Surgical and Nonoperative Management of Olecranon Fractures in the Elderly: A Systematic Review and Meta-Analysis

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Objectives: The aim of this comparative effectiveness study was to perform a meta-analysis of adverse events and outcomes in closed geriatric olecranon fractures, without elbow instability, after treatment with surgical or nonoperative management.

Data Sources: PubMed, Web of Science, and Embase databases.

Study Selection: Articles were included if they contained clinical data evaluating outcomes in patients ≥65 years of age with closed olecranon fractures, without elbow instability, treated surgically, or with nonoperative management.

Data Extraction: Data regarding patient age, olecranon fracture type, fracture union, adverse events, reoperation, elbow range of motion, and surgeon and patient reported outcome measures were recorded according to intervention. The interventions included for analysis were tension band wire fixation, plate fixation, or nonoperative management.

Data Synthesis: Separate random effects meta-analyses were conducted for each outcome according to intervention. Prevalence and 95% confidence intervals were calculated for dichotomous variables, whereas weighted means and confidence intervals were calculated for continuous variables.

Conclusions: Comparable outcomes were achieved with surgical or nonoperative management of olecranon fractures in geriatric patients. Surgical intervention carried a high risk of reoperation regardless of whether plate or tension band wire fixation was used. Functional nonunion can be anticipated if nonoperative treatment is elected in low-demand elderly patients.

Key Words: geriatric, olecranon fracture, implant removal

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Olecranon fractures are increasingly common in the elderly.[1,2] As with other fractures of the distal radius and proximal humerus, olecranon fractures in this population predominantly occur after low-energy falls and should be considered fragility fractures.[1–3] Poor bone quality and a fragile soft tissue envelope present challenges when treating these injuries surgically.[3,4]

Plate or tension band wire (TBW) fixation is commonly used for stabilization during open reduction and internal fixation (ORIF) of displaced olecranon fractures.[5] Although plating is associated with a reduced rate of loss of fixation in comminuted and osteoporotic bone in comparison with TBW, complications, including wound dehiscence, infection, and symptomatic implants, with high rates of reoperation for removal, have been reported for both constructs.[6–12]

Nonoperative management of displaced stable olecranon fractures in the elderly has recently gained interest. Several authors have observed good outcomes and minimal complications, despite a high nonunion rate, suggesting that a fibrous pseudoarthrosis of the olecranon in the low-demand patient may provide adequate elbow function for activities of daily living.[9,13–16] A systematic review of geriatric olecranon fractures similarly found excellent patient reported outcome measures (PROMs) and functional elbow flexion arcs after nonoperative management using pooled data from 4 studies.[17]

Despite the promising results of nonoperative management for geriatric olecranon fractures, there is a lack of high-quality evidence comparing this treatment option with currently recognized surgical interventions. The primary aim of this comparative effectiveness study was to perform

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a meta-analysis of reoperation rates, in closed geriatric olecranon fractures, without elbow instability, after treatment with surgical or nonoperative management. Clinical outcomes and other adverse events after surgical or nonoperative management were secondarily assessed.

METHODS

Literature Search and Study Selection

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[18] The PubMed, Web of Science, and Embase databases were searched on March 17, 2019, using explicit search algorithms (see **Supplemental Digital Content 1**, http://links.lww.com/JOT/B114). Initial screening by title was performed by one author (M.J.C.). All relevant articles were included. Two authors (M.J.C. and S.T.C.) then screened the remaining abstracts and finally the full-text articles.

