Femoral shaft fractures fixation with locking antegrade intramedullary nails

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Abstract

Modern intramedullary nails with interlocking screws offer wider range of options for treatment of the femoral shaft fractures. They can be used as a method for biological fixation. They offer many advantages over conventional methods of fixation. At the present time they are biomechanically superior. Their placement is easier comparing to plates used in biological way. At the Deparment for Traumatology in University Medical Centre Maribor, Slovenia, we've been using this method since 1991. An average of 32 patients are treated each year, 75 % of them with anterograde intramedullary nails with interlocking screws. The best results can be achieved with individual selection of the most appropriate way of fixation. Intramedullary nailing with intelocking screws is presently the most widely used method for fixation of femoral shaft fractures and is superior to other methods.

Introduction

Femoral shaft fractures always require surgical fixation, except in children. Conservative treatment cannot give satisfying results neither in anatomic nor in the functional sense (leading to invalidity) (1). Recent discoveries that the particles of the femur do not require anatomic reposition as long as they charge well, that during the process of bone reparation absolute stability is not necessary, and that secondary bone reparation is better and faster than primary, have accelerated the development of so-called "biological" osteosynthesis. This method causes minimal additional damage to the tissues during surgery. But despite that, it must fit the following criteria:

- we must achieve the correct length and eliminate any movement causing deformity (such as rotation of particles, angular or side movement),
- fixation must be stable enough to allow early rehabilitation. This method of fixation usually leads to fewer complications during treatment. Contemporary intramedullary nails with interlocking screws offer a wider range of possible techniques for fixation of shaft femoral fractures. Progress in metallurgy, technique and computer science allows thinner intramedullary nails which require minimal reaming of the medullary canal, but are at the same time strong enough to ensure sufficient stability and are therefore appropriate for biological fixation.

Antegrade intramedullary fixation of femoral shaft fractures with the use of modern intramedullary nails, carried out in biological way, is currently the best method of shaft femoral fracture fixation in adults because it allows:

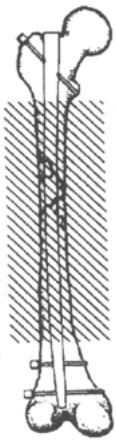
- good reposition despite minimal tissue damage,
- good fixation, bio mechanically superior to plates,
- secondary reparation,
- immediate rehabilitation,
- fewer complications,
- compared to classical plates or locking plates, used in a biological way, the placement of locking antegrade intramedullary nails is usually easier and faster.

The modern locking antegrade intramedullary nail for fixation of the femoral shaft fractures must be physiologically curved. It must require minimal (or no) reaming of the femur canal, with 9-12 mm in diameter, but must at the same time be strong enough to offer stability. It can be hollow. It has openings for one locking screw at the upper side and for two locking screws at the bottom. It can be applied to the right or the left femur. Locking screws have approximately 5 mm in diameter. They prevent the fragments from moving - collapsing, torsion after fixation (picture 1).

Indications and contraindications

Antegrade intramedullary fixation with the use of locking screws can be applied on all femoral shaft fractures placed 2 cm below the less trochanter and 4 cm above the knee. It can also be used for fixation of T-shaped unmoved fractures on the area of distal epiphysis and epiphyseal fractures that can only be repositioned by traction, if they are fixed with individual nails before fixating them with a locking nail (picture 2). This method cannot be used when:

- other materials have already been inserted in the proximal femoral area and stand in the way of the nail (hip prosthetics, other osteosynthetic material),



Picture 1. *Area of fixation by the locking antegrade intramedullary nail.*

Picture 2. *Cannulated IM nail (left), solid IM nail with holes for the locking screws (right). The upper hole of the full IM nail (right) is oval, what allows dynamic locking.*

- deformities on the femur bone disable the nail to be inserted,
- the patient is suffering from hypovolemic shock,
- in polytraumatized patient with severe lung contusion
- type IIIC open fractures,
- patients are coagulopathic,
- in children (presence of the growing cartilage in the epiphysis)
- in pathological fractures because of primary tumours,
- in pathological fractures because of metastases (here, another type of nail is used for fixation).

Surgical procedure

1. Timing of the surgical procedure

Femoral shaft fractures call for immediate fixation within less than 24 hours to avoid numerous complications. The modern intramedullary method of fixation - mainly due to the relatively easy technique and short duration of the procedure - should not be avoided by the duty doctor and left to programmed operations like when plates were used (1).

2. Clinical examination of the patient

Before the operation, the surgeon must always examine the patient, paying much attention to the condition of the vessels and the nerves in the injured area (vein and nerve damage can also occur during surgery)!

