Original Research

Elbow stiffness: Arthritis and heterotopic ossification

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ABSTRACT

In elbow stiffness, pre-operative assessments should identify the articular and peri-articular tissues involved and, more specifically, they should determine how preserved the articular surfaces and osteo-articular congruity are.

We will focus on the most important conditions and tissue reactions after trauma in order to understand the causes of joint stiffness.

A logical surgical planning is based upon a deep knowledge of the anatomical obstacles and of the associated lesions that the trauma provoked with.

The peri-articular soft tissue contractures.

The osteo-articular incongruity.

What are the new findings

- In elbow stiffness, preoperative evaluations should identify the involved articular and periarticular tissues and, more specifically, should determine whether the articular surfaces and osteoarticular congruence are preserved.

- The main factors that decrease elbow movement after trauma include: osteo-articular malunions and nonunions, heterotopic ossification and peri-articular soft tissue contracture.

- Peri-articular soft tissue contractures are related to: skin contractures, contractures due to muscular imbalance, Capsular capsular and ligament contractures, and heterotopic ossification.

- The choice of treatment for elbow stiffness should take into consideration: non-surgical management (rehabilitation program), and surgical management (arthroscopic capsular release, opencapsular release, arthroplasty with debridement, distraction interposition arthroplasty, elbow replacement).

1. Peri-articular soft tissue contractures

1.1. Skin contractures

Serious skin burns, post-traumatic contracture wounds or hypertrophic scars often cause skin retraction of the anterior surface of the elbow.

An aggressive passive motion therapy after burns has been identified as a contributing factor in the development of heterotopic ossification (HO). Thus, this procedure should be avoided [1,2], especially in patients with an altered level of consciousness. These late painful and functionally limiting sequela of burn injuries are very common for the elbow joint.

1.2. Contractures due to imbalanced muscles

Neurological lesions (such as poliomyelitis or obstetrical palsy in children and brachial plexus lesions in adults) can be associated to chronic and static paresis of the elbow.

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1.3. Capsular and ligament contractures

The most common cause of extrinsic contracture with no osteo-articular damage is a simple elbow dislocation.


In a retrospective study, Mehlhoff et al. [4] discovered the relationship between time of immobilization and capsular contracture with no degenerative joint disease. Authors recommend gentle active and passive motions as soon as pain allows it.

Linscheid and Wheeler [5] reported true HO in 4.5% out of 110 elbow dislocations whereas more than 25% presented calcification in the collateral ligaments.

Injuries to the collateral ligaments are not frequently recognized until the development of post-traumatic ossification at the original ulno-humeral insertion. A secondary shortening of the MCL can lead to significant elbow stiffness: a retracted MCL posterior band can cause a flexion contracture beyond 60° while a tauter anterior part can provoke an extension contracture beyond 80°.

In case of a scarred and retracted LCL (with or without ossification) elbow motion is decreased in flexion and extension until ankylosis.

1.4. Heterotopic ossification

Ectopic para-articular bone formation is a sequela of a traumatic event in which a highly organized bone forms and substitutes the surrounding injured soft tissues. Etiology is still unclear and subject to misunderstandings. A possible explanation is that after trauma in presence of a bone morphogenetic protein the mesenchymal cells or fibroblasts differentiate and proliferate into cartilage and osteoblasts [6,7]. Direct trauma and its magnitude are the most frequent causes of HO. In a simple dislocation, Thompson and Garcia [8] reported a 3% incidence of HO. In complex instabilities with radial head (RH) fractures, incidence of HO rose from 15% to 20%.

Bromberg and Morrey [9] reported 9% HO after delayed excision of the fractured RH. Elbow trauma combined with central nervous-system injury increases the development of HO. In a simple dislocation, Thompson and Garcia [8] reported a 3% incidence of HO. In complex instabilities with radial head (RH) fractures, incidence of HO rose from 15% to 20%.

