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# The Bone & Joint Journal

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## **Elbow replacement research methods, outcome domains and instruments in clinical outcome studies: a scoping review**

Journal:	<i>The Bone &amp; Joint Journal</i>
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Manuscripts

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3 Title: Elbow replacement research methods, outcome domains and instruments in clinical  
4 outcome studies: a scoping review  
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## 8 Abstract

### 9 Aim

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11 Prosthetic joint replacement of the elbow including total elbow replacement,  
12 hemireplacement, radial head replacement and radiocapitellar replacement, are rare  
13 procedures. This scoping review aims to map current research to inform the development of  
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15 future research.  
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### 20 Materials and Methods

21 A scoping review was undertaken adhering to the Joanna Briggs Institute (JBI) guidelines  
22 using Medline, Embase, CENTRAL and trial registries limited to studies published between  
23 1<sup>st</sup> January 1990 and 7<sup>th</sup> February 2021. Endnote software was used for screening and  
24 selection and was limited to randomised trials, non-randomised controlled trials, prospective  
25 and retrospective cohort studies, case-control studies, analytical cross-sectional studies and  
26 case series of ten patients or more reporting clinical outcomes of elbow replacement. The  
27 results are presented as frequency counts of types of studies reported, sample size, length of  
28 follow up, clinical outcome domains and instruments used, funding sources and a narrative  
29 review.  
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### 39 Results

40 362 studies met the inclusion criteria. The majority were of total elbow replacement (246,  
41 68%), followed by radial head replacement (100, 28%), distal humerus hemireplacement (11,  
42 3%) and radiocapitellar replacement (5, 1%). Most studies were retrospective (326, 90%)  
43 and most were observational (315, 87%).  
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49 The median study sample size for all implant types across all studies was 36 implants. The  
50 median length of follow up for all study types was 56 months. A total of 583 unique outcome  
51 descriptors were used that were categorised into 18 domains. A total of 105 outcome  
52 instruments were used to measure 39 outcomes.  
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### 58 Discussion

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3 This review has found the majority of published research into elbow replacement consists of  
4 retrospective observational studies with small sample sizes and short follow up. A large  
5 number of outcome descriptors were used with a high number of different outcome  
6 instruments employed indicating a need to define a core outcome set for elbow replacement.  
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12 Key words: Arthroplasty, Replacement, Elbow, Outcome, Methods, Funding  
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For Review Only

## **Introduction**

Prosthetic joint replacement (elbow replacement) of all or part of the elbow has been performed routinely for a number of indications since the cemented replacement design of Dee in the 1960's, including inflammatory arthropathy, osteoarthritis, acute trauma, trauma sequelae, instability and (rarely) tumour.(1) The term elbow replacement is often taken to mean total elbow replacement, that is replacement of the distal humerus and proximal ulna with or without the radial head, but also includes distal humerus replacement in isolation (distal humerus hemireplacement), replacement of the capitellum of the humerus and radial head (radiocapitellar replacement) and radial head replacement in isolation. The purpose of elbow replacement is to relieve pain, restore function and quality of life for the patient.

Clinical practice should be underpinned by robust scientific evidence, and randomised controlled trials are viewed as the gold standard method for assessing interventions. Undertaking evaluations of the effectiveness of elbow replacement techniques and devices is challenging as the intervention is relatively rare. The National Joint Registry Annual Report for England, Wales and Northern Ireland reported a total of 834 cases of elbow replacement in the year 2019 (prior to the Covid-19 outbreak) divided between acute trauma (455 cases) and elective indications (379 cases) across 172 units and 249 surgeons.(2) These low numbers mean that innovative approaches to the design and delivery of trials are required to ensure surgical practice is underpinned by high quality evidence.

To inform the development of future research assessing the effects of elbow replacement it is important to have an understanding of the research methods that have been employed. In addition, with uncertainty as to the most appropriate outcomes to use in evaluation of elbow replacement, work is required to determine the outcome domains that have been assessed and the outcome instruments used to support development of a core outcome set as outlined in the COMET handbook.(3) Further, it is important to map the traditional sources of funding for elbow replacement research in order to understand the limitations and opportunities available. This mapping is best undertaken by a scoping review of evidence sources to examine how research is undertaken in this field.(4)

A preliminary search of Pubmed conducted on 28<sup>th</sup> December 2020 for previous systematic or scoping reviews on elbow arthroplasty or replacement identified eight relevant articles.