3. X-ray pictures

Before the operation, it is necessary to obtain X-ray pictures of the whole femur, including the hip and knee area, to have a complete oversight of any additional fractures or obstacles the might have been overlooked during the check-out, and then choose the proper method and materials for fixation.

4. Pre-operative preparation

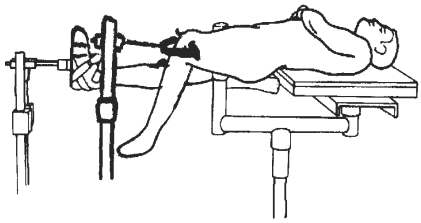
We must monitor and replace any loss of fluids; the patient must be given proper analgesics.

5. Preventive antibiotic protection and thromboprophylaxis

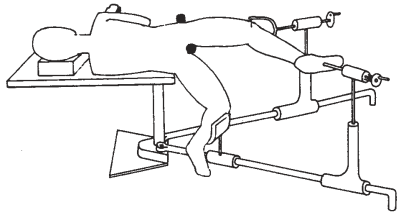
The operation is performed with antibiotic protection (cephalosporins of the first and second generation) and antithrombotic prophylaxis (low-molecular heparins) to diminish the risk of infections and thromboembolism.

6. Reposition

The purpose of reposition is to prevent movement of the fragments that could lead to deformities later. This must be done before fixation. Biological way of fixation is preferred; therefore closed reposition is required, unless when this is not possible because fragments are trapped between the muscles. We can perform closed reposition by traction on the extension table, or with a distractor on a flat operative table. The patient can be placed on the extension table and operated on in two different positions (2). It is necessary that the surgeon checks the position of



Picture 3. *Supine position.*

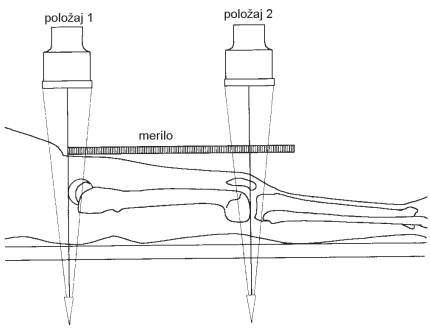


Picture 4. *Lateral position.*

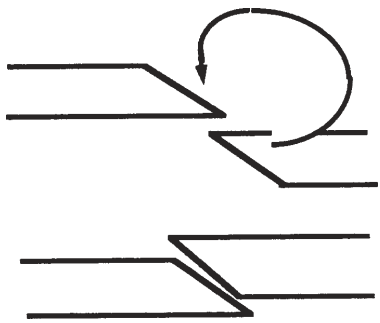
the patient with an image intensifier before washing up to avoid iatrogenic (vessels-nerves) damage caused by inadequate position of the patient on the extension table, to avoid unnecessary complications during surgery, and to sufficiently reposition the fragments.

When the patient is placed on their back, it is harder to enter the femur canal, whereas the rest of the operation is easier to perform. The injured leg is placed a bit lower, the body is slightly moved in the opposite direction, the arm on the injured side is placed over the chest of the patient or on a vertical handle. This way there is enough space to work in the hip area. We should not pull too hard on the healthy extremity to avoid damage on the femoral, pudendal and ishiadic nerve (traction over the knee).

We must always perform skeletal traction on the injured limb over the condyles of the femur bone, using the Steinman nail. We must place the Steinman nail as low as possible, close above the inter-condylar fosa so it does not disrupt the insertion of the nail later. This way traction over the ligaments, vessels and nerves of the knee is avoided, as is any iatrogenic damage on the peroneal nerve (picture 3). If the patient is placed on their side, it is easier to enter the femoral canal, but the reposition is harder. It is very important to set the support on the perineum at the right height, because if it is placed too high, it can damage the pudendal nerve, cause movement of the upper particle and make the reposition harder to perform (picture 4).



Picture 5. *Measuring the length of the uninjured femur with an image intensifier.*



Picture 6. *In reducing oblique fragments, we must sometimes release the traction and correctly move the particles (twist one around the other at 180°).*

Longitudinal movement of the particles

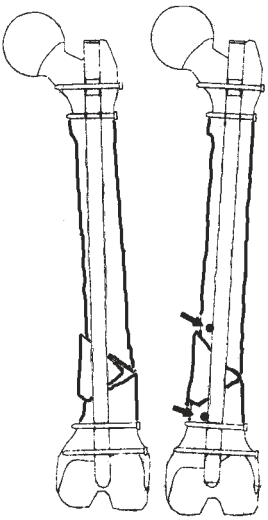
In simple, transversal and short inclined fractures, we can accomplish the correct length of the bone simply by reposition. In long spiral fractures and extensive comminuted fractures this is not always possible. Therefore we must always measure the length of the healthy femur with the image intensifier before the operation, and bear in mind the result while repositioning and fixating the broken bone (picture 5) (3).