Hastings and Graham [12] proposed a radiographic and clinical classification distinguishing among three classes of elbow HO:

- **Class I:** HO with no functional limitation
- **Class II:** HO with:
  - IIA limited flexo-extension
  - IIB limited prono-supination
  - IIC limited flexo-extension and prono-supination
- **Class III:** Ankylosis

While Garland identified two separate sites of HO in the elbow [13] (anterior and posterior), Hastings and Graham [12] recognized three location of HO: in anterior, posterior and lateral sites of the elbow joint. In each area any tissue can be involved and HO can arise from:

In anterior site:

- Coronoid
- Humero-ulnar
- Humero-radial
- Peri-articular soft tissue such as capsule or brachial muscle

In the posterior site:

- Olecranon
- Humero-ulnar
- Olecranon fossa

In the lateral sites:

- Medial collateral ligament
- Lateral collateral ligament

2. Osteo-articular incongruity

Osteo-articular deformities due to mechanical limitations are likely to be associated to loss of mobility, capsular contractures, and heterotopic ossification.

A proper understanding of the anatomy and biomechanics of the elbow joint aids the surgeon in avoiding mal-union of the extra-articular or intra-articular fractures during operative management. After trauma, the complex bone anatomy has to be restored in the coronal, sagittal and horizontal planes.

The main factors that decrease elbow movement after trauma include:

- malunions and nonunions
- HO
- contracture of the peri-articular soft tissues

2.1. Supracondylar and inter-condylar fractures

1. Malunion

In the sagittal plane, anterior or posterior malalignment of the lateral column and capitellum with respect to the medial column and the trochlea changes the bone articular geometry. The anatomical axis of the elbow rotation changes in two axes: due to the ulno-trochlear joint and to the malaligned radio-capitellum joint.

In supracondylar fractures malunion, elbow stiffness is often due to loss of anterior rotation of the articular condyles.

Around 10°–20° loss of condyles antervation is well tolerated and patients preserve full elbow motion. However, when loss of anteverion exceeds 30°, the elbow loses its flexion of about 30°–40° (Fig. 1).

In the frontal plane, loss of elbow valgus tilt can often provoke a cubitus varus in children, with limitations of elbow movement. In particular, full elbow extension is due to the olecranon impingement in the olecranon fossa. In these cases a possible secondary postero-lateral rotatory instability can emerge later [14]. The exuberant callus with HO can reduce the coronoid or olecranon fossa sizes with loss in elbow range of motion (ROM).

2. Nonunion

Supracondylar nonunions are rare complications but their level represents a typical localization in the distal humerus fractures. Nonunion is due to inability to achieve a stable rigid fixation combined with early mobilisation.

The pain is often presented.

2.2. Intra-articular comminuted fractures

1. Malunion

Failing the reposition of the articular fragments results in a distorted anatomy of the trochlea and capitellum. The humeral joint loses congruent bone interfaces of the ulno-trochlea and radius-capitellum joints.

Care must be taken not to narrow the dimension of the trochlea and the anatomical position of the capitellum because this may prevent the proper seating of the articular surfaces of the olecranon and the radial head (Fig. 2).
Malunion of the distal articular surfaces produces a mechanical obstacle for the ulna-trochlear motion with a secondary limitation both in flexion and in extension: osteoarthritis is likely to arise, increasing elbow stiffness and pain.

2. Nonunion

Nonunions are rare complications after operative treatment of intra-articular fractures of the distal humerus. Fracture comminution or inappropriate initial treatment are involved in nonunion developments. In addition, surgical trauma and presence of intra-articular synovial fluid can compromise the fragments' blood supply [15]. In Mayo experience most nonunions are extra-articular and only 7% developed pseudarthrosis [16]. Patients often complain about pain and instability, and a high percentage of them presents motion loss [17,18].

2.3. Condyles fractures

Malunion or nonunion of a single column can lead to elbow deformation. Displaced lateral condyle fractures may cause cubitus valgus deformity and ulnar nerve entrapment while displaced medial condyle fractures produce cubitus varus with loss of ROM.

