Original Article

Conventional methodes of osteosynthesis in open tibial schaft fractures Type I, II, IIIA, IIIB

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Abstract

Based on a personal statistical study conducted on a serie of 30 cases with open fractures of the leg, in a 12-year period (2001-2012), we aimed to analyze signs and limits of osteosynthesis with plates and intramedullary rods in these fractures, very common and not infrequently very serious. If in open fracture type I and II Gustilo, this fixation is by far the most accurate, in open fracture type IIIA and especially Gustilo type IIIB, plate and rods should be used with judgment and responsibility. This fixation has precise indications and techniques, so, their presentation outlines precisely its place today, in an era full of car, sports and work accidents.

Distribution of cases in our serie by age and sex, as well as in relation to the fixation methods used by us, with very good anatomofunctional results in 90 % of cases, emphasize their value in strict and precise technique indication cases.

Keyword: osteosynthesis, intramedullary nail, open fracture, tibial, external fixator.

Rezumat

Pe baza unui studiu statistic personal, efectuat pe o serie de 30 de cazuri cu fracturi deschise de gambă, într-o perioadă de 12 ani (2001-2012), ne-am propus să analizăm indicaţia şi limitele osteosintezei cu placi si tije centromedulare în aceste fracturi, foarte frecvente şi nu rareori, deosebit de grave. Dacă în fracturile deschise de tip I si II Gustilo, această osteosinteză este, de departe, cea mai corectă, în fracturile deschise de tip III A dar mai ales de tip IIIB Gustilo, placa şi tijele trebuie folosite cu mult discernământ şi responsabilitate. Această osteosinteză are indicaţii şi tehnici precise, aşa încât, prezentarea lor conturează cu precizie locul ei în prezent, într-o epocă încărcată de accidente rutiere, sportive şi de muncă.

Repartizarea cazurilor din seria noastră pe grupe de vârstă şi sexe, precum şi în raport cu metodele de osteosinteză folosite de noi, cu rezultate anatomofuncţionale foarte bune în 90% din cazuri, subliniază valoarea lor în cazuri cu indicaţie strictă şi tehnică precisă.

1. General date

Before deciding on the technique of osteosynthesis, we must do a rigorous assessment of the degree of stretching and deep soft tissue injuries.

If primary suture is possible, we can achieve internal stability with intramedullary nails and plates screwed.

Typically, in these cases, we carried out a large classic incision or incision was made so that the " skin bridge " remaining to be at least 5 cm wide.

When primary suture or vital local flaps can not cover broken bone, plate fixation is absolutely contraindicated, regardless of the type of plates. Even if the soft tissue state allow fixation plate, the devitalization risk, particularly in comminuted fractures, is a clear contraindication [2, 28, 19, 25, 12].

If hospital's equipment is poor and surgical team is inexperienced and there aren't a plastic and a vascular surgeon, it is better to practice a fracture stabilization with pinless fixator better than plate osteosynthesis or nailing. After healing of the soft tissue, this osteosynthesis can be replaced with a intramedullary rod or a plate screwed (sequential osteosynthesis) [24,13,22,6,21].

2. Osteosynthesis methods

2.1. Locked intramedullary nailing without reaming

It is indicated as initial and unique therapy, in open fractures type I, type II, type IIIA and IIIB Gustilo, and grade 1, grade 2 and grade 3 after Tscherne.

Primary blocked intramedullary nailing without reaming is a relatively simple technique, causing no serious circulatory disorder in the medular canal, provides good rotational stability by blocking screws, allows accurate and complete care of soft tissue injuries and gives a comfort to the patient **(Figure 1-2) (Figure 3-5).** We must not overlook the fact that presents some risk of infection, misalignment of the fracture, blockage and even rupture of the screw and/or even nail.

Figure 1: ***Comminuted fracture of both bones of the left leg, union of middle tibial shaft with lower tibial shaft in type II opening tibial diaphyseal fractures. Preoperative radiologic appearance (left) and profile (right)***

Figure 2: ***Previous case. Postoperative radiological aspects of front (left) and profile (right) blocking intramedullary nail with proximal cortical screw (top). Postoperative radiological aspects of front (left) and profile (right) with a distal cortical screw lock***

Figure 3: ***Right tibial fracture, comminuted, with intermediate piece, type IIIA. Preoperative radiologic appearance (left) and profile (right)***

Figure 4: ***Previous case. Postoperative radiological aspects of front (left) and profile (right) with cortical screw proximal lock (top). Postoperative radiological aspects of front (left) and profile (right) with distal cortical screw lock (bottom)***

Figure 5: ***Fracture of both bones of the right leg and important dislocation of type II open tibial fracture. Preoperative radiological aspects of front and profile (left). Postoperative radiologic appearance of the face and profile (right) tibia fracture fixation with intramedullary static blocked (2 screws proximal and distal)***

Same as is in all other methods of fixation, it requires a thorough debridement and excision of all the soft tissues compromised.

