

Surgical Treatment of the Frontal Plane Distal Humerus Fractures

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Abstract – The frontal plane fractures of the distal humerus are rare. The small intraarticular fragments, the commonly encountered osteoporosis and the specific anatomy make the successful osteosynthesis a challenge.

For a period of 15 years in First Clinic of Orthopaedic Traumatology 27 patients with capitulotrochlear fractures were treated. Of them, 12 women and 3 men were followed. The fractures were classified after Dubberley as follows: Type 1A - 1, type 2A - 2, type 2B - 3, type 3A - 5, type 3B – 1, and type 4B - 3. A plethora of surgical exposures were used - extended lateral, paratricipital, a combination of medial and lateral, dorsal with olecranon osteotomy. Primary TEA was performed in 3 patients: Type 3A - 1, type 3B – 1, and type 4B - 1. The patients were followed for a period of 12 months to 8 years. The results were evaluated by the MEPS, DASH and McGowan scores. The final ROM, compared to the contralateral side, was recorded. The average scores are comparable with the ones in a number of publications in the referent literature. As evaluated by MEPS, excellent results were found in 53% of patients, good – in 27%, fair in 7%, and poor – in 13%. The most serious problem was the elbow stiffness. Early deep infection was found in 1 patient with type 4B fracture. Ectopic ossification Hastings type I was found in 1 patient. The modern surgical treatment is based on anatomical reduction through fracture type-specific surgical exposure and rigid osteosynthesis. The treatment of choice for irreparable fractures is total elbow arthroplasty (TEA). We discuss the fixation devices, the surgical exposures and the osteosynthesis construct. Our own osteosynthesis preferences are centered around the fixation in the frontal plane and the additional augmentation with sagittal plane implants.

Keywords – frontal plane fractures, capitellum, trochlea, distal humerus, osteosynthesis

1. Introduction

The frontal plane fractures of the distal humerus (capitulotrochlear) are rare and predominantly seen in females. They comprise less than 1% of all fractures around the elbow^{1,2}.

The simple fracture types are usually two-part and are usually sustained in young patient with good bone quality after low-energy trauma³. These relatively beneficial fracture types with intact dorsal bone are the subject of predictable surgical treatment by means of lateral exposure through the Kocher or Kaplan intervals, compressive osteosynthesis with screws (conventional, Herbert, cannulated, etc.), plates and/or K-wires, and are expected to have good or excellent functional results^{4,5,6}. Specific problems could be posed by the multifragmentary morphologic fracture types with dorsal comminution due to the small fragments, osteoporosis and specific anatomy of the epiphysis of the distal humerus. In these cases, the reduction and stable osteosynthesis can be quite a challenge. Furthermore, sometimes even in the hands of an expert surgeon, in these scenarios the stable osteosynthesis is impossible and elbow arthroplasty is the only rational solution^{7,8}.

The evolution in the treatment of the complex frontal plane fractures was to an extent prompted by the introduction of new orthopaedic hardware – classic small-diameter screws (1.5 mm 2.0 mm, 2.4 mm and 2.7 mm), as well as cannulated and headless compression screws. Another important factor is the improved understanding of their morphology⁹. With the publication of the Dubberley classification¹⁰ and its recent extension by Watson and Phadnis¹¹, the operative reconstruction through specific exposure and by means of stable osteosynthesis is by large predictable. Regardless, there are some unresolved issues. There is some dispute in recent literature as to which is the best exposure for the type 2, 3 and 4 fractures^{3,10,11,14}, which is the fixation method of choice in order to obtain stable osteosynthesis with early mobilization of the elbow joint, should the thickness of the subchondral bone influence the osteosynthesis technique^{3,10,11,12}, what should be the surgical tactics in fracture types, in which, after detailed imaging, the accurate reduction and stable fixation seem possible, but not completely certain^{7,15}. This study presents the surgical treatment of the frontal plane fractures of the distal humerus through our preferred exposures, as well as the methods we employ.

The aim of the study is to analyze the results after the specific surgical technique, we use in the treatment of different fracture types according the modified Dubberley classification.

Our hypothesis states, that in 2A, 2B and 3A fractures with subchondral bone with sufficient thickness, as well as preserved medial trochlear ridge and/or medial epicondyle, the use of lateral or a combination of lateral and medial exposure, coupled with frontal plane fixation and dorsal and/or lateral plate augmentation, the results are predictable.

2. Materials and Methods

For a period of 16 years (2007-2022), 27 patients with frontal plane fractures of the distal humerus were treated in First Clinic of Orthopaedic Trauma, Emergency University Hospital “N. I. Pirogov, Sofia, Bulgaria. According to the modified Dubberley classification¹¹, the fracture distribution was as follows: Type 1A - 3, type 2A - 6, type 2B

- 4, type 3A - 7, type 3B - 3, type 4B - 4. Of them, 15 patients with capitulotrochlear fractures were followed – type 1A - 1, type 2A - 2, type 2B - 3, type 3A - 5, type 3B - 1, and type 4B - 3. (fig. 1). The patients were mostly female – 12, with only 3 males. The majority of fractures in our series were type 2 and 3 after Dubberley – a total of 11. The mean age of the patients was 52.8 (27-77) years.