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3 One of the systematic reviews had been retracted leaving one scoping review and six  
4 systematic reviews.(5)(6)(7)(8)(9)(10)(11) Two studied the clinical outcomes of primary  
5 elbow replacement, two compared the clinical outcome of radial head replacement with  
6 osteosynthesis, one analysed the trends in indication for total elbow replacement and one was  
7 a review of revision of infected primary elbow replacement. The scoping review was also on  
8 the diagnosis and management of infected elbow replacement.(5) An additional internet  
9 search of Google Scholar conducted on 29<sup>th</sup> December 2020 identified a further seven  
10 systematic reviews, six of which reviewed the outcome of total elbow replacement and one  
11 reviewed the causes for failure of elbow replacement.(12)(13)(14)(15)(16)(17)(18) No  
12 systematic or scoping reviews have been identified that map the research methods, outcome  
13 domains and instruments, and funding sources used in elbow replacement research.  
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24 We therefore undertook a scoping review to identify and map the research methods, domains  
25 and outcome instruments used in elbow replacement research of clinical outcomes to inform  
26 future research in this field and to describe the sources of funding used for published elbow  
27 replacement research.  
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### 34 **Review questions**

35 This scoping review addressed the following research questions:

- 36 a) What research methods are used to study the clinical effectiveness of elbow  
37 replacement surgery?
- 38 b) What outcome domains are assessed and which instruments have been used to  
39 evaluate clinical outcomes of elbow replacement surgery?
- 40 c) What funding sources are identified in clinical outcome studies of elbow  
41 replacement?  
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### 50 **Methods**

51 The protocol was developed in accordance with the JBI guidelines(19) and is available online  
52 at Open Science Framework (<https://osf.io/t6qyh/>)  
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### 56 **Eligibility criteria**

57 Studies of adults with a diagnosis of inflammatory arthropathy, osteoarthritis, post-trauma  
58 sequelae, and acute trauma undergoing primary elbow replacement were eligible for  
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3 inclusion. Reports of replacement for tumour or other rare indications were excluded. In-  
4 vitro studies and studies of surgical approaches, biomechanics, health economics and revision  
5 elbow replacement were excluded. Studies of populations with heterogeneous diagnoses  
6 were included as long as at least 90% of the participants had one of the eligible diagnoses.  
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11 The context for the scoping review was all primary elbow replacement studies published  
12 between 1<sup>st</sup> January 1990 and 7<sup>th</sup> February 2021 and any trials on international registries that  
13 met the inclusion criteria. The types of evidence included were randomised trials, non-  
14 randomised controlled trials, prospective and retrospective cohort studies, case-control  
15 studies, analytical cross-sectional studies and case series of ten patients or more published in  
16 the English language. Review articles, surveys, case reports and conference abstracts were  
17 excluded.  
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#### 27 Search strategy

28 An initial limited search of Medline was undertaken to perform an analysis of text words in  
29 titles and abstracts and index terms to inform the full search strategy. A full search was  
30 conducted, with support from an information specialist on 7<sup>th</sup> February 2021 of Medline,  
31 Embase, and CENTRAL using the terms “Elbow Prosthesis”, “Arthroplasty, Replacement,  
32 Elbow”, “Hemiarthroplasty”, “Radial head arthroplasty or replacement” and “Radiocapitellar  
33 arthroplasty or replacement”. This was adapted for the other databases. A search was  
34 conducted of the reference lists of reports selected for inclusion in the review to identify any  
35 additional studies. The reference lists of prior reviews in elbow replacement were also  
36 searched. The ISRCTN Registry and Clinicaltrials.gov websites were reviewed to identify  
37 any ongoing trials meeting the inclusion criteria. No search of grey literature was  
38 undertaken. The full search strategy for Medline is included in table 1.  
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#### 51 Evidence selection

52 Endnote software Version X9; Clarivate Analytics, Philadelphia, PA, USA was used for  
53 management of the results of the search. Duplicates were excluded before initial screening  
54 based on title and abstract was undertaken by two reviewers (AW, ZH) with independent  
55 selection of evidence based on the pre-specified inclusion criteria. The full article of  
56 potentially relevant records were obtained and screened by two reviewers (AW, ZH) to  
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3 identify eligible studies. Where there was disagreement the two reviewers reviewed the  
4 manuscripts together to reach consensus.  
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#### 8 Data extraction 9