Regarding the stabilization of the fracture, the surgical technique is simple in Tscherne Grade 1 and 2 fractures [29, 3, 18, 33].

Endosteal circulation is reduced by 30% in case of intramedullary nailing without reaming, and 70% with reaming.

Intramedullary nailing without reaming has a much lower risk of infection and much lower magnitude (**Figure 6-8).**

In fractures type IIIA and IIIB after Gustilo, Anderson and Mendoza or grade 3 Tscherne, the intramedullary locked nail fixation has special indications [17, 7, 11].

In the cases with of proximal migration of the intramedullary rod, the occurrence of misalignment in the fracture or delayed consolidation it is absolutely indicated a resumption of fixation.

In comminuted fractures and open fractures located in the 1/3 upper tibia, a normal rod does not confer sufficient stability and therefore resorted to other means of fixation, such as Poller correction screws, extra special implants, including the board "T" or intramedullary rods designed for third upper tibia with a special angle and stable, perfectly anatomically adapted [4, 9, 11, 5].

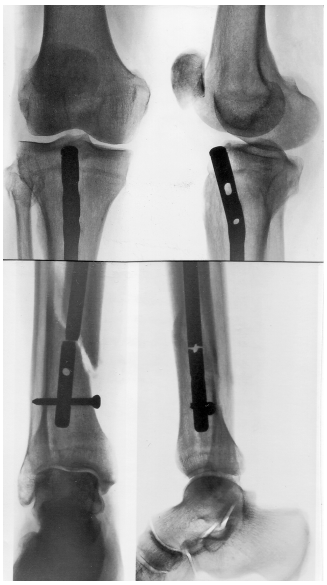

Figure 6: ***Failure of an intramedullary nail with distal blocking without reaming,to the former fracture site in a patient operated on 6 weeks ago. Radiologic appearance of the front knee (left) and profile (right) with associated fibular fracture (above). Radio-logical aspect at the union medium- third lower face (left) and profile (right) on which stands the nail failure and distal locking screw (bottom)***

Figure 7: ***Previous case. Postoperative radiological aspects of front (left) and profile (right) after extracting the nail and ostheosyntesis with plate and 8 cortical screws***

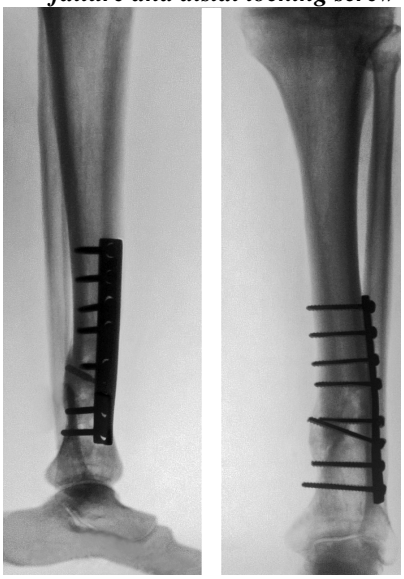

Figure 8: ***Previous case. Radiologic appearance after consolidation (after 5 months) face (left) and profile (right)***

2.2. Elastic intramedullary osteosynthesis rods

There were used Rush, Lottes or Ender rods, which have the advantages of intramedullary fixation without reaming, but without locking. In addition, in comminuted fractures, these rods do not provide sufficient stability to the fracture site and are followed, often of vicious consolidation [10, 11, 32, 16].

Based theoretical research and clinical interest, Samota (1999) recommended the combinated fixation with tibial elastic rods “arc secant" and a bone suture "8", saying that this type of attachment is a biological fixation with indication for unstable fracture or spiroid opening angle, including type IIIB [30,31]. Most modern type seems to be the elastic rod type Marchetti - Vicenza, allowing a double block: screws (proximal) and by fixing divergent rods in cancellous bone (distal). The elastic rod fixation preserves the advantages of elastic intramedullary fixation benefits without reaming and blocking. Stabilization of the fracture is not rigid but dynamic.

