

### 3.2.3 Tension band principle

#### 1 Biomechanical principles

Early concepts of load transfer within bone were developed and described by Frederic Pauwels [1]. He observed that a curved, tubular structure under axial load always has a compression side as well as a tension side (Fig | Animation 3.2.3-1).

From these observations the principle of tension band fixation evolved.

- A tension band converts tensile force into compression force at the opposite cortex. This is achieved by applying a device eccentrically, on the convex side of a curved bone.

The concept can most easily be understood by examining the femur under mechanical load (Fig 3.2.3-2).

If a fracture is to unite, it requires mechanical stability, which is obtained by compression of the fracture fragments. Conversely, distraction or tension interferes with fracture healing. Therefore, tension forces on a bone must be neutralized or, more ideally, converted into compression forces to promote fracture healing. This is especially important in articular fractures, where stability is essential for early motion and a good functional outcome. In fractures where muscle pull tends to distract the fragments, such as fractures of the patella or the olecranon, the application of a tension band will neutralize these forces and even convert them into compression when the joint is flexed (Fig 3.2.3-3a–b). Similarly, a bone fragment can be avulsed at the insertion of a tendon or ligament. Examples include the greater tuberosity of the humerus (Fig 3.2.3-3c), the greater trochanter of the femur, or the medial malleolus (Fig 3.2.3-3d). Here, too, a tension band can reattach the avulsed fragment, convert tensile force into compression force allowing immediate motion of the joint.