Inclusion criteria were studies available in the English language reporting on outcomes after surgical or nonoperative treatment of isolated closed olecranon fractures and stable type 1 or 2 patterns according to the Mayo olecranon classification system (OTA/AO 21-B1).[19,20] Inclusion age was ≥65 years, as with other studies examining management of upper extremity fragility fractures in the elderly[21,22] and the definition of elderly according to the World Health Organization (WHO).[23] Observational studies and randomized controlled trials (RCTs) were included, given the limited number of RCTs reporting on the topic, and the similar effect estimates found between meta-analyses based on RCTs and observation studies.[24–26] Furthermore, observational studies are proved to provide valid results in clinical effectiveness research.[27] Exclusion criteria were articles that reported on biomechanical data, case reports or case series with <2 patients, systematic reviews, letters to the editor, studies with abstract-only available, or articles published before 1980. Studies that included patients with open or Mayo type 3 fractures or age <65 years were excluded if individual patient data meeting inclusion criteria were unavailable for extraction. Article methodological quality was graded using the Effective Public Health Practice Project Quality Assessment Tool (EPHPP).[28] Oxford Center for Evidence-Based Medicine levels of evidence were determined for each article.[29]

Data Extraction

Study methodology, demographics, Mayo fracture classification, and intervention data were extracted from all articles. The primary outcome was reoperation in surgically treated patients and delayed surgical intervention in nonoperatively managed patients. The reason for reoperation (implant prominence/symptomatic metalwork, infection, symptomatic nonunion, and failure of fixation) was recorded if available. Secondary outcome data were extracted on other postoperative complications (superficial infection and wound problems), fracture union, elbow range of motion, surgeon reported outcomes, and PROMs. Aside from reoperation, only specific adverse events and outcomes with appropriate data from 2 or more studies in each group were included in the meta-analysis.

Statistical Analysis

A professional biostatistician (author A.K.F.) was consulted for the statistical analysis. Random effects meta-analyses were conducted for outcomes using R (R Core Team, Vienna, Austria) and RStudio (RStudio Team, Boston, MA) and meta and metafor packages.[30,31] For dichotomous outcomes, prevalence and 95% confidence intervals (CIs) were calculated. For continuous outcomes, weighted means and CI were calculated if the standard deviations were known or could be determined from individual patient data. PROMs included for meta-analysis were the Disabilities of Arm, Shoulder, and Hand (DASH) and the Mayo Elbow Performance Index (MEPI), which were the only PROMs that had data from at least 2 studies in each group. Separate meta-analyses were conducted according to intervention. Heterogeneity was assessed using the I^2 statistic, and heterogeneity P values were obtained. A regression test for funnel plot asymmetry was used to assess publication bias.

RESULTS

Summary of Evidence

The literature search is summarized in Figure 1. Of the 1044 initial studies identified, 16 articles met inclusion criteria. Of these, 2-suture anchor[32,33] and one intramedullary screw[34] case series were excluded based on insufficient sample sizes of 6 and 3 patients, respectively. One recent publication from the senior author's institution was included outside of the search.[35] Fourteen articles were included for analysis describing outcomes after plate fixation, TBW fixation, or nonoperative management.

Table 1 summarizes the characteristics of the included studies. There were 10 case series,[12–15,35–40] 2 retrospective cohort studies,[8,41] one prospective cohort study,[16] and one RCT.[9] There were 7 articles regarding plate fixation with a total of 83 patients, 5 articles regarding TBW with a total of 97 patients, and 6 articles regarding nonoperative management with a total of 120 patients. The methodological quality of all included studies according to the EPHPP assessment tool was weak.

The mean patient age ranged from 75 to 85 years for plate studies, 70–80 years for TBW studies, and 78–88 years for nonoperative studies. All fractures treated with plates were Mayo type 2. In the TBW group, one fracture was Mayo type 1 and the rest (99%) were type 2. Of the nonoperative patients, 9 fractures were Mayo type 1 and the rest (93%) were type 2. Distinction between Mayo type 2A and 2B was not regularly reported with respect to outcome. Implant selection and fixation technique were variable across studies and not routinely specified according to results. Precontoured locking and nonlocking, reconstruction, dynamic compression, and minifragment plates were used. Intramedullary and transcortical Kirschner (K) wires were used in TBW constructs. Nonoperative management varied with the

