5 Complications

5.1 Malunion
5.1 Malunion

1 Terminology and classification

The term malunion in an adult patient is not clearly defined and its natural history and biology in different locations is not well known. It could be described as a consolidation of a fracture in a position of deformity and malalignment. The classification of malunions is based on the location, i.e., intraarticular, metaphyseal, and diaphyseal. Furthermore, they can be defined as simple (one plane) or complex (several planes and translation) deformities.

- Some malalignments are better tolerated and compensated by the neighboring joints than others.

For example, malunions of the upper extremity are much better tolerated than those of the weight-bearing lower extremity, and at the lower leg valgus is more acceptable than varus. This means that there are both absolute and relative indications to correct malalignments and leg length discrepancies.

1.1 Leg length discrepancies

- The indication for operative correction of leg length is not absolute and cannot be expressed in centimeters.

Decisions must be made on an individual basis. Shortening the leg by intertrochanteric osteotomy is a very safe operation; corrections of up to 5 cm can be expected to have a low complication rate [1]. The same is true for the intertrochanteric single-step lengthening. Lengthening of up to 3.5 cm can be achieved, but this operation is only indicated when other corrections at hip level are also necessary. A monoaxial lengthening device such as the Wagner distractor can be used to apply Ilizarov’s principles of compression followed by callus distraction. This allows safe metaphyseal and even diaphyseal lengthening of more than 5 cm. The combination of intertrochanteric shortening on one side and diaphyseal lengthening on the other is a very elegant method of correcting differences of more than 6 cm (Fig 5.1-1).

1.2 Intraarticular malunion

- Painful and disabling articular incongruity leading to progressive arthritic changes with instability is an absolute indication for surgery, particularly in the lower extremity.

The decision as to whether secondary reconstruction, extraarticular correction osteotomy, arthrodesis, or arthroplasty is performed depends on

- the condition of the soft tissues;
- the function of the joint;
- the age and functional demands of the patient;
- socioeconomic factors;
- available surgical expertise and facilities.

In young patients with severe joint destruction, arthrodesis is still the method of choice. The technique of fusion should allow for total joint replacement at a later stage (hip, knee).

1.3 Metaphyseal malunion

- In the absence of pain and functional disability there are only relative indications to correct a metaphyseal malunion.

Such a situation should be discussed individually, taking particular account of the long-term prognosis. The fact that procedures at this level are technically relatively easy may influence decision making. Both open and closed wedge osteotomy techniques have their own specific indications. The plate is the implant of choice, whereas external fixation and intramedullary nailing are rarely indicated.
1.4 Diaphyseal malunion

The main question in diaphyseal malunion is the level of corrective osteotomy. The primary goal is to restore alignment and function. However, the condition of the soft tissues and the bone at the level of the deformity may be a high risk factor.

Biomechanically, if the center of the hip, knee, and ankle joints are in correct line to one another, the deformity itself is often not problematic (Mikulicz). A simple diaphyseal malunion can be corrected in the metaphyseal area where the healing potential is much greater. At the proximal tibia, two-plane metaphyseal osteotomies may be indicated to restore the normal inclination of the joint. In case of diaphyseal deformity and shortening, correction can be combined using a lengthening device.

2 Decision making and planning

Any correction of a clinically apparent malunion must be planned carefully [2]. 3-D thinking and planning is of great importance, but the ability to improvise may also be required (chapter 2.4). Good quality standard x-rays of the affected and the healthy limbs, including both adjacent joints, are needed. For intraarticular corrections, conventional x-ray techniques in different directions form a good basis. CT imaging including 3-D reconstructions especially with computer programs may be helpful, but are not absolutely necessary. After evaluating the soft-tissue and bone condition at the level of the deformity, the first drawings of the different possible constructions are made to obtain correct alignment of the extremity. The level of the osteotomy must then be decided on (at the deformity or in an unaffected area). Sometimes a double osteotomy has to be considered. The need for a bone graft, bone substitute, or even growth factors must be anticipated and included in the planning.

Fig 5.1a–d 8 cm leg length discrepancy after multiple nonunion operations. Lengthening of the right femur using the Wagner distractor (a), followed by interposition of bone graft, and plating (b). A 4 cm shortening intertrochanteric osteotomy of the left femur (c) equalized leg length and led to normal hip and knee function (d).
3 Reduction and fixation techniques

3.1 Choice of implant

- The same principles of stable internal fixation that are applied to acute fractures are fully valid for corrective osteotomies.

