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Primary Linked Total Elbow Arthroplasty for Acute Distal Humerus Fracture Management: A Systematic Review of Clinical Outcome

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Background: The treatment of distal humerus fractures is often challenging in osteoporotic elderly patients. Total elbow arthroplasty (TEA) is a salvage option for non-reconstructable fractures. The aim of this systematic review was to evaluate the clinical evidence for primary TEA in patients with acute distal humeral fractures.

Methods: Literatures were searched through PubMed, Ovid/Medline, Cochrane, Google Scholar, and Embase databases with the keywords, "distal humerus fracture," "total elbow arthroplasty," and "outcome" according to the MeSH (Medical Subject Headings) index for English-language studies published from April 2009 to April 2019. We performed a systematic review using Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.

Results: Ten articles with a total of 269 patients were included in the review. The Bryan-Morrey approach was the most common surgical approach (33.7%) with triceps reflecting (42%) for triceps tendon management. The most common implant design used was the Coonrad-Morrey system (83%). The mean postoperative motion arc was 102.3° for flexion-extension and 145.8° for pronation-supination. The average functional outcome score was 89.5 with Mayo Elbow Performance Score (MEPS). An excellent MEPS was found in studies with less than 7 days of average time from injury to surgery. The overall complication rate was 21.5%.

Conclusions: The current review showed favorable outcome of primary linked TEA for acute distal humerus fractures. Despite the promising functional outcomes, the complication rate was still considerably high. This systematic review will give surgeons help in explaining to patients regarding the expected outcome after primary TEA for acute distal humerus fractures.

Keywords: *Total elbow arthroplasty, Linked, Fracture, Distal humerus, Systematic review*

Comminuted distal humerus fractures in the geriatric population are a challenging injury to treat. The principle of treatment of a displaced intra-articular distal humerus fracture is anatomical reduction of the joint surfaces with stable fixation of fracture fragments, hence promoting early mobilization.[1-3] Nevertheless, anatomical reduction and stable internal fixation are often unachievable due to severe comminution in osteoporotic bone particularly in the elderly population. The complication and loss of reduction rates are reported to be as high as 50% for comminuted distal humerus fractures after open reduction and internal fixation (ORIF).[4] With the improvement of prosthetic designs and surgical techniques, total elbow arthroplasty (TEA) is starting to gain recognition as a safe and effective alterna-

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tive to ORIF. TEA has become an option to treat severely comminuted distal humerus fractures in the elderly population. Although potential benefits of TEA, compared with ORIF, include faster rehabilitation and improved short-term outcomes,[5] weight-bearing activity limitation and mechanical loosening are still being considered as major drawbacks that necessitate a revision procedure.[5,6] Thus, the debate has been continued regarding the use of primary TEA in comminuted distal humerus fractures. There is no universal agreement on the management of comminuted distal humerus fractures in the geriatric population.

Arthroplasty of the elbow joint has been improved for technical and prosthetic design considerations over the past 20 years.[7] In the meantime, there has been several investigations regarding elbow arthroplasty for the treatment of distal humerus fractures in the geriatric population.[2,4,8] However, the reported surgical outcomes are conflicting.

The primary objective of the current systematic review was to provide an overview of the surgical outcomes of primary linked TEA for the treatment of acute comminuted distal humerus fractures. The secondary objective was to investigate complication rates of primary linked TEA for the treatment of acute comminuted distal humerus fractures.

METHODS

Search Strategy

This systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[9] We searched PubMed, Ovid/Medline, Cochrane, Google Scholar, and Embase databases with the keywords chosen according to MeSH (Medical Subject Headings) and All Fields index. The used search string was "total elbow arthroplasty" (MeSH terms), "distal humerus fracture" (All Fields), and "outcome" (All Fields). Due to the limited number of studies, there were no restrictions on patient demographics, specific surgical procedures, publication status, and publication date. The bibliographies of the retrieved studies were manually cross-checked for potential relevant articles. The flowchart of study selection is shown in Fig. 1.

