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REVIEW

Intra-articular fractures of the distal humerus—a review of the current practice

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Abstract
Intra-articular fractures of the distal humerus are complex injuries that can considerably limit elbow function if not treated appropriately. Surgical management is indicated for most intra-articular distal humerus fractures with the goal of restoring elbow range of motion and function. Open reduction and internal fixation (ORIF) with plates and screws has been the preferred surgical option. Double plating is recommended for bicolumnar fractures and plates can be applied either parallel or orthogonal to each other. Surgical approach for ORIF of the distal humerus can be performed through an olecranon osteotomy, but other approaches that preserve the olecranon are also in use, such as the triceps-reflecting, triceps-splitting, paratricipital, and triceps-reflecting anconeus pedicle approach. The ulnar nerve is identified during the approach, followed by either in situ decompression or anterior transposition. Elbow arthroplasty has also emerged as a viable alternative to ORIF for fixation of these fractures in elderly patients with poor bone quality.

Keywords Distal humerus · Fracture · Fixation · Approach · Ulnar nerve

Introduction

Distal humerus fractures are relatively uncommon injuries with an incidence of 5.7 per 100,000 persons per year [1]. There is a bimodal age distribution of these injuries with one peak in young males, caused by high-energy trauma, and a second peak in elderly females over 60, caused by low-energy injuries [1].

Surgical management is indicated for most intra-articular distal humerus fractures with the goal to achieve early motion of the elbow and a good functional outcome. Open reduction and internal fixation (ORIF) with plates and screws has been the preferred surgical option for most of these fractures. However, the distal humerus offers limited bone stock and ORIF can be very challenging in the presence of comminution and osteoporotic bone. Elbow arthroplasty has emerged as an alternative surgical option for elderly patients.

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The aim of this review was to summarize the data available in literature concerning the available options for treatment of intra-articular distal humerus fractures in adults.

Classification

Distal humerus fractures can be classified based on the Orthopedic Trauma Association / Arbeitsgemeinschaft für Osteosynthesefragen (OTA/AO) classification system as extra-articular fractures (type A), partial articular fractures (type B), and complete articular fractures (type C) [2].

Intra-articular distal humerus fractures can be classified as single-column fractures, bicolumnar fractures, capitellum fractures, and trochlea fractures [3]. This review will focus on single-column and bicolumnar fractures.

Clinical evaluation and imaging studies

Associated injuries should be ruled out, especially in patients who sustained high-energy trauma. The injured extremity should be circumferentially inspected for wounds indicative of an open fracture. A careful neurovascular exam should be performed and documented and the patient should be

monitored for development of compartment syndrome. Evaluation of the ipsilateral shoulder and wrist is essential to avoid missing adjacent joint injuries. A detailed history should include hand dominance, prior function of the upper extremity, functional demands and medical comorbidities of the patient.

Standard good-quality anteroposterior and lateral radiographs of the elbow are necessary for diagnosis, evaluation of fracture characteristics, decision-making and pre-operative surgical planning (Fig. 1a, b). Traction views of the injured elbow can be helpful. Computed tomography (CT), especially with three-dimensional reconstructions, provides detailed information about the fracture pattern, which can be very useful in cases of articular comminution (Fig. 2 a, b).

Non-operative treatment

Non-operative treatment of intra-articular distal humerus fractures has been significantly associated with decreased elbow range of motion compared to surgical treatment, especially in type C fractures [4]. On the other hand, non-operative treatment appears to be a good option for low-demand, elderly patients, or patients with a high surgical risk due to comorbidities [5]. Desloges and colleagues reported on 19 such patients treated with immobilization for a mean of five weeks followed by active motion; at a mean follow-up of 27 months, the mean flexion-extension arc was 106 degrees and 68% (13 of 19) of patients reported good to excellent subjective outcomes [5].

Open reduction and internal fixation

Surgical approach

Surgical approaches for ORIF of intra-articular distal humerus fractures include olecranon osteotomy [6, 7], triceps-reflecting (Bryan-Morrey) approach [8], triceps-reflecting anconeus pedicle (TRAP) approach [9], triceps-splitting approach [10], and paratricipital approach [11]. All approaches use a posterior midline skin incision with elevation of medial and lateral skin flaps. The ulnar nerve is routinely identified, released from the fracture site, and protected during fracture reduction and fixation. Depending on how proximally fixation is needed on the lateral column, the radial nerve may also need to be identified and mobilized [12].