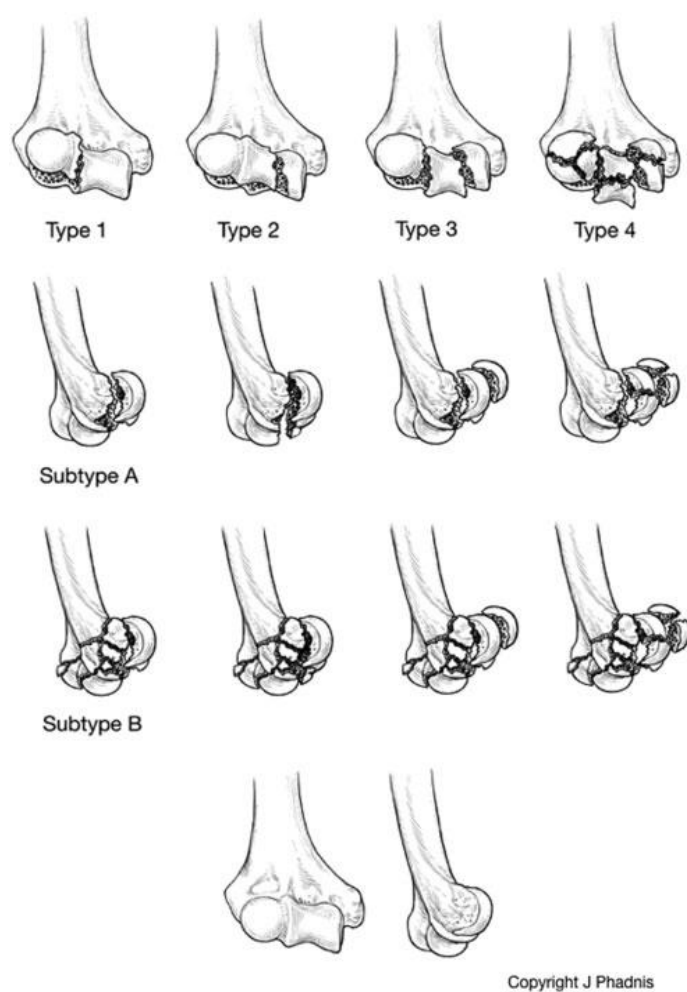


Fig. 1 The Watson and Phadnis' modification of the Dubberley classification, 2109. Type 4 are rare multifragmentary fractures of the capitulotrochlear segment. The scheme is borrowed from Watson and Phadnis' original article, 2019.

Table 1. Patient distribution by gender, age, fracture type, osteosynthesis type, bone grafting, associated injuries, primary/secondary arthroplasty (PA, SA).

N	Gender	Age	Type	Osteosynthesis	Bone grafting	Associated injuries	PA/SA
1	F	27	2A	1 plate	No	No	
2	F	34	2B	1 plate	No	LCL avulsion	
3	F	69	3A	1 plate + K-wires	No	No	
4	F	71	2B	1 plate + K-wires	Yes	No	
5	F	43	2B	1 plate	No	LCL avulsion	
6	F	47	3A	2 plates + medial screw	No	LCL avulsion	
7	F	38	3A	1 plate + medial screw	No	No	
8	F	57	4B	2 plates + K-wires	Yes	No	
9	F	75	4B	N/A	No	LCL avulsion	PA
10	F	48	4B	2 plates + K-wires	Yes	LCL and MCL avulsion	SA
11	F	77	3A	N/A	No	LCL avulsion	PA
12	F	73	3B	N/A	No	LCL avulsion	PA
13	M	27	1A	Screws	No	No	
14	M	49	2A	Screws	No	No	
15	M	58	3A	1 plate	No	No	

LCL – lateral collateral ligament. MCL – collateral ligament.

All fractures were operated by one of the authors. A plethora of approaches were used – lateral, extended lateral, paratricipital, paraolecranon, a combination of lateral and medial, dorsal with olecranon osteotomy. All patients were tested preoperatively for vascular and neurologic deficits.

Anatomic reduction was achieved in all fractures but two. Osteosynthesis was performed in 12 patients. TEA was performed as primary in 3 patients: Type 3A - 1, type 3B - 1, type 4B – 1, and in one patient with type 4B fracture, TEA was performed as secondary procedure after osteosynthesis failure. All surgeries were performed under general anesthesia and pneumatic tourniquet. The mean surgical time was 130 (55-300) min. Dynamic X-ray control was used in all cases. When the surgical time exceeded 90 minutes, the tourniquet was deflated and, if necessary, after 30 minutes was re-inflated. At the end of each surgery thorough hemostasis was performed. The range of motion and the stability of the fixation construct were tested. Post-operative immobilization was used for 48 hours in 13 cases. In 2 patients with osteosynthesis it was continued for 14 and 21 days. After this all patients were started on active rehabilitation.

