Percutaneous Reduction Techniques

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Short segment tibial fractures can be stabilized using different implants like plates, screws, external fixators and nails. This syllabus deals mainly with reduction techniques in the context of the use of intramedullary nails.

1.1 PREOPERATIVE PLANNING AND MANAGEMENT

1.1.1 Primary shortening and secondary overdistraction eases definitive nailing

In the acute setting primary shortening of a shaft fracture is a helpful strategy to decrease soft tissue tension and intra-compartmental pressure. However, reduction gets more difficult and more time consuming, the longer the fracture is kept in a shortened position. The concept of primary shortening (acute phase) and secondary (after 3 or 4 days) overdistraction eases definitive nailing. Using a electro-mechanical load cell, our group has compared the reduction forces in patients undergoing femoral nailing after Damage Control in shortend vs overdistracted fracture configuration. In the overdistraction group, the reduction forces were lower (200 N +/- 43.1 N vs. 336 N +/- 51.9 N, p = 0.007) and the reduction time was shorter (5.8 min +/- 4.0 min vs. 28.3 min +/- 21.8 min, p = 0.056). It was concluded, that DCO with the fracture shortened leads to higher restraining forces & prolonged reduction time. Overdistraction should be performed as soon as possible under careful soft-tissue monitoring [1a, 2a].
Primary shortening and secondary overdistraction eases definitive nailing

Example of a femoral shaft fracture stabilized in shortening first with an external fixator. At day 4, once the soft tissues were uncritical, shortening is corrected and a few mm overdistraction is accomplished by temporary opening the exfix while pulling on the leg. At day 7, this is repeated and a few additional millimeters are achieved [1a, 2a].

1.1.2 Patient positioning

Fracture table or radio-lucent standard table with or without the use of the distractor are alternatives for intra-operative patient positioning for tibial nailing (Table) Use of the fracture table will maintain a defined reduction throughout the procedure, which might be helpful in the placement of reamed nails. However, the fracture table can put skin and neurovascular structures at risk and the set-up time needed is significant. Recent studies in which a fracture table was not used showed a significantly shorter operative time compared to when a fracture table or femoral distractor was used.\textsuperscript{17}

With the unreamed nail insertion, accurate reduction is only necessary at the time of passing the nail from the proximal fragment into the distal fragment. As opposed to a reamed nail where fracture reduction is necessary for the time it takes to pass each reamer and finally the nail. Since in the unreamed situation, this takes only a short time, it can be achieved without the use of a fracture table. The avoidance of the fracture table significantly reduces setup time, which was measured as approximately 30 minutes for a tibial nailing. In multiply injured patients, it also allows ipsilateral and/or bilateral tibial and/or femoral fractures to be treated with a single positioning and draping technique.\textsuperscript{14}

A simple frame, constructed from the tubular external fixator and 4 tube-to-tube clamps supports the injured leg in the padded hollow of the knee, resulting in a gross reduction by gravity.\textsuperscript{15}
## PATIENT POSITIONING

