"OVIDIUS" UNIVERSITY OF CONSTANȚA
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PhD Thesis Summary

The value of surgical treatment in the management of tibial pilon fractures: modern therapeutical aspects

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The PhD thesis includes:

- A general part consisting of 5 chapters
- A personal part consisting of 6 chapters
- 194 figures
- 86 tables
- 293 bibliographic references
- List of personal published papers

Keywords: tibial pilon fractures, therapeutic algorithm, two-stage osteosynthesis, staged protocol, minimal invasive procedure, locking-plate.

NOTE: In the summary, we included several tables and figures that comply to the numbering from the thesis. We enclose the table of contents from the PhD thesis.

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GENERAL PART

Introduction. Level of knowledges

Tibial fractures pilon represents 11% of all fractures of the tibia and are frequently caused by trauma with high kinetic energy in younger patients. The treatment is in most of the cases complex and the result is frequently marked by functional disabilities of the ankle joint.

For that reason, the surgeon has the responsibility of a good understanding of the relevant anathomical and physiological elements by applying of a diagnostic examination protocol, which include all the imagies necessary for a rational therapeutical approach of this lessions. At this moment, there are known the importance and the attention which must be accorded to the soft tissues around the ankle. An important fact of each surgical procedure at that level must take in consideration the preservation of soft tissue condition, to avoid the late complications which can result after an unproper treatment of tibial pilon fractures. [1-3]

Presently exists numerous controversies regarding the best method of treatment of tibial pilon fractures. Factors as delaying of surgery, method of stabilisation, surgical technique and postsurgical recoveri were intense debate and sometimes even contested in speciality literature.

PERSONAL PART

CHAPTER VI. The aim of the study

The paper propose a complex annalysis regarding the diagnostic and therapeutic approach of tibial pilon fractures, evaluating at final the results obtained at discharging from hospital and the late results.

The motivation of the study regards the statistical annalysis of a retrospective group of tibial pilon fractures, hospitalised between 2007-2011 in our clinic, by evaluating different methods of osteosynthesis and implants we used, in relation with the fracture type and with the moments of their use, the evaluation of the early and late results serving as model to establish a modern therapeutical protocol, which were subsequent applied, to verify his efficiency, upon a prospective group of patients, hospitalised between 2012-2015, their evaluation being made by same research criterions I used in case

of retrospective group of patients. This fact permit us to make an objective evaluation by compairing the results of the two groups and with the results from literature.

The statistical study of tibial pilon fractures treated in the Orthopaedic-Traumatology Clinic of Constanta was completed by a clinical and biomechanical study of distal peroneal fractures, associated to tibial pilon fractures, operated with the use of a new implant, which permit the minimal invasive osteosynthesis or a open limited approach. That innovative implant of osteosynthesis of distal peroneal fractures and even of tibial pilon fractures in some cases, is a base component of bone and soft tissue stabilisation protocol, especially in staged approach of tibial pilon fractures which associate peroneal fractures, in Orthopaedic-Traumatology Clinic of Aschaffenburg in Germany, under the supervisor of professor doctor Wilhelm Friedl, between January 2013 and December 2014.

CHAPTER VII. Material. Methods

The study consist of tibial pilon fractures hospitalised and treated in Orthopaedic-Traumatology Clinic of Constanta, in a period of time of 9 years, between 2007-2015. The initial group we studied was a retrospective group which consisted of 245 patients, hospitalised and treated between 2007-2011. The conclusions of the retrospective study guided to a modern and unitary diagnostical and therapeutical protocol, which was evaluated on a prospective group of 196 patients (198 fractures), between 2012-2015.

Method of work

Inclusions criterions:

- fractures of distal extremity of tibia with articular component

Exclusion criterions:

- fractures of distal extremity of tibia without articular component
- tibial malleolar fractures

1. *Statistical annalysis was made by following criterions:* sex, age, etiology, traumatic mechanism.
   - aspect of fracture site: AO – Műller, Ruedi şi Allgöwer classifications
   - soft tissue quality (lesional graduality) - Cauchoix-Gustilo-Anderson classification
   - fracture localisation

2. Annalisation of local early complications in relation with traumatic energy.

3. Pressional compartmental measurements for the fractures produced by high energy (prophylaxy and dyagnosis of Compartmental syndrome).

4. Evaluation of therapeutical protocol in emergency (local and general) and definitive treatment.

5. Evaluation and opportunity of drug therapy.

6. Evaluation of late results..

CHAPTER VIII. The statistical evaluation of the retrospective group of patients with tibial pilon fractures

VIII.1. Results

Table no.1 *Demographis profile of patients*

Criteria		***No***
Mean age (years)		44.2 (17-81)
Evaluation period (months)		17.5 (12-25)
Sex (men/women)		186/59
Simple trauma / high energy trauma		78/167
Type 43 B (AO)		127
Type 43 C (AO)		118
Open fractures	Type I	19
	Type II	17
	Type IIIA	14
	Type IIIB	9
	Type IIIC	2

Evaluation of therapeutic protocol

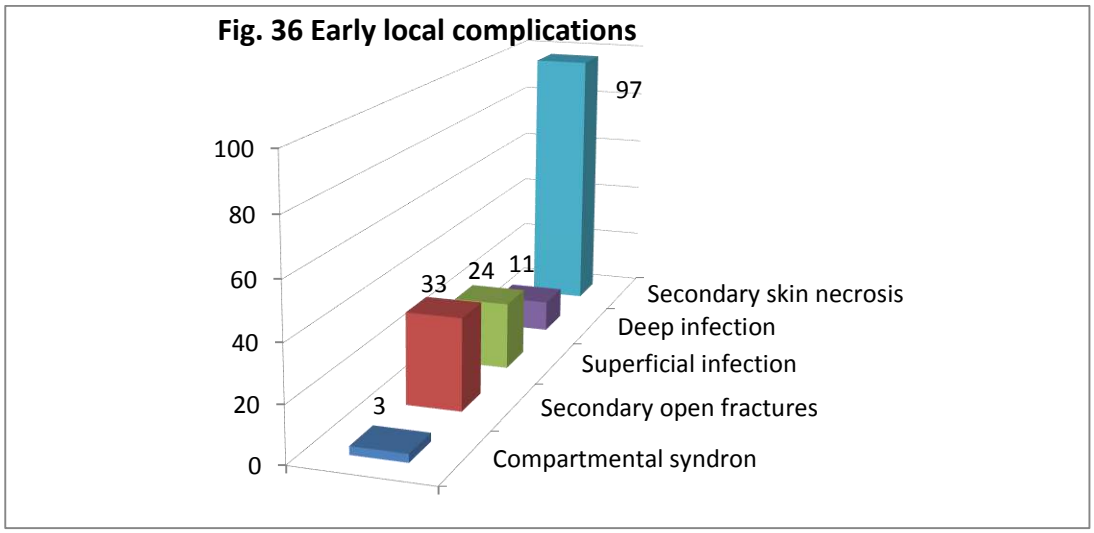
Definitive stabilisation of fracture site (osteosynthesis)

Table no.10 *Methods of osteosynthesis depending of Ruedi-Allgower classification*

	Definitive stabilisation methods	**Nr.**
	Orthopedic treatment (plaster cast)	24
Fractures type I – 82 cases	*Open reduction internal fixation*	
	-1 plate and screws	29
	- isolated screws	15
	- screws + K wires	9
	- screws + K wires + transcalcaneo-tibial wire	5
Fractures type II – 80 cases	*Open reduction internal fixation*	
	-1 plate and screws	40
	- 2 plates and screws	2
	- 1 plate + K wires	26
	External fixation	
	- external fixator	7
	- external fixator + K wires	5
Fractures type III - 83 cases	*Open reduction internal fixation*	
	-1 plate and screws	7
	- 2 plates and screws	14
	- 1 plate + K wires	21
	External fixation	
	- external fixator	17
	- external fixator + K wires	23
	- amputation	1

Complications

Table no.16 Early local complications



Late local complications

Table no.20 *Systematisation of retrospective group complications*		
Complications	No	%
Stiffness	118	48.1
Neuroalgodistrophy	108	44.08
Chronic oedema	82	33.46
Delay of consolidation	63	25.71
Vicious callus	100	40.81
Pseudarthrosis	21	8.57
Arthrosis	105	42.85
Osteitis	9	3.67
Refracture	1	0.4
Secondary arthrodesis	3	1.2

Table no.24 *Late complications depending of used definitive treatment*

Complications	**Orthopedic treatment**	**Open reduction internal fixation**	**External fixator**
Stiffness	21 (87.5%)	53 (31.54%)	44 (83%)

Neuroalgodistrophy	17 (70.8%)	56 (33%)	35 (66%)
Chronic oedema	14 (58%)	45 (26.78%)	23 (43.4%)
Delay of consolidation	3 (12.5%)	35 (20.8%)	25 (47%)
Vicious callus	11 (45.8%)	51 (30.3%)	28 (52%)
Pseudarthrosis	2 (8.3%)	5 (3%)	12 (22.6%)
Arthrosis	5 (20.8%)	59 (35%)	41 (77%)
Osteitis	0	4 (2.4%)	5 (9.4%)
Refracture	0	1 (0.6%)	0
Secondary arthrodesis	0	0	3 (1.5%)

Evaluation of the late results (minimum 1 year after surgery)

After at least 1 years was made a clinical evaluation based on the Olerud and Molander score, Ovadia and Beals score and radiologic evaluation of arthrosis modifications using Kellgren and Lawrence score. [4-6]

Fig.51 Olerud and Molander score

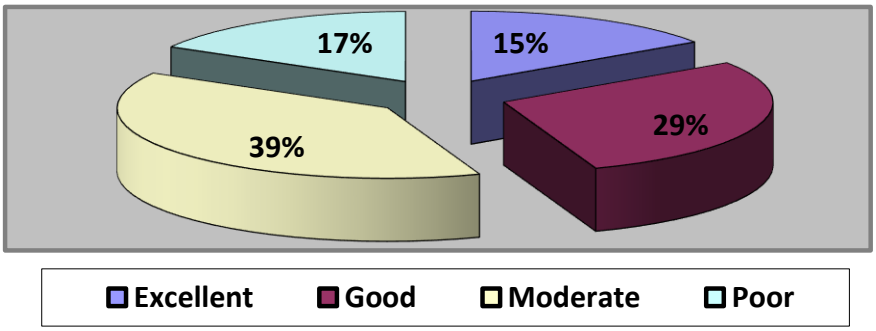


Table no.27 *Late results according Ovadia and Beals score after 1 year*

Result	**Objective**		**Subjective**	
Excellent	120	49%	76	31%
Good	68	28%	89	36%
Satisfactory	25	10%	61	25%
Poor	32	13%	19	8%

Table no.33 *Correlation between fracture type, quality of reduction radiological appreciate and results obtained in relation with definitive treatment method*

Type	***Treat.***	***No***	***Reduction***			***Objective results***				***Subjective results***			
			Good	***Medium***	***Poor***	***Exc.***	***Good***	***Satisf.***	***Poor***	***Exc.***	***Good***	***Satisf.***	***Poor***
RA I	**Ort.**	24	17	5	2	22	2	0	0	6	15	3	0
	ORIF	58	42	14	2	42	16	0	0	19	29	10	0
	EF	0	0	0	0	0	0	0	0	0	0	0	0
RA II	**ORIF**	68	39	18	11	44	19	5	0	38	15	15	0
	EF	12	3	4	5	8	2	2	0	6	4	2	0
RA III	**ORIF**	42	19	15	8	3	21	11	7	6	19	8	9
	EF	41	8	13	20	1	8	7	25	1	7	23	10
AO B	**Ort.**	24	8	9	7	9	8	5	2	8	9	6	1
	ORIF	96	51	35	10	47	29	12	8	42	22	22	10
	EF	7	2	2	3	5	1	1	0	4	2	1	0
AO C	**ORIF**	72	34	21	7	16	22	21	13	21	19	15	17
	EF	46	9	17	20	7	9	8	22	7	7	19	13

*Ort.-orthopedic, ORIF-open reduction internal fixation, EF-external fixator, RA-Ruedi-Allgower, AO- AO classification, treat.-treatment, exc.-excellent, satisf.-satisfactory.