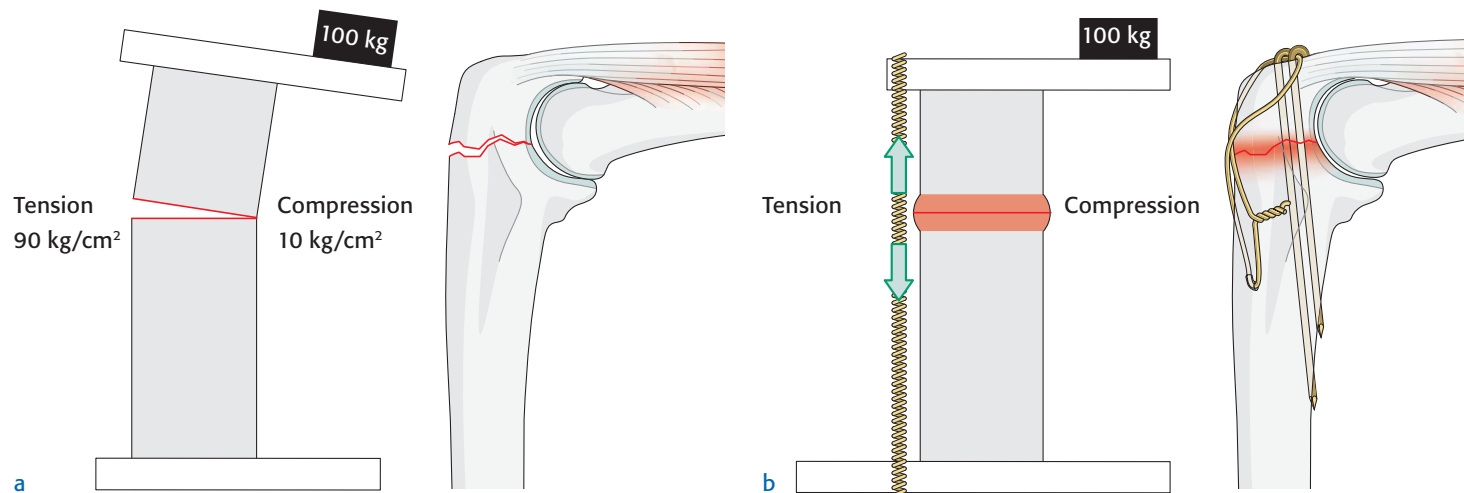
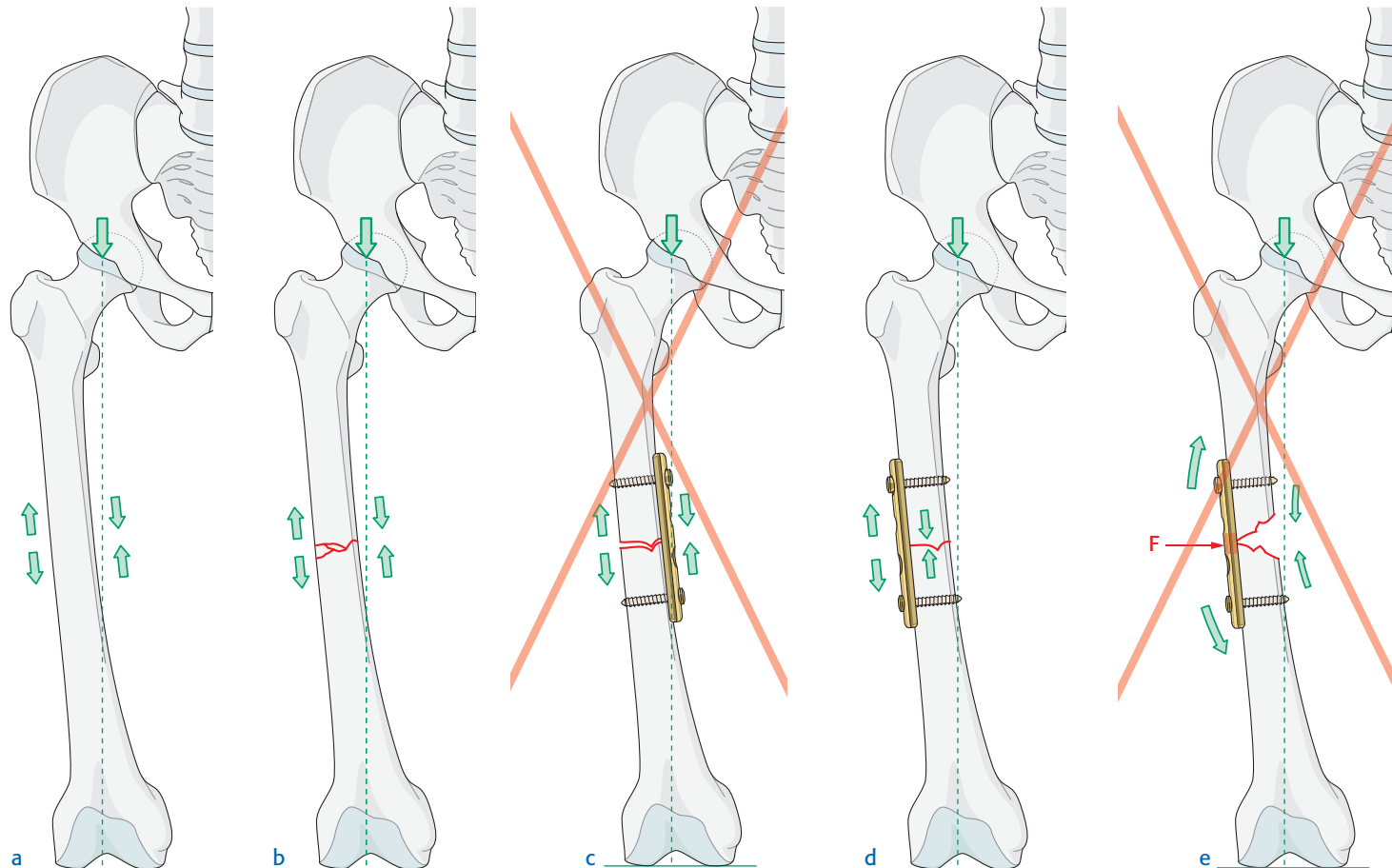


Fig | Animation 3.2.3-1a–b The tension band principle.

- a An eccentrically loaded bone has a tension and a compression side.
- b A tension band converts tension into compression at the opposite cortex.

Animation



**Fig 3.2.3-2a–e** When applied to the tension side of the bone, a plate acts as a dynamic tension band.

- a** The mechanical axis of the bone is not necessarily within the center of the bone.
- b** Under axial load the curved femur creates a tension force laterally and a compression force medially.
- c** A plate positioned on the side of compressive forces cannot neutralize the tension force, and gapping will be observed opposite to the plate. A plate should not be applied in this position.
- d** A tension band plate converts tensile force into compression on the opposite cortex. This cortex must provide a buttress. The plate remains under tension while the bone is compressed.
- e** With a medial cortical defect, the plate will undergo bending stresses and eventually fail due to fatigue at point F. A tension band plate should not be used in this situation.

