Intramedullary nailing of proximal femoral fractures

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Abstract

Intramedullary fixation of trochanteric fractures is biomechanically one of the best methods and enables early rehabilitation and weight-bearing of the fractured extremity. It has some important advantages in comparison to other extramedullary fixation methods like less blood loss, extrafocal (fracture) opening, firm fixation with indirect healing and reduced number of local and systemic complications. There are three commonly used intramedullary methods (and modifications) for the fixation of trochanteric fractures: intramedullary hip screw, long intramedullary hip screw and reconstructive intramedullary nail. For the good end result of intramedullary fixation all the instructions and criteria for the use must be taken into consideration.

Introduction

Proximal femoral fractures are characterictic injuries in senior patients. Their number rise exponentially after the age of sixty and are twice as common in women. Because of reduced thickness of the bones, even weak forces, e.g. simple falls can cause fractures. Young patients usually suffer such fracture under the influence of strong forces, which occur in falls from a certain height, traffic and other accidents. We are often dealing with poly-traumatized patients.

Until the end of the 19th century bed rest was the only treatment prescribed to patients suffering from proximal femoral fractures. In the beginning of the 20th century, such fractures were treated with traction. First operative attempts took place in the 1930, and they flourished in the 1960's when the AO method was developed. Based on numerous biomechanical studies, rapid development of osteosynthetic materials and consideration for biomechanical features of the fractures and implants, operative techniques improved and became more and more efficient.

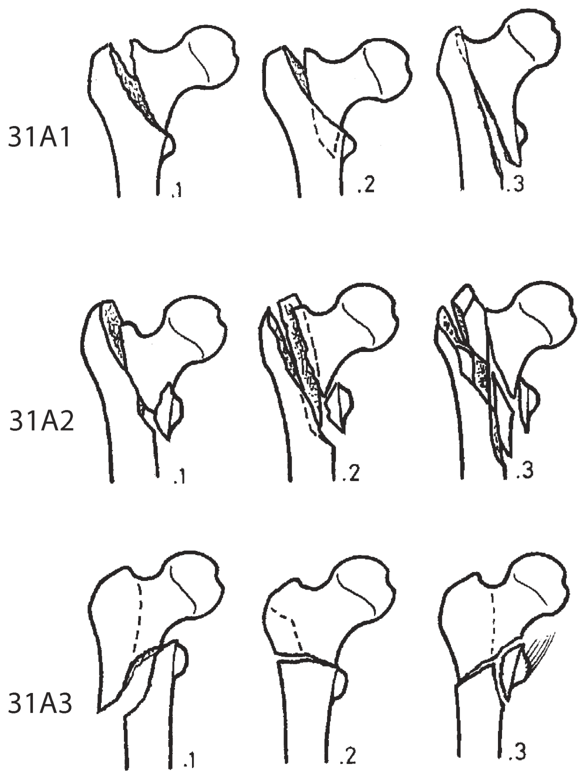
Proximal femoral fractures are usually treated surgically and only in exceptional cases conservatively. Mortality in the first year is still high, 14-50 %, 25 % in average. Only immediate and carefully planned fixation can allow the patient to survive the injury, rehabilitate and return to normal life.

