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Assessment of femur shaft fractures healing treated by closed locked intramedullary nailing in reference to other methods of osteosynthesis and including indications to dynamization

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SUMMARY

The paper presents our observations of femur shaft fractures healing treated by closed locked intramedullary nailing. The method is, from biological and biomechanical point of view, adventageous connection of conservative fracture treatment and operative method fulfilling stable osteosynthesis requirements and standards. Callus formation in the vicinity of fracture site confirms some elasticity of stabilization, even in spite of static locking. The indications to dynamization should be considered thoroughly. In bone healing stimulation bone marrow injection in the fracture site is efficient. The high effectivenes of method together with low number of complications decides that it almost entirealy replaced plate osteosynthesis.

Key words: femur, intramedullary nailing, fracture healing, dynamization

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Closed locked intramedullary nailing is an effective method for treating femoral shaft fractures. Due to fixation locking and utilization of reconstruction nails this method can be widely recommended in treatment of fractures located outside the femoral isthmus, comminuted fractures in some cases accompanied by severe shaft damage, and two-level fractures with epiphyseal or pertrochanteric fracture [1,2,3,4,5,6,7]. Clinical observations confirm quick bone healing and a small number of complications when compared to other treatment methods [1,2,4].

The aim of this article is to evaluate the morphology and dynamics of femoral shaft fracture healing when the closed locked intramedullary nailing method is used in comparison with other methods of surgical treatment applied previously by our medical team; and to specify recommendations for fixation dynamization.

Treatment of long bone shaft fractures using closed locked intramedullary osteosynthesis has been performed in our hospital department (which is a part of the Trauma Center of the Barbara Regional Specialist Hospital No 5 in Sosnowiec) since 1993. Annually we treat circa 45 patients with femoral shaft fractures which results in a few hundred surgical procedures performed by 2013. The vast group of patients we treat suffer from multifocal and multi-organ injuries. Our patients are qualified for the surgical procedure based on the analysis of radiograms of the knee joint and femur in anterior-posterior and lateral projection as well pelvis radiograms in anterior-posterior projection. If there is a suspicion of transcervical or pertrochanteric fracture located on the same side of the femur and the image from the standard radiogram is ambiguous, a CT scan has to be performed. It has to be noted that in majority

of cases the femoral epiphysis fracture accompanying the shaft fracture is not displaced, which makes it harder to detect [8,9].

In everyday orthopedic practice the evaluation of bone union is based primarily on the analysis of fracture's radiograms that present at least one joint and were performed in anterior-posterior and lateral projection. In the event of accompanying transcervical or pertrochanteric fracture it is necessary to perform an axial image of the hip joint. Because of internal bone splinting with intramedullary nail, clinical evaluation is difficult to perform. Improper bone union can be determined if the patient feels pain at the fracture site when load is applied to the extremity. However, in most cases the patient may have difficulty specifying the exact location of the pain. Even if bone union does not occur at all, the intramedullary nail rarely breaks as opposed to plate osteosynthesis where signifi-

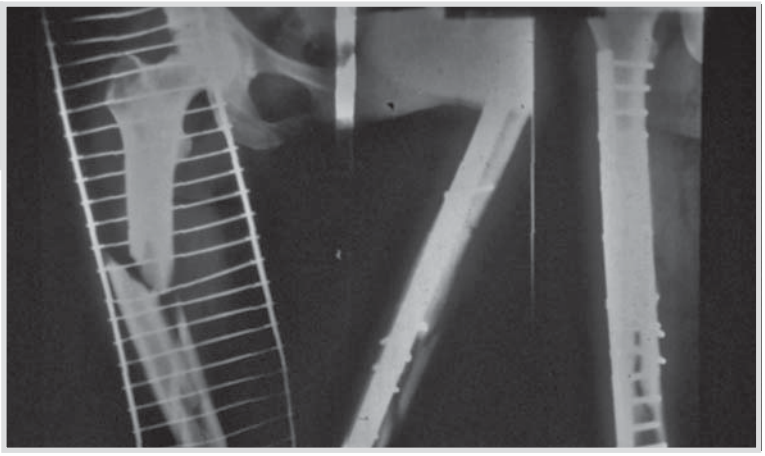

Fig.1. Comminuted fracture of the femoral shaft fixed with plate and srews. Stable osteosynthesis. The lack of periosteal callus four months after the operation impede to assess the dynamics of bone union

