the arm. The olecranon is situated directly under the skin of the elbow, which makes it vulnerable to injury.

Olecranon fractures account for approximately 1% of all upper extremity fractures ([Duckworth 2012](#)), with an annual incidence of 11.5 to 12 per 100,000 population ([Duckworth 2012](#); [Karlsson 2002](#)). These fractures are caused by either direct or indirect trauma ([Bailey 2001](#); [MacDermid 2001](#); [Newman 2009](#); [Veillette 2008](#)). With direct trauma, people commonly present following a direct fall onto the elbow. A direct blow to the olecranon will force it into the distal end of the humerus, causing comminuted fractures (where the bone is broken into more than two fragments) ([Hotchkiss 1996](#)). In indirect trauma, which is more common in older people, people present following a fall onto an outstretched arm. This causes fractures of the olecranon as a result of forceful contraction or sudden pull of the powerful triceps muscle through its insertion point onto the olecranon. This often produces transverse (crosswise) or short oblique (slanting) fractures ([Newman 2009](#)).

Many classification systems describe olecranon fractures, most notably the AO classification system ([Muller 1991](#)), the Mayo Classification System ([Morrey 1995](#)), and the Schatzker-Schmelting Classification System ([Schatzker 1987](#)). All are descriptive and classify fractures based on pattern and morphological appearance of fractures. Currently, there is no consensus in favour of any one system.

The aim of fracture treatment is to achieve anatomical reduction of the fracture and provide stable fixation that allows early mobilisation and restores function ([Veillette 2008](#)). Non-surgical or conservative treatment of olecranon fractures usually involves plaster immobilisation. It is generally considered for non-displaced or minimally displaced fractures, where the gap or step-off between fracture fragments is less than two millimetres, the extensor mechanism is intact and there is no displacement with elbow flexion ([Newman 2009](#); [Schatzker 1987](#)). Fractures meeting all these criteria can be successfully treated without surgery ([Hak 2000](#)).

Description of the intervention

Conventional indications for surgical treatment include open fractures, displaced fractures and fractures causing disruption to the extensor mechanism affecting the insertion of triceps muscle into the olecranon. There are four common methods in the surgical management of olecranon fractures: tension band wiring, plate fixation, intramedullary fixation and excision of the proximal fractured fragment with re-attachment of triceps tendon.

Tension band wiring

The principle of tension band wiring, which was first described in 1883 ([Lister 1883](#)), utilises a 'figure of 8' loop and two parallel pins. The aim of this method is to convert the extensor forces of the triceps muscle into compressive forces along the articular surface to cause compression of the fracture. Tension band wiring with Kirschner wires (K wires) has become a well-considered standard, especially in non-comminuted transverse fractures ([Newman 2009](#); [Wolfgang 1987](#)).

Plate fixation

Plate fixation uses a metallic plate attached to the fracture fragments with screws to bridge the fracture gap and facilitate fracture healing. It can be used for any type of olecranon fracture but is particularly recommended for the following indications: comminuted fractures, Monteggia fracture dislocations, oblique fractures (particularly those distal to midpoint of the trochlear notch) and fractures that involve the coronoid process ([Hak 2000](#)). One-third tubular, 3.5-mm contoured limited contact dynamic compression, 3.5-mm reconstruction, hook plates and pre-contoured locking plates are frequently used ([Lavigne 2004](#)).

Intramedullary fixation

Nailing systems and intramedullary screws are used to align and stabilise fractures, including olecranon fractures. The screws and nails are usually inserted into the bone marrow canal of long bones. In oblique or simple transverse olecranon fractures, a single intramedullary cancellous screw can be used with or without tension band wiring. More complex forms of intramedullary fixation with interlocking intramedullary nailing devices have been used for more complex injuries.

Olecranon excision and triceps advancement

Olecranon excision and triceps advancement has been adopted by many clinicians, particularly in older people with osteoporotic bone, extensive comminution or a fragment too small for internal fixation. This technique involves excision of fracture fragments with triceps tendon advancement or re-attachment to restore the extensor mechanism.

Less commonly used surgical options include closed reduction and external fixation, and 'total elbow replacement' for complex elbow fractures including the olecranon.

How the intervention might work

Fractures of the olecranon represent a wide spectrum of injuries with multiple management options available. Anatomic reduction through surgical fixation ensures fracture stability and reconstruction of the articular surface to speed recovery. This also allows return to previous activities. This aim has been achieved with plate fixation and tension band wiring (Bailey 2001; Holdsworth 1984; Romero 2000; Veillette 2008), and to a lesser extent with olecranon excision and triceps advancement (Hak 2000; Horthkiss 1996; Lavigne 2004; Newman 2009).

However, the subcutaneous location of the olecranon makes it prone to complications from metal implants used in surgical interventions, which can lead to pain and skin breakdown. Metalwork prominence is the most common complication of tension band wiring (Romero 2000) and plate fixation (Bailey 2001), often requiring removal of metal implants through a second operation (Rommens 2004).

Why it is important to do this review

Olecranon fractures vary in their severity and can have poor outcomes. There are several different surgical interventions available and in current use. Thus, there is a need to inform practice by systematically reviewing the evidence for the use of these different surgical interventions. To our knowledge, there is no recent systematic review that focuses on the surgical treatment of olecranon fractures in adults.

OBJECTIVES

To assess the effects (benefits and harms) of different surgical interventions in the treatment of olecranon fractures in adults.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials (RCTs) and quasi-RCTs (where the method of allocating participants to a treatment was not strictly random and where allocation could be predicted, e.g. by

date of birth, hospital record number, alternation) controlled trials that compared different surgical interventions for the treatment of olecranon fractures in adults.

Types of participants

We included adults with unilateral or bilateral olecranon fracture. We included all severities of fracture, both open and closed. We included trials containing participants with other elbow injuries provided the primary focus was on the treatment of the olecranon fracture.

We excluded trials that specifically focused on treating people with a primary bone disease (e.g. fibrous dysplasia), pathological fractures (from metastatic cancer) or periprosthetic fractures. We also excluded trials including children or people with primary bone diseases or pathological fractures unless separate data could be provided for adults with non-pathological fractures or the proportion of children or adults with primary bone diseases or pathological fractures was small (less than 5%).

Types of interventions

We included trials comparing different surgical interventions for the treatment of olecranon fractures. As described in the [Description of the intervention](#), the main interventions under consideration were tension band wiring, plate fixation, intramedullary fixation and olecranon excision with triceps advancement. The tension band wiring technique is considered the standard intervention and, hence, we considered this the control group against which the other interventions were compared. The selection of the experimental and control groups in trials evaluating other comparisons was based on an assessment of the relative novelty of the interventions being compared. We also included trials making other comparisons, including of different surgical techniques for the same intervention. We excluded trials comparing surgical with non-surgical interventions.

Types of outcome measures

Primary outcomes

1. Functional assessment, including generic and upper-limb-specific validated clinical scores (e.g. Mayo Elbow Performance Score (MEPS; Morrey 1993), Broberg and Morrey rating system (Broberg 1987), and patient-reported outcomes measures (e.g. participant-rated elbow evaluation score (MacDermid 2001)).
2. Adverse events (e.g. surgical complications, non-union, malunion, painful stiff elbow, persistent instability of the elbow, post-traumatic arthritis, heterotopic ossification and problematic prominent hardware), generally requiring secondary procedures (e.g. further surgery).
3. Long-term or persistent pain (assessed using self reported scales, e.g. visual analogue scale).

Secondary outcomes

1. Reduced range of elbow movements.
2. Patient-reported health-related quality of life measures (e.g. 36-item Short Form (SF-36)).
3. Return to work and former activities, such as sport.
4. Participant satisfaction, including the cosmetic result.
5. Operation time, blood loss.
6. Resource use and other costs (e.g. hospital stay, number of outpatient attendances, physiotherapy and other costs).
7. Others (as detailed in each individual study).

Search methods for identification of studies

Electronic searches

We searched the Cochrane Bone, Joint and Muscle Trauma Group's Specialised Register (22 September 2014), the Cochrane Central Register of Controlled Trials (CENTRAL, 2014, Issue 8), MEDLINE (1946 to September week 2 2014), MEDLINE In-Process & Other Non-Indexed Citations (19 September 2014) and EMBASE (1980 to 19 September 2014). We also searched [Current Controlled Trials](#), [ClinicalTrials.gov](#), and the [World Health Organization \(WHO\) International Clinical Trials Registry platform](#) for ongoing and recently completed trials (22 September 2014). We did not restrict the inclusion of reports based on publication language.

In MEDLINE, we combined the subject-specific search strategy with the sensitivity-maximising version of the Cochrane Highly Sensitive Search Strategy for identifying randomised trials ([Lefebvre 2011](#)). [Appendix 1](#) shows the search strategies for CENTRAL, MEDLINE and EMBASE.

Searching other resources

We checked reference lists of articles. We also attempted to contact researchers in the field for information on existing or ongoing trials. We searched the specific proceedings of shoulder and elbow surgery meetings and conferences from the following organisations: [British Elbow & Shoulder Society](#) (BESS) (2008 to 2013), [American Orthopedic Trauma Association](#) annual meetings (1996 to 2013) and [American Academy of Orthopedic Surgeons](#) annual meetings (2010 to 2013).

Data collection and analysis

Selection of studies

Two review authors (HM and HA) independently examined the titles and abstracts of articles identified in the search as potentially relevant trials. We obtained the full texts of trials that fulfilled

our inclusion criteria and those that were unclear from perusal of the abstracts. We resolved any disagreements by discussion and, if necessary, arbitration by a third review author (NG). The review authors were not blinded to the journal or study authors.

Data extraction and management

For each included trial, two review authors (HM and HA) independently extracted data using a pre-piloted form. We resolved any differences in data extraction by consensus, and by referring back to the original article. We resolved any disagreements by discussion and, where necessary, by consultation with a third review author (NG, AA).

Assessment of risk of bias in included studies

Two review authors (HM and HA) independently assessed risk of bias of the included studies using The Cochrane Collaboration's 'Risk of bias' tool ([Higgins 2011](#)). We assessed the following domains:

1. random sequence generation;
2. allocation concealment;
3. blinding of participants and personnel;
4. blinding of outcome assessment;
5. completeness of outcome data;
6. selective reporting;
7. other bias (e.g. major baseline imbalance; and risk of bias associated with inexperience of surgeons and other care providers with the interventions, and differences in rehabilitation).

We judged each of these domains as being at low risk of bias, high risk of bias or unclear risk of bias (either lack of information or uncertainty over the potential for bias). We resolved disagreements between authors regarding the risk of bias for domains by consensus.

Measures of treatment effect

For dichotomous outcomes, we expressed the treatment effects as risk ratios (RR) with 95% confidence intervals (CI). For continuous outcomes, we expressed treatment effects as mean differences (MD) and 95% CI. Had there been sufficient data to pool data from different outcome measures, we would have used standardised mean differences (SMD) and 95% CI.

Unit of analysis issues

All included trials were parallel-group trials; there were no cross-over trials. The units of randomisation and analysis were clearly individual participants in five of the included trials; however, there was a lack of information on one participant with bilateral fractures in one trial ([Hume 1992](#)). It was unclear how the study authors dealt with the issues around this participant but it is clear that the disparity between the units of analysis and randomisation would have been small ([Hume 1992](#)).

