

Distal humeral fractures treated with ORIF or hemiarthroplasty: A matched-pair analyses

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ABSTRACT

Introduction: Fractures of the distal humerus are common in older patients with osteoporotic bone, often presenting as complex, multi-fragmentary injuries involving the articular surface. This complexity complicates the decision between open reduction and internal fixation (ORIF) and total elbow arthroplasty (TEA), as both procedures carry specific risks. Hemiarthroplasty (HA) may be a viable alternative, yet few studies have compared its outcomes with those of ORIF. In this retrospective matched-pair study, we aimed to compare primary HA versus ORIF for complex distal humerus fractures. Our hypothesis was that HA could achieve functional outcomes equivalent to ORIF when joint reconstruction is not feasible.

Materials and methods: We matched 10 pairs of patients who underwent HA or ORIF between 2018 and 2022. Matching criteria included age, gender, and fracture classification (Orthopaedic Trauma Association (OTA) or Dubberley classification for coronal shear fractures). Functional outcomes were assessed using the Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) score and the Mayo Elbow Performance Score (MEPS). The mean follow-up was 29 months for the HA group and 33 months for the ORIF group.

Results: Both treatment groups exhibited satisfactory functional outcomes. In the HA group, the median MEPS was 89.5 and a qDASH score of 21.6. Mean range of motion in extension/flexion was 105.9°. The ORIF group had a median MEPS of 81.5, a qDASH of 17 and a mean range of motion of 116.5°. No significant differences in functional outcomes were observed between the two groups.

Conclusions: HA can yield functional results comparable to ORIF in managing complex distal humerus fractures. When ORIF is not feasible, HA is an effective alternative, particularly for physically active patients over 60 years, as it avoids the limitations associated with linked total elbow arthroplasty, such as weight restrictions and the risk of ulnar component loosening.

Level of evidence: Level III

Introduction

Fractures of the distal humerus frequently occur in older patients with osteoporotic bone, typically presenting with a complex, multi-fragmentary morphology categorized as Type B or C according to the OTA classification [10,14]. Surgical treatment is therefore indicated, as conservative treatment for these fractures can only be justified in multimorbid patients who present with a high surgical risk and very low

functional demands [10]. However, anatomical reconstruction of the joint is not always feasible due to the intricate geometry of the fracture. In 1997, Cobb and Morrey proposed the consideration of primary total elbow arthroplasty (TEA) as a treatment option for complex distal humerus fractures [5]. Previous studies have demonstrated that both endoprosthetic and osteosynthetic treatments of distal humerus fractures in older patients can yield comparable functional outcomes. Notably, McKee et al. reported in their randomized controlled study that

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in 25 % of cases, the surgical approach was altered from open reduction and internal fixation (ORIF) to fracture arthroplasty intraoperatively, due to the inability to achieve proper reconstruction [11]. This underscores the importance of having the option of arthroplasty available for complex distal humerus fractures. Furthermore, this treatment modality offers shorter operative times and consistently satisfactory functional outcomes in comparison to open reduction and internal fixation (ORIF), particularly in older patients. However, one drawback of arthroplasty is the associated risk of deep infection, component loosening, and periprosthetic fractures. Additionally, total elbow replacement imposes lifelong weight restrictions on the affected limb [3,11,15]. For this reason, we only recommend primary total elbow arthroplasty (TEA) for the treatment of fractures in patients aged 70 years or older. Hemiarthroplasty (HA) serves as an alternative to TEA for managing distal humeral fractures. In recent years, studies by Nestorson et al. and Smith et al. have demonstrated particularly convincing outcomes in patients treated with HA for comminuted fractures of the distal humerus [12,16]. One advantage is the lack of weight restriction with HA compared to TEA [1]. Furthermore, hemiarthroplasty (HA) eliminates the risks associated with loosening or infection of the ulnar component. While HA presents several advantages from this perspective, a comparative analysis with open reduction and internal fixation (ORIF) has not yet been conducted. In our retrospective matched-pair study, we aim to compare primary HA for specific distal humerus fractures with ORIF. Our hypothesis posits that hemiarthroplasty can achieve functional outcomes equivalent to those of ORIF. Consequently, HA could represent a viable treatment option for patients with non-reconstructable distal humerus fractures.