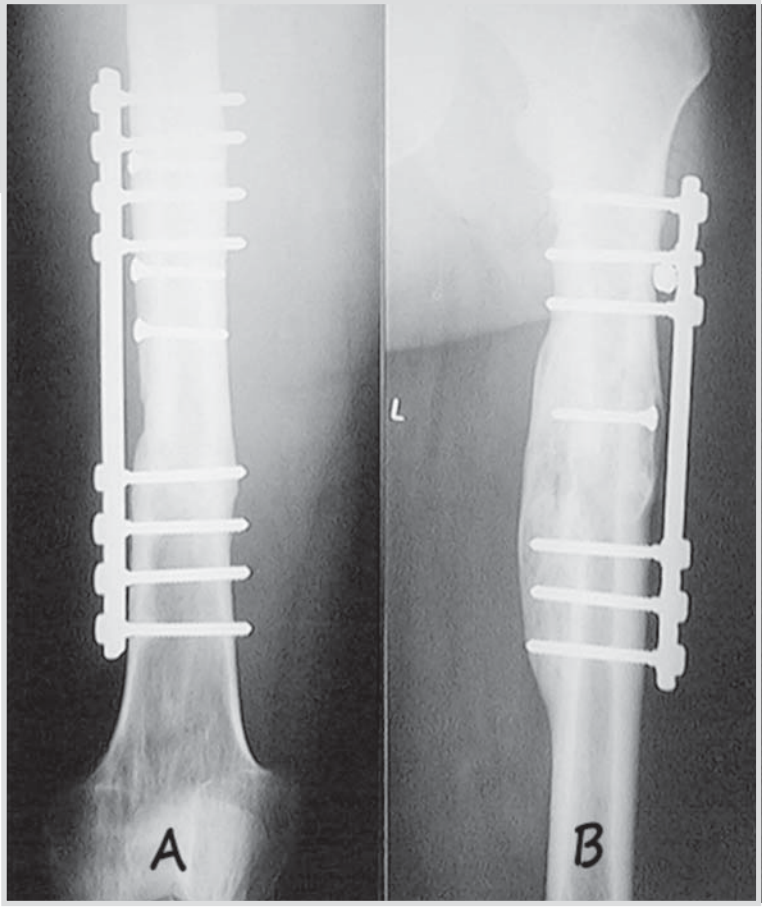

Fig. 2. (a) Fracture of the femoral shaft. Fixation of Zespol plate. The lack of periosteal callus – too rigid fixation. (b) Fracture of the femoral shaft. Fixation of "Zespol" plate. Periosteal callus – symptom „banana" confirms the flexibility of fixation

cant percentage of complications were caused by implant damage.

The principle of stable plate osteosynthesis is that the bone damage site is completely excluded from any mechanical activity. The aim of this method was to obtain a direct bone union, and (in some cases) was characterized by the lack of periosteal callus, which limited the possibility to radiologically evaluate the union dynamics. The biological structure of the bone was weakened due the plate adjoining the bone. This increased the risk of refracture, especially in the early period following the removal of plates (Fig. 1) [7,10 ,11,12].

The radiological proof of osteosynthesis elasticity in fractures treated with the stabilizer, which confirms the proper stress distribution in its vicinity, was the formation of periosteal callus described by Ramotowski and Granowski as the „banana symptom". Due to the presence of callus on the bone side opposite to the plate, a clamp-like fixation became a frame-like fixation which is more advantageous from the biomechanical perspective. According to the authors, the lack of callus resulted in fixation being too rigid [13]. As in case of plate osteosynthesis, this could result in refracture after the removal of implants. This could happen even in case of periosteal osteosynthesis in which the stabilizer's plate did not adjoin the bone directly (Fig. 2a, 2b).