Radiologic score of arthrosis depending on Ruedi and Allgower fracture type after 1 year

Table no.35 *Kellgren and Lawrence score*

Grade	1	2	3	4	Total
Type I	37	25	18	2	82
Type II	21	23	29	7	80
Type III	13	16	21	33	83
Cazuistry	71	64	68	42	245

Late results – X-rays

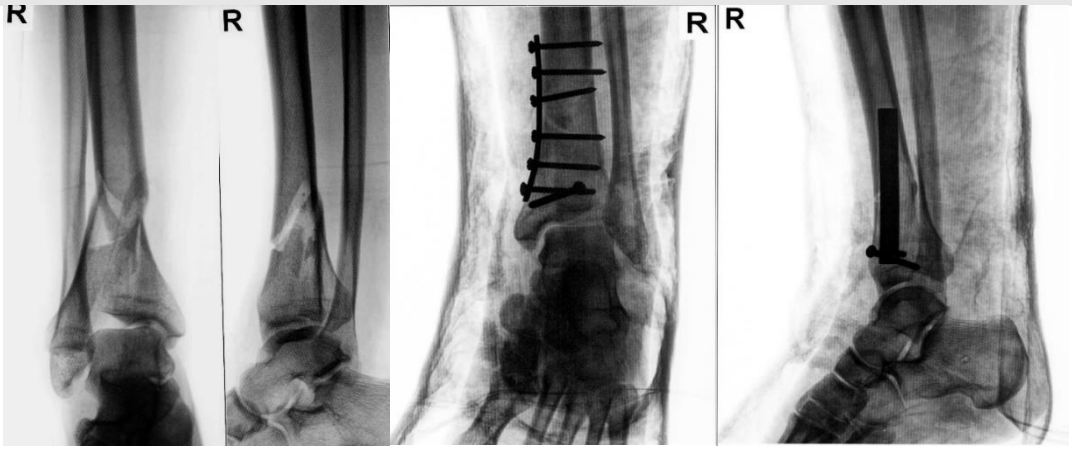


Fig.71 43 C2 Osteosynthesis with plate and screws

Fig.72 43 C3 Osteosynthesis with plate and screws tibia and peroneus, K-wires tibia and cortical-cancellous graft.

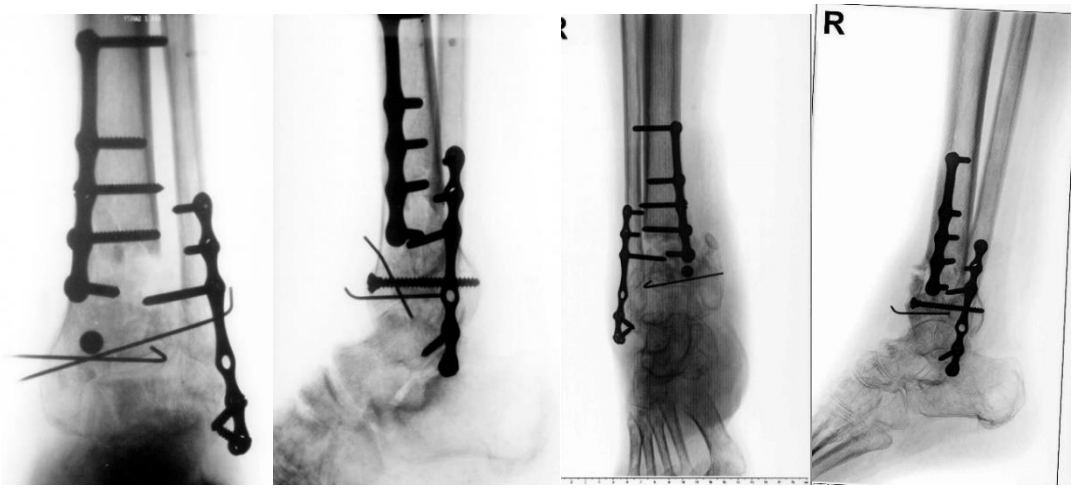
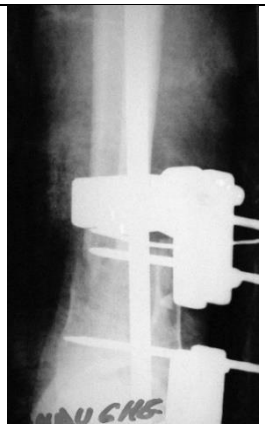
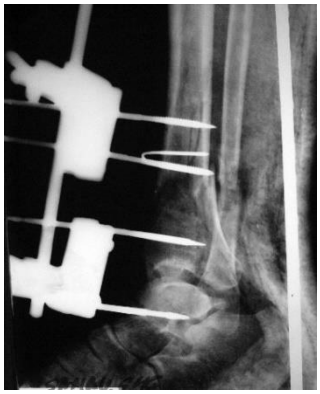


Fig.73 Aspects after 9 months, 12 months, disfunctional ankle.

VIII.2. Cazuistry –selective aspects

Fig.82 CASE 1



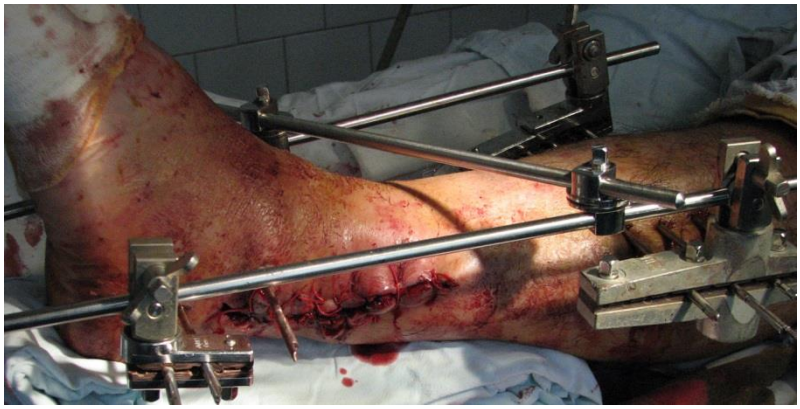
S.G., 65years, M, Fracture type IIIB 43 C2. Score MESS 6. Debridement, external fixator.


Open wound and debridement dayly.

Skin and muscle graft.


Aspects after 8 months. Fracture is consolidated, severe ankle arthrosis. Incomplete functional recovery.

Fig.86 CASE 5



N.I., 46, M, Open fracture type IIIA 43 C3 left shank. Score MESS 4. Debridment in emergency. External fixator.



Aspect after 1 month.




Aspect after 1 year. Advanced arthrosis, incomplete functional recovery.

VIII.3. Discussions

Treatment of tibial pilon fractures

Surgical treatment objectives were:

1. Surgical approach which preserve local vascularisation
2. Anathomic reduction
3. Stable osteosynthesis
4. Quick mobilisation.

The most frequent implants used are cloverleaf plates or “T” plates, applied medially to prevent varrus diformity, the direction of forces imposing anteromedial surface fixation.

Fracture site stabilisation (osteosynthesis)

Osteosynthesis of tibial pilon fractures was the definitive treatment in 90% of cases, being the only one which can reach the therapeutic objectives we reminded before. The articular surface reconstruction is posibile only by open reduction and stable internal fixation.

We found that with increasing of comminution and the necesity of articular surface reconstruction, has increased the degree of skin lesion, secondary to a high traumatic energy which produced the fracture, which make hard the use of open reduction, the only method which can ensure this reconstruction. This is the reason that we used external fixation as preferred method of osteosynthesis in the same time with the increasing of fracture grade according Ruedi-Allgower classification. Direct or secondary skin lesions, which appears in next days, impose the choose of an osteosynthesis method less agressive for soft tissues, in our case frequently used in combination with percutaneous osteosynthesis with K-wires. In such a manner is trying to limitate immediate local skin complications, but with the risk of late arthrosis complications, secondary to a not anathomic reconstruction.

Annalysis of late complications

The percent of late complications increase in direct relation with comminution and articular interesting degree according to AO and Ruedi-Allgower classification.

Annalysing the late complications in relation with the osteosynthesis method applied, we notice that open reduction and internal fixation asociated the lowest rate of complications which are normally

induced by prologed immobilisation of affected limb: stiffness 31.54%, neuroalgodistrophy 33%, chronic oedema 26.78%. That fact is absolutely normal because is a method which ensure a firm stabilisation and permit a quicker functional recovery than orthopedic treatment or external fixator. These complications typically for prolonged immobilisation of limb dominated the cases treated corservatory (external fixator and plaster cast) or by externan fixator.

Delay of consolidation, vicious callus and pseudarthrosis were the most rare complications in case of open reduction internal fixation because is a method which ensure a bone reconstruction superior to external fixator. The higher proportion of cases which evoluated with vicious callus was in case of external fixation, 52% of cases, which evoluate subsequently with arthosis.

Clinical and radiological evaluation of the late results

In case of type III fractures it is noticed a good quality fracture reduction than external fixation, but in lower proportion of succed than type II fractures, because of important comminution characteristic tp this fractures. The good quality fracture reduction, ensured by open reduction and internal fixation had favourable objective and subjective result, superior for this osteosynthesis method than external fixation.

Advanced arthrosis confirmed radiologically is in high proportion in case of type III Ruedi-Allgower and type C AO, with significant statistic corespondence and proportionally with the clinical result obtained at minimum 1 year after surgery. (figure 67-69)

Olerud and Molander score was proved to be an efficiently method of evaluation of the late results, coordinated with Ovadea and Beals criterions and mostly with Kellgreen-Lawrence radiologic score, so we can appreciate cumulative good and excellent results of the retrospective group as being 44% good. Compairing our results with the cumulative results of other 6 studies from literature regarding tibial pilon fractures, we can appreciate the results obtain after evaluation of retrospective group as being not good, as their position being the last, equally to other 3 studies from years 1960.

VIII.4. Conclusions

None of the osteosynthesis methods we evaluate is recommended as being the only method of treatment in all the cases of tibial pilon fractures. Each fracture must be treated individually, and the osteosynthesis methid should be choosen according to a preestablished protocol, in which the surgical moment must be choosen in relation to soft tissue condition. Another important aspect is the staging of the surgical moments because surgery in one stage has important complications, and external fixator seems to have a key role as bone and soft tissue stabilisation method.

The respecting of base principles regarding bone stabilisation and soft tissue approaching wasn't enough to obtain better results than the results from the studies citated in literature. It is strong necessary to establish a new therapeutical protocol, in which the bone stabilisation and articular reconstruction must be staged, respecting local skin condition and by applying modern principles of minimal invasive osteosynthesis. Based on the obtained results, we propose a staged therapeutical protocol, in two stages, with the stabilisation in first stage, in emergency, of the peroneal fracture (when exists) by open reduction and internal fixation with plate and screws, stabilisation of the pilon fracture with external fixator transarticulary, followed in stage two, depending on the local conditions, by reconstruction of articular surface and stabilisation by open reduction and internal fixation of the tibial pilon.

CHAPTER IX. The statistical evaluation of the prospective group of patients with tibial pilon fractures

IX.1. Results

Fracture systematisation on research criterions

Table no.41 *Demographis profile of patients*

Criterion	***No***
Mean age (years)	46.5 (19-83)
Evaluation period (months)	16 (12-24)
Sex (men/women)	156/40
Simple trauma / high energy trauma	57/139
Type 43 B (AO)	119

Type 43 C (AO)		79
Open fractures	Type I	17
	Type II	14
	Type IIIA	11
	Type IIIB	6
	Type IIIC	0

Evaluation of therapeutic protocol

Table no. 51 *Definitive stabilisation of fracture site – osteosynthesir protocol*

Method	**No**	**Percent**
Single stage osteosynthesis	46	23.24
Staged osteosynthesis	127	64.14
External fixator as definitive method	25	12.62

Table no.53 *Methods of osteosynthesis depending of Ruedi-Allgower classification*

	Definitive stabilisation methods	**Nr.**
Fractures type I – 66 cases	*Minimal invasive osteosynthesis* – locking plate	**50**
	Open reduction external fixation – isolated screws	**14**
	External fixator	**2**
Fractures type II – 64 cases	*Minimal invasive osteosynthesis* – locking plate	**23**
	Open reduction external fixation	
	- 1 simple plate	**7**
	- 1 locking plate	**25**
	External fixator	**9**
Fractures type III – 68 cases	*Minimal invasive osteosynthesis* – locking plate	**8**
	Open reduction external fixation	
	- 2 simple plates	**3**
	- 1 locking plate	**42**
	- arthrodesis	**1**
	External fixator	**14**

To realise osteosynthesis with locking plate there were used 2 types of surgical approaches: antero-medial approach modified by Assal and antero-lateral approach. The decision between the two approaches depends of fracture tipology, and the minimalisation or extension of aproach depends on the quality of the initial reduction of fracture, obtained in the first surgical stage. [7-11]

Modalities of solving of the wounds and posttraumatic skin lessions

Table no.56 *Localisation of skin lessions in case of closed fractures*

Ruedi-Allgower classification	*Medial side*	*Antero-lateral side*
I	0	0
II	0	0
III	10	1