Inclusion/Exclusion Criteria

All included studies were written in English and contained original data on patients undergoing primary TEA for acute distal humerus fractures with a minimum follow-up of 1 year. Studies with a minimum of 5 patients were included. The included studies reported the types of implant, outcomes, and complications of surgery. Revision TEA, single-case reports, expert opinions, review articles, and studies involving cadavers and *in vitro* or animal models were excluded. Because of the evolution of TEA techniques, only articles published from April 2009 to April 2019 were considered for review. Articles presenting data that were thought to have been presented previously were included once; if there was any doubt, the corresponding author (IHJ) was contacted.

Quality Appraisal

Six reviewers (LAA, AA, RA, HK, DP, and EK) reviewed each article independently. The decision to include or exclude any article was based on group discussion and consensus. The Oxford Centre for Evidence-Based Medicine criteria were used to assess the level of evidence of each study.[10]

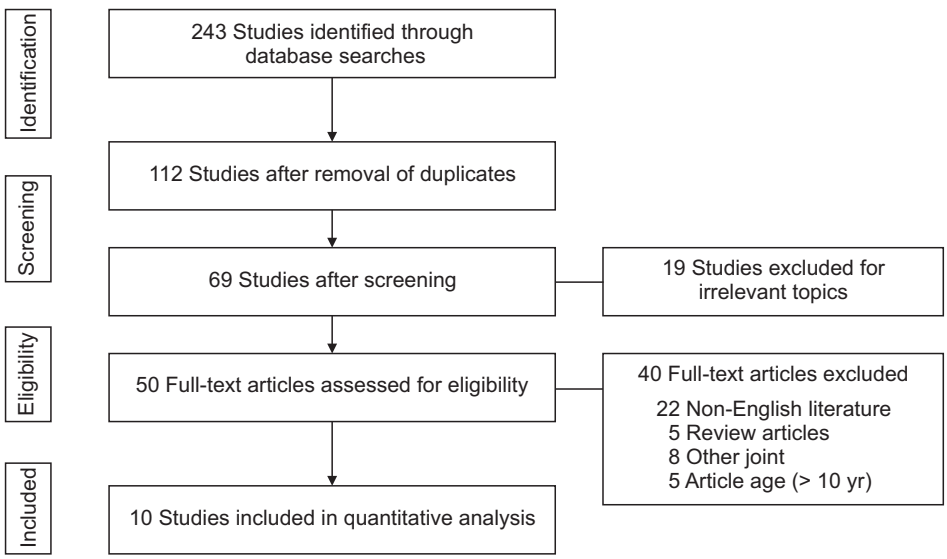

Fig. 1. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart for study selection.

Data Extraction and Analysis

After the initial assessment for inclusion, 4 reviewers (LAA, AA, RA, and EK) extracted data from the included articles. Data extraction was performed from the text, figures, and tables of each of the included studies. These data included study characteristics, patient characteristics, injury characteristics, surgical characteristics, and clinical outcomes. Study characteristics included author names, publication year, study design, level of evidence, and the number of patients at the final follow-up. Patient characteristics included gender distribution, age, follow-up period, and affected site. Injury characteristics included fracture type (open or closed), Orthopaedic Trauma Association (OTA) classification for distal humerus fracture, the presence of underlying disease, and associated history. Surgery characteristics included the average time to surgery, type of surgical approach, type of triceps management, and implant system. Clinical outcomes data included the range of motion (flexion-extension and pronation-supination), quantitative outcome assessment (functional outcome mea-

