

Treatment Algorithm for Pilon Fracture – Clinical and Radiological Results

Algoritmus léčby zlomenin pilonu – klinické a radiologické výsledky

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ABSTRACT

PURPOSE OF THE STUDY

The aim of the present study was to evaluate the postoperative outcome of patients with pilon tibial fractures with a minimum follow-up of 24 months, treated according to a staged treatment algorithm.

MATERIAL AND METHODS

In total, 27 patients (mean age 43.6 ± 13 years, range 18–69) with a pilon tibial fracture and a minimum follow-up of 24 months were included in the study. Medical recordings (discharge documents and surgical reports) and radiographic examinations were analyzed. All enrolled patients were invited for a clinical and radiological follow-up examination (ROM, AOFAS hindfoot score, Kellgren score). The mean follow-up time was 44.5 ± 16 months (range 24–82).

RESULTS

In 21 cases a two-stage operative strategy with initial closed reduction and external fixation was necessary prior to definitive osteosynthesis. Overall, the patients scored 82.1 ± 20 points (range 30–100) in AOFAS hindfoot score, which represents a good clinical outcome. Patients with B-type fractures scored significantly better than those with C-type fractures. Patients with closed pilon tibial fractures reached significantly higher values in the AOFAS hindfoot score than those with open ones. Age and gender did not affect the functional outcome. Total ankle range of motion was $41^\circ \pm 10^\circ$ for B-type fractures (range 20° – 55°) and $35^\circ \pm 17^\circ$ (range 0° – 60°) for C-type fractures respectively ($p > 0.05$). Only five patients reached higher scores (Grade III) in Kellgren classification system.

DISCUSSION

Within the last decades, the therapeutic algorithm of pilon fractures underwent a paradigm shift; a two-stage protocol has prevailed today. However, the initial severity of the fracture in terms of initial absorbed energy, bony comminution and soft-tissue trauma still affects the outcome. Moreover, the necessity for bone grafting, as an indirect measurement of bone comminution and bone defects, resulted in higher degrees of osteoarthritis in the final follow-up. Higher initial soft-tissue injury also had an impact on the functional outcome of the patients, as patients with closed fractures scored better in AOFAS at the final follow-up. In order to counteract these risk factors and to reduce complications that define the outcome of these severe injuries, clearly defined surgical principles and standardized treatment protocols are needed.

CONCLUSIONS

The present study confirms the fact that meticulous planning, respect of the soft-tissues and choice of the optimal time-point for the definitive osteosynthesis and overall treatment according to standardized protocols can optimize the outcome of this severe injury.

Key words: pilon, distal tibia fracture, outcome, algorithm.

INTRODUCTION

Pilon tibial fractures are characterized in most cases by complex fracture patterns and severe soft-tissue injuries (22). Both require a differentiated treatment algorithm, in order to prevent complications and to succeed a good outcome. Pilon tibial fractures set often a challenge for the treating surgical team and require meticulous analysis and thorough planning, in order to be able to minimize the complications and the risk for postoperative ankle arthritis (15, 22, 28). While in the early days of the surgical treatment of pilon tibial fractures the primary de-

finitive treatment with open reduction and internal fixation was regarded as safe (4, 10, 26, 33), there has been a worldwide shift over the last years towards a staged treatment protocol of these complex fractures with widely accepted principles, like the respect of the soft-tissues, or the necessity of a CT-scan before the definitive treatment (15, 17, 22, 31, 37). Despite the fact that the main points of the operative treatment strategy of Rüedi and Allgöwer remain still the same (osteosynthesis of the fibula, reduction of the articular surface, bone grafting for the metaphyseal

impression zone and osteosynthesis of the tibia) (30), a consensus has been also reached regarding the necessity of initial external fixation and closed reduction through ligamentotaxis in the emergency setting in cases where the soft-tissues are compromised (20). Nevertheless, already at this early point, different opinions can be found in the literature (primary fixation of the fibula or not, use of hybrid- or ring-external fixators, use of vacuum-assisted systems etc.), a fact that does not permit the extrapolation of certain conclusions. The direct comparison of different treatment protocols would require huge numbers of patients that cannot be found, given the relatively low incidence of pilon tibial fractures. In order to overcome this problem, the necessity for standardized, phased treatment protocols cannot be overestimated, as they permit the treatment of the patients according to clearly defined principles, can be reproduced and in general lead to better functional outcomes with lower complication rates (17, 22, 28, 34). Additionally, such protocols can permit the evaluation of the prognostic

value of fractures of different severity (e.g. patients with B-type pilon fracture or with a monotrauma or closed soft-tissue injury compared with C-type pilon fracture or patients with multiple fractures of the hindfoot or open fractures).

Under this scope, the aim of the present study was to evaluate the postoperative outcome of patients with pilon tibial fractures with a minimum follow-up of 24 months, treated according to a staged treatment algorithm.