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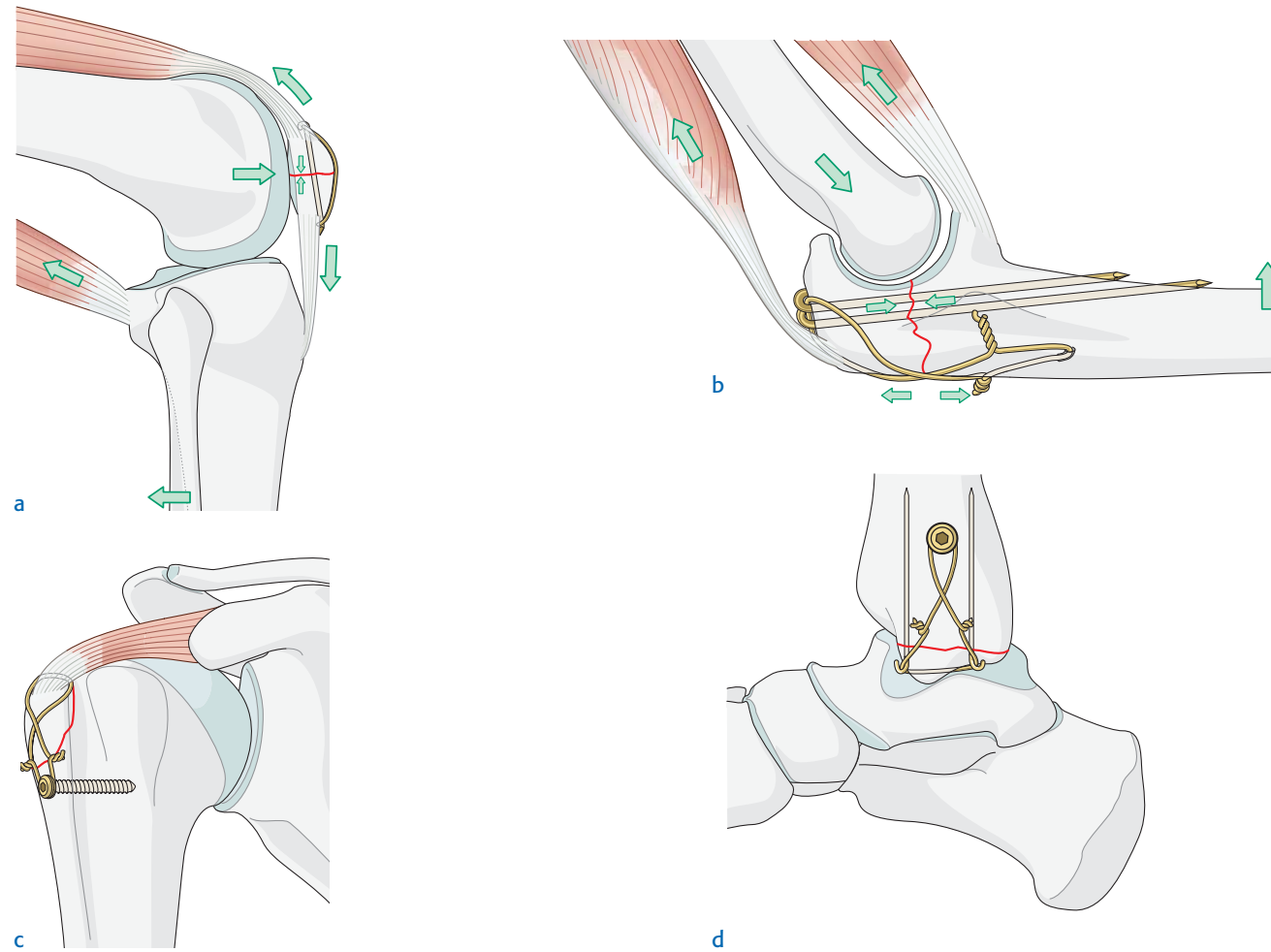


