Complex post-traumatic elbow stiffness: nonunion, malunion, and post-traumatic arthritis

G.A. Fierro Porto¹, R.M. Greiwe²
¹Universidad del Rosario – Fundación Santa Fe de Bogotá, Bogotá, Colombia; ²Commonwealth Orthopaedic Centers, Edgewood, KY, USA

15.1 Introduction

Post-traumatic stiffness is the most common and oldest known complication after elbow trauma [1,2]. The elbow is particularly susceptible to contracture after trauma because of its congruent nature, proximity of the triceps and brachialis, and potential to develop heterotopic ossification (HO) and capsular inflammation [1,3,4].

Complex post-traumatic elbow stiffness includes elbow stiffness related to non-union, malunion, and post-traumatic osteoarthritis. Post-traumatic elbow stiffness can range from mild to severe and may be extremely difficult for the patient because of pain and resultant limitations in activities of daily living. Because of the multitude of factors involved, the technical challenges surrounding surgery, and the refractory nature of the injury, the treatment of post-traumatic elbow stiffness can be complex and frustrating for patient and surgeon.

This chapter begins with an overview of the epidemiology and pathophysiology associated with post-traumatic elbow stiffness related to post-traumatic osteoarthritis, nonunion, malunion, and associated soft-tissue contractures. The body of the chapter discusses proper patient evaluation, including history, physical examination, imaging techniques, and laboratory examination so as to identify the primary cause of the patient’s stiffness. The chapter concludes with a summary of the available surgical and nonsurgical treatment strategies and the anticipated outcomes after treatment of complex elbow stiffness. Finally, the complications frequently encountered after surgical intervention are discussed.

15.2 Pathophysiology

Post-traumatic elbow stiffness occurs in approximately 5% of all traumatically injured elbows, including 20% of intercondylar and supracondylar elbow fractures [5]. A good framework must be established when addressing the etiology of joint stiffness. The following section will assist in understanding the biology behind capsular stiffness and will describe the ways in which joint stiffness can develop. Post-traumatic elbow stiffness may be organized by the tissues affected by contracture and their location of
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Involvement (Table 15.1 and Figure 15.1) [6,7]. Contracture may occur because of bone development in the form of spurs or heterotopic bone, or via soft-tissue contracture, either intra-articularly or extra-articularly. Soft-tissue contracture may be divided into stiffness caused by the capsule, muscle/tendon units, and ligaments.

15.2.1 Capsular contracture

The capsule is the primary mode of stiffness in a nonarthritic elbow joint. It typically is a thin, translucent membrane, but elbow trauma usually causes the capsule to become thickened and inflamed. In its thickened state, the capsule contains a multitude of myofibroblasts as well as increased collagen (Type I, III, V) levels and matrix metalloproteinases (MMP-1, -2, -9, -13, and -15). It also contains less proteoglycan, water content, and MMP tissue inhibitors [7–11].

Traumatic injury causes the release of several inflammatory enzymes, including tumor necrosis factor (TNF)-α, transforming growth factor (TGF)-β, and interleukin (IL)-3. Capsular myofibroblasts are the primary cell behind capsular contracture and are affected by the inflammatory mediators. Flexion contracture appears to be more common than extension contracture in elbow injury. Interestingly, studies demonstrate

| Table 15.1 Pathophysiology of the post-traumatic stiff elbow |
|--------------------------------|--------------------------------|
| **Intra-articular** | **Extra-articular** |
| Soft tissue | · Intra-articular adhesions | · Capsule contracture |
| | | · Ligament: Medial or lateral collateral ligament contracture |
| | · Intra-articular fracture | · Brachialis muscle |
| | · Articular malalignment | · Triceps |
| | · Loss of articular cartilage | · Skin |
| | · Joint incongruity | · Subcutaneous tissue contracture |
| | · Arthritis | · Extra-articular fracture |
| | · Loose bodies | · Extra-articular malunions |
| | · Osteophyte impingement | · HO |
| | · Coronoid fossa | · Myositis ossificans |
| | · Olecranon fossa | · Periarticular calcifications |
| | · Osteophytes | |
| Mixed | · Coronoid | · Extrinsic contractures secondary to intrinsic pathology |
| | · Olecranon | |
| | | |
a higher number of myofibroblasts in the anterior capsule than posterior capsule [12]. Whether this stems from the anterior capsule being more at risk for scarring or an inherent property of the anterior capsule is unclear. Mast cells and female sex hormones, such as estrogen and relaxin, have been shown to influence activity and differentiation of myofibroblasts; thus, they may also play a role in capsular contracture [7,12–36].

15.2.2 Muscular contracture

Muscular inflammation because of elbow trauma may also play a role in elbow contracture. When traumatized, the brachialis and triceps muscles are involved in a mechanism called co-contracture, which leads to diminished motion and stiffness [37,38]. The brachialis becomes tight in extension whereas the triceps limits flexion movement. The triceps also limits elbow motion via adhesions to the posterior humerus and joint capsule. Muscular contracture is thought to develop early in the process of post-traumatic elbow stiffness. Muscular contracture may be one of the more challenging areas to surgically resolve because of potential changes associated with muscular stiffness and atrophy [39].

15.2.3 Ligamentous contracture

Contracture of the collateral ligaments is considered an important factor in the etiology of elbow stiffness. The medial collateral ligament (MCL) and lateral collateral ligament (LCL) cause elbow contracture because they assume a shortened posture when the elbow is flexed. When the ligaments become contracted, it can be challenging

![Figure 15.1](image.png)

Figure 15.1 Causes of elbow stiffness.
to return them to their original length and tension with conservative measures. Occasionally, in severe cases in which patients lack flexion, the posterior band of the MCL may be sectioned to improve range of motion \[1,40\].

### 15.2.4 Contracture of skin

Skin plays an important role in elbow stiffness after trauma because it is frequently affected in open fractures; burns; or in large, open surgical approaches that in some cases cause hypertrophic scars and contractures (Figure 15.2) \[41\].

### 15.2.5 Heterotopic ossification and bone formation

HO occurs after traumatic injury to the elbow. Other forms of bone dedifferentiation occur in the form of myositis ossificans (MO) and periarticular calcifications. HO is most likely to limit elbow motion and is thoroughly discussed in Chapter 13. A more severe form of HO is ankylosis or synostosis of the elbow. Ulnohumeral, radioulnar, or radiohumeral ankylosis or synostosis may occur in severe traumatic episodes or in patients with extensive surgery, neurologic injury, or other risk factors. Ankylosis or synostosis is rare but extremely disabling. MO and periarticular calcifications are not common causes of post-traumatic elbow stiffness, but they are discussed in this chapter (Figure 15.3).