Interfragmentary compression is the key to safe healing, especially in sclerotic and poorly vascularized bone. Compression is best achieved by lag screws and plates. If the soft tissues are not at risk, plates, especially the angled blade plates adapted to the deformed bone, are ideal for axial compression of metaphyseal osteotomy surfaces. It is important to use the articulated compression device, which allows compression of the osteotomy surfaces, before any screws are inserted. Respecting basic principles, new anatomical locking compression plates with locking head screws might be indicated in the presence of severe osteoporosis (proximal and distal humerus, distal radius, proximal and distal tibia). Careful planning of the order of screw insertion is essential. For osteotomies the LCP is probably best used as a compression plate with the locking head screws providing angular stability. It is not appropriate to use the LCP as an internal fixator as delayed union of the osteotomy is likely. An exception is the Tomofix for high tibial osteotomies [3].

An external fixator can only compress the osteotomy surfaces adequately if a biplanar frame construction is used. To avoid soft-tissue irritation that limits functional postoperative treatment, this fixation technique should be restricted to the tibial plateau and supramalleolar osteotomies.

Stabilization of osteotomies by an intramedullary nail is restricted to the shaft. Reaming the canal is necessary to increase the area of nail-bone contact and to improve stability in all directions. Reaming of an intramedullary canal obliterated with sclerotic bone carries a high risk of bone and soft-tissue necrosis. In cases where hardware is still in situ, there must be good reasons for switching from one implant system to the other. With a plate still in place, the approach will be a direct one and usually it is a logical and safe solution to again stabilize the osteotomy with a plate. Intramedullary nailing is indicated when fixation allows immediate weight bearing without causing additional damage to the bone.

3.2 Metaphyseal and diaphyseal osteotomies

In the metaphyseal area, an osteotomy should be close enough to the joint (where the cortex is already thin) in order to break or crack it without causing displacement. The constantly cooled oscillating saw should, therefore, not go all the way across the bone. Small drill holes (drill osteoclasis) may complete the cut while a large chisel helps to break the cortex for an open and closed wedge osteotomy. A more stable fixation is needed after rotational osteotomies or displacement osteotomies.

- In the diaphysis, corrective osteotomies have a tendency to slow or delayed healing. A decortication producing vital bone pieces at the level of the osteotomy is advisable and may also help to loosen tight adhesions between the adjacent muscles and bone.

3.3 Single-plane osteotomy

The deformity of a long bone can sometimes be corrected by an osteotomy in a single plane, provided there is no large rotational deformity. This osteotomy is oblique and provides a large healing surface that can be fixed with lag screws. Some increase in bone length can be achieved, but this technique is not appropriate if more than 2 cm of true shortening must be corrected.
Careful preoperative planning is essential as well as the use of the image intensifier during surgery (Fig 5.1-2a–h). The limb is rotated under image intensifier and the plane of maximum bone deformity identified. This plane is marked with a K-wire at the apex of the deformity. The limb is then rotated through 90° so there is no apparent deformity visible on the x-ray. This is the plane of no deformity and will be the plane of the osteotomy. It is marked with a K-wire, which should be at 90° to the first K-wire. The osteotomy is centered at the apex of the deformity and the starting point and length of the osteotomy must be planned in advance [4, 5]. A long osteotomy allows some correction of rotation and will determine the direction of rotation. For example, a proximal lateral to distal medial osteotomy in the lower limb will cause the distal fragment to rotate internally; a proximal medial to distal lateral osteotomy in the lower limb will cause the distal fragment to rotate externally. During surgery the peristemeum must be preserved. The osteotomy site is predrilled and then osteomized using an oscillating saw or osteotome. Thermal damage to the bone must be avoided. Once completed, the two fragments can be rotated around the plane of the osteotomy to correct the deformity. With a long oblique osteotomy the bone may be lengthened up to 2 cm while maintaining bone contact. The two cross sections are compressed with one or two lag screws and a protection plate. Absolute stability allows early mobilization of the limb.

