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ORIGINAL ARTICLE

# Factors influencing functional results after surgery for ankle fractures

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## Abstract
Ankle fractures are frequent and have a significant impact upon the function of the lower limb, as this joint has a crucial role in standing and especially in walking. Several classification systems have been developed concerning these fractures, connecting the traumatic mechanism to their treatment. Due to their character of articular fractures, functional restoration of local anatomy is necessary; therefore, surgery is mandatory in displaced fractures, affecting the congruency, the stability or the mobility of the ankle joint. The purpose of this paper is to describe the factors influencing the results of surgical treatment in these fractures, as it results from the experience of a level 1 Trauma Centre.
Keywords: ankle fractures, ankle surgery

## Introduction

Ankle fractures represent the second most frequent fracture of the lower limb, after proximal femoral fractures; their total incidence was approximated at 9% of all the fractures [1]; a study published in 2018 estimated the mean age of the patients to be 41.4 (24.3 SD) years, and the incidence 168.7/ 100,000 (adults/ year) between 2005-2014 [2].

The incidence of these fractures has a bimodal distribution [2].

– The first peak is that of young patients, who have sport accidents; men are mainly affected before 40 years old, but after this age, the incidence increases for women

– The second peak refers to the post-menopausal period, and is produced by the decreased bone mineral density, including the so-called "fragility fractures".

Most of ankle fractures are produced due to fall from standing or during running or other sport incidents, which are rather common circumstances, therefore the increased incidence of these fractures.

Several classification systems were developed for these fractures, the most widely used being the anatomical, the Danis-Weber and the Lauge Hansen classification systems, which correlate the injuries with the mechanism and are used for establishing the treatment.

The anatomical classification refers to:

– The injured bones -

- Unimalleolar fractures - affecting the internal malleolus (IM) or the external malleolus (EM),
- Bimalleolar fractures - internal and external malleolar fractures,
- Trimalleolar fractures - bimalleolar fractures with fracture of the posterior marginalis (affecting less or more than 1/ 3 of the articular surface of the tibia).

– The status of the syndesmosis - which can be intact or injured, with tibio-peroneal diastasis

– The contact between the articular surfaces of the distal tibia and talus - which can be normal or affected, resulting in subluxations/ luxations of the talus, which can be external, posterior (or a combination of them), or, rarely in other direction

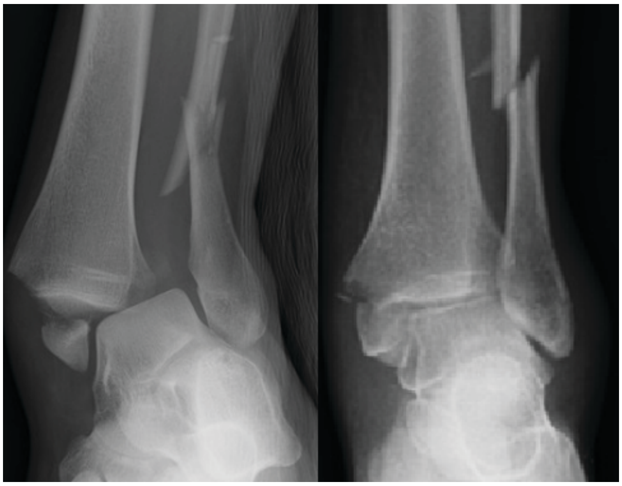
The Danis-Webber is based on the characteristics of the peroneal fracture, and describes :

– Type A - infra-syndesmotic fracture,

– Type B - intra-syndesmotic fracture, with partial, rarely total syndesmotic injury,

– Type C - supra-syndesmotic fracture, with total syndesmotic injury and ankle instability [3].

*a* *b*



*c* *d*

*Fig. 1 Lauge Hanssen classification (a) SA, (b) SER, (c) PA, (d) PER*

The Lauge Hansen classification (Fig. 1) is based on the traumatic mechanism, describing:

– Supination-Adduction (SA) injury: corresponding to type A Danis-Weber,

– Supination-External Rotation (SER), corresponding to type B Danis-Weber,

– Pronation-Abduction (PA) - corresponding to type C Danis-Weber,

– Pronation-External Rotation (PER) - corresponding to type C Danis-Weber [4].