2.3. Plate fixation

It is indicated in metaphyseal open fractures Gustilo type I or Grade 1 Tscherne, particularly if the fractures have intraarticular lesions and contamination is reduced (**Figure 9-10**).

Figure 9: ***Fracture of both bones of the left leg at the union medium- lower tibial shaft displacement and type I open tibial fracture. Preoperative radiological aspects of front and profile (left). Postoperative radiologic appearance of the face and profile (right) osteosynthesis with plate and 7 screws***

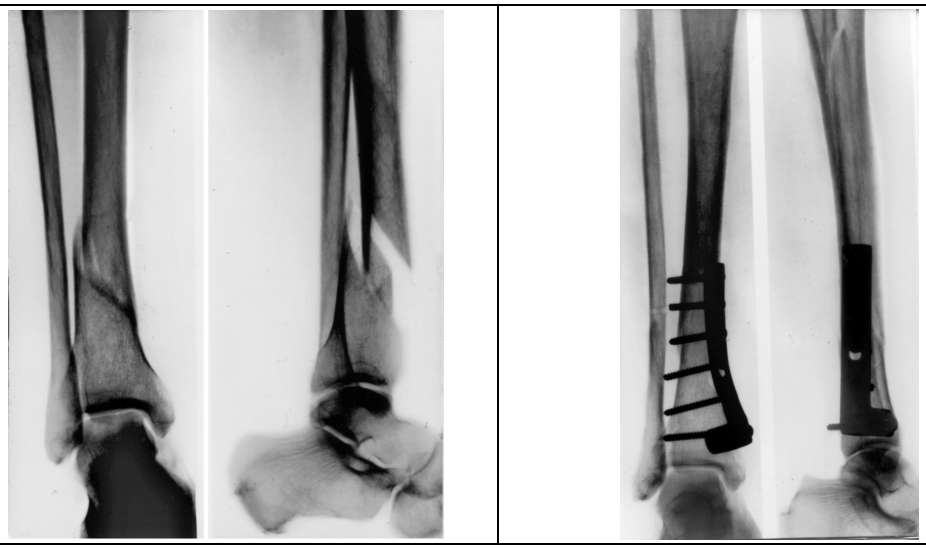

Figure 10: ***Diaphyseal fractures of both bones of the right leg, dislocated and type I open tibial fracture. Preoperative radiological aspects of front and profile (left). Postoperative radiologic appearance of the face and profile (right) tibial ostheosyntesis plate adapted " in L " and 6 cortical screws***

In the type II Gustilo open fractures and Tscherne grade 2, the number of complications is higher when osteosynthesis with plate is performed, due to contusion of the soft tissues in the neighborhood, the need for additional skin incisions to reduce the fracture, the largest bone deperiostation for the application of the plate and the plate cortical necrosis.

In comminuted fractures with strong soft tissue bruise with large and fragmented movement deperiostation, stretched plate fixation is contraindicated (**Figure 11-12**).

Figure 11: ***Comminuted fracture of both bones of the left leg union medium- lower third dislocated, type II open tibial fracture and double floor peroneal fracture. Preoperative radiologic appearance (left) and profile (right)***

Figure 12: ***Previous case. Postoperative radiological aspects of front (left) and profile (right) open source reduction + tibia osteosynthesis plate " in the club " 7 cortical screws through the plate, 3 screws isolated cortical assembly and two anteroposterior isolated cortical screws, intramedullary fibular anterograde K wire and two circles of wire***

Only after healing of soft tissue injuries, we use minimally invasive plate osteosynthesis LISS or LCP, introduced by sliding over the outbreak and fixed with screws percutaneously without denudation fragments.

The advantages of these plates are: stability reduction, immediate functional recovery and extremely comfortable for the patient (**Figure 13-14**).

The disadvantages are not negligible: relatively difficult technique, interception periosteal circulation, increased risk of infections, bone and skin defects, and delay the total load only after consolidation.