![Figure 15.2](image)

**Figure 15.2** Soft-tissue-related injury to the anterior elbow resulted in a skin and soft-tissue contracture. (a, b) Demonstrate a thoracoabdominal flap utilized to improve elbow motion. Note that the flap extends beyond the elbow flexion crease so as to improve motion. © Vivian Otavo, MD
A 52-year-old woman was involved in a motorcycle accident in which a deer ran out in front of her. She sustained a Grade 3A open olecranon fracture. (a, b) Three-dimensional renderings of her fracture. (c, d, e, f) Anteroposterior (AP) and lateral radiograph 6 months following ORIF of the fracture. (e, f) The patient had developed extreme HO and had lost all but 5° of flexion and extension. (g, h) AP and lateral radiographs after removal of hardware and excision of HO through a lateral column approach. The patient’s final range of motion was 10–120°. Courtesy of R. Michael Greiwe, MD
15.2.5.1 Periarticular calcifications

Periarticular calcifications are usually found in the capsule and collateral ligaments. They are amorphous calcium pyrophosphate collections without trabecular organization. In general, they signify significant trauma, but they do not lead to loss of elbow motion as they are currently understood [42, 43].

15.2.5.2 Myositis ossificans

MO rarely causes limitation in motion and frequently occurs after significant muscular trauma. Myositis represents a non-neoplastic, heterotopic bone formation within muscle or fascia, presumably because of acute trauma or repeated injury [44]. Some

Figure 15.3 Continued.
theories have been proposed to explain its pathophysiology, including displacement of bony fragments into the soft tissue and hematoma with subsequent proliferation, detachment of periosteal fragments into the surrounding tissue with proliferation of osteoprogenitor cells, and differentiation of extraosseous cells exposed to bone morphogenic protein (BMP). According to this theory, trauma has bone fragmentation that may result in autolysis and release of BMP into the soft-tissue mass, leading to progressive ossification [45]. Lesions result in significant functional deficit in only 10–20% of patients and rarely cause ankylosis of the elbow [46]. It is more common in muscles that are repeatedly strained or injured [47], and bandaging and repeated massage for traumatic conditions increase the risk of MO. In its early stages, it is possible to see radiographic hyperintense specks around the joint that later become fully ossified bone [46].

15.2.5.3 Osteophytes

Bone formation occurs after the development of post-traumatic osteoarthritis of the elbow. In this scenario, osteophytes fill the olecranon and coronoid fossae and form on the olecranon and coronoid tip, causing bony impingement and limiting motion. These osteophytes may be covered with apparently normal hyaline cartilage, which is thought to be a biologic response to resurface the diseased joint [48].

15.2.6 Post-traumatic osteoarthritis

When a traumatic injury causes damage to the articular cartilage of the elbow, a progressive sequence of cell and matrix changes results in loss of articular cartilage structure. Damage to the articular cartilage subsequently increases inflammatory and injury-mediated breakdown of the joint, resulting in the formation of fissures, focal erosive cartilage lesions, cartilage loss and fragmentation, subchondral bone sclerosis, cyst and large osteophyte formation at the margins of the joint, capsular thickening, and contracture [48]. The spectrum of post-traumatic osteoarthritis includes that caused by isolated malunion, nonunion, impact- and fracture-related cartilage damage, iatrogenic cartilaginous injury, or combinations thereof. The elbow is not thought of as a weight-bearing joint, but during heavy manual labor, the ulnohumeral joint carries up to 3 times body weight and up to 0.5 times body weight during activities of daily living [49]. Therefore, post-traumatic arthritis of the elbow may result in significant pain and disability after treatment for those who still are functionally active.

Few long-term studies detail post-traumatic elbow osteoarthritis. In 2010, Guitton et al. followed 139 patients over a period of 10–34 years after elbow injury and noted that osteoarthritis was more common after an elbow fracture-dislocation or an intra-articular fracture of the distal humerus than other fractures about the elbow [50]. Another article demonstrated that intra-articular fractures of the distal humerus are susceptible and are responsible for a rate of osteoarthritis of 80% at 12–30 years after injury [51]. Intra-articular Mason Type II and III radial head fractures demonstrated a rate of arthritis that was 60% higher than the contralateral uninjured side at an average follow-up of 18 years in another study [52]. It is interesting to note that radial head resection
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significantly altered joint mechanics enough that 100% of patients that underwent this procedure for a severe radial head fracture developed arthritis [53].

Elbow fracture-dislocations have an extremely high rate of post-traumatic osteoarthritis, particularly if persistent subluxation occurs [54,55]. These patients will develop post-traumatic osteoarthritis fairly quickly, and it is seen in 46–76% of cases [54]. Other proximal ulna fractures have a worse prognosis, including those with a joint step-off of 2 mm or greater or Regan and Morrey Type III coronoid process fractures.

What appears consistent is that rates of osteoarthritis are high for fracture-dislocations and distal humerus fractures, especially in situations of persistent subluxation or intra-articular step-off. When studying the effects of the particular fracture pattern on osteoarthritis rates, it is difficult to eliminate the other variables, including iatrogenic cartilage injury and malunion in these results. Nonetheless, it is worthwhile to discuss these particular issues with patients before their surgeries (Figure 15.4).

15.2.7 Malunion

Malunion of the distal humerus results in abnormal biomechanics of elbow flexion and extension. Distal humeral malunion typically results in diminished motion, secondary arthritis, and capsular contracture. Reduction of the articular surface may be challenging because many small and irregular fragments may exist; however, anatomical reduction must be performed to maintain joint congruence and normal movement. Intra-articular fractures are especially susceptible to malunion, which is associated with loss of motion [1,56–59].

15.2.7.1 Intra-articular malunion

Joint incongruity caused by a malunion between the ulna and trochlea or the radial head and capitellum produces a mechanical obstacle for movement leading to a lack in flexion, extension, or both. In these cases, osteoarthritis is common, leading to pain and stiffness [41]. In cases of radial head malunion, pronation and supination will be compromised [41,59–61]. Flexion and extension may be obstructed via a malunion of the greater sigmoid notch. Any alteration in its shape or size could lead to impingement between the notch and trochlea, restricting movement.

In comminuted fractures, it may be challenging to anatomically reconstruct the joint surface, but it is important to do so (Figure 15.5). The cartilage surface must be appropriately reconstructed to allow for adequate range of motion (Figure 15.6) [41].

15.2.7.2 Extra-articular malunion

The axis of the articular surface in relation to the long axis of the humeral shaft should also be reconstructed with flexion (30°), internal rotation (5°–7°), valgus inclination (6°–8°), and anterior offset (4°–8°). The lateral column flexes more anteriorly, whereas the medial epicondyle and medial column are more in line with the humeral shaft [1,41,62]. The most common malalignment in the sagittal plane is extension, which results in decreased elbow flexion [63–65].

In the coronal plane, alterations in the normal elbow valgus limit extension because of olecranon impingement and they may compromise elbow stability [41,66].
In addition, shortening of the lateral column leads to cubitus valgus deformity and associated tardy ulnar neuropathy whereas malalignment of the medial column may lead to cubitus varus and loss of range of motion [41].