Table 1. Study Characteristics

No	Study	Journal	Country of investigation	Design	Level of evidence	No. of patients
1	Chalidis et al. (2009)[11]	Injury	UK	Retrospective case series	4	11
2	Baksi et al. (2011)[12]	International Orthopaedics	India	Retrospective case series	4	21
3	Antuna et al. (2012)[13]	Acta Orthopaedica Belgica	Spain	Retrospective case series	4	14
4	Ducrot et al. (2013)[14]	Orthopaedics & Traumatology: Surgery & Research	France	Retrospective case series	4	20
5	Mansat et al. (2013)[15]	Orthopaedics & Traumatology: Surgery & Research	France	Retrospective multicenter	4	87
6	Giannicola et al. (2014)[16]	Journal of Hand Surgery Am	Italy	Retrospective case control	3b	10
7	Linn et al. (2014)[17]	Injury	USA	Retrospective case series	4	7
8	Sorensen et al. (2014)[18]	World Journal of Orthopedics	Denmark	Retrospective case series	4	20
9	Barco et al. (2017)[19]	Journal of Bone and Joint Surgery	USA	Retrospective case series	4	44
10	Lami et al. (2017)[20]	Orthopaedics & Traumatology: Surgery & Research	France	Retrospective case series	4	21

Table 2. Patient Characteristics

No	Study	Sex (male : female), no (%)	Age (yr), median (range)	Follow-up (mo)	Affected site, no (%)
1	Chalidis et al. (2009)[11]	2 (18.2) : 9 (81.8)	79.6 (75–86)	33.6	4 Right (36.3), 7 left (63.7)*
2	Baksi et al. (2011)[12]	NS	64 (56–78)	55.5	NS
3	Antuna et al. (2012)[13]	NS	77.6 (63–89)	57	10 Dominant (62.5), 6 nondominant (37.5)
4	Ducrot et al. (2013)[14]	2 (10) : 18 (90)	80 (65–93)	43.2	16 Dominant (80), 4 nondominant (20)
5	Mansat et al. (2013)[15]	7 (8.1) : 80 (91.9)	79 (65–73)	37	46 Dominant (52.8), 41 nondominant (47.2)
6	Giannicola et al. (2014)[16]	9 (37.5) : 15 (62.5)	69 (45–89)	41	NA
7	Linn et al. (2014)[17]	2 (71.5) : 5 (28.5)	74 (56–86)	43	NA
8	Sorensen et al. (2014)[18]	2 (10) : 18 (90)	77 (55–95)	21	15 Dominant (75), 5 nondominant (25)
9	Barco et al. (2017)[19]	11 (25) : 33 (75)	70.7 (38–93)	> 10 yr†	24 Left (55), 20 right (45)*
10	Lami et al. (2017)[20]	1 (4.8) : 20 (95.2)	81.3 (70–92)	38.4	15 Dominant (71.4), 6 nondominant (28.6)

NS: not specified, NA: not available.
*Study only reported dexterity, and hand dominance was not specified. †All patients were mentioned to have more than 10-year follow-up with no specific time period.

surement tool and score), qualitative outcome assessment (satisfaction rate), and the presence of residual symptoms and complications. Data were recapitulated in tables in Microsoft Office Excel 2013 (Microsoft, Redmond, WA, USA). Descriptive statistics were used for data interpretation.

RESULTS

Study Characteristics

The article selection process is shown in Fig. 1. We included 10 of the 112 articles identified in the total search. There were 9 studies categorized as level 4 (retrospective

