Tension Band Wiring in Upper Extremity Surgery

Abstract

Tension band wiring is a simple, inexpensive, and effective technique to treat many upper extremity fractures. When tension forces result in a mechanical failure of bone, tension band wiring provides stability and promotes early mobilization by converting tensile forces across a fracture into compressive forces. The tension band principle has distinct advantages of reducing periosteal stripping, technical ease, and cost effectiveness when compared with other operative strategies. This technique can be implemented in a variety of fractures and avulsions about the upper extremity as well as small bone arthrodeses.

First described by Pauwels1 in 1935 for the treatment of femoral neck fractures, tension band wiring has been expanded to treat many fractures caused by tension or bending forces. Constructs usually consist of one to two steel wires twisted in a figure of eight pattern around the tension side of a fracture, which may be supplemented by Kirschner wires or screws placed across the fracture site.

Although a variety of alternative fixation strategies exist, tension band wiring retains some distinct advantages such as minimal periosteal stripping, mechanical stability, fracture site compression, early mobilization, relative technical ease, and cost effectiveness.2 This article will discuss the applications of tension band wiring in upper extremity surgery related to biomechanics, technique, rehabilitation, and outcomes.

Biomechanics of Tension Band Wiring

Pauwels1 originally observed that when a long bone is subjected to eccentric loading, it experiences both tensile and a compressive force on opposite cortices. When stress is increasingly applied to a long bone, a fracture will form first on the tension side and propagate to the opposite cortex where it fails from compressive forces. The tension band concept asserts that if a stabilizing construct is placed along the tension side of a deformity, then it will neutralize distractive forces. When the bone is eccentrically loaded, it will convert the stress to a compression force. Thus, “tension is converted to compression” on the opposite cortex (Figure 1).

Mechanical stability is required for bony union. To achieve stability with this technique, the construct must be placed along the tension side of the bone, which is the convex side of the deformity. It is also critical to recognize that the opposite cortex must be in contact and able to absorb the compressive forces. If the opposite cortex is comminuted, an axial load placed on a long bone will create a bending force on the construct rather than a pure tensile force, which will increase the risk of mechanical...
failure. Most steels have an endurance limit, roughly half of their tensile strength. The endurance limit is the maximum value of a reversed bending stress that a material can withstand without any failure for an infinite number of cycles. Thus, because metals are less able to resist bending forces, wires and plates are more likely to experience fatigue failure if the opposite cortex is not intact.

A static tension band compresses the fracture at the time of application. The forces across the fracture are relatively constant throughout the range of motion. Examples in the upper extremity include condylar avulsion fractures of the humerus or collateral ligament avulsion fractures at the base of the proximal phalanx. A dynamic tension band will produce an increased compressive force with physiologic loading. Examples include fractures displaced by musculotendinous insertions, such as an olecranon fracture or a central slip avulsion.

**Basic Technique**

Any fixation device can be used as a tension band if applied to the tension side of a fractured bone. Plates or external fixators applied to the convex side of a long bone deformity act like tension bands. Although not always necessary, avulsion fractures can be supplemented with Kirschner wires or screws to fix the fracture in the reduced position before applying the tension band. Applying a tension band requires a wire or suture to be passed through a bone tunnel in the shaft of the intact bone. The wire is then crossed in a figure of eight fashion and passed through Sharpey’s fibers of the avulsed fragment and tightened. This construct produces a single twist of the wires and may be considered for smaller gauge wire or where hardware bulk may be prominent under the skin. If two twists are preferred (which may provide more uniform compression on both sides of the fracture), a small loop is created before passing the remainder of the wire, and this, along with the free ends, is twisted (Figure 2). Alternatively, two separate pieces of wire can be passed, one is crossed and then the ends twisted together.

When twisting the wires, the surgeon should be mindful of few technical points: the ends are usually twisted two or three times while pulling upward tension to achieve sufficient compression. If the surgeon does not pull while twisting, then one wire limb will be straight while the other spirals around it; each wire should spiral equally around the other to prevent slippage. At least two twists are required for adequate strength of the construct, but overtightening the wires will result in weakening or breakage. The surgeon should look for loss of metallic sheen or cracks on the surface of the metal, which would indicate overtightening and the need to replace the wire.