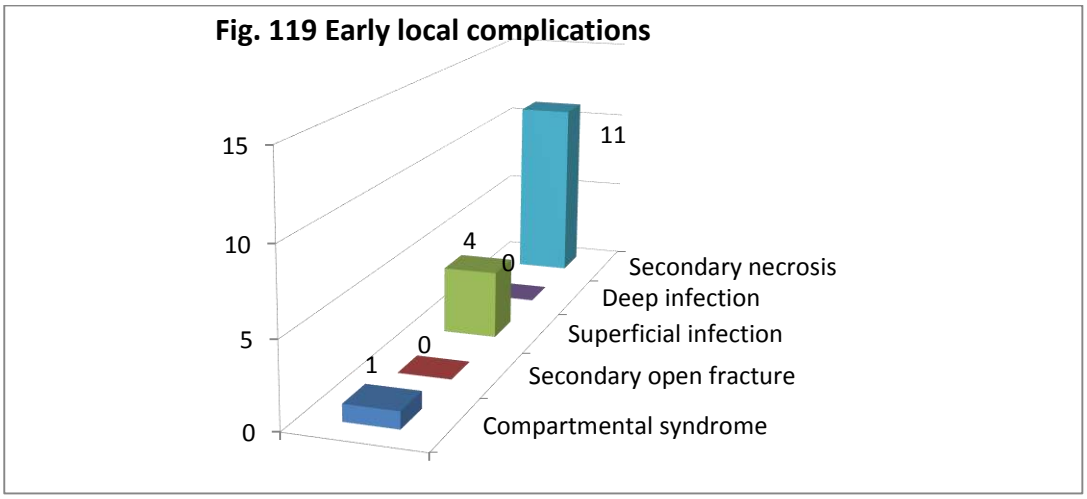
Table no.57 *Localisation of skin lessions in case of opened fractures*

Gustilo-Anderson classification	*Medial side*	*Antero-lateral side*
I	15 (31.25%)	2 (4.16%)
II	10 (20.8%)	4 (8.3%)
IIIA	8 (16.6%)	3 (6.25%)
IIIB	5 (10.4%)	1 (2%)
48 cases	38 (79.16%)	10 (20.84%)

Complications

Early local complications

Fig. 119 Early local complications



Late local complications

Table no.64 *Systematisation of retrospective group complications*		
Complications	No	%
Stiffness	42	21.21
Neuroalgodistrophy	18	9.1
Chronic oedema	8	4
Delay of consolidation	6	3
Vicious callus	7	3.5
Pseudarthrosis	2	1
Arthrosis	25	12.6
Osteitis	0	0
Refracture	2	1
Secondary arthrodesis	0	0

Table no.68 *Late complications depending of used definitive treatment*

Complications	**Minimal invasive osteosynthesis**	**Open reduction internal fixation**	**External fixator**
Stiffness	7 (8.64%)	10 (10.86%)	25 (100%)
Neuroalgodistrophy	0	2 (2.17%)	16 (64%)
Chronic oedema	0	0	8 (32%)
Delay of consolidation	1 (1.2%)	1 (1.08%)	4 (16%)
Vicious callus	0	1 (1.08%)	6 (24%)
Pseudarthrosis	0	1 (1.08%)	1 (4%)
Arthrosis	1 (1.2%)	4 (4.3%)	20 (80%)
Osteitis	0	0	0
Refracture	1 (1.2%)	1 (1.08%)	0
Secondary arthrodesis	0	0	0
Total	81	92	25

Evaluation of the late results (minimum 1 year after surgery)

Fig.127 Olerud and Molander score

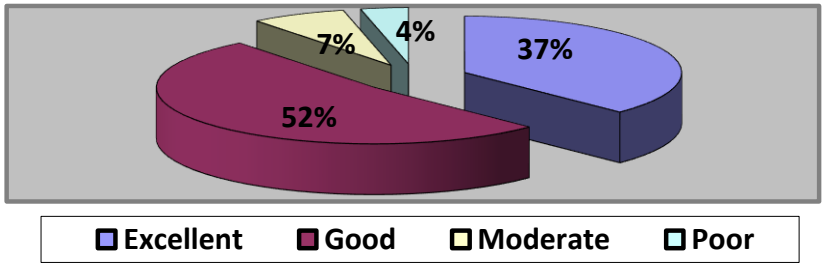


Table no.71 *Late results according Ovadia and Beals score after 1 year*

Result	**Objective**		**Subjective**	
Excellent	105	53%	73	37%
Good	76	38%	87	44%
Satisfactory	11	6%	31	16%
Poor	6	3%	7	3%

Table no.77 *Correlation between fracture type, quality of reduction radiological appreciate and results obtained in relation with definitive treatment method*

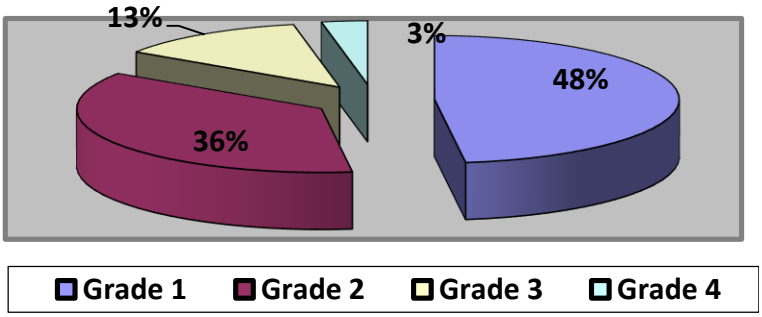
Type	***Treat.***	***No***	***Reduction***			***Objective results***				***Subjective results***			
			Good	***Medium***	***Poor***	***Exc.***	***Good***	***Satisf.***	***Poor***	***Exc.***	***Good***	***Satisf.***	***Poor***
RA I	**MI**	50	44	6	0	46	4	0	0	9	41	0	0
	ORIF	14	12	2	0	14	0	0	0	14	0	0	0
	EF	2	0	2	0	0	2	0	0	0	0	2	0
RA II	**MI**	23	21	2	0	19	4	0	0	17	6	0	0
	ORIF	32	28	3	0	29	3	0	0	27	5	0	0
	EF	9	5	4	0	0	7	2	0	2	3	4	0
RA III	**MI**	8	5	3	0	2	3	3	0	4	3	1	0
	ORIF	46	39	6	1	6	33	7	0	7	34	4	1
	EF	14	0	11	3	0	0	0	9	0	1	8	5
AO B	**MI**	67	51	16	0	45	22	0	0	44	23	0	0
	ORIF	45	31	14	0	20	22	3	0	18	25	2	0
	EF	7	0	6	1	0	4	3	0	0	3	3	1
	MI	14	12	2	0	11	3	0	0	10	3	1	0

AO	**ORIF**	47	12	2	0	11	3	0	0	10	3	1	0
C	**EF**	18	0	11	7	0	2	9	7	0	0	11	7

MI – minimal invazive, ORIF – open reduction internal fixation, EF – external fixator, Treat.-treatment, No.-number, Exc.-excellent, Satisf.-satisfactory

Radiologic score of arthrosis depending on Ruedi and Allgower fracture type after 1 year

Fig.133 Kellgren and Lawrence score



Comparative evaluation of the results obtained after 1 year with other similary studies from literature

Tabel no.80 *Evaluation of the results in relation with the osteosynthesis type* [12]

Study	Year	No	Open reduction internal fixation	External fixator	Good results %
Bonnier	**1960**	**30**	**20**	**10**	**43**
Decoulx	**1961**	**49**	**25**	**23**	**45**
Gay	**1963**	**142**	**70**	**72**	**50**
Fourquet	**1959**	**29**	**8**	**21**	**55**
Rüedi	**1968**	**84**	**0**	**84**	**74**
Heim	**1976**	**128**	**0**	**128**	**90**
Constanta retrospective	**2013**	**245**	**168**	**53**	**44**
Constanța prospective	**2016**	**198**	**173**	**25**	**89**

Table no.81 *Evaluation of the results in relation with complication type* [13]

Complication / Study	**Sreevathsa et al. (2010) 59 fractures**	**Gülabi et al. (2012) 32**	**Ovadia și Beals (1986) 145**	**El-Admar et al. (2009) 42**	**Bartolozzi și Lavini (2004) 42 fractures**	**Constanța (2013) 245 fractures**	**Constanța (2016) 198 fractures**
Superficial infection	2 (3%)	12.5%	10	4 (9.5%)	20%	24 (9.8%)	4 (2%)
Deep infection	3 (5%)	---	---	---		11 (4.5%)	0
Skin necrosis	---	6.25%	5	3 (7.1%)	---	97 (39.6%)	11 (5.5%)
Amputation	1 (2%)	---	---	---	---	1 (0.4%)	0
Delay of consolidation	5 (9%)	---	---	2 (4.8%)	---	63 (25.7%)	6 (3%)
Vicious consolidation	---	3%	27	5 (11.9%)	42%	100 (40.8%)	7 (3.5%)
Arthrosis	---	22%	---	---	50%	105 (42.8%)	25 (12.6%)
Algodistrophy	---	21%	5	4 (9.5%)	27%	108 (44%)	18 (9.1%)
Pseudarthrosis	---	9%	3	2 (4.8%)	18%	21 (8.57%)	2 (1%)
Late infection (osteitis)	---	3%	10	6 (14.3%)	17%	9 (3.67%)	0
Refracture	---	---	1	---	---	1 (0.4%)	2 (1%)

IX.2. Cazuistry –selective aspects

Fig.140 Case 2. Fracture 43 C1, RA type II, minimal invasive osteosynthesis with locking plate type L. Complet functional recovery. Olerud-Molander score 91, Kellgreen-Lawrence grade 1.

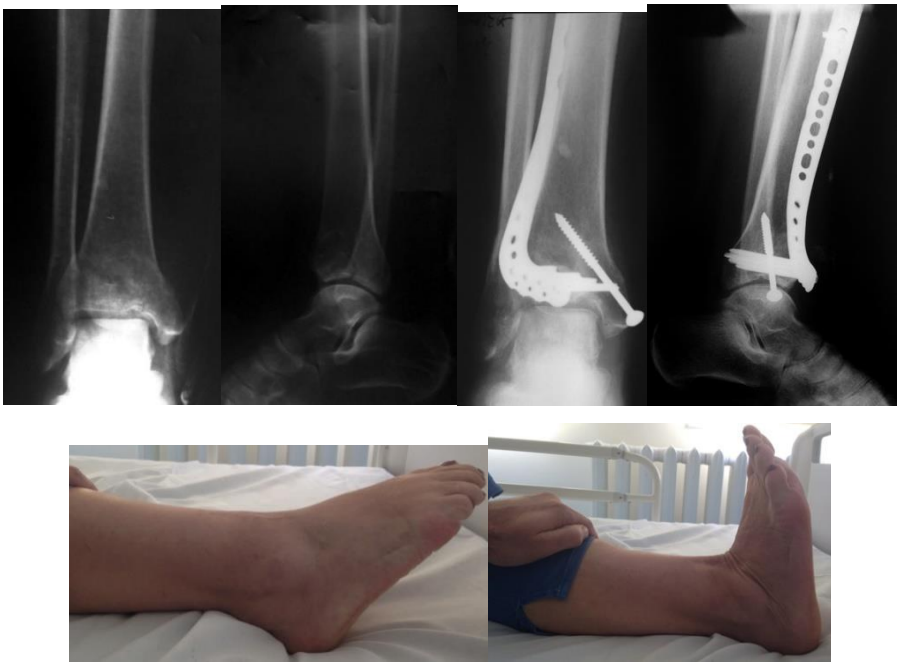


Fig.144 Case 6. 43 B3, RA type 2, minimal invasive osteosynthesis with locking plate type L, aspect at 1 year. Complet functional recovery. Olerud-Molander score 92, Kellgreen-Lawrence grade 1.

Fig.145 Case 7. 43 C1, RA type 2, staged osteosynthesis. Aspect at 8 months. Complet functional recovery. Olerud-Molander score 98, Kellgreen-Lawrence grade 1.