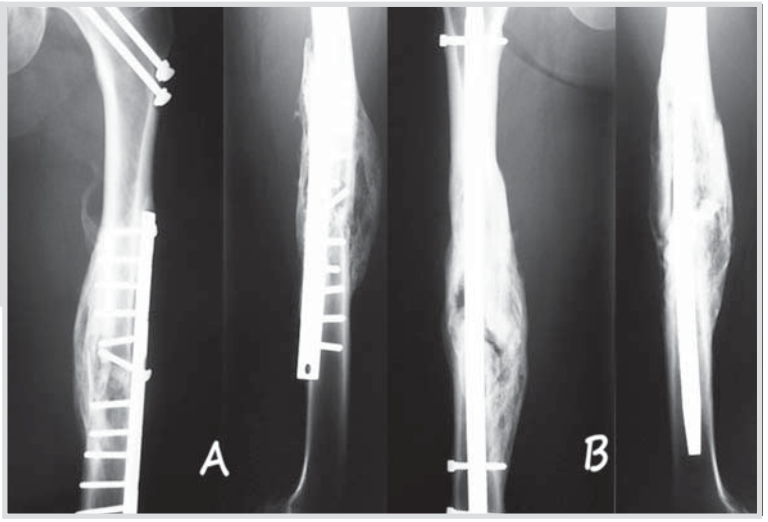

Fig. 3. (a) Fracture plate fixation of the femoral shaft. Rebuilt bone graft on the medial side of the fracture. Next to trochanteric fracture of the femoral neck fixed with screws to trabecular. (b) Intramedullary nail fixation of fracture of the second femoral shaft in the same patient. Image of periosteal callus on the medial side of the shaft, similar to plate fixation assisted bone graft

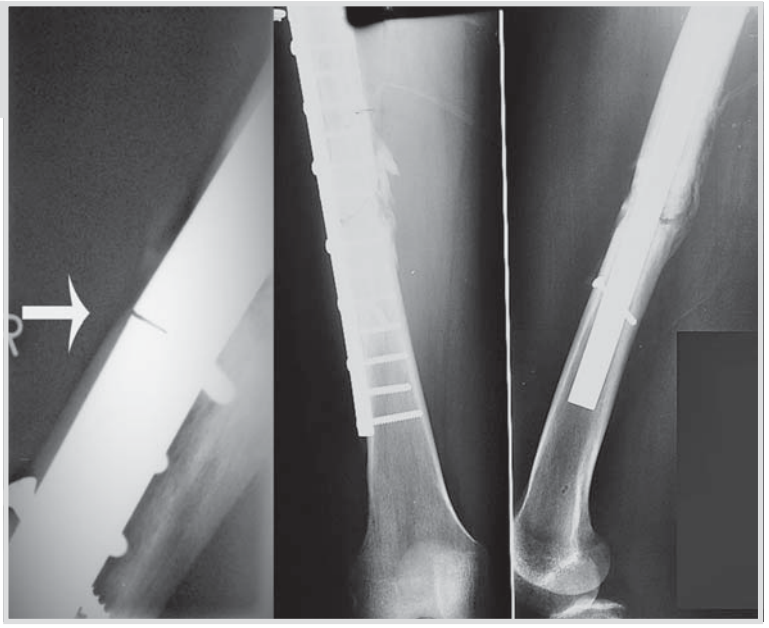

Fig. 4. Comminuted fracture of the femoral shaft fixed with plate and srews. Targeted photo revealed stress fracture of plate (arrow)

The positive process of periosteal callus formation in plate osteosynthesis was obtained by placing the auto or allo bone graft in places where bone was missing or fragmented, especially at the medial side of the shaft where the compressive stress is concentrated (Fig. 3a, 3b). The lack of stable, mechanical support in this place led to fixation loosening and implant damage, including breaking the plate (Fig. 4).