<table>
<thead>
<tr>
<th>fracture table</th>
<th>advantages</th>
<th>disadvantages</th>
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<tbody>
<tr>
<td></td>
<td>+ more stable intraoperative situation</td>
<td>– increases time for positioning and preoperative preparation</td>
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<tr>
<td></td>
<td>+ pre-reduction possible before draping</td>
<td>– permanent traction increases compartment pressures</td>
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<td></td>
<td>+ preoperative fixation of rotation possible</td>
<td>– elevation reduces tissue perfusion by reduction of perfusion gradients</td>
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<td>+ more stable intraoperative situation</td>
<td>– increased risk of over-distracting the fracture</td>
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<td></td>
<td>+ pre-reduction possible before draping</td>
<td>– over-distraction has a negative effect on fracture healing</td>
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<td></td>
<td>+ preoperative fixation of rotation possible</td>
<td>– over-distraction has a negative effect on compartmental pressures</td>
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<td></td>
<td>+ more stable intraoperative situation</td>
<td>– increased risk of positioning related nerve lesion (peroneal nerve)</td>
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<td></td>
<td>+ pre-reduction possible before draping</td>
<td>– clinical estimation of varus-valgus alignment difficult</td>
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<td></td>
<td>+ preoperative fixation of rotation possible</td>
<td>– C-arm control of the entire proximal metaphyseal area difficult</td>
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<tr>
<td></td>
<td>+ more stable intraoperative situation</td>
<td>– C-arm based intraoperative control of rotation (according to Clementz and Olerud) with flexed knee not possible</td>
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<tr>
<td></td>
<td>+ pre-reduction possible before draping</td>
<td>– once preoperatively malpositioned, correction of leg-position difficult</td>
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<tr>
<th>Radiolucent standard table</th>
<th>advantages</th>
<th>disadvantages</th>
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<tbody>
<tr>
<td></td>
<td>+ less time needed for preoperative preparation and positioning</td>
<td>– unstable intraoperative situation requires manual support and more experienced assistance</td>
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<td></td>
<td>+ more flexibility for reduction</td>
<td>– instability might increase soft tissue damage and knee has to kept flexed, until insertion instruments are removed</td>
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<td></td>
<td>+ more flexibility for C-arm control</td>
<td>– accidental extension with insertion instruments in place might harm soft tissues around insertion site (patellar ligament, praepatellar skin) or might bend the aiming arm</td>
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<td>+ in case of concomitant injuries (i.e. bilateral tibia fractures or ipsilateral femoral shaft fractures) stabilization of several injuries can be performed with a single positioning and draping procedure. If needed, two operating teams are possible.</td>
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<td></td>
<td>+ traction is only applied during the reduction process</td>
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<td></td>
<td>+ less risk for overdistraction than with fracture table</td>
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<td></td>
<td>+ flat position does not increase compartment pressure like on fracture table</td>
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<td></td>
<td>+ less risk for positioning related nerve lesion</td>
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<td></td>
<td>+ easy clinical estimation of varus-valgus alignment</td>
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<td>+ easier C-arm control of the proximal metaphyseal fragment</td>
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<td>+ Radiological, C-arm based intraoperative control of rotation (according to Clementz and Olerud) with extended knee possible</td>
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<td></td>
<td>+ Clinical intraoperative control of rotation with flexed knee possible</td>
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<td>+ position of tibia can be changed easily according to the actual needs</td>
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1.1.3 Implant selection

1.1.3.1 Length

1.1.3.2 Preoperative implant length selection
Templates are commonly recommended for the preoperative planning of intramedullary osteosynthesis. The accuracy of templates for the selection of the appropriate implant, however, is dependent upon the amount of radiographic magnification. Unfortunately, there is no currently accepted factor for long bones, and figures range from 10% to 20% magnification. In a recent study, 200 randomly selected femoral and tibial radiographs were studied following fracture stabilization with an intramedullary nail. The mean magnification factor in the femur was 1.09 and in the tibia 1.07\textsuperscript{13}. It was concluded that the currently used templates are highly unreliable for selecting implant length. The clinical implication of this discrepancy is illustrated by the following example: if a tibia requiring a 38 cm nail is templated with a magnification of 15%, the chosen implant will be 3.0 cm too short. This discrepancy could result in increased operating time, additional radiation, and the cost of a second implant. Therefore, implant selection should be based on the contralateral scanogram or on intraoperative clinical or image intensifier based measurements\textsuperscript{14}.

1.1.3.3 **Intraoperative implant length selection with the use of radiolucent rulers**

Intraoperative implant length determination with a radio-lucent ruler under C-arm control is an accurate method. If the proximal and distal end of the bone are centered in the x-ray beam and the ruler is placed parallel to the shaft, projection induced misjudgment of implant length is minimized.

1.1.3.4 **Intraoperative implant length selection by clinical means**

Implant selection can easily and accurately be performed clinically. Landmarks are drawn on the skin using a sterile pen and measured by a meter stick.

The proximal landmark in the femur is the tip of the greater trochanter, which is felt with the finger tip after the approach has been performed and marked on the skin. The distal landmarks are the lateral knee joint space and/or superior edge of the patella. In simple fracture patterns, one shot with the image intensifier allows for correct measurement and the choosing of the appropriate size nail.

Proximal landmarks on the tibia are the medial or lateral knee joint space and anterior part of the ankle joint with a dorsi-flexed foot. These joint lines are usually easier to identify during dynamic, rather than static examination.

1.1.3.5 **Diameter**

The radiolucent ruler also has a section for implant diameter determination. A technical trick for diameter analysis of the cavity is the use of the power reamer as a probe.