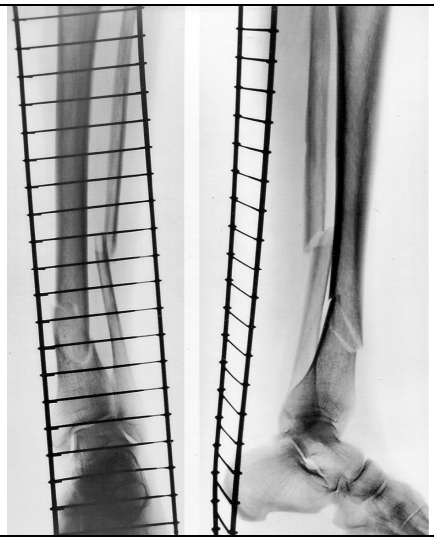

Figure 13: ***Diaphyseal fractures of both bones of the left leg with dislocation in open type II tibial fracture. Preoperative radiologic appearance (left) and profile (right)***

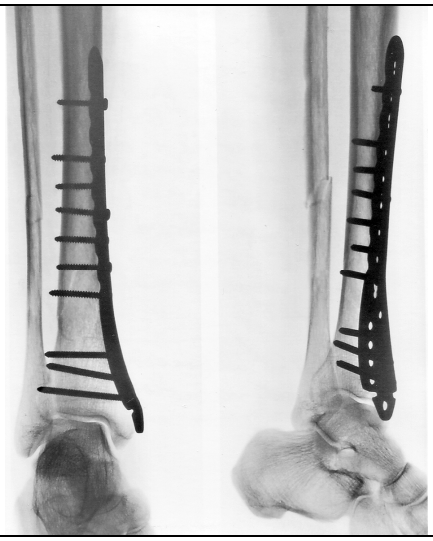

Figure 14: ***Previous case. Postoperative radiological aspects of front (left) and profile (right) closed reduction under control RxTv face and profile + LCP plate osteosynthesis miniminvazive and 10 cortical screws. Note: fibula fracture was reduced simultaneously and perfectly***

There is recommended that the board to be placed on the external side under the muscle, so that it can be well covered by soft tissue.

Primary suture can usually, if not possible, recourse to clearance incisions, temporary or artificial skin or "seal" of the vacuum.

3. Discussions and results

Ma, Wu, Tu and Lin presented their experience with metaphyseal blocked plate as a definitive external fixation in the treatment of open tibial fractures [20]. They conducted two studies, one clinical and the other experimental.

In the clinical study there are presented 8 cases with open fractures of the tibia, the lower shaft, for which they used blocked plates and 10 cases in which they used external fixator.

Finite element analysis revealed that the rotational and axial stability decrease with increasing distance from the axis of the bone, with 12 to 21 % for blocked plate and 84-94 % for external fixator. In other words, these authors recommend a metaphyseal blocked plate in open fractures of the lower tibia.

In open fractures of the tibia and fibula on the lower shaft, Yu Huang suggest, minimally invasive plate osteosynthesis slide type LCP [34].

Their study is based on 26 human cadaver legs and 49 patients (29M/20F) with open fractures in the third lower tibia. Instead of two incisions for stable fixation of these fractures, the cited authors used a single path approach, anterolateral, which involved minimal tissue damage, but requires careful attention to neurovascular axis.

In 1993, Haas and his colleagues practiced fixation with AO type nailing without reaming and without blockage, which provides increased stability and greater sparing endosteal circulation. In a series of 30 open fracture type II, type IIIA, and type IIIB Gustilo, they obtaine consolidation in 12-40 weeks, without having any infection [14].

In a larger series of 117 open fractures (38 cases with fractures of grade 3 Tscherne), Sanders (1994) successfully practiced this method of fixation and pointed the types of fractures for which the method should not be used: open fractures located at the top of the tibia and the lower part, open fractures in the metaphysis open fractures with vascular injury complication. Consolidation was achieved within 4.8 months - 9.3 months, depending on the severity of of the open fracture [27].

The literature date regarding the consolidation by this method varies significantly. Court- Brown (1991) speaks of a mean of 38 weeks (21-94 weeks) [8].

Melcher and colab. (1995) noted that infection after intramedullary nailing with reaming is significantly more common.

Kealing et colab. (1997) obtained comparable clinical and radiological results, in open fractures of type I to type III B, using two methods of intramedullary fixation with and without reaming, but blocking. On this occasion, they noted that screws and rods rupture were more frequent in the technique without reaming [17].

In other words, reaming increase stability but compromises largely endosteal circulation.