The olecranon osteotomy provides excellent visualization of the fracture and is particularly useful in comminuted intra-articular fractures (Fig. 3). Wilkinson and Stanley demonstrated in a cadaveric study that the median exposed articular surface for the triceps-splitting, triceps-reflecting and olecranon osteotomy approaches was 35%, 46%, and 57%, respectively [13]. The chevron-type intra-articular osteotomy is performed at the area of the bare spot of the olecranon. The osteotomy is fixed with a plate, intramedullary screw, or tension band construct following fixation of the distal humerus fracture. Complications include nonunion of the osteotomy site and prominence of the olecranon hardware. Coles et al. reported one delayed union and eventually union of the osteotomy in all 67 patients [7]. Ring et al. reported union of the osteotomy in 44 of 45 patients (98%) [6]. The rate of symptomatic hardware that necessitated re-operation for removal ranges from 8 to 13% [6, 7].

The triceps-reflecting (Bryan-Morrey) and the TRAP approaches have been proposed in order to avoid complications related to the olecranon osteotomy but there are concerns regarding triceps weakness and suboptimal visualization of the fracture. Chen et al. compared 33 elbows managed through an olecranon osteotomy and 34 managed through a triceps-reflecting (Bryan-Morrey) approach, but found no significant difference in elbow range of motion. However, they reported inferior results for the Bryan-Morrey approach in patients over 60 years old in terms of extension loss and functional outcome. The authors concluded that the olecranon osteotomy may be a better choice for patients over the age of 60 [8]. Pankaj et al. reported that 35 (88%) of 40 patients treated

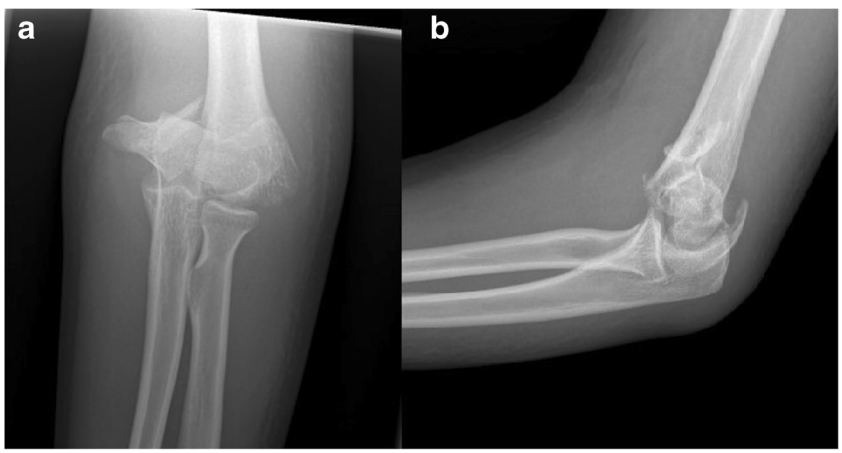

Fig. 1 Anteroposterior (**a**) and lateral (**b**) elbow radiographs of a patient with an intra-articular distal humerus fracture

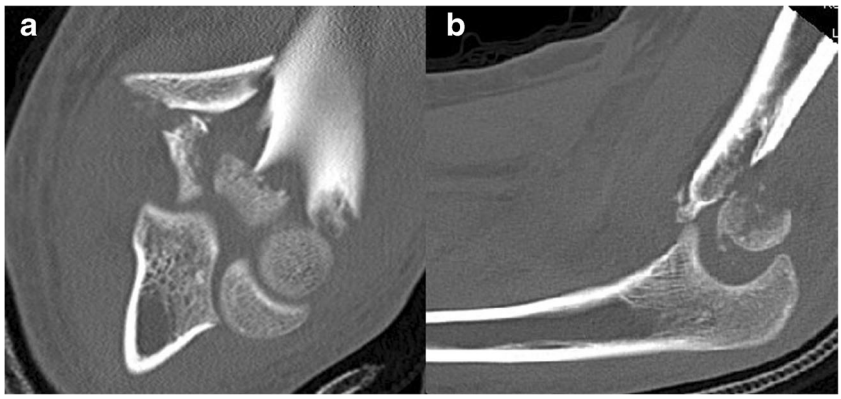

Fig. 2 Elbow coronal (**a**) and sagittal (**b**) CT images of a patient with an intra-articular distal humerus fracture