Table 3. Injury Characteristics

No	Study	Fracture type, no (%)	OTA classification (OTA 13), no (%)	Underlying disease and associated history
1	Chalidis et al. (2009)[11]	Closed fracture	C2, 3 (27.2)	1 Polytrauma
			C3, 8 (72.8)	1 Intertrochanter femur fracture
				1 Femoral neck fracture
				1 Proximal humerus fracture
2	Baksi et al. (2011)[12]	Closed fracture	C2, 12 (57.1)	1 Diabetes mellitus
			C3, 9 (42.9)	4 Hypertension
3	Antuna et al. (2012)[13]	Closed fracture	B3, 2 (14.2)	NA
			C2, 2 (14.2)	
			C3, 12 (71.6)	
4	Ducrot et al. (2013)[14]	Closed fracture, 18/20 (90)	A2, 2 (10.5)	3 Rheumatoid arthritis
		Open fracture (type I Gustillo), 2/20 (10)	B2, 1 (5.2)	
			B3, 1 (5.2)	
			C1, 1 (5.2)	
			C2, 5 (26.3)	
			C3, 9 (47.3)	
			Unclassified, 1 (5.2)*	
5	Mansat et al. (2013)[15]	Closed fracture, 80/87 (91.9)	A, 9 (10.3)	8 Inflammatory arthritis
		Open fracture, 7/87 (8.1)	B, 8 (9.1)	5 Osteoarthritis
		Type I Gustillo, 6 (85.7)	C1, 16 (18.3)	10 History of osteoporotic stress fracture
		Type II Gustillo, 1 (14.3)	C2, 17 (19.5)	9 Neuropsychiatric disease
			C3, 37 (42.5)	4 Long-term steroid treatment
6	Giannicola et al. (2014)[16]	NA	C3, 8 (80)	None
			C2, 2 (20)	
7	Linn et al. (2014)[17]	Open fracture, 7	C, 7 (100)*	NA
		Type I Gustillo, 2/7 (28.5)		
		Type II Gustillo, 5/7 (71.5)		
8	Sorensen et al. (2014)[18]	Closed fracture	C3, 17 (85)	NA
			B2, 1 (5)	
			A2, 2 (10)	

Table 3. Continued

No	Study	Fracture type, no (%)	OTA classification (OTA 13), no (%)	Underlying disease and associated history
9	Barco et al. (2017)[19]	NA	NA	NA
10	Lami et al. (2017)[20]	Closed fracture, 19/21 (90.4)	A3, 2 (9.5)	1 Ulnohumeral osteoarthritis
		Open fracture (type I Gustillo), 2/21 (9.6)	C1, 7 (33.3)	1 Ipsilateral proximal humerus fracture
			C2, 4 (19.1)	
			C3, 8 (38.1)	

OTA: Orthopaedic Trauma Association, NA: not available.
*All fractures were classified as OTA 13 type C without subtype.

Table 4. Surgery Characteristics

No	Study	Time to surgery (day), mean (range)	Surgical approach, no (%)	Triceps management, no (%)	Implant system, no (%)
1	Chalidis et al. (2009)[11]	4.3 (2–8)	Bryan-Morrey	Reflecting	Discovery
2	Baksi et al. (2011)[12]	7 (2–13)	Postero-medial	Sparring	Baksi (local implant)
3	Antuna et al. (2012)[13]	8 (2–45)	Paratricipital Alonso-Llames	Sparring	Coonrad-Morrey
4	Ducrot et al. (2013)[14]	NS*	Bryan-Morrey, 17 (85)	Reflecting, 17 (85)	Coonrad-Morrey
			Transolecranon, 3 (15)	Sparing, 3 (15)	
5	Mansat et al. (2013)[15]	NA	Bryan-Morrey, 58 (66.6)	Reflecting, 78 (89.6)	Coonrad-Morrey, 85 (97.7)
			Gschwend, 20 (23)	Splitting, 6 (6.8)	Discovery, 1 (1.1)
			Reversed V, 6 (6.9)	Sparing, 3 (3.6)	Latitude, 1 (1.1)
			Transolecranon, 2 (2.3)		
			Laterotricipital, 1 (1.2)		
6	Giannicola et al. (2014)[16]	NA	Paratricipital Alonso-Llames, 11 (45.8)	Sparring, 7 (29.2)	Discovery[†]
			Bryan-Morrey, 6 (25)	Reflecting, 6 (25)	
			Newcastle, 6 (25)	Splitting, 1 (4.2)	
			Transolecranon with anconeus flap, 1 (4.2)	Unspecified, 10 (41.6)	
7	Linn et al. (2014)[17]	6 (2–19)	NA	NA	Coonrad-Morrey
8	Sorensen et al. (2014)[18]	9.1 (1–22)	Posterior	Splitting	Coonrad-Morrey
9	Barco et al. (2017)[19]	NA	Bilateroricipital or Bryan-Morrey[‡]	Sparing or reflecting[‡]	Coonrad-Morrey
10	Lami et al. (2017)[20]	9 (2–22)	Medial paratricipital approach	Sparring	Coonrad-Morrey

NS: not specified, NA: not available.
*The study reported 1 patient with 6 weeks of delay for surgical treatment. [†]Implant system was not specified in the article and thus was decided by agreement among senior surgeons of the current study based on the published radiographic images. [‡]The study did not specify the exact number of patients for each designated approach or triceps management.