10 Pilot testing of a customised excel data extraction tool was undertaken using 25 articles  
11 selected at random and screened by AW and ZH. A meeting was held to review the  
12 screening results to determine whether any changes needed to be made, with 75% agreement  
13 required before the data extraction tool was accepted. Full text screening of the remaining  
14 articles was conducted by AW including citation details (author/s, date, title, journal, volume,  
15 issue, pages), the country in which research has been undertaken, further details of the  
16 research methodology (RCT, non-randomised controlled trials, prospective and retrospective  
17 cohort studies, case-control studies, analytical cross-sectional studies and case series of ten  
18 patients or more), implant studied, population (diagnosis, age and sex), setting, sample size,  
19 length of follow up (minimum, maximum, mean/median), outcome assessed, instruments  
20 used to assess outcomes and funding sources for the research.  
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#### 31 Analysis of the evidence

32 Data were tabulated and key study characteristics described. The planned analyses were  
33 frequency counts of types of studies reported, length of follow up, domains and outcome  
34 instruments used. Where possible, findings were stratified by diagnosis (inflammatory  
35 arthropathy, osteoarthritis, post-trauma sequelae, and acute trauma) and type of elbow  
36 replacement (total elbow replacement, distal humerus hemireplacement, radial head  
37 replacement and radio-capitellar replacement). Outcomes were recorded verbatim from  
38 source and categorised into domains after extractions using the taxonomy described by Dodd  
39 et al.(20) For ease of reporting the most common outcomes for each domain were  
40 rationalised into a common term. For example, in the adverse events domain the outcomes  
41 “pain”, “residual pain”, “proximal forearm pain”, “severe pain” and “post-operative pain”  
42 were recorded in the table as post-operative pain. The instruments were categorised according  
43 to the outcome that the source reported they were being used to assess. No assessment of the  
44 quality of the studies or reporting was undertaken, in keeping with guidelines for scoping  
45 reviews, as the review is not designed to inform clinical decision making.(21) A full list of  
46 included studies and outcomes is available from the corresponding author.  
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## **Results**

The findings of the literature search are reported in a flow chart adhering to the PRISMA-ScR statement and PRISMA-S extension (Figure 1).(22)(23) From a total of 2,197 de-duplicated titles identified from the searches, 402 full text articles were reviewed, of which 40 were excluded for the reasons stated in Figure 1, leaving 362 studies for final inclusion in the scoping review.

### **Scope of included studies**

Of the 362 studies published between 1<sup>st</sup> January 1990 and 7<sup>th</sup> February 2021 the subject of the study was total elbow replacement in 246(68%), radial head replacement in 100(28%), distal humerus hemireplacement in 11(3%) and radiocapitellar replacement in 5(1%). Over this time period there has been an overall increase in the number of publications per annum, although a decrease in the annual number of publications on total elbow replacement has been observed since 2015 (Figure 2). Studies were reported from 34 countries, with one international collaboration. The top ten locations for published English language elbow replacement studies by country are listed in table 2.

The majority of studies were conducted in a hospital setting (329, 91%) with few community-based studies (32, 9%). Most studies were retrospective (326, 91%) and most were observational (321, 89%). There were 23 administrative database studies, 21 of which were conducted in the USA and 8 national implant registry studies from Australia, Denmark (2 studies), Norway, Finland, Sweden and New Zealand. There were 6 prospective randomised controlled trials (RCT),(24)(25)(26)(27)(28)(29) one retrospective review of patients from a previous RCT(30) and three RCT protocols.(31)(32)(33) Two RCT sources described comparison of total elbow replacement to osteosynthesis of distal humerus fractures, one reporting study results at two years and one retrospective review of the same cohort at an average of 12.5 years.(25)(30) One source reports the outcome of total elbow arthroplasty with two different ulna components.(28) Three sources compare the outcome of radial head replacement to osteosynthesis for acute radial head fracture, and one compared radial head replacement to radial head excision.(24)(26)(29)(27) Two protocols described comparison of total elbow replacement to distal humerus hemireplacement for distal humerus fracture, and one protocol was for a study comparing distal humerus hemireplacement to osteosynthesis. (31)(33)(32) None of the RCTs compare elbow replacement to a non-surgical intervention.