through a TRAP approach had good triceps strength (able to extend against resistance with no extension lag), five patients had fair strength (able to extend against gravity with no extension lag), and one patient had an extension lag of 10°. No patient had a triceps rupture [14].

The triceps-slitting and the paratricipital approaches maintain the extensor mechanism intact but provide limited visualization of the articular surface. Interestingly, Erpelding et al. reported a median 10% loss of triceps strength, which was as high as 30% in type C3 fractures, after fracture fixation through a paratricipital approach [15].

Ulnar nerve management

The ulnar nerve is routinely identified during ORIF of distal humerus fractures followed by either in situ decompression or anterior transposition. Ulnar nerve neuropathy following distal humerus fracture fixation has been reported in 16–38% of cases [16–19], which underscores the importance of careful pre-operative examination to identify existing nerve dysfunction and of meticulous nerve dissection to minimize disruption of its vascular supply.

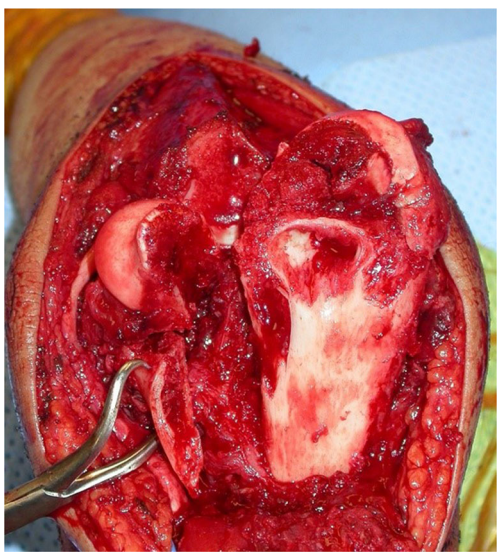

Fig. 3 Visualization of the distal humerus following an olecranon osteotomy

Anterior transposition of the ulnar nerve is beneficial when pre-operative nerve dysfunction is present. Anterior transposition also avoids direct contact of the ulnar nerve with the medial plate used for fixation of the medial column but it is unclear whether this prevents nerve dysfunction post-operatively. Chen et al. reported that anterior ulnar nerve transposition was associated with a significant increase of the rate of ulnar neuritis compared to no transposition (33% vs. 9%) [17], but most studies evaluating patients without pre-operative ulnar nerve symptoms found no difference in the rate of ulnar nerve compromise between in situ release and anterior transposition of the nerve [16, 18, 19].

Implant selection

Intra-articular distal humerus fractures involving both columns are preferably fixed with two plates [3, 20, 21]. Biomechanical and clinical studies have shown the superiority of double plating compared to other fixation constructs [22, 23]. Helfet and Hotchkiss concluded that a double plate construct was biomechanically superior to a single plate or two screws for fixation of distal humerus fractures [22].

The 3.5-mm limited contact dynamic compression plates provide sufficient strength, but their ability to be contoured is limited. Therefore, they are more suitable for the posterior aspect of the lateral column. The 3.5-mm reconstruction plates can be easily contoured and can be placed around the medial epicondyle on the medial aspect of the medial column. These plates can also be bent in a J-shape and placed on the lateral aspect of the lateral column. Pre-contoured anatomic elbow plates are also available. They are easier to apply, decrease operative time, and facilitate insertion of increased number of screws in the articular fragments [12].

Although there is consensus on the necessity of achieving stable fixation of intra-articular bicolumnar distal humerus fractures using a double plate construct, the optimal plate configuration has been controversial. The two proposed

configurations include orthogonal and parallel plating. In the orthogonal configuration the two plates are applied at 90 degrees to each other, with a medial plate on the medial column and a posterior plate on the lateral column [24, 25]. The parallel configuration uses a medial plate on the medial column combined with a lateral plate on the lateral column [21, 26] (Fig. 4).