Table 2 Exposures used

Dubberley type	N	Approaches
1A	1	Lateral (Kaplan) – 1
2A	2	Lateral (Kaplan) – 2
2B	3	Lateral (Kocher) – 1 Extended lateral (Kocher) – 2

3A	5	Lateral (Kocher) and medial – 2 Extended lateral (Kocher) – 1 Paraolecranon – 1 Transolecranon – 1
3B	1	Paraolecranon – 1
4B	3	Paratricipital – 1 Paraolecranon – 1 Transolecranon – 1

The exposures were relevant to the fracture type and the surgeon's preferences. The main factor for the choice of exposure was the morphology of the fracture, as well as the surgeon's skills. Arthroplasty was performed in 4 cases. Primary total elbow arthroplasty (TEA) was chosen as treatment method in 3 cases – in fractures type 3A (1 patient), 3B (1 patient) and 4B (1 patient). In a type 4B fracture, treated with osteosynthesis through transolecranon approach, which ultimately failed, secondary TEA was performed.

In this series there were no radial head fractures. Seven patients had bony avulsions from the lateral epicondyle (LCL rupture equivalent), and 1 of them had avulsion from the medial epicondyle as well. Bone grafting was performed in 3 of the cases with dorsal comminution. In 2 of them the graft was taken from the iliac crest, and in 1 – from the olecranon.

The surgical strategy is based on the conventional X-rays and the CT⁹. The latter shows the true morphology of the fracture and the thickness of the intact subchondral bone in the sagittal plane. The age of the patient and the expected bone density are taken under consideration as well. In patients aged below 60, our first choice was osteosynthesis. In the cases with no dorsal comminution (type A fractures), we used lateral exposures (including extended) in 4 cases, a combination of lateral and medial in 2 cases, paraolecranon in 1 case and olecranon osteotomy in 1 case. In intact LCL we used the Kaplan exposure. In 2, 3A fractures we used both lateral and medial approaches, and in only one fracture of this type osteotomy of the olecranon was performed. In these cases the patients were in supine position and the surgery was performed on an auxiliary table, except when paratricipital, paraolecranon and transolecranon exposures were performed, when the extremity was placed on the chest. In type B fractures 1 lateral, 2 extended lateral, 1 transolecranon, 2 paraolecranon and 1 paratricipital exposures were used. Primary arthroplasty was performed through paratricipital and paraolecranon exposures. The secondary TEA was performed after olecranon osteotomy and failed osteosynthesis. In all cases the patients were supine on the operating table. The fixation devices used were 3.5 mm, 2.7 mm, 2.0 mm screws and corresponding plates, 1/3 tubular and, most commonly, 2.7 mm reconstruction plates. In 4 cases K-wires in the frontal plane were used for the fixation of small osteochondral fragments. We haven't used transarticular screws – Herbert's or the newer headless, allowing for subchondral placement and compression. We haven't used locking plates. It is our view that conventional plates are better suited in the presence of small fragment, as they allow the surgeon the liberty of choosing the screw trajectory. In all cases the optimal number of screws were introduced through the plate in order to achieve maximum 2-plane stability of the osteosynthesis. The presence of sufficient subchondral bone in the frontal plane

was paramount for the choice of frontal plane fixation. Plate contouring was performed with a Stryker pelvic bender. It allows for accurate plate placement – dorsal, dorsolateral and/or lateral, as well as very precise choice of screw direction as necessitated by the fracture morphology. The number and length of the screws was optimal in all cases, reaching the medial border of the trochlea and/or the medial epicondyle and allowing for stable fixation even in osteoporotic fragments. This way a 2-, 3- or 4-part fracture is being reduced to a single fragment, which is then reduced to the posterior part of the epiphysis and fixed with postero-anterior screws – either free, or through a plate. Screw placement was performed under visual or digital control, and verified by X-ray.

Reduction and fixation technique

The technique employ is based on the thickness of the subchondral bone in the frontal fragment and the presence of spared medial ridge and epicondyle. For the verification of the fragment thickness we rely on the CT. When the subchondral thickness is sufficient, irrelevant of the Dubberley type, we employ the described below methods for reduction and fixation.

Type 1A fractures are usually straightforward to reduce and fix. In rare cases, they have a couple of osteochondral fragments. These morphologic types are better treated by transarticular fixation or another relevant method. In most cases however, the fragment is solid, with good subchondral bone. After the restoration of the radial fossa and the reduction of the fragment posteriorly – over the intact dorsal bone, we fix it with postero-anterior compression. Then we proceed to subchondral placement of a screw in the frontal plane (Fig. 3).

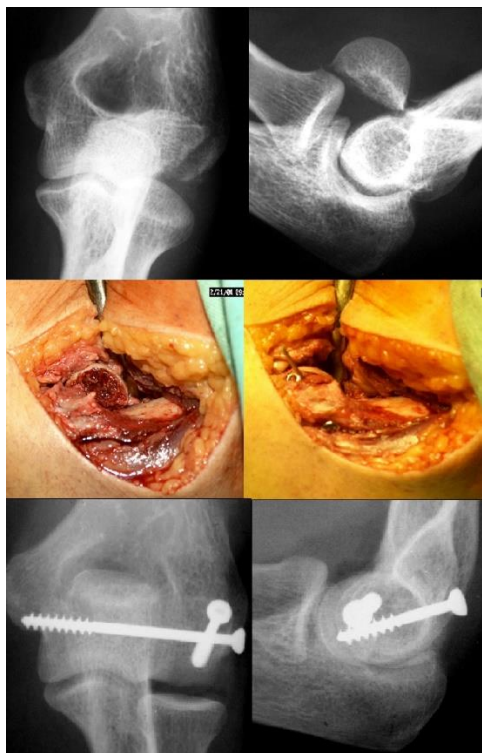


Fig. 3 Type 1A fracture. In most cases the capitellum is a solid fragment, with good subchondral bone stock with sufficient thickness. According to the Broberg-Morrey classification, this is type 1 – Hahn-Steinthal fracture. Kaplan approach. After the restoration of the radial fossa and the reduction of the fragment posteriorly, over the intact dorsal bone, we fix it with postero-anterior compression. Then we proceed to subchondral placement of a frontal plane compression screw, directed towards the centre of the trochlea.