Side-ways movement of the particles

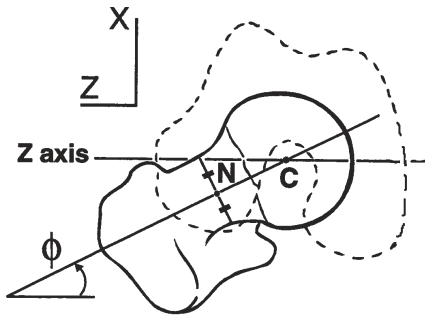
Reposition of these particles is the way to achieve the correct axis of the femur bone. By traction and placement of an intramedullary nail, we ensure the particles to fit closely. Sometimes, side-ways movement cannot be adjusted this way in inclined fractures. In that case, we must loosen the traction, place the particles in the proper position and then reposition them again (picture 6). Reposition of the particles that have moved side-ways at a certain angle, especially in fractures under the narrowest part of the femoral isthmus, can be additionally achieved by using the so-called Poller nails. These nails direct the intramedullary nail in the correct position, which eliminates angular movement (picture 7) (5).

Torsion between particles

In these cases, reposition of the particles is the most difficult to perform. The number of errors in closed reposition and fixations of rotated fragments is the highest. Because of possible differences in the anteversion of the femoral neck in a normal population, most authors agree that only torsion exceeding 15° should be fixed, which considering the diameter of the femur bone means only 5 mm of deviation (3). In general, when adjusting the torque movement between particles, we must bear in mind that the angle between the axis of the femoral neck and the



Picture 7. *Correctly placed additional screws force the IM nail in the right direction and by that additionally correct the femoral axis.*



Picture 8. *The angle between the axis of the neck and the axis over the femur condyles.*

axis over the femur condyles (anteversion) measures approximately 15° (picture 8). When the patient's hip of the injured extremity is supported while the patient is placed on their back on the extension table so that we get a complete side picture of the femoral neck which is in a horizontal position, parallel to the surgical table (which at the same time facilitates the entry into the femur canal), we must rotate the distal particle (condyle and the patella) inwards at an angle of 15° in regard to the uninjured extremity.

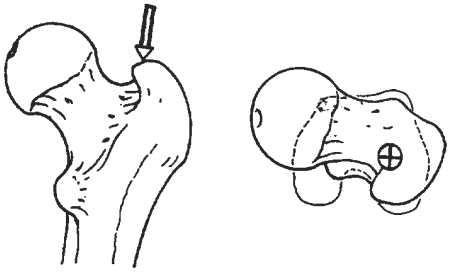
Additional reposition can be done with an image intensifier. We can achieve precise reposition if we measure the angle of the anteversion on the healthy extremity before reposition. The measured angle is then considered during reposition (3, 6). The method of observing the *lesser trochanter shape sign (LTSS)* can also be applied for clinical use. LTSS means that, when rotated outwards the shadow of the less trochanter is smaller, whereas when rotated inwards it is bigger. The method is based on comparison to the healthy extremity. We place the lower particle in the same position as on the healthy extremity while we rotate the upper particle with the help of the Schanz nail, applied for this purpose, until the shape of the less trochanter is the same as of that on the healthy extremity (3). We further monitor reposition of the rotated movement of particles with the help of an image intensifier.

We observe the *cortical step sign* (the difference in diameter of the cortical bone in adjoining particles) and the *diameter difference sign* (difference in bone diameter), which occur if torsion is not prevented (the femur has an oval shape in the transversal section).

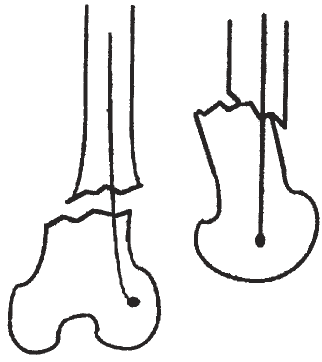
After fixation of the bone, we must always compare the adjusted femur to the uninjured bone in the operating room – especially the length and the reposition of rotating particles (rotation in the hip must be the same on both extremities). Some authors report of lower number of errors in closed reposition of the rotated fragments with the use of the distractor, because it allows intra-operative control of axis, rotation and length in comparison to the healthy extremity (3, 5).

7. Surgical incision

The surgical incision is made at the outer side, from the top of the large trochanter up. It should be approximately 5 cm long. It should not be made too much in front because it could prevent proper entry into the femur canal.