Indications and contraindications

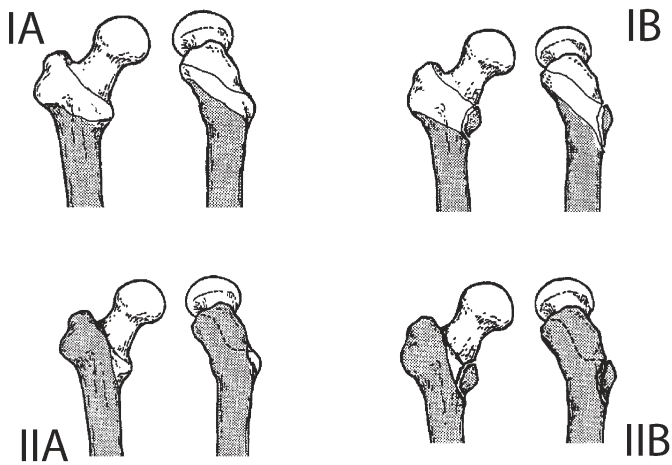
Decision for intramedullary fixation of proximal femoral fracture is based on the X-ray pictures in two projections and on the Russell-Taylor's criteria for fracture classification. Because of the diversity of proximal femoral fractures, several approaches to the treatment have been presented in the past. AO/ASIF typology divides trochanteric fractures into 3 groups, based on the anatomy of the proximal femoral bone: 31A1, 31A2, 31A3 (Picture 1). Each group is further divided into three groups, meaning fractures are divided into 9 groups. The first group is pertrochanteric fractures where the fracture line leads oblique from the greater to the lesser trochanter. Inter-trochanteric fractures, with a various number of particles, where the lesser trochanter is divided, form the second group. The third group includes subtrochanteric fractures, which occur in the area bellow (or reversely between) both trochanters and lead to the upper third of the femur. The greatest disadvantage of this classification is if there are fractures that occur in two or three areas what makes a problem how to include them into any of these three groups.

Russell – Taylor's typology (picture 2) of proximal femoral fractures is very useful as it also suggests the fixation method to choose. It was developed through years of experience in the field of intramedullary fixation, and finally published in 1989. The division considers 2 criteria:

1. In regard to the fracture in the area of fosa piriformis:
   I. fosa piriformis **is not** fractured
   II. fosa piriformis **is** fractured
2. In regard to the condition of the lesser trochanter:
   A. lesser trochanter **is not** fractured
   B. lesser trochanter **is** fractured



Picture 1. *AO/ASIF classification of fractures.*



Picture 2. *Russel-Taylor classification of fractures.*

This way, four combinations are possible:

1. group **IA**: fractures, leading below the lesser trochanter to the greater trochanter without fracture of fosa piriformis.
2. group **IB**: fractures of the lesser trochanter, leading to the greater trochanter, while fosa piriformis in not fractured.
3. group **IIA**: fractures, spreading from above the lesser trochanter, which is not broken, to the fractured fosa piriformis
4. group **IIB**: fractures of the lesser trochanter and of fosa piriformis.

The proper definition of the fracture is crucial for the choice of intramedullary fixation (Table 1). We must also consider the age of the patient. The method cannot be applied on children, where the growing zones are still opened. We should avoid the procedure in adult patients when general contra-indications for the operation occur. Fractures in patients with severe pulmonary damage should not be treated by intramedullary fixation because of increased threat of lung complications (ARDS, pulmonary embolism). Disruptions in coagulation and thrombocyte aggregation are also considered as relative contra-indications. In those cases, patients require proper treatment before operation. Intramedullary fixation is also applicable in pathological fractures, caused by metastasis of known source.

Russel-Taylor	**METODA**
IA	CHS, DHS
IB	RN, UFN
IIA	IMHS, GN, UFN
IIB	CHS, DHS + avtologna kost, RN

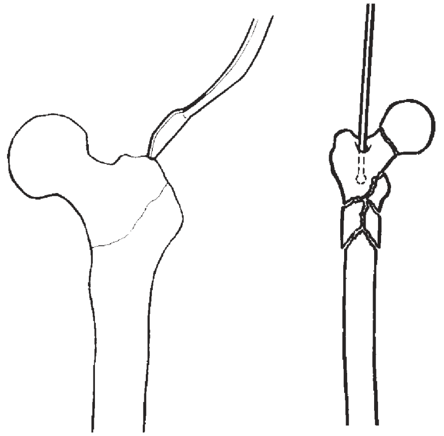
Table 1. *Russel-Taylor typology of fractures and recommended fixation methods. Legend: GN – gamma nail, IMHS – intramedullary hip screw, UFN – undreamed femur nail, DHS – dynamic hip screw, CHS – dynamic hip screw with a cranial supporting plate, RN – reconstruction nail.*