Materials and methods

We conducted a retrospective matched-pair study for the period from 2018 to 2023. We identified a total of 76 patients who underwent surgical intervention at our clinic for distal humerus fractures. Among these patients, 23 were treated with a hemiprosthesis (study group), while 53 underwent open reduction and internal fixation (ORIF; control group). We excluded all patients with:

- (1) Secondary HEP implantation following a failed osteosynthesis attempt or an infection related to the osteosynthesis material.
- (2) Patients who were under 50 years of age at the time of surgery on the osteosynthetic side, as younger patients do not qualify for prosthetic treatment, as outlined in the introduction).

(3) Patients with OTA 13 A fractures

Hemiarthroplasty was performed by two senior elbow surgeons from our team, utilizing the Latitude EVTM (Stryker, Kalamazoo, Michigan, USA) implant and a paratricipital approach. After the median skin incision, the medial and lateral intermuscular brachial septa are identified, following the stabilization of the ulnar nerve medially. The triceps brachii muscle is detached from the septum and is then released from the humerus in a proximal to distal direction. At the level of the joint, the collateral ligaments at the epicondyle, as well as the origins of the extensor and flexor muscles, are dissected. The joint can be dislocated through rotational movements.

Open reduction and internal fixation (ORIF) with anatomic locking plates (Aptus®, Medartis AG, Basel, Switzerland) were conducted by three different senior elbow surgeons. Two patients receiving headless screws alone had surgery via an extended Kocher approach. For the lateral approach according to Kocher, the skin incision was made in a curved manner from the lateral epicondyle to the level of the radial head. After incising the lateral fascia, dissection was performed in depth between the anconeus muscle and the extensor carpi radialis, leading to the exposure of the joint. In cases requiring additional posterior plate fixation, an extended lateral approach was employed (see Table 1). For this purpose, the previously described Kocher approach was extended proximally and dorsally.

The patients were reassessed six weeks postoperatively and at a final follow-up appointment as part of this study. The functional outcome of the patients was assessed using the Mayo Elbow Performance Score (MEPS) and the Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) score. Additionally, complications and instances of revision surgery were documented. The arc of motion in extension and flexion, as well as in pronation and supination, was assessed for all patients.

Two investigators (TL and MMW) independently classified all patients according to the OTA and Dubberley classification system. In instances of disagreement, a senior trauma surgeon (LPM) was consulted for resolution. Subsequently, we excluded patients who underwent reosteosynthesis following failed osteosynthesis. This resulted in a final cohort of 15 patients treated with hemiprosthesis and 22 patients who underwent open reduction and internal fixation (ORIF) available for matching. For each patient receiving a hemiprosthesis, we initially selected a corresponding patient from the pool of 22 ORIF patients based on similar fracture patterns, according to the Orthopaedic Trauma Association (OTA) or Dubberley classification, age and gender. If a match could not be found based on fracture classification, we selected the

Table 1

Overview of performed procedures, complications and revision surgery.

Hemiprotheses					ORIF				
Pat.	Accompanying injuries	Procedure	Complications	Revision	Pat.	Accompanying injuries	Procedure	Complications	Revision
1a	-	HA	-	-	1b		2xCC screws+posterior plate	-	-
2a	-	HA	-	-	2b		Double plate humerus + 4 CC screws	-	-
3a		HA	-	-	3b		Double plate humerus +double plate olecranon	-	-
4a	radial head fracture (Mason II)	HA	-	-	4b	radial head fracture (Mason II)	3xCC screws+LCL repair, radial head resection	-	-
5a	olecranon fracture (Mayo 3b)	HA+ORIF ulna	wound infection	wound revision + hardware removal	5b	olecranon fracture (Mayo 2b)	Double plate humerus	-	-
6a	MCL-/LCL ruptur	HA	-	-	6b		Double plate humerus	-	-
7a	-	HA	-	-	7b		Double plate, 2xCC screws, MCL and LCL repair	CRPS	-
8a	-	HA	-	-	8b		3xCC screws+LCL repair	-	-
9a	-	HA	-	-	9b		-	Irritating hardware	Hardware removal
10a		HA	-	-	10b		Double plate+3 CC screws	Irritating Hardware	Hardware removal

patient whose fracture morphology most closely resembled that of the hemiarthroplasty patient. Consequently, 15 pairs were formed for data collection. However, five were lost to follow-up resulting in a final inclusion of 10 pairs within the study (Fig. 1).