1.2 **INSERTION TECHNIQUES**

1.2.1 **Surgical approach**
Several textbooks including the recent AO manuals recommend relatively long incisions for nail insertion. In unreamed nailing, the approach can be much smaller for three reasons: 1) the position of the starting hole is not identified by direct vision, 2) soft tissue protection from the reamer is not necessary, and 3) clinical observation has shown, that usually only the most proximal portion of these approaches is used. Stab incision techniques have been developed for the femur\textsuperscript{14} and the tibia\textsuperscript{15}. In both, femur and tibia care must be taken to place the approaches in line with the axis of the medullary cavity and not too close to the bone starting point (Fig. 1 and Fig. 2).

![Diagram](image_url)

**Fig. 1** Anatomical considerations for skin incision and starting point selection (from \textsuperscript{7}).

These approaches decrease the amount of blood loss\textsuperscript{22} which is reduced by unreamed nailing already thereby decreasing the risk for heterotopic ossification\textsuperscript{5}.
Recently, several approach techniques have been described. They all have advantages and disadvantages. We prefer a direct stab incision like approach through the patellar ligament.

1.2.1.1 Antegrade tibial nailing
In the tibia, a 15 to 20 mm, 'stab'-incision using a large blade is made in line with the medullary cavity. The incision passes through skin, and the patellar tendon at the inferior pole of the patella. The knee is flexed greater than 90° (see Figure 2). The proximal-anterior edge of the tibia can be easily identified by palpating with the tip of the guide pin.

1.2.1.2 Femoral retrograde nailing and tibial antegrade nailing (floating knee)
In the case of retrograde femoral and antegrade tibial nailing, both insertions can be performed through the same skin incision. In this situation the surgeon must be sure, that the incision for the retrograde nail is proximal enough (close to the patella).

1.2.2 Principles of starting hole preparation
Preparation of starting holes are important key steps in intramedullary nailing, since the alignment of the bone is defined by the placment of the starting hole. The cannulated
technique allows an exact placement and the ability to change position with only minimal bone destruction.

1.2.2.1 Starting hole in the tibia
In the tibia, after placing of the guide pin through the proximal-anterior edge of the tibia in the direction of the center of the medullary canal, the protective sleeve is inserted through the 'stab'-incision and through the patellar ligament directly onto the bone. If there is doubt about the center of the medullary cavity, a 20 mm K-wire can be placed in the middle of the shaft at the level of the tibial tubercle under fluoroscopic contro. This provides a better landmark during the entire canal opening and implant insertion while decreasing fluoroscopy time. For proximal fractures, it is essential to obtain a starting point exactly in line with the center of the medullary cavity to prevent malalignment. In the tibia, the opening instrument for the medullary cavity cuts out a cylinder of cortico-cancellous bone. This bone may be used as bone graft.

1.2.3 Relation of geometry of medullary cavity and implant
In the early days of intramedullary nailing, the implants were inserted without reaming. This technique limited the use of intramedullary nails to fractures of a short midshaft segment of the diaphysis. To increase the indication of intramedullary nailing to more complex diaphyseal fractures, the medullary cavity was reamed. This improved the contact between bone and implant, and increased friction and strength for fracture fixation.

1.2.3.1 Technique of reaming
Power reamers are more convenient and faster and therefore are used for standard situations. For more difficult situations, (i.e. pseudarthrosis with sclerosis of the medullary cavity) however, specially designed hand reamers are more effective and safer.

It is well known, that intramedullary reaming results in an increase in intramedullary pressure and temperature. Recently, the influence of reamer type, geometry of reamer shaft, quality of reamer cuts and technique of reaming on intramedullary pressure and cortical temperature was analyzed. It could be shown, that blunt reamers, high axial forces, large diameters of the reamer shaft and low depth of the cuts of the reamer caused increased pressure and/or temperature\textsuperscript{19}. It was shown by Pape, that for different reamer constructions, the risk for pulmonary damage differs.

The efficacy of a distal venting hole is strongly dependent on its diameter and similarly, a proposed flushing technique for the reduction of viscosity\textsuperscript{21} is not widely used amongst orthopaedic surgeons, but may decrease the chance of complications.

1.2.3.1.1 Power reamers
The power reamer can be used with a cannulated system or with an air drill and a special tool. The reamer shaft is flexible and may be used for reaming depths of up to 440 mm. The reamer head is cannulated and may be used over a guide wire. The reamer heads are available in diameters of 9.5 mm to 19.5 mm in 0.5 mm increments.

