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Challenges in selecting surgical approaches for intra- and juxta-articular fractures of the distal *humerus*

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ABSTRACT

Fractures of the distal metaepiphysis of the *humerus* are relatively common injuries affecting the bones of the elbow joint. These fractures are often associated with soft tissue damage, including tendon and muscle injuries, which is a typical feature of trauma to these structures. In current trauma practice, surgical methods are preferred for distal *humerus* fractures, typically involving open reduction of bone fragments and stable functional osteosynthesis. However, despite advances in surgical techniques for managing long bone fractures, the disability rate following distal *humerus* fractures remains high, particularly among individuals of working age.

The choice of an optimal surgical approach is a critical factor in osteosynthesis of this fracture type, as it must minimize soft tissue trauma while providing adequate visualization of the bone fragments. Despite extensive experience in managing these fractures, the global orthopedic community still lacks a unified algorithm for selecting the most appropriate surgical approach for distal *humerus* osteosynthesis.

This review aims to summarize data from the international literature on various aspects of managing distal *humerus* fractures, with a particular focus on surgical approaches and criteria for selecting the optimal treatment strategy.

Keywords: humeral condyle fractures; elbow joint; surgical access; fractures osteosynthesis.

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Проблема выбора хирургических доступов при оперативном лечении внутри- и околосуставных переломов дистального отдела плечевой кости

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АННОТАЦИЯ

Переломы дистального метаэпифиза плечевой кости являются довольно распространённой травмой костей, образующих локтевой сустав. Кроме того, при переломах дистального отдела плечевой кости (ДОПК) повреждаются мягкие ткани, в том числе сухожилия и мышцы, что является характерным для травм этих структур. В настоящее время в травматологической практике при лечении переломов данной локализации предпочтение отдают хирургическим методам, при которых выполняют открытую репозицию костных отломков и стабильно-функциональный остеосинтез. Однако, несмотря на развитие хирургических методов лечения переломов костей конечностей, при переломах ДОПК по-прежнему высоким остаётся процент инвалидизации, в том числе среди пациентов трудоспособного возраста.

При выполнении остеосинтеза данного типа переломов огромное значение имеет выбор оптимального хирургического доступа, который позволяет как сократить травматизацию мягких тканей, так и обеспечить достаточный визуальный обзор костных отломков. Несмотря на многолетний опыт лечения данного типа переломов, в мировом травматолого-ортопедическом сообществе по-прежнему отсутствует единый алгоритм выбора хирургического доступа при выполнении остеосинтеза.

Целью обзора является обобщение данных мировой литературы о различных аспектах лечения переломов ДОПК, хирургических доступах и подходах к выбору оптимального метода лечения.

Ключевые слова: перелом мыщелка плечевой кости; локтевой сустав; хирургические доступы; остеосинтез переломов.

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BACKGROUND

Fractures of the distal metaphysis of the *humerus* are very common injuries to the bones that form the elbow joint; they can occur in people of all age groups [1, 2]. In adults, intra-articular fractures of the distal *humerus* (DH) account for up to 10.0% of all joint injuries [3, 4].

Despite the progress gained in the development of surgical treatment methods for intra- and juxta-articular DH fractures, their treatment is still a challenge for surgeons [2, 5, 6]. Contributing to the development of combined contractures in the postimmobilization period, concomitant damage to ligaments of the elbow joint is a common issue associated with this fracture. Many authors noted that options to prevent these complications include early internal osteosynthesis with low-trauma surgical approaches together with an appropriate rehabilitation treatment program for a specific patient [2, 7, 8].

EPIDEMIOLOGY

Fractures of the distal metaphysis of the *humerus* account for 0.5% to 5% of musculoskeletal injuries in people over 18 years of age [1–4]. In 18% to 85% of cases, patients develop various complications after treatment (such as elbow joint contracture, heterotypic ossification, posttraumatic arthrosis, etc.); approximately 30% of patients become disabled due to persistent elbow dysfunction [5–7].