Intramedullary fixation technique

The final result of the fracture treatment depends not only on the choice of the type of intramedullary fixation, but also on the technique and the post-operative treatment. Therefore it is important to realize the pros and cons of the chosen type of intramedullary fixation. Complete instrumentary, nails and screws of various sizes are required. We must carefully decide on when to operate. We should treat isolated proximal femoral fractures immediately if the patient's condition allows it. When there is more than one fracture, we should treat all of them within 24 hours. Open fractures should be supplied within 8 hours. If the operation must be delayed for more than 12 hours, a skeletal traction can be performed. Anaesthesia can be local or general, depending on the age of the patient, their medical condition (diseases, etc) and associated injuries.

The patient is placed on the back on an extension table during any of the intramedullary fixation techniques, performed on proximal femoral bone. The traction of the injured extremity can be performed with a cuff over the foot or with a Steinman nail through the lower part of the femoral bone. When using the classical intramedullary nail (*Intra Medullary Hip Screw*-IMHS, *Gamma Nail*-GN, *Proximal Femur Nail*-PFN), the non-injured extremity is maximally abducted in a stretched-out position. When using the long classical nail (*long* IMHS, *long* GN) or the reconstruction nail (*Standard Recon Nail*, *Delta Recon Nail*, *Spiral Blade Nail*), the healthy extremity is abducted, slightly stretched out and bent in the knee, so that the lower part of the femur can be visible with an image intensifier in order to apply the distal locking screws.

Reposition of the fracture is usually closed. We perform moderate traction of the extremity in the outer rotation and then twist it to inner rotation to central position. If this in not possible, we must do a reposition the fracture in an open way, which lasts longer and adds risk to the procedure. We control the success of the reposition in two ways. First is through controlling the imaginary line connecting *spina iliaca anterior*, the patella and the thumb, which allows us to successfully adjust axis of the femur. The X-ray (C-arm) monitor (machine) allows us to observe any side deviations (valgus, varus, anteversion, retroversion), movement of the fractured particles in the horizontal plane (lateral, medial, anterior, posterior), proper rotation and length. Two X-ray monitors facilitate and accelerate the control. One can be set to film the anterior-posterior projections, and the other can monitor the side projection. The application of two X-ray monitors also reduces the possibility of a wider-spread contamination, because it does not require any turning or moving of the device which would require repeated sterile covering of the X-ray monitor and of the operation table.

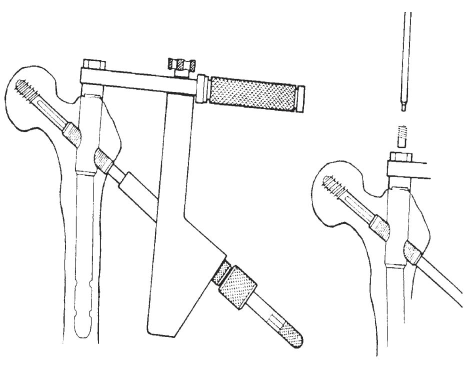


Picture 3. *Entry point for the classical and long IMHS (left) and for reconstruction nail (right).*

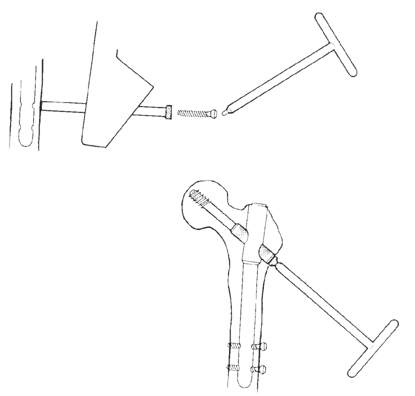
The incision is the same in all methods and leads from the top of the large trochanter up and slightly backwards. It is 5 to 10 cm long, depending on the anatomic conditions. After incision of the skin and subcutaneous tissue, we cut through fascia and move the gluteal muscle in order to reach the top of the greater trochanter. The location of the entry is different in different techniques (picture 3). We insert classical and long nails close to the top of the greater trochanter, whereas the reconstruction nail is inserted into fosa piriformis.