Treatment of ankle fractures means restoration of the congruency, stability and mobility of the ankle joint; as these fractures are usually displaced, and surgical treatment is required to fulfill these objectives. The type of approach and osteosynthesis depends on the fracture pattern, as well as on the status of the soft tissues, as blisters or wounds (open fractures) need a special approach.

This paper presents the prerequisites of the surgical treatment for an optimal functional result, according to the experience of a Level 1 Trauma Centre.

## Material and Method

This prospective study included patients with closed ankle fractures operated using ORIF

(Open Reduction Internal Fixation) between 01.01.2013-01.01.2015 in the Orthopaedic and Trauma Clinic in a Level 1 Trauma Centre, Clinical Emergency Hospital Bucharest, which respected the following inclusion criteria:

- Age above 18 years
- Closed fractures
- Unique injury or with associated injuries that did not interfere with the recovery after this fracture or with the evaluation protocol
- Surgical treatment by ORIF
- Complete evaluation protocol (follow-up at 1, 2, 3, 6, 12, 24 and 36 months post-operative).

Applying these criteria to all the patients operated for ankle fractures in our Clinic, the authors evaluated 66 patients with ankle fractures, the long-term follow-up severely decreasing the number of the patients in the study group. The criteria used for analysis were:

- Age, gender and type of fracture
- Surgery: position of the patient, approaches and type of fixation
- Post-operative result in terms of restoration of the functional anatomy
- Functional result after 12, 24 and 36 months
- Incidence of complications

## Results

The analysis of the study group regarding the demographic criteria and the types of fractures (Fig. 2) revealed that 33 patients (50%) sustained bimalleolar fractures, 16 (24.24%) had equivalent of bimalleolar fractures (fracture of EM with injury of the deltoid ligament), and 17 (25.75%) had trimalloelar fractures.

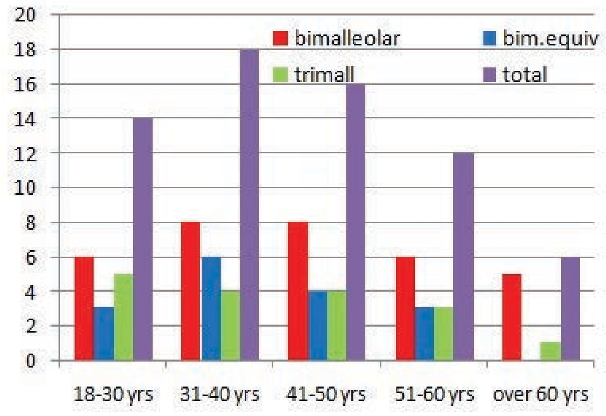



*Fig. 2 Demography and types of the fractures in the study group*

According to the Danis Weber/ Lauge Hansen classification, they were:

- 2 fractures type A (Suspiration - Adduction)
- 38 fractures type B (Suspiration - External Rotation)
- 26 fractures type C (14 by Probation - Abduction, 12 by Pronation - External Rotation).

The position of the patients was supine, except for the 17 patients with tri-malleolar fractures, whose prone position was used to fix the posterior fracture; then, in 8 cases, the patients were repositioned in the supine position, while in other 9 cases, all the approaches were performed in prone position. In all the cases, the fixation of the posterior fracture was performed from posterior to anterior, after open reduction of the fracture. In all the 8 cases operated with alternative prone-supine position and in 2 cases operated in prone position, 3 approaches were used, while in 7 cases a single posteroexternal approach was used to fix both the EM and the posterior fracture.

For the trimalleolar fractures,

The fixation was performed with:

- tension band for the IM
- syndesmotic screw: 36 cases
- plates and screws for the EM in all the cases, with:
  - compression plate - 6 cases

- lag screw and neutralization plate – 46 cases
- bridging plate - 8 cases

– screws (15 cases) and plates with screws (2 cases) for the posterior marginal fractures.

Repeated intra-operative fluoroscopic evaluation was performed for all patients, to be sure about the quality of the reduction and the position of the implants.

The post-operative protocol was the same for all the patients:

– thromboprophylaxis on the duration of time on risk,

– active movements started early with no full weight bearing 8 weeks for bimalleolar fractures and 12 weeks for trimalleolar fractures,

– clinical and radiological (AP and lateral views) at 1, 2, 3, 6, 12, 24 and 36 months after surgery.