According to different sources, intra- and juxta-articular DH fractures in adult patients account for 0.5% to 2% of DH fractures and 3% to 24% of all fractures of the upper limbs [8–11]. The incidence of DH fractures has a bimodal structure, peaking both in elderly patients with low-energy injuries and concomitant osteoporosis and young patients with high-energy injuries [12, 13]. Being more common in people of working age, this type of injury leads to disability in approximately 30% of cases [14–16]. Such a high disability rate is explained by frequent elbow joint contractures, heterotopic ossification, and posttraumatic arthrosis [17–20].

TREATMENT CHALLENGES AND COMPLICATIONS

Axial load transmitted through the elbow joint when the elbow is flexed more than 90° is a common cause of fractures of the distal metaphysis of the *humerus* [17]. Acting like a wedge, the *olecranon* process is pressed between the two columns of the distal metaphysis of the *humerus*, splitting and displacing them. All this explains the fact that the vast majority of fractures in the lower third of the shoulder in adults are intra-articular and affect both columns of the *humerus* [20, 21].

Challenges that surgeons face in treating fractures of the bones that form the elbow joint are related to its structural and biomechanical characteristics, the proximity of neural structures, and a high probability of heterotopic ossification in this area. Various complications in the postoperative period of DH fractures are often associated with poor functional results, thus requiring revision surgery [22]. Therefore, developing minimally invasive methods for surgical treatment of DH fractures with reduced surgical aggression in the surgical area is still relevant in modern traumatology and orthopedics [23].

A relatively high rate of complications in the treatment of DH fractures can be explained both by their intra-articular localization and high patients' requirements for elbow function [24]. The most common complications associated with this injury include ulnar nerve neuropathy, elbow joint contractures, delayed repair, pseudoarthrosis, *olecranon* osteotomy-associated complications, osteoarthritis, and infections [6, 15, 25, 26]. High variability of DH fracture types and forms makes their surgical treatment difficult and often requires an extended surgical approach, anatomical reduction of intra-articular fragments, and stable fixation. Due to the multi-fragment nature of these fractures, which often occur in patients with systemic osteoporosis, anatomical reduction can be challenging even for experienced surgeons [26–28].

EVOLUTION OF TREATMENT METHODS

Classification of DH fractures by Arbeitsgemeinschaft für Osteosynthesefragen or the Association of the Study of Internal Fixation (AO/ASIF) includes three types [27–29]:

- A, extra-articular (supracondylar) fractures;
- B, juxta-articular (unicondylar) fractures;
- C, complete intra-articular (bicondylar) fractures.

Key prerequisites for good treatment outcomes in patients with DH fractures include early qualified trauma care within the first 24 h from the injury, adequate and final choice of the treatment method depending on the fracture type, restoration of joint congruence during osteosynthesis, and elimination of displacements, diastasis of bone fragments, and interposition of soft tissues.

Treatment for patients with DH fractures should be chosen on the basis of their history, fracture type, displacement of bone fragments, and integrity of the skin, blood vessels, and nerves of the upper limb. In most cases, an X-ray in two standard projections is usually enough for competent preoperative planning. However, computed tomography also may be useful in understanding the nature of the fracture, especially when coronal plane injuries such as humeral head and *trochlea* fractures are suspected [9, 30].

The treatment methods that were previously used for intra-articular fractures of the distal metaphysis of the *humerus* (plaster immobilization and skeletal traction) do not allow completely restoring the anatomy of the elbow joint and are associated with complications; therefore, they can be recommended only in exceptional cases for patients with absolute contraindications to osteosynthesis [2, 31–33].

Surgical treatment options for intra-articular fractures of the distal metaphysis of the *humerus* are dominant in many aspects; they are based on the principles proposed by the AO/ASIF group [23, 34].