Dealing with missing data

Participants of all included trials completed the follow-up and there were no missing data. If there had been missing data, we would have tried to contact the authors of primary studies to request missing data, such as number of participants, details of drop-outs, means, measures of uncertainty (standard deviation or error) or number of events. In the event, the available data allowed an intention-to-treat analysis in which all randomised participants were analysed in the groups to which they had been originally assigned. For continuous outcomes with no standard deviations reported, we calculated standard deviations if possible from standard errors, P values or CIs using the methods outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We did not impute data.

Assessment of heterogeneity

We planned to judge clinical heterogeneity within all comparisons between included trials, and visually inspect forest plots in order to investigate the possibility of statistical heterogeneity. This was to have been supplemented using the I^2 statistic, which provides an estimate of the percentage of variability due to heterogeneity rather than to chance alone. An I^2 estimate of 75% or greater indicates the presence of high levels of heterogeneity (Higgins 2003).

Assessment of reporting biases

For future updates of the review, we will explore the possibility of publication bias using a funnel plot if we find data from over 10 trials for pooling.

Data synthesis

For each comparison, we calculated a summary estimate of treatment effect together with 95% CIs for individual outcomes. We had planned to use the fixed-effect model and to consider using the random-effects model, especially where there was unexplained and substantial heterogeneity. However, we were unable to perform meta-analyses giving the included trials tested different comparisons. Instead, we presented results using a narrative approach and in table format.

Subgroup analysis and investigation of heterogeneity

We performed no meta-analyses because of the heterogeneity of the included trials. We had planned, where relevant, to perform the following subgroup analyses:

1. polytrauma versus isolated injuries;
2. open versus closed injuries;
3. fracture pattern: comminuted versus non-comminuted;
4. young adults versus older adults (generally over 65 years of age).

Should subgroup analyses be possible in future, we will investigate whether the results of subgroups are significantly different by inspecting the overlap of CIs and performing the test for subgroup differences available in Review Manager 5 (RevMan 2012).

We had also planned, for multiple trial comparisons with substantial heterogeneity, to perform sensitivity analyses to explore the effects on heterogeneity and outcome of the removal of outliers.

Sensitivity analysis

We performed no sensitivity analyses. We had planned sensitivity analyses to examine the effect of missing data, of excluding trials at high or unclear risk of bias (such as selection bias arising from the lack of allocation concealment) and of excluding trials only reported in conference abstracts.

Quality of the evidence and 'Summary of findings' tables

We used the GRADE approach to assess the quality of evidence related to each of the primary outcomes listed in [Types of outcome measures](#) (Higgins 2011; see Chapter 12.2). We prepared a 'Summary of findings' table for the key comparison of plate versus tension band wiring.

RESULTS

Description of studies

See [Characteristics of included studies](#); [Characteristics of excluded studies](#); [Characteristics of studies awaiting classification](#); [Characteristics of ongoing studies](#).

Results of the search

The search was completed in October 2013. We screened 203 records from the following databases: Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (seven records); CENTRAL (14 records), MEDLINE (62 records), EMBASE (94 records), Current Controlled Trials (nine records), ClinicalTrials.gov (nine records) and the WHO International Clinical Trials Registry platform (eight trials). We also identified one potentially eligible study from reference lists of included studies and 11 abstracts from meetings and conferences.

The search resulted in the identification of 23 potentially eligible studies (see [Figure 1](#)). Upon study selection, we included six studies (Ahmed 2008; Chen 2013; Hume 1992; Juutilainen 1995; Larsen 1987; Liu 2012), excluded 15 studies (Frankle 1996; Gartsman 1981; Hamid 2010; Hope 1991; Jaskulka 1991; Karlsson 2002; Lan 2013; Ma 2012; Miyagi 1985; Mullett 2000a; Mullett 2000b;

Murphy 1987; Partio 1992; Schliemann 2014; Teasdall 1993), and listed one study as awaiting classification (Sui 2008). We also identified one ongoing study (NCT01391936).

Figure 1. Flow diagram of search results.

We attempted to contact the corresponding author of one trial for further information and clarification about study design, but unfortunately, these attempts were unsuccessful (Sui 2008).

Four included trials were RCTs (Hume 1992; Chen 2013; Juutilainen 1995; Liu 2012), and two were quasi-RCTs (Ahmed 2008; Larsen 1987).

Included studies

The six included trials involved 244 participants (Ahmed 2008; Chen 2013; Hume 1992; Juutilainen 1995; Larsen 1987; Liu 2012). Full details of these trials are in the [Characteristics of included studies](#).

Sample sizes

The populations of included trials were all small: 30 participants (Ahmed 2008), 40 participants (Chen 2013), 41 participants (Hume 1992), 25 participants (Juutilainen 1995), 46 participants (Larsen 1987), and 62 participants (Liu 2012).

Design

Settings

All trials were hospital based. One trial was conducted in two hospitals in China (Liu 2012). The remaining five trials were single centre and were carried out in Egypt (Ahmed 2008), China (Chen 2013), the USA (Hume 1992), Sweden (Juutilainen 1995), and Denmark (Larsen 1987).

Participants

In total, there were 244 participants, comprising 125 men and 119 women: Ahmed 2008 (21 men, nine women), Chen 2013 (22 men, 18 women), Hume 1992 (30 men, 11 women), Juutilainen 1995 (eight men, 17 women), Larsen 1987 (14 men, 32 women) and Liu 2012 (30 men, 32 women). Participants' ages ranged from 16 to 87 years; mean ages were 33.4 years (Ahmed 2008), 48.4 years (Chen 2013), 30.9 years (Hume 1992), 49.8 years (Juutilainen 1995), and 47.1 years (Liu 2012); the median ages of the two groups in Larsen 1987 were 60 and 67 years. Most participants had displaced transverse or oblique olecranon fractures requiring surgical fixation. Three trials excluded comminuted fractures (Ahmed 2008; Juutilainen 1995; Liu 2012). The percentage of comminuted fractures in the other three trials were: 32.5% (Chen 2013), 29.3% (Hume 1992), and 32.6% (Larsen 1987). Three trials explicitly excluded participants with open fractures (Chen 2013; Juutilainen 1995; Liu 2012). One trial included four participants with open fractures (two in each group) (Hume 1992), of which one participant had bilateral fractures but it was not clear to what group this participant belonged.

Interventions

Each trial made a different comparison.

In five trials, the standard tension band wiring fixation technique was the control group (Ahmed 2008; Hume 1992; Juutilainen 1995; Larsen 1987; Liu 2012). One trial compared plate fixation with tension band wiring (Hume 1992). The other four trials evaluated the use of modified techniques or additional interventions. Ahmed 2008 compared intramedullary screw plus tension band wiring versus tension band wiring. Juutilainen 1995 compared biodegradable pins and screw versus metal wires for tension band wiring. Larsen 1987 compared the use of Netz pins versus standard K-wires. Liu 2012 compared the cable pin system (see Appendix 2) versus standard tension band wiring. The sixth trial compared a novel olecranon memory connector (OMC) fixation technique versus locking plate fixation (Chen 2013).

Outcomes

Duration of follow-up ranged from an endpoint of fracture healing (Larsen 1987) to 36 months (Liu 2012). We summarised only the primary outcomes below.

Only Chen 2013 reported a patient-reported outcome measure; this was the Disabilities of the Arm, Shoulder and Hand (DASH)

questionnaire (Appendix 3). Both Chen 2013 and Liu 2012 used the MEPS (Morrey 1993; Appendix 4), which includes assessment of pain, movement, stability and activities of daily living. Ahmed 2008 used the Modified Murphy Scoring System (Appendix 5), which is a composite score based on pain, function, range of movement and radiologically assessed joint space. Hume 1992 used the Helm criteria (Helm 1987; Appendix 6), based on assessment of pain, range of movement and revision surgery for operative failure. Juutilainen 1995 used a non-validated outcome measure of clinical improvement. Larsen 1987 did not report on function.

All trials reported on adverse events or complications, which always included metalwork prominence. Larsen 1987 reported in full on reasons for metalwork removal, which included routine removal as well as removal because of symptoms.

No trial reported separately on pain.

Excluded studies

We excluded 15 studies: 12 clinical or comparative studies and three RCTs (Frankle 1996; Hamid 2010; Hope 1991). Of these, no isolated olecranon fractures were included in Frankle 1996, which compared total elbow replacements with open reduction and internal fixation for the treatment of complex elbow fractures in older women; there was no comparison of surgical interventions in Hamid 2010, which evaluated single-fraction radiotherapy for prevention of heterotopic ossification in elbow fractures including the olecranon; and Hope 1991 included only children, which examined biodegradable pins fixation in children with elbow fractures (see the Characteristics of excluded studies).

Studies awaiting classification

There is one study awaiting classification (Sui 2008). This article, reported in Chinese, is of a comparative study of plate fixation versus tension band wiring in 63 participants with olecranon fractures. The English abstract contains numeral inconsistencies and did not describe the study design, including whether there was randomisation (see the Characteristics of studies awaiting classification).

Ongoing studies

We identified one ongoing trial (NCT01391936). This is an RCT involving 67 participants who were allocated either plate fixation or tension band wiring for olecranon fractures in older people. The one year follow-up is now complete (September 2014) and the trial analysis and report underway. This study is likely to be included in future updates of this review and data pooled, where possible, with Hume 1992. See further details in the Characteristics of ongoing studies.

Risk of bias in included studies

[Figure 2](#) and [Figure 3](#) and the 'Risk of bias' tables in the [Characteristics of included studies](#) summarise the risk of bias judgements on all six trials.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Ahmed 2008	-	-	-	-	+	?	?
Chen 2013	?	?	-	+	?	?	?
Hume 1992	?	?	-	-	-	?	+
Juutilainen 1995	?	?	-	-	+	?	?
Larsen 1987	-	-	-	-	?	?	?
Liu 2012	+	+	-	+	+	?	+

Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

Allocation

We assessed both quasi-RCTs at high risk of bias for selection bias, reflecting non-random sequence generation and lack of allocation concealment (Ahmed 2008; Larsen 1987). Three trials provided no details of their methods of sequence generation or allocation concealment and we judged them to be at unclear risk of selection bias (Chen 2013; Hume 1992; Juutilainen 1995). We attempted to contact the trial authors for further details but were unsuccessful. We judged one trial at low risk for random sequence generation (an adaptive biased coin design was used for sequence generation to protect against prognostic imbalance between the groups) and allocation concealment (sealed envelopes were opened after the consent form was signed) (Liu 2012).

Blinding

We judged all six trials at high risk of performance bias, reflecting the inevitable lack of blinding of surgeons and the lack of mention of blinding of trial participants. Two trials blinded outcome assessors of clinical outcomes and we judged them at low risk of detection bias (Chen 2013; Liu 2012). We judged the other four trials at high risk of detection bias, as they appeared not to have taken measures to blind outcome assessment.

Incomplete outcome data

There was no loss to follow-up in any of the included trials. However, while we judged three trials at low risk of attrition bias, we judged Chen 2013 and Larsen 1987 at unclear risk and Hume 1992 at high risk. The judgements reflected some small discrepancies between text and tables in Chen 2013, the variation in length of follow-up and lack of clarity on the criteria used to determine the time of follow-up in Larsen 1987, and because follow-up spanned several years and no information was given on one participant with bilateral fractures in Hume 1992.