Within the hemiarthroplasty (HA) group, three patients presented with concomitant injuries: one patient sustained a Mason Type II radial head fracture, another patient had an olecranon fracture classified as Mayo Type IIIb, and a third patient exhibited ruptures of both the lateral collateral ligament (LCL) and the medial collateral ligament (MCL). Due to our matching process, we were able to assign patients with fractures of the radial head and olecranon to corresponding ORIF patients who also exhibited a Mason Type II radial head fracture and an olecranon fracture (Table 1).

Data collection and statistical analyses were conducted using Microsoft® Excel® 2011 for Mac and GraphPad Prism 10 for Mac. To evaluate differences in interval-scaled data (range of motion), an unpaired t-test with Welch's correction was employed. For ordinal-scaled data (MEPS, qDASH), Mann-Whitney tests were utilized to determine differences between the two groups. G*Power 3 was used to for statistical power analyses [7].

Results

There were 10 patients in the HA group consisting of 10 women, ORIF group of 9 women and one man. Mean age was 67 years, final follow-up period was 29.7 and 33 months (Group HA vs. ORIF).

Six weeks postoperatively, the Mayo Elbow Performance Score (MEPS) and range of motion were evaluated. The results indicated a MEPS of 82.5 for the hemiarthroplasty (HA) group and 81.5 for the open reduction and internal fixation (ORIF) group. The range of motion in extension/flexion was recorded at 105.9 degrees for the HA group and 116.5 degrees for the ORIF group (Tables 2 and 3).

At final follow-up Patients treated with HA showed a median Mayo Elbow Performance Score of 89.5, (range 68–100), the median qDASH was 21.6, (range 2.3–47). The mean range of motion in extension/flexion was 105.9° (± 17.4 STD, range 75–130°; Table 4). Patients treated with ORIF showed a median Mayo Elbow Performance Score of 81.5, (range 48–100), median qDASH was 17.0 (range 6.8–84.1). Mean range of motion in extension/flexion was 116.5° (± 23.1 STD, range 7–140°; Table 5). No significant differences could be found between the two groups (Fig. 2) regarding MEPS, qDASH, or range of motion. We conducted a power analysis for the MEPS values, which yielded an effect

Table 2

Overview of data collection of patients treated with hemiarthroplasty 6 weeks after surgery. Age of patients, gender, follow-up, OTA-classification, MEPS, qDASH and range of motion are depicted. We calculated the median for MEPS and qDASH, indicated by $\emptyset$. Mean was calculated for follow-up, age and ROM, indicated by *.

6 weeks post surgery						
Hemiprostheses						
Patient	Age	Gender	AO classification	MEPS	ROM Ex/Flex	ROM Pro/Sup
1a	80	f	AO 13 B3, Dubberley 2B	73	90	140
2a	64	f	AO 13 C3	81	110	175
3a	68	f	AO 13 C3	100	130	160
4a	71	f	AO 13 B3, Dubberley 3B	100	110	170
5a	66	f	AO 13 C3	77	90	160
6a	59	f	AO 13 C3	100	110	170
7a	70	f	AO 13 B3, Dubberley 3B	84	120	180
8a	58	f	AO 13 B3, Dubberley 3B	76	75	90
9a	72	f	AO 13 B3, Dubberley 3B	74	90	140
10a	69	f	AO 13 C3	100	120	160
Median/ $\emptyset$ / mean*	68*			82.5 $\emptyset$	105.9*	154.5*

size of 0.162 and a power of 0.063. For the qDASH we yielded an effect size of 0.157 and a power of 0.099. Effect size of the comparison of the range of motion was 0.48 and 0.51 for the statistical power.

In group HA, one patient underwent revision surgery due to a wound infection. No further complications occurred in the HA group. Two patients in group ORIF suffered from interfering hardware, which led to elective hardware removal. One patient developed CRPS, which led to significant functional limitations. During the follow-up period, patients treated with a HA showed no evidence of loosening of the prosthesis. In the ORIF group fracture healing was confirmed by X-rays 6 and 12 weeks postoperatively. For patients in the hemiarthroplasty group, x-rays were taken at the last follow-up appointment. There was no evidence of loosening or a periprosthetic fracture.