Biomechanical studies comparing the two configurations have overall been in favor of the parallel configuration. Jacobson et al. found that an orthogonal construct had significantly higher relative stiffness in sagittal plane loading than a parallel construct. However, a 3.5-mm dynamic compression plate was used at the lateral column in the orthogonal construct, compared to a 3.5-mm reconstruction plate in the parallel construct [27]. In the same study, there was no difference between the parallel and orthogonal constructs when a 3.5-mm reconstruction plate was used in both constructs. Some authors reported no significant differences in the stiffness of the two configurations [28–30], although a trend toward higher stiffness of the parallel construct in anteroposterior, mediolateral, and torsional testing was found by Kollias et al. [29].

Several biomechanical studies demonstrated that parallel plating has superior biomechanical properties compared to orthogonal plating [31–35]. Self et al. reported that parallel plates had significantly higher stiffness in axial compression compared to orthogonal plates [32], and Arnander et al. found that the parallel construct was significantly stiffer in sagittal plane loading [33]. Stoffel et al. reported that the parallel construct was significantly stiffer in axial compression as well as in external rotation [34]. Zalavras et al. compared parallel to orthogonal constructs in an intra-articular distal humerus fracture model with a metaphyseal defect in matched pairs of cadaver elbows [35]. Parallel plate constructs had significantly higher stiffness than orthogonal ones during cyclic varus loading without any screw loosening compared to screw loosening in all posterior plates of orthogonal constructs. Parallel constructs had significantly higher ultimate torque in varus loading to failure as well as significantly higher ultimate load in axial/sagittal loading to failure [35].

A prospective randomized clinical study by Shin et al. compared parallel to orthogonal plating in closed intra-articular distal humeral fractures [36]. The authors reported no significant differences in outcome between the two groups at a minimum follow-up time of two years. However, there were two nonunions (one with implant loosening) in the orthogonal group (12%, 2/17) compared to none in the parallel group (0%, 0/18). This difference was not significant ($p = 0.23$) but the study was underpowered [36].

The development of locking plates has found application in fixation of intra-articular distal humerus fractures, since these angular-stable implants may offer biomechanically superior fixation. Biomechanical studies have found that in the presence of poor bone quality locking plates are biomechanically superior to non-locking ones, but this is not the case when good bone quality is present [37, 38].

A clinical study retrospectively compared 65 intra-articular distal humerus fractures fixed with locking plates to 31 fractures fixed with non-locking plates and reported no significant differences in clinical outcomes [39]. Loss of fixation at six weeks occurred in 2% (1/65) of locking implants compared to 6% (2/31) of non-locking implants. The difference was not significant ($p = 0.24$), however the study was underpowered. Moreover, there was a selection bias as older patients were significantly more likely to receive locking plate fixation. A prospective randomized clinical study by Lee et al. compared parallel to orthogonal locking plate fixation in intra-articular distal humeral fractures and reported no nonunions and no differences in outcome between the two groups at a minimum follow-up time of two years [40].

External fixation is an option for provisional or definitive fixation of intra-articular distal humerus fractures in select