Basically, in intramedullary fixation with reaming,the lock becomes useless.

In the period 2003-2009, Kreb and colab. studied 29 patients with diaphyseal fractures of the femur and tibia, including 16 closed fractures and 13 open fractures of type I and type II, for which they used nailing without reaming [18]. This series included only diaphyseal fractures with axial and rotational stability for which they recommend intramedullary rod without blocking, because the blocking had difficulties as prolongs and complicates surgery. By this method the authors have achieved a reduction in the average of 43 minutes, fracture consolidation in 96 % of the cases, with only six surgical complications and a single resume. In conclusion, they consider that a simple method with a shorter duration of intervention and allowing consolidation in the majority of cases.

In 2006-2010, Agrawal and colab. practiced closed intramedullary tibial blocked nailing without reaming, in 32 cases with open fracture type I (10 cases), type II (7 cases), type IIIA (3 cases), type IIIB (7 cases) and type IIIC (3 cases) [1].

The stimulation was done in only 9 cases.

Time to consolidation gradually increased from 16 weeks in type I open fractures up to 32 weeks in type IIIC, with an average of 20.7 weeks.

The conclusion of these authors is that locked intramedullary nailing without reaming, simultaneous coverage of soft tissue defect is followed by a rapid healing with very good mechanical stability and a minimum rate of infection (only 3 cases).

Whittle, Russell, Taylor (1992) and Lavalle reported a series of open tibial fractures treated by intramedullary nailing osteosynthesis without reaming, followed up for a period of one year [35].

Most of them were produced by high-energy trauma, 68 % of cases of type IIIA open fractures, and 32% of type I and II open fractures.

In 5 cases (10 %) they had screw locking break without compromising reduction in 4 cases with type IIIA fractures, secondary infection, in 2 cases the rod was broke in the nonunion fracture, and in one case, the rod was broke in the consolidated fracture.

The results obtained are significantly better than those obtained by other processes for osteosynthesis, such as plaster device, nail without locking and the external fixator.

The authors reject fixation with plate and screws, which would result in a higher risk of infection.

The rate of secondary infection after intramedullary nail reamed is significantly higher. In turn, the external fixator, considered by many authors as the treatment of choice, does not allow a perfect reduction, has a rigid frame and present, often a risk of infection of the sheets.

In intramedullary nailing with static block and reamed, with early support and stimulation provides perfect consolidation, as it is perfectly clear from the study done by Hernández - Vaquero et al. [15]. This comparative study includes two groups of patients with closed fractures and open fractures of the tibia type I, a first batch of 32 cases who underwent stimulation with early support and the second group of 35 cases who underwent static block no support since the consolidation.

The authors compared the five parameters:

- Consolidation periode (21 săptămâni/27 weeks);
- Incidence of nonunion (3 cases / 3 cases);
- Delay of consolidation (1/5);
- Incidence Malunion (fifth) and

- Number of reinterventions (4/10).

All these parameters shows net superiority of locked and stimulation with early support.

Salem conducted a complete study on 101 open fractures type II and IIIA of the lower tibia, who underwent fixation on the outbreak closed intramedullary nail without reaming [26]. After thorough analysis of the results obtained, the author concluded that this method involves a relatively large number of complications (22.8 %) (delay of consolidation, nonunions, infections) and should be used more rare in these fractures.

Park, Uchino, Nakamura et al. (2007) published a series of 23 patients with type IIIB Gustilo open tibial fractures, divided into two groups [23]. A first group of 9 patients received primary osteosynthesis nails blocked and the second group of 14 patients received primary fixation with external fixators, then converted to osteosynthesis nails blocked. Based on their study and numerous multicentre, prospective, randomized, made by various authors, Park and colab. have concluded that there is a significant difference between the two methods, the second option is the best.

4. Personal statistical study

In a period of 12 years (2001-2012) we recorded 30 cases of open fractures of the tibia, which were resolved by osteosynthesis with different methods, excluding external fixators.

I noticed a minimum age of 15 years (m), a maximum age of 90 years (f) and an average of 50.8 years (Table I).

Table I. Distribution of cases by age and sex

Age group	M	F	Total
15-24	3	3	6
25-34	2	-	2
35-44	-	1	1
45-54	5	4	9
55-64	4	-	4
65-74	3	3	6
75-84	1	-	1
85 years >	-	1	1
Total	**18 (60%)**	**12 (40%)**	**30**

Distribution of cases on other grounds, showing twice of frequency on the right side, the higher frequency of type II open fractures, followed at a short distance from type I fractures and only one case of fracture type IIIA and type IIIB (Table II).