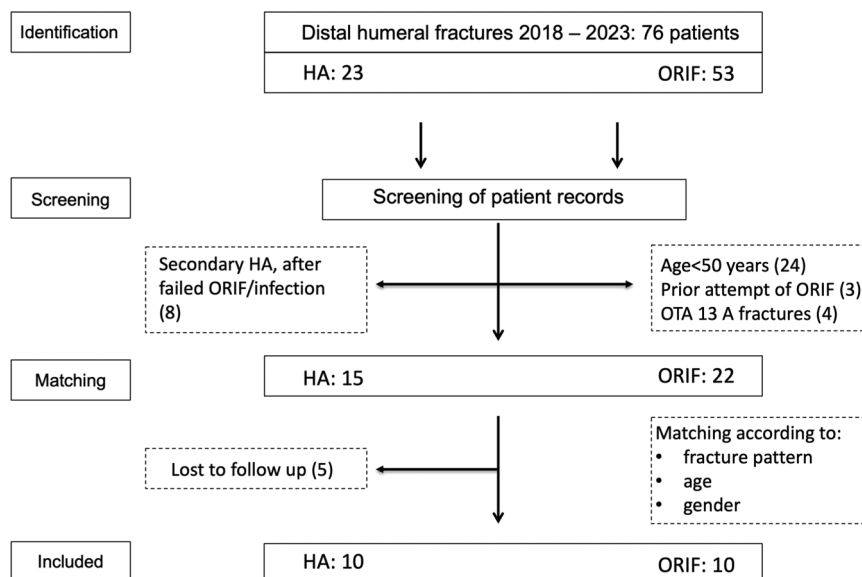


Fig. 1. Flow-chart diagram of the matching process and composition of the two study groups.

Table 3

Overview of data collection of patients treated with ORIF 6 weeks after surgery. Age of patients, gender, follow-up, OTA-classification, MEPS, qDASH and range of motion are depicted. We calculated the median for MEPS and qDASH, indicated by Ø. Mean was calculated for follow-up, age and ROM, indicated by *.

6 weeks post surgery						
ORIF						
Patient	Age	Gender	AO classification	MEPS	ROM Ex/Flex	ROM Pro/Sup
1b	75	f	AO 13 B3, Dubberley 1B	85	90	160
2b	61	f	AO 13 C3	66	65	80
3b	61	f	AO 13 C3	86	80	160
4b	68	m	AO 13 B3, Dubberley 3B	75	70	160
5b	69	m	AO 13 C3	94	110	160
6b	66	f	AO 13 C3	85	130	180
7b	62	f	AO 13 B3, Dubberley 3B	64	60	100
8b	55	f	AO 13 B3, Dubberley 3B	71	100	80
9b	61	f	AO 13 B3, Dubberley 3B	50	45	160
10b	76	f	AO 13 C3	15	5	40
MedianØ/ mean*	65*			81.5 Ø	116.5*	128*

Discussion

In our matched-pair study, we achieved satisfactory functional results for both treatment groups. No significant differences were observed in terms of functional outcomes or complication rates, suggesting that both treatment modalities can yield adequate functional results. When comparing our findings with other studies on hemiarthroplasty,

Nestorson et al. reported a slightly better Mayo Elbow Performance Score (MEPS) of 90 (range 50–100), noting that they calculated the mean rather than the median in their analysis. However, with respect to the Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) score and range of motion, our results were comparable, indicating a qDASH score of 20 and a mean range of motion of 105.5 [12]. Celli et al. also showed similar functional results in their study, even though both primary and secondary HA were investigated [4]. In a meta-analysis Nielsen et al. found no superiority of ORIF over hemiarthroplasty [13].

Dirckx and colleagues also conducted a comparison between hemiarthroplasty (HA) and open reduction and internal fixation (ORIF) and found no significant differences between the two treatment groups. The mean range of motion in the HA group was slightly superior to that observed in our study, measuring 120° compared to our 106°. Similar findings were noted in the ORIF groups regarding range of motion. Their study reported no significant differences in age, fracture classification, or follow-up duration between the two groups. However, unlike our approach, they did not employ a patient-by-patient matching process, which we utilized to enhance the comparability of the two cohorts [6].

The complication rate in our study was relatively low, recording one revision surgery and two elective hardware removals. However, due to the limited number of cases, it is possible that the complication rate may be underestimated. Revision rates reported in the existing literature demonstrate considerable variability, which is likely attributable to the overall small sample sizes. In one meta-analysis, a complication rate for hemiarthroplasty (HA) as high as 33% was noted, yet the cumulative number of cases included in that analysis was only 96 patients [13].