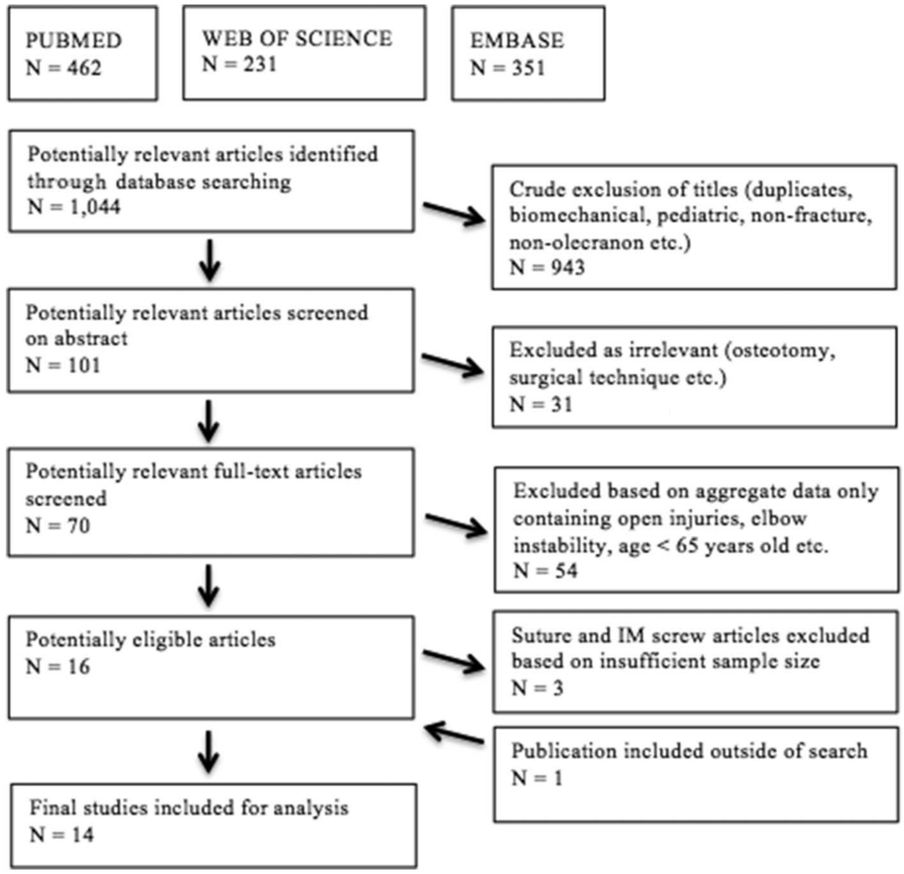

FIGURE 1. Flowchart of studies identified, excluded, and included. IM, intramedullary.

immobilization method (plaster or sling) and duration (mean range 1–4 weeks).

Meta-Analysis of Reoperation

The reoperation rate for TBW fixation was 40% (CI = 31%–51%) (Fig. 2A). Heterogeneity was low (3%), and there was no evidence of publication bias. The overall reoperation rate for plate fixation was 33% (CI = 18%–53%) (Fig. 2B). Heterogeneity was moderate (49%), and there was no evidence of publication bias. No subsequent surgical interventions were reported for nonoperative patients.

Most reoperations occurred for symptomatic implants or wound complications (Table 2A). In the TBW group, there was one reoperation for nonunion[41] and one for hematoma evacuation.[39] In the plate group, there were 3 reoperations for deep infection[9,35] and one for nonunion.[41]

Meta-Analysis of Other Adverse Events

Meta-analyses of other complications are reported in Table 2, A. Implant removal occurred in 38% (CI = 29%–49%) of the TBW group and 32% (CI = 18%–51%) of the plate group. Deep infection occurred in 9% (CI = 4%–22%) of patients treated with plates and no patients treated with TBW. Superficial infection was reported in 5% (CI = 2%–14%) after TBW and none after plate fixation. Wound problems occurred in 12% (CI = 4%–30%) of the plate group and 7% (2%–27%) of the TBW group. No instances of skin breakdown were reported in nonoperative patients.