We have observed that, from the biological and biomechanical point of view, closed locked intramedullary nailing is an advantageous combination of conservative fracture treatment and operative method fulfilling stable osteosynthe-

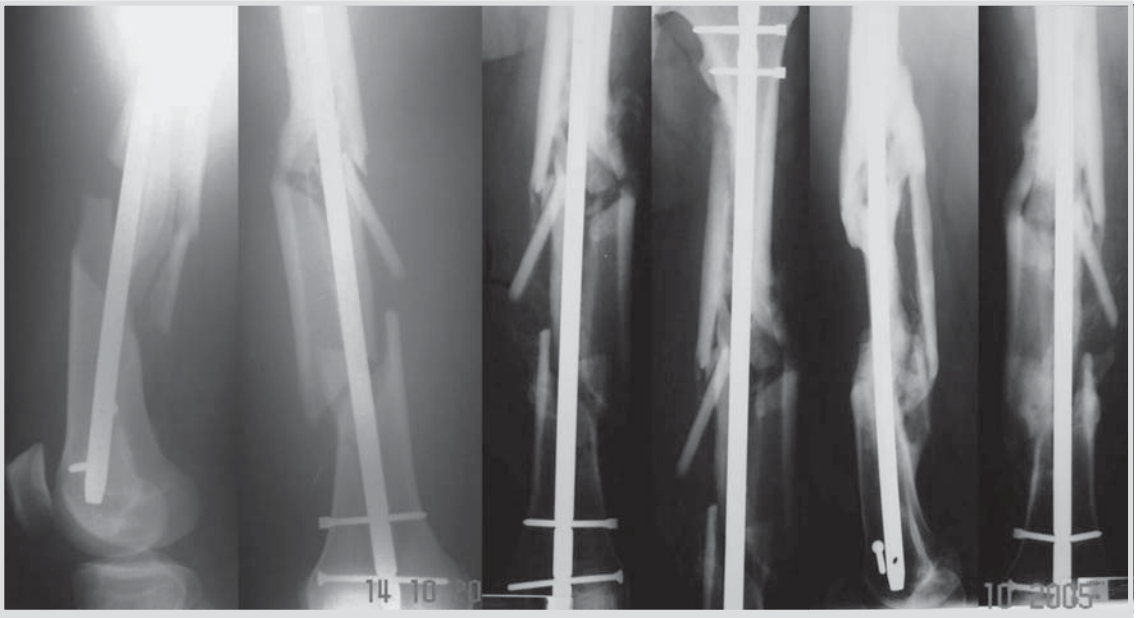

Fig. 5. Comminuted fracture of the femoral shaft fixed with intramedullary nail. The massive callus surrounding the implant and connecting all factions of bone. Fracture of the lower locking screws – natural dynamic of the fixation. The second lower locking screw placed beyond the nail gap