In type 2A and 3A fractures with intact dorsal bone, it is used as a template for fracture reduction. The reduction starts from the most medial fragment – the trochlea. The intact medial ridge in type 2A and medial epicondyle in type 3A serve as support of the fixation (Fig. 4).



Fig. 4 Type 2A fracture in a 27-years old patient. Lateral approach. Reduction proceeded from medial to lateral. After temporary stabilization with K-wires, a 2.7 mm reconstruction plate was used due to dorsal wall impaction, as well as postero-anterior screw. Immediate rehabilitation was started. DASH 10, MEPS 90.

If necessary, the reduction can be aided by a small medial exposure. Temporary fixation is performed with K-wires. After reduction and fixation of the frontal fragments, including compression in the sagittal plane, with which a single fragment is created, the latter is reduced, compressed in the frontal plane and stabilized from posterior to anterior. In insufficient dorsal bone, the stability of the construct is aided by a 2.7 mm reconstruction plate. In the sagittal plane the fixation can be strengthened by means of a lateral or dorsolateral plate. (Fig 5).



Fig. 5 Type 3A fracture in a 58-years old male. The fracture was classified as 3A due to an additional fracture line, adjacent to the medial trochlear ridge. The above described surgical technique was used.

In the type 2B fractures, the dorsal comminution is at the level of the capitellum, engaging part of the posterior surface of the trochlea as well. The same surgical technique is applicable, with the reduction starting from medial to lateral. There is intact support in the antero-medial and posterior part of the trochlea. It is used as a starting point of the reduction, then postero-anterior and frontal plane screws are introduced in the capitulotrochlear fragment. The comminuted dorsal bone is reduced over the anterior components of the fracture and is fixed with screws only or is being ignored, as with normal bone stock the frontal plane fixation is sufficient. In the case shown below, the construct stability was enhanced by the addition of a 2.7 mm reconstruction plate. (Fig. 6).

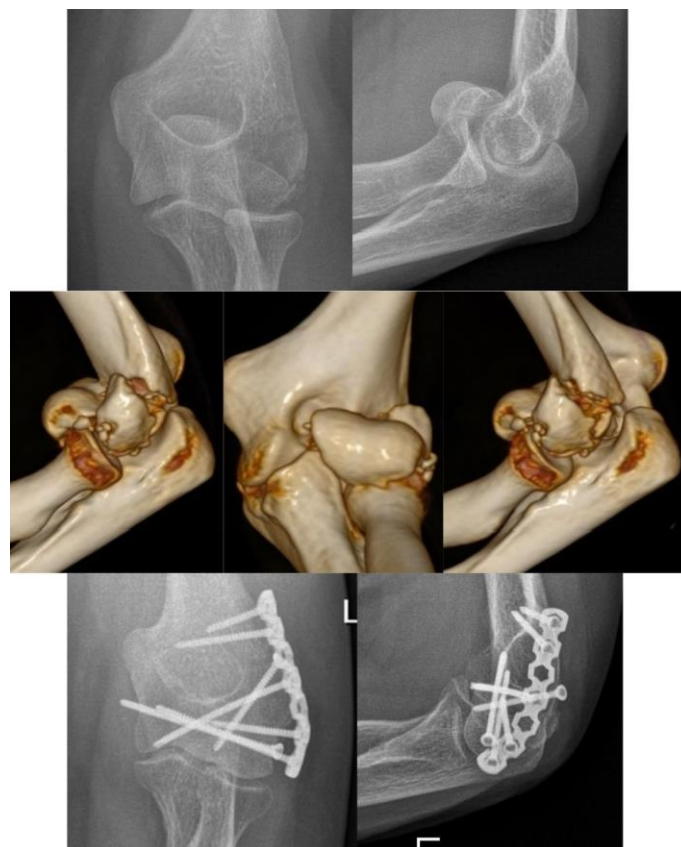


Fig. 6 Type 2B. The patient is 34 years old. The dorsal comminution is on the level of the capitellum and part of the posterior surface of the trochlea. The surgical technique, described above, is also applicable, with the reduction starting from frontally and medially. The preserved medially anterior and posterior part of the trochlea is used as support. It is also starting point of the reduction, after which the frontal plane screws are into it. The comminuted posterior surface is reduced over the anterior component, and fixed with screws only or ignored, as the fixation in the frontal plane is sufficient in preserved bone density. Augmentation with a 2.7 mm reconstruction plate.