Table II. Distribution of cases on other grounds

- ***Age***
  - minimum age = 15 years(m, obs.16)
  - maximum age = 90 years (f, obs.19)
  - mean age = 50,8 years
- ***The injured***
  - right = 20
  - left = 10
- ***Type of opening***
  - type I = 12
  - type II = 16
  - type IIIA = 1
  - type IIIB = 1

Different surgical approaches have been used, most frequently as a minimum longitudinal subrotulian transligamentar approach (11 cases), followed by longitudinal approach for external tibial condyle and the oblique approach on the two condyles, each in 5 cases, longitudinal approach for internal tibial condyle 4 cases and curved approach for internal tibial condyle in 2 cases (Table III).

Table III. Approach used

- minimum subrotulian longitudinal approache = 11 cases
- longitudinal approache on the external condyle = 5 cases
- oblique approche on the two tibial condyles = 5 cases
- longitudinal approache on the internal condyle = 4 cases
- anterointern approaches curved on the internal condyle = 2 cases

Note: In Note 6, we performed the reduction under control RxTv and tibial fixation with Kwire thick and transplantar.
In note 8 ostheosyntesis transplantar was performed 3 K thick wires and one thick K wire from tibial internal cortical to external malleolus. In note 21, we performed reduction and percutaneous fixation with 4 K wires cross under RxTv control

In three cases, there was not necessarily a typical approach, regarding to the outbreak closed osteosynthesis (with K wires).

As a type of osteosynthesis, as shown in Table IV, intramedullary osteosynthesis prevailed (17 cases), of which statically locked intramedullary nail and without reaming (8 cases), Ender flexible intramedullary rods (6 cases) and intramedullary nail fixation reamed without blocking (2 cases) and intramedullary nailing with and without reaming dynamic block (1 case). It follows that the intramedullary nail static or dynamic blocked, and the rods Ender was used in the majority of cases (56.7 % of the cases).

Table IV. Distribution of cases in relation to the method of ostheosynthesis

Ostheosyntesis with intramedullary nail lock without reaming - 4 cases with static block, one distal and one proximal - 2 cases, static block proximal and distal with two cortical screws - 2 cases blocked with one screw proximal and two screws distal	**8 cases**
Ostheosyntesis with elastic rods type Ender - 1 case with one prespinal Ender rod - 2 cases with two prespinal Ender rods - 3 cases with two Ender rods through tibial condyle	**6 cases**
Ostheosyntesis with adapted plate with 7-10 screws through plate and 1-2 isolated screws	**6 cases**
Ostheosyntesis with adapted plate with 7-10 screws through plate	**3 cases**
Ostheosyntesis with intramedullary nail with reaming but without locking	**2 cases**
Ostheosyntesis with 1-3 K wires transplantar	**2 cases**
Ostheosyntesis intramedullary with dynamic block	**1 case**
Ostheosyntesis with two cortical screws	**1 case**
Percutaneus ostheosyntesis with 4 cross K wires	**1 case**

In second place, is screwed plate fixation with or without screws isolated (9 cases) (30.3% of cases). In an open fracture type II with long paths spiroid I practiced fixation on open source, cross with two screws and in three cases, osteosynthesis minimum cross K wires.

5. Conclusions

a) In open tibial fractures with simple wounds and relatively low soft tissue damage neighboring bone fracture, the indicated fixation is the same used in closed fractures: intramedullary nailing with or without reaming, with or without blocking, elastic rods, plates screwed or cortical screws isolated.

b) Our series includes 30 cases of open tibial fractures, 28 cases with open type I and type II, one case type IIIA and one case IIIB Gustilo.

c) Intramedullary nail fixation was used in 56.7% of cases, static and dynamic locked, but without reaming, but rarely unlocked nails and flexible rods Ender type.

d) osteosynthesis with plate screwed ranks second at some distance. Note that in some cases it was done an interfragmentary compacting with the device Müller.

e) We rarely used K wires.

f) In the higher severity of soft tissue damage, these methods lose their indication and put under the external fixators.

g) Endowment of the service material and experience of the surgical team are absolutely necessary factors to achieve fixation of open fractures with limited soft tissue damage.

h) The results we obtained were very good in 90% of cases. In one case, a month after surgery for a broken nail which resumed the fixation with a screwed plate and obtained consolidation in nearly five months. The other two cases developed local sepsis, which required repeated writedowns but osteitis occurred.