15.2.8 **Nonunion**

Nonunions can be particularly difficult and can lead to pain, instability, stiffness, intra-articular adhesions, and (in some cases) blood supply compromise [59,67].
Figure 15.5 A 27-year-old Hispanic man was involved in a fall from a ladder. (a, b) Anteroposterior and lateral radiograph after the injury. (c, d) Three-dimensional renderings of the comminuted intra-articular distal humerus fracture. (e, f) Post-ORIF after the fracture. (g, h) Three-dimensional CT after fracture fixation. Final range of motion was excellent (5°), lacking full extension to 135° of flexion.

Courtesy of R. Michael Greiwe, MD
15.2.8.1 **Distal humeral nonunion**

Supracondylar nonunion is a rare complication after supracondylar fracture. Ackerman and Jupiter published a series of 20 patients with distal humerus nonunion after an average 16 years of follow-up [68]. Nonunion is typically due to the inability to obtain stable rigid fixation of the fracture at the supracondylar level after fracture. Intra-articular fracture comminution or inappropriate initial treatments are commonly involved in this entity because the surgical trauma and presence of intra-articular synovial fluid can compromise the fragments’ blood supply and healing potential [41,69].

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**Figure 15.5** Continued.
Distal humerus nonunions are becoming increasingly rare with the advent of locked bicondylar plating and principles for fixation; however, they can be extremely challenging whether they occur in the metaphysis or intra-articular region. Movement generally occurs through the site of the nonunion rather than through the joint; therefore, intra-articular adhesions and capsular contractures are proliferative. Evidence of a nonunion in the metaphyseal or intra-articular region, with evidence of good surgical technique, proper principles of fixation, and bicondylar locked plating, should prompt the surgeon to consider indolent infection as a cause. Distal humeral nonunion is discussed further in Chapter 12.

Figure 15.6 Comminuted distal humerus fractures may go on to nonunion, leaving the patient with poor function. (a) A comminuted distal humeral fracture with significant metaphyseal comminution. © Felix H. Savoie, III, MD. (b, c) A comminuted fracture of the distal humerus before and after fixation. Courtesy of R. Michael Greiwe, MD
15.2.8.2  **Ulnar and radial head nonunion**

Nonunion of the ulna is rare and may be caused by inadequate fixation, infection, or poor bone quality. Depending on the site of the nonunion, range of motion of the elbow may occur through the nonunion site; however, intra-articular nonunions generally result in less extension because the proximal ulna displaces posteriorly [41,67,70,72]. The treatment of ulnar nonunion is discussed more thoroughly in Chapter 13.

Radial head nonunion can cause stiffness in pronation and supination and is more common at the surgical neck. Fortunately, symptoms rarely require operative management because pain and range of motion loss can be minimal. In more extensive cases, open reduction and internal fixation (ORIF) with bone grafting or radial head replacement may be utilized [59,73,74]. The treatment of radial head nonunion is discussed further in Chapter 11.

15.3  **Classification**

Several classifications of post-traumatic elbow stiffness have been described. The most common classification for post-traumatic elbow stiffness is the Morrey classification, which details stiffness according to the origin of the pathology. The Kay classification describes the underlying cause of elbow contracture, including soft tissue (Type I), HO (Type II), healed periarticular fracture (Type III), nonunion or malunion (Type IV), or ankylosis (Type V) (Table 15.2) [43,75–77].

15.4  **Medical decision-making**

15.4.1  **Assessment**

A comprehensive clinical evaluation is essential to identify the primary source of elbow stiffness as well as guide treatment decisions. Adequate understanding and evaluation of these patients requires a thorough history, physical examination, and appropriate imaging. A detailed medical history should be obtained, paying particular attention to comorbidities that may negatively affect the body’s wound- and bone-healing ability, including any history of diabetes and oral corticosteroid use [78].

The history can vary based on the source of elbow stiffness. In general, patients with a capsular-based etiology gradually lose motion, beginning with loss of full extension without significant impairment in daily life. Pain may be noted at end range of motion followed by progression to a more serious flexion contracture [79]. Patients who suffer from impingement-related pain have discomfort at terminal extension and flexion due to osteophytes on the coronoid, olecranon, or adjacent fossae [7]. In contrast, osteoarthritis, loose bodies, ulnar nerve dysfunction, and articular incongruity produce pain in the middle arc of motion [79,80]. In patients who experience pain at rest and have had prior surgery, infection should be suspected and appropriate laboratory studies should be ordered [81]. Early presentation
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of elbow stiffness can be confused with cellulitis, deep infection, reflex sympathetic dystrophy, and thrombophlebitis. If loss of motion appears within the first 2 weeks after trauma, then HO should be considered [82].

Patients should be questioned about any previous injury to the elbow and subsequent treatment, including surgical intervention, periods of immobilization, and history of infection. Duration of elbow stiffness and previous rehabilitation efforts should be ascertained. It is essential to understand the patient’s previous level of function, occupation, and expectations after surgery. Morrey et al. described a functional arc of motion necessary for most activities of daily living as a flexion–extension arc of 30–130° and 50° of forearm pronation and supination [83]. Patients with active lifestyles and those with physically demanding occupations may have expectations that exceed this range. Conversely, elderly patients and those with very low physical demands may require less motion. This is valuable knowledge to consider when considering treatment options for a patient with elbow stiffness.

The physical examination should begin with visual inspection of the involved extremity, assessing for skin integrity, scars, deformity, contractures, and swelling. The elbow should be palpated and areas of tenderness noted. A thorough neurovascular examination must be performed and documented. Ulnar nerve pathology is commonly associated with elbow stiffness [84,85]. In cases of prior radial head surgery, special attention should be given to the posterior interosseous nerve (PIN) function. Elbow range of motion should be evaluated, both actively and passively, and compared to the

<table>
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<tr>
<th>Classification</th>
<th>Intrinsic component</th>
<th>Extrinsic component</th>
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<tr>
<td>Morrey</td>
<td>• Intra-articular adhesions &lt;br&gt; • Articular malalignment &lt;br&gt; • Articular malunion/nonunion &lt;br&gt; • Loss of articular cartilage &lt;br&gt; • Adhesions</td>
<td>• Capsular, ligamentous, or muscle contracture &lt;br&gt; • HO</td>
<td>Most contractures are a combination of intrinsic and extrinsic components</td>
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<td>Kay</td>
<td>Type I</td>
<td>Soft-tissue contracture</td>
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<td></td>
<td>Type II</td>
<td>Soft-tissue contracture with ossification</td>
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<td>Type III</td>
<td>Nondisplaced articular fracture with soft-tissue contracture</td>
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<td>Type IV</td>
<td>Healed periarticular fracture with soft-tissue contracture</td>
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<td>Type V</td>
<td>Post-traumatic ankylosis</td>
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Table 15.2 Elbow stiffness classification according to anatomical location and clinical aspects
contralateral side. Painful points and areas of catching or locking should be recorded, and elbow stability should be tested. Given that most stiff elbows are stable, elbow stability is generally good. However, a fixed dislocation may occasionally present as a stiff elbow.