Fig 5.1-2a–h Malunion corrected with a single-plane osteotomy.
a–b 30° malunion of a femur with knee pain and severe quadriceps muscle weakness.
c Careful preoperative planning.
5.1 Malunion

Fig 5.1-2a–h (cont) Malunion corrected with a single-plane osteotomy.

d The plane of maximum deformity is located on image intensifier and marked with a K-wire.
e The limb is rotated through 90°; there is no apparent deformity so that the K-wire is seen “end-on” (arrow).
f Osteotomy on this plane allows correction of deformity.
g–h Fixation with an angled blade plate and two lag screws. Good healing and function at 8 weeks.
4 Specific osteotomies—indications and techniques

4.1 Clavicle

Malunion of clavicle fractures is usually well tolerated. Shortening and angulation, causing brachialgia and local symptoms are rare (in about 2%). Lengthening osteotomy, leading to an enlargement of the subclavicular space, can relieve any impingement of neurovascular structures. The reconstruction plate 3.5 or LC-DCP 3.5 must be carefully contoured to the surface of the bone or into a slightly “waved plate”. An alternative is the use of a LCP with locking head screws. A cancellous bone graft is often indicated (chapter 6.1:2).

4.2 Humerus

4.2.1 Humerus, proximal

Bone avulsed by the rotator cuff and malunions of the proximal humerus can lead to impingement syndrome which limits shoulder motion. Subcapital osteotomies or reconstruction osteotomies to decompress the rotator cuff can be performed using tension band techniques and small angulated plates or a LCP with locking head screws. The standard deltopectoral approach (chapter 6.2.1) can be used for such osteotomies and/or an arthrodesis. Varus or rotational malunions lend themselves to subcapital correction osteotomies (Fig 5.1-3).

Malunion of the greater tuberosity usually causes impingement during abduction. After identification and mobilization of the supraspinatus and the infraspinatus tendon insertions, a 1 mm wire loop is placed through Sharpey’s fibers using a cannulated needle. The greater tuberosity is then osteotomized and pulled distally. After testing shoulder mobility, the reduced fragment is secured with a lag screw and one or two tension band wires.

In malunited four-part fractures, the anatomical relationship between the center of the humeral head and the tuberosities should be restored (Fig 5.1-4).

4.2.2 Humerus, shaft

Although quite frequent, malunited humeral shaft fractures rarely require correction. Serious malrotation is easily corrected by a subcapital osteotomy. Correction at the deformity and intramedullary nailing are valid alternatives.

4.2.3 Humerus, distal

The most frequent malunions are varus and valgus deformities. After failed arthrolysis, loss of elbow extension can be another indication for an osteotomy (Fig 5.1-5) [6]. The radial approach with stable plate fixation is a safe procedure in both open or closed wedge technique. Intraarticular osteotomies of the distal humerus are rarely indicated and carry a high risk of necrosis for the intraarticular fragment (Fig 5.1-6).

In the presence of an ulnar nerve irritation, the medial approach with neurolysis of the ulnar nerve is indicated. A transposition of the nerve is usually not necessary.

In single-plane deformities, the oblique osteotomy (Fig 5.1-5) creates a bigger surface and optimal stability using the lag screw-protection plate principle. In multi-plane correction osteotomies a stepwise wedge resection is recommended, allowing temporary reduction by pointed reduction forceps to check elbow movement (Fig 5.1-5d).
5.1 Malunion

Varus malunion of the proximal humerus. Deformity of the proximal humerus after subcapital fracture.

- Placement of the guide wire for the plate, respecting the calculated correction. Osteotomy of the humeral shaft. A wedge is excised allowing a correction of 30° valgus.
- An angled blade plate for adolescents, or a 4-hole, 40 mm, 90° angled, cannulated blade plate 4.5 is placed into the proximal fragment. Reduction is performed with a pointed reduction forceps. Distal cortex screws (1, 2) then apply compression. Finally, two lag screws (3, 4) provide additional compression of the osteotomy.
- Preoperative x-ray.
- Postoperative x-ray.
- Result at the 2-year follow-up.
Malunited four-part fractures.

a  Malunited four-part fracture with interposition of both tuberosities.

b  Deltopectoral exposure, identification of the rotator cuff muscles, osteotomy of the tuberosities, reinsertion, and fixation by tension band wiring.