Table 5. Functional Outcome Assessment

No	Study	Motion arc, mean (range)		Quantitative assessment		Qualitative assessment (satisfaction rate, %)
		Flexion-extension	Pronation-supination	Outcome measurement tool	Score, mean (range)	
1	Chalidis et al. (2009)[11]	107 (10–117)	122 (61–61)	MEPS	90 (80–95)	NA
2	Baksi et al. (2011)[12]	105 (25–130)	125 (65–69)	MEPS	96.42*	NA
3	Antuna et al. (2012)[13]	90 (28–117)	153 (78–75)	MEPS	73 (30–100)	Very satisfied, 2 (14.2)
				DASH	52 (7.5–100)	Satisfied, 7 (50)
				VAS	6.5 (10–1)	Unsatisfied, 3 (21.4)
						Unsatisfied, 2 (14.2)
4	Ducrot et al. (2013)[14]	97 (33–130)	152 (NA)†	MEPS	83 (60–100)	Satisfied, 14 (93)
5	Mansat et al. (2013)[15]	97 (50–145)	NA	MEPS	86 (45–100)	NA
				Quick-DASH	24 (0–68)	
				Katz score	5 (1–6)	
6	Giannicola et al. (2014)[16]	119 (17–136)	163 (80–83)	MEPS	96*	NS
				Quick-DASH	20*	
				Modified ASES	84*	
				MEPI	20 Excellent, 3 good, 1 fair	
7	Linn et al. (2014)[17]	92 (21–113)	NA	DASH	48*	NA
8	Sorensen et al. (2014)[18]	114 (NA)†	165 (NA)†	MEPS	94 (65–100)	Excellent, 8 (40)
						Good, 10 (50)
						Fair, (10)
						Poor, 1 (5)
9	Barco et al. (2017)[19]	99 (24–123)	141 (70–71)	MEPS	90.5 (60–100)	NA
				VAS	0.6 (0–4)	
10	Lami et al. (2017)[20]	103 (22–125)	Full ROM, 19/21 (90.4)	MEPS	84*	Very satisfied, 15 (71.4)
			50% Impaired, 1/21 (4.8)	Quick-DASH	32.4*	Satisfied, 4 (19.1)
			Not reported, 1/21 (4.8)			Dissatisfied, 2 (9.5)

MEPS: Mayo Elbow Performance Score, NA: not available, DASH: Disabilities of the Arm, Shoulder and Hand, VAS: visual analog scale, NS: not specified, ASES: American Shoulder and Elbow Society, MEPI: Mayo Elbow Performance Index, ROM: range of motion.
*The study did not provide range value. †The study did not specify the starting and ending motion arc end point position.

case series) and 1 as level 3 (case-control study). One included study was multicenter study.[15] Table 1 summarizes the study characteristics.

Patient Characteristics

The 10 studies included 255 patients who underwent primary TEA for distal humerus fractures, including 36 men (13.4%) and 198 women (73.6%). Sex was not specified for 35 patients (13%). The mean age ranged from 64 to 81.3 years, with the largest population in their 7th decade of life. The mean follow-up period ranged from 21 to 57 months. One study reported to have more than 10 years of follow-up period without specific duration.[19] Surgery was performed in the dominant extremity for 92 patients (62.1%).[14,15,18,20] Six studies did not specify whether the surgery was performed in the dominant extremity.[11-13,16,17,19] Table 2 summarizes the patient characteristics.