Fig 3.2.3-3a-d

- a Tension band principle applied to a fracture of the patella. The figure-of-eight wire loop lies anterior to the patella and fracture. Upon knee flexion, the tensile force (between the quadriceps muscle and the tibial tuberosity) is converted into compression at the articular surface.
- b In the olecranon fracture, the figure-of-eight wire loop acts as a tension band during flexion of the elbow. This is an example of a dynamic tension band.
- c Application of the tension band principle at the proximal humerus for an avulsion of the greater tubercle. The wire loop is anchored to the humerus by a 3.5 mm cortex screw.
- d Application of the tension band principle to the medial malleolus. The wire loop may be anchored to the tibia by a 3.5 mm cortex screw. This is an example of a static tension band.

## 2 Concepts of application

The tension band principle with wire loops is often applied to articular fractures of the patella and olecranon, converting tension from muscle pull into compressive force on the articular side of the fracture. In addition, small avulsion fractures may benefit from the principles of tension band fixation (Fig 3.2.3-3c).

The principles of tension band fixation with a plate can also be applied in diaphyseal fractures such as the femoral shaft.

- In curved long bones, the convex side of the diaphysis indicates the tension side.

Similarly, in delayed bony unions or in nonunions, where the presence of angular deformity creates a tension side in the bone, adherence to the tension band principles becomes extremely important.

- Whenever feasible, any internal or external fixation device should be applied to the tension side [2].

Bony union will then occur quite consistently. Loops of wire, cables, resorbable, and nonresorbable suture material can function as a tension band. When appropriately placed, intramedullary nails, plates, and external fixators can also fulfill the function of a tension band (Fig 3.2.3-4).

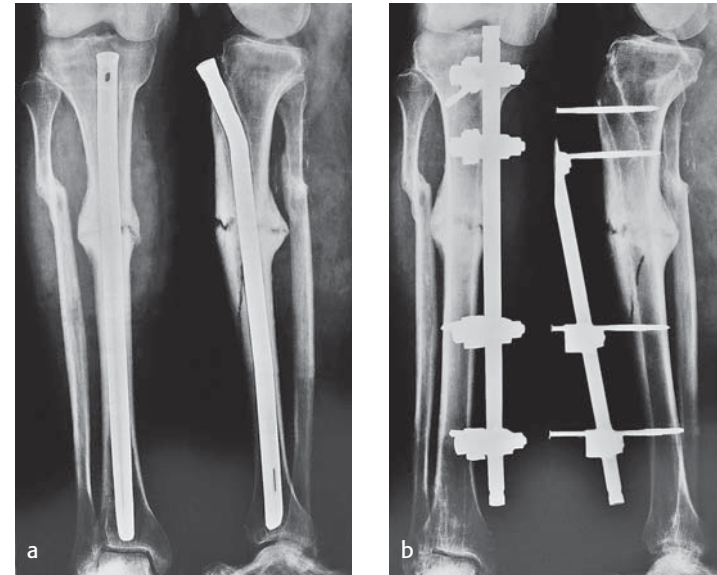


Fig 3.2.3-4a–b Clinical example of an external fixator acting as a tension band in a nonunion after intramedullary nailing.

- Symptomatic nonunion with nail in place—note the hypertrophic area on the posterior side of the tibia and the gap anteriorly.
- After removal of the intramedullary nail, a unilateral external fixator was applied anteriorly in the sagittal plane, and full weight bearing was encouraged. The nonunion consolidated.

### 3.2.3 Tension band principle

- A tension band that produces compression at the time of application is called a static tension band, as the forces at the fracture site remain fairly constant during movement.

Tension band application to the medial malleolus is an example of a static tension band (Fig 3.2.3-3d).

- If the compression force increases with motion, the tension band is a dynamic one.

A good example is the application of the tension band principle to a fracture of the patella. Upon knee flexion, the increased tensile force is converted to compression force (Fig 3.2.3-3a).