1.2.3.1.2 Hand reamers
Speed of rotation of hand reamers is much less compared to power reamers and therefore produce less heat. Two different types of hand reamers are available. One, a reamer with a sharp tip and a fixed T-handle which comes in 3 standard sizes (6 mm, 7 mm and 8 mm). Other sizes are available.
Short Segment Tibia Fx - Reduction Techniques

The other type of hand reamer is cannulated and uses the cannulated reamer heads of the power reamer (see above) with a dull tip and a removable, cannulated T-handle.

1.3 REDUCTION TECHNIQUES

1.3.1 Digital control in reduction of tibia fractures

One of the most effective and sensitive instruments for the reduction of acute tibia fractures are fingers and hands. In contrast to the femur, large parts of the tibia, especially the antero-medial surface and the anterior crest are located directly underneath the skin and are therefore easily palpated. Since most fractures are A and B types in the mid-shaft or distal diaphysis, these are especially suitable for pure digital/manual reduction control during implant insertion. Temporary over-correction during translation of the fracture zone is sometimes advantageous and helpful in oblique fractures. With the tip of the unreamed nail, the distal fragment can be ‘felt’ during manipulation. The correct insertion of the nail into the medullary cavity of the distal main fragment gives a tremendous increase in stiffness.

In contrast to the tibia, the femur is much less amenable for digital manipulation. Therefore, the need for reduction instruments and tools exists.

1.3.2 Reduction aids

Reduction of acute fractures is usually not difficult in acute midshaft tibial fractures and manual reduction alone is usually sufficient. However, in tibial fractures or femoral shaft fractures that are delayed for a long time or relaxation is poor, reduction might become difficult. For these situations, several techniques and tools are available.

1.3.2.1 Sling techniques

Using the 'towel-sling' technique' and 'bean bag technique' are cheap, easy and non-invasive ways to manipulate the main fragments. Disadvantages to this are limited tactile feedback, limited fine regulation of reduction forces and the need for 'additional hands'.

1.3.2.2 Reduction clamps

The use of reduction clamps (Matta, King-Tong) can be used in tibial fractures. The clamp application can be performed percutaneously (tibia), and avoids additional dissection (open fractures) along with avoiding soft tissue bruising.

1.3.2.3 Schanz Screws

The use of temporarily inserted Schanz screws is an effective way to get direct, short lever arm contact to the bone and also serves as a control tool. This is especially helpful in femoral fractures or delayed tibia cases\textsuperscript{14,15}. The three principles are: 1) placement close to the fracture, 2) uni-cortical or out of the nail path in the proximal fragment (anterograde nailing), and 3) connection with T-handles for easier manipulation. In the 'surgical coordinate system' there are 2 planes where reduction has to be controlled: anteroposterior and lateral. The frontal plane is controlled by the anteroposterior image, the sagittal plane with the control of Schanz screws. Use of the image intensifier can be reduced by fixing T-handles to the Schanz screws and analyzing their position relative to each other. The visual control of the relative position of both T handles can decrease the use of the C-arm. The tactile control of the main fragments in the sagittal plane may also decrease the need for C-arm (Fig. 4).
1.3.2.4 Distractor

The main indication for the use of a distractor is the need for longitudinal distraction against high resistive forces. Its use is especially helpful in delayed cases {Baumgaertel, 1994 #6162}. The need for controlling the sagittal and frontal displacement or rotation is much less, since the single Schanz screw tends to bend and rotate. If a distractor is not available, a tube-to-tube construct and a distraction tool can be used for the same purpose (Fig. 5).

1.3.2.5 Poller screws (PS)

Nailing of metaphyseal fractures is associated with an increase in malalignment due to strong muscular forces$^4$ and residual post-fixation instability$^{15}$. As there is a large difference between the implant and metaphyseal diameters with no nail-cortex contact, the nail may translate along the interlocking screws. Blocking screws, placed adjacent to the nail, have been proposed as a possible solution for decreasing the translation in both the tibia$^{15}$ and the femur$^{14}$. These screws, also termed “Poller screws”, decrease the width of the metaphyseal medullary cavity, physically blocking transverse nail translation, and increasing the mechanical stiffness of the bone-implant-construct. Blocking screws can be used as: 1) an alignment tool, 2) stabilization tool and 3) as a manipulation tool.

If used as an alignment tool, the bone-implant construct is sufficiently stable, but malaligned. In this case, the implant has to be removed temporarily, the PS in this situation has been placed in the wrong place, which should be avoided. The direction of PS placement is perpendicular to the direction that implant will displace to (Fig. 6).
If used as a **stabilization tool**, the bone-implant construct with the nail in place is unstable, and may also be malaligned. In this case, the implant may stay in place during correction and the PS is placed in a position of slight over-correction of the deformity. Again, the direction of PS placement is perpendicular to the direction that the implant will displace. This is specifically helpful in oblique metaphyseal fractures of the distal tibia and femur, because shear forces become transformed to compression forces.