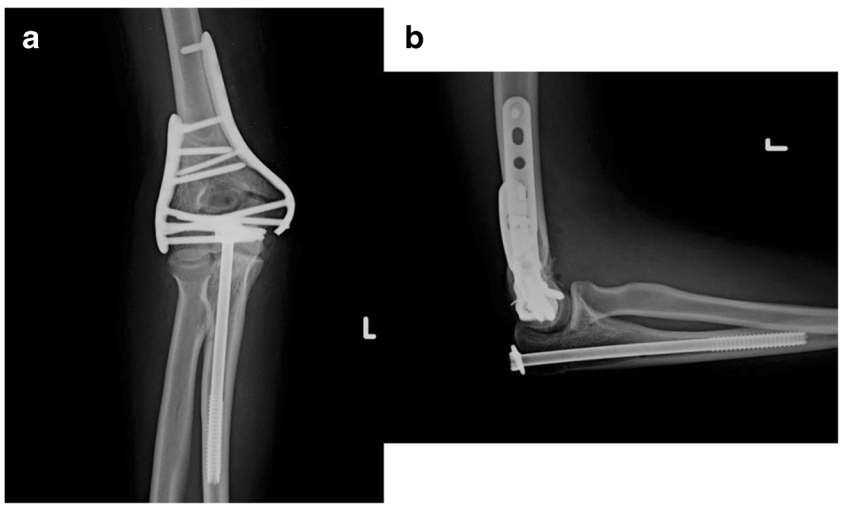

Fig. 4 Anteroposterior (**a**) and lateral radiographs following osteosynthesis of a distal humerus fracture with dual plating in a parallel configuration. Olecranon osteotomy was used for the approach and the olecranon has been fixed with an intramedullary screw

cases. Open fractures may be temporarily stabilized with a bridging external fixator followed by definitive plate fixation at a second stage [41]. Closed reduction and percutaneous insertion of a non-bridging ring fixator has been used with good results in elderly patients with osteoporotic bone [42].

Outcome

Although the specific details of the optimal plate construct (parallel vs. orthogonal, locking vs. non-locking) for intra-articular distal humerus fractures have not been clarified, when anatomic reduction of the articular surface, stable bicolumnar internal fixation, and early motion are achieved, satisfactory outcomes can be expected. This has been shown in earlier studies [24, 25, 43], as well as in more recent ones [10, 15, 26, 44–49] (Table 1).

Helfet and Schmeling compiled the results of the literature from 1985 to 1990 and found that on average excellent and good results were achieved in 75% of intra-articular distal humerus fractures [25]. Athwal evaluated 17 case series with 501 patients published between 2002 and 2009 and found that on average 85% of patients experienced good to excellent outcomes at a mean follow-up of approximately four years [45].

Gofton et al. reviewed 43 patients managed with orthogonal plate fixation at a mean time of 45 months post-operatively and found that patients achieved a 122 degree range of motion and reported a Disabilities of the Arm, Shoulder and Hand (DASH) score of 12 [46]. The authors emphasized that a third plate was required in almost 40% of patients for stable fixation.

Sanchez-Sotelo et al. treated 34 complex distal humerus fractures (26 fractures had comminution of the articular surface and 14 fractures were open) with parallel plate fixation [26]. The authors reported a good or excellent outcome in 27 (84%) of 32 elbows at a mean follow-up of two years. There were no hardware failures, no fracture displaced, and union was achieved primarily in 31 (97%) of 32 fractures. The mean elbow extension-flexion arc was 99 degrees and the mean Mayo elbow performance score (MEPS) was 85 points.

Recent retrospective studies have reported on the outcome of locking plates with satisfying results [50–52]. At a mean follow-up ranging from 10 to 31 months, the mean arc of elbow motion ranged in these studies from 103 to 113 degrees, MEPS ranged between 85 and 91, and DASH score between 19 and 23 [50–52].

The study with the longest, to our knowledge, follow-up was performed by Doornberg and colleagues, who evaluated a series of 30 patients at a mean time of 19 years (range 12–30 years) after ORIF of intra-articular fractures of the distal humerus [47]. Good or excellent results were achieved in 26 patients (87%) and mean elbow motion arc was 106 degrees. The mean ASES (American Shoulder and Elbow Surgeons) score was 96 points, and the mean DASH score was 7 points. The authors demonstrated that the results of ORIF are durable long-term, despite the development of arthrosis. Twenty-four patients (80%) developed arthrosis (11 had slight joint space narrowing, 11 had moderate narrowing, and 2 had severe arthrosis) but this did not correlate with impairment or disability [47].

Elbow arthroplasty

Although it has been shown in the literature that ORIF of intra-articular distal humerus fractures based on the principles of anatomic reduction, stable fixation, and early motion results in excellent or good outcome in most patients, there has been concern regarding fixation of these fractures in elderly individuals. The presence of poor bone quality, especially when combined with fracture comminution, may preclude stable fixation and lead to prolonged immobilization and a poor outcome. As a result, total elbow arthroplasty (TEA) has been proposed as a primary treatment method for comminuted intra-articular distal humerus fractures in elderly patients [53].