There are more than one ways to make the opening. We can insert the Kirschner wire into the upper part of the femur, check its position with an X-ray monitor and ream a hole with a drill over the wire. Using a special awl or another instrument, we can enter the medullary canal easier. Trepanation is followed by the insertion of the guiding wire into the medullary canal. The wire has a thickening at the lower end to prevent the drill to fall into the medullary canal if it was to break or fall off the reamer. We check the position of the wire and of the fractured particles with an X-ray monitor. The next step is reaming the medullary canal, which varies in different techniques. After reaming, we insert a special plastic tube over the reaming wire, and then we remove this wire and replace it with a guiding wire without the thickened end. After we remove the plastic tube, we insert the intramedullary nail (picture 4). Before that, we must couple the nail and a handle for the dynamic and locking screws. We must check the position of the nail with an X-ray monitor and when we reach the desired depth (with the central hole); we insert the guiding wire through the proper metal sleeve for the dynamic screw. The position of the wire should be slightly below the middle of the femoral neck in AP projection, in the middle of the neck in lateral projection and in the centre of the femoral head in both projections. The position must be checked with an X-ray monitor. With the help of a measuring scale, applied on the guiding wire, we can determine the length of the dynamic screw. Then we ream the canal for the dynamic screw over the guiding wire. The reamer is so designed that the depth of the reamed canal can be set in advance to prevent reaming through the femoral head into the joint. Finally we must drill the cortical bone at the outer side with another thicker reamer above the guiding wire.

After this steps have been done, we tap (engrave the coils) the hole for the dynamic screw which should be screwed to the proper depth. With a special inserter we apply (hammer) a keyed centering sleeve (metal bolt) above the dynamic screw into the nail. We fasten this sleeve tightly with a special (locking) set screw, which is placed into the canal of the nail from the



Picture 4. *Placement of dynamic (lag) screw (left) and screw for fixation of a key centering sleeve (right).*



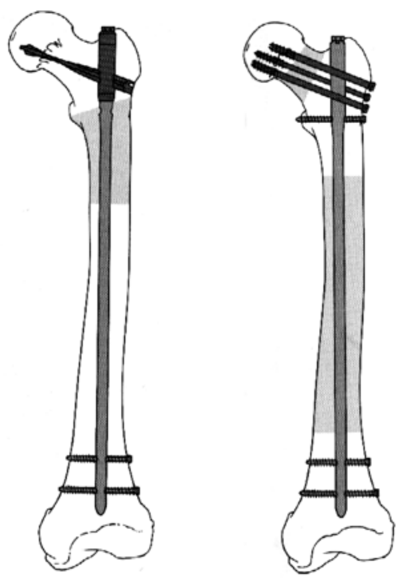
Picture 5. *Placement of locking screws and compression screw.*

top. This construction enables the compression of the particles with an additional compression screw (picture 5), which we fasten into the bottom part of the dynamic screw after removing the guiding wire.

In the next step, we insert the distal locking screws through the arm holder and special sleeves. With the help of an adjusted measure we determine the length of the screws. Taping (engraving the coils) for the screws is not necessary. At the end the position of the screws must be checked in both projections. Finally we remove the guide (arm), check the wound, and close it in layers with drainage.

The technique of applying long IMHS follows the described procedure, the difference occurs because the long IMHS does not have a guide for the insertion of distal locking screws, which have to therefore be inserted with the help of an X-ray monitor, properly placed for the correct side-ways projection. It is important that the holes on the projection have the perfectly round shape, because this shape ensures the screws to be inserted in the ideal position. We can drill the holes with a special X-ray radiolucent drill-handle. The handle allows non-stop control of the drilling direction to hit the holes in the nail. If such an instrument is not available, we can also insert the screws in a ”free-hand” technique. First we insert the Kirschner wire through the femur and the holes in the nail, and control the position with an X-ray monitor. Then we ream a hole for the screw above the wire, or remove the wire if we do not have the proper drill, enlarge the hole in the femur with the suitable drill, and fasten the locking screw.