Meta-Analysis of Fracture Union

A majority of fractures treated with plates (94%, CI = 85%–98%) and TBW (94%, CI = 79%–99%) went onto union (Table 2B). There were 14% (CI = 9%–23%) of nonoperative patients who went onto fracture union (Table 2B).

Meta-Analysis of Range of Motion

The average elbow extension deficit was 11.0 degrees (CI = 3.3–18.7 degrees) after plate fixation, 10.7 degrees (CI = 2.5–18.9 degrees) after TBW, and 15.2 degrees (CI = 13.1–17.3 degrees) after nonoperative management (Table 3). The average elbow flexion arc was 124.0 degrees (CI = 116.1–131.9 degrees) after plate fixation, 129.2 degrees (CI = 125.1–133.6 degrees) after TBW, and 121.5 degrees (CI = 116.8–126.1 degree) after nonoperative management (Table 3).

Meta-Analysis of Disabilities of Arm, Shoulder and Hand and Mayo Elbow Performance Index

Mean DASH scores were 27.1 (CI = 17.5–71.8) for plate fixation, 17.5 (CI = 11.5–23.5) for TBW, and 12.3 (CI = 1.3–23.2) for nonoperative management, indicating similar

TABLE 1. Characteristics of Included Studies Analyzing Plate Fixation, TBW Fixation, and Nonoperative Management After Treatment of Closed Olecranon Fractures (Mayo Type 1 or 2) in Patients >65 Years of age

Article (Year)	EPHPP	Design	Level of Evidence	Subjects, n	Mean Age, y	Mayo Type 2, n (2A, %)	Implant Type	Mean FU, mo
Plate fixation								
Duckworth et al[9] (2017)*	Weak	RCT	1	2	84.5	2 (100)	PN	12
Melamed et al[36] (2015)	Weak	R	4	4	75	4 (75)	PL, DC, Rc	15
Niglis et al[38] (2015)	Weak	R	4	4	81.8	4 (0)	PL	18
Morwood et al[37] (2015)	Weak	R	4	2	85.5	2 (50)	PL	10
Wellman et al[40] (2015)	Weak	R	4	15	75.7	14 (47)	Rc	23
Liñán-Padilla et al[41] (2017)*	Weak	R	3	23	78	23 (43)	PL	15
Campbell et al[35] (2019)	Weak	R	4	33	83	33 (NR)	PL, MF	10

Article (Year)	EPHPP	Design	Level of Evidence	Subjects, n	Mean Age, y	Mayo Type 2, n (2A, %)	Wire Placement	Mean FU, mo
TBW fixation								
Duckworth et al[9] (2017)*	Weak	RCT	1	9	85.3	9 (44)	NR	12
Mullett et al[12] (2000)	Weak	R	4	34	80.4	NR	IM, TC	41
Villanueva et al[39] (2006)	Weak	R	4	19	79.2	18 (74)	IM, TC	50
Liñán-Padilla et al[41] (2017)*	Weak	R	3	26	70	26 (62)	IM, TC	15
Batten et al[8] (2016)*	Weak	R	3	9	>74	9 (NR)	NR	>6

Article (Year)	EPHPP	Design	Level of Evidence	Subjects, n	Mean Age, y	Mayo Type 2, n (2A, %)	Immobilization, wk	Mean FU, mo
Nonoperative management								
Duckworth et al[9] (2017)*	Weak	RCT	1	6	78	6 (33)	~2	12
Gallucci et al[14] (2014)	Weak	R	4	28	82	28 (64)	~1	12
Batten et al[8] (2016)*	Weak	R	3	17	>74	16 (NR)	NR	>6
Marot et al[16] (2018)	Weak	R	3	22	88.8	14 (71)	~2	6
Veras Del Monte et al[13] (1999)	Weak	R	4	11	81.5	11 (73)	~4	16
Duckworth et al[15] (2014)	Weak	R	4	36	80.1	36 (50)	~4	3.3 (72)