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3 Only one RCT had a stated source of funding which was from a commercial source.(25) In  
4 five RCTs it was stated that there was no funding or conflict of interest for the  
5 trial,(32)(24)(30)(27)(28) and for four it was not stated if there was any funding or conflict of  
6 interest.(31)(26)(33)(29) The median sample size by study design is given in table 3.  
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### 10 11 12 Properties of included studies

13 The median study sample size by implant type was 17(range 10 to 44) implants for distal  
14 humerus hemireplacement, 20(range 10 to 31) for radiocapitellar replacement, 32(range 11 to  
15 528) for radial head replacement and 41(range 10 to 56,379) for total elbow replacement.  
16 The indication for surgery by procedure type is presented in table 4. Differences were found  
17 between procedure types in the mean percentage of female study participants and mean age  
18 of participants (Table 5).  
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26 The median of the mean length of follow up for all study types was 56 months(range 1 to 216  
27 months). It was longest for registry studies with a median follow up of 96 months(range 67  
28 to 126 months). The median follow-up in observational case series, which was the largest  
29 group, was 57 months(range 6 to 216 months). For randomised trials the median of the mean  
30 follow-up was 29 months(range 15 to 151 months). The median of the mean reported follow  
31 up for studies of total elbow replacement was 60 months(range 1 to 216 months), for radial  
32 head replacement 42 months(range 10 to 145 months), distal humerus hemireplacement 35  
33 months(range 12 to 82 months) and radiocapitellar replacement 59 months(range 23 to 100  
34 months).  
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### 43 Reported outcomes

44 A total of 583 unique outcome descriptors were used across 362 included studies and were  
45 categorised into 18 domains (Table 6). Many of these outcome descriptors reported the same  
46 outcome using different terms and in 76 cases the outcome instrument was reported without  
47 specification of what was being assessed. The largest group of outcomes are categorised in  
48 the adverse events domain (311, 53%) despite the fact that complications were not a pre-  
49 specified outcome in most studies. The physical function domain contains the second largest  
50 number of outcome descriptors (93, 16%). These can be grouped into four outcomes:  
51 function/disability, range of movement, strength and activities of daily living. Strength was  
52 often poorly defined but most commonly described an assessment of strength of elbow  
53 extension as a measure of triceps function. Radiographic appearance of the elbow was  
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3 assessed by 19 separate outcomes in the musculoskeletal domain including implant  
4 alignment, congruency, fixation, success, lengthening, head size, stem size, stem positioning,  
5 implant positioning, prosthetic sizing, quality of cementing technique, bone graft integration  
6 or incorporation, cortical fit, cement mantle, valgus tilting, congruence of the proximal radio-  
7 ulnar joint, cement technique, and joint congruity.  
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### 13 Outcome instruments

14 A total of 105 outcome instruments were used to measure 39 outcomes, of which 26 were  
15 clinical and 13 were radiographic. The average number of instruments used per outcome  
16 where an instrument was described was 5(range 1 to 26). The list of instruments used to  
17 assess each of the 39 outcomes is provided in table 7. For implant survival the listed  
18 instruments are methods of analysis but are included for completeness. Some instruments are  
19 included in more than one outcome category and may be listed for outcomes and domains  
20 that may seem inappropriate, but these are taken verbatim from the included studies.  
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### 29 Discussion