The triangular shape of the distal *humerus* consists of medial and lateral bony columns with the intervening *trochlea*. In the treatment of DH fractures, the stable fixation of all three components is a prerequisite for good functional results [35].

To restore elbow joint function during surgery, normal anatomical relationships should be achieved in the joint with absolute stability between bone fragments, thus allowing early active movements in the postoperative period [36–38]. Functional treatment results can be assessed using the criteria recommended by Morrey [39–41].

A special niche in the treatment of elbow fractures is taken by compression distraction osteosynthesis, which was developed by Ilizarov et al. [42]. This method is effectively used in Gustillo–Andersen type II and III open fractures, gunshot fractures, and fractures with suppurative septic complications [43].

In multifragmentary fractures of the distal metaphysis of the *humerus*, where open reduction and internal fixation are contraindicated due to the small size of the fragments or poor bone quality, total elbow arthroplasty is a treatment of choice. This method is especially suitable for patients with preexisting elbow osteoarthritis. Absolute contraindications for total elbow arthroplasty include neurologic compromise affecting hand function and the demented or noncompliant patient. Relative contraindications include open fractures or if the patient does not want to limit weight bearing through their upper extremity [44].

Summarizing all of the above, we can conclude that various devices to ensure stability in the fracture area, a need for careful selection of plates, screws, spokes, wire, spoke-rod external fixation devices, and orthopedic implants for arthroplasty require multiple aspects of the stability of bone fragment fixation, which is an important element for achieving good and excellent functional treatment results [23].

CHOOSING OPTIMAL SURGICAL APPROACH

The global orthopedic community still lacks a unified algorithm for selecting a surgical approach that would take into account both the nature and type of displacement in DH fractures and individual patient's characteristics. Based on the fracture nature, displacement of bone fragments, and joint incongruence, different approaches can be chosen: lateral, posterior, medial, or anterior [6, 45].

According to modern literature, we can conclude that the optimal choice of the surgical approach is based on the following basic principles [46]:

1) the approach should ensure ample visualization to perform manipulations in the surgical site;

2) the approach technique should consider a likelihood of an intraoperative need to extend the approach in different directions;

3) the risk of damage to important anatomical structures during the approach should be as low as possible;

4) if the surgical site is extended, reliable hemostasis and adequate drainage should be ensured;

5) the approach can be considered safe if the dissection is performed along the natural layers of soft tissues and not through muscles, tendons, or ligaments;

6) the approach should allow recreating normal anatomy after stitching the wound; exit from the approach should be performed without tensioning the soft tissues, thus allowing early rehabilitation.

The approach for any specific fracture should be based on both the patient's anatomical findings and requirements for functional results.

APPROACHES TO THE LATERAL COLUMN OF THE DISTAL *HUMERUS*

Approaches to the lateral elbow include the Kocher approach, the Kaplan approach, the Mayo modification of the extended posterolateral approach, and the modified lateral *m. extensor digitorum communis* split approach.

Indications for these approaches include surgery for fractures of the radial head, removal of intra-articular loose bodies, DH fractures, resection of osteophytes, excision of the synovial membrane during synovectomy, and total elbow arthroplasty [47, 48].

Kocher Approach

A modified Kocher approach is the most common in traumatology practice. This approach provides visualization for surgical manipulations both on the lateral column of the humeral condyles and the entire elbow joint. This approach is performed between *m. anconeus* and *m. extensor carpi* ulnar*is*, thus minimizing the risk of damage to the deep branch of the radial nerve. This interval is also located anteriorly to the lateral ulnar collateral ligament, thus minimizing the risk of its damage when the joint capsule is dissected [48].

The advantages of this approach also include early elbow mobility after osteosynthesis, improved range of motion in the postoperative period, and a low risk of posterior interosseous nerve injury (as compared with Kaplan). The Kocher approach may be extended both proximally and distally, thus allowing surgical manipulations along the whole DH. However, when extending this approach proximally, the surgeon should consider that the posterior interosseous nerve passes in this area [48, 49].