With this type of fracture, depending of the surgeon's preferences, plate for fixation augmentation can be used. If necessary, bone grafting can be performed. A specific problem in some of the fracture types described is the proximal impaction of the trochlea over the coronoid fossa. In these cases the trochlea should be desimpacted, then the coronoid and radial fossae should be restored, after which the reduction of the frontal- and sagittal plane fragments can be performed. The support, over which the fixation can be performed, is the intact medial part of the trochlea. Type 3B and 4B preclude

the use of the posterior surface as support. The comminution is extreme frontally and dorsally and the bone is usually osteoporotic. In these cases the posterior approaches – paraolecranon, paratricipital and transolecranon, are the only option. The use of plates for the osteosynthesis is the only option.

For those types in young patients with good bone stock, our preferred approach is the transolecranon one. The good bone stock is a prerequisite for successful reduction and stable fixation. However, in our series in a 48-years old patient with 4B fracture, the osteosynthesis failed, requiring alloplasty with the olecranon osteotomized, jeopardizing the positioning and the fixation of the ulnar component of the endoprosthesis.

In our series in fractures of this type and patient ages 73, 75 and 77 years, we preferred primary alloplasty with the Coonrad-Morrey III (Zimmer, Biomet, Warsaw, IN, USA) endoprosthesis – the sole available in our country. The only case of a 4B fracture in a younger (57-years old) woman was operated by paratricipital approach and osteosynthesized with 2 parallel plates.

3. Results

The patients were followed for 12 to 96 months. The mean follow-up was 46 months. All were followed for a minimum of 12 months. The postoperative follow-up visits were on 12th week, 6th and 12th month. The patients with TEA were followed for a mean of 56 months. The mean age of the patients was 52.8 years. In 9 of the patients the dominant extremity was affected. The fractures were sustained by fall from own height in 11 cases, fall with bicycle in 2 cases, and fall during sport activities in 2 more cases. All fractures were closed and had no vascular or neurologic trauma. No patients in our series had any concomitant trauma. The mean time to surgery was 3.5 days (2 to 10). Rehabilitation under kinesiologist guidance was started 48 hours post-surgery in all but 2 patients – one with a type 4B fracture (started on day 21) and one with type 3A fracture (started on day 14).

Anatomic reduction was achieved in 10 fractures. In the rest 2 fractures, near anatomic reduction was achieved, with the non-anatomic “part” being the comminuted dorsal (extraarticular) part of the capitellum. Seven patients had obvious osteoporosis. Four of them had TEA, the rest 3 were osteosynthesized – one had type 3A fracture (plate and K-wires), one had type 2B fracture (plate and K-wires), and the third – type 4B fractures (2 plates and K-wires). The mean extension was 15.6°, the mean flexion – 129.8°. The mean result, as evaluated by MEPS, was 74.90 points. In the series we have 8 excellent, 4 good, 1 fair and 2 poor results. A subgroup of 8 patient (the ones with excellent results) had a mean MEPS of 92.2 points, 4 patients (the good results) – a mean of 80 points, 1 patient (fair result) had 65 points, and 2 patients (the poor results) had a mean of 52.5 points. The mean MEPS of the TEA patients was 83,75 points (Table 3.)

Table 3. Results according to the Mayo Elbow Performance Score (MEPS)

MEPS	N	Average score	%
Excellent (>90)	8	92.2	53%
Good (75-89)	4	80	27%
Fair (60-74)	1	65	7%
Poor (<59)	2	52.5	13%

The mean result, as evaluated by the DASH score, was 15.93 points. The worst result was 45 points in the patient with type 4B fracture after osteosynthesis with 2 plates and K-wires. Eight patients had excellent results, 4 – very good, 1 – good, and 2 – poor. The mean DASH score after TEA was 9.37 points (Table 4)

Table 4. Results according to the Disabilities of the Shoulder, Elbow and Arm (DASH) scale

DASH	N	%
Excellent (0-10)	8	53%
Very good (11-20)	4	27%
Good (21-40)	1	7%
Poor (>41)	2	13%

In summary, 12 patients had excellent and very good results, and had complete functional recovery. All had stable joints and were satisfied with the surgery.

Complications

Early deep infection was found in 1 patient with type 4B fracture with failed osteosynthesis. She was treated with debridement, spacer and TEA. Ectopic ossification Hastings type I (with no clinical manifestation) was found in one patient with type 2A fracture¹⁶. Partial avascular necrosis, affecting only the capitellum, was seen in 2 patients with type 3A and 2B fractures. Migration of K-wires only was found in 1 case of type 2B fracture, without this affecting the functional result, but requiring secondary intervention. In one patient with a type 4B fracture, the open reduction with internal fixation led to failure of the osteosynthesis. Both patients have stable elbows and good function. The function of the ulnar nerve was assessed after the McGowan classification. Three patients had transitory paresthesia in the ulnar nerve sensory zone after nerve transposition during TEA, which subsided after 12-14 weeks. We had no patients with permanent neurologic damage (table 5).

Table 5. Complications

Complication	N	Fracture type
Early deep infection	1	4B
Ectopic ossification Hastings I	1	2A
Partial avascular necrosis of the capitellum	2	3A, 2B
K-wire migration	1	2B
Osteosynthesis failure	1	4B
Ulnar neuritis McGowan I	3	3A, 3B, 4B

4. Discussion

The low incidence of these fractures is a serious obstacle for the build-up of surgical expertise in their treatment¹¹. It is not a rarity for this type of fracture, when seen in an emergency department, to be treated by a surgeon, whose experience covers no more than a couple of cases over the span of his career. This has frustrating effect on the surgeon and negative influence on the outcome. In our hospital these patients are treated by surgeons with subspecialization in elbow surgery. Elsewhere however, this problem remains unsolved.