When malunion or nonunion condylar fractures occur in children, the deformed elbow is often associated to an excellent function in adults. These patients usually develop arthritis with pain and loss of motion during their sixth or seventh decade [19].

2.4. Capitellum fractures

Capitellum malunions often depend on a missing diagnosis of the fracture after a trauma. When small fragments lie in the superior part of the joint, anteroposterior radiographs or low quality lateral views often do not allow specialists to determine fracture presence. Capitellum fractures in non anatomical positions can lead to elbow stiffness at 90° flexion due to impingement of the radial head with capitellum mal-union (Fig. 3).

2.5. Olecranon fractures

After surgical reduction and internal fixation, elbow stiffness is often caused by an inadequate understanding of the anatomy of the articular surfaces of the olecranon and radial head.

Fig. 1. More than 30° loss of condyles antiversion is not tolerated and the elbow loses its flexion with over extension.

Fig. 2. The anatomical position of the capitellum and the correct size and shape of the trochlea must be recovered in the fracture of the distal humerus to prevent the proper seating of the articular surface of the olecranon and radial head.
olecranon surface. After fracture reduction, the surgeon should evaluate the alterations of the shape and size of the articular anatomy and the presence of bone impingement between the olecranon and the trochlea during flexion-extension movements.

In a different way, in comminuted fractures it is useful to set in line the posterior cortex of the ulna (length, size and shape) whereas the articular cartilage often presents fragments which are difficult to set in a correct anatomical position, especially in the mid-portion of the sigmoid notch.

Loss of elbow extension is often about 30° while flexion is rarely reduced. This occurs in 50–75% of the patients [20]. With an incidence of 2% [21]–20% [22] reported in long term follow-ups, inadequate fracture reductions are the main factors leading to post-traumatic degenerative arthritis.

The main predisposing factor causing olecranon nonunion is an inadequate fixation with early motion; the patient preserves a false motion between the bone ends with less pain.

2.6. Radial head fractures

The most common complications of radial head fractures are:

- Malunion or nonunion of the displaced or comminuted fractures:
  - The distorted anatomy of the radial head can lead to incongruity with the lesser sigmoid notch of the ulna and with the capitellum (Fig. 4).
  - The angular deviation of the radial head with sub-luxation of the proximal radio-ulnar joint will lead to a mechanical block.

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Fig. 3. Capitellum fractures can lead to elbow stiffness due to impingement of the radial head with the capitellum mal-union.

Fig. 4. Mal-union or non-union of the radial head fractures can lead to an incongruity with the lesser sigmoid notch and with the capitellum producing a mechanical block.
3. Evaluation

In patients presenting elbow stiffness, the physician should gather:

- Their precise history
- Physical examinations
- Imaging studies to determine osteo-articular integrity of the joint and presence of HO. Non-operative treatments should be considered only if the imaging studies show absence of mechanical block caused by a distorted bone anatomy or presence of HO with or without bone bars linking the joint.

3.1. History

Causes of contractures are usually explained by:

- Imaging studies after trauma and before treatment
- Duration of the clinical symptoms and their progression
- Previous treatments including duration of prolonged immobilization and aggressive physical therapy or surgery
- Presence of internal fixation devices and knowledge of any remote complications (infection, skin suffering, neurological problems) or periodical complications such as elbow inflammation or edema after physical therapy

3.2. Physical evaluation

It includes general information and a detailed evaluation of the elbow and the remaining joints in both upper limbs.

- General information that has to be considered include:
  - age
  - dominant arm
  - entity of the disability during daily living activities, manual work and recreational program
  - Skin around the elbow of the involved limb should be inspected to take evidence of any previous surgical approaches
  - Neurological state with special attention to the ulnar nerve
  - Patient capacity to have regular motor strength and voluntary muscles control
  - Functional evaluation of the elbow uses a simple and sensitive rating system that considers subjective and objective symptoms such as pain, motion, stability, and ability to perform daily activities

Many authors have described [22–27] elbow functional assessment and rating schemes to evaluate the outcomes of prosthetic replacements. The Mayo Elbow Performance Score (MEPS) described by Morrey [28] is well suited to represent the residual function of the post-traumatic elbow and it also allows surgeons to compare the outcomes of the surgical treatment over the follow-ups. Elbow post-traumatic stiffness is often painless but presence of pain should be noted in terms of intensity, location, radiation and where it occurs along the arc of movement.