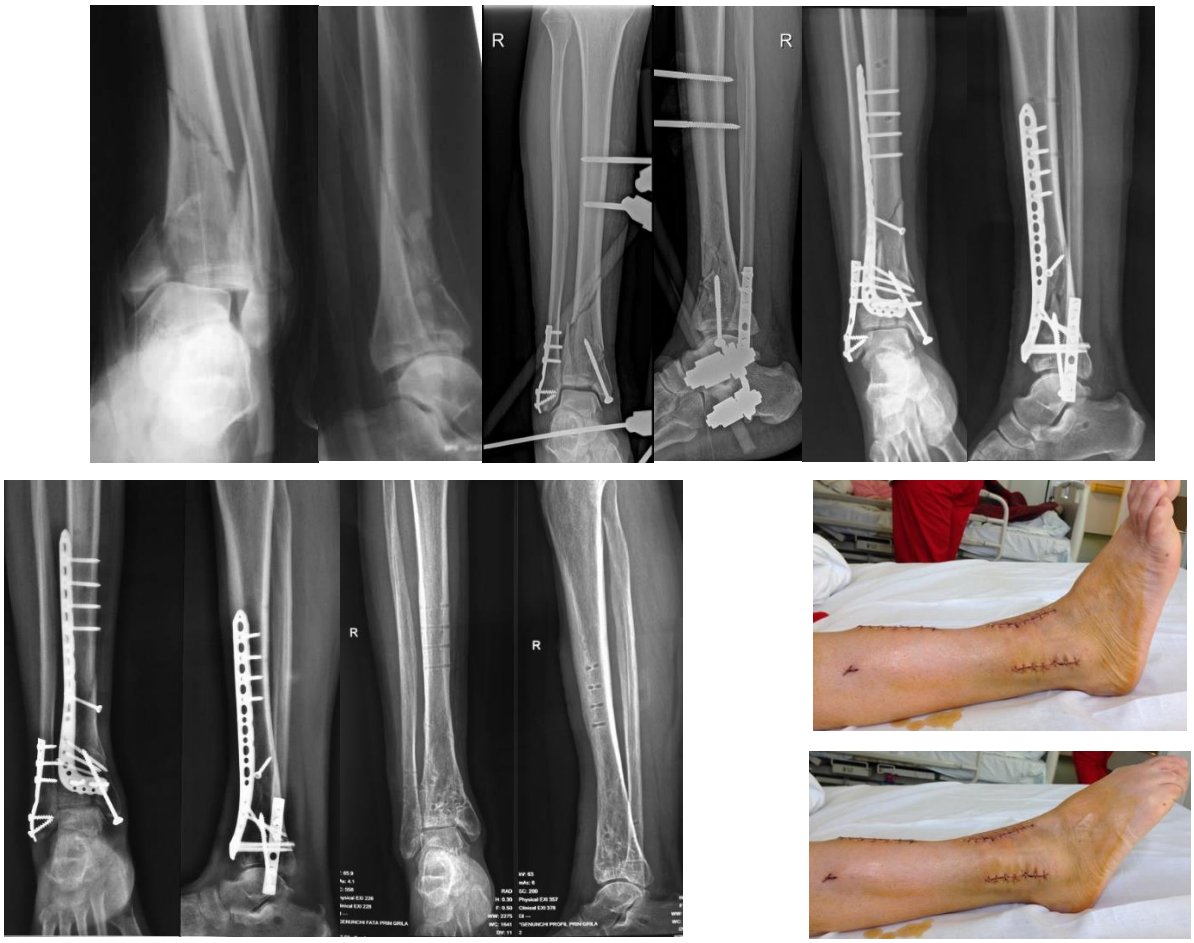
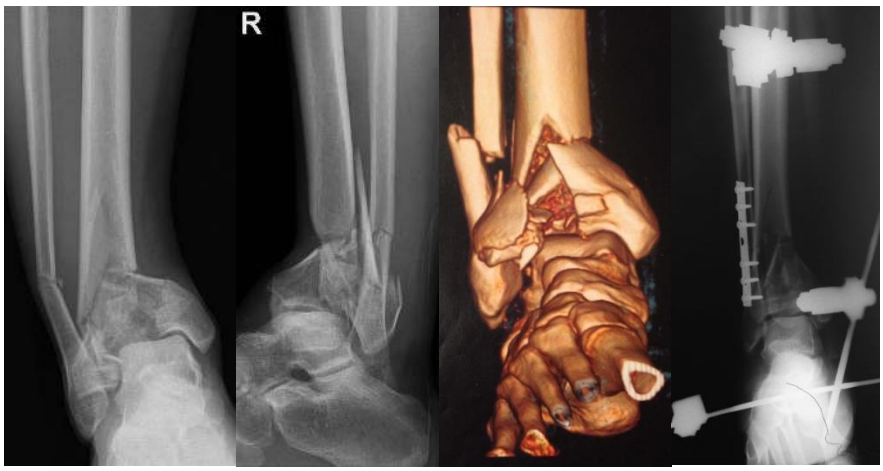


Fig.146 Case 8. Fracture 43 C3, RA type 3, staged osteosynthesis, first osteosynthesis of peroneus and external fixator tibial pilon, followed by open reduction internal fixation with locking plate of tibial pilon. Aspect at 1 year, after implant extraction. Complet functional recovery. Olerud-Molander score 82, Kellgreen-Lawrence grade 2.



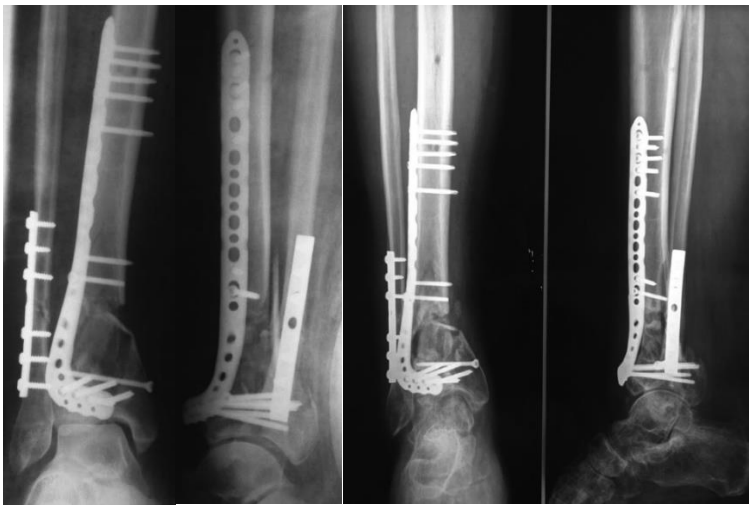


Fig.147 Case 9. Fracture 43 C3, RA type III, staged osteosynthesis. At 3 months image of delay of consolidation and broken implant after full weight-bearing of lower limb.

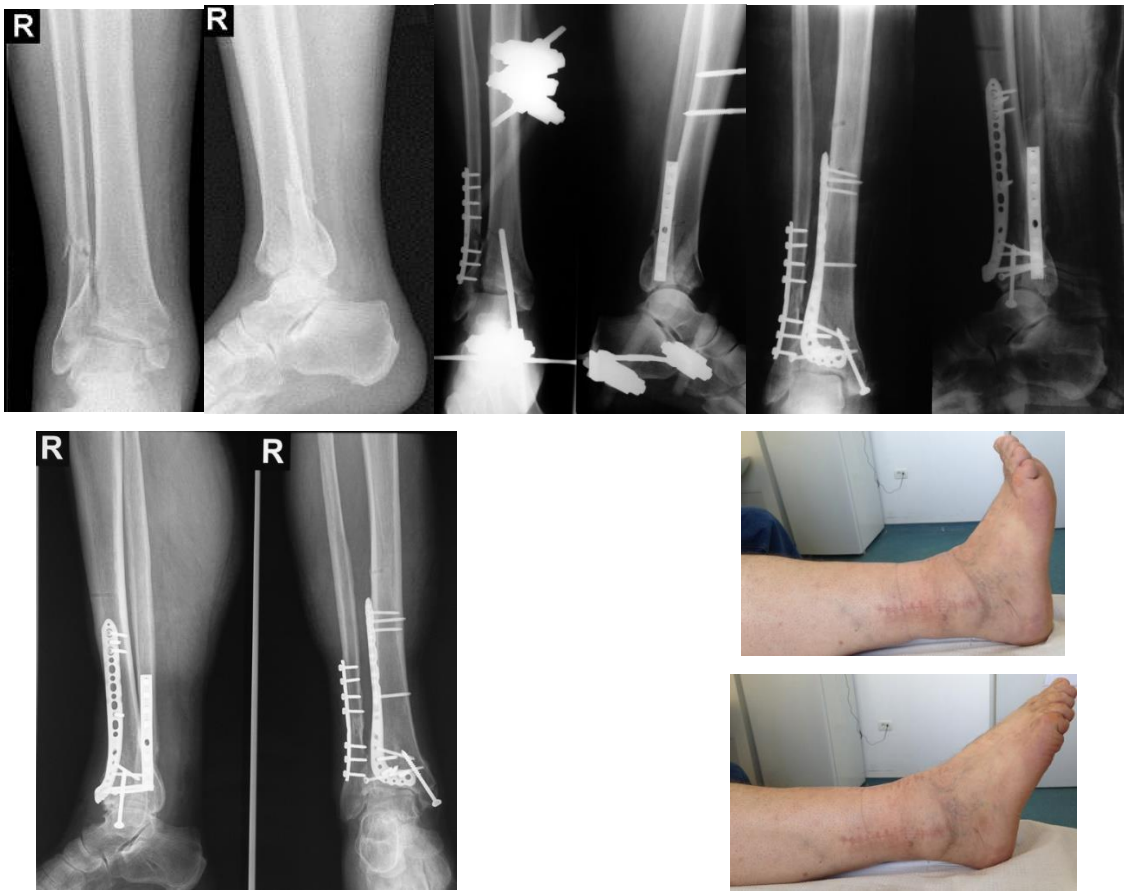


Fig.151 Case 13. Fracture 43 C1, RA tip 2, staged osteosynthesis, first osteosynthesis of peroneus and external fixator tibial pilon, followed by minimal invasive osteosynthesis with locking plate of tibial pilon. Consolidated fracture, aspect at 10 months. Complet functional recovery. Olerud-Molander score 84, Kellgreen-Lawrence grade 2.

Fig.152 Case 14. Fracture 43 C1, RA type 2, staged osteosynthesis, first osteosynthesis of peroneus and external fixator tibial pilon, followed by open reduction internal fixation with locking plate of tibial pilon. Delay of consolidation at 4 months. Complet functional recovery. Olerud-Molander score 89, Kellgreen-Lawrence grade 1.

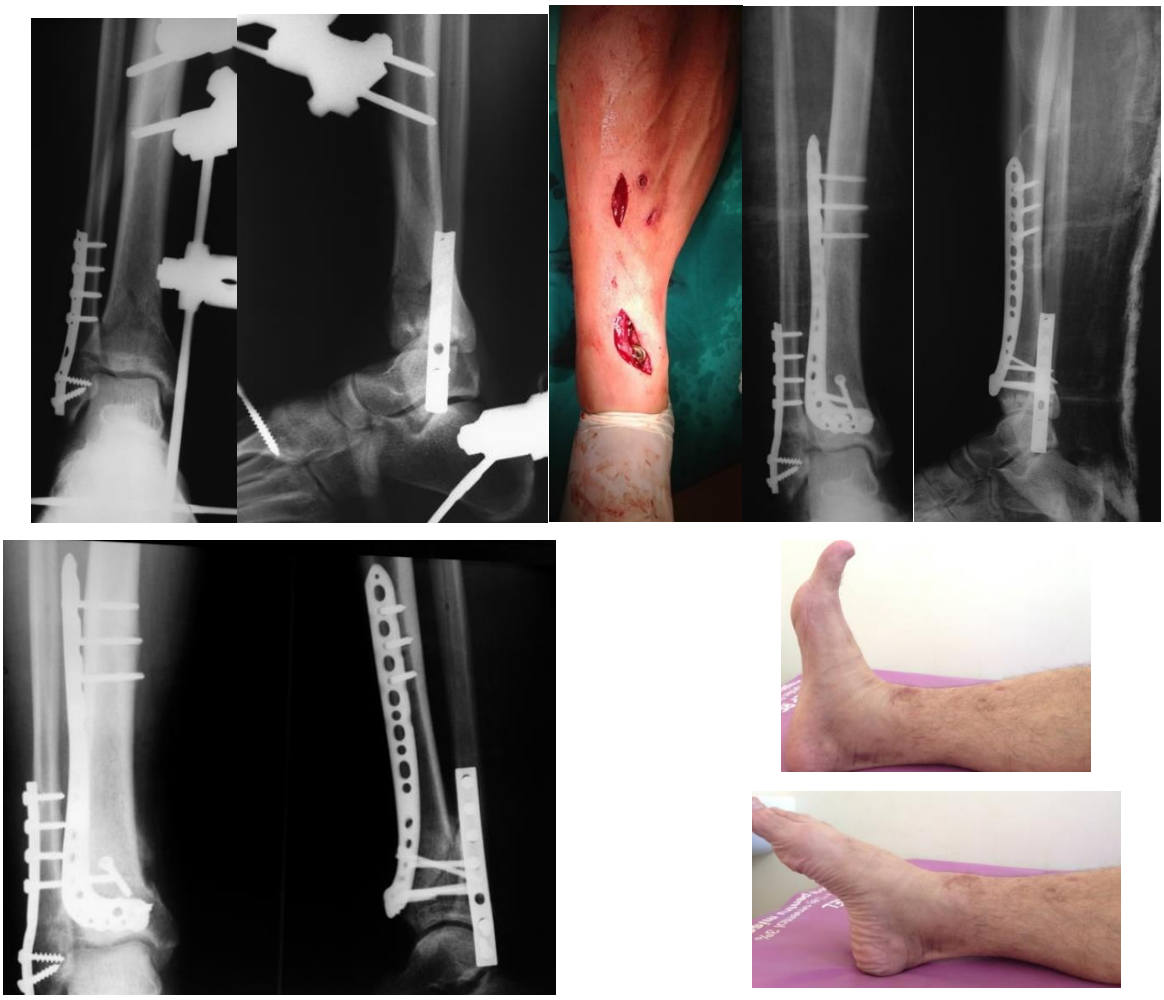


Fig.154 Case 16. Fracture 43 C1, RA type 2 right tibial pilon, staged osteosynthesis, first osteosynthesis of peroneus and external fixator tibial pilon, followed by minimal invasive osteosynthesis with locking plate of tibial pilon. Fracture consolidated, aspect at 8 months. Complet functional recovery. Olerud-Molander score 100, Kellgreen-Lawrence grade 1.