If the PS are used as a **manipulation tool**, the problem is the correct placement of the implant. On one hand, this can be used in situations where a previously malplaced nail prevents placement of the new nail into the correct position, because the nail may tend to slip again into the old nail path. On the other hand, it can also be used in situations...
where the antegrade starting point to the femur or tibia was originally misplaced. Even if a new correctly placed approach is created, the implant tends to slip back into the previously created one. In this case again, the implant has to be removed temporarily, the PS is placed to block the incorrect path and the nail is reinserted (Fig. 7).

![Diagram](image-url)

**Fig. 4** 'Poller screws' as manipulation tool (from 7)

However, when placing the PS (like with locking screws), potential damage to the nail can be done during drilling and corrosion between nail and screw interface has to be considered. Other potential complications would be blockade of the nail by an incorrectly placed PS or screw break out.

1.3.2.6 **Tourniquet technique**

The use of a tourniquet as a reduction tool for closed tibial fractures has been described. Inflation and longitudinal traction result in a smooth reduction and temporary stabilization. In addition to the tourniquet the use of a distractor is possible20. However, this technique contains certain risks in cases of fractures with severe soft tissue injury. Therefore, the tourniquet pressure should not be too high, and the application time should be as short as possible.

1.3.2.7 **Sequence of locking**
During insertion, unreamed nails frequently push the distal fragment distally resulting in fracture diastasis. This acutely increases compartment pressures, and may prolong fracture healing. During weight bearing with fracture diastasis, locking screws are under high bending stresses. Axial deformities, especially in distal metaphyseal fractures are more likely to develop. In contrast to previous issues of this manual and teaching videos, the routine performance of first distal locking is recommended. This gives the opportunity for application of the 'backstrike technique', which is performed after distal locking, providing compression of the fracture fragments (Fig. 8). Neglecting this sequence of locking results in an increased chance of fracture diastasis, which increases the transmitted forces to the locking screws or nail and increases the risk for screw or nail failure.

1.3.3 Intraoperative alignment control techniques
1.3.3.1 Length
Distal locking before proximal locking has the additional advantage of the distal fragment being fixed to the nail and is therefore easier to manipulate with the insertion handle. This assists in maintaining length, fragment position and rotation. After distal locking of...
almost all C fractures and certain A1 and B1 fractures, length should be assessed radiologically.

In femoral fractures, under image intensification, the upper margin of the femoral head is brought into line with the measuring device (Fig. 9).
Fig. 6 Radiographic determination of length intraoperatively with the use of the image (from ⁷)
This already has the length of the contralateral femur marked on it with a clip (upper margin of the femoral head to the lower margin of the lateral femoral condyle). Subsequently, the knee joint is viewed and the amount of length correction required is read off as the difference between the lower margin of the lateral femoral condyle and the position of the clip. By using the sliding hammer, limb length can be continuously changed in both directions (Fig. 10).

![Image](image_url)

**Fig. 7** Control of length after distal locking with the sliding hammer and the insertion instruments in place. (from 7)

For other simple fractures (generally A2/3 and B2/3), there is usually no need for length measurement and fragment positioning can be achieved using the ‘reverse coaptation’ or ‘backstrike’ technique. Clinical comparison of the length of the tibia is much easier to evaluate than the femur and is usually sufficiently evaluated by clinical means.

### 1.3.3.2 Frontal-sagittal plane

In simple midshaft fractures of the femur and tibia, frontal and sagittal plane malalignment is usually not a problem. However, the correct restoration of the femoral neck-shaft angle, the course of the weight bearing line through the middle of the knee joint and a horizontal position of the ankle joint are at risk. If fractures are complex and/or located more metaphyseal rather than diaphyseal this can be a problem. While CCD angles can be measured and controlled from C-arm images, the control of the weight bearing line is usually based on long standing x-ray films and are not available intraoperatively.