When inserting the reconstruction nail (picture 6), the access to the greater trochanter is the same as in other techniques. The difference lies in the entry point into the medullary canal. We insert the reconstruction nail through fosa piriformis. The processes of inserting the guiding wire and reaming are the same. The medullary canal must be reamed approximately 2 mm wider than the diameter of the nail, meaning about 16 mm in the upper area of the femur,



Picture 6. *Examples of reconstruction nails.*

as the nail applied there reaches up to 15 mm in diameter. The fixation of the upper area is also different. There are two types of reconstruction nails: standard and delta recon nail. They differ in a diameter of the locking screws, whereas the locking method is the same in both nails. Proximal locking screws are inserted through the guide (arm holder) who facilitate the insertion and enables the insertion even without x-ray monitor. First we insert the guiding wires through the special sleeves in the guiding arm. K-wires which are later replaced by special screws must lay along-side, parallel to each other. The superior one must be positioned in the upper third and the inferior one in the lower third of the femoral neck and head (in anterior-posterior projection). In the side-ways (lateral) projection the screws must be positioned in the middle of the femoral neck and femoral head line. Distal locking screws are applied in the same way as in long IMHS. There is also a specially designed guide for the application of the distal screws, but its use requires experiences for reliable and quick use. Reaming of the medullary canal must be adjusted to the (minimal) necessary width, because reaming thins the cortical bone and therefore increases the possibility of fracture, prolongs the operative procedure and increases bloodloss, which can lead to fat embolism, pulmonary embolism, and ARDS.

Post-operative treatment

Post-operative treatment and monitoring of the patient is important, too. Experts dealing with intramedullary fixation divide the post-operative treatment into 5 stages:

- first period, within first **6 weeks**: During this time, the patients should not bear weight on the operated on extremity. The patient requires assisted physical treatment (exercising the joints, strengthening of the musculature, learning to walk with remedies – crutches, walker…).
- second period, from **6-12 weeks**: The patient must gradually start to burden the injured extremity, depending on their physical strength, the fixation technique and the healing process, associated with the formation of callus.
- third period, **3-6 months**: The patient must be able to completely bear weight on the operated on extremity and achieve full range of motion of the joints. Callus must be visible in X-ray pictures.
- fourth period, **6-9 months**: If the extremity has not healed by then, a delayed healing is presented and dynamization is recommended (removal of the locking screws).
- fifth period, **more than 9 months**: If the fracture has not healed by now, non-union (pseudoarthrosis) has occurred. Operative treatment is recommended.

Complications

Intra-operative complications

Excessive traction during the operation can damage the ishiadic or the pudendal nerve. Skeletal traction can damage the peroneal nerve. Nerve damage treatment is conservative, rarely operative. Preventive measures are immediate and quick operation, cautiousness during traction on the operating table and when placing the skeletal traction. Reaming the medullary canal and inserting the intramedullary nail can additionally damage the bone. Therefore the operative technique must be precise. In comminuted fractures, we might place the nail or the proximal locking screw in the wrong position. Incorrect positioning of the locking screws in the femoral neck could be avoided if we constantly check the position of the screws with the X-ray monitor.

Precise placement of the guide and correct X-ray projection can prevent improper insertion of the distal locking screws.

Post-operative complications

Infection is the most common post-operative complication. When the post-operative condition is associated with other diseases, open fracture, after late fixation or excessive reaming of the intramedullary canal, infection is even more likely to occur. If the fixation is stable and the fracture is not healed, temporary perfusion of the wound is carried out and we prescribe antibiotics according to the microbiological samples results. If the fixation is not stable, we must temporarily remove the nail, apply proper external fixator, send the bioptic material for further microbiological tests, and then treat the patient with parenteral antibiotics when the probable source of infection is established. If the infection occurs in the healed fracture, we must remove all the osteosynthetic material, perform necretomy (reaming of the medullary canal), send the tissue samples (or osteosynthetic material) to microbiological tests, and treat the patient with suitable antibiotics. It is important to keep in mind that many infections can be prevented if a proper surgical technique is used, excessive reaming of the canal is avoided and if proper antibiotic prophylaxis is applied.