15.4.2 Imaging

Standard radiographs, including anteroposterior and lateral views, should be obtained in all cases of post-traumatic elbow stiffness. Radiographs may be evaluated for osteophytes, fracture reduction, healing, and fracture fixation. Computed tomography (CT) is recommended in most cases of post-traumatic stiffness because it provides good detail of the bony anatomy. When hardware is present, metal artifact diminishes the effectiveness of CT [79,86].

15.4.3 Labs

An erythrocyte sedimentation rate, C-reactive protein level, white blood cell count should be performed preoperatively, in addition to joint aspiration and possible cultures and frozen section during surgery. All cultures should be held for at least 21 days to effectively rule out Propionibacterium acnes [59,68,70,71].

15.5 Treatment

When managing elbow stiffness, it is important to clarify the expected outcomes after treatment with patients and their families. Emotional factors should be considered in addition to anatomical and functional components associated with treating elbow stiffness. Patients and families may feel that there is some failure in the initial treatment of the elbow if the expectation to obtain a functional elbow at the same level as before the injury is unmet. Patients must understand the difference between nonsurgical or surgical management and their anticipated outcomes (Table 15.3) [37].

15.5.1 Conservative management

Nonsurgical treatment is indicated in the first 6 months after trauma and in cases with minimal arc of motion impairment. Several conservative methods are utilized, including physical therapy, serial casting, static and dynamic splinting, continuous passive motion (CPM), manipulation under anesthesia (MUA), and botulin toxin A injections [87].

15.5.1.1 Rehabilitation

A comprehensive rehabilitation program requires appropriate communication among physician, therapist, and patient. The therapist must understand any prior treatment received by the patient along with its limitations, advantages, and disadvantages.
There currently are few published studies providing high-level evidence supporting stretching exercises, joint mobilizations, or heat for the treatment of post-traumatic elbow stiffness [88]. Despite the lack of formal evidence, physical therapy is still the first line of treatment for elbow stiffness.

The theory behind current physical therapy regimens is based on inflammation control, early range of motion, and increasing the functional use of the extremity [89]. Early programs focus on protecting healing structures, maintaining stability, controlling pain, minimizing edema, and moving the elbow through a stable arc of motion. This typically involves passive and active-assisted exercises. After 6 weeks, therapy is focused on continued stretching and later strengthening [89–91].

### 15.5.1.2 Heat

Therapeutic heat prepares the tissue for stretching by increasing blood flow and tissue extensibility while decreasing pain and muscle spasms related to joint stiffness. When applied in combination with prolonged, low-load, steady stretch, increased plastic elongation of connective tissue can be achieved. Therapeutic heat can be applied superficially using hot packs, electric heating pads, and fluid therapy or more deeply through the use of ultrasound [39].

### 15.5.1.3 Range of motion and strengthening exercises

Exercises can be divided into passive, active (with or without assistance), and strengthening exercises. Range of motion decreases intra-articular adhesion formation, promotes articular cartilage healing, and improves blood flow to the area. In some cases, it is advisable to establish a safe arc of motion to provide a baseline in the first days after surgery [89].

Active motion increases the tensile strength of the healing tissues, stimulates arterial flow, assists in cartilaginous regeneration, increases venous and lymphatic flow,
and decreases co-contraction of antagonist muscles. Passive motion helps decrease collagen density. One should avoid extremely aggressive exercises that increase elbow swelling and pain because they may enhance stiffness development. The adequate frequency and timing of exercises is still unknown [41,89].

15.5.1.4 Bracing

To preserve the gained arc of motion, dynamic or static orthoses (braces or splints) have been designed in conjunction with the active and passive exercises [7,41,92].

The goal of dynamic bracing is to apply a constant stretching load without pain using an adjustable spring. Static braces maintain the maximum load that can be achieved with passive or active elbow motion in a comfortable position [7,41,92].

Several retrospective studies have been published regarding the treatment of elbow stiffness using static progressive splinting. On the basis of a study, static progressive splinting demonstrates an average success rate of 82% (67–100%) with 39° total arc of motion improvement after treatment for several weeks [88,93–98]. The market currently offers hinged braces with adjustable blocks to the range of motion that may be utilized similar to static splints [7].

Fewer articles have been published examining the treatment of elbow stiffness with dynamic splinting. Shewring et al. described patients who were treated between 2 and 41 months after surgery with reverse dynamic slings with average flexion contracture of 55° improved to 35° [99]. Gallucci et al. reported 30 patients with an elbow arc mobility of 100° (or less) and stable congruent joint without HOs. An articulated brace with springs was utilized 2 months after surgery for elbow stiffness and was continued for 75 days. Average follow-up was 23 months. Total arc of motion improved by 37°. Despite this, almost one-third of the patients did not recover a functional range of motion, although more than 75% were satisfied with the treatment [100].

Several studies compare static with progressive and dynamic splinting. Lindenhovius et al. performed a prospective, randomized control trial that compared static progressive splinting and dynamic splinting. There was no statistically significant difference between groups (P=0.87° at 3 months, P=0.72° at 6 months, and P=0.71° at 12 months). All studies demonstrate that motion is gained most during the early rehabilitative phase. Motion gains continue to occur, but at a slower rate 3° months after trauma [88,101].

The exact protocol for bracing is at the surgeon’s discretion and is based on the degree of contracture, splint tolerance, personal circumstances, and desired rate of deformity correction [7]. Morrey described guidelines for splint wear that can be used to guide therapy (Table 15.4) [102].

15.5.1.5 Manipulation under anesthesia

In general, patients who undergo MUA have participated in rehabilitation without adequate results. Before manipulation, it is critical to establish fracture healing. In addition, hardware should never be removed before MUA because new fractures may occur through areas weakened by screw holes.
Under anesthesia, it is possible to assess passive range of motion, soft or hard endpoints, crepitance, intra-articular tracking, and joint stability. These clues may assist in identification of the etiology of the joint contracture [7,103,104]. Complications of MUA include fracture, elbow instability, HO, and increased risk of nonunion [41]. After manipulation, it is critical to begin therapy in the first several days after MUA so as to maintain the passive range of motion achieved during the procedure. Communication with the therapist is important at this time to maintain the range of motion achieved.

**15.5.2 Surgical treatment of elbow stiffness**

If conservative management fails to improve elbow range of motion to the desired level, then surgical management should be considered. The etiology of joint stiffness may be multifactorial. Surgeon experience and skill level are also important to consider when choosing an appropriate technique [1,4,7,41,79,105].

The decision to perform surgery should occur in patients with significant limitations in elbow movement (between <30° and 130° of flexion) and painful or difficult activities of daily living [79,106]. Regardless of the chosen technique, the principles of surgical management of post-traumatic elbow stiffness are [41]

1. Restore elbow motion by removing all of the contracted structures and intra-articular deformities.
2. Preserve the anterior band of the MCL and lateral ulnar collateral ligament to maintain elbow stability.
3. Avoid damage to neurovascular structures.