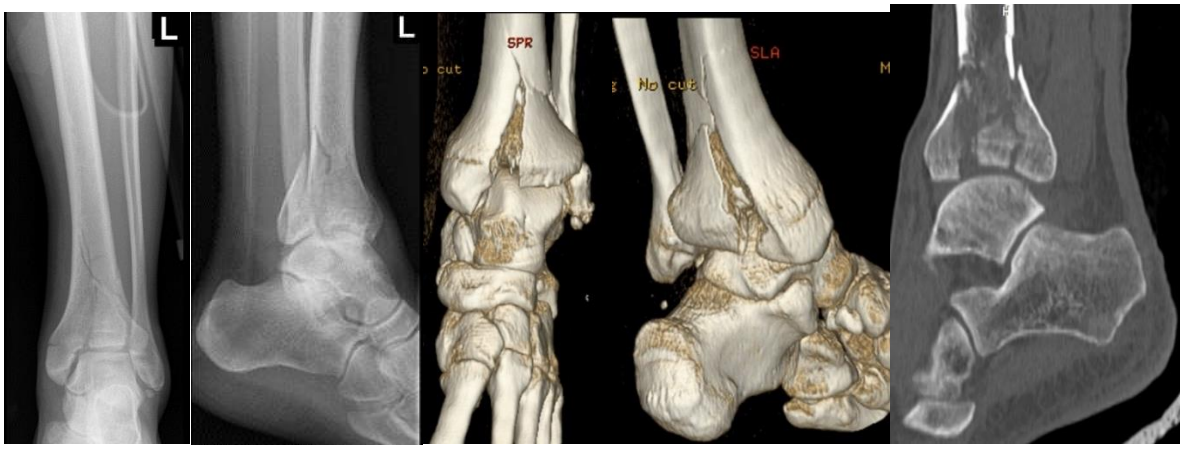
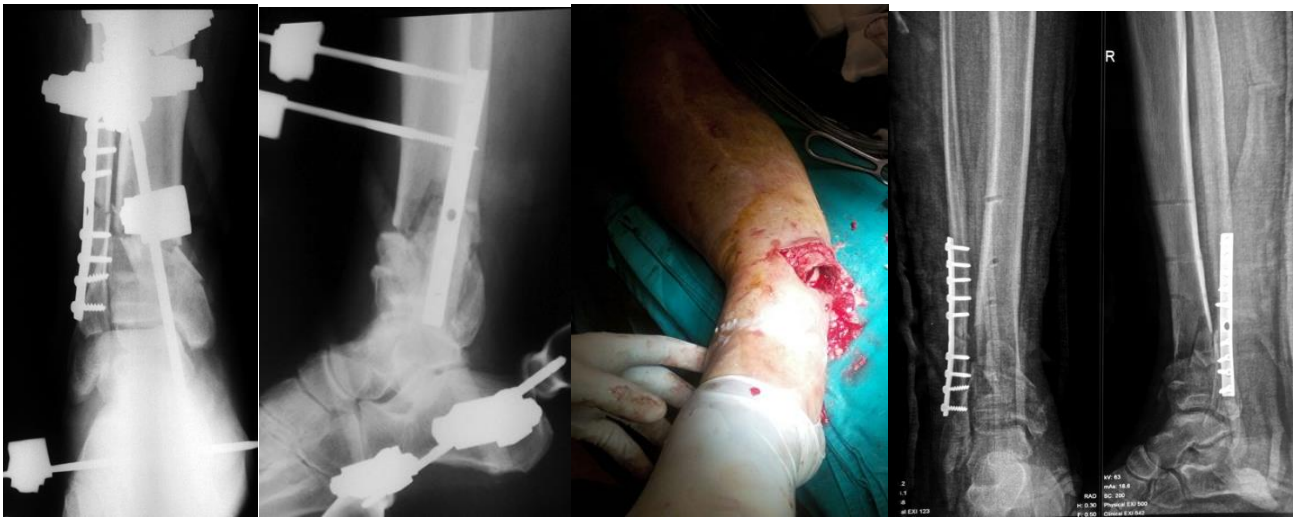
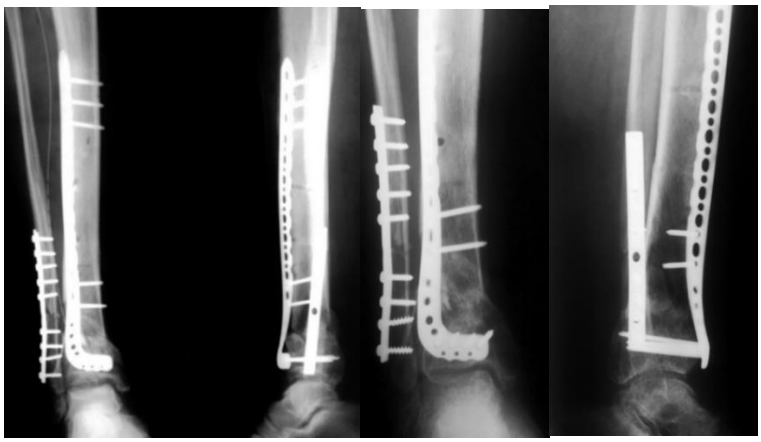


Fig.158 Case 20. Fracture 43 C1, RA type 3 left tibial pilon, open reduction internal fixation with locking plate of tibial pilon. aspect at 6 months, fracture consolidated, complet functional recovery. Olerud-Molander score 92, Kellgreen-Lawrence grade 1.

Fig. 159 Case 21





Fracture 43 C2, RA type 3, open type IIIB, staged osteosynthesis. Good functional recovery. Olerud-Molander score 75, Kellgreen-Lawrence grade 2.

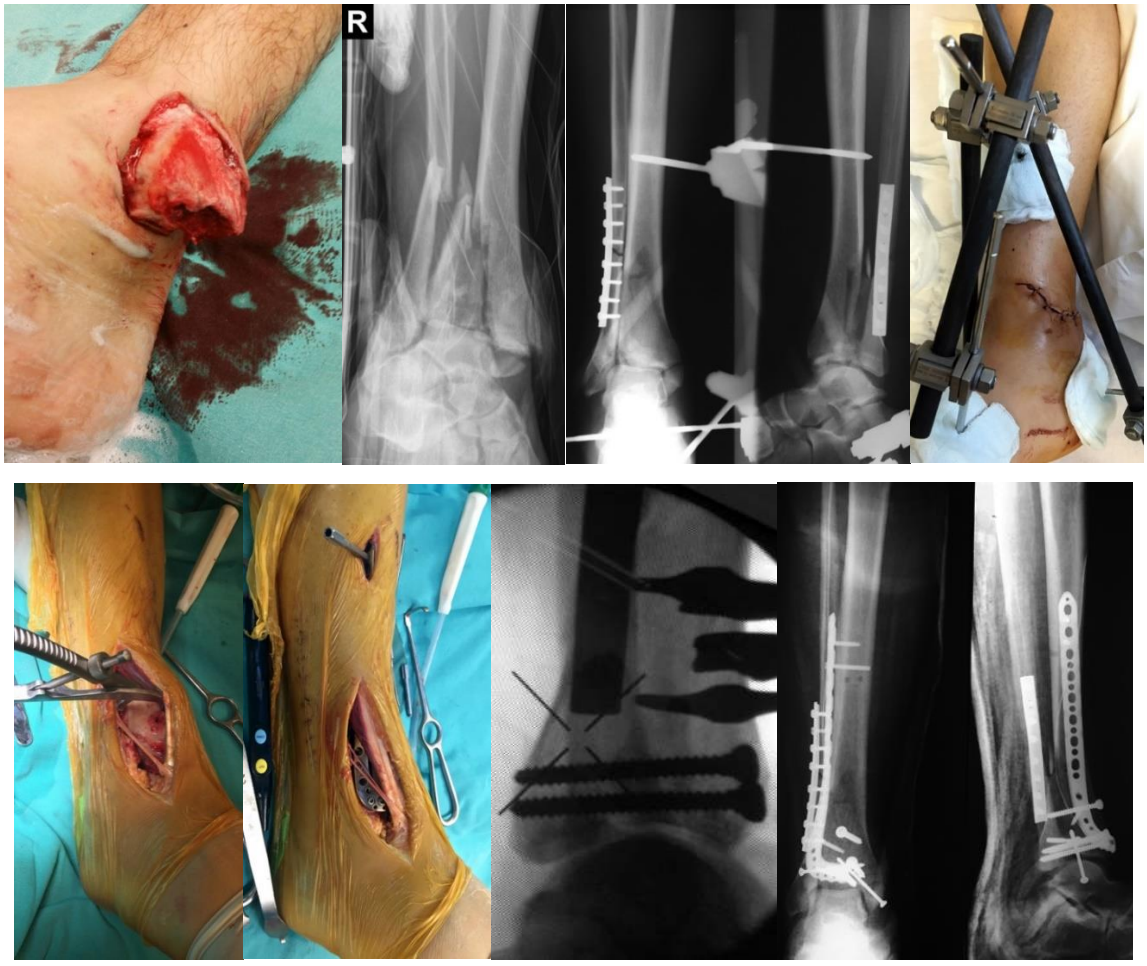


Fig.161 Case 23. Open fracture IIIB 43C2 right tibial pilon with peroneal fracture. Staged osteosynthesis: first stage, debridment and washing, external fixation pilon and plate for peroneus, late closing of wound after 48 hours, at 16 days, minimal osteosynthesis tibial pilon.

IX.3. Discussions

Treatment of tibial pilon fractures

Therapeutical protocol consist in the first stage of peroneal fracture osteosynthesis, with remake of peroneus length, when it is fractured and stabilisation of tibial pilon fracture with delta frame external fixator, followed in the second surgical stage, moment choosen depending on soft tissue quality, by tibial pilon osteosynthesis with minimal invasive approach or limtated approach of fractute site and stabilisation with locking plate L type. Preoperative planning need the exact diagnosis of fracture by using front and lateral X-rays and routine make of CT evaluation, plane and 3D. In the second surgical stage, the localisation of the surgical approach and the type of implant we use was imposed by the localisation of skin lessions, which were predominant on medial side of distal tibia, and impose to avoid these region. [14, 15]

Final stabilisation of fracture site (osteosynthesis)

The osteosynthesis of tibial pilon fractures was the final treament we choose in 100% of case, single stage osteosynthesis was applied in 23.24% of cases, external fixator was the final treatment in 12.6% of cases, and two-staged osteosynthesis was used in majority of cases as 64.14% of cases. (tabel 51) The choose of the moment we make osteosynthesis is important to avoid skin and infectious complications, especially in case of primary osteosynthesis. The most dangerous moment is considered to be between day 3 and 5 postoperatively, with the bigest rate of local complications. [16]

The peroneal malleolar fracture or supramalleolar fracture was stabilised through osteosynthesis with semitubular plate and screws in 144 cases and 1 case of peroneal dyaphiseal fracture was stabilised with Kirschner wire. The reduction of peroneal fracture must be anathomically, because a non-anathomically reduction will make difficult the reduction of tibial pilon fracture, compromising the next surgical stage.

The two stage surgery approach of tibial pilon fractures stabilised in emergency the soft tissue, fact which permitted the ulterior reconstruction and stabilisation of articular surface, which made possible the touch of two esential objectives for the treatment of any articular fracture, the anatomical reconstruction and the rapide mobilisation of the articulation. The choose of the moment is make the osteosynthesis depend on the local soft tissue condition, very important being the decrease of oedema and the normal aspect of tegument. [17,18]

The minimal invasive osteosynthesis was most frequent used in type I fractures because the fragments were not displaced and cominution wasn't important, fact which become more complicate in case of type II fractures, where lesional energy increase, cominution and displacement of fragments became more important, which made to decrease the number of cases we used this method. In the cases where the initial displacement wasn't corrected after the first osteosynthesis stage with external fixator in emergency, it was necessary the limited open as possible was of the fracture site to obtain the articular reconstruction.