Selective reporting

We did not have access to any of the included trial protocols; hence, we judged the risk of reporting bias as unclear.

Other potential sources of bias

We considered two trials at low risk of other bias reflecting lack of major differences in baseline characteristics and similar care programmes (Hume 1992; Liu 2012). We judged the risk of other bias as unclear in the other four trials; this reflected uncertainty in terms of potential confounding from between-group differences in baseline characteristics in Ahmed 2008, and lack of information on baseline characteristics in Juutilainen 1995 and Larsen 1987. We judged one trial at unclear risk of other bias because the novel device being tested was designed by the trial authors (Chen 2013).

Although no trial mentioned surgeon experience with the devices under test, we felt this would not be an important source of bias for any of the comparisons.

Effects of interventions

See: [Summary of findings for the main comparison](#) Plate fixation compared with tension band wiring for treating olecranon fractures in adults

Each of the six included trials made a difference comparison.

Plate fixation versus tension band wiring

[Hume 1992](#) compared one-third tubular plate fixation with tension band wiring for displaced olecranon fractures in 41 adults who were followed up for a mean of 28.5 weeks (range 16 to 86 weeks).

Primary outcomes

[Hume 1992](#), which did not report on function or provide separate data on pain, rated clinical results as good, fair or poor using the Helm criteria ([Helm 1987](#); [Appendix 6](#)), which are based on pain, loss of movement and operative failure requiring revision surgery. Results were rated 'good' if there was no more than slight or occasional pain, loss of movement was less than 15° at the elbow and no revision surgery. There were twice as many participants with a 'good' outcome after plate fixation than tension band wiring (19/22 with plate fixation versus 9/19 with tension band wiring, RR 1.82 favouring plate fixation, 95% CI 1.10 to 3.01; P value = 0.02; [Analysis 1.1](#)).

There was incomplete information on the number of participants incurring an adverse event and contradictory statements in the trial report in terms of the number of participants developing an infection. One participant in the plate fixation group compared with eight participants in the tension band group developed symptomatic metalwork prominence (1/22 with plate fixation versus 8/19 with tension band wiring; RR 0.11 favouring plate fixation, 95% CI 0.01 to 0.79; P value = 0.03; [Analysis 1.2](#)). Two participants in the tension band group with non-union at six months had had surgically treated infections. Another participant in the tension band group developed heterotopic ossification and subsequently ulnar neuropathy (*see* [Analysis 1.2](#)).

Secondary outcomes

[Hume 1992](#) reported an absence of a statistically significant difference in elbow range of motion between the two groups at final follow-up. The mean loss in elbow extension was 7° in the plate group and 10° in the tension band wiring group. The mean operation time was 120 minutes (range 85 to 120 minutes) in the plate fixation group and 94.5 minutes (range 75 to 120 minutes) in the tension band wiring group.

Intramedullary screw plus tension band wiring versus tension band wiring

[Ahmed 2008](#) compared intramedullary screw plus tension band wiring fixation with standard tension band wiring for displaced olecranon fractures in 30 adults, who were followed up for a mean of 8.2 months (range six to 14 months).

Primary outcomes

Using the Modified Murphy Scoring System ([Murphy 1987](#); [Appendix 5](#)), a composite score rating pain, activity restriction, loss of range of motion and joint space (0 to 19, where 19 = best outcome), [Ahmed 2008](#) found little difference between the two groups at final follow-up (mean score: 18 with screw plus tension band wiring versus 17.07 with tension band wiring; MD 0.93, 95% CI -1.30 to 3.16; P value = 0.41; [Analysis 2.1](#)). All 15 participants in the screw plus tension band wiring group had an excellent or good result based on scores of 17 or over; this applied to 11 of the 15 participants in the tension band group (RR 1.35, 95% CI 0.98 to 1.85; P value = 0.07; [Analysis 2.2](#)).

Hardware prominence was reported in one of the 15 participants in the screw plus tension band wiring group and eight of the 15 participants in the tension band wiring group (RR 0.13, 95% CI 0.02 to 0.88; P value = 0.04; [Analysis 2.3](#)). Hardware removal in the eight of the 15 participants in the tension band group was after fracture union; prior to metalwork removal, one participant had plaster cast immobilisation for two months. There was one infection in the tension band wiring group that resolved only upon metalwork removal.

Secondary outcomes

None of the trial participants had loss of forearm rotation. Substantial loss of range of motion (flexion contracture or limitation) occurred in one participant of the screw plus tension band wiring group and five participants in the tension band wiring group (RR 0.20, 95% CI 0.03 to 1.51; [Analysis 2.4](#)).

Biodegradable wire plus screw versus metal wire and two K-wire tension band wiring

[Juutilainen 1995](#) compared biodegradable materials (wire and screw) versus metal wire for olecranon fractures in 25 adults, who were followed up for a mean of 19.7 months (range six to 24 months).

Primary outcomes

Functional assessment was carried out using a binary scale of 'good' or 'poor'. Subjective outcome was considered 'good' if the participants could move the fractured side without pain six months after operation and if the use of the injured elbow was similar to the

use of their other elbow. A 'good' objective outcome was when participants had good functional movement and their elbow joint was stable. Good results, whether assessed using 'subjective' or 'objective' criteria, were reported in all 15 (100%) participants who had biodegradable fixation compared with eight of the 10 (80%) of participants in the metal wire fixation group (RR 1.25, 95% CI 0.90 to 1.75; P value = 0.18; [Analysis 3.1](#)). Fourteen of the 15 participants in the biodegradable fixation group and eight of the 10 participants in the metal wire fixation group had a painless elbow joint at final follow-up (RR 1.17, 95% CI 0.83 to 1.64; P value = 0.37; [Analysis 3.2](#)). There were no cases of non-union in either group and no sinus or fluid accumulation in participants treated with biodegradable implants. Notably all metal implants were routinely removed one year post fixation surgery.

Secondary outcomes

More participants of the biodegradable group had normal range of elbow movement at final follow-up (12/15 with biodegradable fixation versus 5/10 with metal wire fixation; RR 1.60 favouring biodegradable fixation, 95% CI 0.82 to 3.13; P value = 0.17; [Analysis 3.3](#)).

Netz pins versus K-wires tension band wiring

[Larsen 1987](#) compared Netz pins versus K-wires for tension band wiring for displaced olecranon fractures in 46 adults, who were followed up to fracture healing (median 13 weeks, range four to 54 weeks).

Primary outcomes

[Larsen 1987](#) did not report on function or pain, other than stating that pain was a reason for implant removal. Removal of metalwork for any reason ('routine', young age, symptoms) occurred less often in the Netz pins group (11/21 with Netz pins versus 17/25 with K-wires tension band wiring; RR 0.77, 95% CI 0.47 to 1.26; P value = 0.30; [Analysis 4.1](#)). The removal of metalwork because of symptoms (pin affecting skin, cerclage affecting skin or pain) was also less common in the Netz pins group (6/21 with Netz pins versus 11/25 with K-wires tension band wiring; RR 0.65, 95% CI 0.29 to 1.46; P value = 0.29; [Analysis 4.1](#)). There were no deep infections but one participant in each group had a superficial infection. Two of 21 participants in the Netz pins group incurred intraoperative complications: these were an intra-articular fracture in one participant with a comminuted fracture and dropping of a Netz pin into the intramedullary canal during metalwork removal.

Secondary outcomes

The median time to fracture healing and attainment of final range of elbow motion was 13 weeks in both groups.

Cable pin system versus tension band wiring

[Liu 2012](#) compared the cable pin system, a modified tension band wiring technique, with the standard tension band wiring in 62 adults with olecranon fractures, who were followed up on average 21 months (range 12 to 36 months).

Primary outcomes

The MEPS (range 0 to 100: 100 = best outcome; [Appendix 4](#)) results were higher in the cable pin system group (mean: 88.67 with cable pin versus 80.78 with tension band wiring; MD 6.90 favouring cable pin, 95% CI 7.89, 95% CI 3.14 to 12.64; P value = 0.001; [Analysis 5.1](#)). There was also a lower rate of postoperative complications in the cable pin system group (1/30 with cable pin versus 7/32 tension band wiring; RR 0.15, 95% CI 0.02 to 1.17; P value = 0.07; [Analysis 5.2](#)). The only complication in the cable pin group was skin irritation from raised metalwork, which did not require treatment or implant removal. Five of the seven complications (two implant loosening, four metalwork prominence and one pain due to fracture of the steel wire) in the tension band wiring group required removal of metalwork. All fractures united.

Secondary outcomes

There was little difference between the two groups in operation time (MD -0.73 minutes, 95% CI -2.84 to 1.38; [Analysis 5.3](#)) or intraoperative blood loss (MD -1.19 mL, 95% CI -6.23 to 3.85; [Analysis 5.3](#)).

Nickel-titanium olecranon memory connector versus locking plate fixation

[Chen 2013](#) compared a novel OMC versus locking plate fixation for displaced olecranon fracture in 40 adults, who were followed for a mean of 37 months (range 24 to 56 months). The OMC, which was designed by the trial authors, conformed to the anatomical structure of the olecranon and was manufactured from nickel-titanium shape memory alloy plate.

Primary outcomes

There was no clinically important difference between the two groups in the DASH scores (range 0 to 100: 100 = worst outcome; [Appendix 3](#)) at two or more years' follow-up (mean: 3.3 with PMC versus 4.0 with locking plate fixation; MD -0.70 favouring OMC, 95% CI -4.20 to 2.80; P value = 0.69; [Analysis 6.1](#)). The MEPS (range 0 to 100: 100 = best outcome; [Appendix 4](#)) results were higher in the OMC group (mean: 86.7 with PMC versus 79.8 with locking plate fixation; MD 6.90 favouring OMC, 95% CI -0.79 to 14.59; P value = 0.08; [Analysis 6.2](#)).

All fractures healed. The only recorded adverse event was a superficial infection, which occurred in one participant in the locking plate fixation group ([Analysis 6.3](#)).

Secondary outcomes

There were no clinically significant differences between the two groups in range of motion (Analysis 6.4).

Seventeen (85%) participants in each group stated that they were very satisfied with their outcome. The only person expressing dissatisfaction was the same person in the locking plate fixation group who had had a superficial infection after surgery and pain during rehabilitation (Analysis 6.5).

DISCUSSION

Summary of main results

We included only four RCTs and two quasi-RCTs involving 244 participants. Each trial tested a different comparison, although tension band wiring, which is a standard surgical treatment for olecranon fracture, acted as the control group in five of these trials. Of these five trials, one compared plate versus tension band wiring, and the other four essentially compared modified techniques of tension band wiring with the established standard tension band wiring. The sixth trial compared a novel OMC fixation technique with locking plate fixation. There was little consistency in the clinical outcome measures used and presentation of data.