c–e  Clinical case:

c  Malunited four-part fracture; painful, stiff joint 5 months after the accident.

d  Osteotomy and reinsertion of the two tuberosities, restoring the rotator cuff.

e  Excellent shoulder function after 13 years. Slight impingement symptoms treated by local infiltrations of steroids.
5.1 Malunion

Fig 5.1-5a–f Varisation-extension osteotomy of a distal humerus with valgus and flexion deformity.

a–d Ulnar approach, dissection of the ulnar nerve. Closed wedge osteotomy proximal to the fossa olecrani with the basis of the wedge placed posteromedially; reduction by a pointed reduction forceps to check elbow movement.

e–f Contouring of a DCP 3.5 to the ulnar side of the humerus and fixation compressing the osteotomy.

Fig 5.1-6a–d Malunited 13-C3 fracture; unstable, nonfunctional elbow in varus and internal rotation after 1 year (a–b). Olecranon osteotomy was performed in prone position, the ulnar nerve was released, followed by osteotomy of the radial condyle, correction of all deformities, length, varus (25°), flexion (30°), lag screw fixation, and supracondylar valgisation. The external rotational osteotomy was fixed with a DCP 3.5 (c–d). The elbow was stable and painfree, and full extension was possible, with flexion gradually increasing.
4.3 Forearm

4.3.1 Radius and ulna, proximal
The unreduced radial head in malunited Monteggia fractures is a difficult problem and causes considerable loss of forearm function. Corrective osteotomy of the ulna together with release of the radiohumeral joint leads to stable reduction of the radial head as long as there are no deformities of the proximal radius and capitellum.

4.3.2 Forearm, shaft
- The forearm bones must be considered to function as a joint, where even slight malalignment of one of the two bones disturbs pronation and supination, as well as elbow and wrist function.

In the shaft, angulation osteotomies restore the physiological distance and bow between ulna and radius; release of the interosseous membrane may be necessary, but must be done cautiously.

Supination stiffness limiting the use of the forearm can be treated by rotational osteotomy of one or both forearm bones, depending on the nature and site of the stiffness.

4.3.3 Wrist
Malunions following fractures of the distal radius are frequent but often well tolerated by elderly patients. In the young patient, metaphyseal osteotomies of the radius may be indicated. The approach chosen depends upon the direction of angulation, but the palmar approach is preferred. Relevant shortening should be treated with an open wedge osteotomy. For stabilization, conventional plates or the LCP with locking head screws are used (Fig 5.1-7) [7, 8].

Fig 5.1-7a–b Malunion after fracture of the distal radius.

a 30° of dorsal angulation with shortening and radial angulation.
b A palmar approach and a transverse open wedge osteotomy of the radius were performed, correcting all deformation. Fixation with the LCP and locking head screws maintains the reduction. A bone graft is often used.
5.1 Malunion

Shortening of the ulna alone is indicated in the presence of minor axis deviation of the distal radius. Beware of irritation or compression of the median nerve! Intraarticular osteotomies may be performed on malunions of single intraarticular fragments of the radius. Functional postoperative treatment is the rule.

4.4 Femur

4.4.1 Femur, proximal

In the presence of a malunion of the proximal femur with normal hip movement, the intertrochanteric osteotomy restores the correct biomechanical situation in all planes [1, 9–11]. Special indications may be the correction of leg length discrepancies by shortening or lengthening.

In general, the indications for surgery in a malunion of the proximal femur are varus and rotational deformities in combination with shortening leading to limping, abductor weakness, and overuse of the neighboring joints.

Preoperative planning is based on AP and lateral x-rays of the proximal femur and the calculation of all correction angles, including the gain of leg length by valgisation (open or closed wedge osteotomy). Valgisation should restore the biomechanical balance, but on the other hand, to avoid an abduction contracture the amount of correction is limited by current hip function (Fig 5.1-8).

The universal implant is the condylar blade plate. Depending on the amount of valgisation, a 95° angled blade plate can

![Intertrochanteric valgisation osteotomy for varus deformity after femoral neck fracture. Lateral approach; placement of K-wires for the control of anteversion, rotation, and the calculated angle for the seating chisel.](image)

a) Introduction of the seating chisel, osteotomy more or less parallel to the chisel, creating a large bony surface; stepwise removal of a lateral wedge.

b) Introduction of a 120° angled blade plate after repeated reduction using the seating chisel as lever arm until the calculated correction is achieved without creating an abduction contracture.

c) Stabilization of the osteotomy with compression using the tension band principle. The medial defect is filled with the removed wedge.
Complications

easily be bent to any desired angle, the 120° and 130° angled blade plates are useful for special indications (malunion and nonunion of the femoral neck).