The goal of surgical treatment is to achieve full range of motion in all planes: flexion, extension, pronation, and supination. In doing so, pain may also be improved. It is not typical for patients to be able to maintain this motion after surgery, but when done correctly, surgery should be able to achieve nearly full motion unless joint malunion is present [106]. When treating contracture, several structures should be addressed to

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<th>Table 15.4 Morrey typical splint program</th>
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Complex post-traumatic elbow stiffness

Most importantly, the underlying pathology must be addressed to successfully improve motion.

### 15.5.2.1 Treatment of malunion/nonunion

Fracture malunion and nonunion should be evaluated in light of how much compromise there is to the articular surface. The goal of treatment is to restore the normal shape and size of the intra-articular distal humerus and its congruency with the olecranon and radial head. Fixation should be stable and allow for early aggressive motion.

It is critical to differentiate between intra-articular and extra-articular nonunions or malunions because this will assist in determining appropriate treatment. A CT scan is the best imaging modality to differentiate between intra-articular and extra-articular malunion if simple radiographs are not clear [107].

The most common location for extra-articular malunion or nonunion is the supracondylar distal humerus. In the vast majority of the cases, the elbow will be in extension with retroversion of articular condyles. This change in the distal humeral version changes the anatomical flexion–extension axis, leading to decreased flexion [41,63,70].

Treatment of distal humerus malunion and failure of fixation is covered in detail in Chapter 12. All attempts should be made to establish an anatomic elbow relationship. In younger patients with intra-articular humerus nonunion or malunion, ORIF should be considered with iliac crest bone grafting if necessary. Rates of union after surgery for distal humerus nonunion can reach 95% [41,68].

In patients with severe malunions of the intra-articular region, it is important to re-establish articular alignment. A supracondylar osteotomy is recommended, taking into account the risk of narrowing the trochlea. Once the procedure is complete, the relationship between the coronoid and trochlea and radial head and capitellum should be evaluated for the presence of impingement [41].

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<tr>
<th>Movement to gain</th>
<th>Structures to treat</th>
</tr>
</thead>
</table>
| Flexion          | • Anterior compartment.  
• Coronoid fossa: Remove osteophytes. 
• Posterior compartment: Release soft-tissue contracture and debridement of posterior band of MCL. Triceps tenolysis. 
• Subluxation: Release and debride adhesions/stabilize incongruent humero-ulnar joint. |
| Extension        | • Anterior compartment: Anterior capsule release. 
• Posterior compartment: Debridement of olecranon fossa/drill, removal of osteophytes in olecranon tip. 
• Subluxation: Release and debride adhesions/stabilize incongruent humero-ulnar joint. |
| Pronation–supination | • Radial head resection. 
• Debridement of adhesions in radial neck. 
• Remove synostosis or scarring between radius and ulna. |

Table 15.5 Anatomic structures involved in elbow contracture
Poor reduction and fixation of the olecranon may narrow the greater sigmoid notch, resulting in decreased range of motion due to bony impingement. Malunion or non-union of the olecranon should be treated with surgical intervention if motion loss is significant. An extensive discussion on olecranon malunions and nonunions is found in Chapter 13 [41,108].

In general, olecranon malunion and nonunion goals are to restore the congruity of the sigmoid notch, re-establish the coronoid process, establish elbow stability, and begin early motion [41].

In nonunions, the addition of autologous cancellous bone graft is mandatory for improve the healing. In cases of malunion or nonunion with associated osteoporosis or degenerative osteoarthritis, total elbow arthroplasty is an appropriate treatment option for low-demand patients.

Whether elbow stiffness is related to nonunion, malunion, or post-traumatic arthritis, the capsule is almost always involved and must be released. Capsular and soft-tissue releases may be performed in an open or arthroscopic fashion. Both techniques have demonstrated good improvement in range of motion and pain control [1,4,6,8,40,84,109–129].

Open capsular release is indicated in cases with functional deficit despite rigorous rehabilitation efforts. In most cases, patients have attempted at least 6 months of formal therapy with the addition of static or dynamic bracing without improvement. On occasion, in the setting of bony osteophytes or hardware-related impingement, little improvement can be made without surgical intervention [7,106].

Several open approaches have been described, including posterior, medial column procedure, lateral column procedure, or the extensive Kocher approach. The pathology, plane of elbow contracture, location of previous elbow incisions and scars, need for nerve decompression or transposition, location of HO, goals of treatment, and the surgeon’s experience and preference all influence decisions regarding approach [41,106].

Giannicola et al. [130] analyzed the factors that affected the choice of surgical approach for elbow stiffness and concluded that the degree and site of elbow cartilage wear was most important for surgeons. He recommended that treatment focus on removing the causes of pain and recovering range of motion.

15.5.2.2 Global: posterior midline

The posterior midline incision allows joint access posteriorly, medially, and laterally. Through this approach, the surgeon may release the posterior capsule, decompress the ulnar nerve, and release the posterior band of the MCL. Anteriorly, the surgeon may elevate the common extensor origin off of the capsule and perform a capsulectomy. Detaching the triceps is not recommended at this time for elbow contracture release [7,131].

15.5.2.3 Column procedure: medial column

This procedure consists of an open arthrolysis of the elbow through a limited medial approach and has been dubbed the “column procedure” [79]. It is recommended in patients who have medial-sided contracture of the elbow, severe capsule contracture associated with posteromedial or anteromedial HO, and anterior and posteromedial osteophytes with osteoarthritis or ulnar nerve symptoms [79,132].
Surgical technique
The patient is positioned supine and prepped and draped in sterile fashion. Sterile tourniquet use is recommended. Before starting the procedure, landmarks are identified and shoulder motion is tested to ensure adequate external rotation for access to the posteromedial aspect of the elbow [79].

Using the medial humeral epicondyle as reference, the skin incision is made staying anterior to the ulnar nerve. The medial antebrachial cutaneous nerve is identified and protected as it crosses obliquely near the medial epicondyle. The medial intermuscular septum is identified and resected. An incision is made just anterior to the raphe in the flexor carpi ulnaris (FCU), allowing access to the anterior capsule. The anterior capsule is then elevated off of the medial-sided musculature (pronator teres, flexor carpi radialis (FCR), flexor digitorum superficialis (FDS), FCU) and may then be resected. The ulnar nerve is then carefully decompressed and, if necessary, transposed, and the posterior band of the MCL can be transected [41]. The anterior band of the MCL must be preserved for stability [7,79].

The advantages of this procedure include exposure to the medial, anteromedial, and posteromedial aspects of the elbow with good visualization of the ulnar nerve, preservation of the MCL, and access to the anterior part of the coronoid. In cases of heterotopic bone on the lateral side of the elbow or radiocapitellar osteophytes, a radial-sided approach should be performed (Figure 15.7) [79].

15.5.2.4 Column procedure: lateral column
The lateral column procedure is recommended for treatment of capsular elbow contracture and osteoarthritis with anterior and posterolateral osteophytes [79,106]. The lateral column procedure allows exposure of the anterior and posterior compartment; preserves the LCL, reducing the risk of postoperative instability after release; and allows exposure of the radial head. The goals of this approach are to release the anterior and posterior capsule, remove coronoid osteophytes, debride the olecranon osteophytes, and remove intra-articular loose bodies (Figure 15.8) [41,79].