Kaplan Approach

Indications for the Kaplan approach include radial head fractures that require its resection, osteosynthesis, or arthroplasty [50, 51].

The incision is made from the apex of the lateral epicondyle of the *humerus* towards Lister's tubercle, with the length of the approach of approximately 4 to 5 cm. The surface of the head of the radius is isolated between *m. extensor digitorum communis* and *m. extensor carpi radialis brevis*.

Due to the proximity of the radial nerve, this approach should be performed with forearm pronation and elbow flexion at an angle of 90°, which ensures the displacement of the radial nerve from the surgical intervention area [51].

In a study in cadavers, Barnes et al. showed that the modified lateral Kaplan approach afforded significantly greater visible surface area of the proximal radius than the Kocher approach [52].

The Boyd approach to the elbow joint has been also described in literature. This approach is used for the surgical treatment of fractures affecting the proximal radius and *ulna*, including the coronoid process, capitulum humeri, and lateral column of the distal *humerus*. This approach gives good visualization of the lateral elbow joint surface, thus minimizing the risk of posterior interosseous nerve damage [53, 54].

All these surgical approaches allow performing any reconstructive surgery on the elbow joint.

POSTERIOR APPROACH TO THE ELBOW JOINT

Four posterior approaches to the DH have been classified: *triceps*-splitting, paratricipital (described by Alonso–Llames), *triceps*-preserving, and *transolecranon* (Table 1) [55, 56].

The posterior approach to the elbow joint is universal and provides optimal visualization of the articular surface of the elbow joint, regardless of whether the surgery is performed for fractures or orthopedic conditions [57]. Different authors noted that almost all types of elbow surgery can be performed with this approach [57–63].

Wilkinson et al. showed that the percentage of visible distal humeral articular surface for the *triceps*-splitting, paratricipital, and *transolecranon* posterior approaches was 35%, 46%, and 57%, respectively [64].

Indications for the posterior approach with *olecranon* osteotomy include DH fractures below the line connecting the epicondyles of the *humerus*. Of note, this approach is not suitable for total elbow arthroplasty because the repair of the osteotomy site would be impaired by the cemented *ulna* component [48].

A *triceps*-sparing modified Mayo approach is also known where the *triceps* is mobilized from the *olecranon*

Table 1. Comparison of posterior approaches to the elbow joint

Approach	Indications	Contraindications	Advantages	Disadvantages
Posterior *transolecranon* approach to the elbow joint	Open reduction and internal fixation of fractures involving both columns of the humeral condyles	Total elbow arthroplasty	Good visualization of the posterior articular surface of the distal *humerus*	*Olecranon* osteosynthesis is required after exit from the approach Poor visualization of *humerus* head
Posterior approach with direct dissection of the *triceps*	Open reduction and internal fixation for fractures involving both columns of the humeral condyles, total elbow arthroplasty	Use of *olecranon* osteotomy Factors associated with poor healing of soft tissues (diabetes mellitus, soft tissue defect, severe edema)	Avoiding complications related to *olecranon* osteotomy	Poor visualization of the articular surface for osteosynthesis Risk of *triceps* avulsion
Posterior paratricipital approach with *triceps* abduction	Open reduction and internal fixation of juxta-articular fractures of the distal *humerus*	Use of olecranon osteotomy Factors associated with poor healing of soft tissues (diabetes mellitus, soft tissue defect, severe edema)	Preservation of the *extensor apparatus* of the forearm without complications associated with osteotomy of the *olecranon* process	Difficult reduction in intra-articular fractures of the *trochlea* and capitate eminence of the *humerus*, limited visualization of the anterior articular surface of the elbow joint
Posterior *triceps*-sparing approach	Bone defect of the lower third of the *humerus*, primary and revision total elbow arthroplasty, pseudoarthrosis	Use of olecranon osteotomy Factors associated with poor healing of soft tissues (diabetes mellitus, soft tissue defect, severe edema)	Elbow arthroplasty can be performed; stabilizing function of the elbow muscle is preserved	Incomplete visualization of the articular surface of the *humerus*, damage to the *extensor apparatus* of the forearm Risk of *triceps* avulsion