Total elbow arthroplasty

Cobb and Morrey were the first to report on the use of TEA (Coonrad-Morrey semi-constrained arthroplasty) for treatment of 21 distal humerus fractures in 20 patients with a mean age of 72 years (range, 48–92 years) [54]. Ten patients had a history of rheumatoid arthritis, while the rest were all over 65 years old. At a mean follow-up time of 3.3 years (range, 3 months to 10.5 years) the mean arc of motion was 25–130 degrees and according to the MEPS 15 elbows had an excellent and five a good result. Complications included one ulnar component fracture after a fall, one superficial wound infection, three ulnar neurapraxias, and one case of reflex sympathetic dystrophy. Three elbows had radiolucent lines immediately post-operatively but these had not progressed by the time of final follow-up. The authors concluded that, under strict criteria of patient selection, TEA is a viable option for treatment of comminuted distal humerus fractures in patients older than 65 years or in patients with rheumatoid arthritis [54].

Additional studies have reported encouraging results [55–58]. Garcia et al. reported on 19 patients over 60 years old treated with TEA (Coonrad-Morrey semi-constrained) and followed for a minimum of three years [55]. The mean MEPS was 93, the mean DASH score was 23 and the mean arc of motion was 24 to 125 degrees. There was one patient with a non-progressive radiolucent line on X-rays. Kamineni and Morrey reported on 43 distal humerus fractures in patients of a mean age of 67 years treated with a TEA and followed-up for a mean time of seven years [56]. The average motion arc was 24–131 degrees and the mean MEPS was 93. Heterotopic ossification developed in seven elbows. Ten re-operations,

Table 1 Outcome of open reduction internal fixation of intra-articular distal humerus fractures

Study	Patients	Age (years)	Fracture type	Fixation	FU (months)	Primary union[a]	Elbow ROM (°)	Functional scores	Complications and reoperations
McKee et al. [10]	25 (of 35)	47	C: 25	Various implants	37	96%	108	DASH = 20	6 re-operations: 1 for nonunion with hardware failure, 2 for stiffness, 3 for removal of prominent hardware from olecranon
Erpelding et al. [15]	24 (of 37)	47	C: 17 A: 6 B: 1	Various implants	27	100%	126	DASH = 16 MEPI = 92	3 re-operations for stiffness 1 ulnar neuropathy with permanent loss of ulnar nerve function (no reoperation)
Sanchez-Sotelo et al. [26]	32 (of 34)	58	C3: 26 C2: 5 A3: 3	PA non-L	24	97%	99	MEPS = 85	9 re-operations: 1 for revision of hardware and bone grafting, 5 for HO, 2 for wound healing complications, 1 for deep infection, 2 ulnar neuropathies (no reoperation)
Shin et al. [36]	17 (35 of 38)	52	C2:9 C3:5 C1:3	OR non-L	34	88%	106	MEPS = 92	8 re-operations: 2 for nonunions, 1 for stiffness, 5 for symptomatic hardware
Shin et al. [36]	18 (35 of 38)	56	C2:7 C1:7 C3:4	PA non-L	28	100%	112	MEPS = 94	8 re-operations: 1 for HO, 1 for ulnar nerve symptoms, 6 for symptomatic hardware
Lee et al. [40]	32 (of 35)	58	C2:19 C3:9 C1:4	OR L	35	100%	98	DASH = 25 MEPS = 85	8 re-operations for symptomatic hardware
Lee et al. [40]	35 (of 37)	55	C2:19 C3:8 C1:5	PA L	26	100%	100	DASH = 23 MEPS = 90	18 re-operations: 2 for screw removal, 1 for HO, 1 for olecranon osteotomy fixation failure, 1 for periprosthetic fracture, 13 for symptomatic hardware
Henley et al. [43]	33	32	C1:23 C2:8 C3:2	Various implants	18	94%	107	N/A	2 re-operations for fixation failure and nonunion 2 infections, 2 cases of HO 9 olecranon osteotomy complications
Tyllianakis et al. [44]	26 (of 31)	46	C3:10 C2:8 C1:8	Various implants	70	92%	N/A	Morrey score: excellent:6 good:15 fair:5	10 re-operations: 1 for malreduction, 3 for stiffness, 1 for infection, 4 for K-wire migration, 1 for hardware removal 1 fixation failure (no reoperation, healed by cast immobilization)
Gofton et al. [46]	23 (of 28)	53	C2:11 C3:9 C1:3	OR non-L	45	96%	122	DASH = 12 ASES = 10	7 re-operations: 1 for capitellum nonunion, 2 for olecranon osteotomy nonunion, 1 for intra-articular screw penetration, 1 for symptomatic hardware, 2 for stiffness/HO
Doornberg et al. [47]	30	35	C3:11 C2:11 C1:8	Various implants	228	93%	106	DASH = 7 MEPI = 91 ASES = 96	12 re-operations: 2 for hardware failure, 2 for stiffness, 1 for ulnar nerve symptoms, 1 for infection, 5 for symptomatic hardware, 1 for painful arthritis
Flinkkilä et al. [48]	47 (functional scores in 27 of 47)	60	C:47	PA non-L	47	94%	123	MEPS = 88 DASH = 26	17 re-operations: 1 for nonunion, 3 for infection with exposed hardware, 13 for symptomatic hardware No re-operation needed for 1 nonunion, 1 malunion after hardware failure, 1 nonunion of olecranon osteotomy