Duckworth et al[15] (2014) reported 3.3 months short-term follow-up for entire cohort and 72 months long-term follow-up for the 23 surviving patients.
*Data were extracted according to intervention.
Implant Type: DC, dynamic compression; MF, minifragment; PL, precontoured locking; PN, precontoured nonlocking; Rc, reconstruction.
Wire Placement: IM, intramedullary; TC, transcortical.
2A, % of Mayo type 2 fractures with "2A" pattern; FU, follow-up; NR, not reported; R, retrospective design.

upper extremity function compared with the general uninjured population (Table 3).[42] Mean MEPI scores were 94.6 (CI = 91.4–97.8) after plate fixation, 92.1 (CI = 85.9–98.2) after TBW, and 95.1 (CI = 93.0–97.2) after nonoperative management, indicating comparable excellent elbow function (Table 3).[43]

Other Secondary Outcomes

Elbow extension strength was only evaluated in one nonoperative management study.[14] Gallucci et al reported grades M5 (65%) and M4 (35%) strength in 28 patients using the Medical Research Council scale despite an 82% nonunion rate.

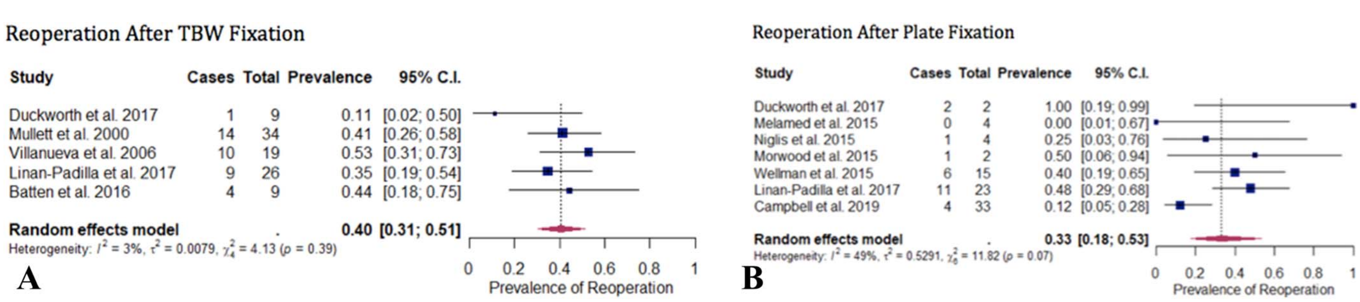

FIGURE 2. Forest plot and meta-analysis of reoperation rates after (A) TBW and (B) plate fixation. Prevalence with 95% CI presented. **Editor's Note**: A color image accompanies the online version of this article.

TABLE 2. Results of Meta-Analysis for (A) Commonly Reported Complications and (B) Fracture Union After Treatment With Plate Fixation, TBW Fixation, or Nonoperative Management

	Plate Fixation				TBW				Nonoperative			
	Studies, n	Prevalence (CI)	I^2	*P*	Studies, n	Prevalence (CI)	I^2	*P*	Studies, n	Prevalence (CI)	I^2	*P*
A: Complications												
Reoperation	7	33% (18%–53%)	49%	0.07	5	40% (31%–51%)	3%	0.39	N	—	—	—
Implant removal	7	32% (18%–51%)	44%	0.10	5	38% (29%–49%)	0%	0.30	N	—	—	—
Deep infection	5	9% (4%–22%)	0%	0.43	N	—	—	—	N	—	—	—
Superficial infection	N	—	—	—	3	5% (2%–14%)	0%	0.86	N	—	—	—
Wound problems	5	12% (4%–30%)	15%	0.32	3	7% (2%–27%)	33%	0.22	N	—	—	—
B: Fracture union	7	94% (85%–98%)	0%	0.84	4	94% (79%–99%)	41%	0.17	5	14% (9%–23%)	0%	0.91

Prevalence with 95% CI, level of heterogeneity (I^2), and *P* values presented.
N, no reported cases.