One trial (41 participants; 22 in plate fixation group, 19 in tension banding wiring group), which did not report participant-assessed function, provided very low quality evidence of a better clinical outcome, based on an assessment of pain and loss of elbow range of motion, at a mean of six months' follow-up after plate fixation compared with tension band wiring (Hume 1992; see Summary of findings for the main comparison). There was very low quality evidence that plate fixation resulted in fewer cases of symptomatic hardware prominence. Although the two cases of non-union and the one case of heterotopic ossification occurred in the tension band wiring group, the very quality of the evidence for these and all outcomes of this trial means that we are very uncertain about the findings of this trial. Evidence from one ongoing trial (67 participants) is pending (NCT01391936).

One trial (30 participants; 15 in each group) provided very low quality evidence of little difference at a mean of 8.2 months between intramedullary screw plus tension band wiring fixation versus standard tension band wiring using the mean Modified Murphy Scoring System, which assessed function, pain, range of motion and joint space (Ahmed 2008). Although when presented in terms of excellent or good scores, the results favoured the screw group, where all had such scores, the arbitrary nature of the categorisation means that this result was insecure. There was very low quality evidence that hardware prominence was lower in the screw group. One infection occurred in the tension band wiring group. One trial (25 participants; 15 in biodegradable group, 10 in metal wire fixation group) provided very low quality evidence of little

difference in subjectively or objectively assessed good outcome at a mean of 20 months between tension band wiring with biodegradable implants versus metal wire fixation implants (Juutilainen 1995). One (6.6%) participant in the biodegradable group versus two (20%) participants in the metal wire fixation group had a painful elbow joint at final follow-up. There were no adverse events reported. It was noted that all 10 participants in the metal wire fixation group had another routine operation to remove the metalwork at one year.

One trial (46 participants; 21 in Netz pin group, 25 in K-wires tension binding group), which did not report on function or pain, provided very low quality evidence of lower rates of metalwork for any reason or for symptoms after Netz pin fixation compared with K-wire tension band wiring (Larsen 1987). However, the evidence also supported the possibility of higher rates of metalwork removal in the Netz pins group. Two intraoperative complications (intraoperative fracture; a dropped Netz pin into the intramedullary canal during metalwork removal) occurred in the Netz pin group. One trial (62 participants) provided low quality evidence of better objectively rated function based on MEPS with the cable pin system compared with standard tension band wiring (Liu 2012). It also found low quality evidence of a lower rate (1/30 with cable pin versus 7/32 with tension band wiring) of postoperative complications in the cable pin group; five of the tension band wiring group required removal of metalwork. All fractures united.

One trial (40 participants; 20 in each group) provided low quality evidence of similar patient-reported function using DASH at two or more years after fixation using a novel OMC compared with locking plate fixation (Chen 2013). Although there was very low quality evidence of better objectively rated function based on MEPS in the OMC group, the wide CI values did not rule out the converse for locking plate fixation. The only adverse event was one of superficial infection in the locking plate group.

Overall completeness and applicability of evidence

This review included data from only six small trials with 244 participants. The available data for each comparison were from studies with only 25 to 62 participants.

The trial populations were representative of the populations generally treated by tension band wiring. The treated fractures were predominantly transverse or oblique fractures; and three trials excluded comminuted fractures. Around one-third of participants had comminuted fractures in the other three trials (Chen 2013; Hume 1992; Larsen 1987). Only Hume 1992 included open fractures; there were two in each group. The mechanisms of injury in most participants were direct falls or road traffic accidents. In all trials, the evidence mainly focused on a cohort of participants with isolated transverse or oblique olecranon fractures amenable to surgical interventions. While this cohort was not fully representative of all people with olecranon fractures, it was representative

of most people presenting to clinicians with olecranon fractures for whom surgery would be considered. Furthermore, trials were conducted in different geographical and healthcare settings spanning the globe (USA, Finland, Denmark, Egypt and China), thus providing good representation of people with olecranon fractures. The tension band wiring technique is the most commonly used surgical intervention for the treatment of transverse and oblique olecranon fractures and five trials used it as the control group. The use of plate fixation, especially locking plate fixation, is growing for the treatment of several fractures and, thus, appropriate interventions for comparison in [Chen 2013](#) and [Hume 1992](#). However, the novelty of the nickel-titanium OMC means that the applicability of this device is questionable. Other interventions, such as olecranon excision and triceps advancement, which is mainly used in older people with osteoporotic bone or extensive comminution, have not been investigated in controlled clinical trials. Most participants with simple transverse or oblique olecranon fractures are expected to have good functional outcomes irrespective of the type of surgical intervention ([Flinterman 2014](#)). Our included trials all reported good outcomes in relation to fracture healing and return to near normal function. While there was some low or very low quality evidence of better clinical or functional outcome of the plate fixation or the cable pin system when compared with standard tension band wiring, the key difference was the rate of adverse effects and, on occasion, the need for further surgery. This pertains mainly to hardware prominence, which is the most commonly reported adverse effect of tension band wiring ([Duckworth 2012](#); [Newman 2009](#); [Rommens 2004](#)), and in our review. As emphasised in [Juutilainen 1995](#), early or routine metalwork removal both incur further costs and risks of surgery.

Quality of the evidence

This review included only six small trials with 244 participants with olecranon fractures. There were four RCTs ([Chen 2013](#); [Hume 1992](#); [Juutilainen 1995](#); [Liu 2012](#)) and two quasi-RCTs ([Ahmed 2008](#); [Larsen 1987](#)), both of which we judged to be at high risk of selection bias. We judged all six trials to be at high risk of performance bias, reflecting lack of blinding, and four trials at high risk of detection bias. Most judgements for the other domains were unclear, reflecting uncertainty and lack of information. There was little consistency in the clinical outcome measures used and presentation of data. Although final follow-up was usually spread over several months or years in the individual trials, all participants were included in the final analyses.

We used the GRADE approach to assess the quality of the evidence and help interpret the findings ([Schünemann 2008](#)). When examining the outcome-specific information concerning the overall quality of evidence from each included trial for every comparison, the evidence was of low quality for all included trials. For each comparison, there was only one study with few participants. We double-downgraded each outcome in each comparison because of

limitations in the study designs as stated above and imprecision in the results with wide CI values.

We downgraded the evidence from [Hume 1992](#) (plate fixation versus tension band wiring), two levels for limitations in study design and implementation (reflecting lack of blinding and the spread of follow-up of several years) and one level for either indirectness (reflecting the unsatisfactory nature of the clinical assessment tool) or imprecision (reflecting the wide CI values (adverse events)).

We downgraded the evidence from [Ahmed 2008](#) (intramedullary screw plus tension band wiring versus tension band wiring) two levels for limitations in study design and implementation (reflecting selection bias and lack of blinding) and one level for either indirectness (reflecting the unsatisfactory nature of the composite assessment tool for assessing outcome) or imprecision (reflecting the wide CI values (adverse events)).

We downgraded the evidence from [Juutilainen 1995](#) (biodegradable wire plus screw versus two K-wire tension band wiring) two levels for limitations in study design and implementation (reflecting lack of blinding and overall uncertainties about study methods) and one level for either indirectness (reflecting the unsatisfactory nature of the assessing clinical outcome) or imprecision (reflecting the absence of data on adverse events).

We downgraded the evidence from [Larsen 1987](#) (Netz pins versus K-wires tension band wiring) two levels for limitations in study design and implementation (reflecting selection bias and lack of blinding) and one level for imprecision (reflecting the wide CI values (adverse events)).

We downgraded the evidence from [Liu 2012](#) (cable pin system versus K-wires tension band wiring), one level for limitations in study design and implementation (reflecting performance bias, related to unavoidable lack of blinding), and one level for either indirectness (reflecting the non-validated and non-subjective nature of the measurement of function) or imprecision (reflecting the wide CI values (adverse events)). Although we have no evidence for publication bias and could not test for it, we emphasise that it is inappropriate to rely on the evidence from one small trial, however well run.

We downgraded the evidence from [Chen 2013](#) (a novel nickel-titanium OMC versus locking plate fixation) two levels for limitations in study design and implementation (reflecting uncertainties relating to lack on reporting on methods, discrepancies in reporting, and lack of clinician and participant blinding), and one further level for imprecision reflecting broad CI values for objective outcomes. The novel nature of the intervention designed by the trial authors should also be noted.

Potential biases in the review process

The review was conducted as per the published protocol with no changes. We tried to minimise publication bias by undertaking a comprehensive search strategy and checking non-English language citations. However, one Chinese comparative study identified in

the search is awaiting classification (Sui 2008). Our search also included ongoing trials and we identified one RCT comparing tension band wiring with plate fixation, which has now completed follow-up (NCT01391936). This will be added to the review in any future update. None of the review authors have conflicts of interest regarding this review.

Agreements and disagreements with other studies or reviews

To the best of our knowledge, this is the first systematic review of RCTs and quasi-RCTs of surgical interventions for olecranon fractures. However, our findings are in line with other reviews of case-series, non-randomised controlled trials and current concept reviews, particularly in terms of the hardware prominence in tension band wiring (Duckworth 2012; Karlsson 2002; Newman 2009; Romero 2000; Veillette 2008).

AUTHORS' CONCLUSIONS

Implications for practice

There was insufficient evidence to draw robust conclusions on the relative effects of the surgical interventions evaluated by the included trials. Although tension band wiring fixation remains the standard surgical intervention for transverse or oblique olecranon fractures, hardware prominence remains the most commonly encountered adverse effect often requiring removal of metalwork.

Although there was some low or very low quality evidence from the included trials that other methods, such as plate fixation and the cable pin system, may reduce hardware prominence, there is a notable lack of evidence from validated patient-reported measures of outcome.

Implications for research

Further evidence, including patient-reported data, on the relative effects of plate fixation versus tension band wiring is already pending from one recently completed RCT (NCT01391936). Further adequately powered, well conducted, CONSORT (Consolidated Standards of Reporting Trials)-reported, randomised controlled trials, using good quality methods and reporting validated patient-reported measures of function, pain and activities of daily living at set follow-ups, are needed, including trials to check positive findings such as those relating to the use of an intramedullary screw and the cable pin system. Trials should also include the systematic assessment of complications, further treatment including routine removal of metalwork and use of resources.

ACKNOWLEDGEMENTS

We would like to thank Andrew Duckworth, Joanne Elliott, Lindsey Elstub, Xavier Griffin, Helen Handoll and Laura MacDonald for their helpful feedback and support at the review stage.

We are grateful to Andrew Duckworth, Helen Handoll and Lindsey Elstub for their help on the protocol and to Joanne Elliott and Catherine Deering for developing the search strategies.

REFERENCES

References to studies included in this review

Ahmed 2008 *{published data only}*

Ahmed AR, Sweed T, Wanas A. The role of cancellous screw with tension band fixation in the treatment of displaced olecranon fractures: a comparative study. *European Journal of Orthopaedic Surgery and Traumatology* 2008;**18**(8):571–6.

Chen 2013 *{published data only}*

Chen X, Liu P, Zhu X, Cao L, Zhang C, Su J. Design and application of nickel-titanium olecranon memory connector in treatment of olecranon fractures: a prospective randomized controlled trial. *International Orthopaedics* 2013;**37**:1099–105.

Hume 1992 *{published data only}*

Hume MC, Wiss DA. Olecranon fractures. A clinical and radiographic comparison of tension band wiring and plate fixation. *Clinical Orthopaedics and Related Research* 1992;**285**:229–35.