Picture 9. *Entry point for femoral nails in the piriformis fossa.*



Picture 10. *Position of the ball tipped guide wire (rod) in fractures distally from isthmus.*

8. Entry

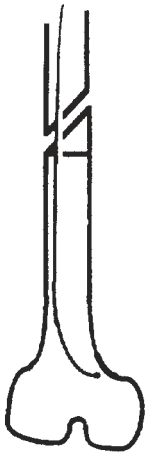
The entry into the femur canal lies in fosa piriformis (picture 9). We can make it with a hollow drill that is applied over the guiding wire, with a special chisel, or with a bodkin. Entering the canal at the wrong place can bring to additional - iatrogenic fracture. *Ramus ascendens* of the *arteria circumflexa femoris medialis*, which supplies the most of the femoral head lies medially, very close to fosa piriformis, and choosing the wrong entry may bring to aseptic necrosis of the femoral head.

9. Insertion of the guiding wire

We insert the guiding wire through the entry into the femur canal and over the fracture to the end of the canal. It has a thickened and slightly bent top. By inserting the guiding wire, we ensure additional reposition of the particles, and we ream the canal over it. The thickening and the bending allow easier insertion. We can use the thickening to remove the drill if it breaks during reaming, and it disables the wire to go too deep. In fractures below the isthmus, we must insert the wire and then the nail as deep as possible – into the condyle. This way movement of the particles is eliminated later (picture 10). In fractures with non-moving wedge-shaped particle the bended end of the wire should slide towards the wedge-shaped particle, so that additional fracture, caused by reaming, can be avoided (picture 11).

10. Reaming of the femur canal

There is no proof in practice that non-reamed nails lead to faster reparation of the bone in comparison to those that need to be inserted with minimal reaming. In fact, the latter result in less unrepaired fractures and implant fractures (11). Reaming is minimal, until we can feel the cortical resistance. Excessive reaming damages the vessels or does thermal damage to the bone, increases the pressure inside the femur canal, causes embolization, increases fragmentation, reduces the firmness of the cortical bone, increases blood loss and extends the duration of the operation. Drills must always be sharp. The force used for reaming should be small. We should begin reaming with the 8 mm drill and then gradually enlarge the diameter by 0.5 mm.



Picture 11. *Position of the wire in fractures with wedge-shaped particle.*

11. Placement of the intramedullary nail

We insert the nail over a straight guiding wire without the thickened end. First we insert the guiding wire with the thickened and slightly bent end through the medullary canal. Over that wire, we insert the plastic quiver and then remove the bent wire with the straight wire without a thickened end. The guiding wire without the thickened top guides the nail in the right direction. We remove it after the nail has been inserted. In fractures in the

area above the isthmus of the femur, the nail must reach below the isthmus, as far as possible – into the femoral condyle. Upside, the nail mustn't exceed the height of the large trochanter. In simple fractures, we appoint the length of the nail during the operation, for example with the help of a metal measure on the image intensifier. In complicated fractures, when we must define the length of the fractured femur before the operation, the length of the nail is also chosen in regard to the comparison with the healthy bone. Diameter of the nail should be 0.5 – 2 mm smaller than the diameter of the reamed femur canal. In practice this means 10 mm nail for most women and 11 mm nail for most men.

12. Locking the intramedullary nail

After inserting the intramedullary nail, we must fasten the locking screws. The upper locking screw is fastened with a handle, and the lower screws are locked with the use of the image intensifier (*free hand technique*). There are also some specially designed devices available for locking the lower screws without the use of an image intensifier, but they require extreme precision and an additional opening at the lower part of the femur for a sensor.

Some nails allow dynamic locking at the upper part, but this method is being abandoned because many studies show that dynamization is not necessary for the reparation process in 98 % of all fractures, whereas 10 % of all fractures move later because of dynamization and therefore repair with deformity (Brumback, 1988).

When locking the lower screws, their length is very important. If they are too long, they irritate the soft tissues at the inner side of the knee, limit its flexibility, and cause pain. Forgetting that the front side of the femoral condyles is narrower in the back usually causes deciding on the wrong length. After inserting the lower locking screws, we must check if they are not too long. If they are, we can feel them at the inner side of the knee.

13. After the operation we must always check...

Besides the position of the adjusted particles and rotation of both hips, we must check the knee ligaments while the patient is under anaesthesia in the operation room. Later, we check blood for complete blood count and electrolytes, look for any iatrogenic damage... Post-operative X-ray pictures film the achieved reposition, any iatrogenic damage or overlooked fractures.