Because the majority of cases from the prospective group presented skin lessions or integument opening on the medial side of distal tibial, the region most exposed to this kind of lessions because the anathomical particularities already exposed anteriorly, the surgical approach for internal osteosynthesis will avoid it and the surgical approaches we used were antero-medial or modified antero-lateral. These classical approaches were adapted after the principles of minimal invasive osteosynthesis, being actually limited direct approaches of the distal tibia, which avoid disadvanteges of the clasical extensive approaches and implies direct access to the fracture site, with maximum protection of soft tissues. [19]

The plate we prefered was the "L" shape. Excepting the fact that locking plates enssure superior stability to the simple plates, these plates are already anathomically modeled, making easier their insetion and the reduction of fracture site, another major advantage being the biology favourable to consolidation of bone, by preserving the periosteal vascularisation. That important thing is realised due to their special profile which has limited contact to dyaphiseal bone. [20-23]

The annalysis of early results

If in case of retrospective group of patients we met closed fractures, but the skin disorders due to ischemia leaded to secondary open of tegument in 13.46% of casuistry, in case of prospective group, after fracture stabilisation in emergency with semitubular plate of the peroneus combined with external fixator transarticulary for pilon, none of the cases evoluated with the secondary opening of the fracture site, allthough there were 11 closed fractures (5.5%) which presented soft tissue lessions, due to an unfavourable local evolution, but were stabilised after applying the therapeutic protocol in emergency.

The annalysis of late results

The comparative annalysis of the dates obtained after the evaluation of tho groups, retrospective and prospective, reveal a significant lower rate of complications in case of prospective group. First of

all, was no case of osteitis, allthough was a significant number of open fractures. The percent of arthrosis was reduced four time, due to anathomic articular reconstruction, realised in stage two of osteosynthesis, ankle stiffness, chronic oedema and neuroalgodistrophy were found in percents four time smaller by shortening the period of immobilisation of ankle, rapide mobilisation being possible because of the firm osteosynthesis we obtained.

The highest proportion of the cases which presented an important number of late complications were the ones we used external fixator as definitive treament. The choise of external fixation as final treatment was imposed by the presence of ischemic skin lessions or by a fracture wound with an unfavourable evolution in case of open fractures, that made difficult the staged osteosynthesis in second time with locking plate, because of high risk for deep skin necrosis and infection.

Clinical and radiological evaluation of the late results

Olerud and Molander clinical score at 1 year after the last surgical procedure showed significant superior results than the results of the retrospective group: excellent results 37% than 15% in first group, giid results 52% than 29%, moderate results 7% than 39% and poor results 4% than 17%.

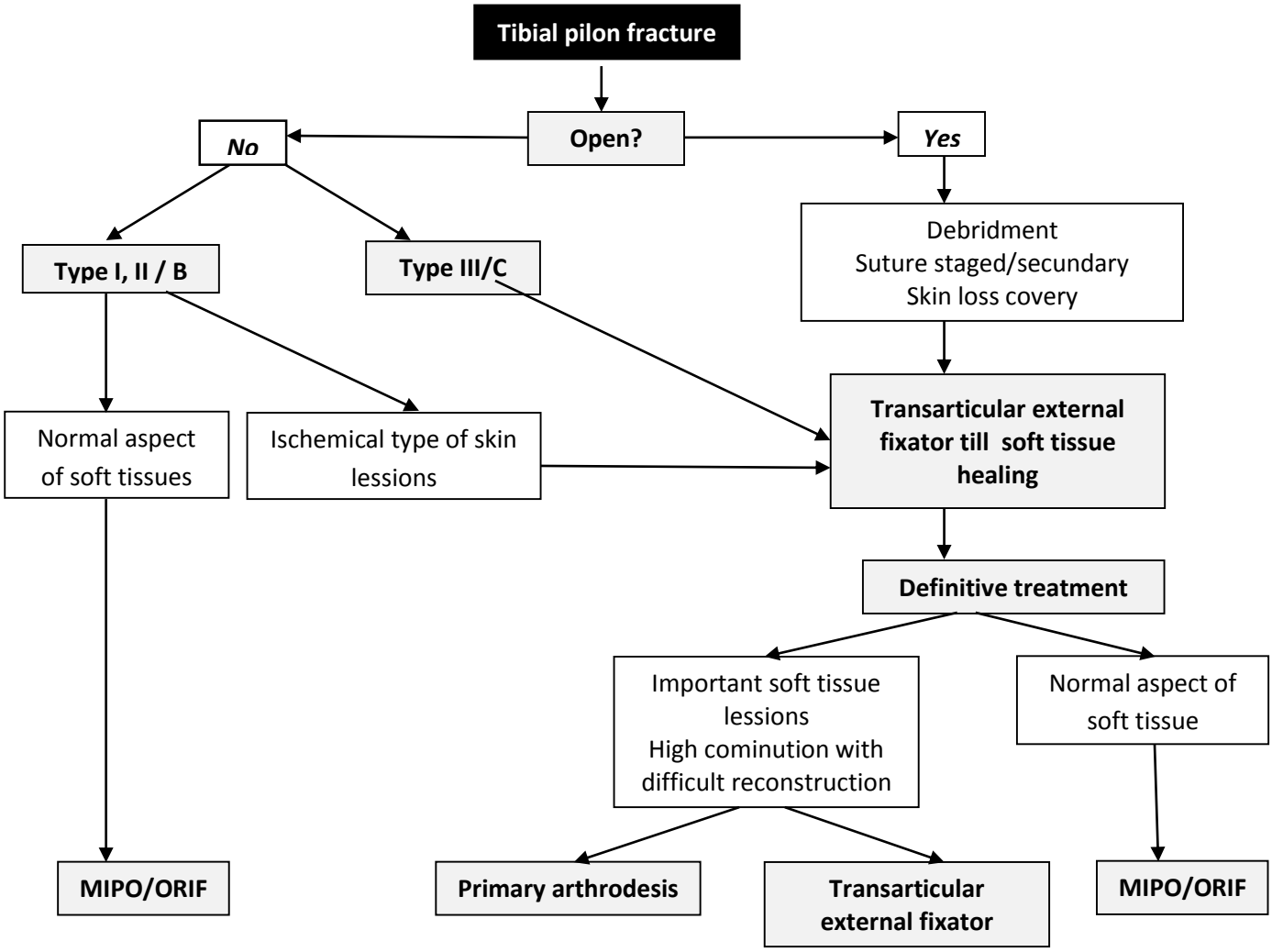
The evaluation of the quality of fracture reduction in relation with the osteosynthesis applied showed an anathomical reduction in case of minimal invasive osteosynthesis and of open reduction and internal fixation for all types of fractures and a medium reduction, sometimes poor, for Ruedi-Allgower type III and type C AO, stabilised by external fixator. The favouranle functional results are statistically correlated with a very good Kellgreen Lawrence radiologic score, with significant higher percent for the prospective group than retrospective group, regarding the good results.

If in retrospective group excellent and good results aggregate were 44% from the cases, this time we can say that by applying the twp staged therapeutic protocol in prospective group, we managed to obtain a net score higher 89 % of casuistry.

Applying two-stage fixation in fractures of the tibial pilon had the effect of a significant reduction of specific complications of the condition, compared to other similar statistical evaluation of literature, which confirms the effectiveness of the proposed treatment protocol. I note again that retrospective and prospective value of the comparative study performed in our clinic is supported by the large number of cases, more than the number of patients enrolled in studies published similar due to diversity of casuistry, which belonged to complex fractures.

Treatment algoritm for tibial pilon fractures

Fig.162 Therapeutical protocol for tibial pilon fractures



IX.4. Conclusions

Internal fixation in the open fractures is associated with a high risk of infectious complications and the kind that come from suffering ischemic skin, because the surgery is done on a soft tissue compromise. When performing gradual osteosynthesis stabilization of the soft tissues is possible.

External fixation of tibial pilon after remaking of poeroneus length and his stabilisation with semitubular plate is the ideal therapeutic option in emergency for tibial pilon fractures, realising a true local “damage control” by both stabilisation of soft tissue and fracture.

Transarticular external fixator delta type influenced mostly positive local developments of prospectively group compared with Hoffmann external fixator type that had mediocre results as a method of external fixation, in retrospectively group.

Minimally invasive internal fixation ensures environmental conditions favorable natural healing process, preserving and respecting the fractured fragments vascularization biology bones that occurs rapidly and without incident.

External fixator as a definitive method for stabilizing bone is an excellent therapeutic option where lesions of the soft tissues do not allow for internal fixation during the second surgery stage, with a rate of local early and late complications slightly higher than after fixation in two stages, but more lower than the primary internal fixation.

Fibula osteosynthesis benefit by providing superior stability to external fixation of tibial pilon, preserves fractured limb length and rotational movements control of tibial fracture site.

The localisation of skin lessions on antero-medial part of distal tibia impose the avoide of this region in second surgical time, imposing the use of modified antero-medial and antero-lateral approach, and the L shape of the plate.

CHAPTER X. The minimal invasive osteosynthesis of distal peroneal fractures – an innovative therapeutical approach

X.1. The aim of the study

The purpose of the study is to retrospectively evaluate the immediate and late results of a new minimally invasive distal fibula fractures osteosynthesis, the only one currently cited in literature with very good results, by using a centromedullary static blocked implant, called XS-nail.

X.2. Material. Methods

The study covered all distal fibula fractures, addmited and treated in the Clinic of Orthopaedics-Traumatology of the Clinic Aschaffenburg Hospital in Germany, under the guidance of the Head of the clinic Prof. Dr. Wilhelm Friedl, in a timeframe of 2 years, January 2013 – December 2014. The study lot was retrospective and includeda number of 214 patients, diagnosed and treated in this timeframe.

The study focused primarily on the distal fibula fractured associated with tibia pilon fractures in which minimally invasive fibula approach is crucial to stabilize the local soft tissue.

Fig.163 XS-nail: way of asembling and instruments, the rod having different diameter and length, depending on fibula anatomy and fracture site.

X.3. Results

Table no. 82 *Demographic case profile*

Evaluation time		January 2013 - December 2014
Number of patients		214
Minimum evaluation time		6 months
Average age		51 years
Sex (M/F)		88 (41%) / 126 (59%)
Fracture type	Bimalleolar	75
	Weber B	82
	Weber C	57
Fracture association	Tibia pilon	47
	Tibial shaft	19

The biomechanical comparison study between the locked plate and the XS-nail in terms of resistance to axial compression, highlights the superior strenght of the XS-nail. For the study was used synthetic fibula (Sawbones), to wich an oblique type B or c Weber fracture was made, followed by fixation with XS-nail and locked plate, for each type on fracture.

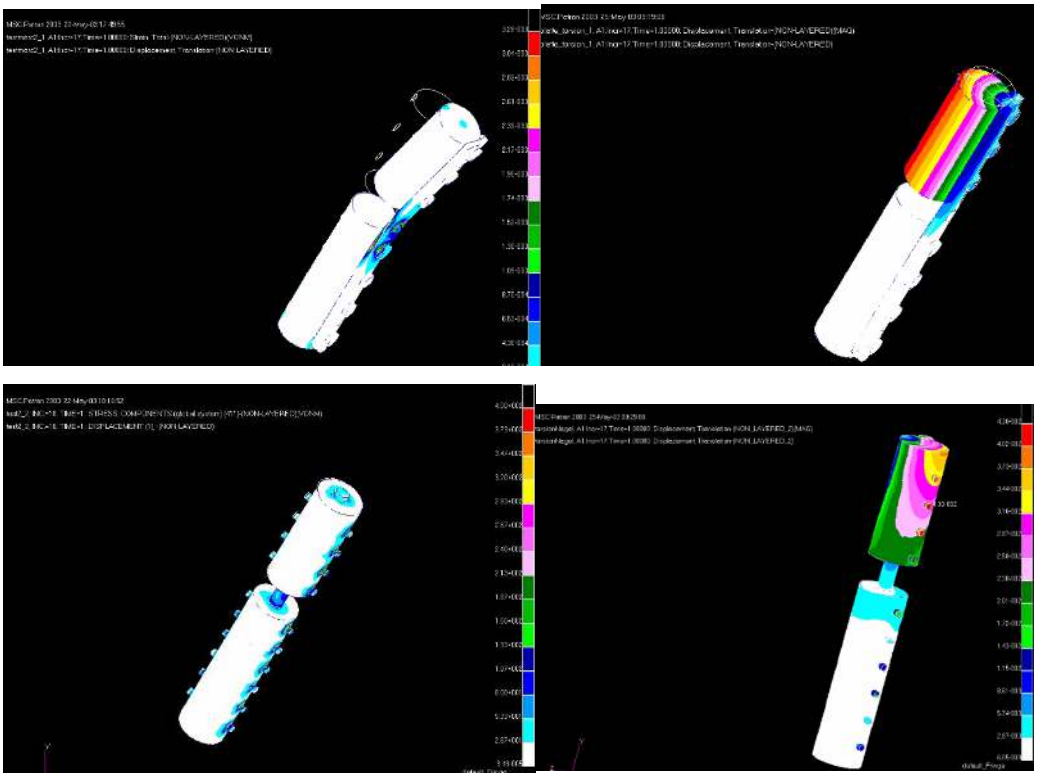


Fig.165 Mathematical model of resistance to axial compression: top images locked plate, below images XS-nail. Xs nail shoes void diformity on same parametres.