Values indicate means

FU follow-up, *ROM* range of motion, *OR* orthogonal, *PA* parallel, *L* locking, *HO* heterotopic ossification

[a] Primary union of distal humerus fracture

Table 2 Outcome of open reduction internal fixation of intra-articular distal humerus fractures in elderly patients

Study	Patients with FU	Age (years)	Fracture type	Fixation	FU (months)	Primary union[a]	Elbow ROM (°)	Functional wcores	Complications and reoperations
Ducrot et al. [51]	43 (of 46)	80	C3: 12 C2: 11 C1: 2 B: 6 A: 15	L	25	95%	104	MEPS = 87	6 re-operations: 2 for infection, 4 for symptomatic hardware No re-operations: 1 failure of fixation, 2 nonunions, 2 nonunions of olecranon osteotomy, 4 persistent ulnar neuropathies, 2 HO
Frankle et al. [59]	12	74	C3: 8 C2: 4	OR non-L	57	75%	100	MEPS = 81	4 re-operations: 3 for fixation failure, 1 for deep infection
Egol et al. [60]	11 (of 12)	76	C: 8 B: 3	No details provided	13	83%	98	DASH = 32 MEPS = 85	3 re-operations: 1 early failure of fixation (not included in the group of 11 pts), 2 for stiffness 1 nonunion with collapse (good function – no reoperation)
McKee et al. [62]	15	77	C3: 9 C1: 5 C2:1	10 OR non-L, 5 PA non-L	24	93%	95	DASH = 43 MEPS = 73	4 re-operations: 1 for fixation failure, 1 for ulnar nerve symptoms, 2 for stiffness
Liu et al. [64]	32 (of 35)	69	C1:15 C2:13 C3:7	OR non-L	25	100%	103	MEPS = 94	1 HO with poor motion (no reoperation)

Values indicate means

FU follow-up, *ROM* range of motion, *OR* orthogonal, *PA* parallel, *L* locking, *HO* heterotopic ossification

[a] Primary union of distal humerus fracture

including five revision arthroplasties were required. Kalogrianitis et al. reported on the use of an unlinked prosthesis for distal humerus fractures in nine elbows followed-up for a mean time of 3.5 years [57]. All elbows were stable, pain relief was satisfactory, and the median MEPS score was 95.

Few studies have directly compared TEA to ORIF for intra-articular fractures of the distal humerus in elderly patients [59–63]. Frankle et al. reported that at a minimum follow-up of two years (mean 57 months) all 12 patients treated with TEA had an excellent or good outcome based on the MEPS, compared to eight of 12 patients treated with ORIF. There were three failures of fixation in the ORIF group that were treated with conversion to TEA and three re-operations in the TEA group, but none for revision. The authors concluded that TEA is a viable option for women over 65 with associated comorbidities [59].