#### 3 Operative technique

Fractures that are subject to distraction forces are at risk of displacement if movement occurs, eg, the patella upon knee flexion or the greater tuberosity of the humerus during contraction of the supraspinatus muscle. By applying a figure-of-eight or a simple loop to the anterior aspect of the patella, and by obtaining good purchase within the insertions of the tendons at either end of the patella, an excellent tension band mechanism is created, which compresses the fracture under dynamic load (Fig | Animation 3.2.3-5). The 1.0 or 1.2 mm wire must be anchored as close to the bone as possible. It can either be directed through the insertion of the tendons with a large gauge needle or run around longitudinal K-wires (Fig 3.2.3-3a). In olecranon fractures the tension band loop can also be placed through a 2 mm drill hole in the proximal ulna (Fig 3.2.3-3b),

while in the proximal humerus or medial tibia a screw head may serve as an anchor (Fig 3.2.3-3c-d). A plate or external fixator that functions according to the tension band principle must be applied to the tension side of the bone or the convex side of a deformity or nonunion (Fig 3.2.3-4).

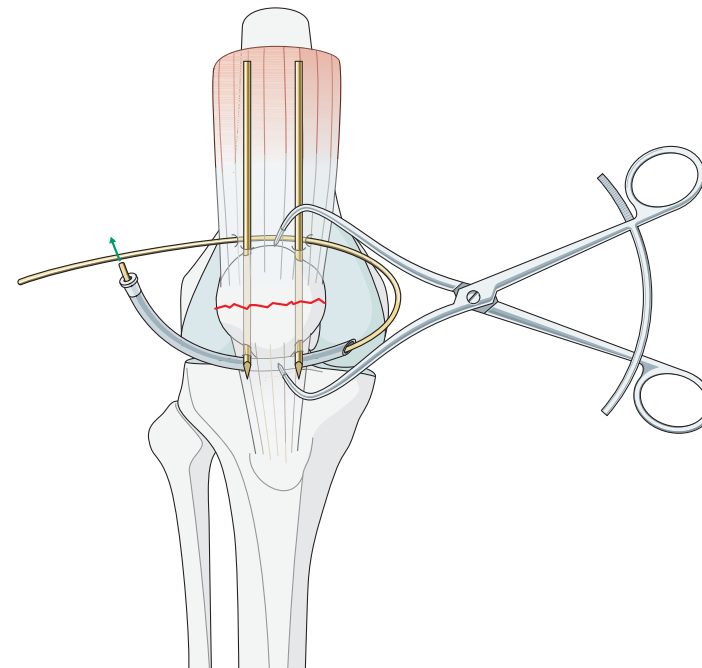


Fig | Animation 3.2.3-5 Technique for tension band wiring of the patella. The tension band is placed underneath the quadriceps tendon and patellar ligament.

Animation

### 3 Reduction, approaches, and fixation techniques

#### 3.2 Techniques of absolute stability

The following prerequisites are essential:

- a fracture pattern or bone that is able to withstand compression;
- an intact cortical buttress opposite to the tension band;
- a fixation that withstands tensile forces.

Traditionally, stainless steel wire has been used for tension band fixation; braided metal cables have also been made popular because of their strength and ease of tightening. The use of nonresorbable braided polyester suture has been studied and is the mechanical equivalent of 1.25 mm diameter stainless steel wire [3]. Biodegradable implants have been applied with success and potentially minimize the complication of painful hardware and decrease the need for implant removal [4]. On the other hand, biodegradable materials often produce an acute inflammatory soft-tissue reaction that may resemble an infection.

#### 4 Pitfalls and complications

The most common complication is implant failure.

- **A wire put under pure tension is very strong. However, if bending forces are added, it will break quite rapidly due to fatigue. This principle of fatigue failure also holds true for plates.**

In simple diaphyseal fractures undergoing plate fixation, the plate should be placed on the tension side of the bone, assuming that the opposite cortex is able to withstand compression forces (Fig 3.2.3-2c-d). When the cortex opposite the plate is comminuted, the plate is exposed to repeated bending stresses,

which invariably will lead to plate breakage, if the fracture does not unite rapidly. Early bone grafting may be required to create enough strength to withstand compression forces along the cortex opposite to the plate.

#### 5 Bibliography

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#### 6 Acknowledgments

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