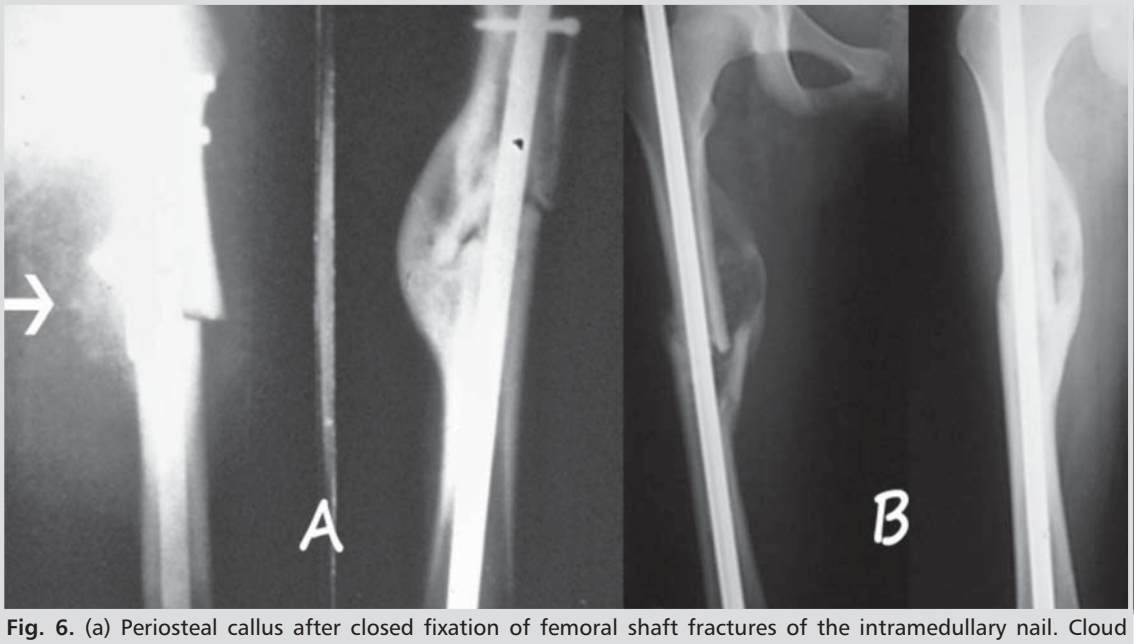

Fig. 6. (a) Periosteal callus after closed fixation of femoral shaft fractures of the intramedullary nail. Cloud of forming callus in the early postoperative period (arrow). Another radiograph shows a consolidated after several months of periosteal callus, but without closing the gaps fracture. (b) Comminuted fracture of the femoral shaft fixed with Kuntscher's nail. The early step of forming periosteal callus on the medial side of the shaft and its good consolidation of them, several months after the operation

sis requirements and standards. Reaming of medullary canal damages the nourishing vessels within it, but on the other hand makes it possible to obtain and implement bone tissue in its vicinity. The tissue acts as a bone graft and is a natural promoter of bone healing process. According to Brumback and Virkus, this significantly reduces the risk of improper bone healing [6].

Substantial femoral shaft fragmentation accompanied by medullary canal destruction constitutes a contraindication against reaming the canal as it may damage the neurovascular structures. To prevent this, the whole preparation process of implementing a nail into the medullary canal shall be radiologically supervised with great caution. In such cases the formation of often massive periosteal callus that joins the main and intermediate bone fragments and surrounds the intramedullary nail depends to a great extent on the formation of large fracture hematoma that tends to develop in such bone injuries (Fig. 5). The hematoma acts as a foundation for multipotent granulation tissue, and its removal (for instance in open fractures or when open reposition is necessary) may lead to bone healing complications. However, according to Jen-Chung and co-authors, in certain cases (for instance simple fractures in patients with multiple body injuries) the open reduction of bone fragments through a small incision in the fracture site substantially reduces the procedure duration and does not bear significant risk of such complications [14].

Radiograms of many femoral shaft fractures treated using closed locked intramedullary nailing, that was performed soon after the surgical procedure and later, confirm the formation and consolidation of callus on the medial side of the bone. The callus matches the rebuilt bone graft implemented at this site during plate osteosynthesis. This confirms certain elasticity of the intramedullary osteosynthesis, even in spite of static locking applied in vast majority of fixations (Fig. 2a, Fig. 3a, 3b). Typically massive at the early stage of bone union, the callus gradually rebuilds and consolidates over time (Fig. 6a, 6b). Along with intramedullary nail it constitutes an effective counterweight to the forces that encourage implant damage. As a result it is possible to conduct early, safe and effective rehabilitation, with just a small risk of mechanical complications. During experimental studies Klein and co-authors showed that the formation and consolidation of callus at the early stage of fracture healing depends on slight mobility between the fragments, which in turn is conditioned by the way these fragments are stabilized [15]. In Brumback's opinion, the locked intramedullary nailing method provides a stable fixation of bone fragments and in the same time allows for slight movement within these fragments. This facilitates fracture healing and confirms this method is better than rigid, stabilized plate osteosynthesis [6]. We think that the shape, size and location of the callus are conditioned by the positive outcome of biological factors (fracture

Fig. 7. (a) Unjustifiable dynamic of fixation. Stress fracture of intramedullary nail following the application of shear forces (arrow). (b) The total destabilization of the fixation wiith accomplished fractur with intramedullary nail

hematoma, bone tissue acting as an autograft) and biomechanical properties of the fixation. In our assessment, the bone union dynamics can be facilitated by means of active motor rehabilitation and gradual application of load to the operated extremity, according to recommendations.