An intramedullary nail with locking option nail does not allow precise correction of complex deformities but may be indicated for purely rotational deformities.

The postoperative treatment is usually functional with 8 weeks of partial weight bearing.

Subtrochanteric osteotomy in different planes to correct a malunion and shortening: The indication for this surgery is a leg length discrepancy in combination with other malalignments of the proximal femur. This osteotomy is technically demanding and experience in individual contouring of plates is required (Fig 5.1-9). Lengthening and reduction can be difficult; temporary interposition of artificial bone blocks may be helpful before interposing autogenous bone grafts [11].

Subtrochanteric shortening to establish equal leg length [1, 11]: This is a low-risk operation for shortening of up to 5 cm; only one nonunion in 70 cases was observed. Preoperative planning is extremely important. The plate has to fit the greater trochanter and the femur exactly in order to achieve adequate contact and to avoid fracture of the lesser trochanter.

Fig 5.1-9a–f 3-D subtrochanteric osteotomy of the proximal femur (valgisation, rotation, lengthening).

a Placement of the seating chisel and adaptation of the osteotomy plane, respecting the desired corrections.

b Distraction with a strong bone spreader with the plate in situ.

c Interposition of corticocancellous bone grafts (from the ipsilateral iliac crest), internal fixation with contoured 95° condylar plate or a 6-hole 90°angled blade plate.
5.1 Malunion

Fig 5.1-9a–f (cont) 3-D subtrochanteric osteotomy of the proximal femur (valgisation, rotation, lengthening).

d–f  Clinical case:
d  Slight varus, shortening, and extreme malrotation after intramedullary nailing of a femoral shaft fracture in a 24-year-old female.
e  50° derotation, 10° valgisation, and 1.6 cm lengthening; stable fixation with a condylar plate.
f  Consolidated corrective osteotomy after implant removal.
4.4.2 Femur, shaft

- Diaphyseal malunions with serious angulation/rotation and shortening should be corrected at the level of the deformity. If there is major shortening, the plate is the implant of choice—intramedullary nailing of the sclerotic malunion is dangerous and reserved for minor correction.

The approach with decortication stimulates healing of post-traumatic osteotomies. As stepwise lengthening of osteotomies compromises the vascularity; autogenous bone grafting is indicated (Fig 5.1-10).

Deformities and nonunions combined with severe shortening should be corrected with a versatile lengthening device, eventually combined with an intertrochanteric shortening of the other side (Fig 5.1-1).

**Fig 5.1-10a–c** Correction and lengthening osteotomy of a malunited femoral shaft fracture.

a  Decortication of the region of shortening, especially on the posterior aspect (linea aspera), and fixation of the distraction apparatus anterolateral, outside the area of future plating.  

b  Oblique osteotomy and distraction of the fragments until the desired length is achieved. Osteotomy of the tips of the fragments and adaptation on the level of the transverse osteotomy.  

c  A tension band plate (wave plate) compressing the osteotomy with the articulated compression device. Autogenous bone is grafted if the contact area is small and the decorticated fragments do not provide a sufficient, vascularized, bony bridge.
4.4.3 Femur, distal
Malunions in a position of valgus, varus, antecurvation, or recurvation, and, exceptionally, rotational and intraarticular deformities are indications for surgery.

There are two techniques to correct malunions of the distal femur. In both the open and the closed wedge technique the rather thin contralateral cortex should remain intact so as to create some intrinsic stability. The 90° angled blade plate with 10–20 mm offset is the ideal implant for medial application in valgus deformities, while the 95° condylar plate fits exactly to the lateral side of the distal femur in varus, antecurvation, recurvation, and rotational malunions. Both can be used for the open wedge technique [1]. The techniques for osteotomy to correct varus and valgus deformity are illustrated in Fig 5.1-11.