Generally, early motion of the joint can begin when the incised skin can tolerate it. In dynamic tension bands, active motion exercises not only prevent stiffness but also provide compressive forces across the fracture. By contrast, passive motion does not compress the fracture and is generally delayed until clinical union is achieved.

**Applications in Upper Extremity Surgery**

**Greater Tuberosity Fractures**

Isolated greater tuberosity fractures are rare injuries because the greater tuberosity is frequently injured in association with three or four part proximal humerus fractures. The greater tuberosity is avulsed from the humerus by the pull of the supraspinatus and infraspinatus tendons. Placement of a tension band laterally neutralizes the deforming force imparted by the rotator cuff. The tension band can be placed in isolation or as supplemental fixation with plate and screw constructs for more complex fractures.

The surgical approach depends on the fracture pattern, but isolated greater tuberosity fractures are best visualized by using a direct lateral deltoid-splitting approach. A suture is placed through the avulsed bone and then can be looped through a bone tunnel. In complex fractures, the suture may be passed through the Kirschner wire holes or screw holes of a locking plate.
Pendulum exercises can be performed for the first 6 weeks postoperatively. Active-assisted range of motion can then begin followed by strengthening exercises at 3 months postoperatively. Excellent functional outcomes have been reported with this technique for both isolated greater tuberosity fractures and complex fractures using the tension band as augmentation to plate fixation.5

**Lateral Acromion Fractures**

Lateral acromion fractures and Os acromiale are typically treated non-operatively, but fixation may be required in the setting of multiple scapula and shoulder suspensory complex injuries or an unstable Os acromiale.6 The acromion can be approached through the proximal portion of the deltopectoral interval or directly above the acromion. Two K-wires or cannulated screws can be inserted anterior to posterior across the fracture site (or unstable Os acromiale). The tension wire can be passed around the K-wires or through the cannulated screws and twisted into a figure of eight.

The superficial location of the acromion may result in symptomatic hardware.6-8 Placing sutures instead of wires may minimize soft-tissue irritation and has been shown to have similar biomechanical strength.6

**Distal Humerus Fractures**

Historically, tension band wires were an accepted form of fixation for transverse or Y type distal humeral fractures,9 but current technology with locked plates has replaced tension banding as an independent technique. However, tension bands may still be applied to the humerus for epicondylar avulsion fractures or to augment plate fixation. Avulsion fractures of the lateral or medial epicondyles occur through supraphysiologic varus or valgus forces, respectively. Medial avulsion fractures can be associated with an elbow dislocation or chronic valgus loading, such as with throwing athletes.

Medial epicondyle fractures are approached through a medial-based incision. We recommend routine identification and decompression of the ulnar nerve to avoid inadvertent injury. The fragment is left attached to the ulnar collateral ligament but can be rotated to débride the fracture site. The tension band wire is passed through the origin of the ulnar collateral ligament distally and secured proximally through a bone tunnel in the humeral shaft.10 Lateral epicondylar fractures can be treated in a similar fashion for isolated fractures, as an adjunct for complex fractures, or for lateral epicondylar osteotomies for complex trochlear fractures.11,12

Outcomes measuring motion and union with tension band wiring are similar to plating.2,11 Tension band wiring for medial epicondylar fractures consistently yields stability and return to sport in throwing athletes.10

**Olecranon Fractures**

Olecranon fractures typically result from a direct blow to the olecranon. More complex fracture-dislocation patterns may be the result of indirect forces such as a fall onto the outstretched hand. In the indirect injuries, a forceful contraction of the triceps against resistance causes the fracture. Simple transverse or short oblique fractures at or slightly proximal to the midpoint of the olecranon process are most amenable for tension band fixation (Figure 3, A and B). However, if fragmentation of the anterior cortex is present, the surgeon should choose an alternative technique.