Technique [79]
The patient is positioned supine or semilateral. Before prepping and draping, the elbow should be evaluated radiographically so that radiographs can be reliably performed during the procedure. The arm is steriley prepped and draped and a sterile tourniquet is placed proximal to the ipsilateral arm.

An incision is made from the lateral epicondyle proximally and continued distally over the mid- to posterior portion of the radial head. The lateral supracondylar ridge is identified and a plane is developed on either side of the ridge until the capsule is identified. Care is taken not to stray too far anteriorly, risking injury to the PIN. The anterior and posterior capsule is released from the underlying musculature. Next, the extensor carpi radialis longus and distal fibers of the brachioradialis are retracted from the underlying capsule. The capsule is then incised laterally and the anterior capsule is isolated from the brachialis muscle and excised as widely is possible. The remaining medial capsule is incised. Coronoid osteophytes and anterior loose bodies can now be removed.
Shoulder and Elbow Trauma and its Complications

Posteriorly, the capsule is released from the underlying anconeus. The capsule is identified, excised, and the olecranon osteophytes and posterior loose bodies may be removed. Depending on the complexity of the operation and the surgeon preference, surgical drains may be utilized to decrease postoperative hematoma.

Unfortunately, the lateral column procedure does not allow for improvement in patients with medial heterotopic bone or ulnar nerve pathology that requires surgical treatment. In this setting, a medial approach would be more appropriate [41,79].

Figure 15.7 Illustration depicting the medial column approach for release of the stiff elbow. (1) Medial skin incision. (2) Retracted subcutaneous tissue and release it surrounding medial epicondyle. (3) Pronator teres and brachialis muscle is reflected anteriorly from medial epicondyle to expose joint capsule. (4) Incised anterior capsule and expose the joint. (5) Transposed ulnar nerve. (6) Release posterior medial collateral ligament. Nandi S, Maschke S, Evans PJ, Lawton JN. The stiff elbow. HAND 2009;4(4):368–79 with permission of Springer Science + Business Media.
Figure 15.8 Illustration depicting the lateral column surgical approach for release of the stiff elbow. (1) skin incision. (2) Define anterior and posterior intervals with lateral epicondyle and septum as a reference. (3) Anterior and posterior intervals carried down to joint capsule. (4) Capsular incision anterior to radial collateral ligament. (5) Posterior capsular release. Nandi S, Maschke S, Evans PJ, Lawton JN. The stiff elbow. HAND 2009;4(4):368–79 with permission of Springer Science + Business Media.
15.5.2.5 Interposition arthroplasty

Interposition arthroplasty is a salvage procedure that changes the morphology of the joint by placing tissue (autologous or allograft soft tissue such as muscle, tendon, skin) inside of the joint to provide a pivot surface upon which to pivot [133].

Younger patients who have suffered irreparable articular cartilage damage have few treatment options beyond arthrodesis or interposition arthroplasty [41,133,134].

Interposition arthroplasty is typically considered in patients younger than 40 years of age who have loss of motion or incapacitating pain and rheumatoid arthritis. This option can also be considered for patients younger than 60 years of age with traumatic arthritis and near-normal bony anatomy [135].

Proper candidate selection for interposition arthroplasty largely depends on specific pathology as well as patient needs and expectations [133]. Worse outcomes occur in patients with instability, deformity, or severe pain at rest. The presence of normal bone anatomy is an absolute prerequisite for successful interposition arthroplasty [6,133,136–142].

Interposition arthroplasty should not be considered in a patient with infection, elbow instability, absence of flexion power, use of the extremity for ambulation, or patients who use the elbow for heavy manual labor [6,111,143].

15.5.2.6 Elbow arthroplasty

Total elbow replacement is considered a salvage procedure for very stiff or ankylosed elbows with articular involvement. It is reserved for older, less active patients in which no other treatment options are available [1]. Despite this, total elbow arthroplasty has been shown to demonstrate substantial functional improvement and pain relief in these patients [144–148]. Unfortunately, postoperative limitations of lifting no more than 5 lb may limit the use of this prosthesis in older individuals.

Linked designs are commonly recommended in elbows with deficient bone stock, deformity, and capsuloligamentous instability with post-traumatic contracture [81,144–146,149].

Peden and Morrey reported on 13 patients with spontaneously ankylosed elbows who underwent total elbow arthroplasty with use of the Coonrad-Morrey total elbow prosthesis [7,150,151]. Elbow stiffness was secondary to trauma in 10 of 13 patients. The position of ankylosis ranged from 35° to 95° of flexion. After surgery, a mean arc from 37° of extension to 118° of flexion was achieved and seven patients were able to complete all activities of daily living [150].

Figgie et al. reported 78% excellent or good results after total elbow arthroplasty performed by a Bryan-Morrey posteromedial approach after complete ankylosis in 19 elbows (16 patients). Postoperatively, the average flexion was 115°, extension was 35°, and pronation and supination were 95°. The duration of ankylosis before total elbow arthroplasty appeared not to be related to postoperative motion [7,144].

In most cases of post-traumatic elbow stiffness, aggressive soft-tissue releases and an ulnar nerve release are mandatory [81,115,122,146].

Elbow arthroplasty is a good option of treatment in elbow stiffness, but complications such as infection, ulnar nerve dysfunction, mechanical failure, loosening, infection, triceps disruption, and fractures can occur [1,115,144–146,148,152–156].
15.5.2.7 Distraction arthrolysis

New options have emerged using a hinged external fixator and articular distraction. Despite being technically demanding, mechanical distraction increases the joint space without an incision, decreasing the scarring and secondary trauma that worsen stiffness. Furthermore, it provides the advantages of joint stability and continuous elbow motion [157].

Wand et al. reported on 25 patients with post-traumatic stiff elbows who received distraction arthrolysis for periarticular soft-tissue contracture, HO, or joint malunion. Because of the heterogenous group, it is difficult to determine the effectiveness of distraction arthrolysis, but range of motion markedly increased, from 33.4° (range, 0°–75°) preoperatively to 105.6° (range, 80°–140°) postoperatively. No serious complications occurred [157].

In younger patients with painful elbow post-traumatic arthrosis, distraction interposition arthroplasty is a good treatment option [134].

Erşen et al. evaluated the long-term radiological and functional results in five patients with stiff elbow and arthrosis treated with distraction interposition arthroplasty using an Achilles tendon allograft. After treatment, the arc of flexion–extension increased by 56° and Disabilities of Arm, Shoulder, and Hand score improved from 75.3 preoperatively to 18.9 postoperatively [158].

15.5.2.8 Arthroscopic management

Arthroscopic management of the stiff elbow is becoming increasingly popular because of its advantages and promising outcomes. After trauma, surgery, or systemic disease, it is common to develop elbow stiffness with capsular contracture, intra- and periarticular adhesions, and arthrofibrosis [159]. Utilizing arthroscopy, it is possible to improve range of motion globally utilizing a minimally invasive approach. In this chapter, we specifically discuss post-traumatic elbow stiffness and its treatment using elbow arthroscopy. Elbow arthroscopy for post-traumatic stiffness is a complex procedure with significant neurologic and arterial risks and should only be attempted by those with considerable experience in elbow arthroscopy for other, less challenging diagnoses.