The post-operative results were evaluated according to the following criteria:

– the talocrural angle,

– the lengths of the peroneum, expressed by the angle between the bimalleolar line and the horizontal line (normally 8-15 degrees),

– the width of the joint space compared to the ipsilateral ankle, referring to: the space between talus and the IM and the space between the talus and the inferior tibial plafond,

– the status of the syndesmosis, evaluated by the overlapping of the anterior tibial tubercle on the peroneum, 1 cm proximal form the joint line (normally - 2/ 3 from the width of the peroneum); these criteria will also be presented when discussing the illustrative clinical cases.

The results were considered:

– very good, when the difference between the operated leg and the healthy one was less than 20%,

– good, when the difference was 20-40%,

– satisfactory, when the difference was 40-60%,

– unsatisfactory, when the difference was 60-80%,

– poor, when the difference was 80-100%.

There were no unsatisfactory or poor results in terms of post-operative restoration of anatomical landmarks in the study group. According to these criteria, the post-operative results are presented in Table 1.

*Table 1. Post-operative restoration of functional anatomy*

| | Very good | Good | Satisfactory |
|---|---|---|---|
| Talocrural angle | 62 | 4 | |
| Peroneum length | 61 | 3 | 2 |
| Joint space | 62 | 3 | 1 |
| Syndesmosis | 62 | 3 | 1 |

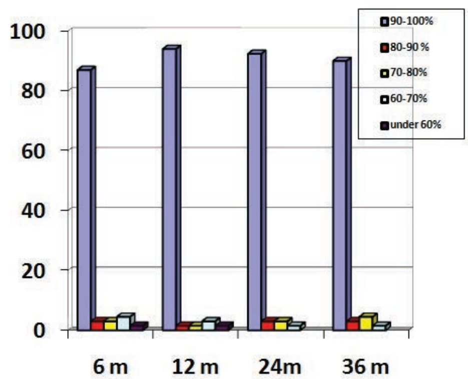
The functional outcome of the patients was evaluated according to the following scores:

– FADI (Foot and Ankle Disability Index Score).

– AOFAS (American Orthopaedic Foot and Ankle Society, which were used to evaluate the patients 6, 12, 24 and 36 months after surgery.

Also, gait analysis was used to evaluate these patients, and a global assessment was achieved (as gait analysis had multiple parameters).

The results in terms of FADI and AOFAS are presented in Fig. 3 (a,b).

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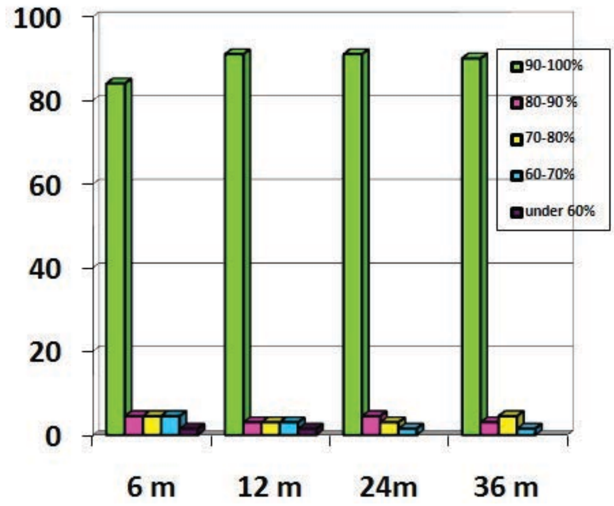



*b*

*Fig. 3 Functional results according to FADI (a) and AOFAS (b) scores*

In the study group, the following complications were described:

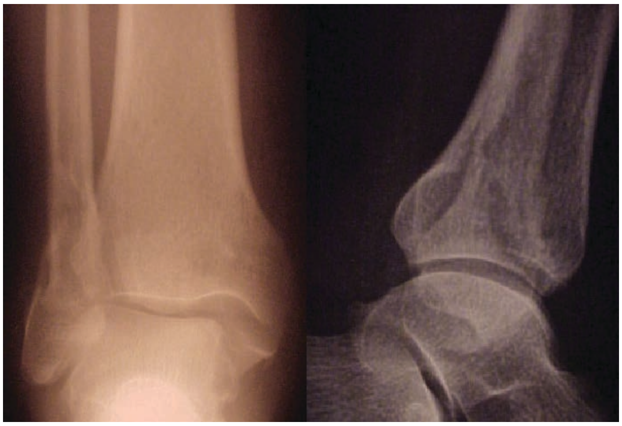
- Ankle stiffness – 1 patient,
- Ankle osteoarthritis 3 years after surgery - 1 patient,
- Deep venous thrombosis - 2 patients,
- Superficial sepsis - 1 patient,
- Algoneurodystrophic syndrome - 4 patients, amended by treatment
- Compartment syndrome - 1 patient - fasciotomy was performed, with favorable outcome, no sequelae

The following cases are representative for the results of this study:

**Case 1**

Male, 45 years old, heavy smoker, accidentally falls from standing 24 hrs before. Clinical elements suggested an ankle fracture, therefore radiological evaluation was recommended. Fig. 4 a,b shows an ankle injury; for the analysis of this injury, the following landmarks were used:

- The articular surface of the tibial plafond (1)
- The horizontal line (2)
- The axis of distal tibia (3)
- The articular surface of the talus (4)
- The vertical axis of the talus (5)
- The bimalleolar line (6)



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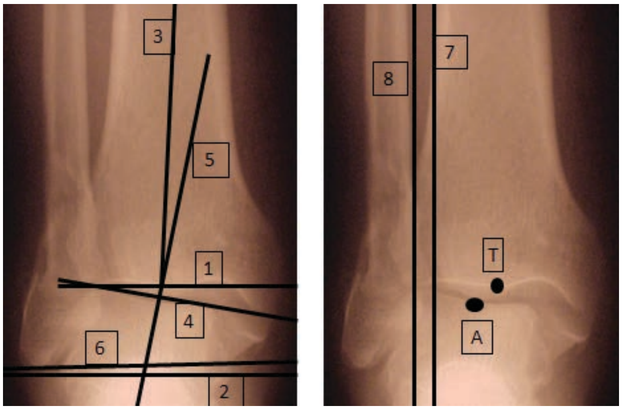



*b*

*Fig. 4 Post-traumatic X-rays (a) AP view, (b) lateral view, (c) radiological functional landmarks to be restored*

- The vertical live through the incisura fibularis tibiae (7)
- The vertical line through the internal aspect of the peroneal malleolus (8)
- The middle point of the articular surface of the tibial plafond (T)
- The middle point of the articular surface of the talus (astragalus) (A)

According to the normal anatomy of the ankle, the following aspects need to be amended.

(Fig. 4c):

- The talocrural angle, which is

diminished due to the malleolar fractures, with the shortening of the peroneum,

– The impairment of the articular space: normally, lines 1, 2 and 4 are parallel, meaning that the articular surfaces of the tibial plafond and those of the talus are parallel; in this case, line 4 is not parallel with lines 1 and 2, meaning that the talus is tilted,

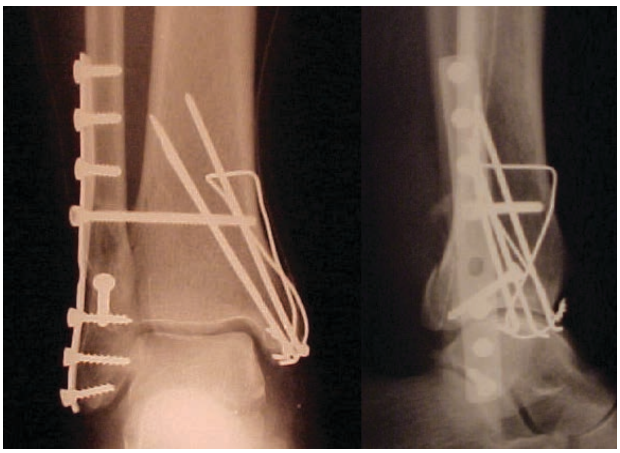
– The middle point of the articular surface of the talus (A) is externally displaced compared to the middle point of the distal tibia (T),

– The peroneum sustained a type B (Danes Weber) fracture and

– The space between the incisura fibularis (line 7) and the internal aspect of the peroneum (line 8) is larger than 5 mm (1 cm proximally from the joint line).