Bibliografie

1. AGRAWAL A., CHIAUDAN V.D., MARESHWARI A.K. – Primary Nailing in the Open Fractures of the Tibiale is it woorth?, J.Clin.Diagn.Res. 2013, vol.7, no.6, p.1125-1136
2. ANTONESCU M.D.şi colab. – Patologia aparatului locomotor, vol.I, Editura Medicală, Bucureşti, 2006, p.250-254 şi p.p.336-346
3. BACH A.W., HANSEN S.T.Jr. – Plates versus external fixation in severe open tibial shaft fractures. A randomized trial, Clin.Orthop., 1989, vol.241, nr.1, p.89-94
4. BONE L.B., JOHNSON K.D. – Treatment of tibial fractures by reaming and intramedullary nailing, J.Bone Jt.Surg., 1986, vol.68-A, no.7, p.877-887
5. BROWN P.V., URBAN J.G. – Early weight-bearing treatment of open fractures of the tibia. An end-result study of sixt-three cases, J.Bone Jt.Surg., 1969, vol.51-A, no.1 p.59-75
6. CAUDLE R.J., STERN P.J. – Severe open fractures of the tibia, J.Bone Jt.Surg., 1978, vol.69-A, no.7, p.801-807
7. CLANCEY G.J., HANSEN S.T.Jr. – Open fractures of the tibia. A review of one hundred and two cases, J.Bone Jt.Surg., 1978, vol.60-A, no.1, p.118-122
8. COURTH-BROWN C.M., McQUEEN M.M., QUABA A.A., CHRISTIE I. – Locked intramedullary nailing of open tibial fractures, J.Bone Jt.Surg., 1991, vol.73-B, no.6, p.959-964
9. FILIPESCU N. – Dispozitivul de fixare externă minim invazivă. Un nou concept în fixarea, axarea şi stabilizarea fracturilor deschise ale oaselor gambei, Editura „Gr.T.Popa", UMF Iaşi, 2008
10. FIRICĂ A., POPESCU R., SCARLET M., DIMITRIU M., IONESCU V., PROTOPOPESCU C., BUGA M., CONSTANTINESCU I., ILIESCU N. – L'ostéosynthèse stable élastique, nouveau concept biomécanique-étude experimental, Rev.Chir.Orthop.(Paris), 1981, vol.67, no.1, p.82-91
11. GORUN N. – Traumatologie osteoarticulară generală, Editura „Curtea Veche", Bucureşti, 2011, p.3-52, p.502-507
12. GORUN N., TROIANESCU O. – Fractura deschisă, Editura medicală, Bucureşti, 1979
13. GUSTILO R.B., MENDOZA R.M., WILLIAMS D.N. – Problems in the management of type III (severe) open fractures: a new classification of type III open fractures, J.Trauma, 1984, vol.24, no.6, p.742-746
14. HAAS N., KRETTEK C., SCHANDELMAIER P., FRIGG R., TSCHERNE H. – A new solid unreamed tibial nail for shaft fractures with severe soft tissue injury, Injury, 1993, vol.24, no.1, p.49-54