![Fig 5.1-11a–d Correction osteotomies of the distal femur.](image)

**a–b** Valgisation osteotomy. The patient is in a supine position, with sterile draping of the whole leg and the iliac crest. There is a possibility of bending the knee up to 90°.
Lateral approach in the interval anterior to the lateral intermuscular septum. Positioning a K-wire through the joint and under the patella. Insertion of the seating chisel taking into consideration the planned correction with a 95° condylar blade plate.

**a** Long, oblique, closing wedge osteotomy. Careful osteoclasis of the contralateral cortex with an oscillating saw, small drill holes, and chisels. The wedge is removed and the osteotomy secured with two pointed reduction forceps before introducing the plate.

**b** Full compression using the articulated compression device.

**c–d** Varisation osteotomy. The same positioning of the patient as in a–b, approach through the medial septum, identical oblique osteotomy and osteoclasis, stabilization with a 90° hip plate.
Postoperative positioning of the knee in 90° flexion and early exercise (a CPM splint is helpful) are recommended as is partial weight bearing for 6–8 weeks.

Displacement of the contralateral cortex is avoided by careful introduction of the plate, especially with the 90° angled blade plate on the medial side. The 90° plate is chosen, with an appropriate offset (10–15–20 mm). Delayed unions and non-union are rare.

4.5 Tibia

4.5.1 Tibia, proximal
Indications for surgery are deformities of the proximal tibia in all three planes, intraarticular malunions after unicondylar fractures, as well as residual joint impaction in combination with ligamentous instability.

Preoperative planning is difficult but very important. It is done on the basis of AP, lateral, and oblique views, as well as CT scan reconstruction in intraarticular deformities.

Posttraumatic malalignments and deformities of the tibial plateau are corrected with the open wedge technique to compensate for the lost bone substance and to increase tension to the loosened ligaments. This is valid for valgus (most frequent), varus, and genu recurvatum, but also for unicondylar and complex intraarticular malalignments. To achieve full correction, an osteotomy of the fibula is almost always indicated, but seldom needs to be fixed. In the particular situation of a genu recurvatum with a normal femoropatellar joint, the technical principles are the same, but, in general, the osteotomy starts below the tuberosity; otherwise a reorientation of the patella is necessary. Functional postoperative treatment with partial weight bearing for about 8 weeks is the rule (Fig 5.1-12).

Intraarticular malunions with circumscribed impaction of the joint surface can be elevated and buttressed in combination with an open wedge varisation osteotomy. Weight-bearing forces are thereby transferred to the less damaged part of the joint.

Valgus deformity is progressive due to unicompartmental degenerative changes after fracture or meniscectomy. The correction may be unicondylar or bicondylar (Fig 5.1-13), depending on the extent of the malunion.

Intraarticular osteotomy, as a single procedure, is rarely indicated. In most cases, axial correction by open wedge osteotomy of the tibial head is added. Slight overcorrection of the axis is of great importance in order to eliminate extreme forces on the partially destroyed compartment. This means a correction to neutral in varisation osteotomy or to a few degrees in hypervarvalgus in valgisation osteotomy.

The aim of all osteotomies is to postpone arthrodesis or joint replacement.

4.5.2 Tibia, shaft
The decision to correct a malunion at the level of the diaphysis depends on the localization, the bone configuration, and the soft-tissue conditions. This also applies to the choice of fixation. A reamed intramedullary nail—to be inserted without using a tourniquet—can provide excellent stability and allows early weight bearing, but tension band plating has clear advantages if the medullary canal is obliterated by sclerotic callus (chapter 5.1:4.4.2) [1].
5.1 Malunion

Fig 5.1-12a–j

a–c 22-year-old female with a malunion of the proximal tibia, years after a car accident she had sustained as a child.

d–g Osteotomy and gradual correction of the axis were performed. Over a period of 3 months a ring fixator was employed to lengthen the leg about 4.5 cm.

h–j 8-month follow-up: consolidation and good function after removal of the ring fixator.

(With permission by Gerhard Schmidmaier.)
4.5.3 Tibia, distal

Indications for surgery are:
- symptomatic malalignment after asymmetric closure of the growth plate following ankle fracture in children;
- malunion of pilon fractures with good ankle function;
- rotational deformities after fractures of the lower leg.

Intraarticular malunions can sometimes be an indication for joint reconstruction.