It is critical to realize that the joint is less distensible and the elbow more prone to neurovascular injury (capsular volume is reduced from 25 to 6 mL) [160]. In addition, the capsule is thicker and more difficult to enter, and neurovascular structures around the elbow have usually changed their position and are not safely displaced [159].

The brachialis muscle is the anterior limit because neurovascular structures such as the brachial artery and median and radial nerves lie anterior to it. The radial nerve courses between the brachioradialis and brachialis muscles on the lateral aspect of the elbow, dividing at the level of the elbow into the superficial radial nerve and the PIN, which cross distally and laterally to the brachialis muscle just anterior to the capsule. The space between the ulnar nerve and joint capsule is minimal, placing the nerve at risk of injury during medial arthroscopic capsular release. The ulnar nerve should always be identified and protected, retracting it either arthroscopically or with a Penrose drain through a small, open incision over the nerve [159].
Surgical technique
Supine, lateral, and prone positions have all been described for elbow arthroscopy. The lateral position is preferred because it allows for more range of motion and better access to the anterior and posterior capsular structures. Furthermore, the lateral position can be easily converted to an open procedure [77,159].

Instrumentation
A 4.5- or 2.9-mm 30° arthroscope with arthroscopic shaver and burrs are utilized, along with standard camera and video-recording equipment. Elbow cannulas should not have outflow holes because the space between the tip of the cannula and joint capsule is so small. A Penrose drain may be used to surround and protect the ulnar nerve before attempting arthroscopy, especially in the setting of prior ulnar nerve transposition. Angled retractors and an 18-gauge spinal needle are also needed.

Surgical technique
The elbow is insufflated with 30 cc of normal saline through the soft spot. Utilizing a blunt trocar, a proximal anteromedial portal is then established and the camera is introduced through this portal. The anterior compartment of the elbow is evaluated. A proximal anterolateral portal is established utilizing an outside-in technique. The spinal needle is introduced into the joint in a safe zone just anterior to the radial head and capitellum. The camera is then placed through the lateral portal to complete the evaluation of the anterior compartment. Next, distal anterolateral and anteromedial portals may be established so that the surgeon can retract or protect anterior structures.

At this time, the capsule can be excised. With the shaver in the lateral portal, the capsule is excised from proximal to distal and from lateral to medial. It is critical to avoid passing through the brachialis muscle. After this, the scope direction is reversed and capsular excision is completed from the medial side.

Resection of bony osteophytes can now be performed as well as removal of any loose bodies if not already completed. The radial fossa is debrided using a burr or motorized shaver from the proximal anterolateral portal and resection of the coronoid osteophyte is completed at this time.

If the radial head requires resection, first excise the anterior aspect avoiding injury to the PIN by avoiding capsular penetration. After the anterior resection, a protective retractor can be introduced through the anterolateral portal and placed between the radial head and the anterior capsule. A burr may then be introduced through the soft spot portal to complete the radial head resection.

At this time, all anterior work has been completed and the arthroscope is introduced through a posterior central portal and the shaver through a proximal posterolateral portal. This positioning allows for debridement of the olecranon fossa and elevation of the triceps from the posterior distal humerus.

During the posterior evaluation, one can debride all loose bodies, joint adhesions, and osteophytes while protecting the ulnar nerve with retractors or a Penrose drain.
Complex post-traumatic elbow stiffness

The lateral and medial gutter can also be evaluated for adhesions and bony osteophytes. Most importantly, the olecranon fossa is cleared of any offending osteophytes and the range of motion is assessed. In general, a well-performed arthroscopy will allow for excellent range of motion in the stiff elbow unless malunion or hardware-related impingement has occurred (Table 15.6).

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Scope from portal</th>
<th>Working portal</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Proximal anteromedial</td>
<td>Proximal anteromedial</td>
<td>1. Establish a proximal anterolateral portal</td>
</tr>
<tr>
<td></td>
<td>Proximal anterolateral</td>
<td></td>
<td>2. Excise the capsule, from medial to lateral</td>
</tr>
<tr>
<td></td>
<td>Proximal anteromedial</td>
<td></td>
<td>3. Complete capsular excision in the anterolateral side of the joint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4. Debride the radial fossa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Resection of anterior part of radial head</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6. Resection of coronoid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7. Resection of posterior radial head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soft spot</td>
<td>8. Debride olecranon fossa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9. Detach capsule from humerus</td>
</tr>
<tr>
<td>Posterior</td>
<td>Posterior–central</td>
<td>Proximal posterolateral</td>
<td>10. Debride loose bodies, joint adhesions, osteophytes</td>
</tr>
<tr>
<td>Medial gutter</td>
<td>Proximal posterolateral</td>
<td>Posterior–central</td>
<td>11. Debride adhesions, lateral capsule, plica, synovitis</td>
</tr>
<tr>
<td>Lateral gutter</td>
<td>Posterior–central</td>
<td>Proximal posterolateral</td>
<td></td>
</tr>
</tbody>
</table>

The lateral and medial gutter can also be evaluated for adhesions and bony osteophytes. Most importantly, the olecranon fossa is cleared of any offending osteophytes and the range of motion is assessed. In general, a well-performed arthroscopy will allow for excellent range of motion in the stiff elbow unless malunion or hardware-related impingement has occurred (Table 15.6).

**15.6 Complications**

**15.6.1 Neurologic injury**

When appropriate precautions are taken, open and arthroscopic management of the stiff elbow is considered safe procedure, although catastrophic neurologic complications have been reported. In all series, nerve damage is the primary complication after elbow arthroscopy [121,161–172].

Nelson et al. evaluated 417 consecutively elbow arthroscopies performed during a 13-year period. The rates of superficial and deep infection were 6.7% in minor procedures and 2.2% in major procedures. Major complications included nine deep infections, six cases of HO, and seven cases of transient sensory nerve irritation without
motor deficit. No difference in complication rates were seen among low-, moderate-, and high-complexity procedures, but patients without intraoperative steroid injections had less superficial and deep infection (2.0% vs 14.1% and 0.4% vs 4.9% respectively). The reoperation rate was 5% and was frequently associated with deep infection and a history of prior surgery [173].

15.6.2 Stiffness

Recurrent stiffness is debilitating after open or arthroscopic contracture release. In the setting of complex elbow stiffness, the contractures are typically long-standing, making attempts at adequate range of motion difficult. Therefore, prevention of elbow stiffness is one of the most important objectives after elbow surgery and includes a multidisciplinary effort among the surgeon, therapist, family, and patient. The keys to prevention include anatomic reconstruction of the joint, appropriate medical management, and physical therapy.

When the surgeon deems it appropriate, the rehabilitation program should begin immediately to prevent contracture formation [7,87,174].