Juutilainen 1995 *{published data only}*

Juutilainen T, Patiala H, Rokkanen P, Tormala P. Biodegradable wire fixation in olecranon and patella fractures combined with biodegradable screws or plugs and compared with metallic fixation. *Archives of Orthopaedic & Trauma Surgery* 1995;**114**(6):319–23.

Larsen 1987 *{published data only}*

Larsen E, Lyndrup P. Netz or Kirschner pins in the treatment of olecranon fractures?. *Journal of Trauma-Injury Infection & Critical Care* 1987;**27**(6):664–6.

Liu 2012 *{published data only}*

Liu QH, Fu ZG, Zhou JL, Lu T, Liu T, Shan L, et al. Randomized prospective study of olecranon fracture fixation: cable pin system versus tension band wiring. *Journal of International Medical Research* 2012;**40**(3): 1055–6.

References to studies excluded from this review

Frankle 1996 {published data only}

Frankle MA, DiPasquale T. Randomized retrospective study comparing total elbow arthroplasty to open reduction internal fixation of elbow fractures in the elderly female. *Orthopaedic Transactions* 1996;**20**:153.

Gartsman 1981 {published data only}

Gartsman GM, Sculco TP, Otis JC. Operative treatment of olecranon fractures. Excision or open reduction with internal fixation. *Journal of Bone and Joint Surgery - American Volume* 1981;**63**(5):71821.

Hamid 2010 {published data only}

Hamid N, Ashraf N, Bosse MJ, Connor PM, Kellam JF, Sims SH, et al. Radiation therapy for heterotopic ossification prophylaxis acutely after elbow trauma: a prospective randomised study. *Journal of Bone and Joint Surgery - American Volume* 2010;**92**(11):2032–8.

Hope 1991 {published data only}

Hope PG, Williamson DM, Coates CJ, Cole WG. Biodegradable pin fixation of elbow fractures in children. A randomised trial. *Journal of Bone and Joint Surgery - British Volume* 1991;**73**(6):965–8.

Jaskulka 1991 {published data only}

Jaskulka R, Harm T. Conservative therapy of closed, dislocated fractures of the olecranon in geriatric patients. *Unfallchirurg* 1991;**94**(8):424–9.

Karlsson 2002 {published data only}

Karlsson MK, Hasselius R, Besjakov J, Karlsson C, Josefsson PO. Comparison of tension-band and figure-of-eight wiring techniques for treatment of olecranon fractures. *Journal of Shoulder and Elbow Surgery* 2002;**11**(4):377–82.

Lan 2013 {published data only}

Lan TY, Chen CY, Liao PF, Chen WC, Wu K, Pao JL, et al. Comminuted olecranon fractures treated with anatomically preshaped locking and nonlocking plates: a retrospective comparative study. *Formosan Journal of Musculoskeletal Disorders* 2013;**4**(1):1–5.

Ma 2012 {published data only}

Ma HJ, Shan L, Zhou JL, Liu QH, Lu T, Sun S. Case-control study on cable-pin system in the treatment of olecranon fractures. *Zhongguo Gushang* 2012;**25**:393–6.

Miyagi 1985 {published data only}

Miyagi S, Goto T, Kanazawa C, Nohno S, Shiba N, Shirahama M, et al. Experimental and clinical study of the figure-of-eight wiring for fracture of the olecranon, patella and other bones - crossed double figure-of-eight wiring. *Kurume Medical Journal* 1985;**32**(1):37–57.

Mullett 2000a {published data only}

Mullett JH, Shannon F, Noel J, Lawlor G, Lee TC, O'Rourke SK. K-wire position in tension band wiring of the olecranon - a comparison of two techniques. *Injury* 2000;**31**(6):427–31.

Mullett 2000b {published data only}

Mullett H, Shannon F, Noel J, O'Rourke SK. Transcortical placement of K-wires prevents backout - a clinical and biomechanical study of tension band wiring for olecranon

fractures. *Journal of Bone and Joint Surgery - British Volume* 2000;**82**(Supp 1):15.

Murphy 1987 {published data only}

Murphy DF, Greene WB, Dameron TB Jr. Displaced olecranon fractures in adults: clinical evaluation. *Clinical Orthopaedics and Related Research* 1987;**224**:215–23.

Partio 1992 {published data only}

Partio EK, Hirvensalo E, Böstman O, Pätäälä H, Vainionpää S, Vihtonen R, et al. Absorbable rods and screws: a new method of fixation for fractures of the olecranon. *International Orthopaedics* 1992;**16**(3):250–4.

Schliemann 2014 {published data only}

Schliemann B, Raschke MJ, Groene P, Weimann A, Wahnert D, Lenschow S, et al. Comparison of tension band wiring and precontoured locking compression plate fixation in Mayo type IIA olecranon fractures. *Acta Orthopaedica Belgica* 2014;**80**(1):106–11.

Teasdall 1993 {published data only}

Teasdall R, Savoie FH, Hughes JL. Comminuted fractures of the proximal radius and ulna. *Clinical Orthopaedics and Related Research* 1993;**(292)**:37–47.

References to studies awaiting assessment**Sui 2008 {published data only}**

Sui J, Fang W, Tong LM. Effect comparison of two kinds of therapeutic methods of olecranon fracture. *Zhongguo Gu Shang* 2008;**21**:60–1.

References to ongoing studies**NCT01391936 {published data only}**

Duckworth A. [personal communication]. Conversation with: H Handoll (Co-ordinating Editor, Cochrane Bone, Joint and Muscle Trauma Group) 17 September 2014.
* Duckworth AD, McQueen MM. A prospective randomised trial of plate fixation versus tension band wire for olecranon fractures. clinicaltrials.gov/show/NCT01391936 (accessed 29 October 2014).

Additional references**Bailey 2001**

Bailey CS, MacDermid J, Patterson SD, King GJ. Outcome of plate fixation of olecranon fractures. *Journal of Orthopaedic Trauma* 2001;**15**(8):542–8.

Broberg 1987

Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. *Clinical Orthopaedics and Related Research* 1987;**216**:109–19.

Duckworth 2012

Duckworth AD, Clement ND, Aitken SA, Court-Brown CM, McQueen MM. The epidemiology of fractures of the proximal ulna. *Injury* 2012;**43**(3):343–6.

Flinterman 2014

Flinterman HJ, Doornberg JN, Guitton TG, Ring D, Goslings JC, Kloen P. Long-term outcome of displaced,

- transverse, noncomminuted olecranon fractures. *Clinical Orthopaedics and Related Research* 2014;**472**(6):1955–61.
- Hak 2000**
Hak DJ, Golladay GJ. Olecranon fractures: treatment options. *Journal of the American Academy of Orthopaedic Surgeons* 2000;**8**(4):266–75.
- Helm 1987**
Helm RH, Hornby R, Miller SW. The complications of surgical treatment of displaced fractures of the olecranon. *Injury* 1987;**18**(1):48–50.
- Higgins 2003**
Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;**327**: 557–60.
- Higgins 2011**
Higgins JPT, Altman DG, Sterne JAC. Chapter 8: Assessing risk of bias in included studies. In: Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
- Holdsworth 1984**
Holdsworth BJ, Mossad MM. Elbow function following tension band fixation of displaced fractures of the olecranon. *Injury* 1984;**16**(3):182–7.
- Hotchkiss 1996**
Hotchkiss RN. Fractures and dislocations of the elbow. In: Rockwood CA Jr, Green DP, Bucholz RW, Heckman JD editor(s). *Fractures in Adults*. 4th Edition. Philadelphia: Lippincott-Raven, 1996:984–96.
- Hudak 1996**
Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder and Hand). The Upper Extremity Collaborative Group (UECG). *American Journal of Industrial Medicine* 1996;**29**(6):602–8.
- Lavigne 2004**
Lavigne G, Baratz M. Fractures of the olecranon. *Journal of the American Society for Surgery of the Hand* 2004;**4**(2): 94–102.
- Lefebvre 2011**
Lefebvre C, Manheimer E, Glanville J. Chapter 6: Searching for studies. In: Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
- Lister 1883**
Lister J. An address on the treatment of fracture of the patella. *British Medical Journal* 1883;**2**(1192):855–60.
- MacDermid 2001**
MacDermid JC. Outcome evaluation in patients with elbow pathology: issues in instrument development and evaluation. *Journal of Hand Therapy* 2001;**14**:105–14.
- Morrey 1993**
Morrey BF, An KN, Chao EYS. Functional evaluation of the elbow. In: Morrey BF editor(s). *The Elbow and its Disorders*. 2nd Edition. Philadelphia: WB Saunders, 1993: 86–9.
- Morrey 1995**
Morrey BF. Current concepts in the treatment of fractures of the radial head, the olecranon, and the coronoid. *Instructional Course Lectures* 1995;**44**:175–85.
- Muller 1991**
Muller ME, Allgower M, Schneider R, Willenegger H. *Manual of Internal Fixation: Techniques Recommended by the AO-ASIF Group*. 3rd Edition. Berlin: Springer-Verlag, 1991.
- Newman 2009**
Newman SD, Mauffrey C, Krikler S. Olecranon fractures. *Injury* 2009;**40**:575–81.
- RevMan 2012 [Computer program]**
The Nordic Cochrane Centre, The Cochrane Collaboration. Review Manager (RevMan). Version 5.2. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012.
- Romero 2000**
Romero JM, Miran A, Jensen CH. Complications and re-operation rate after tension-band wiring of olecranon fractures. *Journal of Orthopaedic Science* 2000;**5**(4):318–20.
- Rommens 2004**
Rommens PM, Kühle R, Schneider RU, Reuter M. Olecranon fractures in adults: factors influencing outcome. *Injury* 2004;**35**(11):1149–57.
- Schatzker 1987**
Schatzker J. Fractures of the olecranon. In: Schatzker J editor(s). *The Rationale of Operative Fracture Care*. Berlin: Springer-Verlag, 1987:89–95.
- Schünemann 2008**
Schünemann HJ, Oxman AD, Vist GE, Higgins JPT, Deeks JJ, Glasziou P, et al. Chapter 12: Interpreting results and drawing conclusions. In: Higgins JPT, Green S editor(s). *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester: John Wiley & Sons, 2008:359–83.
- Veillette 2008**
Veillette CJH, Steinmann SP. Olecranon fractures. *Orthopedic Clinics of North America* 2008;**39**:229–36.
- Wolfgang 1987**
Wolfgang G, Burke F, Bush D, Parenti J, Perry J, LaFollette B, et al. Surgical treatment of displaced olecranon fractures by tension band wiring technique. *Clinical Orthopaedics and Related Research* 1987;**(224)**: 192–204.
- References to other published versions of this review**
- Matar 2012**
Matar HE, Ali AA, Buckley S, Garlick NI, Atkinson HD. Surgical interventions for treating fractures of the olecranon

in adults. *Cochrane Database of Systematic Reviews* 2012,
Issue 10. DOI: 10.1002/14651858.CD010144

* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Ahmed 2008

Methods	Study design: quasi-RCT Method of randomisation: based on odd or even participant [record?] numbers Setting: Elhadara University Hospital, Alexandri, Egypt Study period: December 2004 to July 2005	
Participants	30 adults with displaced transverse or oblique fracture of the olecranon Mean age: 33.4 years (range 17-70 years) Sex: 21 men, 9 women Mechanism of injury: direct blow 26.7%, fall on elbow 40%, fall from height 10%, road traffic accident 23.3% Side: 15 right side, 15 left side Fracture population: 16 (53.3%) transverse fractures, 14 (46.7%) oblique fractures Inclusion criteria: displaced transverse or oblique fracture of the olecranon Exclusion criteria: people with comminuted, avulsion fractures or fracture dislocations All participants were included in the final analysis	
Interventions	1. Intervention group: intramedullary screw plus tension band fixation (n = 15) 2. Control group: standard AO tension band wiring (n = 15) All participants had their arms put in an arm sling except those with less rigid intraoperative fixation who were put in a back slab. Gentle active exercises were started gradually after removal of stitches	
Outcomes	Mean follow-up: 8.2 months (range 6-14 months) 1. Modified Murphy scoring system 2. Adverse events: hardware prominence and infection 3. Loss of range of motion	
Notes	The following description was largely copied from Ahmed 2008 Operative technique for the intervention group: using a dorsal longitudinal incision and exposure of the fracture site, reduction was done using 2 reduction forceps. A small stab was made in the triceps aponeurosis then a drill hole was made in the olecranon passing towards the medullary canal of the ulna, tapping was done through the drill hole; the tap was used to determine the screw length at which the tap got 2 or 3 turns of solid cortical contact in the distal medullary canal. A 6.5-mm cancellous screw with a washer was inserted through the drill hole leaving about 1 cm outside to pass the stainless steel wire around it. A 2.5-mm transverse hole was drilled in the posterior cortex of the distal fragment about 2 cm from the fracture site, then a figure of 8 loop was applied deep to the triceps aponeurosis and around remaining part of the screw	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement

Ahmed 2008 (Continued)

Random sequence generation (selection bias)	High risk	Participants were randomly divided into 2 groups of equal number where participants with odd numbers were allocated to the control group and participants with even numbers allocated to the intervention group
Allocation concealment (selection bias)	High risk	Quasi-randomised: hence, allocation was not concealed
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	High risk	Unclear whether outcome assessors were blinded to treatment allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	All participants were included in the final analysis
Selective reporting (reporting bias)	Unclear risk	No access to trial protocol
Other bias	Unclear risk	There were potentially important imbalances in the baseline characteristics. Similar care programmes were applied although varied according to perceived postoperative fracture stability

Chen 2013

Methods	Study design: RCT Method of randomisation: participants were randomised to intervention groups (no further details) Setting: Changhai Hospital, Shanghai, China Study period: May 2004 to December 2009
Participants	40 adults with olecranon fractures requiring surgical fixation Mean age: 48.4 years (range 21-77 years) (or 49.4 years if using data in text rather than table 2 in trial report) Sex: 22 men, 18 women Mechanism of injury: fall 57.5%, road traffic accident 32.5%, sports injury 5%, falling objects 5% Fracture type: 19 Mayo type IIA, 10 Mayo type IIB, 8 Mayo type IIIA, 3 Mayo type IIIB (data from text) (see footnote for explanation) Inclusion criteria: closed Mayo classification type II/III olecranon fractures, transverse or slight oblique fracture, no neurovascular compromise, stable vital signs, written consent Exclusion criteria: Mayo type I fracture, non-traumatic fractures, severe comminution,

	old fractures, or participants with psychological and social conditions with poor compliance All participants were included in the final analysis
Interventions	1. Intervention group: OMC fixation (see Notes section below) (n = 20) 2. Control group: locking plate fixation (n = 20) Postoperatively: all participants were given antibiotics after surgery as per local protocol. Cast immobilisation applied for 2 weeks followed by rehabilitation with gentle elbow flexion and extension started
Outcomes	Mean follow-up: 36.65 months (range 24-56) (taken from text of report) 1. MEPS 2. Disabilities of the Arm, Shoulder and Hand Score (DASH) 3. Complications 4. Participant satisfaction
Notes	The following description was largely copied from Chen 2013 . OMC: the OMC was designed on the basis of the anatomical structure of the olecranon and manufactured from 1.8-2.5 mm thick Ni-Ti shape memory alloy plate. It was composed of an intramedullary fixing lock, a base arc and 2 compression fixing arms. Depending on material properties, the memory direction of OMC is set as a 1-way memory in order to obtain the largest memory kinetic energy. The transition temperature was set between 28 °C and 33 °C, so that memory kinetic energy and elastic force were produced during transition from plastic deformation phase in low temperature (martensite phase) to previous shape in high temperature (austenite phase), which can continuously provide lateral compressive force. The OMC was cooled with ice for 2-4 minutes before implantation. A hole was drilled at the tip of olecranon, where the intramedullary fixing lock was inserted parallel to the ulnar. Then 2 holes were drilled at the ulnar diaphysis with a hole on each side, consistent with the head hook of the compression fixing arm. The OMC was fixed to the olecranon automatically with warm water after inserting the head hooks into the ulnar diaphysis

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants were "randomly divided" into treatment groups - no further details
Allocation concealment (selection bias)	Unclear risk	Unclear whether the allocation was concealed
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	Low risk	All clinical assessment in this research was done by independent observers. "All assessors who evaluated the postoperative

		function were blinded by means of a randomised block design”
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	All participants were included in the final analysis and completed the follow-up. However, there were some small discrepancies in the reporting of baseline characteristics, timing of follow-up and MEPS
Selective reporting (reporting bias)	Unclear risk	None noted. No access to trial protocol
Other bias	Unclear risk	Both groups were similar at baseline and were provided with similar rehabilitation. However, the OMC was designed by the study authors and, while they claim no conflict of interest, it is uncertain whether this could be a source of bias

Hume 1992

Methods	Study design: RCT Method of randomisation: no details Setting: Los Angeles Medical Centre, California, US Study period: 1 January 1986 to 1 January 1987
Participants	41 participants with displaced olecranon fractures requiring surgical fixation Mean age: 30.9 years (range 18-67 years) Sex: 30 men, 11 women Mechanism of injury: fall 35%, direct blow 47%, road traffic accident 18% Side: 25 non-dominant side, 16 dominant side; 1 participant had bilateral olecranon fractures Fracture population: 3 simple reverse oblique, 11 simple transverse, 15 simple oblique and 12 comminuted; 4 participants had open fractures; 2 in each group Inclusion criteria: involvement of at least 1 cm of the olecranon, fracture extension into the semilunar notch, and articular displacement of at least 1 mm Exclusion criteria: small avulsion fractures not amenable to internal fixation, fractures associated with injury to the radial head or distal humerus All participants were included in the final analysis
Interventions	1. Intervention group: plate fixation (n = 22). Plate fixation: 1/3 tubular plate with 3.5-mm screws used, plate contoured along the posterior surface of the proximal ulna and olecranon. Lag screws were used when possible across the fracture line to obtain interfragmentary compression 2. Control group: standard tension band wiring (n = 19). After reduction, 2 parallel 1.5 mm K-wires were introduced; 18-gauge wire was used to form a figure of 8 loop. After tightening, the protruding wire ends were bent at least 90° Postoperative care: long arm cast splint used for 2-3 days then active flexion and extension were encouraged for all participants

Outcomes	Mean follow-up: 28.5 weeks (range 16-86 weeks) 1. Helm criteria (Appendix 6) 2. Postoperative complications 3. Range of motion loss 4. Operation time	
Notes	All procedures performed according the standard techniques	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomised to treatment groups, no further details
Allocation concealment (selection bias)	Unclear risk	Unclear whether the allocation was concealed
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no report of measures taken to blind outcome assessment
Incomplete outcome data (attrition bias) All outcomes	High risk	All participants completed the follow-up. However, follow-up spanned several years, which could have been a source of bias. In addition, no information was given on participant with bilateral fractures. There was also some discrepancies in the reporting of infection
Selective reporting (reporting bias)	Unclear risk	None noted. No access to trial protocol
Other bias	Low risk	It was reported that the groups were similar at baseline. In addition, there was similar postoperative care

Juutilainen 1995

Methods	Study design: RCT Methods of randomisation: not reported Settings: Helsinki University Central Hospital, Finland Study period: 1982 “through” 1984	
Participants	25 adults with closed olecranon fractures Mean age: 49.8 years (range 17-85 years) Sex: 8 men and 17 women Side of fracture: 12 right sided and 13 left sided Mechanism of injury: no details Fracture population: no details aside from inclusion criteria Inclusion criteria: participants > 16 years of age with closed olecranon fractures; transverse or oblique fractures in 2 or 3 parts without additional fragmentation Exclusion criteria: participants with mental illness or chronic alcoholism All participants were included in the final analysis	
Interventions	1. Intervention group: biodegradable wire and screw tension band wiring (n = 15). A special biodegradable wire made of self reinforced poly-L-lactide acid (SR-PLLA) was developed. The length of the wire was 50 cm and the diameter, 0.5 or 0.9 mm. This wire was used together with self reinforced polyglycolide acid (SR-PGA) screws or SR-PLLA plugs 2. Control group: standard tension band wiring (n = 10). 2 K wires and metal cerclage wire Postoperatively, participants wore a splint for 4 weeks, and slight elbow movements (75°-95°) were allowed. Stitches were removed after 2 weeks All metallic implants were removed 1 year after the primary operation	
Outcomes	Mean follow-up: 19.7 months (range 6-24 months) 1. Clinical improvement: was considered as 'Good' or 'Poor'. Objective assessment of 'good': participant had good functional movement and the joint was stable. Subjective assessment of good: participant could move the fractured side 6 months after operation without pain and the use of the elbow was practically the same on both sides. Poor: otherwise 2. Pain: painful or painless 3. Range of movement: normal or restricted	
Notes	The trial also included 9 participants with patella fractures	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants were randomised to 2 groups - no further details
Allocation concealment (selection bias)	Unclear risk	Unclear whether the allocation was concealed

Juutilainen 1995 (Continued)

Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no report of measures taken to blind outcome assessment
Incomplete outcome data (attrition bias) All outcomes	Low risk	All participants were included in the final analysis, all participants completed the follow-up
Selective reporting (reporting bias)	Unclear risk	None noted. No access to trial protocol
Other bias	Unclear risk	It is unclear whether both groups were similar at baseline

Larsen 1987

Methods	Study design: quasi-RCT Method of randomisation: participants were divided to intervention groups according to whether they were admitted on even or odds days Setting: Gentofte Hospital, University of Copenhagen, Denmark Study period: 1982 “through” 1984
Participants	46 participants with displaced olecranon fractures requiring surgical fixation Median age: 60 years (men); 67 years (women) (range 16-87 years) Sex: 14 men and 32 women Side: not stated Mechanism of injury: no details Fracture population: 26 transverse, 5 oblique, 15 comminuted Inclusion criteria: olecranon fracture Exclusion criteria: no details All participants were included in the final analysis
Interventions	1. Intervention group: modified tension band wiring using Netz pins (n = 21): Netz pins are non-sliding pins made of stainless steel, diameter 2.0 mm, available from 60-120 mm in length; they have a lancet-shaped point and a hole of 1.1 mm at the base for introduction of the cerclage wire 2. Control group: standard tension band wiring (n = 25) To prevent the cerclage wire from sliding off, the K-wires at the tip were bent 180° Postoperative care: not stated
Outcomes	Follow-up: until fracture healing and elbow range of motion was considered stationary, median 13 weeks (range 4-54 weeks) 1. Intraoperative complications 2. Postoperative complications (reasons for removal of devices) 3. Time to fracture healing and range of motion stabilisation