However, the recently described 'cable-technique' gives adequate information about the frontal plane axis. With the patella directed anterior, the center of the femoral head and ankle joint are visualized fluoroscopically and marked on either the skin or the surgical sheets. The cautery cable is then spanned between these two points with the image intensifier centered on the knee joint. Using the projection of the position of the cable, varus/valgus alignment can be determined (Fig. 11). The sagittal alignment is determined using a lateral fluoroscopic image.
Fig. 8  Cable technique for control of frontal plane alignment. (from 7,12)
### 1.3.3.3 Rotation

Several methods are available for an intraoperative assessment of femoral and tibial torsion and for the prevention of rotational malalignment.

#### 1.3.3.3.1 Clinical assessment of femoral malrotation

Clinical techniques vary according to the operating table used and the position of the leg during measurement. Preoperatively and before draping, the rotation of the intact limb is established with the knee and the hip flexed at 90° (e.g. external rotation / internal rotation 50°/0°/30°). Intraoperatively, after nailing and temporary locking of the fractured bone, rotation is checked again. However, the insertion handle does not allow hip flexion of 90°, therefore the handle has to be removed prior to this test (Fig. 12).

![Fig. 9](image)

**Fig. 9**  Clinical determination of rotation intraoperatively depending on locking technique and position. (from 7,12)

Alternatively, with the folds of the OR table flexed down, the examination can be done with the knee flexed at 90°, but the hip extended. This allows the insertion handle to remain fixed to the nail and makes secondary corrections easy. Sources of errors in this method may be unrecognized secondary to position changes of the pelvis during surgery. This must be taken into account.

#### 1.3.3.3.2 Radiographic assessment of femoral malrotation

Recently, several signs were described for the assessment of femoral rotational alignment. These include the ‘lesser trochanter shape sign’, cortical step sign, and diameter difference sign.14
1.3.3.2.1 *Lesser trochanter shape sign:*

The position of the uninjured lesser trochanter postero-medial behind the proximal femoral shaft has a typical radiographic appearance in anteroposterior radiographs, which is strongly dependent on rotation of the femur. Preoperatively, the shape of the lesser trochanter from the limb (with the patella directed anterior or the leg resting free over a table hinged at the knee) is analyzed and stored in the image intensifier's memory. Before locking the distal main fragment (again with the patella directed anterior or the leg resting free over a table hinged at the knee), the proximal fragment is rotated (using a Schanz screw) around the nail until the shape of the lesser trochanter of the ipsilateral side is the same as the contralateral shape. In the case of an external rotation deformity, the shape of the lesser trochanter is diminished, because the lesser trochanter is partially hidden by the proximal femoral shaft. While in the case of an internal rotation deformity, the shape of the lesser trochanter is enlarged, because the lesser trochanter is not hidden as much by the proximal femoral shaft (Fig. 13).

![Lesser Trochanter Shape Sign](image)

*Fig. 10* Radiological determination of rotation intraoperatively depending on the comparison of shape of the lesser trochanter on the ipsi- and contralateral side (lesser trochanter shape sign). *(from 7,12)*
1.3.3.2.2 Cortical step sign
In the presence of a rotational deformity, cortical structures of the proximal and distal fracture fragments can be projected with different thicknesses. However, compared to the lesser trochanter shape sign, this sign is much less sensitive\textsuperscript{14} (Fig. 14).

![Diagram of cortical step sign](image)

**Fig. 3.3.1-11** Radiological determination of rotation intraoperatively depending on the cortical step sign and the diameter difference sign. (from \textsuperscript{7,12})

Diameter difference sign
This sign is positive at levels where the diameter is oval, rather than round. In these cases, transverse diameter of proximal and distal fracture fragments are projected with different diameters. However, compared to the lesser trochanter shape sign, this sign is also much less sensitive\textsuperscript{14} (Fig. 14).
1.3.3.3 Clinical assessment of tibial malrotation
Similar to the femur, during clinical assessment of rotational deformities of the tibia, the surgeon has to be aware, that the tibia can rotate in the knee joint and that the indicator ‘foot’ consists of several joints. Tibial rotation should be checked with the knee in flexion and the foot dorsiflexed. However, besides the comparative analysis of foot position, range and symmetry of foot rotation has to be taken into account.

1.3.3.4 Radiographic assessment of tibial malrotation
In cases where the fracture pattern does not exclude rotational deformities, the method according to Clementz should be used for assessing thigh-foot angles. This includes a preoperative measurement of tibial torsion of the contra-lateral side by the use of a C-arm. In fractures with significant comminution (Type B & C), the contra-lateral tibial rotation is routinely established under fluoroscopic control.