MATERIAL AND METHODS

For the purpose of the present study, an electronic search in our patient database was conducted (Level 1 trauma center). From January 2005 to December 2009 all patients, who sustained a pilon tibial fracture and had been treated according to our clinic-internal protocol (Fig. 1), were reviewed for inclusion criteria. The inclusion criteria were: age over 18 years with a pilon tibial fracture, no other previous injury of the lower ex-

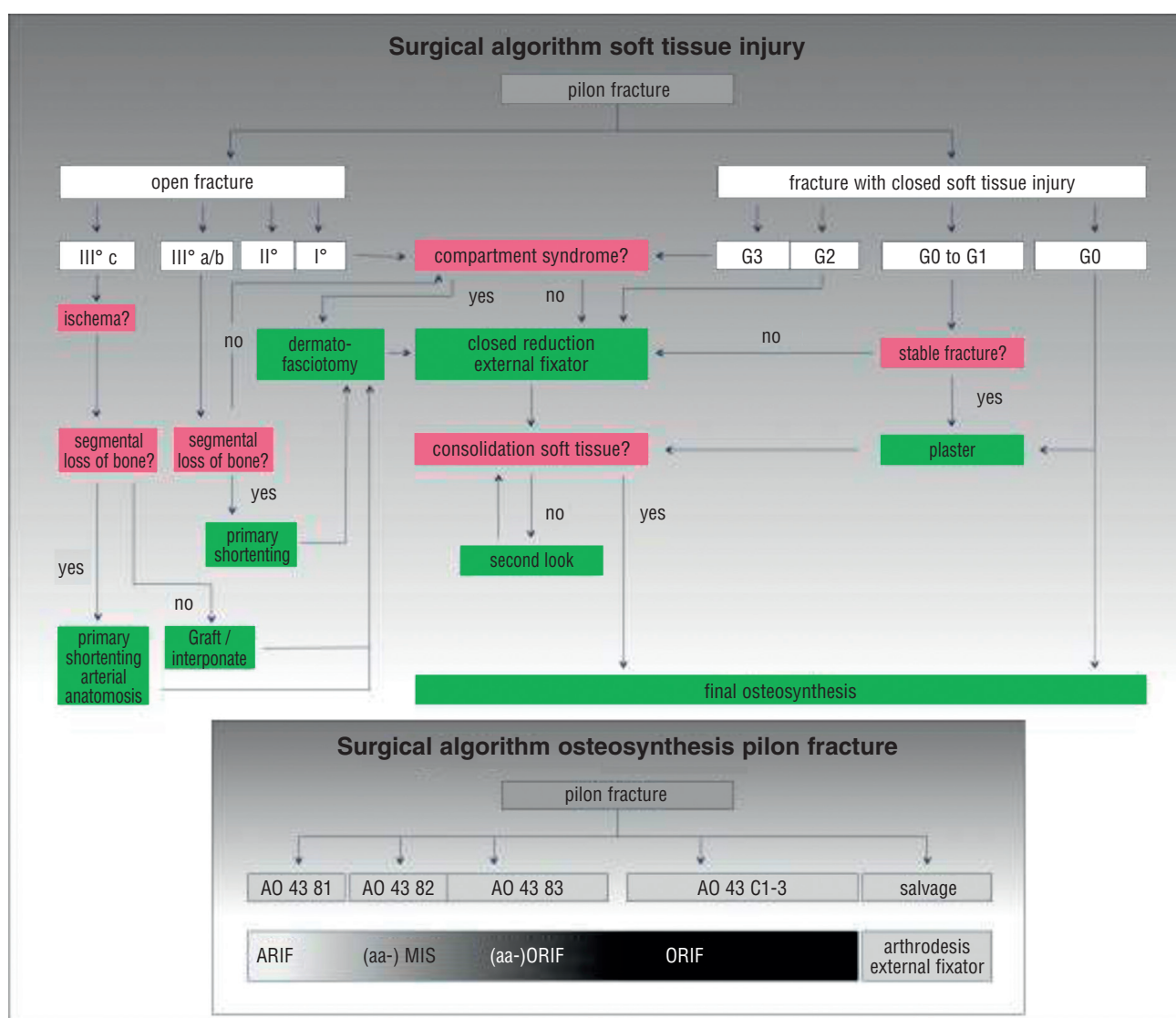


Fig. 1. Surgical algorithm for the treatment of pilon tibial fractures. (ARIF: arthroscopic reduction and internal fixation, aa: arthroscopically-assisted, MIS: minimal invasive surgery, ORIF: open reduction and internal fixation).

tremity and a minimum follow-up of 24 months. Overall, 52 patients met the inclusion criteria. Because of missing current postal address or telephone number, we were unable to contact ten of them. Fifteen patients did not take part into the study either due to lack of interest/time, severe illness/death or imprisonment. In total, 27 patients (20 males and 7 females; mean age 43.6 ± 13 years, range 18–69 years) could be enrolled into this study, which resulted in a follow-up ratio of 52%.