Therefore, the complete diagnosis in this case is "Bimalleolar fracture right ankle with external subluxation with syndesmotic injury, type B (Danis-Weber), supination-external – rotation (Lauge Hansen).

Treatment consisted of ORIF (Open Reduction Internal Fixation): the internal malleolus was stabilized with a tension band (on 2 Kirschner wires) and the external malleolus with 1 lag screw and neutralization plate fixed with 6 bicortical screws and one peroneo-tibial screw for syndesmotic protection (Fig. 5).



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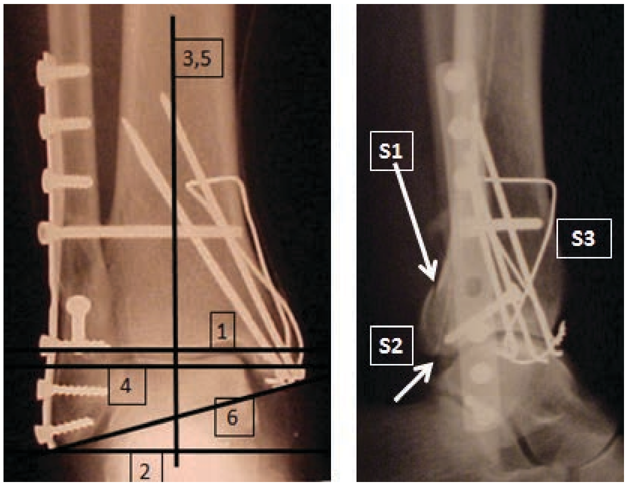


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*Fig. 5 Post-operative result*

According to the above-mentioned criteria, Fig. 5 reveals the complete restoration of the functional anatomy:

– The lines 1, 2 and 4 are parallel, therefore the articular surfaces of the tibial and talus are parallel,

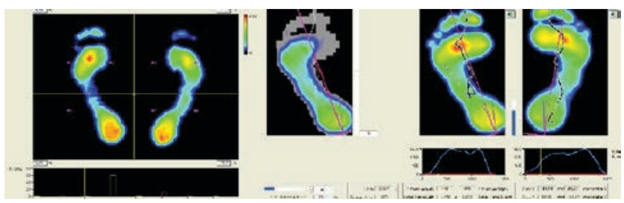
– The talus is centrally and stable within the ankle mortis (lines 3 and 5 are overlapping and pass through the middle points T and A,

– The joint space has the same width internally and superior area,

– The length of the peroneum was restored, therefore the talocrural angle (between lines 4 and 6) is normal,

– Post-op lateral X-ray reveals a posterior marginal fracture, which does not require surgery.

The outcome of the patient was favorable, with a 92 points FADI and 93 points AOFAS one year after surgery and fracture healing. Gait analysis at 6 months (Fig. 6a) after surgery shows differences between the two legs, but the one performed 12 months after surgery (Fig. 6b) shows an optimal functional recovery, directly connected with the restoration of functional anatomy.



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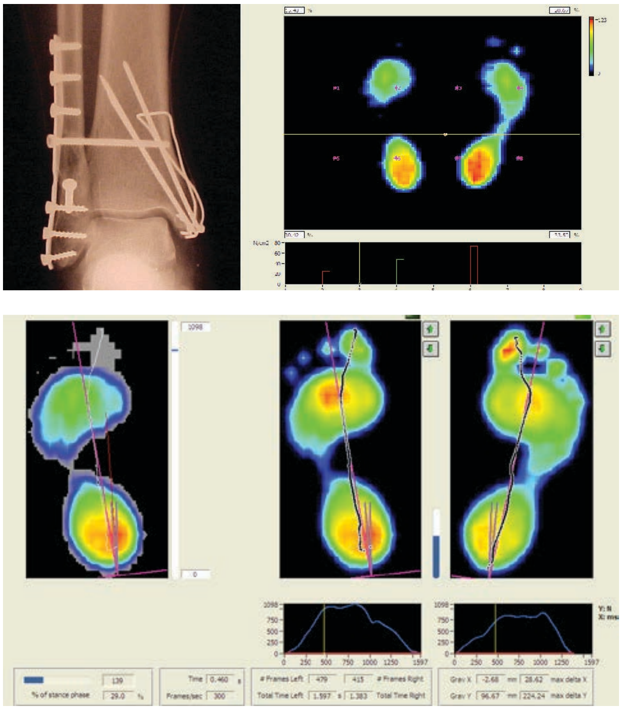