1.3.4 Special reduction techniques for delayed cases and nonunions
In delayed cases, depending on the time passed since the fracture we frequently are faced with the following problems: 1) There is deformation (shortening, angulation and/or translation). 2) The initial phases of fracture healing with connective tissue ingrowth and callus formation make reduction difficult. 3) The fracture site is sclerotic and narrowed or locked, but the main fragments are osteoporotic and soft. These situations make intramedullary nailing difficult, even if only small deformities are present, because instruments (reamer) and nails become deflected and tend to penetrate the cortex. While angular deformities can be corrected by the use of a distractor, the fragment translation offset is much more difficult to overcome.

In these situations, the use of Poller-screws as a manipulation tool helps to guide instruments and implants the desired way. The incoming devices hit the Poller screws and get deflected in the appropriate direction. The effect can be increased, if several Poller screws are placed in a series. Each will add additional manipulation effects to the previous one (Fig. 15)
Fig. 12  Nail manipulation in delayed cases by the use of sequential 'Poller screws' as manipulation tool. (from ')

1.3.5 Techniques for prevention or secondary correction of malalignment
Careful selection of a correct starting point and nail position in the proximal and distal fracture fragments is the most important step for avoiding varus-valgus and ante-curvatum deformities.

In the case of proximal or distal metaphyseal fractures, the relative loose contact and resulting 'play' between locking screws and nail can be used for correction of malalignment. An increase in stiffness of the bone-implant construct can be obtained with temporary external fixator devices, Poller screws, or plates.

1.3.5.1 Callus deformation by temporary external fixation:
A temporarily applied external fixator (conventional trans-cortical pins or pinless fixator) is used for a stepwise correction of the deformity and its maintenance.14

1.3.5.2 'Poller'-screws
Again, analogous to the temporary external fixator technique, the relative loose contact and the resulting 'play' between inter-locking screws and nail can be used as an internal solution. After acute, single-step slight over-correction of the deformity, re-displacement of the nail is prevented by so called 'Poller'-screws, which are bicortically placed on one side of the nail with the help of the radio-lucent drill.14,15 These screws prevent re-displacement, while increasing stiffness and strength of the bone-implant complex. In the case of a malpositioned starting point, these Poller screws can block the old starting point and avoid 'slipping' back of the implant or instruments (Fig. 16)
Fig. 13  Prevention of reentering a malpositioned starting point in antegrade femoral nailing by the use of 'Poller screws' (from 8).
1.3.5.3 **Fibula osteosynthesis**

Metaphyseal fractures with same level fibula fractures have been shown in a recent (AO A6) multicenter study to have higher rates of delayed union compared to fractures at different levels, despite the experimental observation by Weber et al that stabilization of the fibula in a 'nailed' tibia defect model did not change defect site motion significantly.

The sequence of fixation is important:

- Start with the fibula, which serves as a fulcrum or center of rotation for the final frontal plane alignment.
- Insert the nail and lock it distally, leave the instrument in place.
- Gentle blows with the hammer result in more valgus, gentle back-slaping results in more varus.
- In the perfect neutral frontal plane alignment the nail is proximally statically locked.

1.3.5.4 **Buttressing and tension band plate**

In proximal metaphyseal fractures, a plate can also be applied to the tibia. However, care should be taken to avoid soft tissue stripping and bulky implants. Depending on the type of deformity, these plates act as a butress or tension band.
1.3.5.5 **Implant rotation**

In case of varus or valgus deformities in proximal fractures, the curve in the implant proximally can be used for the correction of axial deformities in the femur or tibia\(^{14,15}\). After temporary removal of the distal and proximal locking screws, the main fragments can be rotated around the implant. The locking screws are re-drilled and replaced after the correct alignment is obtained. This procedure can change both the varus-valgus alignment and recurvatum which may not always be desired, *(Fig. 17).*

![Fig. 14](image)

**Fig. 14** Implant rotation for correction of axial deformity. Bolts have to be removed before implant rotation. Implant is rotated according to the direction of deformity, which corrects malalignment in the coronal (frontal) plane. *(from 7,15)*

### 1.4 **FIXATION TECHNIQUES**

#### 1.4.1 **Interlocking screws**

In unreamed nailing, all fractures, and in reamed nailing most fractures undergo both proximal and distal interlocking. Stable patterns are locked in a dynamic mode. This prevents post-operative rotational instability when only proximal or distal interlocking is performed. Using solid implants, we no longer rely on the implant-isthmus friction to act as nail interference stabilization. Distal interlocking can be done with a free-hand technique using a radiolucent drill with the help of the distal aiming device. Proximal interlocking is performed with an attached guide without the need for fluoroscopic image.
Two distal interlocking screws are recommended. Studies have shown no statistically significant difference in torsional stiffness or axial load to failure when one versus two distal interlocking 6 mm screws are used. However, two distal interlocking screws are recommended for the following reasons.