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32 Randomised controlled trials (RCTs) are considered the gold-standard for evaluation of  
33 healthcare interventions but in orthopaedic surgery the number of RCTs undertaken is  
34 consistently low. A systematic review of orthopaedic literature found that only 20% of  
35 procedures had at least one low risk of bias RCT supporting the operative intervention when  
36 compared to non-operative treatment.(34) We did not identify any for elbow replacement.  
37 Many different reasons have been proposed for this and the cause is likely to be  
38 multifactorial.(35)(36) One of the challenges of performing a randomised trial in some areas  
39 of orthopaedics where the condition is rare is the feasibility of recruiting sufficient  
40 participants to address the research question.  
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50 The European Union defines rare diseases as those with a prevalence of less than 50 per  
51 100,000 population for the purposes of orphan drugs, where normal economic models prevent  
52 research and development.(37) Elbow replacement is a “rare” procedure with an annual  
53 incidence estimated from Scottish data as 1.4 per 100,000 population and the same economic  
54 and scientific challenges apply, with low investment in research and barriers to conventional  
55 frequentist approaches to investigate clinical outcomes due to the feasibility of randomised  
56 controlled trials (RCTs). (38)  
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5 This scoping review has found that the literature on elbow replacement consists largely of  
6 unfunded retrospective observation studies with small sample sizes. It is interesting to note  
7 that the number of studies on total elbow replacement has declined in recent years. The cause  
8 of this is unknown, but it may be due to the contracting usage resulting from improved  
9 medical management of inflammatory joint disease. Only 9 prospective randomised  
10 controlled trials were identified, three of which are protocols of ongoing trials rather than  
11 reports of trial results. The sample size of these RCTs ranges from 20 to a maximum of 60  
12 participants. Only one randomised trial had a stated source of funding, and that funding was  
13 from a commercial body. This review has not identified any RCTs comparing joint  
14 replacement to non-operative treatment in the elbow. It is beyond the scope of this review to  
15 determine the causes for the quality of the evidence but there remain many questions  
16 regarding elbow replacement that require robust unbiased scientific investigation.  
17 Researchers designing future RCTs in elbow arthroplasty will need to explore solutions for  
18 investigation of rare diseases with multi-centre and possibly international collaborations to  
19 ensure sufficient statistical power and exploration of alternative trial designs. The moral  
20 hazard of enrolment of patients into underpowered trials could be avoided through a planned  
21 meta-analysis of duplicate studies.(39) However, this would require co-ordination and  
22 establishment of a musculoskeletal rare intervention trials registry and a mechanism to ensure  
23 data sharing and individual patient data (IPD) meta-analysis.(40)(41) Alternative trial  
24 designs have been explored for investigation of rare diseases including crossover designs, N-  
25 of-1 trials and adaptive designs, but most are not suitable for surgical research due to the  
26 irreversible nature of surgical interventions and the time period required to determine the  
27 outcome of the intervention.(42)(43) Bayesian analysis methods, however, could be used to  
28 exploit all available data to strengthen the findings from smaller RCTs.(44) Appropriate  
29 funding will be required to ensure the successful delivery of these more complicated  
30 investigations and qualitative research may be needed to understand the barriers and  
31 facilitators within the elbow replacement community that may be affecting research practice.  
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53 Alternative approaches to tackling the paucity of information may mean pooling data from  
54 multiple sources. The combination of data for meta-analysis is hindered, however, by the  
55 diversity of outcome domains and instruments used to measure outcomes. The 583 individual  
56 descriptors identified in this scoping review for clinical outcomes of elbow arthroplasty can  
57 be rationalised to 41 outcomes over 18 domains using the taxonomy adopted by the COMET  
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3 initiative, however this is still a large number of domains and it is unclear which of these  
4 might be considered most important by patients, carers and treating clinicians.(20) An  
5 average of five instruments have been used for the 39 outcomes where an outcome instrument  
6 has been described. This review has not sought to analyse the psychometric properties of the  
7 instruments used but rather to map the domains, outcomes and instruments without an  
8 assessment of quality or validity. Once core outcomes have been defined it will be necessary  
9 to undertake an assessment of relevant instruments to determine if any meet the criteria of  
10 truth, discrimination and feasibility.(45)  
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19 This review has highlighted a clear need to define the core outcome domains for elbow  
20 replacement research that can then lead to the development of a set of core outcome  
21 instruments.  
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## Legends

Table 1: Medline search string.

Table 2: The 10 countries with the highest number of recorded publications on elbow replacement (frequency, % of total).

Table 3: Sample size of studies by study type.

Table 4: Primary diagnosis at the time of surgery by type of procedure.

Table 5: Sex and Age of patients included in studies by type of procedure.

Table 6: Reported outcomes categorised by domain.

Table 7: Outcome instruments used in included studies (no assessment of psychometric properties has been conducted). (*ASES – American Shoulder and Elbow Score; DASH – Disabilities of the Arm Shoulder and Hand; HSS – Hospital for Special Surgery; JOA – Japanese Orthopaedic Association; PREE – Patient Rated Elbow Evaluation; SANE – Single Assessment Numeric Evaluation; VAS – visual analogue score; RAND-36 – early version of SF-36; MMSE – Mini-Mental State Evaluation*)

Figure 1. PRISMA flow chart

Figure 2. Histogram of the number of publications per year categorised by type of procedure.