In the recent past a number of classifications were used - Ring, Broberg-Morrey, McKee, and AO^{12,13,14}. Their principal shortcoming is that though they describe the fracture morphology fairly well, none guides the surgeon in the choice of approach, the type of osteosynthesis and, most important – what should be the treatment of choice in non-reconstructible fractures. Accordingly, the most common treatment was screw fixation – usually 3.5 mm. Small fragment excision was also a well-established procedure¹⁷. The classifications gave no clear directions for plate osteosynthesis, based on the morphological type, and thus the use of plates was at the surgeon's discretion, based on his intuition and experience on a case-by-case basis. The severely comminuted fractures in elderly patients were quite often treated functionally – after Eastwood¹⁸. The functional results showed serious variability. With the publication of James Dubberley's classification (based on CT) and its extension with a 4th type of fractures with severe frontal and dorsal comminution by Watson and Phadnis, the pathomorphology of these fractures became clearer^{10,11}. The surgery, approaches, surgical technique and osteosynthesis were given morphological foundation. For the severe type 3B and 4B fractures, the surgeons' armaments now includes the primary total elbow arthroplasty as well^{7,19,20,21}. Thanks to the evolved understanding of the fracture pathoanatomy, new, small-diameter implants were introduced – with varying diameters depending on the manufacturer– 1.5 mm, 2.0 mm, 2.4 mm 2.7 mm, as well as the small-diameter headless cannulated screws, allowing for compression and straightforward transarticular fixation, perpendicular to the fracture plane^{22,23}. The modern reconstruction of the capitulotrochlear fractures relies mostly on the transarticular fixation with cannulated screws in the type A fractures, and in the dorsally comminuted fractures (type B) – on the addition of a dorsal buttress locking plate^{3,6,10,11,12}. As an exotic solution the use of antiglides plate has been reported, positioned just anterior and proximal to the capitellum²⁴. A number of biomechanic studies support unconditionally the modern surgical concept²⁵. The use of transarticular screws requires an extended lateral approach. For the type 1A fractures the approach is minimally extended and screw placement is fairly straightforward. In type 2A and 3A fractures, frontal placement of the screws requires wide exposure and, from a technical point of view, is not devoid of risks. If bony avulsion of the LCL or rupture is found, the approach is facilitated and epiphyseal dislocation allows for cannulated transarticular screw placement all the way to the medial trochlear ridge. In the absence of such an injury however, the exposure requires ligament section, otherwise perpendicular screw placement is hard to achieve and traumatic. In fractures, engaging the medial epicondyle with trochlear impaction proximally, including in its medial part, the lateral approach is insufficient and additional

medial approach is necessary. In morphological types 1B and 2B this surgical technique is applicable, but requires additional dorsal extension of the exposure for plate placement on the wide posterior aspect of the capitellum. However, the most challenging are the type 3B and 4B fractures. The presence of 3 and more fragments frontally and dorsally, as well as the proximal impaction of the epiphyseal fragment, require a dorsal approach. The widely adopted modern tactic is the use of paraolecranon, paratricipital or transolecranon approach. The former two are advantageous^{3,10,11,12,15,26}. The reason is, that despite the CT, in some cases intraoperatively adequate reduction and stable fixation can be found to be impossible. In these cases the paratricipital or paraolecranon approaches allow for conversion to primary TEA¹⁵. Another factor is the common lateral comminution, the pull-out of the lateral condyle with the LCL, which facilitates the exposure and dislocation of the whole epiphyseal fragment anteriorly, which in turn allows for visualization and fixation with transarticular screws frontally, as well as plate placement dorsally. The transolecranon approach has 2 principal disadvantages. Its use and the subsequent intraoperative decision for conversion to TEA makes the insertion of the ulnar component difficult and unpredictable. The other disadvantage is the relatively high incidence of non-union or necessity for secondary surgeries for implant removal^{3,7,19}. Regarding the hemiarthroplasty, there is no clarity regarding the long-term sequelae for the partially retained articular surfaces of the elbow²⁰.

Ever since open reduction and internal fixation was adopted, there has been no serious debate in the literature regarding the type 1A and 1B fractures. The published results – both recent and long-standing, consistently report good and excellent function with rare complications^{3,10,11,12,15,27,28}. Fixation can be achieved with postero-anterior conventional screws, as well as with cannulated transarticular ones^{3,5,11}.