Egol et al. compared TEA vs. ORIF for intra-articular distal humerus fractures in women older than 60 years and found no statistically significant differences between the TEA and the ORIF group in terms of range of motion (92 vs. 98°), MEPS (79 vs. 85), and DASH score (30 vs. 32) [60]. There was one re-operation in the TEA group (revision for loosening), and two in the ORIF group (contracture release after union for limited elbow range of motion).

Jost et al. reported on 16 elbows in 14 patients with rheumatoid arthritis and distal humerus fracture [61]. Ten elbows were treated with TEA and six with ORIF. Outcome based on the MEPS was similar between the two groups (96 vs. 93) and the authors concluded that distal humeral fractures in patients with rheumatoid arthritis can be treated successfully with immediate open reduction and internal fixation or with total elbow arthroplasty.

The only randomized controlled study to date comparing TEA to ORIF in patients older than 65 years was conducted by McKee et al. [62]. Forty of the initial 42 participants were followed-up for two years. The functional outcome as assessed with the MEPS was significantly better in the TEA group at 12 months (88 vs. 72, $p = 0.007$) and two years (86 vs. 73, $p = 0.015$) compared with the ORIF group. The DASH scores were significantly lower in the TEA group at six weeks and six months, but not at 12 and 24 months. There were no statistically significant differences between the TEA and ORIF groups in terms of re-operation rate (12% vs. 27%) and elbow range of motion (107 vs. 95°). The authors concluded that TEA for the treatment of comminuted intra-articular distal humeral fractures resulted in more predictable two-year functional outcome compared to ORIF.

The functional outcome of TEA in the above comparative studies was at least equivalent to the outcome of ORIF [59–63]. However, TEA has its own limitations and complications. A restriction of lifting no more than five pounds is a considerable limitation for patients. Implant loosening and periprosthetic fractures requiring revision arthroplasty are complications unique to TEA and their rate may be underestimated

in studies without long-term follow-up. On the other hand, recent studies on fixation of intra-articular distal humerus fractures in elderly patients have reported improved results [51, 64]. Liu et al. treated 32 patients with mean age of 69 years with ORIF and reported union in all 32 fractures with a mean MEPS of 94 [64]. Ducrot et al. employed locking plates for fixation of distal humerus fractures in 46 consecutive patients with a mean age of 80 years, 31 of whom had intra-articular fractures [51]. At a mean follow-up of 25 months, 41 (95%) of 43 fractures united and on average patients had a MEPS of 97 and elbow motion arc of 104 degrees. The outcome of fixation of intra-articular distal humerus fractures in elderly patients is summarized in Table 2.

Hemiarthroplasty

Concerns over the longevity of TEA for younger, more active patients led to introduction of distal humerus hemiarthroplasty as a treatment option for severely comminuted intra-articular fractures of the distal humerus. Hemiarthroplasty avoids complications associated with the ulnar component and may require fewer physical restrictions than TEA. The literature on the medium-term outcomes of hemiarthroplasty for distal humerus fractures is limited [65, 66]. Smith and Hughes reported on 26 patients treated with hemiarthroplasty [65]. Four patients died and one patient declined to participate; four of the remaining 21 patients (19%) required revision to TEA and 17 patients were followed-up at a mean time of 80 months postoperatively. The mean MEPS was 90 and the mean quick DASH score was 19. The mean flexion extension arc was 116 degrees and there was no instability. Radiologic evidence of ulnar wear was present in 13 of 17 patients (76%) and increased wear associated with worse patient outcomes. Distal humerus hemiarthroplasty is not currently approved by the US Food and Drug Administration.

Conclusions

Operative treatment with open reduction and internal fixation is the treatment of choice for most intra-articular distal humerus fractures. The principles of anatomic reduction, stable fixation, and early motion are critical. Double plating is recommended for bicolumnar fractures but the literature is inconclusive as to optimal plate configuration and necessity for locking implants. Total elbow arthroplasty is a viable option for management of comminuted intra-articular distal humerus fractures in elderly patients with poor bone quality.

Compliance with ethical standards

Conflict of interest statement On behalf of all authors, the corresponding author states that there is no conflict of interest.

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