Another treatment option for complex distal humeral fractures, in addition to hemiarthroplasty (HA) and open reduction and internal fixation (ORIF), is total elbow arthroplasty (TEA). Comparative analyses of treatment outcomes indicate that there is no significant difference in the functional outcomes of patients treated with hemiarthroplasty

Table 4

Overview of data collection of patients treated with hemiarthroplasty at final follow-up. Age of patients, gender, follow-up, OTA-classification, MEPS, qDASH and range of motion are depicted. We calculated the median for MEPS and qDASH, indicated by Ø. Mean was calculated for follow-up, age and ROM, indicated by *.

Hemiprostheses								
Patient	Age	Gender	AO classification	Follow-up	MEPS	qDASH	ROM Ex/Flex	ROM Pro/Sup
1a	80	f	AO 13 B3, Dubberley 2B	30	73	27,3	90	140
2a	64	f	AO 13 C3	13	81	47,7	110	175
3a	68	f	AO 13 C3	59	100	2,3	130	160
4a	71	f	AO 13 B3, Dubberley 3B	21	100	6,8	110	170
5a	66	f	AO 13 C3	32	77	20,5	90	160
6a	59	f	AO 13 C3	44	100	20,5	110	170
7a	70	f	AO 13 B3, Dubberley 3B	11	84	36,4	120	180
8a	58	f	AO 13 B3, Dubberley 3B	14	76	22,7	75	90
9a	72	f	AO 13 B3, Dubberley 3B	10	95	27,3	90	180
10a	69	f	AO 13 C3	63	100	6,8	120	160
MedianØ/mean*	68*			29.0*	89.5Ø	21.6Ø	105.9*	154.5*

Table 5

Overview of data collection of patients treated with ORIF at final follow-up. Age of patients, gender, follow-up, OTA-classification, MEPS, qDASH and range of motion are depicted. We calculated the median for MEPS and qDASH, indicated by Ø. Mean was calculated for follow-up, age and ROM, indicated by *.

ORIF								
Patient	Age	Gender	AO classification	Follow-up	MEPS	qDASH	ROM Ex/Flex	ROM Pro/Sup
1b	75	f	AO 13 B3, Dubberley 1B	22	53	18,2	140	160
2b	61	f	AO 13 C3	16	80	20,5	100	170
3b	61	f	AO 13 C3	32	85	12,5	130	180
4b	70	f	AO 13 B3, Dubberley 1B	32	85	6,8	135	160
5b	69	m	AO 13 C3	38	83	22,7	120	160
6b	66	f	AO 13 C3	37	100	12,5	130	160
7b	62	f	AO 13 B3, Dubberley 3B	15	39	84,1	70	140
8b	55	f	AO 13 B3, Dubberley 3B	15	85	15,9	130	150
9b	61	f	AO 13 B3, Dubberley 3B	17	80	6,8	100	180
10b	76	f	AO 13 C3	104	43	47,7	90	180
MedianØ/mean*	66*			32.8*	81.5Ø	17.0Ø	116.5*	164*

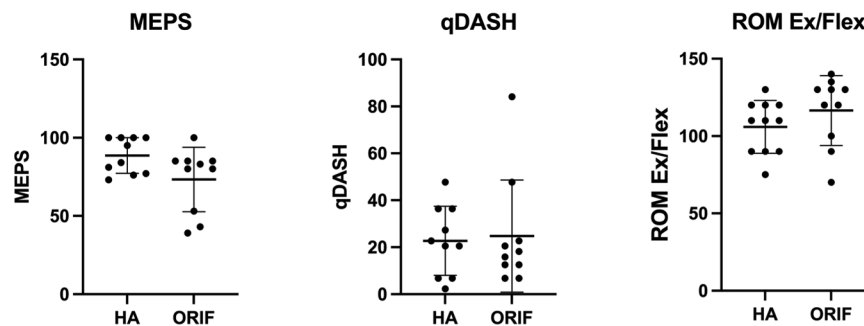


Fig. 2. Comparison of MEPS, qDASH and range of motion (ROM) in patients treated with hemiarthroplasty (HA) or open reduction and internal fixation (ORIF). We carried out Mann–Whitney test to compare MEPS and qDASH score and t-tests with Welch’s correction to compare ROM. No difference was found between the two entities.

versus those receiving total elbow arthroplasty [2,9]. With the incidence of complications and the need for revision surgery in hemiarthroplasty (HA) versus total elbow arthroplasty (TEA), the results remain a topic of ongoing debate. One registry study indicated an elevated risk of revision surgery associated with TEA compared to HA [17]. The most common reason for revision surgery reported in this study was loosening of the ulnar component in total elbow arthroplasty (TEA), which underscores the potential advantages of hemiarthroplasty (HA) over TEA in younger patients. However, studies conducted by Jonsson et al. and Burden found no differences in complication rates between the two treatment modalities; nonetheless, long-term outcomes could not be compared [2, 9,17].