## Table 1.

## Terms for Medline search.

Search Conducted 7<sup>th</sup> February 2021

Ovid MEDLINE(R) ALL <1946 to February 04, 2021>

- 1 Elbow Prosthesis/ or Arthroplasty, Replacement, Elbow/ 485
- 2 (elbow\* adj3 (arthroplast\* or replacement\* or hemiarthroplast\* or  
hemireplacement\*)).tw. 1217
- 3 ((radial head or capitell\*) adj3 (arthroplast\* or replacement\* or  
hemiarthroplast\* or hemireplacement\*)).tw. 453
- 4 1 or 2 or 3 1721
- 5 ((interposition or osteocapsular or arthroscop\*) adj arthroplasty).tw. 430
- 6 4 not 5 1671
- 7 exp animals/ not humans.sh. 4787332
- 8 6 not 7 1653
- 9 limit 8 to yr="1990 -Current" 1480

Table 2.

<b>Country</b>	<b>Number</b>	<b>%</b>
USA	91	25%
UK	52	14%
France	25	7%
Japan	19	5%
Italy	18	5%
Netherlands	18	5%
Canada	16	4%
Germany	16	4%
Sweden	12	3%
Finland	11	3%

Table 3

	<b>Mean</b>	<b>Median</b>	<b>Min</b>	<b>Max</b>
<b>Observational studies</b>	67	32	10	1441
<b>Randomised trial</b>	38	40	20	60
<b>Admin database</b>	7819	1625	176	56379
<b>Registry study</b>	692	584	126	1457

Table 4

	<b>RA</b>	<b>OA</b>	<b>Post Trauma</b>	<b>Acute Trauma</b>	<b>Other</b>
<b>Total elbow replacement</b>	61%	5%	16%	18%	2%
<b>Distal humerus hemireplacement</b>	0%	0%	15%	85%	0%
<b>Radial head replacement</b>	<1%	<1%	12%	87%	<1%
<b>Radiocapitellar replacement</b>	11%	58%	27%	1%	3%

Table 5

	<b>Mean % female</b>	<b>Mean of minimum age in years (range)</b>	<b>Mean of maximum age in years (range)</b>	<b>Mean of mean age in years (range)</b>
<b>Total elbow replacement</b>	76	36 (5-75)	81 (40-97)	61 (28-85)
<b>Distal humerus hemireplacement</b>	85	47 (16-62)	81 (63-90)	67 (45-79)
<b>Radiocapitellar replacement</b>	51	31 (25-40)	74 (69-82)	55 (53-61)
<b>Radial head replacement</b>	46	23 (14-62)	75 (50-93)	49 (31-67)