During passive forced elbow flexion or extension, presence of pain helps to localize the anterior or posterior block with impingement of the olecranon or the radial head against an osteophyte or incongruity of articular surface of the trochlea. The range of elbow movement can be measured through a goniometer in a reproducible way.

Loss of full extension is often indicative of an intra-articular ulno-humeral incongruity.

Morrey [29] noted that most daily living activities can be accomplished with a 30 to 130° arc of motion in flexion and 50° forearm pronation and supination.

In case of elbow stiffness patients tolerate 30–40° loss of extension. Use of the hand is limited to the space around the body. In other cases, patients do not tolerate a 30–40° of flexion because use of the hand is very limited for individual needs.

Fig. 5. In chronic unreduced subluxation, the elbow becomes stiff in flexion extension preserving the prono-supination movements, pain is always present.
Axial bone alignment (varus and valgus deformity) and rotational stability of the elbow should be carefully tested.

In chronic unreduced subluxations the elbow becomes stiff in flexion-extension preserving the pronation-supination movement. Pain is always present (Fig. 5).

After radial head malunion or nonunion the forearm could present rotational stiffness and pain. In case of radial head resection there may be an associated distal radius-ulna dissociation (Essex-Lopresti lesion).

The neurological status which the motor strength of the muscle around the upper limb should be carefully evaluated as well as any peripheral paresthesias and sensory deficit.

3.3. Imaging studies

Imaging studies should be performed before proceeding with the treatment.

Routine, lateral, oblique and antero-posterior radiographs provide most of the information about the osteoarticular causes of the elbow contracture and, in particular, they determine the integrity of the joint and presence of para-articular HO. Computed tomography (CT) scanning should be employed to evaluate the residual articular congruity and the precise localization and extension of the HO around the elbow.

Magnetic resonance imaging (MRI) may be useful to identify any associated loose bodies.

Lateral radiograph is the most helpful to define:

- Correctness of humeral-olecranon and humeral-radius relationships and it may also be valuable to determine the normal articular surface contours
- Presence of HO in the anterior or posterior aspect of the joint

Antero-posterior radiographs are not particularly helpful if the elbow is contracted in flexion. In these cases CTs provide precise information regarding the state of the articular surface, presence of fragment malunion or non-union and HO bone geometry. In order to reduce the risk of HO recurrence after surgery, we have to consider their radiographic “maturity”. HO is defined as “mature” when linear trabeculation is present and the margin separating the HO from the surrounding soft tissues is distinct, with cortical borders identical to the native bone (Fig. 6A–E).

Technetium bone scan is not predictable to assess maturity or biological activity of HO to minimize recurrence after surgical intervention [13,30].

3.4. Treatment options

Choice of treatment of elbow stiffness needs to consider:

- Non-surgical management
  1. Rehabilitation program
- Surgical management with:
  1. Arthroscopic capsular release
  2. Open capsular release
  3. Debridement arthroplasty
  4. Distraction interposition arthroplasty
  5. Elbow replacement

3.5. Non-surgical management

Non-operative treatment should be considered when:

- Articular bone anatomy is preserved
- Contracture is mild and it has not been present for more than 6 months
- Absence of Class II or Class III HO bridge according to Hastings and Graham Radiographic Classification [12]

The end point of the range of motion is springy without firm block as bone impingement.

Non-surgical treatment includes various strategies.