b

*Fig. 6 Gait analysis (a) at 6 months and (b) at 12 months after surgery*

### Case 2

Young male, 25 years old, accidentally falls while running 6 hrs before coming to the hospital. Clinical evaluation suggests an ankle fracture, therefore AP and lateral X-rays were performed, showing a severe injury of the ankle: a bimalleolar and a posterior marginal fracture with posterior dislocation of the ankle (Fig. 7).

a

b

*Fig. 7 AP and lateral X-ray showing a trimalleolar fracture with posterior dislocation*

Due to the dislocation, the first attitude was directed to this; reduction of the dislocation was performed, with partial cast immobilization, followed by post-reduction X-rays (Fig. 8), revealing:

- Internal malleolar fracture
- Syndesmotic injury: the distance between lines 1 and 2 is less than 30% of the width of the peroneum, measured 1 cm proximal form the joint line and the distance between lines 2 and 3 is more than 5 mm.

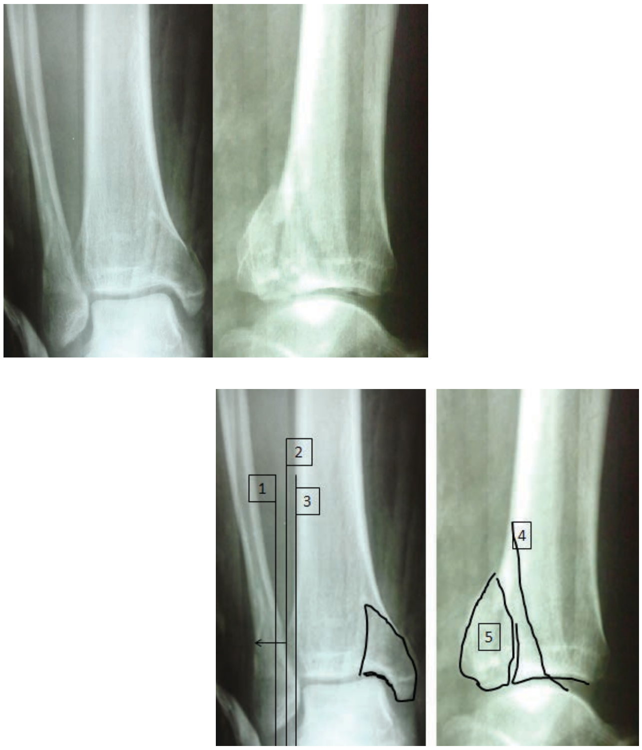


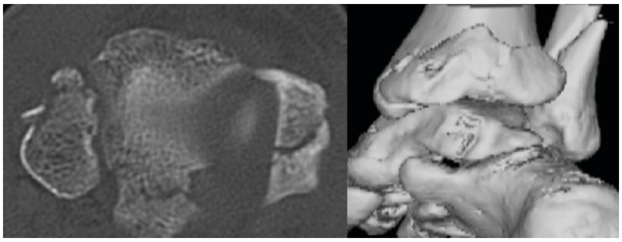

*Fig. 8 AP and lateral post-reduction X-ray*

– External malleolar fracture (type B Danis-Weber) and posterior marginalis fracture affecting more than 1/ 3 from the articular surface (landmark 5 in Fig. 8).

– Because the initial X-rays suggest complex injuries, a thorough evaluation of the ankle was considered necessary, thus a CT scan with a 3D reconstruction was indicated; besides the data already provided by the X-rays, the CT scan revealed (Fig. 9):

– An impaction at the level of the internal corner of the mortise (Fig. 9d),

– Comminution of the internal malleolar and posterior marginalis fracture.