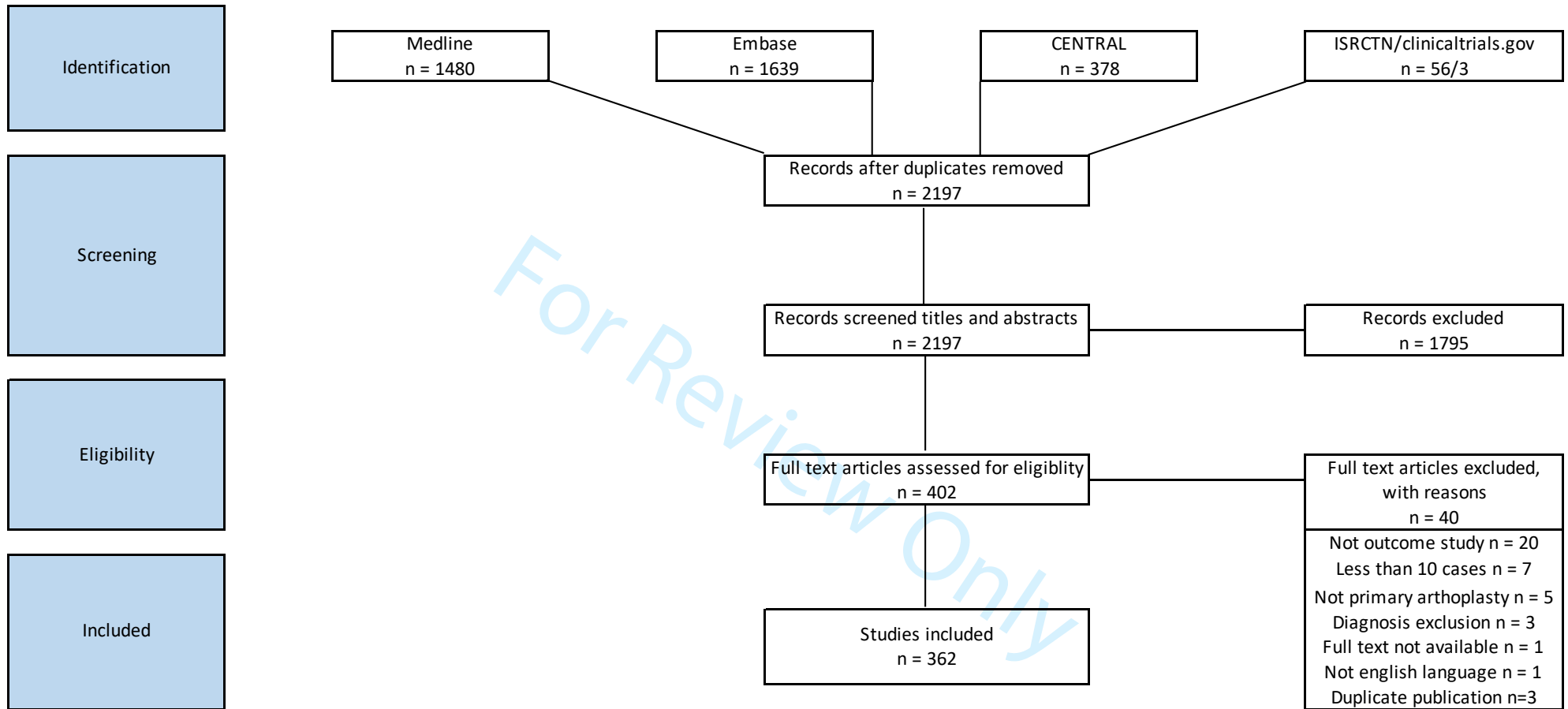
Table 6

Domain	Outcome	
Adverse events (311)	Post-operative pain Radiographic complications Infection Triceps weakness Neurological Effusion/Synovitis	Implant related Wound problems Stiffness Bone problems Transfusion Medical complications
Physical function (93)	Function/disability Range of movement	Strength Activities of daily living
MSK connective tissue (37)	Radiographic appearance Elbow stability	
Need for further intervention (34)	Re-operation Implant revision/survival	
Nervous system (30)	Pain Neurological status	
Delivery of care (15)	Satisfaction	
Social function (13)	Sport participation Social-psychological status	
Hospital resources (11)	Length of stay Re-admission	Return to operating room Length of surgery
Role function (8)	Return to work	
Perceived health (7)	General health	
Economic resource (7)	Hospital costs Non-routine discharge costs	
Mortality /Survival (6)	Mortality	
Psychiatric (3)	Mental health	
Quality of life (2)	Quality of life	
Emotional well-being (2)	Well-being Role emotional	
Cognitive function (1)	Cognitive status	
Personal circumstances (1)	Patient autonomy	
Societal carer burden (1)	Non-homebound discharge	