Only one patient in the plate fixation group experienced reduction loss in the setting of an infection, which was treated with implant removal, fragment excision, and triceps advancement.[35] By contrast, 7 patients in the TBW group had reduction loss without reoperation.[8,9]

The following outcome scores were not routinely reported and were omitted from the meta-analysis but are presented for completeness. Average QuickDASH (abbreviated DASH) scores were 16.4 after plate fixation (one study),[41] 16.3–23.4 after TBW (2 studies),[8,41] and 7.4–4.3 after nonoperative treatment (2 studies).[8,16] Average Broberg and Morrey scores were 88.5–96.3 after plate fixation (2 studies),[9,38] 95.1 after TBW (1 study),[9] and 82.1–89.0 after nonoperative treatment (2 studies).[9,15] Average visual analog scale scores were 2.0 after plate fixation (one study),[41] 2.0–4.1 after TBW (2 studies),[8,41] and 1.0–1.6 after nonoperative treatment (3 studies).[8,14,16]

DISCUSSION

With an increasingly aging population,[44] olecranon fractures in the elderly are likely to be encountered at higher frequency.[1,2] Quality studies evaluating treatment of these fractures in this specific population are limited, with only a single RCT reporting on 19 patients.[9] This systematic review and meta-analysis aimed to improve the current understanding of geriatric olecranon fracture treatment by providing a quantitative assessment of the outcomes observed after surgical and nonoperative management.

This study found that high reoperation rates can be expected in patients treated with TBW or plate fixation, compared with the nonoperative group that experienced no subsequent surgeries to address symptomatic nonunion. Removal of symptomatic implants comprised most reoperations in the operative groups. Plate fixation had less reduction loss in comparison with TBW but had higher rates of deep infection and wound problems. Increased infection may be due to larger implants, which may be associated with more extensive soft tissue trauma and a larger inert surface.[45] High rates of union were equally achieved in both operative groups, whereas nonunion occurred in 86% of nonoperative patients. Although not statistically significant, the nonoperative group experienced the greatest elbow motion deficits. Regardless, functional flexion arcs were achieved in all groups.[46] Functional outcome scores were comparably excellent across all groups.

Although nonunion is anticipated after nonoperative treatment of displaced olecranon fractures, most nonunions seem asymptomatic and may be compatible with the requirements of low-demand elderly patients. In the study performed by Duckworth et al,[15] the authors found that of the patients with displaced olecranon fractures who had been managed

TABLE 3. Results of Meta-Analysis for Commonly Reported Outcomes After Treatment With Plate Fixation, TBW Fixation, or Nonoperative Management

	Plate Fixation				TBW				Nonoperative			
	Studies, n	Mean (CI)	I^2	*P*	Studies, n	Mean (CI)	I^2	*P*	Studies, n	Mean (CI)	I^2	*P*
Extension deficit, degrees	5	11.0 (3.3–18.7)	67%	0.02	2	10.7 (2.5–18.9)	85%	0.01	3	15.2 (13.1–17.3)	0%	0.50
Flexion arc, degrees	5	124.0 (116.1–131.9)	31%	0.21	2	129.2 (125.1–133.6)	16%	0.27	3	121.5 (116.8–126.1)	59%	0.09
DASH	2	27.1 (17.5–71.8)	97%	<0.01	2	17.5 (11.5–23.5)	0%	0.47	3	12.3 (1.3–23.2)	92%	<0.01
MEPI	3	94.6 (91.4–97.8)	0%	0.86	2	92.1 (85.9–98.2)	61%	0.11	2	95.1 (93.0–97.2)	0%	0.79

Weighted means with 95% CI, level of heterogeneity (I^2), and *P* values presented.

nonoperatively with available radiographs (n = 32), 25 (78%) had developed radiographic evidence of nonunion (while remaining asymptomatic and satisfied with their outcome) and the remaining 7 (22%) had union. No patient underwent additional surgery for a symptomatic nonunion or for any other cause within the first year after injury. Furthermore, at a mean of 6 years, overall patient satisfaction was 91%, 19 (83%) reported no limitation in their ability to push themselves up from a chair, and none had undergone additional surgery since the time of their original injury. Nonoperative treatment in the elderly seems an attractive option, particularly in the higher-risk surgical patient, with anticipation of minimal complications and similar functional outcomes when compared with ORIF.