14. X-ray radiation

The necessity of an image intensifier and therefore exposure to damaging radiation (especially of the operator) is the downside to performing femoral shaft fractures fixation with locking antegrade intramedullary nails. Use of modern image intensifiers, protection and application of the convenient surgical technique can notably reduce the amount of X-ray radiation on the operator, even in often operations (4).

Post-operative instructions

The first 6 weeks

Hospitalization usually lasts 10 to 14 days. In the first 3 to 5 days, the injured extremity must be placed on some pillows, the hip and knee flexed at an angle of 90° to facilitate the rehabilitation process (1, 2, 5). Exercises on a dynamic brace should begin as soon as possible. The patient

should be encouraged to get up and walk with the help of crutches. We decide on the amount of burdening individually, with regard to the position and type of fracture, body weight, diameter of the nail, cooperation, and formation of callus. We must give special attention to strengthening the quadriceps, hip abductors and exercising the knee.

6-12 weeks

We allow the patient to gradually burden the injured extremity with regard to the amount of formed callus. Rehabilitation proceeds.

3-6 months

Most patients can burden the treated extremity normally and bend the knee. Most fractures are overgrown with bony tissue. If the fracture is already ossified but the knee can only be bent at an angle of to 110°, we must exercise the knee under anaesthesia. The knee on the injured leg must bend to the same extent as the healthy knee, which requires exercise and physical treatment.

Complications due to associated fractures and injuries

Patients with femoral shaft fractures can have an **associated fracture of femoral neck** that is often overlooked before the operation. Therefore X-ray pictures of the whole femur in proper projections are required before the operation. We fixate such fractures with a reconstruction nail. If this fracture is noticed after having fixed the femur shaft fracture with a locking antegrade intramedullary nail, we must fixate it with individual nails, inserted in front of the intramedullary nail where there is enough space for that. Femoral neck fracture can also occur during the insertion of the intramedullary nail; therefore intra- and post-operative examination of this area is recommended, with the use of an image intensifier.

Femoral shaft fractures are likely to be **associated with a tibial fracture** (*floating knee*). In these patients, fat embolism can occur and can often lead to death. The tibial fracture is often an open fracture. Both fractures must be treated immediately, where the tibial fracture should be treated before the femoral shaft fracture because of the highly sensitive soft tissues. Placing the retrograde nail for fixation of the femoral shaft fracture and the antegrade nail for fixation of the tibial fracture means only one incision is required for fixation of both bones (5).

The femoral shaft fracture can also be **associated with a fractured patella at the same side**. Both fractures are treated under anaesthesia at once. It is the only way the patient can rehabilitate early and long-term reduced flexibility of the knee can be avoided.

The femoral shaft fracture can **coincide with injuries of the knee ligaments at the same side**. We must treat the femoral shaft fracture as soon as possible. The knee ligaments must be checked after fixation. If necessary, we treat the injured knee ligaments surgically later.

In **polytraumatized patients**, the chosen fixation technique of the femoral shaft fracture depends on the condition of the patient. When the patient's condition is instable, we must fixate the fracture with an external fixation, which is later, when the condition is stabilized and there are no signs of infection, replaced by an intramedullary nail (7). If the condition of the poly-traumatized patient is stable enough, we can immediately fixate the femoral shaft fractures with one intramedullary nail, with no or minimal reaming. Intramedullary nailing cannot be used in patients with lung contusion because this would help develop pulmonary complicati-

ons. Femoral shaft fractures in poly-traumatized patients must be treated immediately after the life preserving procedures have been completed in order to avoid numerous complications, fat embolism, infections, etc., and to decrease the possibility of ARDS (8, 10).

Treatment of **open femoral shaft fractures** should be immediate. We should treat those fractures surgically within 6 hours after the injury, because of the high risk of infection. Infection of open femoral shaft fractures after fixation with an intramedullary nail with no or minimal reaming occurs approximately as often as in external fixation (1, 2, 5). Therefore we use the locking intramedullary nail for fixation of all types of open femoral shaft fractures, except of type III C (1). If the fracture was initially fixated with an external fixator, we replace it within 3 weeks by an intramedullary nail, if the soft tissues have healed sufficiently and there is no sign of infection (7).

Removal of the intramedullary nails

We only remove the intramedullary nails in young vital patients, where additional injury could cause much more damage if the nails had not been removed (12). We remove the nails after 18 months or later, but usually after 2.5 to 3 years after the operation. In other patients, nails are only removed if any complications occur.

Conclusion

Fixation with locking antegrade intramedullary nails with no or minimal reaming is currently the most important method in treatment of femoral shaft fractures.

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