The average healing time for fractures treated with closed intramedullary osteosynthesis is shorter than for open osteosynthesis, but in some cases unsatisfactory in treating physicians' opinion. The dynamization of fixation may be initiated, depending on fracture healing progress. Depending on fracture type, the structure of locked intramedullary nail allows for compressive, dynamic or static fixation of fragments. The aim of procedure involving the removal of nail-locking screw or screws that are more distant from the fracture site is to mechanically stimulate the fracture healing process by applying adequate load to the operated extremity. The stimulation shall not cause the fixation to destabilize, and the recommendations for surgical procedure shall be well thought out. (Fig. 7a, 7b). The advantages of this method were confirmed by Egger and co-authors during experimental studies on animals. In their opinion, the fixation dynamization facilitates the process of bringing the fragments together and improves callus rebuilding thus it becomes more

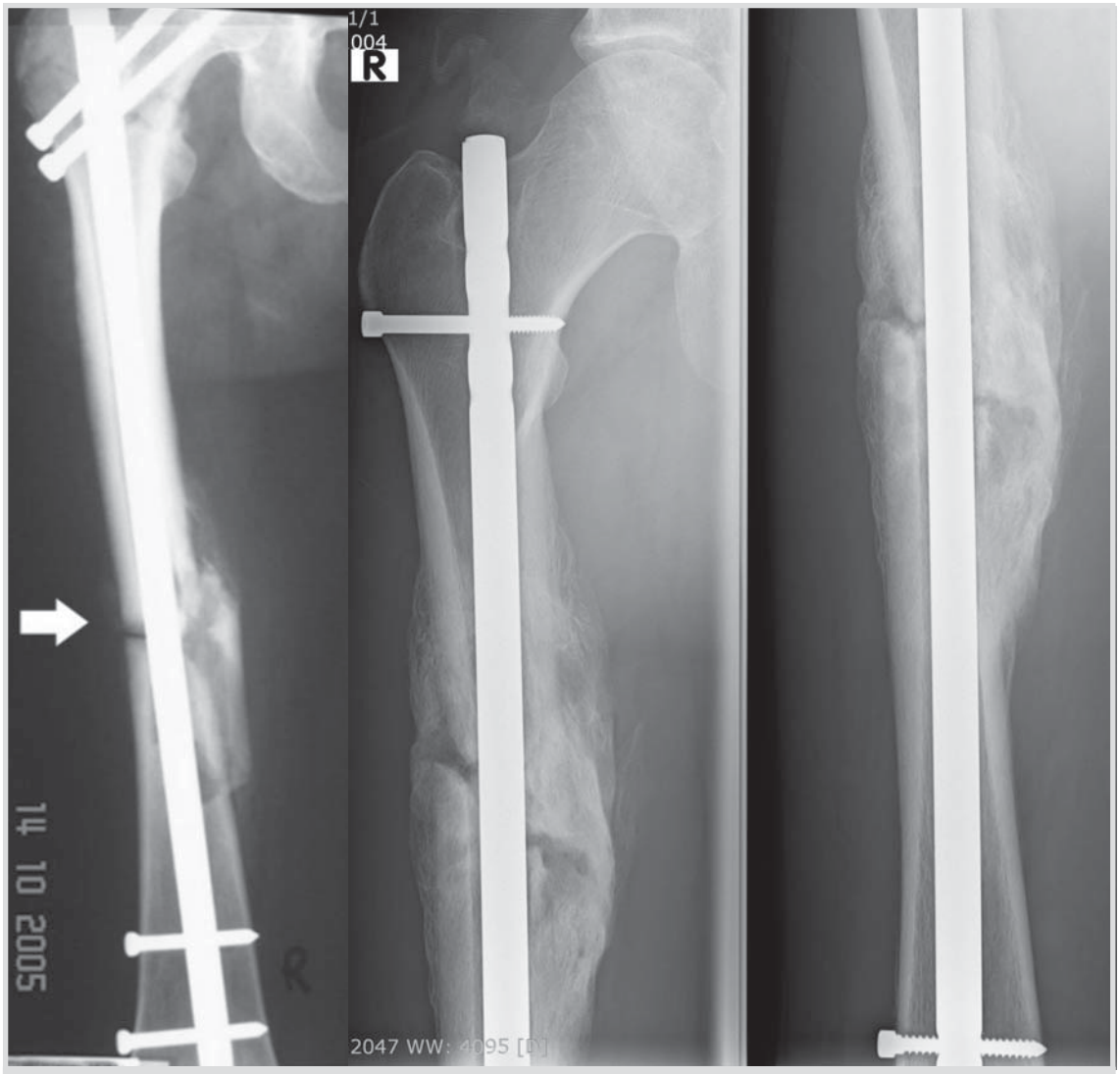

Fig. 8. (a) Fracture of shaft and pertrochanteric of the femur fixed of reconstructive nail. The slit of shaft fractur (arrow) with not fully reconstructed in the calluses in the presence of a well-consolidated periosteal callus, it is non indication to acceleration of fixation. (b) Fracture of the femoral shaft fixed of intramedullary nail, 4 months after surgery. Low rebuilt callus between the main factions, despite of dynamic fixation and well-consolidated periosteal callus on the medial side of the fracture

resilient to rotary displacement without changing its mass significantly [16]. The observations of Augat and co-authors confirmed that axial pressure obtained due to the dynamization of fixation facilitates forming and consolidation of callus in the vicinity of fracture site, which greatly improves its mechanical value; while on the other hand, transverse movement adversely affects the bone healing process [17]. According to Brumback and co-authors, changing a static fixation to a dynamic one after a few months of fracture stabilization may be justified in order to obtain additional callus formation and rebuilding in case a delayed bone void union occurs. The authors suggest that, unless recommended otherwise, a routine fixation dynamization is unnecessary, and the risk of breaking the locking screw is higher if its located too close to the fracture site [3,4].