Overall, satisfactory results can be attained in the management of complex distal humerus fractures through open reduction and internal fixation (ORIF), hemiarthroplasty (HA), or total elbow arthroplasty (TEA). Nevertheless, it has been demonstrated that not all fractures can be successfully reconstructed using ORIF, indicating that arthroplasty may be the only viable treatment option in such cases [11]. In patients aged between 60 and 70 years, treatment with hemiarthroplasty (HA) appears to be preferable, as it circumvents the disadvantages associated with total elbow arthroplasty (TEA), such as weight restrictions and the risk of ulnar component loosening. However, despite these advantages, there are certain considerations that may limit the indications for HA in our view. Specifically, intact or reconstructable collateral ligaments and epicondyles, as well as an intact or reconstructable radial head and proximal ulna, are essential prerequisites for the successful application of HA [8]. Signs of advanced ulno-humeral or radio-humeral osteoarthritis also contraindicate the use of hemiarthroplasty (HA). Currently, there are no established criteria to determine the extent to which fractures are amenable to open reduction and internal fixation (ORIF) versus those that are not. Therefore, in the substantial population of osteoporotic fractures in patients over the age of 60, the decision regarding whether to pursue ORIF, HA, or total elbow arthroplasty (TEA) should be made collaboratively between the surgeon and the patient, taking into account individual circumstances and preferences.

Several limitations apply to our study. Firstly, it is a purely retrospective analysis, which inherently restricts our ability to draw causative conclusions. Additionally, the sample size is relatively small, consisting of only 20 patients, which complicates the statistical analysis of our results, which was also underlined by the low power of the statistical test in our post-hoc power analyses. With a larger sample size, we might observe differences in functional outcomes between the two groups. Moreover, our matching process, while aimed at creating pairs of patients with similar fracture patterns and approximately the same age, may not adequately establish two equivalent groups of patients with distal humeral fractures. Several other factors, such as pre-existing conditions, general health issues, and the intensity and frequency of postoperative rehabilitation, could also influence the functional outcomes of the patients but were not accounted for in our analysis.

Furthermore, our primary matching criterion—fracture classification—is susceptible to interobserver variability, and classification systems themselves are merely an attempt to enhance comparability among fractures.

Overall, there is a need for more prospective studies that compare fracture management between primary hemiarthroplasty and ORIF. Additionally, research is required to identify reliable predictors for determining which fractures are no longer amenable to ORIF and therefore necessitate arthroplasty.

Conclusion

Surgical treatment through hemiarthroplasty provides results comparable to those of open reduction and internal fixation (ORIF) in selected cases of complex distal humerus fractures. For physically active patients over the age of 60 with non-reconstructable distal humerus fractures, hemiarthroplasty (HA) can be a viable therapeutic option, as it circumvents the disadvantages associated with total elbow arthroplasty (TEA), including weight restrictions and the risk of loosening of the ulnar component. There is a pressing need for more prospective studies comparing primary hemiarthroplasty, ORIF, and TEA for distal humeral fractures, particularly to elucidate the incidence of complications during long-term follow-up.

Ethics approval and consent to participate

Data collection in our study was performed in accordance with ethical standards and was approved by the institutional research committee (Ethics Committee of the Medical Faculty of the University of Cologne (no. 21-1290_02), with the 1964 Helsinki Declaration and its subsequent amendments. Informed consent was obtained from every patient included in our study.

CRediT authorship contribution statement

Marc Maximilian Weber: Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Valentin Rausch:** Writing – review & editing, Supervision, Formal analysis. **Lars Peter Müller:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Michael Hackl:** Writing – review & editing, Supervision, Resources, Data curation. **Tim Leschinger:** Writing – review & editing, Project administration, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests
LPM and MH have an advisory contract and receive consultant payments from Stryker GmbH & Co.KG and OTC Germany e.V. MMW,

VR and TL do not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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