In our modest series we treated the type 1A fractures by postero-anterior screw osteosynthesis and a screw in the frontal plane, docked in the trochlear fragment. In this type of fractures the thickness of the subchondral bone is about 5-6 mm and the screw placement in the frontal plane and into the trochlea, alongside with the achieved postero-anterior stability, are completely sufficient. The perpendicular fixation and optimal length of the frontal screw, docked subchondrally in the dense trochlea, allow for immediate rehabilitation. In our opinion the fixation in both the frontal and the sagittal plane is sufficient and this spares the necessity for wider exposure and transarticular fixation. Specific cases are the ones with osteochondral comminution of the capitellum. The options are fragment excision, including arthroscopically, transosseus suture or transarticular fixation, but only with sufficient subchondral bone. (Fig. 7)

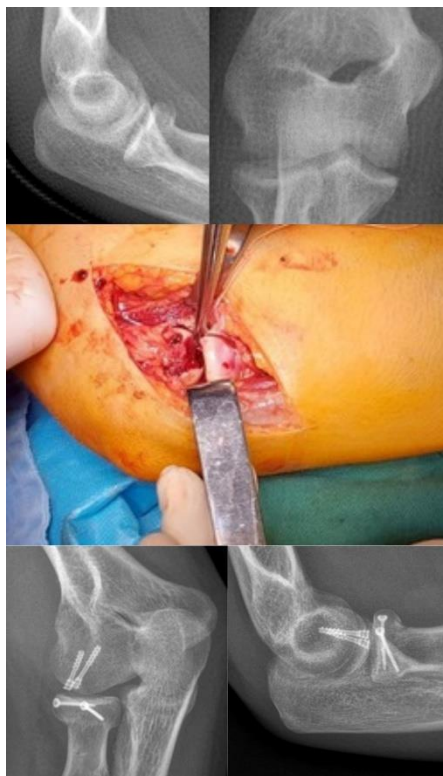


Fig. 7 Type 1A fracture with thin osteochondral fragment. Surgery through Kocher's approach. Transarticular fixation with small cannulated Herbert's screws for the capitellum and subchondrally placed screws for the concomitant radial head fracture.

In the present series we don't have such a case. In type 2A and 2B fractures we have used screw-only fixation in just one case (type 2A). In the rest (one type 2A and 3 type 2B) the fixation was augmented with a plate. We think that the use of plate is key for the stable fixation in the presence of dorsal comminution. In the type 2A case there was no dorsal comminution, but the fragment did not provide good purchase. The use of plate does not require substantial increase of the exposure, but provides good stability and allows for early rehabilitation. In a type 2B case, due to the presence of osteochondral fragments, K-wires were used. We consider this a shortcoming of the technique (Fig 8.).

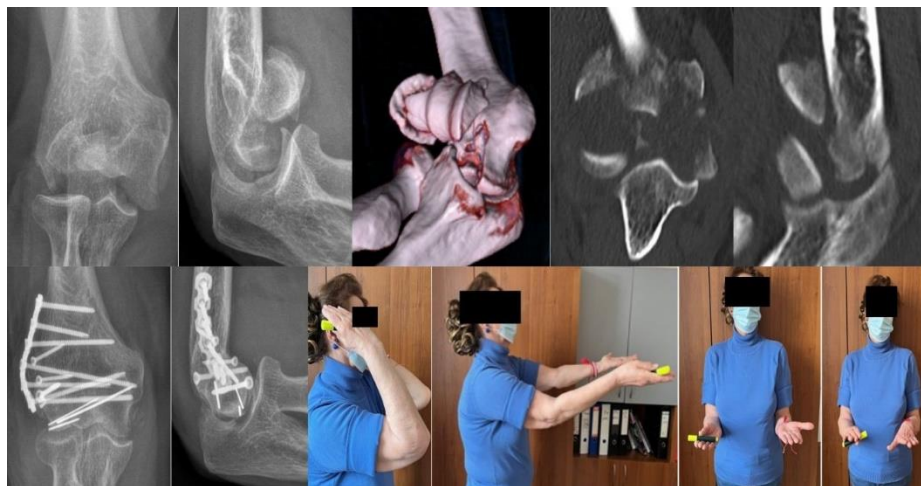


Fig. 8 A patient with type 3A fracture, age 69 years. Extended lateral exposure through the avulsed lateral epicondyle. Augmentation with a 2.7 mm reconstruction plate. K-wires were used due to the capitellum comminution. We consider their use a shortcoming and in these cases the transarticular screw fixation is preferable.

There is risk for migration and we saw it both in this case and in the type 4B case with failed osteosynthesis. In this group we found 2 cases of partial avascular necrosis of the capitellum. In all type 3A fractures we used a laterally-positioned plate, despite the lack of dorsal comminution, and in one case – a second plate, placed dorsally, due to the impaction of both the capitellum and trochlea. In our opinion, except the dorsal comminution, the other significant indication for the use of plate is the proximal pole impaction of the fragments. In 2 cases we employed a second medial exposure due to difficult reduction and fixation of the fractured medial trochlear ridge. In one of the cases – of a young woman with good bone stock, transolecranon approach was used (Fig. 9).



Fig. 9 38-year patient with type 3A fracture. This is one of the rare cases when olecranon osteotomy was used. Except the fracture morphology, the presence of good bone stock is in our opinion a necessary condition for the use of the approach. MEPS 95, DASH 10.