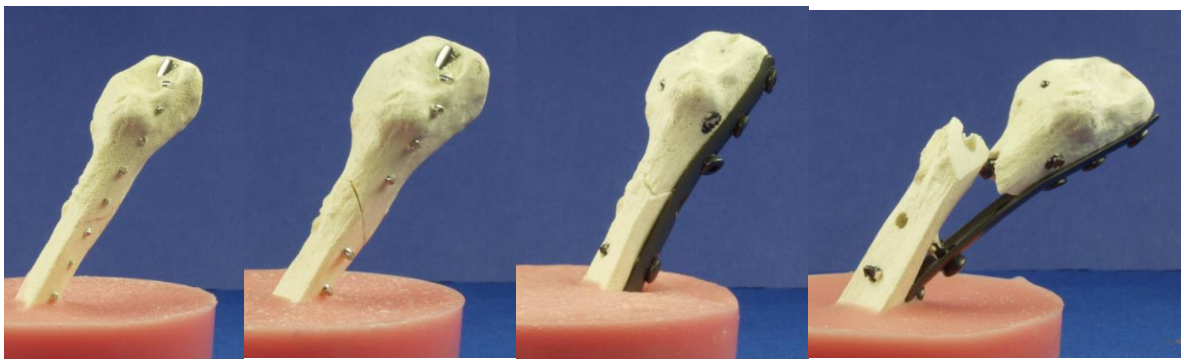


Fig.166 XS-nail has a much higher resistance to axial compression than the locked plate, wich diforms and leads to damage of the fixation assmbly.

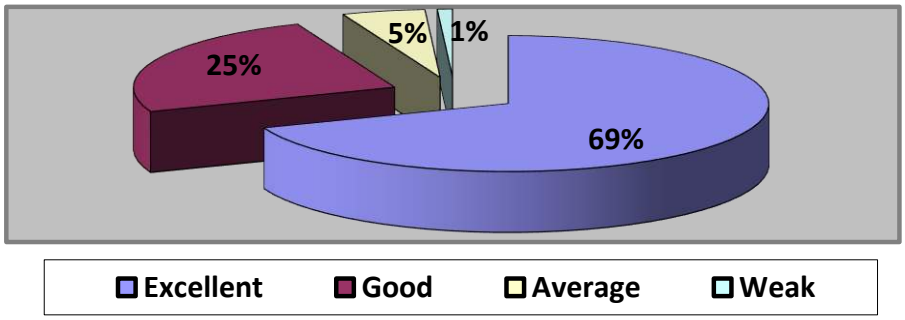
Local complications

Rezultatele imediate au fost excelente, remarcându-se faptul că nu s-au înregistrat complicații de tip necroză cutanată secundară, hematom sau infecție postoperatorie la nivelul focarului fracturar peronier.

Table no.85 *Ovadia and Beals score at 1 year*

Ovadia/Beals Score	*Objectively*		*Subjectively*	
Excellent	75	35%	81	38%
Good	90	42%	96	45%
Average	38	18%	31	14%
Weak	11	5%	6	3%

Fig.170 Olerud & Molander Score XS-nail



X.4. Casuistry –selective aspects

Fig.172 43B3 pilon fracture, Weber B fibular malleola. Phased osteosynthesis: external fixator emergency osteosynthesis, and after 7 days XS-nail fibular osteosynthesis and 2 XS-nail tibial pilon osteosynthesis.

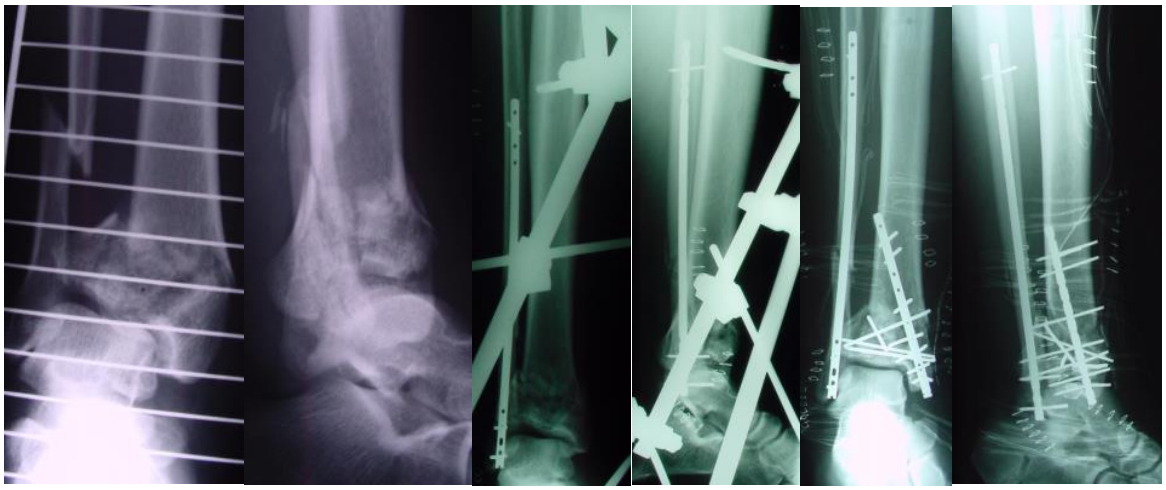
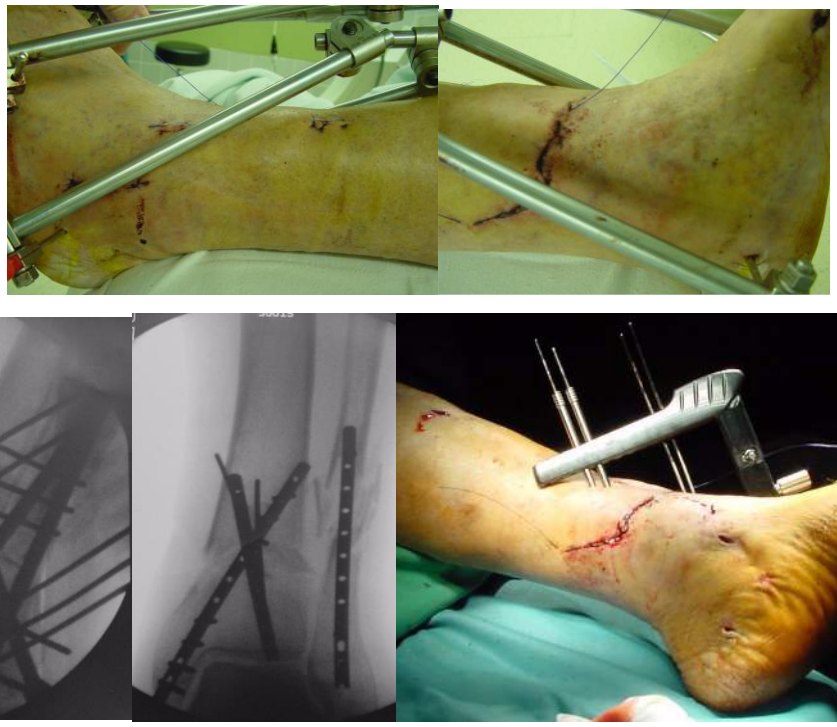
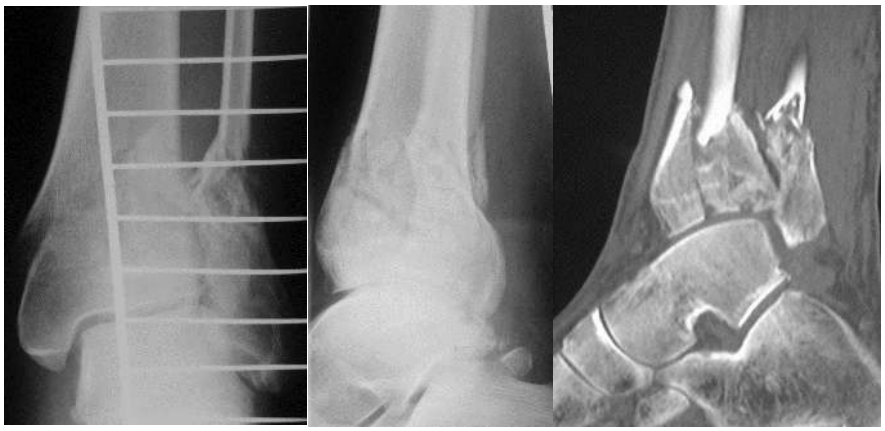


Fig.175 43C2 type II open tibial pilon fracture and Weber C fibula fracture. Sequential osteosythesis: XS-nail closed site fibular osteosynthesis and external tibial fixator, after 12 days XS-nail and brooches osteosynthesis.



Minimally invasive 2 XS-nails tibial pilon osteosynthesis after 21 days. Final aspect 1 year postoperative, after extraction of the implants.



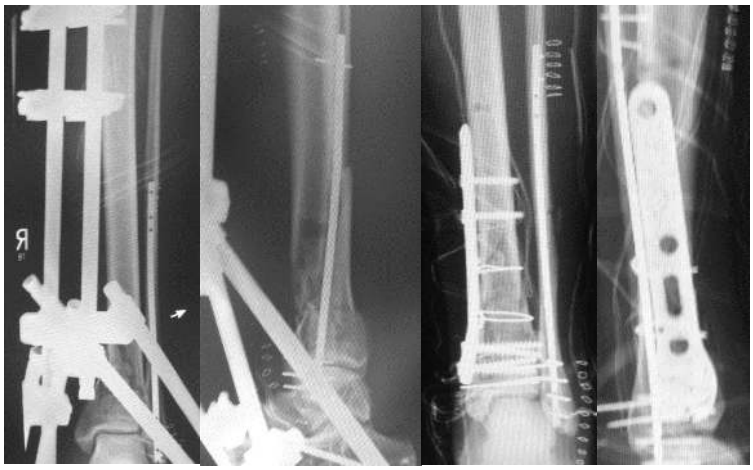


Fig.187 43C1 tibial pilon fracture and Weber C fibular malleola. Staged osteosynthesis: minimally invasive XS-nail fibular and tibial external fixator, after 12 days tibial pilon plate osteosynthesis.

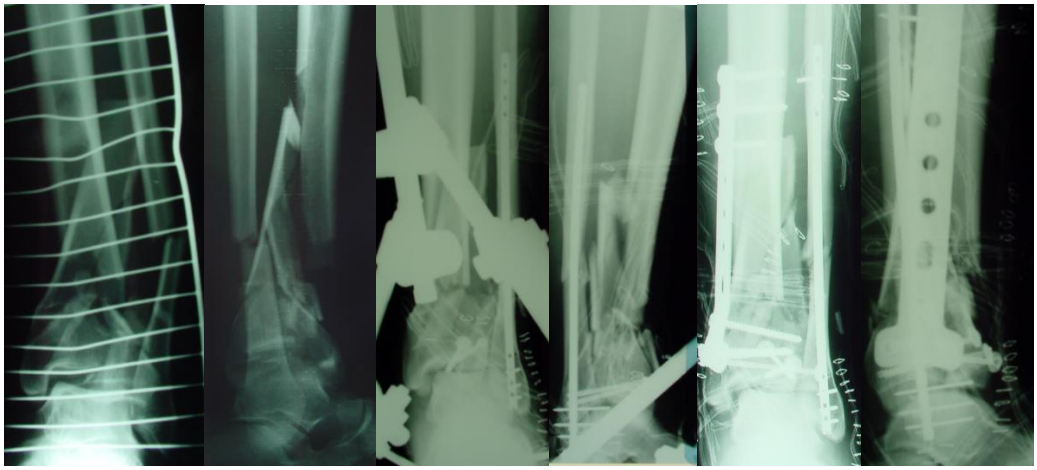


Fig.188 IIIA 43C3 tibial pilon fracture and Weber C fibular malleola fracture. Phased osteosynthesis: minimally invasive XS-nail fibular osteosynthesis and external fixator tibial pilon., after 18 days minimally invasive tibial pilon plate osteosynthesis.

Fig.191 43C1 tibial pilon fracture and Weber C fibular fracture. Minimally invasive XS-nail fibular osteosynthesis and 2XS-nail tibial pilon osteosynthesis, 9 months postoperative.