Larsen 1987 (Continued)

Notes		
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Participants were divided to intervention groups according to whether they were admitted on even or odds days
Allocation concealment (selection bias)	High risk	Allocation was very unlikely to be concealed in a quasi-RCT
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	High risk	There was no report of measures taken to blind outcome assessment
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	All participants were included in the analysis but variable timing of follow-up based on assessment of fracture healing and achievement of maximum range of motion. No criteria for these given
Selective reporting (reporting bias)	Unclear risk	No access to trial protocol
Other bias	Unclear risk	Although the groups were balanced by fracture type, the comparability of other baseline characteristics was not established. No information on postoperative care

Liu 2012

Methods	<p>Study design: RCT</p> <p>Methods of randomisation: participants' fractures were classified according to the Mayo classification system, then randomly divided into 2 groups using an adaptive biased coin design to protect against prognostic imbalance between the groups. Randomisation was carried out by a research assistant once eligible participants admitted, the result was placed in a sealed envelope, both doctors and participants were blinded to the participant's group until the envelope was opened after signing the consent form</p> <p>Settings: 2 university hospitals, Beijing, China</p> <p>Study period: June 2007 to December 2010</p>
---------	---

Participants	62 participants with closed olecranon fractures Mean age: 47 years (range 20-70 years) Sex: 30 men, 32 women Mechanism of injury: fall 55%, road traffic accident 36%, sports injury 8% Fracture population: 50 Mayo type IIA, 12 Mayo type IIIA fractures (see footnote for explanation) Inclusion criteria: aged 20-70 years, with transverse or slight oblique olecranon fractures that were fresh, closed and 2 mm above displacement Exclusion criteria: non-traumatic fracture, serious comminuted fracture, other fractures or injuries that could affect elbow joint function or postoperative function exercise All participants were included in the analysis	
Interventions	1. Intervention group: modified tension band wiring using cable pin system (n = 30) 2. Control group: standard tension band wiring (n = 32) Postoperatively, the elbow was secured in a sling flexed to 90° for 2 days, active flexion and gravity-assisted extension were initiated afterwards	
Outcomes	Mean follow-up: 21 months (range 12-36) 1. MEPS 2. Postoperative complications 3. Operation time 4. Intraoperative blood loss	
Notes	<p>The following description was largely copied from Liu 2012.</p> <p>Cable pin system Zimmer® (CPS): 2 x 4.0-mm diameter, specially sharpened, partially threaded cancellous lag screws (pin length 35-60 mm). The tail of the pin was connected to a stainless steel multi-filament cable (diameter 1.3 mm, length 448 mm) and the other end of the cable was attached to a smooth shank end, which was used as a leader needle</p> <p>Operative technique: 2.5-mm-diameter drill bit was used to drill the holes, the first hole was drilled from the proximal end of the olecranon across the fracture site. The hole depth was measured and a pin of appropriate length was chosen. Next, the threaded portion of the pin was drilled across the fracture site through the hole until the tail was slightly countersunk into the bone. A second 2.5-mm-diameter hole was drilled parallel to the first, and the second pin was drilled across the fracture site in a similar manner to the first. The third drill hole was created perpendicular to the long axis of the ulna and posterior to the pins, at the same or slightly longer distance from the fracture site as the tip of the olecranon (usually 3-4 cm distal to the fracture site). The 2 cables connecting the pins were crossed in a figure of 8 over the posterior surface of the olecranon. The leader needle of 1 cable was passed through the perpendicular drill hole (the third hole) in the ulna and pulled out. The free ends of the 2 cables were passed in opposite directions through a crimp, and the cables were adjusted by turning the button on the tensioning handle. When the appropriate tension was achieved, the arms of the tensioning handle were squeezed to secure the crimp</p>	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement

Random sequence generation (selection bias)	Low risk	Participants were randomly divided into 2 groups using an adaptive biased coin design
Allocation concealment (selection bias)	Low risk	Sealed envelope containing the randomisation were opened immediately after the consent form was signed
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding was practical for surgeons. There was no mention of blinding for the participants
Blinding of outcome assessment (detection bias) All outcomes	Low risk	An independent group of physicians (not involved in the initial fracture treatment and blinded to the fixation method) evaluated the clinical outcomes of all participants
Incomplete outcome data (attrition bias) All outcomes	Low risk	All participants were included in the final analysis, all participants completed the follow-up
Selective reporting (reporting bias)	Unclear risk	No access to trial protocol
Other bias	Low risk	Both groups were similar at baseline with no major differences in baseline characteristics. In addition, there was similar post-operative care

K wires: Kirschner wires; MEPS: Mayo Elbow Performance Score; n: number; OMC: olecranon memory connector; RCT: randomised controlled trial.

Mayo classification: type I fractures are undisplaced, type II are displaced and stable, and type III are displaced and unstable. Each is divided into subtype A (non-comminuted) or B (comminuted).

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Frankle 1996	Study design: RCT Participants: older women with complex elbow fractures including distal humerus fractures. No isolated olecranon fractures Interventions: primary total elbow replacement versus open reduction and internal fixation
Gartsman 1981	Study design: historical cohort study

(Continued)

Hamid 2010	Study design: RCT Participants: people with intra-articular distal humeral fracture or a fracture-dislocation of the elbow with proximal radial or ulnar (or both) fractures were included Interventions: single-fraction radiotherapy postoperatively versus no radiotherapy for prevention of heterotopic ossification
Hope 1991	Study design: RCT Participants: children with displaced elbow fractures
Jaskulka 1991	Study design: concurrent cohort study
Karlsson 2002	Study design: historical cohort study
Lan 2013	Study design: retrospective comparison
Ma 2012	Study design: case-control study
Miyagi 1985	Study design: non-controlled clinical trial
Mullett 2000a	Study design: historical cohort study
Mullett 2000b	Study design: historical cohort study
Murphy 1987	Study design: non-controlled clinical trial
Partio 1992	Study design: historical cohort study
Schliemann 2014	Study design: retrospective comparison
Teasdall 1993	Study design: non-controlled clinical trial

RCT: randomised controlled trial.

Characteristics of studies awaiting assessment *[ordered by study ID]*

[Sui 2008](#)

Methods	Comparative study
Participants	63 participants with olecranon fractures, 41 males and 22 females, mean age 49.6 years (range 15-67)
Interventions	Plate fixation (n = 28) versus tension band wiring (n = 35)

Sui 2008 (Continued)

Outcomes	Follow-up: 6-15 months for all participants PANG Gui-gen criteria used as 'Excellent', 'Good', 'Fair' and 'Bad'. The breakdown results as reported in the English abstract did not add up
Notes	Article in Chinese with English abstract, it is unclear from the abstract whether this was a randomised or quasi-randomised comparative trial. Attempts made to contact the corresponding author (xujie-102@sohu.com; contacted December 2012, November 2013), without success

n: number.

Characteristics of ongoing studies [ordered by study ID]

NCT01391936

Trial name or title	A prospective randomised trial of plate fixation versus tension band wire for olecranon fractures
Methods	Allocation: randomised Intervention model: parallel assignment Masking: single blind (outcomes assessor)
Participants	67 participants with displaced olecranon fractures
Interventions	Plate fixation versus tension band wiring
Outcomes	Primary outcome measures <ul style="list-style-type: none"> Participant-rated outcome measure - Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire at 1 year post injury/surgery Secondary outcome measures <ul style="list-style-type: none"> Mayo Elbow Performance Score (MEPS) Range of motion at the elbow and forearm Pain assessment Radiographic assessment Time taken to return to activities
Starting date	September 2010
Contact information	Andrew D Duckworth, MSc, MRCSEd Royal Infirmary of Edinburgh Tel: 07769701875 andrew.duckworth@yahoo.co.uk
Notes	Follow-up completed: September 2014 Number of participants and completed of follow-up information from conversation with Mr Duckworth (17 September 2014)

DATA AND ANALYSES

Comparison 1. Plate fixation versus tension band wiring

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Good clinical outcome (little pain or loss of elbow motion: Helm criteria) 16-86 weeks follow-up	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
2 Adverse events	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
2.1 Metal prominence	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2.2 Delayed or non-union	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2.3 Heterotopic ossification	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]

Comparison 2. Intramedullary screw plus tension band wiring (TBW) versus tension band wiring

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Functional assessment (Modified Murphy Scoring System)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2 Murphy score (including function, pain, loss of movement, joint space): excellent or good result	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3 Adverse events	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3.1 Hardware prominence	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
3.2 Infection	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
4 Loss in flexion > 20°	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Comparison 3. Biodegradable wire and screw versus metal wires tension band wiring

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Good clinical outcome: objective clinical improvement 6-24 months follow-up	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1 Subjective assessment: move elbow freely without pain, same use as other elbow	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]

1.2 Objective assessment: good functional movement and stable elbow	1	Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
2 Painless elbow joint	1	Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3 Normal range of movement	1	Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Comparison 4. Netz pins versus K-wires tension band wiring (TBW)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Adverse events (4-54 weeks follow-up)	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1 Metalwork removed (all reasons, including 'routine')	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
1.2 Metalwork removed because of symptoms (pin/ cerclage affecting skin; pain)	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
1.3 Superficial infection	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
1.4 Intraoperative complications	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]

Comparison 5. Cable pin system (CPS) versus tension band wiring (TBW)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Mayo Elbow Performance Score 12-36 months follow-up	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2 Postoperative complications	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3 Operation time and blood loss	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3.1 Operation time (minutes)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]
3.2 Intraoperative blood loss (mL)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]

Comparison 6. Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Disabilities of the Arm, Shoulder and Hand Score (DASH) (0-100: 100 = worst outcome) at 2-5 years	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2 Mayo Elbow Performance Score (0-100: 100 = best outcome) at 2-5 years	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3 Adverse events	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3.1 Any adverse event	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
3.2 Superficial infection	1		Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
4 Range of elbow motion	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1 Flexion (°)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]
4.2 Extension (°)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]
4.3 Pronation (°)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]
4.4 Supination (°)	1		Mean Difference (IV, Fixed, 95% CI)	0.0 [0.0, 0.0]
5 Participant dissatisfaction	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 1.1. Comparison 1 Plate fixation versus tension band wiring, Outcome 1 Good clinical outcome (little pain or loss of elbow motion: Helm criteria) 16-86 weeks follow-up.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 1 Plate fixation versus tension band wiring

Outcome: 1 Good clinical outcome (little pain or loss of elbow motion: Helm criteria) 16-86 weeks follow-up

Analysis 1.2. Comparison 1 Plate fixation versus tension band wiring, Outcome 2 Adverse events.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 1 Plate fixation versus tension band wiring

Outcome: 2 Adverse events

(1) both had had debridement for infection

(2) Participant developed ulnar neuropathy subsequently

Analysis 2.1. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 1 Functional assessment (Modified Murphy Scoring System).