Fig. 6. A–E: Heterotopic Ossification (HO) is defined as “mature” when linear trabeculation is present and the margin separating from the surrounding soft tissue with cortical borders.
1. Rehabilitation program

Physical therapy with actively and passively assisted elbow motion is often not sufficient to gain functional ROM. Passively assisted therapy has to avoid aggressive exercises that can increase elbow swelling and pain and secondary risk of HO and stiffness development.

Short, everyday active or passive exercises alone will not effectively lengthen the contracted soft tissues. Continuous passive motion (CPM) shows to be an important adjunct to achieve this goal.

In order to preserve the gained arc of motion after active and passive exercises we can use static adjustable splinting or dynamic splinting. The inflammatory and fibroplasia phase that stretches the periarticular soft tissue after forced motion can be protected through splints. Splints allow to maintain the soft tissue at its maximal length (static or serial static progressive splint).

Guidelines for the use of splints, their specific position and their wearing time were described by Morrey [31].

3.6. Surgical management

Choice of surgical technique and timing of the surgical management needs to consider:

- Patients' needs and expectations and their involvement
- Etiology and clinical assessments of elbow stiffness
- Operative techniques and surgeons' skills

The general principles of the surgical technique are:

1. Remove all contracted structures and intra-articular deformities to obtain elbow motion
2. Maintain elbow stability preserving the anterior band of the MCL and the posterior band of the LCL
3. Avoid any damage of neuro-vascular structures

Decisions about the operative techniques are taken on the basis of presence of elbow stiffness with:

- Intact articular surface with preserved congruity
- Violated articular surface without congruity for malunion or non-union

3.7. Stiffness in preserved articular surfaces with preserved congruity

1. Arthroscopic release

This procedure can be helpful in properly selected cases, but it is technically demanding and it requires experience to be performed safely [32–34].

In the elbow stiffness the capsular volume is reduced from 25 ml to 6 ml [35] and the potential damages to neurovascular structures are high, especially for the ulnar nerve and the deep motor branch of the radial nerve.

Arthroscopic capsular release for “simple” elbow contracture can be performed with three possible options [36]:

- Capsular detachment from the humerus
- Capsulotomy
- Capsulectomy

The capsular release is completed with synovectomy and debridment of all olecranon and coronoid osteophytes, of the RH resection, and also of the olecranon fossa fenestration (Outerbridge-Kashiwagi procedure) [37].

2. Open capsular release

Isolated open capsulectomy is often associated with HO resection. Consequently, the choice of the surgical approach depends on type, localization and extension of HO.

The limited or extensile lateral approach (Fig. 7) is carried out when the contracture of the anterior or posterior capsule is associated with lateral HO with olecranon and coronoid osteophytes or radial head malunion or non-union [38–40].

After capsulotomy, if elbow flexion is not achieved, Wada et al. [41] suggest that the thickened and scarred posterior oblique bundle

![Open capsular release (Lateral side)](image-url)

**Fig. 7.** Open capsular release (Lateral side) (A) Kocker’s skin incision is performed (B) The interval between the anconaeus and the extensor carpi ulnaris is identified (C) Proximally on the distal humerus a Column approach is performed (D) The anterior capsule is exposed with the lateral collateral ligament complex (E) anterior and posterior capsulectomy is performed, preserving the lateral collateral and annular ligaments.
of the MCL play an important role in post-traumatic flexion contracture [42].

The medial operative approach described by Hotchkiss [43] for the treatment of post-traumatic elbow contractures is indicated when we have ulnar neuropathy or postero-medial heterotopic ossification located over the postero-medial aspect of the elbow. The medial extensive approach is also indicated when a severe capsule contracture is associated to postero-medial or antero-medial HO bone bars (class IIA-III or III according to Hastings and Graham classification) [12] (Fig. 8). In these cases, the ulnar nerve is often encased in the HO, without clinical symptoms of nerve entrapment [44]. The ulnar nerve should be carefully protected by any surgical injury when the operative bone excision and capsulectomy are performed.

### 3.8. Stiffness in violated articular surfaces without osteo-articular congruity

In pre-operative clinical and radiographic assessments, presence of significant articular deformity for fracture malalignment often creates a refashioning of the articular surface with painful elbow stiffness.