Table 7

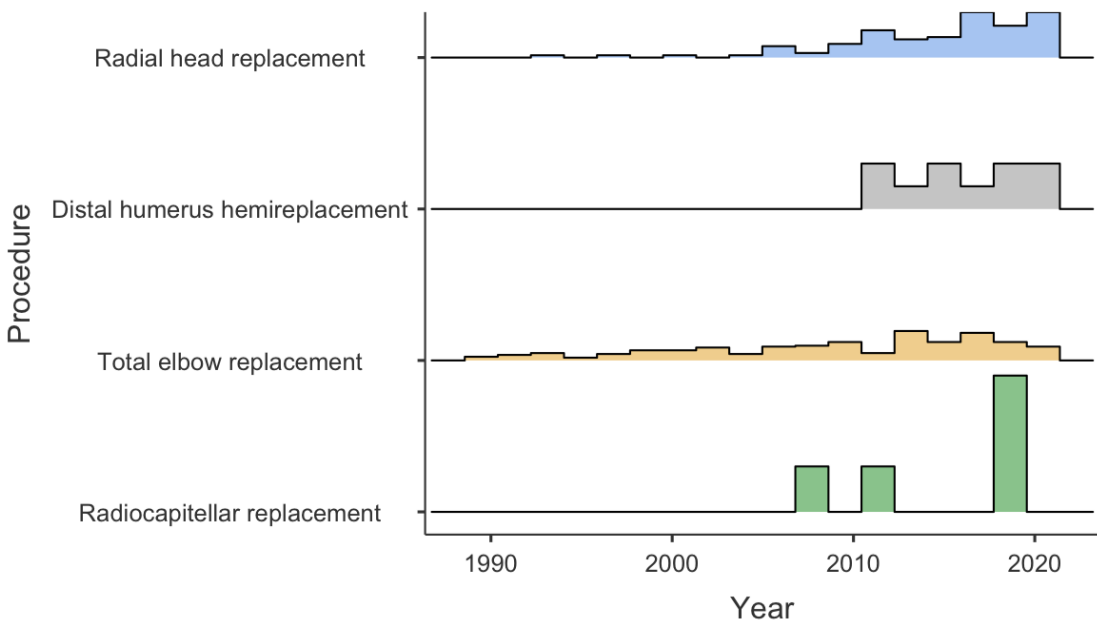
Outcome	Instrument
Activities of daily living	Liverpool elbow score, Mayo elbow performance index, Mayo elbow performance score, UCLA Activity score, Wrightington score
Cognitive status	MMSE
Complications	Voloshin
Cost utility analysis	QALY
Deformity	Ewald scoring system, JOA score
Function	Andrews score, ASES score, Broberg Morrey score, DASH score, Elbex score, Elbow functional assessment, Ewald score, Inglis score, JOA score, Khatri score, likert scale, Liverpool elbow score, Mayo elbow performance index, Mayo elbow performance score, numerical rating scale, Oxford score, PREE, QuickDASH, SANE, SECEC, Souter, Stanford health assessment questionnaire, VAS
Global Health	EQ5D
Grip strength	ASES, Broberg Morrey, Dynamometer, NK hand evaluation system
Implant Survival	Dobbs, Kaplan-Meier, Life table, Murray
Joint position sense	Propriometer
Locomotion	Linkoping
Mental health	SF-12 Mental
Pain	ASES, Broberg Morrey, DASH, Elbow functional assessment, Ewald score, Inglis score, JOA score, Khatri score, likert scale, Mayo elbow performance score, Modified Andrews score, numeric rating scale, Oxford elbow score, Liverpool elbow score, Pain intensity scl, PREE, VAS
Patient Autonomy	Katz
Physical health	SF-12 physical
Quality of life	RAND-36, SF-36
Radial Nerve Palsy	Hirachi, Electrophysiology
Range of motion	ASES, Broberg Morrey, Cassebaum, Elbow functional assessment, Ewald score, HSS score, JOA score, Inglis score, Khatri score, likert, Liverpool elbow score, Mayo elbow performance index, Mayo elbow performance score, Modified Andrews, NK hand evaluation system, Propriometer
Return to Work	binary
Satisfaction	ASES, binary, Jungbluth, likert scale, numerical rating scale, SANE, VAS
Sport participation	Allain, Liverpool elbow score
Stability	ASES, Broberg Morrey, Elbow functional assessment, JOA score, likert, Mayo elbow performance index, Mayo elbow performance score, Modified Andrews score
Strength	ASES, Broberg Morrey, HSS score, Isobex, Kindeyn Dynamometer, Lido workset, Mayo elbow performance index, Mayo elbow performance score, MRC scale, likert, Liverpool elbow score
Success of treatment	VAS
Tenderness	ASES
Ulnar nerve function	Electrophysiology, Liverpool elbow score, McGowan grade
Radiographic alignment	Figgie, H index, O'Driscoll, RSA analysis, Stoen's line, U index, Wrightington
Radiographic bushing wear	Gill, Llamas, Lee, Mayo, Ramsey, Schneeberger
Radiographic capitellum erosion	Broberg Morrey, likert scale, Llamas
Radiographic heterotopic ossification	binary, Brooker, Hastings and Graham, Ilahi, likert
Radiographic loosening	Berschback, binary, Cil, Gill and Morrey, Goldberg, Grewal, Harris, King, likert scale, Madsen, Mayo, Morrey and Adams, Popovic, Schneeberger, Wagener, Wrightington
Radiographic lucency	binary, Fehringer, Gruen, Kodde, Kudo and Iwano, Morrey, Souter, Tanaka, Wrightington
Radiographic medial collateral ligament healing	Ultrasound
Radiographic osteoarthritis	binary, Broberg Morrey, Kellgren Lawrence, Knirk and Jupiter, Lindenhovius, likert scale
Radiographic overstuffing	Rowland, Van Riet
Radiographic quality cement technique	Schneeberger
Radiographic radial head prominence	Doornberg
Radiographic synovitis	Forster
Radiographic ulna wear	Smith and Hughes

**Flow Diagram Scoping Review Literature Search**





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