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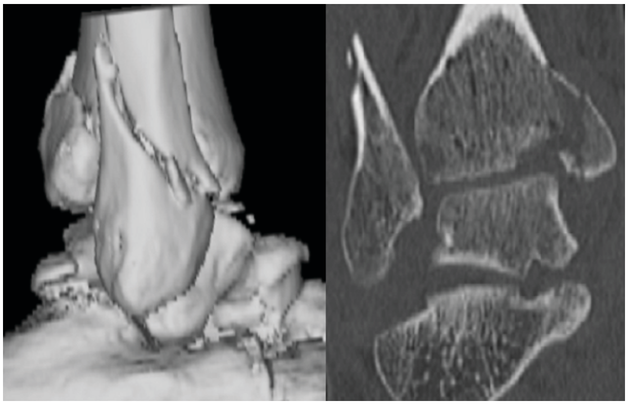


*c* *d*

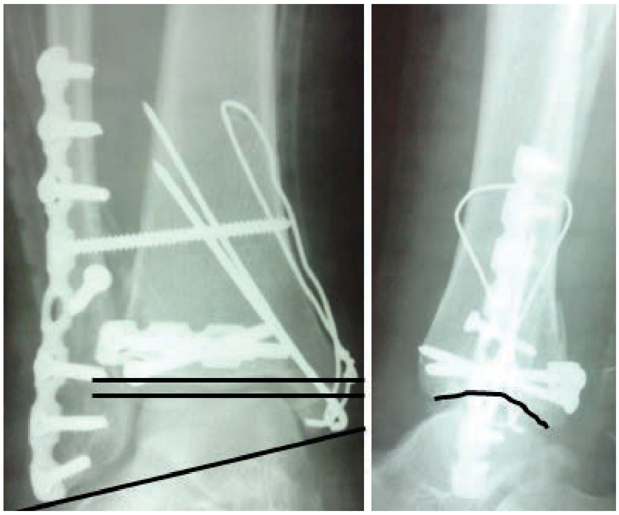
*Fig. 9 CT scan with 3D reconstruction*

– The treatment was surgical, open reduction was performed for all the fractures, which were stabilized using:

– plate and screws for the posterior fracture, using a posterior approach (Fig. 10a); the plate was used in order to obtain a washer effect: due to comminution, compression only by screws had an increased risk of fracturing the posterior fragment, therefore the plate spreads the compression over its whole length;

– tension band for the internal malleolus, using a medial approach;

– 1 lag screw and a neutralization plate, with 6 bicortical screws, using the same posterior approach, and a syndesmotic protection screw.



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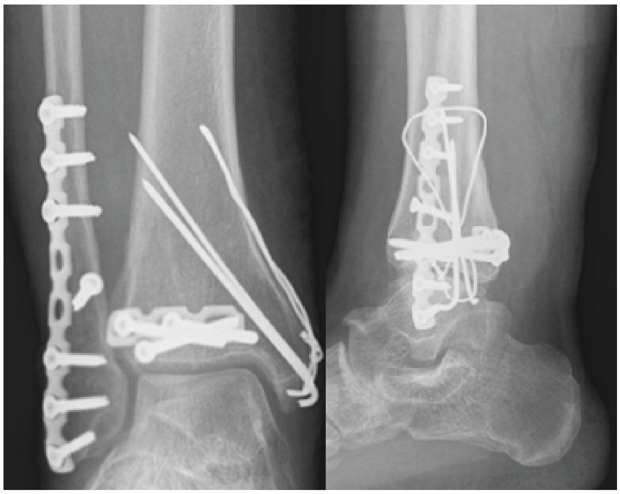

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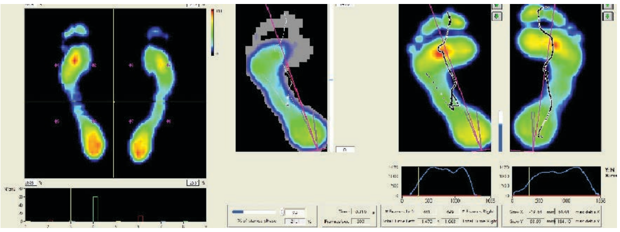
*Fig. 10 Post-operative result - restoration of the local functional anatomy*

The outcome of the patient was favorable, with 95 points according to FADI score and 94 points according to AOFAS, one year after surgery, and optimal healing (Fig. 10b). Gait analysis revealed differences between left/

right 6 months after surgery, but one year after surgery, the gait was symmetric (Fig. 11 a,b).