Epiphyseal dislocation was used in one patient with type 3A fracture and osteosynthesis with 2 parallel plates. This, together with the type 4B fracture, fixed with 2 plates, are the only cases, in which the technique was used, facilitated by the bony avulsion of the LCL. In our opinion the use of plates does not require significantly wider exposure and makes early rehabilitation securer. In the presented type 1A, 2A and 3A fractures, mobilization was started early under kinesietherapist's control. Of these 11 cases, 1 had fair result (58-year old man with type 3A fracture) and 1 had poor result (71-year old woman with type 2B fracture) due to the development of severe stiffness. The other poor result is with the 57-year old woman with type 4B fracture, operated with 2 plates and K-wires. All other patients had excellent and good results. The average result, evaluated by MEPS, was 74.90 points. In the series we had 8 excellent, 4 good, 1 fair and 2 poor results. Eight patients (the excellent results) had a mean of 92.2 points, 4 patients (the good results) had a mean of 80 points, 1 patient (fair result) had 65 points, and 2 patients (the poor results) had a mean of 52.5 points. The average MEPS of the TEA patients was 83.75 points. The average DASH score was 15.93 points. Eight patients had excellent result, 4 had very good, 1 – good, and 2 – poor result. The average DASH score after TEA was 9.37 points. In type 3B and 4B fractures, especially with concomitant osteoporosis, the morphology of the fracture can render it unrepairable. Primary arthroplasty is a viable solution, notwithstanding the problem with the implant survival. In 3 cases – one with type 3A fracture and two with type 3B fracture, reconstruction was impossible and we did primary arthroplasty (Fig. 10).



Fig. 10 Primary TEA in a 75-year old woman with non-repairable type 4B fracture. 60 months after the alloplasty. DASH 24, MEPS 85

In the fourth case in a 48-year old woman after fixation failure, deep infection and sanitation by antibiotic spacer, in a secondary procedure we performed alloplasty. Our judgement in this case was erroneous and today we would prefer the paraolecranon approach, which, even in fixation failure, does not jeopardize the alloplasty.

The results we obtained are very good. The longest alloplasty follow-up is 11 years. In all TEA cases, we did ulnar nerve transposition. The neurologic complications were transient, without affecting the motor function of the nerve²⁹. These results are in-line with a number of literature reports and confirm the recent understanding that TEA is a part of the treatment of these fractures.

Secondary surgeries were performed in 4 cases. In the patient with type 4B fracture, fixation failure and deep infection, we had to remove the hardware, including the K-wires, perform debridement, implant spacer and, as a second procedure, do TEA. K-wire removal due to migration was necessary in a patient with type 2B fracture, mentioned above, without this influencing the final result. In the olecranon osteotomy case, in a second surgery we removed the plate. A second surgery was also necessary for screw removal in a united fracture with excellent range of motion.

We don't think that transarticular fixation has no place in the treatment of these fractures – on the contrary, it is well-sustained, when the fracture morphology requires it, i.e. when the thickness of the subchondral bone is insufficient for osteosynthesis with

conventional screws, there are osteochondral fragments in the frontal plane or the fracture is severely comminuted and requires the use of extended or lateral exposures. The use of K-wires for the fixation of osteochondral fragments is risky. In these situations the transarticular fixation with headless cannulated screws is definitely preferable. But the question still remains whether the fixation is sufficiently stable in advanced osteoporosis and dorsal comminution. In these cases the addition of a plate is mandatory and transarticular screws only cannot be relied upon. It is a well-recognized fact that the avascular necrosis is rare – although there are no soft-tissue insertions on the fragments. However, the placement of transarticular screws is impossible through normal lateral approach. This is possible only with the use of extended lateral approach and/or dislocation with exposure of the whole epiphysis. We think that these wide approaches are worthy only in some type 3A fractures and mostly in the type 3B and 4B fractures, where they are even necessary.

If we accept that the proximal impaction creates a defect in the centre of the capitulum and trochlea, the indications for the use of plates should be wider. Furthermore, a wave of young surgeons have adopted the transarticular screws as a primary fixation method and often forget to use plates. This is also a reason for them to use extended or dorsal approaches in most cases. Dorsal approaches, sometimes with olecranon osteotomy, are being used for relatively simple fractures with the intention of performing proper fixation. However, the results are quite often poor. The common use of transarticular screws reminds of the story of the introduction of the locking plates with the initial widespread misunderstanding of the indications and technique of their application.

The technique we presented has not been supported by biomechanic studies. It is based on the thickness of the subchondral bone, spared medial trochlear ridge and medial epicondyle. We think that the series confirms our hypothesis – that most of the frontal plane fractures of the distal humerus can be treated plainly with a minimal approach and robust plate fixation. In spite of all shortcomings of this report (retrospective study with a small number of patients, a substantial part of them – inadequately followed), in our opinion the conventional fixation through simple approaches is still a viable option for the treatment of these fractures.

5. Conclusion

The distal humerus fractures in the frontal plane pose challenge with regards to the surgical approach, reduction and osteosynthesis. The adoption of the Dubberley classification and the Watson-Phadnis modification aided their understanding and made their treatment more predictable. In our view the surgeon's aim when treating those fractures should be to achieve anatomic reduction through exposure, dictated by the morphology of the fracture and facilitated by the recognition of the preserved bony buttress to be used as reconstruction basis, and stable osteosynthesis in both the frontal and sagittal plane, allowing for early motion. Nevertheless, sometimes those complex fracture can

be non-reconstructible, and in these cases the primary total elbow arthroplasty is a viable treatment option.

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