In this study, variable plate selection did not affect the rate of union or quality of fixation because there was only one case of nonunion and one case of fixation loss in the setting of infection. The use of locking and nonlocking implants for comminuted olecranon fractures has biomechanical evidence of similar construct stability.[47] Plate selection should be based on surgeon experience and fixation requirements unique to the fracture. Regarding the variability in K-wire placement for TBW fixation, we did not compare failure rates for intramedullary versus transcortical wires due to inconsistent reporting. Van der Linden et al[48] reported a 78% instability rate when intramedullary wires are used for TBW, as defined by wire migration or fracture displacement, compared with a 36% instability rate when using transcortical wires. If TBW fixation is used for the appropriate noncomminuted pattern, transcortical wire placement is recommended to avoid these aforementioned complications.[12,48]

The conclusions of this study are limited by the heterogeneity and lower levels of evidence of the previously published articles. However, several authors have reported similar estimates of effect between meta-analyses based on RCTs and observational studies.[24–26] A review by Shrier et al[49] provides a compelling argument for the inclusion of observational studies when performing a meta-analysis. We acknowledge this study sought to determine more precise estimates of effect, regarding adverse events and other outcomes, after surgical or nonoperative management of geriatric olecranon fractures. Although heterogeneity assessment was performed to determine consistency, the authors recognize the limitations in determining causal inference.[50] Results of meta-analyses for elbow motion and PROMs are less impactful due to the limited number of studies with available data. More uniform reporting of outcomes in future studies is recommended. Two of the nonoperative studies, Marot et al[16] and Duckworth et al,[15] had less than ideal average follow-up of 6 and 3.3 months, respectively. However, the 3.3 months reported by Duckworth et al[15] was regarding short-term follow-up for the entire cohort, and the authors actually reported on all alive patients (n = 23) at a mean of 6 years using validated PROMs and reported complications.

Other limitations include lack of independent data extraction and no process to confirm the data from previous investigators. The data also assumed that any operation to address nonunion or painful implants would have occurred within the follow-up period. Certain interventions used to treat olecranon fractures are also not included in this study because of the articles not meeting inclusion criteria, specifically fragment excision with triceps advancement[51,52] and intramedullary nailing.[53,54] In addition to other potential confounding factors, the nonoperative patient mean age range was marginally older that may have biased outcomes, including the decision not to pursue delayed surgery in the setting of a poor outcome. Moreover, the study design is limited by comparing 2 patient populations that face different post-treatment challenges. Infection, wound dehiscence, and implant removal occur exclusively in surgical patients, whereas nonunion is predominantly associated with nonoperative treatment. The results of the comparisons should be interpreted with this recognition. A further limitation is generic to all literature regarding geriatric patients. Although the WHO definition of elderly is 65 years of age,[23] chronologic age is a crude marker for physiological age and functional activity, with little supporting evidence.[55] Currently, there is no system that is universally advocated for scoring physical activity or fragility, to allow better stratification in the geriatric patient.[56]

The conclusions from this systematic review and meta-analysis are as follows: (1) Nonoperative treatment or ORIF of geriatric olecranon fractures can achieve excellent and comparable functional outcomes, (2) TBW and plate fixation have comparable high rates of reoperation for symptomatic implants or wound problems in elderly patients, and (3) Given the frequency of reoperation after surgery and the similar outcomes achieved with nonoperative management, patients should be educated on the likelihood of reoperation to address symptomatic implants or wound problems with surgery. Despite the limited evidence available, the literature seems to support the use of primary conservative management of stable, displaced olecranon fractures in the low-demand elderly.

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