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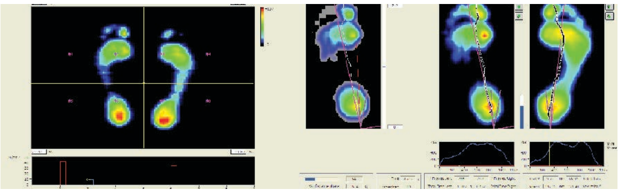

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*Fig. 11 Gait analysis (a) - six months and (b) - one year after surgery*

## Discussion

Ankle fractures are classified according to the injuries, in connection with the traumatic mechanism; different classification systems were proposed, based on the imagistic findings after radiological (AP and lateral views) evaluation, completed with the CT scan, whenever the information are not complete after X-rays [5,6].

Surgical treatment of ankle fractures must restore functional anatomy, which is why it must be based upon the traumatic mechanisms, which determine the main features of surgery: the position of the patient, the approach, and the type of implant. The position of the patient is supine unless there is an associated posterior fracture requiring surgical fixation (affecting more than 1/ 3 of the articular surface); in cases like this, surgery begins with the fixing of the posterior fragment; in our study, this was performed by open reduction and fixation from posterior to anterior, in order to achieve an optimal restoration of the articular surface, therefore, the principle of anatomical reduction and absolute stability was applied. After fixing the posterior fracture, as demonstrated by our study, the patient can remain in the prone position (which requires an optimal spatial reference, as all the landmarks are reversed) or he can be positioned in the supine position.

Regarding the approaches, the surgeon has two possibilities: the first one is to perform three separate approaches - internal, posterointernal and posteroexternal; this has the advantage of optimal visualization of all the injuries, but the main problem is the vitality of the skin flaps between the incisions, as this can be compromised if the distance between the incisions is less than 8 cm, resulting in skin necrosis; this incident did not appear in our study, but care must be taken especially when patients have impaired arterial blood supply (due to occlusive arterial disease, diabetic arteriopathy or other similar circumstances) [7].

As for the fixation, restoration of the articular surface may be problematic when (as demonstrated by case 2), there is comminution or depression especially at the level of the IM, and the internal angle of the mortise is severely affected; intra-articular position of the Kirsches wires of the tension band must be avoided, and the fluoroscopic control is mandatory for this fact. Osteosynthesis of the EM must restore the length of the peroneum, and this may be difficult when multiple fragments with low bone contact result form either high trauma energy or a poor bone stock. In these situations, bridging plate is a good option and the bimalleolar angle must be restored in order to obtain a stable joint. Syndesmotic injuries were approached in the study group by intra-operative evaluation of the stability of the joint after fixing the EM fracture; the proper position of the peroneum in the syndesmosis and of the trans-peroneo-tibial screw (which had always penetrated 4 cortices) introduced with foot dorsiflexion were fluoroscopically checked, thus avoiding residual subluxation of the talus which could have resulted from an insufficient syndesmosis [8-11].

It must be underlined that in the study group, besides the functional scores, all the criteria used for evaluating the post-operative results were objective and reproducible, the radiological landmarks and the gait analysis being used as parameters for monitoring the patients [12].

The functional results in the study group proved that this approach, based on a physiopathological approach and on objective landmarks, therefore underlining the necessity of building a proper pre-operative planning as well as an objective system of measurements for long-term evaluation of the outcome of the patients.

## Conclusions

Ankle fractures are frequent and considerably affect the quality of the life of the patients; therefore, they require a proper treatment in order to obtain full recovery. Surgical treatment is indicated in displaced fractures and must be based on the traumatic mechanism, reflected by the Danis-Weber and Lauge-Hansen classifications, which suggests the reduction maneuvers and the position and type of the implant. The position of the patient and type of incisions must be chosen to allow maximal visualization of the injuries, with minimal soft tissue impairment. Care must be taken when local (especially arterial) blood supply is compromised by a pre-existing condition or by trauma itself, as the position of the bones is superficial and a skin necrosis will automatically expose the implants.

The anatomical landmarks of the ankle must be known, evaluated pre-operatively and restored accordingly, otherwise not only that the recovery of the ankle will not be optimal, but all the activities depending on the standing position, especially walking, will be severely compromised, thus globally affecting the life of these patients.

### Acknowledgments

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