15. HERNANDEZ-VAQUERO D., SUÁREZ VÁSQUEZ A., IGLESIAS-FERNANDEZ S., GARCIA-GARCIA J., CERVERO-SUÁREZ J. – Dynamisation and early weight-bearing in tibial reamed intramedullary nailing: its safety and effect on fracture union, Injury, 2012, vol.43, suppl.2, p.S63-S67
16. HOLBROOK J.L., SWIONTKOWSKI M.F., SANDERS R. – Treatment of open fractures of the tibial shaft: Ender nailing versus external fixation. A randomized, prospective comparison J.Bone Jt.Surg., 1989, vol.71-A, no.9, p.1231-1238
17. KEALING J.E., O'BRIEN P.J., BLACHUI P.A., MEEK R.N., BROEKHUYSE H.M. – Locking intramedullary nailing wit hand without reaming for open fractures of the tibial shaft. A prospective randomized study, J.Bone Jt.Surg., 1997, vol.79-A, no.2, p.334-338
18. KREB D.L., BLOKHUIS T.J., van WESSEM K.J., BEMELMAN M., LANSINK K.W., LEENEN L.P. – Intramedullary nailing without interlocking screews for femoral and tibial shaft fractures, Acta Orthop.Trauma.Surg., 2013, vol.133, no.8, p.1109-1113
19. LASCĂR I. – Principii de chirurgie plastică şi microchirurgie reconstructivă, Editura „Naţional", Bucureşti, 2005, p.29-43, p.99-110, p.217-242
20. MA C.H., WU C.H., TU Y:K., LIN T.S. – Metaphyseal locking plate as a definitive external fixator for treating open tibial fractures outcome and a finite element study, Injury, 2013, vol.44, no.8, p.1097-1101
21. MEDREA O., VOINEA A., STAN ŞT., SGARBURĂ I., GORUN N., POPESCU M., NICOLESCU M. – Experienţa noastră în tratamentul fracturilor deschise de gambă, Revista sanitară militară (Bucureşti), 1972, vol.75, nr.6-7, p.925-930
22. OBADĂ B. – Etapele terapeutice în fracturile deschise de gambă, Revista de Ortopedie şi Traumatologie (Bucureşti), 2007, vol.17, nr.1, p.3-11
23. PARK H.J., UCHINO M., NAKAMURA M., LLENO M., KOJIMA Y., ITOMAN M., YOKOYAMA K., SUZUKI T., NEMETO M. – Immediate interlocking nailing versus external fixation by delayed interlocking nailing for Gustilo type III B open tibial fractures, J.Orthop.Surg. (Hong-Kong), 2007, vol.15, no.2, p.131-136
24. POP A. – Fractura deschisă de tibie, University Press „V.Goldiş", Arad, 1999
25. POPESCU M. – Stabilizarea focarului în fractura deschisă de tibie, Ed.Sofitech, Bucureşti, 1997
26. SALEM K.H. – Unreamed intramedullary nailing in distal tiabial fractures, Int.Orthop.(Cairo), 2013, vol.37, no.10, p.2009-2015
27. SANDERS R., JERSINOVICH I., AGLEN J., DIPASQUALE T., HERSCOVICI D. – The treatment of open tibial shaft fractures using an interlockend intramedullary nail without reaming, J.Orthop.Trauma, 1994, vol.8, no.6, p.504-510

28. STAMATE T., BUDURCĂ A.R. – Transfer microchirurgical de lambou compozit osteo-mio-fascio-cutan peronier în rezolvarea unei fracturi III B de gambă – prezentare de caz, Rev.medico-chirurgicală (Iaşi), 2002, vol.106, nr.3, p.611-613

29. SWANSON T.V., SPIEGEL J.D., SUTHERLAND T.B., BRAY T.J., CHAPMAN M.W. – A prospective, comparative study of the Lottes nail versus external fixation in 100 open tibia fractures, Orthop.Trans., 1990, vol.14, no.6, p.716-717

30. ŞAMOTĂ I. – Fixarea endomedulară elastică în fractura deschisă de gambă, Ed.C2 design, Braşov, 1999

31. ŞAMOTĂ I. – Principii generale de tratament în fractura deschisă de tibie, Revista de Ortopedie şi Traumatologie (Bucureşti), 1999, vol.9, nr.2, p.69-80

32. ŞOVA D., FILIPESCU N. – Studiu biomecanic în endosinteza elastică a fracturii de gambă, Revista de Ortopedie şi Traumatologie (Bucureşti), 2004, vol.14, nr.3-4, p.159-162

33. VELAZCO A., WHITESIDES T.E.Jr., FLEMING L.L. – Open fractures of the tibia treated with the Lottes nail, 1983, vol.65-A, no.9, p.879-885

34. YU B., HUANG G., GEORGE J.T., LIL W., PAN S., ZHAN H. – Single – incision technique for the internal fixation of distal fractures of the tibia and fibula: a combined anatomic and clinical study, Arch.Orthop.Trauma.Surg., 2013, vol.133, no.10, p.1011-1015

35. WITTLE A.P., RUSSELL Th.A., TAYLOR Ch.J., LAVELLE D.G. – Treatment of Open Fractures of the Tibial Shaft with the Use of Interlocking Nailing without Reaming, J.Bone Jt.Surg., 1992, vol.74-A, no.8, p.1162-1171