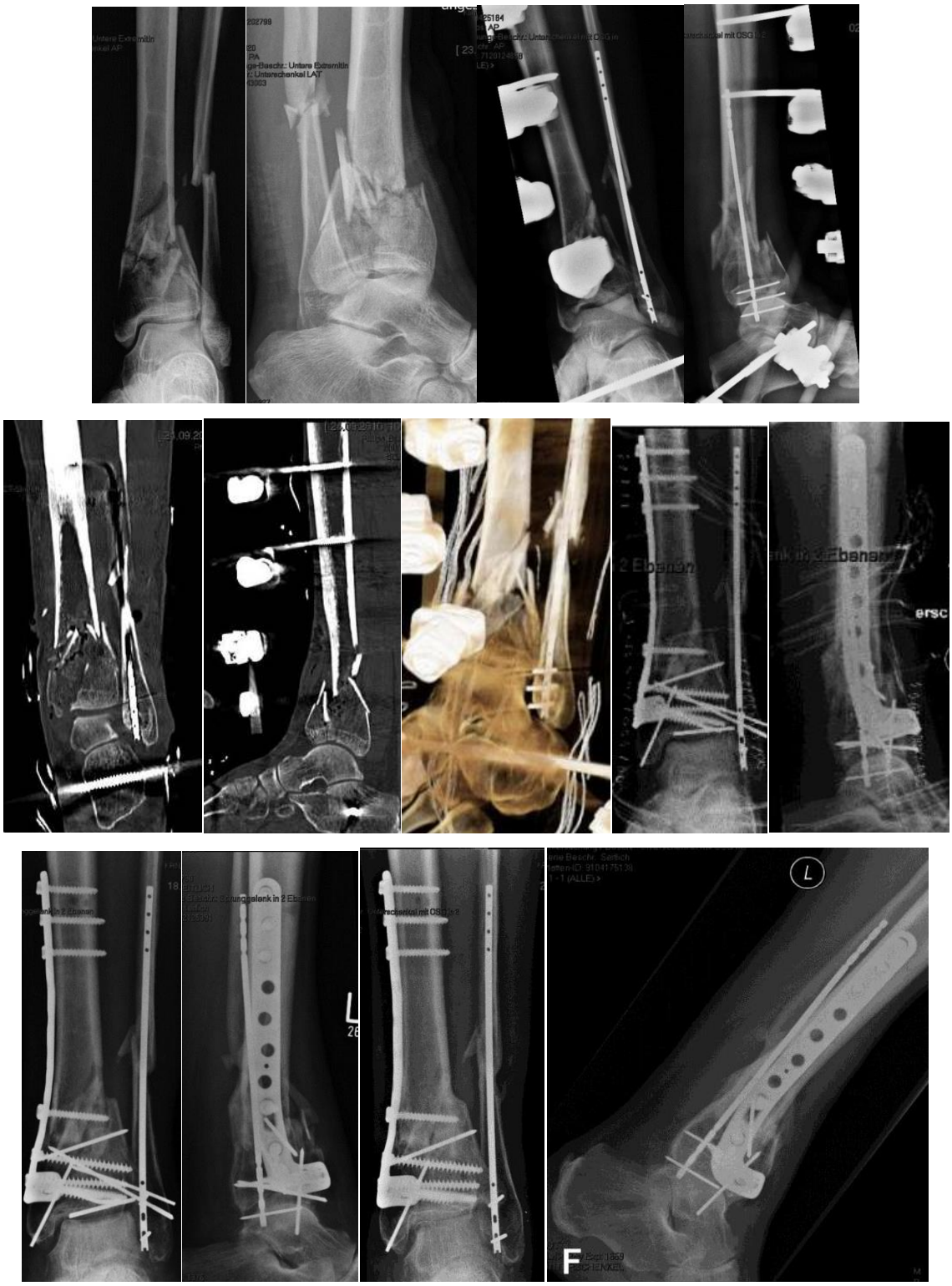


Fig.194 43C2 IIIB open site fracture. Staged osteosynthesis: internal XS-nail fibular osteostynthesis and external fixator tibial pilon; Ct scan is part of the second stage planning, internal limited approach and “L” plate tibial pilon osteosynthesis. 1 year postoperative aspect, strong ankle arthrosis.

X.5. Discussions

At the time, open site plate distal fibular osteosynthesis is the universally accepted stabilizing standard of these types of fractures, but the method is predisposed to skin complications, especially in the previous mentioned situations. For this reason it was necessary to develop an implant to stabilize the peroneal fracture, to protect the soft parts, trough a minimally invasive percutaneous approach or limited open site approach, to protect the vascularization. The idea came from the intramedullary locked rod osteosynthesis principles, because fibula has a small intramedullary canal, but that might allow the passage of a thin rod. Even in the situations where the fracture site needs a minimum approach for an anatomic reduction, intramedullary rod placement preserves periosteal vascularization, which plays an important role for consolidation in this region. [24,25]

In case of dyaphiseal or supramalleolar fibular fractures, fracture reduction and XS-nail fixation can be done in closed outbreak. In case of transsyndesmothic or subsyndesmothic fractures, the anatomic reduction is mandatory, because of the articular interest, being the basic principle to reduce the risk of osteoarthritis. In this case it it necessary to approach the fracture trough an open site.

XS-nail implant key feature is not only the periosteal vasculature and skin preservation but also is more stable than conventional plates and even the angular stable locked plates.

Biomechanical study demonstrates superior resistance to XS-nail stabilized fibular fracture put trough a continuous axial compression. Quantification of stability and resistance to axial loading showes values at least double for the intramedullary rod. This type of stabilization allows immediate and complete loading of the operated limb, when the fibular fracture is the only present fracture. (figura 167)

Regarding fibular fractures who associated tibial pilon fractures or in case of open site fractures, the therapeutic approach was phased osteosynthesis, with XS-nail fibular osteosynthesis and emergency external fixator tibial pilon, followed as a second surgical step, when the soft tissue condition allowes it, by minimally invasive or limited approach open site locked plate tibial pilon osteosynthesis.

We note that, where comminuted tibial pilon fractures were associated, Xs-nail was considered to be a possible viable alternative to emergency external fixator osteosynthesis, sometimes even using 2 XS-nail placed in “X”, with good results in soft tissue protection and fracture stability.

X.6. Conclusions

Emergency fibula fixation is mandatory when associated with fractures of the distal tibia or tibial pilon. Percutaneous osteosynthesis technique with XS-nail used to treat concomitant fracture of the fibula associated with tibial pilon fractures allowed abandoning a second lateral surgical approach. This way, and additional stress underlying soft tissue injuries was avoided.

Minimally invasive osteosynthesis of the fibula with XS-nail meets all the criteria for the preservation of soft tissue and is an optimal preparation for the treatment of tibia in terms of restoration of the axis, length and rotation.

Tibia osteosynthesis of fractures with soft tissue injuries can be done with an external fixator but, when the soft tissue injury is important, the use of intrameduullary XS-nail tibia fixation can be used, having almost the same results as an external fixator.

XS-nail breathes new life into the concept of "damage control surgery", especially in distal fibula fractures associated with severe fractures of the tibial pilon by maintaining the soft tissue around the peroneum, which is equally exposed to ischemic suffering as the tibial pilon surrounding skin.

CHAPTER XI. Final conclusions

1. High frequency of tibia pilon fractures among men (77.5%) is due to gender specific traumatic circumstances (working place with high traumatic risk, car crashes, alcohol consumption). The etiology was dominated by falls from height (50.5%) and the most common skeletal lesion associated was fibula fracture (70%). The statistics regarding the age groups shows the highest frequency at 31-60 years (63.7%), the most active group, followed by the group between 16-30 years and those over 61 years. Comminuted fractures (76.6%) dominated in frequency, because of a relation between the intensity of the traumatic event (high energy trauma were dominant 69%) with the skin lesion type.

2. Primary lesion assessment is based on Ruedi Allgower and AO classifications that allow a full diagnosis, therapeutic guide conduct and suggest immediate and long-term prognosis. Soft tissue injury assesment is based on Gustilo Andersen clasification, the only one who can corectly evaluate the grade and severity of lesions.

3. Emergency or after primary fixation osteosynthesis plane 3D reconstruction CT scan, is mandatory and completes the data given by standard radiology because certain tracks, or clogging

degree of articular comminution may be omitted on the front and profile X-rays, and gives the precision diagnosis on sagittal and coronal fractures accurate trajectory.

4. The absence of a therapeutic algorithm approach on tibia pilon fractures led to the report of a high number of unfavorable outcomes (56%) in the retrospective lot case, and is currently the main cause of increased complications that are quoted in specific literature. The therapeutic algorithm proposed and successfully applied in our clinic provides a very low rate of these complications, reported to similar studies in the literature. (89% good results)

5. According to the applied algorithm, per primam internal osteosynthesis is allowed only in closed tibial pilon fractures type I and II Rudy-Allgower and B AO, with normal aspect soft tissue. Any local ischemic suffering (edema, bruising, blistering, skin necrosis or opening) leads to phased surgical protocol.

6. The principles of "damage control surgery" underlie therapeutic management of tibial pilon fractures. External fixation of tibial pilon after fibula osteosynthesis plate or XS-nail is ideal therapeutic option in emergency, realizing concomitant stabilization of fractures and soft tissue.

7. External fixation as a definitive method for stabilizing bone is a therapeutic option to be considered, with good results, where soft tissue injuries do not allow second step osteosinthesys.

8. Staged surgical approach allows optimizing the management of soft tissue and late good quality anatomical reconstruction of the articulation, with very good long term results.

9. Minimally invasive osteosynthesis or limited open approach with locked plate, performed in the second surgery step allows anatomical reconstruction of joint with a decreased risk of osteoarthritis and preservation of bone blood vessels , preventing the delaying of the consolidation or pseudarthrosis.

10. XS nail peroneum osteosythesis trough percutaneous or open limited approach, done in emergency, fullfils all the preservation for soft tissue criteria and allows the avoidance of a second lateral extended surgical approach giving a higher stability than plate osteosynthesis. In case of comminutive fractures, sometimes an open limited approach is used for anatomic reconstruction of fracture fragments.

11. XS nail brings a new look on the damage control surgery concept, trough soft tissue preservation of the peroneum area, wich is as exposed to ischemic complications as tibial pilon area. Tibial pilon osteosynthesis in comminutive fractures with important soft tisue lesions, can be done with either XS nail or external fixator, with similar results.

12. The location of skin injuries, more frequent on the medial side (79% in case of open fractures) led to avoidance of this area in the second surgical step and the use of modified latero medial and antero lateral approach as well as the design of the implant with the use of "L" type locked plate.

13. The criteria that define arthrodesis as a final treatment method for tibial pilon fractures are the surface and quantity of missing articular bone, the severity of the comminution and the degree of articular impaction. The arthrodesis of tibial pilon fractures whos recontruction seems impossible is most likely to be done with locked retrograde rod because of the lower risk of local complications.

14. The late bad results and arthrotic risk are negatively influenced by the severity of the fracture according to AO or Rudy – Allgower classification, type C fractures (22% low results), type III (24%), having a more weak functional prognosis than type B fractures (3%), also type i(0%) and II (8%).

15. The severity of the radiologic arthrosis in case of tibial pilon fractures does not always correspond to the clinical objective and subjective results, being pretty well clinically and functionally tolerated. The comparing evaluation of the subjective appreciation of the patient towards the objective measurment of the ankle function shows the fact that the patient tollerates a moderate functional limitation and adapts to it, without being bothered by it.

Personal contributions

The thesis presents a final therapeutical approach of tibial pilon fractures succesfully applied in ur clinic and that should be considered a golden standard in the approach of this pathology in any trauma clinic. This therapeutical protocol will significantly reduce the unfavorable results, insuring the social-professional reinsertion of the patients and significantly reduces the costs of hospitalization and subsequent social assistence.

In that thesis I proved that minimal invasive surgical approach of tibial pilon is possible in antero-medial and antero-lateral side too, much sure from the point of view of ischemical skin lessions than the medial side, region of high risk because of weak local vascularisation and the high frequence of localisation of traumatic skin lessions.

The thesis includes a clinical and biomechanical study of a new centromedullary implant, XS-nail, especially used in the peroneum osteosinthesys, but also tibial pilon. What makes the XS-nail special is that is the only osteosinthesys material that allows minimally invasive or limited open approach, preserves the periosteal peroneum vascularization, as well as the skin vascularization, avoiding a large lateral incision that happens in case of plate osteosynthesis.

Perspectives opened by PhD thesis

The evaluation of the treatment protocol applied to treated tibial pilon fractures submitted in the Orthopaedics and Traumatology Clinic Constanta, and the good results obtained, turn it into a national standard operative treatment, but at the same time, the surgical supplies of each romanian clinic is mandatory, to be able to appy the mentioned therapeutic protocol.

An annalisys of arthrotic risk should look not only on the fracture risks, on wich the majority of the actual studies regard upon, but also an annalisis of the associated ligament lesions, because of their importance in the movement of the ankle, trough the emergency MRI evaluation, and including of their solution in the therapeutic algoritm.

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