1.4.1.1 Screw-nail relationship

1.4.1.1.1 Toggling problems

Due to the manufacturing process, there are dimensional tolerances in nail interlocking holes as well as in interlocking screws. This results in a toggling phenomenon between screws and nails, since the nail can shift along the longitudinal axis of the screw. This toggling can cause instability and malalignment in the frontal and horizontal planes (rotation), and less in the sagittal plane. However, in clinical use, this problem is usually diminished by non-perpendicular and imprecise insertion of the interlocking screws. For this reason, the use of 2 distal screws is recommended, despite the fact that studies have shown that there is no significant difference in the torsional rigidity or axial load to failure.

1.4.1.1.2 Screw breakage

In any fixation system in orthopaedic trauma, implants or implant components can undergo fatigue failure. This is dependent on material, design, surface finishing, cross-sectional area as well as on the amount of applied load and number of cycles. With smaller diameter nails (unreamed systems), there are also smaller diameter locking bolts. This can result in increased rates of screw breakages. However, in the vast majority of cases without clinical consequences. Since the distal interlocking screws are usually the weak part of small diameter nail systems, all attempts should be taken to increase mechanical strength in this area. The easiest, cheapest and most effective way is to use the full range of locking options in the distal end of the nail, i.e. 3 screws in the tibia and 2 in the femur.

1.4.1.2 Techniques for interlocking hole placement

1.4.1.2.1 Radiolucent drill

The radiolucent drill (RD) made from radiolucent synthetic material allows drilling under image intensifier control, without placing the hands in the direct beam of the image intensifier. Special three-fluted 4.0 mm and 3.2 mm drill bits with tips reduce the tendency to slip off the bone surface. The spiral portion is short, minimizing the likelihood of soft tissue spooling and eliminating the need for a drill sleeve.

1.4.1.2.2 Distal aiming device (DAD)

Radiation exposure during interlocked nailing continues to be a controversial issue. Recently, Mehlman and DiPasquale demonstrated that operating room personnel within 24 inches of the fluoroscopy beam (such as the free-hand technique for interlocking screw insertion using a radiolucent drill) receive significant amounts of radiation exposure, particularly to the unprotected eyes, neck and hands.

Proximal aiming arm based techniques have failed, because a simple aiming arm cannot compensate for the implant deformation due to insertion-related bending and rotational forces. Therefore, the ‘free hand’ technique remains the most popular method of distal interlocking screw insertion.

Recently, a radiation-independent proximally mounted distal aiming device (DAD) has been developed for unslotted intramedullary nails. Unslotted nails have been shown...
to have no significant insertion related implant torque. The DAD is based on an aiming arm which is readjusted to the deformed nail through a distal working channel and an asymmetric spacer. In a prospective randomized study using human hole body specimens, the DAD and the RD in the hands of an un-experienced surgeon were compared. In the aiming system group compared to the free-hand technique, the total operation time, distal locking time, total fluoroscopy time and screw placement time were statistically less. In the DAD group, distal locking fluoroscopy time was zero while failure rates were equal in both groups (1.6 percent or one of sixty screws). These results suggest that aiming devices can eliminate the need for radiation during distal interlocking screw placement (Fig. 18).
1.4.1.2.3 Other

Almost all current methods for distal interlocking continue to be dependent upon image intensification. In order to circumvent the need for radiation during distal interlocking, a variety of devices and techniques have been developed: proximally mounted aiming arms, devices fixed to the image intensifier, the use of magnetic fields, flexible reamers from inside the implant, and nail shape analysis. Of these methods, the proximally mounted aiming arms have received the greatest interest.

1.4.2 Dynamization

In the femur, dynamization of statically locked nails is rarely necessary. In the tibia, routine dynamization is recommended in combination with bone graft for certain fracture patterns with a high risk of delayed fracture healing. However, in their paper large fracture gaps and distraction of the main fragments were present. It is probably more advisable, to 'dynamize' the fracture during initial surgery by distal locking first and then ‘impacting’ the main fragments by gentle blows of the hammer ('backstrike technique') (Fig. 6).
Bibliography