Through a posterior approach, the fracture is identified, débrided, and reduced with a large tenaculum. A 2-mm drill hole in the dorsal surface of the ulna can be a useful foothold...
for placement of the distal tine of the clamp. The K-wire trajectory enters the proximal olecranon and either can exit the anterior ulnar cortex distal to the coronoid process or can be in line with the medullary canal. The K-wires, which should be placed as parallel as possible, are then retracted 5 to 10 mm to allow room for passage of the tension band wire. A 50-cm 18-gauge stainless steel wire is ideal for the olecranon. Wire passage through the triceps insertion near the K-wires can be guided by using a large angiocatheter (Supplemental Digital Content 1–5: Supplemental Figure 1a, http://links.lww.com/JAAOS/A534; Supplemental Figure 1b, http://links.lww.com/JAAOS/A535; Supplemental Figure 1c, http://links.lww.com/JAAOS/A536; Supplemental Figure 1d, http://links.lww.com/JAAOS/A537; and Supplemental Figure 1e, http://links.lww.com/JAAOS/A538). A variation on this technique is to pass two smaller caliber tension bands (24 or 22 gauge). Theoretically, two small wires may reduce the hardware prominence while maintaining adequate strength, but clinical trials have not proved this to be superior in outcomes (Supplemental Digital Content 6, Supplemental Figure 2, http://links.lww.com/JAAOS/A539).13

Another method to secure the olecranon is to place a large intramedullary cancellous screw. The screw is sized to fit within the canal but must be large enough such that the threads engage the inner cortex. Advantages of this technique include ease of placement, safety in avoiding placing hardware near the anterior interosseous nerve, and comparable biomechanical strength14 (see Video, Supplemental Digital Content 7, http://links.lww.com/JAAOS/A540).

Tarallo et al15 compared tension band wiring with plating of simple olecranon fractures and found that both techniques result in satisfactory functional improvement and rates of union, but the tension band group had an increased risk of symptomatic hardware prominence. However, a recent study by Amini et al16 showed that cost containment favors the tension band construct. Tension band materials had cost $208, whereas the plate construct had cost $6,689.

**Distal Radius Fractures**

In the wrist, avulsion type fractures include radiocarpal fracture dislocations or transstyloid perilunate dislocations. Dumontier et al17 noted that these high-energy injuries may present with sizable fractures of the radial styloid and/or the volar rim (Figure 4, A and B), which if stabilized can impart stability to the joint through their ligamentous attachments. An internal fixation strategy that incorporates tension band principles can be applied to a subset of these injuries. In greater arc perilunate fractures, the radial column is stabilized on the tension side of the fracture before the fixation of the carpal bones. In radiocarpal fracture dislocations, the radial and central columns of the radius can be secured using tension band principles if the bony fragments are large enough to retain the integrity of radioscaphocapitate and short and long radiolunate ligaments, respectively.17,19

The radial styloid fragment may be approached through the first dorsal compartment. Wiring the radial styloid is now considered a historical technique due to soft-tissue irritation and radial sensory neuritis, but applying a low-profile plate along a radial column acts as a tension band (Supplemental Figure 3, Supplemental Digital Content 8, http://links.lww.com/JAAOS/A541).

An avulsed volar lunate facet is often found rotated on its ligamentous attachments between 90° and 180° from its anatomic position. The operative interval is between the ulnar neurovascular bundle and the flexor tendons. The ulnar and distal pronator quadratus is elevated, and the volar cortical rim is provisionally reduced. A tension band wire, a thick suture, or a low-profile plate can be used as a tension band. When placing a wire, a free needle can be used to pass through the ligamentous insertion and a bone tunnel is created in the volar cortex of the radius with two 2.5-mm drill holes (Supplemental Figure 3, Supplemental...
Digital Content 8, http://links.lww.com/JAAOS/A541. An alternative method is to place a supplemental screw in the radial metaphysis as a “post.” The figure-of-eight wire is then wrapped around this screw (Figure 5, A and B).

After the avulsed fragments have been stabilized, the wrist is assessed radiographically to decide the need for further fixation. In cases where large fragments have been adequately stabilized and the radiocarpal joint is congruent and concentric in orthogonal views, the wrist may be simply immobilized for 8 to 12 weeks. If the fragments are small and/or comminuted, or if there is any concern with radiocarpal joint stability or with concentric reduction, additional stability should be conferred with an external fixator or spanning plate.