Table 6. Summary of Clinical Outcome and Complications

No	Study	Summary of outcome score				Residual pain	Complication, no (%)						
		Excellent	Good	Fair	Poor		Wound problem	Loosening	Infection	HO	Ulnar nerve symptom	Fracture or periprosthetic fracture	Stiffness
1	Chalidis et al. (2009)[18]	+									1/11 (9.1)	Periprosthetic fracture (revision delayed for 3 yr due to patient preference, 1/11 (9.1)	
2	Baksi et al. (2011)[17]	+							Delayed infection, 1/21 (4.7)				
3	Antuna et al. (2012)[16]			+		Mild pain, 7/14 (50); moderate pain, 1/14 (7.1)		Loosening, 1/14 (7.1)	Infections (2 acute, 1 late), 3/14 (21.4)		Mild ulnar nerve symptoms, 7/14 (50); moderate ulnar nerve symptoms, 1/14 (7.1)	Periprosthetic humerus fracture, 2/14 (14.2)	
4	Ducrot et al. (2013)[13]		+			Moderate pain, 2/20 (10); minimal pain, 4/20 (20)				HO, 6/20 (30)	Ulnar nerve symptom, 2/20 (10)		
5	Mansat et al. (2013)[11]		+			Minimal pain, 20/87 (24)					Ulnar nerve symptom, 1/87 (1.1)		
6	Giannicola et al. (2014)[19]	+							Wound infection, 1/24 (4.1)		Transient ulnar neuropathies, 2/24 (8.3)	Epicondyle fracture, 1/24 (4.1)	
7	Linn et al. (2014)[20]*				+			Arm pain with loosening in X-ray, 1/7 (14.2); loose humeral stems (2.5 yr and 11.5 yr after index TEA–no treatment due to patient preference), 2/7 (28.5)		HO with contracture (capsular release), 1/7 (14.2)		Olecranon fracture (following fall–conservative treatment), 1/7 (14.2)	
8	Sorensen et al. (2014)[14]	+						Loosened locking pin (1 revised), 2/20 (10)	Deep infections (all revised), 2/20 (10)		Ulnar nerve symptoms (dysaesthesia), 2/20 (10)		
9	Barco et al. (2017)[12]	+							Deep infection (resection debridement), 2/44 (4.5); reoperation for acute infection, 3/44 (6.8)			Periprosthetic fracture (2 underwent ORIF, 1 revision TEA), 3/44 (6.81); loosening or component fracture, 4/44 (9.1)	
10	Lami et al. (2017)[15]		+				Skin necrosis at olecranon tip, 1/21 (4.7)						Severe stiffness, 1/21 (4.7)

Values are presented as number (%).
HO: heterotopic ossificans, TEA: total elbow arthroplasty.
*The study used Disabilities of the Arm, Shoulder and Hand score as the only quantitative measurement tool whereas the others used Mayo Elbow Performance Score.

Injury Characteristics

Four studies included only the closed fracture type,[11-13,18] 1 study included only the open fracture type,[17] 3 studies included both open and closed fractures,[14,15,20] while 2 studies did not report regarding the fracture type.[16,19] Overall, there were 18 open fracture cases (7%) included in this review. Twelve patients (66.7%) were classified as grade 1 open fracture, and 6 patients (33.3%) were classified as grade 2 open fracture. All distal humerus fractures were classified according to OTA classification as OTA13. The current study included 15 (6%) extra-articular fractures (13A), 13 (5%) partial articular fractures (13B), and 184 (72%) complete articular fractures (13C). Six studies described the underlying disease/history and associated injury.[11,12,14,15,20] The range of time from injury to surgery was 4.3 to 9.1 days but not mentioned in 3 studies.[15,16,19] Table 3 summarizes the injury characteristics.

Surgical Characteristics

All studies described the surgical approach, which was the posterior approach to the elbow joint. Eight studies described the specific surgical approaches: Bryan-Morrey approach for 86 patients (33.7%), posteromedial approach for 21 patients (8.2%), Gschwend approach for 20 patients (7.8%), reversed V approach for 6 patients (2.4%), transolecranon approach for 5 patients (2%), and laterotricipital approach for 1 patient (0.4%). One study[17] with 7 patients did not mention the surgical approach used and 2 studies with 54 patients did not specify surgical approaches for each patient.[16,19]

Broadly, there are 3 options for triceps management for TEA, which were triceps sparring, triceps reflecting, and triceps splitting. Triceps reflecting, sparring, and splitting were used for 106 patients (42%), 62 patients (32%) and 26 patients (10%), respectively. The triceps management was neither mentioned nor specified in 2 studies.[17,19] Triceps reflecting (54.6%) was most frequently used to handle extensor mechanism, followed by triceps sparring (32%) and splitting (13.4%).