In pre-operative planning several factors and surgical options should be considered:

- possibility to restore the distorted articular surfaces anatomically (patients under 50 years old): in order to recover appropriate alignment and osseous union with osteoarticular surgical corrections
- possibility to recognize the articular surfaces if loss of articular cartilage is lower than 50%: the best surgical option is debridement arthroplasty
- presence joint surfaces distortion and more than 50% lack of hyaline cartilage [45]; in young patients with high physical demands the distraction arthroplasty is performed. In the literature when the olecranon and radius articular surfaces are preserved, humerus hemiarthroplasty is advised as a salvage reconstruction
- impossibility to recover any anatomical aspect of the articular surfaces due to mal-union, fixation failure or non-union or secondary osteoarthritis: in elder patients with low physical demands total elbow arthroplasty (TEA) is a salvage procedure

### 4. Arthroplasty with or without total elbow replacement

1) Conservative arthroplasty
2) Replacement arthroplasty (hemi- or total elbow arthroplasty)

Choice of the treatment mainly depends on the state of the joint surface and on the patient's age.

In pre-operative clinical and radiographic assessments the surgeon should define the presence and the entity of the articular abnormalities, which are frequent after-effects of intra-articular fractures.

1. Conservative arthroplasty

#### Historical review

The first era of elbow arthroplasty was characterized by efforts to recover motion through extra-articular elbow resection. Park [47], Park and Moreau [48] and Ollier [49] in Europe and Barton [50] in the US were the main pioneers of this surgical procedure in the nineteenth century.

The second era of elbow arthroplasty began at the dawn of the twentieth century. Surgeons abandoned extra-articular resections because they often caused serious unstable elbows; a new more conservative concept was developing, the intra-articular resection, which implied the removal of any damaged articular surfaces, followed by the interposition of the fascia lata.

In the USA, Murpy [51, 52] was the first surgeon to introduce elbow's arthroplasty with fat interposition, a technique that he furtherly changed by using muscular fascia.

Years later Lexer [53] and Albee [54] affirmed that fat and fascia lata performed better as substances for arthroplasty interposition while excising the value of autologous tissues.

In 1918 Baer [55] used an animal membrane (a pig's bladder) as interposition muscular flap. Meanwhile Putti [56] spread elbow arthroplasty in Europe: in 1921 he performed a high number of interventions which implied the interposition of aponeurotic flap, previously drawn from fascia lata and fixed through catgut suture. Putti always carefully chose his patients: his targets were young and adult patients (more than 20 years old, but less than 50) affected by post-traumatic arthritis.

In 1922 Campbell [57] proposed a trans-tricipital approach to the elbow, while the European School always preferred Kocher's approach: he would carve the aponeurotic tricipital flap which he would then use as interposition tissue between resected articular surfaces, then he would fix this flap to the anterior portion of capsule [58]. According to Campbell's theory this surgical intervention should be proposed to patients affected by post-traumatic ankylosis and acute arthritis (by Staphylococcus, Pnumococcus and Streptococcus), obviously after a careful evaluation of the patient's degree of collaboration. Patients with tubercular infection, high muscular atrophy and large cicatricial tissue were excluded.
In the meantime, Mac Ausland [59] from Boston and Henderson from Mayo Clinic [60] developed the fascia lata interposition. We should also mention remarkable authors like Giuntini [61], Agrifoglio [62] Cappelin [63] as well as Knight and Van Zandt [64] in 1952, and Lars [65] who also played an outstanding role.

Many authors tried out new materials in arthroplasty interposition: in 1976 Froimson [66] testes abdomen skin, whereas in 1977 Kita tested the J-K membrane with good results [67]. Meanwhile, Smith employed a kind of spongy gel called gefoam [68]; in 1983 he also used a silicon membrane in six haemophilic patients with elbow ankylosis.