according to the procedure that was firstly described by Bryan et al. in 1982 [65]. This approach has been widely used mainly for elbow arthroplasty. Although it is associated with postoperative elbow extensor weakness, other complications such as infection, revision surgery, or loss of muscle strength are rare. Guerroudj et al. compared *in vitro* mechanical properties of the *triceps* tendon after simulation of three common exposures. All approaches resulted in a weakening of the *triceps*; however, the Bryan–Morrey lateral *triceps*-reflecting technique provided statistically better strength than V-Yor longitudinal splitting [66]. Indications for this modified approach include DH fractures, surgical interventions for elbow contractures and ankyloses, as well as revision elbow arthroplasty [35, 67].

Compared with the Bryan–Morrey approach, the *olecranon* osteotomy approach to total elbow arthroplasty provides adequate visualization, saves operative time, reduces bleeding, provides better flexion activity, effectively improves elbow function, and achieves satisfactory functional results [69].

A modified Mayo posterior *transolecranon* approach is also known. A universal posterior approach with one long skin incision is used, with medial and lateral skin flaps stitched to the edges of the surgical field. The ulnar nerve is identified proximally in the medial intermuscular septum, decompressed, and protected. Standard *olecranon* osteotomy does not allow preserving the fixation site of the *m. anconeus*, which provides dynamic stability to the lateral elbow. The Mayo modification of this approach addresses this problem: the *m. anconeus* is identified and elevated from its bed by sharp dissection, preserving its attachment to the *triceps*. This modified approach is attractive because the dissection of the elbow muscle can be performed quickly and safely [69]. This approach also preserves *triceps* continuity and the attachment site of the hand extensors.

APPROACHES TO THE MEDIAL COLUMN OF THE ELBOW JOINT

Approaches to the medial surface of the elbow joint are used for osteosynthesis of coronoid process fractures, reconstruction, and restoration of the medial collateral ligament and release of the joint capsule in contractures and ankyloses.

Modified medial approaches include the Hotchkiss anteromedial approach and the Taylor and Scham posteromedial approach. Good visualization of the coronoid process is an advantage of these approaches. The disadvantage is a relatively high risk of injury to the ulnar and medial cutaneous nerves of the forearm [70, 71].

The Taylor–Scham posteromedial approach is used for basilar fractures of the coronoid with plate fixation. When performing this approach, the surgeon should be careful with respect to the ulnar nerve and the medial cutaneous nerve of the forearm [71].

During the Hotchkiss approach, the lower third of the *humerus* is isolated by subperiosteal separation of the brachial and *triceps* muscles. Indications include fractures of the coronoid process and removal of anterior surface osteophytes of the elbow joint [72, 73].

CONCLUSION

Conservative treatment methods for fractures in the lower third of the *humerus* that were used previously cannot completely preserve the function of the upper limb after the end of the immobilization period, and, at the current stage of medicine, they should be used only for patients with contraindications to surgical treatment.

Although methods for surgical treatment of elbow fractures are developing, contractures and ankyloses of the elbow joint develop quite often. Patients have to undergo long-term treatment in outpatient and hospital settings, but their functional results may be poor. Treatment often consists of simply changing the abnormal position of the limb, although it is necessary not only to correct the limb position but also to restore its shape and function.

The recovery period after osteosynthesis of humeral condyle fractures requires monitoring the duration of immobilization and normalization of muscle tone.

Despite significant progress in the development of osteosynthesis methods for juxta- and intra-articular fractures, choosing the optimal approach to the DH during osteosynthesis is still challenging. Treatment methods and surgical approaches should be chosen on the basis of the patient's X-ray findings, the surgeon's experience, and patient's requirements for functional results.

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