The presence of nail in the medullary canal prevents the formation of endosteal callus. This type of callus is difficult to present in a standard radiological examination of plate fixations for long bone shaft fractures. However, Dudko and co-authors point out the need for clearing the medullary canal (which may sometimes be strenuous) in procedures that aim at repairing the improper bone union, especially when the implementation of intramedullary nail is necessary. Technical difficulties arising during this procedure contribute to the risk of intraoperative complications which is higher than in case of treatment of fresh fractures [18]. The observation of bone union dynamics in the radiological imaging shows an early formation of bridging callus which joins main and intermediate bone fragments. Absence or incomplete rebuilding of such callus in the fracture gap does not necessarily have to be alarming, and shall not constitute an indication towards fixation dynamization too early (Fig. 6, Fig. 8a, 8b).

Our observations confirm that in some cases the dynamization takes place naturally which is indicated by the broken locking screw (or screws). This primarily concerns comminuted fractures, as well as fractures with little or no contact between the main fragments (Fig. 5). We think that if significant bridging callus joining main and intermediate fragments is present, recommendations for fixation dynamization may be unjustified. What can be recommended is bigger caution when applying load to operated extremity. However, it has to be noted that such load is also a biological factor that facilitates the formation and consolidation of callus. In order to stimulate the bone union process one shall also consider transplanting bone marrow into the fracture site. This minimally invasive procedure can be performed multiple times and its effectiveness is clinically documented [19,20,21]. If bone void is present, it may be filled with autogenous, allogeneic or mixed bone graft. The procedure shall only performed, if there is certainty that all biological possibilities of formation and consolidation of callus have taken place, and the bone void itself is so large that leaving it unfilled could result in bone refracture after the removal of implants.

The result of seeking new solutions is development and clinical application of intramedullary nails that do not require locking screws [6].

1. The healing dynamics of femoral shaft fractures treated using closed locked intramedullary nailing corresponds to natural, biological healing process.
2. Considering this treatment method, in most cases we observe the formation of valuable (also from the biomechanical perspective) periosteal callus at the medial side of the fracture, in the area of compressive force concentration that causes mechanical damage to the implants.
3. This proves certain elasticity of fixation, even despite the static locking that is used in most cases.
4. As long as massive and well consolidated callus surrounding the fracture site is present, the latter formation of callus in the fracture gap between main fragments or slow callus rebuilding shall not constitute a recommendation for too early or unjustified dynamization of the fixation.

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