Today, after a long period of surgical experience, two different conservative options can be advised:

- debridement arthroplasty
- interposition distraction arthroplasty

**Debridement arthroplasty**

Tsuge described the debridement arthroplasty for elbow advanced primary osteo-arthritis [69,70]. Debridement arthroplasty is generally

![Fig. 9. Anterior and posterior capsulectomy is performed and the elbow joint is exposed.](image_url)

![Fig. 10. The Achilles tendon allograft is interposed to cover the humeral articular surface and to reconstruct the ligaments.](image_url)

![Fig. 11. The external joint fixator is used to protect the ligaments and to distract the joint space.](image_url)

![Fig. 12. A-D Malunion of the distal humerus fractures in a 70-year-old female (A,B). Intra-operative picture (C). Total elbow arthroplasty (Coonrad-Morrey) post-op radiographs (D).](image_url)
are preserved even when a large cartilage de

Debridement arthroplasty does not require soft tissue interposition when the articular cartilage of the ulno-humeral joint is well preserved. Tissue interposition is indicated when the shape and size of the trochlea are preserved even when a large cartilage deficiency is present.

Olecranon fossa fenestration (Kashiwagi’s procedure) during the debridement arthroplasty is advised if the elbow loses the anterior rotation of the articular condyles (supracondilar mal-union) with consequent ulno-humeral impingement. Kashiwagi [71] and Morrey [72] described this technique for osteo-arthritis treatment of the elbow joint. Morrey called this technique “ulno-humeral arthroplasty” [72] and considered it really fit for the treatment of primary osteo-arthritis which had already minimally or moderately restrained elbow extension.

The goal of elbow debridement is to gain a wide exposure to remove all the patho-anatomic structures which cause elbow stiffness.

Interposition arthroplasty

Interposition arthroplasty is a well-defined surgical procedure: it is useful in young and adult patients whose articular surfaces have been severely damaged.

Interposition arthroplasty is indicated when the articular anatomy and congruence cannot be restored. In this case it is necessary to reshape the articular surfaces; therefore, autologous or homologous soft tissue interposition is useful to replace cartilage absence.

Morrey et al. [45] suggested to consider interposition arthroplasty as the first option in case of 50% cartilage loss and incongruity due to articular fractures.

Interposition is also a viable surgical option for persistent dislocation or sub-luxation in younger patients (often involving bone and ligamentous structures with articular cartilage degeneration or articular bone loss).

Froimson and Morrey [73] described the use of Achilles tendon allograft in order to cover the humerus and to reconstruct the lateral and medial collateral ligament.

At the end of the procedure the lateral ligament and tendon complex are reattached to the bone through drill holes placed in the lateral epicondyle. The hinged internal fixator is always applied: the hinged fixation allows a better joint stability until the soft tissues adequately heals during post-operative free motion. It is also possible to distract the joint space (at least 3 mm through a full arc of motion) to protect the interposition material (Figs. 9–11).

The most critical step in the hinged fixation application is the correct placement of the axis pin in the center of the elbow axis of rotation.

2. Replacement arthroplasty (total or hemi elbow arthroplasty)

Total elbow arthroplasties (both linked and unlinked prostheses) are performed in extreme cases:

- If no salvage procedure is possible
- If patients are old, with low physical demands, osteoporotic bones and when a conservative treatment could imply complications [74,75]

Implant failure is the most common complication after total elbow arthroplasty in younger patients.

The choice between linked or unlinked devices depends on the type and amount of joint deformity. linked semi-constrained designs play a predominant role in our institution: we usually implant Coonrad Morrey prostheses. We consider the main indication for elbow replacement in the post-traumatic elbow stiffness in persistent instability (sub-luxation or dislocation) after fracture dislocation or in intra-articular bone deformity for mal-union or non-union (Fig. 12A–D).

Distal humeral hemi-arthroplasty could be fit in younger patients who need reconstruction of mal-union, intra-articular avascular necrosis and unreduced shear fracture involving the capitellum and lateral trochlea [46,76] (Fig. 13A and B).

Declaration of competing interest

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