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring

Outcome: 1 Functional assessment (Modified Murphy Scoring System)

Analysis 2.2. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 2 Murphy score (including function, pain, loss of movement, joint space): excellent or good result.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring

Outcome: 2 Murphy score (including function, pain, loss of movement, joint space): excellent or good result

Analysis 2.3. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 3 Adverse events.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring

Outcome: 3 Adverse events

Analysis 2.4. Comparison 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring, Outcome 4 Loss in flexion > 20°.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 2 Intramedullary screw plus tension band wiring (TBW) versus tension band wiring

Outcome: 4 Loss in flexion > 20

Analysis 3.1. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 1 Good clinical outcome: objective clinical improvement 6-24 months follow-up.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 3 Biodegradable wire and screw versus metal wires tension band wiring

Outcome: 1 Good clinical outcome: objective clinical improvement 6-24 months follow-up

Analysis 3.2. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 2 Painless elbow joint.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 3 Biodegradable wire and screw versus metal wires tension band wiring

Outcome: 2 Painless elbow joint

Analysis 3.3. Comparison 3 Biodegradable wire and screw versus metal wires tension band wiring, Outcome 3 Normal range of movement.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 3 Biodegradable wire and screw versus metal wires tension band wiring

Outcome: 3 Normal range of movement

Analysis 4.1. Comparison 4 Netz pins versus K-wires tension band wiring (TBW), Outcome 1 Adverse events (4-54 weeks follow-up).

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 4 Netz pins versus K-wires tension band wiring (TBW)

Outcome: 1 Adverse events (4-54 weeks follow-up)

(1) I was an intra-operative fracture; in the other, one Netz pin "fell" in the intramedullary nail during removal

Analysis 5.1. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 1 Mayo Elbow Performance Score 12-36 months follow-up.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 5 Cable pin system (CPS) versus tension band wiring (TBW)

Outcome: 1 Mayo Elbow Performance Score 12-36 months follow-up

Analysis 5.2. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 2 Postoperative complications.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 5 Cable pin system (CPS) versus tension band wiring (TBW)

Outcome: 2 Postoperative complications

Analysis 5.3. Comparison 5 Cable pin system (CPS) versus tension band wiring (TBW), Outcome 3 Operation time and blood loss.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 5 Cable pin system (CPS) versus tension band wiring (TBW)

Outcome: 3 Operation time and blood loss

Analysis 6.1. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 1 Disabilities of the Arm, Shoulder and Hand Score (DASH) (0-100: 100 = worst outcome) at 2-5 years.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome: 1 Disabilities of the Arm, Shoulder and Hand Score (DASH) (0-100: 100 = worst outcome) at 2-5 years

Analysis 6.2. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 2 Mayo Elbow Performance Score (0-100: 100 = best outcome) at 2-5 years.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome: 2 Mayo Elbow Performance Score (0-100: 100 = best outcome) at 2-5 years

Analysis 6.3. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 3 Adverse events.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome: 3 Adverse events

(1) Just one infection. There was no nonunion, avascular necrosis or other implant-related complication

Analysis 6.4. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 4 Range of elbow motion.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome: 4 Range of elbow motion

Analysis 6.5. Comparison 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation, Outcome 5 Participant dissatisfaction.

Review: Surgical interventions for treating fractures of the olecranon in adults

Comparison: 6 Nickel-titanium olecranon memory connector (OMC) versus locking plate fixation

Outcome: 5 Participant dissatisfaction

APPENDICES

Appendix I. Search strategies

Cochrane Central Register of Controlled Trials (CENTRAL)

- #1 MeSH descriptor: [Olecranon Process] explode all trees (3)
- #2 olecranon*:ti,ab,kw (25)
- #3 #1 or #2 (25)
- #4 MeSH descriptor: [Fractures, Bone] this term only (1196)
- #5 MeSH descriptor: [Fracture Fixation] explode all trees (1248)
- #6 MeSH descriptor: [Fracture Healing] this term only (402)
- #7 fractur*:ti,ab,kw (9806)
- #8 #4 or #5 or #6 or #7 (9810)
- #9 #3 and #8 (14) [trials]

MEDLINE (Ovid Online)

- 1 Olecranon Process/ (154)
- 2 olecranon*.tw. (1517)
- 3 or/1-2 (1536)
- 4 Fractures, Bone/ or exp Fracture Fixation/ or Fracture Healing/ (89,293)
- 5 fractur*.tw. (178,797)
- 6 or/4-5 (203,618)
- 7 and/3,6 (890)
- 8 Randomized controlled trial.pt. (388,776)
- 9 Controlled clinical trial.pt. (89,842)
- 10 randomized.ab. (308,669)
- 11 placebo.ab. (159,706)
- 12 Drug therapy.fs. (1,744,944)
- 13 randomly.ab. (222,781)
- 14 trial.ab. (321,451)
- 15 groups.ab. (1,405,245)
- 16 or/8-15 (3,447,063)
- 17 exp Animals/ not Humans/ (4,011,377)
- 18 16 not 17 (2,960,678)
- 19 and/7,18 (62)

EMBASE (Ovid Online)

- 1 Olecranon Fracture/ (598)
- 2 Olecranon/ (356)
- 3 olecranon*.tw. (1744)
- 4 or/2-3 (1826)
- 5 exp Fracture Treatment/ or exp Fracture/ (234,864)
- 6 fractur*.tw. (210,718)
- 7 or/5-6 (293,596)
- 8 and/4,7 (1038)
- 9 or/1,8 (1216)
- 10 Randomized controlled trial/ (352,502)
- 11 Clinical trial/ (838,245)
- 12 Controlled clinical trial/ (387,095)
- 13 Randomization/ (63,274)
- 14 Single blind procedure/ (18,833)
- 15 Double blind procedure/ (117,924)
- 16 Crossover procedure/ (40,233)
- 17 Placebo/ (258,577)
- 18 Prospective study/ (261,871)
- 19 ((clinical or controlled or comparative or placebo or prospective* or randomi#ed) adj3 (trial or study)).tw. (784,191)
- 20 (random* adj7 (allocat* or allot* or assign* or basis* or divid* or order*)).tw. (190,578)
- 21 ((singl* or doubl* or trebl* or tripl*) adj7 (blind* or mask*)).tw. (169,613)
- 22 (cross?over* or (cross adj1 over*)).tw. (72,540)
- 23 ((allocat* or allot* or assign* or divid*) adj3 (condition* or experiment* or intervention* or treatment* or therap* or control* or group*)).tw. (251,675)
- 24 RCT.tw. (14,794)
- 25 or/10-24 (1,956,486)
- 26 Case Study/ or Abstract Report/ or Letter/ (948,253)
- 27 25 not 26 (1,917,135)
- 28 and/9,27 (94)

Current Controlled Trials

Search: olecranon

Total = (9)

ClinicalTrials.gov

Search: olecranon

Total = 9

World Health Organization (WHO) International Clinical Trials Registry platform

Search: olecranon

Total = 8

Appendix 2. Cable pin system (CPS)

Cable pin system Zimmer®: 2 x 4.0-mm diameter, specially sharpened, partially threaded cancellous lag screws (pin length 35-60 mm). The tail of the pin is connected to a stainless steel multi-filament cable (diameter 1.3 mm, length 448 mm) and the other end of the cable is attached to a smooth shank end, which is used as a leader needle.

Operative technique: 2.5-mm-diameter drill bit was used to drill the holes, the first hole was drilled from the proximal end of the olecranon across the fracture site. The hole depth was measured and a pin of appropriate length was chosen. Next, the threaded portion of the pin was drilled across the fracture site through the hole until the tail was slightly countersunk into the bone. A second 2.5-mm-diameter hole was drilled parallel to the first, and the second pin was drilled across the fracture site in a similar manner to the first. The third drill hole was created perpendicular to the long axis of the ulna and posterior to the pins, at the same or slightly longer distance from the fracture site as the tip of the olecranon (usually 3-4 cm distal to the fracture site). The 2 cables connecting the pins were crossed in a figure of 8 over the posterior surface of the olecranon. The leader needle of 1 cable was passed through the perpendicular drill hole (the third hole) in the ulna and pulled out. The free ends of the 2 cables were passed in opposite directions through a crimp, and the cables were adjusted by turning the button on the crimper tensioning handle. When the appropriate tension was achieved, the arms of the crimper tensioning handle were squeezed to secure the crimp.

Appendix 3. Disabilities of the Arm, Shoulder, and Hand Score (DASH)

The DASH questionnaire is a regional outcome measure suitable for people with musculoskeletal conditions of the upper limb and consists of 30 items ([Hudak 1996](#)).

DASH score assesses 6 domains: daily activities, symptoms, social function, work function, sleep and confidence. Each item in the daily activities domain is scored on a 5-point scale, from 'no difficulty' to 'unable to do'. The other domains are also scored on a 5-point scale.

The total score ranges from 0 (no disability) to 100 (severe disability).

Appendix 4. Mayo Elbow Performance Score (MEPS)

Pain: scale with a maximum of 45 points ([Morrey 1995](#)): 45 = no pain; 30 = mild pain; 15 = moderate pain; 0 = severe pain

Movement scale: maximum 20 points: 30 = arc > 100°; 15 = arc 50-100°; 5 = arc < 50°

Stability scale: maximum of 10 points: 10 = stable; 5 = moderately unstable; 0 = grossly unstable

Functions of daily living: scale with a maximum of 25 points: 5 points each for being able to comb hair, feed oneself, perform personal hygiene, put on a shirt and put on shoes

MEPS total score is graded as: ≥ 90 points = excellent; 75-89 points = good; 60-74 points = fair; < 60 point = poor.

Appendix 5. Modified Murphy Scoring System

Modified Murphy Scoring System consists of 4 domains - pain, function, range of movement and joint space - with a total score of 4-19 points: 18-19 points = excellent; 17 points = good; 16 points = fair; < 16 points = poor (Murphy 1987).

Appendix 6. Helm criteria

The Helm criteria include pain, range of movement and revision surgery for operative failure (Helm 1987). No more than slight or occasional pain, loss of movement of < 15° at the elbow = good; occasional to moderate pain, loss of movement 15-30° at the elbow = fair; constant pain, loss of movement > 30° at the elbow or operative failure needing revision surgery - poor.

CONTRIBUTIONS OF AUTHORS

HM: conceived the review, designed and wrote the protocol, assessed studies, extracted and analysed data, wrote the review. HM is also the guarantor of the review.

AA: provided general advice on drafts of the protocol and review.

SB: provided general advice on drafts of the protocol and review.

NG: provided general advice on drafts of the protocol and review.

HA: conceived the review, designed and wrote the protocol, assessed studies, extracted and analysed data, helped in writing the review.

DECLARATIONS OF INTEREST

Hosam E Matar: none known.

Amjid A Ali: none known.

Simon Buckley: none known.

Nicholas I Garlick: none known.

Henry D Atkinson: none known.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

There were no differences between the protocol and the review.

INDEX TERMS

Medical Subject Headings (MeSH)

Fracture Fixation [instrumentation; *methods]; Olecranon Process [*injuries]; Randomized Controlled Trials as Topic; Treatment Outcome; Ulna Fractures [*surgery]

MeSH check words

Adolescent; Adult; Aged; Aged, 80 and over; Female; Humans; Male; Middle Aged