All studies described the specific implant design. Coonrad-Morrey implant system was used in 211 patients (82.7%) in 8 studies. Two studies included Discovery implant system for 22 patients and Latitude implant system for 1 patient.[11,15] One study used their local implant for 21 patients (7.8%).[12] Table 4 summarizes the surgical characteristics.

Clinical Outcomes

Table 5 shows the functional outcome score and the measurement tool. All of the included studies made a quantitative assessment of the outcomes; however, only 4 studies were with qualitative assessment.[13,14,18,20] Quantitative assessment included Mayo Elbow Performance Score (MEPS) in 9 studies,[11-16,18-20] Disabilities of the Arm, Shoulder and Hand (DASH) or quick-DASH score in 5 studies,[13,15,16,17,20] and visual analog scale (VAS) in 2 studies.[13,19] Mayo Elbow Performance Index (MEPI), Katz score, and modified American Shoulder and Elbow Society (ASES) were in the minority of outcome measurement tools.[15,16] Patient satisfaction rate was used for qualitative assessment and was described in only 4 studies.[13,14,18,20] The average value of postoperative flexion-extension motion arc reported in all studies was 102.3°. Only 7 studies described the postoperative pronation-supination motion arc, the average of which was 145.8°. Table 6 summarizes the overall clinical outcome and complications for included studies. Residual symptoms were reported as the presence of ulnar nerve symptoms, pain, and fracture. Overall, there were 55 complications (21.5%) among the 255 patients evaluated. Ulnar nerve symptom (12 patients, 4.7%) and periprosthetic fracture (12 patients, 4.7%) were 2 of the most common complications reported, followed by heterotopic ossificans (7 patients, 2.7%) and loosening (6 patients, 2.3%). The less common complications were stiffness (1 patient, 0.3%) and skin necrosis (1 patient, 0.3%).

DISCUSSION

The current systematic review focused solely on the primary linked TEA for the treatment of acute distal humerus fractures. Most studies were classified as level IV evidence. The generally accepted treatment for distal humerus fractures is ORIF, which is expected to achieve stable fixation and later facilitate early range of motion. However, the result of ORIF may be suboptimal in the case where fracture comminution is severe. TEA may be used as a salvage procedure in distal humerus fractures in the elderly population. Up to date, there is no literature regarding the systematic review of primary TEA for the treatment of acute distal humerus fractures, especially for the linked implant design. Our study represents the most comprehensive review of the outcomes of primary linked TEA for acute distal humerus fractures.

TEA, which was formerly indicated for end-stage arthritic elbow, has been expanded to include complex fractures of the distal humerus, which not infrequently present with open fractures. The current systematic review showed that most of the patients were in their 7th decade of life (71.7%). Most of the studies included the closed

fracture type (183 patients, 71.7%)[11-15,18,20] and a small number of open fracture type (18 patients, 7.05%),[14,15,17,20] whereas 54 cases (21.3%) did not specify the type of fracture.[16,19] In the elderly patients who have "paper thin" skin, the presence of a low-grade open fracture is not uncommon. Linn et al. solely evaluated the outcome of primary TEA for open intra-articular distal humerus fractures in which the mean functional outcome score was 48.[17] However, direct comparative evaluation was not possible because this study only used DASH score as the outcome measurement tool. Although the postoperative motion arc was reported to be a mean of 92°, a DASH score of more than 40 points was considered as "unable to work."[21] Five of 7 patients (71.4%) had complications at the end of follow-up, which were loosening, the presence of heterotopic ossificans, and olecranon fracture after a fall with the absence of infection event. There were also 3 studies showing that TEA for open fractures resulted in unfavorable outcomes because of the failure to obtain "excellent" for MEPS.[14,15,20] The complication rates in these studies were 70%,[14] 24.1%,[15] and 9.5%.[20] However, a systematic review and meta-analysis comparing the ORIF versus TEA for the treatment of geriatric distal humerus fractures showed comparable complication rates between the 2 surgical procedures (ORIF 32.6% vs. TEA 33.3%), showing no statistically significant difference.[6] Therefore, we postulate that the clinical outcome of TEA in treating open distal humerus fractures is unpredictable and do not recommend it as the first line of surgical option. We think that a proper indication is essential to achieve a favorable outcome.