Ulnar Styloid Fractures

Ulnar styloid fractures are most commonly associated with distal radius fractures and are often treated nonoperatively. However, larger displaced fractures through the styloid base may contribute to distal radioulnar joint instability and thus would be indicated for fixation. The ulnar styloid can be approached directly through an incision just volar to the extensor carpi ulnaris tendon. One or two oblique Kirschner wires can be placed through the styloid and into the intramedullary canal of the ulna to secure the fragment. A 24-gauge steel wire is placed around the tip of the Kirschner wire and through the ulnar neck in a figure-of-eight fashion. Alternatively, a low-profile wire-form plate can also provide similar fixation. In either case, symptomatic hardware is the most common complication that requires revision surgery.

Proximal Phalangeal Fractures

Avulsion fractures of the base of the proximal phalanx are the result of excessive varus or valgus stresses against the collateral ligaments of the metacarpal-phalangeal joint. Commonly, these partial articular fractures are diagnosed in the thumb but may also be found in the other fingers. The thumb ulnar collateral ligament is approached through an ulnar-based incision, and the adductor aponeurosis must first be divided. In the phalanges, the fracture is approached dorsally through splitting the extensor tendon or releasing the sagittal band. A 26-g wire is often the appropriate size to capture the fragment (Figure 6). Although not always necessary, the construct can be augmented with a Kirschner wire or a screw through the avulsed fragment.

Due to the stresses produced during pinching, the thumb metacarpophalangeal joint is usually protected with a cast or splint for 4 to 6 weeks. However, for phalangeal avulsion fractures, early motion protocol is preferred because the shear forces are minor in the fingers and stiffness is less well tolerated.

In Bischoff’s study of bony avulsions that included bony gamekeeper’s thumbs and proximal phalanx fractures, 38 patients had an average follow-up of 24 months (5 to 73 months). Thirty-one patients had excellent results, whereas one patient had an asymptomatic nonunion. All patients returned to normal activities of daily living, and no patient required repeat surgery or removal of hardware.

Central Slip Avulsions

A volarly directed force against the middle phalanx during forced extension may result in an avulsion fracture of the dorsal base of the middle
A and B, Radiographs showing a displaced bony ulnar collateral ligament avulsion before and after fixation.

Radiograph showing arthrodesis of digital proximal interphalangeal joints for a severe hand contracture.

phalanx with a disruption of the central slip insertion. Large or displaced fractures require surgery to prevent boutonniere deformity and can be treated by tension band wiring. The fracture is approached dorsally and provisionally reduced with a 0.035 Kirschner wire. The surgeon
Small Joint Fusion

Tension band wiring for arthrodesis is most commonly used in the thumb metacarpophalangeal joint and the finger PIP joints. Through a dorsal longitudinal incision, the extensor mechanism and capsule are split. The arthritic joint surfaces are resected with an oscillating saw. Usually, the distal segment (middle phalanx of the finger or proximal phalanx of the thumb) is cut perpendicular to the long axis of the bone, and the proximal segment (proximal phalanx of the finger and metacarpal of the thumb) is cut to the desired fusion angle. Alternatively, the surgeon may shape the fusion surface using convex and concave reamers or a burr (the cup and cone technique), which may reduce the risk of malrotation.26

The thumb metacarpophalangeal joint is commonly fused between 10° and 20° of flexion. The PIP joints are fused at 30° to 40° flexion for the index, 35° to 45° flexion for the long, 40° to 50° flexion for the ring, and 45° to 55° flexion for the small finger (Figure 7). Two parallel K-wires are drilled through the proximal segment perpendicular and central to the osteotomy site, whereas the alignment is held reduced and compressed. The tension wire is then placed through a bone tunnel distally, around the K-wires proximally, and then tightened. The K-wires are then bent and tapped into their final depth. Care must be taken to avoid prominence of the wires into the distal joint or the soft tissues of the finger. A retrospective cohort study by Breyer et al27 reported that small joint arthrodesis by tension band wire had a higher rate of union (93% versus 86%) than compression screw but also had a higher rate of secondary surgery for hardware removal (32% versus 4%). Tension band wiring was also the technique of salvage for failed compression screw arthrodesis.

Summary

Proper selection of the fracture type and meticulous attention to the technical steps are critical to the success of the operation. Tension band wiring is a valuable technique that provides a stable and cost-effective solution for avulsion fractures and small joint fusions.

References

References printed in bold type are those published within the past 5 years.