Delayed unions and pseudoarthrosis are mainly caused by infection and long-term absence of bearing weight on the extremity. Delayed bone healing (up to 6 months) is treated through dynamization of the intramedullary fixation. In cases of non-unions or pseudoarthrosis, we must replace the intramedullary fixation and perform autologue transplantation of the bone (spongioplasty). Preventive measures are proper (closed, minimally-invasive way) operative technique, minimal reaming and weight bearing of the extremity on time. Main causes of insufficiently healed fractures are comminuted fractures and non-locked intramedullary fixation. Treatment of mal-unions is surgical. We perform osteothomy, correct the position (alignment and axis), and fixate the fracture again. Preventive measures are careful adjustment of the fractured parts, correct positioning and stable fixation.

Nails are fragile in the area around locking holes (openings). The nail can easily break here, especially when the fixation is unstable. This must be treated surgically; first we remove the broken nail, and then we fixate the facture again. **Fracture of the nail** can be prevented with primarily stable fixation.

The risk of **pulmonary embolism** increases in poly-traumatized patients, in cases of multiple fractures, late fracture fixation, and after excessive reaming of the canal. Treatment is directed towards supporting the vital organs and fibrinolysis. Preventive measures are early and adequate fixation, use of the non-reamed nail when the fracture is associated with pulmonary damage, early rehabilitation and medical prevention of thrombosis (low molecular heparin).

The **compartment syndrome** is caused by vast injuries of soft tissues, arterial bleeding and disorders with the venous output and pressure disproportions in the tight space. Femoral compartment syndrome most commonly occurs in anterior or posterior part, very rare in adductor muscular compartment. Treatment is operative, with the fasciotomy of the front and the back compartment. Preventive measures are meticulous observation, bleeding control during surgery and optimal strategy in type and timing of fracture fixation.

Due to reaming, muscle damage and hematoma, bony tissue can form in soft tissues (**heterotopic ossification**). Treatment is conservative; operation is only exceptionally performed earlier than 12 months after the occurrence. It can be prevented with the removal of the injured tissue, washing and debridement of the wound. Prevention with radiation and medication (non-steroid anti-inflammatory drugs) is controversial.

Aseptic necrosis of the femoral head occurs rarely, mainly due to damage of the vessels at the entry to the fosa piriformis or as a consequence of comminuted fractures in this area. In those cases, secondary total hip prosthesis is in order.

Discussion

Proximal femoral fractures are usually treated surgically. In the last decade, extramedullary methods of fixation with various angular plates or with a compression hip screw with a plate are more and more replaced by newer intramedullary techniques because of their advantages: the surgical procedure is faster, the blood loss is smaller (even up to two thirds), the bone healing (mainly) remains in the reduced position with a biomechanically strong fixation, what allows earlier weightbearing on the bone with less local and general complications.

There are also some disadvantages to this technique, for example the radiation to which the surgeon and the operating team are exposed while using the X-ray monitor, or the higher cost of the implant (method) in comparison to classical extramedullary fixation techniques. Therefore, like all the other methods, intramedullary fixation is not the ideal method in all types of fractures.

Conclusion

Intramedullary fixation of proximal femoral fractures has grown in the past decade to be the most important operative method of fracture treatment in this area. Locking of the nails and fragments in the proximal and distal part insures stability. It can be applied with minimal reaming or even without reaming of the medullary canal. Results of intramedullary fixation of trochanteric femur fractures are promising if a carefully pre-meditated operative plan is made, if the proper method of fixation and good surgical technique are chosen, if any complications are noticed and prevented in time, and if the optimal post-operative treatment is enabled to the patient.

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