15.6.2.1 Continuous passive motion

One way to decrease stiffness after surgery is through the use of CPM. After operative treatment or trauma, CPM is used to reduce intra-articular bleeding and periarticular edema by pumping fluid away from the affected joint. According to some authors, CPM should be applied from the initial time of surgery until swelling no longer develops. In this way, CPM diminishes the likelihood of interstitial swelling; thus, it improves mobility [7,175].

O’Driscoll and Giori described four stages of post-traumatic and surgical stiffness in the elbow [175]. In the first stage, bleeding occurs, setting off an inflammatory response around the tissue. The second stage occurs during days 1–5 and consists of edema in the periarticular tissues. Granulation occurs after the fifth day and leads to new healing tissue. Finally, fibrosis occurs after 1 month of trauma. The first two stages bring on swelling of soft tissues and decrease the compliance of the elbow; it is in this time period when CPM is most useful [175–177].

Despite its theoretical advantages, the use of CPM has not demonstrated significant advantages in most studies. Despite this, CPM use is becoming more common to maintain motion, reduce bleeding, and interrupt the inflammatory cascade [87]. Some authors do not recommend the use of CPM because of the increased cost without obvious clinical benefits. Lindenhovious et al. retrospectively evaluated the use CPM after open contracture release. In this study, 32 patients who had an arc of flexion and extension of less than 80° underwent surgery. Sixteen patients were given CPM and therapy and 16 patients had therapy alone, and there was no differences noted between the groups [178]. However, Gates et al. demonstrated in a prospective study using CPM after anterior capsulotomy for elbow flexion contracture that CPM increased the arc of motion in flexion but not in extension [179].
15.6.2.2 Static progressive splinting

Static progressive splinting can improve range of motion in flexion, extension, or both. The static progressive elbow flexion splint can be used when bone stability has been achieved. It is used to maintain the elbow in the maximal flexion possible with low load and prolonged stretch. In patients with less than 100° of flexion, a splint with a fixed hinge should be used to absorb the compression force placed on the joint by not having an optimal direction of pull. This transfers only the rotational component of the force. The static progressive extension splint has some hardware in the anterior or lateral part of the splint for increasing the extension stretch applied [89]. Gelinas et al., using a static progressive turnbuckle splint for a mean of 4.5 months on 22 patients who failed to respond to conventional physiotherapy, showed that 95% of patients improved their range of motion and 55% of patients gained a “functional arc of movement” [95].

Using a custom-made progressive stretching (CMPS) static elbow splint postoperatively in 14 patients after instability surgery, Liu et al. demonstrated a final flexion–extension arc of 116° without cases of postoperative instability or nonunion. The disadvantages of his CMPS include cost of the device and repeated appointments for molding the splints [180].

15.6.2.3 Passive stretching exercises

During passive stretching exercises, patients are positioned supine or sitting with the arm on the table supported on pillows to decrease compensatory motion at the shoulder and wrist and to effectively isolate muscle groups during motion. These exercises are most effective if low-load stresses are applied within tissue tolerance and do not illicit pain and the inflammatory process. The passive stresses are modified or adjusted as motion is gained [89].

Aksoy et al. reported positive outcomes after ORIF for intra-articular fractures of the distal humerus, utilizing a physiotherapy program that involved passive stretching exercises during brachial plexus catheter block and active weight exercises after recovery from motor block. They concluded that a pain-free physiotherapy program performed under axillary brachial plexus block increases patient compliance and enables early return to daily activities [181].

15.6.3 Heterotopic ossification

The development of HO is unpredictable and can result in devastating reductions in postoperative motion if clinically significant. Indomethacin and other nonsteroidal anti-inflammatory drugs have been used to prevent formation of HO, but it is unclear what mechanism of action slows the formation of HO [1,87]. A more thorough discussion of HO can be found in Chapter 13.

In addition, radiation can be utilized to prevent the formation of HO. Robinson et al. reported on 36 patients after contracture release and HO treated with single-fraction radiation the day after surgery. All patients demonstrated an improvement in range
of motion and none required further surgery. The authors concluded that single-fraction radiation can result in favorable functional and radiographic results in the elbow [87,182].

Viola and Hanel reported on 15 elbows managed with early excision of post-traumatic HO, immediate postoperative mobilization, and a 5-day course of indomethacin for post-traumatic elbow contractures with HO. These authors were able to achieve a mean flexion/extension arc of 120° and a mean pronation/supination arc of 152° at an average follow-up of 115°weeks. Here, indomethacin and CPM were used postoperatively in most cases. There were no recurrent contractures or loss of motion [183].

Strauss et al. also retrospectively evaluated the outcome of prophylactic single-fraction radiation and the use of a 10-day indomethacin course in 44 patients after high-risk elbow surgery. They found that 48% of patients developed HO after treatment, but it was not functionally significant. None of the patients required another operation. The authors concluded that combination radiation and indomethacin therapy was useful and safe in preventing clinically significant HO [184].

Hamid et al. conducted the only Level I study acutely evaluating the use of single-fraction radiation therapy after fixation of elbow fractures against a control group. They discovered a high rate of nonunion in the treatment group (8 of 21 patients) and terminated the study early. Despite that, these results demonstrate the efficacy of radiation therapy in HO prophylaxis when fracture healing is not a concern [87,185].

Rosenwasser et al. demonstrated that an intraoperative injection of botulinum toxin A into the elbow flexors in patients who had ORIF after elbow fracture or fracture-dislocation resulted in improved postoperative range of motion and function [87]. Botulinum toxin A may combat the mechanism of co-contraction that is involved in elbow stiffness [186–188].

### 15.7 Conclusions/future trends

Elbow stiffness is frequent after traumatic elbow injuries, often resulting in significant disability including lost work, pain, and loss of the ability to perform daily activities. Patients should be made aware of the potential complications and difficulties encountered during recovery and counseled regarding realistic expectations. The most important factor involved in treating elbow stiffness is to understand the underlying cause of post-traumatic elbow stiffness. This may include heterotopic bone, capsular stiffness, synostosis, arthritis, or bony osteophytes. A thorough history, examination, and appropriate radiographs are necessary in developing a treatment plan for improving elbow range of motion. Although multiple surgical options exist, they are technically challenging and have varied outcomes. In general, range of motion is significantly improved with nonsurgical and surgical approaches. However, continued research efforts are necessary to improve patient outcomes and satisfaction. Knowledge of preoperative risk factors may assist in discussing the prognosis of recurrent stiffness.
The prevention of elbow stiffness is an area of orthopedics that is still poorly understood from a biologic and therapeutic standpoint. More basic science research is needed to assist in the prevention of elbow stiffness while still allowing for adequate bone healing. Potential exists to use the blockage of certain enzymatic pathways involved in inflammation, including TNF-α, IL-3, and TGF-β, to improve outcomes after upper extremity trauma, including intra-articular elbow fractures. Further research in this area is necessary to improve patient outcomes.

References


Complex post-traumatic elbow stiffness


Complex post-traumatic elbow stiffness