Surgical techniques of TEA have been reviewed with great interest in the literature, which focused mainly on the surgical approach and particularly on the triceps management. To find the balance between providing adequate exposure and yet preserving the triceps is challenging for all orthopedic surgeons. The key to a successful TEA procedure is to recognize the management of extensor mechanism and balance it. The current review showed triceps reflecting has been mostly used to handle extensor mechanism compared to triceps sparring. The reason may be that triceps reflecting will minimize insult to soft tissue, which is already compromised by the index trauma.[22,23] We observed extension deficit (117° extension end point) in 1 study, in which triceps reflecting was solely used for repair.[11] Extension deficit may be associated with extensor mechanism weakness, which commonly results from inadequate repair, allowing the synovial fluid to be trapped between the triceps and its attachment.[24]

The overall functional outcomes were summarized by the mean MEPS of 89.5, which was considered as a border between good and excellent with the mean follow-up of 41.1 months. The overall functional score was superior to the scores reported with distal humerus hemiarthroplasty.[25] The interesting finding is that those with excellent MEPS (more than 90 points) had less than 7 days of interval time from injury to surgery.[11,12,18] The flexion-extension arc and pronation-supination motion arc were satisfactory (102.3° and 145.8°, respectively), considering the flexion-extension motion arc of 100° (30° extension to 130° flexion) and pronation-supination motion arc of 100° (50° pronation to 50° supination) are required for daily living activities. Therefore, we concluded that linked TEA resulted in favorable outcome for mid-term follow-up in the treatment of distal humerus fractures, which was also supported by other studies.[26,27]

The overall complication rate was not defined by each included article. The overall complication rate of our systematic review was 21.5% (55 of 255 patients). The most common complications were ulnar nerve symptoms (12 patients, 4.7%), and periprosthetic fracture (12 patients, 4.7%), followed by heterotopic ossificans (7 patients, 2.7%) and loosening (6 patients, 2.3%). The lesser complications were stiffness (1 patient, 0.3%) and skin necrosis (1 patient, 0.3%). The complication rate of TEA for managing distal humerus fractures (21.5%) was lower than that of distal humerus hemiarthroplasty (73.9%) but higher than that of total shoulder arthroplasty for managing humeral head fractures (11.6%).[25,28]

The current systematic review has several limitations. First, data from included studies were collected in retrospective manner. Second, study outcomes were not reported by using a single standardized outcome measurement tool, precluding a direct comparison of outcomes, which underscores the need for standardization of outcomes reporting tools. We suggest the use of patient-related outcome measures, which are directly reported by the patient without interpretation by a clinician, thus preventing the risk of bias.[29] Third, the heterogeneity of the surgical approach and triceps management of the reviewed studies hampered direct comparison of outcomes. Forth, as there were not enough studies to perform a meta-analysis, we were unable to provide analytic data based on correlation tests.

This systematic review, based on our analysis of the articles published from April 2009 to April 2019, highlights the favorable mid-term follow-up outcomes of primary linked TEA for acute distal humerus fractures. Early primary TEA may provide an excellent functional score (MEPS). Despite the promising functional outcome, the complication rate after TEA is still considerably high. This

systematic review will give surgeons help in explaining to patients regarding the expected outcome after primary TEA for acute distal humerus fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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