The usual method for correction of varus deformities is the open wedge osteotomy with plate fixation or an external fixator depending on soft-tissue conditions (Fig 5.1-14). In this situation, circular frames can be very useful.

Valgus deformities are easier to manage by closed wedge osteotomy because the fibula can usually remain untouched.

The alternative to this surgery is fusion or prosthetic replacement.

- In younger patients, an attempt at reconstruction of distal tibial malunions should be made. The results can be amazing; arthritic changes are well tolerated where there is perfect alignment.

4.6 Ankle

The diagnosis of malunion of a malleolar fracture is facilitated by careful observation of the lateral joint line and talar tilt (Fig 5.1-15a–b).

- Even in the presence of arthritic changes, malunited ankle fractures are a good indication for reconstruction and can often postpone secondary arthrodeses or prosthetic replacement for many years [12, 13].
5.1 Malunion

Fig 5.1-14a–b  Correction of a supramalleolar varus deformity with external fixation. The soft-tissue situation at the supramalleolar region allows transfixion with Steinmann pins. This method is excellent for closed wedge corrections and rotational osteotomies. An alternative is to use a circular frame system.

a  Introduction of the first Steinmann pin parallel to the joint line, the second one in accordance with the desired correction. Resection of the wedge and resection osteotomy of the fibula.

b  Compression with the external fixator.

Fig 5.1-15a–b  Shortening of the fibula after malleolar fracture.

a  Characteristics of a normal ankle joint: (1) Regular joint line without interruption at the level of the syndesmosis, (2) a circle fits exactly at the tip of the lateral malleolus and the processus lateralis of the talus.

b  After shortening and malrotation of the fibula, the joint line is interrupted (1), the circle (2) does not fit anymore. Lateral tilt and external rotation of the talus is usually the consequence (arrow).
Shortening of the fibula in type C fractures often leads to talar shift and tilt and malrotation. Furthermore, malunion of the posterior malleolus that has displaced proximally can be present. By correction of length and rotation of the fibula, and exceptionally by osteotomy of the posterior malleolus, the anatomy of the ankle mortise can be restored (Fig 5.1-16) (chapter 6.9).

4.7 Calcaneus, mid foot, and Lisfranc area

There are few indications to perform an osteotomy of a malunited fracture of the calcaneus. The treatment of choice is a corrective arthrodesis of the damaged subtalar joint. The same principle applies to deformation of the navicular bone, the cuboid, and the Lisfranc joint.

Fig 5.1-16a–d Correction osteotomy of a malunited fibula after ankle fracture.

a Malunion after type C fracture with shortening of the fibula, talar tilt, and shift. Lateral approach and capsulectomy. Exposure and excision of the syndesmotic scar tissue. Sometimes the medial joint space has to be cleared of interposed scar tissue.

b Transverse osteotomy of the fibula, fixation with a DCP 3.5 in slight valgus at the distal fibula. Lengthening and rotation of the fibula using the articulated tension device or the bone spreader as a distractor.

c Reduction of the lateral malleolus into the incisura tibiae until the articular cartilage of the distal tibia, fibula, and talus are congruous.

d Fixation of the plate and filling of the defect with corticocancellous bone. A malunited posterior malleolus can be inspected and osteotomized through the lateral arthrotomy or by an osteotomy of the medial malleolus.


## 5 Combined malunions

Multiple shaft fractures of the same limb may lead to multiple malunions which compensate for each other. The centers of the hip, knee, and ankle may be in line. Especially in young individuals, the indication to perform a double correction osteotomy is based on the inclination of the knee joint in the sagittal and/or coronal plane, as well as in rotation. In preoperative planning, the level, type of osteotomy, and fixation has to be considered while respecting the soft-tissue situation, function, and aesthetics.

## 6 Conclusion

- The indication for a posttraumatic corrective osteotomy depends on the associated disability in each individual. The natural history of the deformity should be considered.

Advantages and disadvantages of prophylactic osteotomy should be discussed with the patient. The surgeon is responsible for precise planning and should be aware of technical limitations and complications, and be able to predict the end result.

## 7 Bibliography


## 8 Acknowledgments

We wish to thank Flip P Besselaar and Ernst LFB Raaymakers for their contribution to this chapter in the first edition of the AO Principles of Fracture Management.