All patients were treated according to a standard post-operative rehabilitation protocol after soft-tissue consolidation (partial weight-bearing with 15 kg in a walker over 8–12 weeks with passive and active assisted ankle mobilization, and manual lymph drainage).

Radiographs and computer tomography recorded in our database were analyzed. Two independent orthopedic surgeons classified the pilon tibial fractures according to the fracture classification system of the AO (Arbeitsgemeinschaft für Osteosynthesefragen). Medical recordings (discharge documents and surgical reports) were used to collect the following data: trauma mechanism, classification of initial soft tissue damage according to Gustilo-Andersson for open fractures (8) and Oestern-Tscherne for closed fractures (24), surgical procedures, as well as, complications like infections or non-unions.

Finally, all enrolled patients were invited for a clinical and radiological follow-up examination. The mean follow-up time was 44.5 ± 16 months (range 24–82 months). At the time of final examination, the AOFAS hindfoot score questionnaire (maximum: 100 points) (13) was recorded. Ankle range of motion (dorsalextension, plantarflexion) was recorded clinically with the use of a goniometer. Standard weight-bearing radiographs of the ankle were taken in anterior-posterior and sagittal projection to assess posttraumatic osteoarthritis. The Kellgren score was used to classify the degree of osteoarthritis (11).

All the patients gave the informed consent prior to study inclusion; the study was authorized by the local ethical committee and was performed in accordance with the Ethical standards of the 1964 Declaration of Helsinki as revised in 2000.

Statistics

Continuous variables were expressed as means \pm standard deviation (SD), whereas categorical variables as percentages (%). The Kolmogorov-Smirnov test was used in order to assess distribution normality. For parametric variables the paired Student t-test was used for the comparison of two groups; for non-parametric variables the Mann-Whitney-U test was implemented. Differences for categorical variables were assessed with the Fisher's exact test. Correlations were examined with either Pearson product moment correlation coefficient or Spearmann's rank correlation coefficient. Differences were considered statistically significant if $p < 0.05$.

RESULTS

Falls from a great height (33.3%) and road traffic accidents (40.7%) were the two major trauma causes in

our study population. Due to the impact of these high velocity traumata, complex fracture patterns and severe soft-tissue injuries were observed. Almost two thirds of all pilon fractures were classified as C-type fractures (16/27; 59.3%) and among them predominantly subgroup C3 (7/16, 43.8%) was documented (Table 1). Eight fractures presented initially as open fractures (8/27 fractures; 29.6%: 1x I°, 3.7%; 3x II°, 11.1%; 4x III°, 14.8%); seven out of eight of these fractures were classified as C-type fractures. Closed soft-tissue damage was documented in 19 patients, ten (53%) patients with B- and nine (47%) with C-type fracture (Table 2). Besides the pilon tibial fractures, concomitant injuries of the affected extremity were present in eight patients. Most commonly talus (11.1%) and calcaneus fractures (7.4%) were seen as additional fractures on the injured side.

All patients underwent operative treatment according to our treatment protocol, with a staged algorithm with delayed osteosynthesis after soft-tissue consolidation (Fig. 1). Due to soft-tissue injury or fracture instability, in 21 cases a two-stage operative strategy with initial closed reduction and external fixation was necessary prior to definitive osteosynthesis. Except for one case of a C3.3-type fracture, in which primary retrograde ankle fusion was performed, all patients underwent open reduction with screw and plate fixation (Fig. 2). In all seven cases of II° and III° open fractures (1x B-type fracture, 6x C-type fracture), secondary plastic surgery was required after temporary coverage with alloplastic bilayer skin graft. In six of them, meshed skin graft was used for final soft-tissue coverage. In one case of a III° open C3 pilon fracture, a rotational fasciocutaneous

Table 1. Fracture distribution of AO-43 pilon tibial fractures

AO type fracture	Number	Percent
B1.1	1	3.7%
B1.2	2	7.4%
B1.3	0	0,0
B2.1	3	11.1%
B2.2	2	7.4%
B2.3	0	0,0
B3.1	2	7.4%
B3.2	1	3.7%
B3.3	0	0,0
C1.1	4	14.8%
C1.2	0	0,0
C1.3	0	0,0
C2.1	0	0,0
C2.2	4	14.8%
C2.3	1	3.7%
C3.1	2	7.4%
C3.2	2	7.4%
C3.3	3	11.1%

Table 2. Soft tissue injuries and fracture pattern

	B-type fracture	C-type fracture	Total
Closed soft tissue injury	10	9	19
Open soft tissue injury	1	7	8
Total	11	16	27

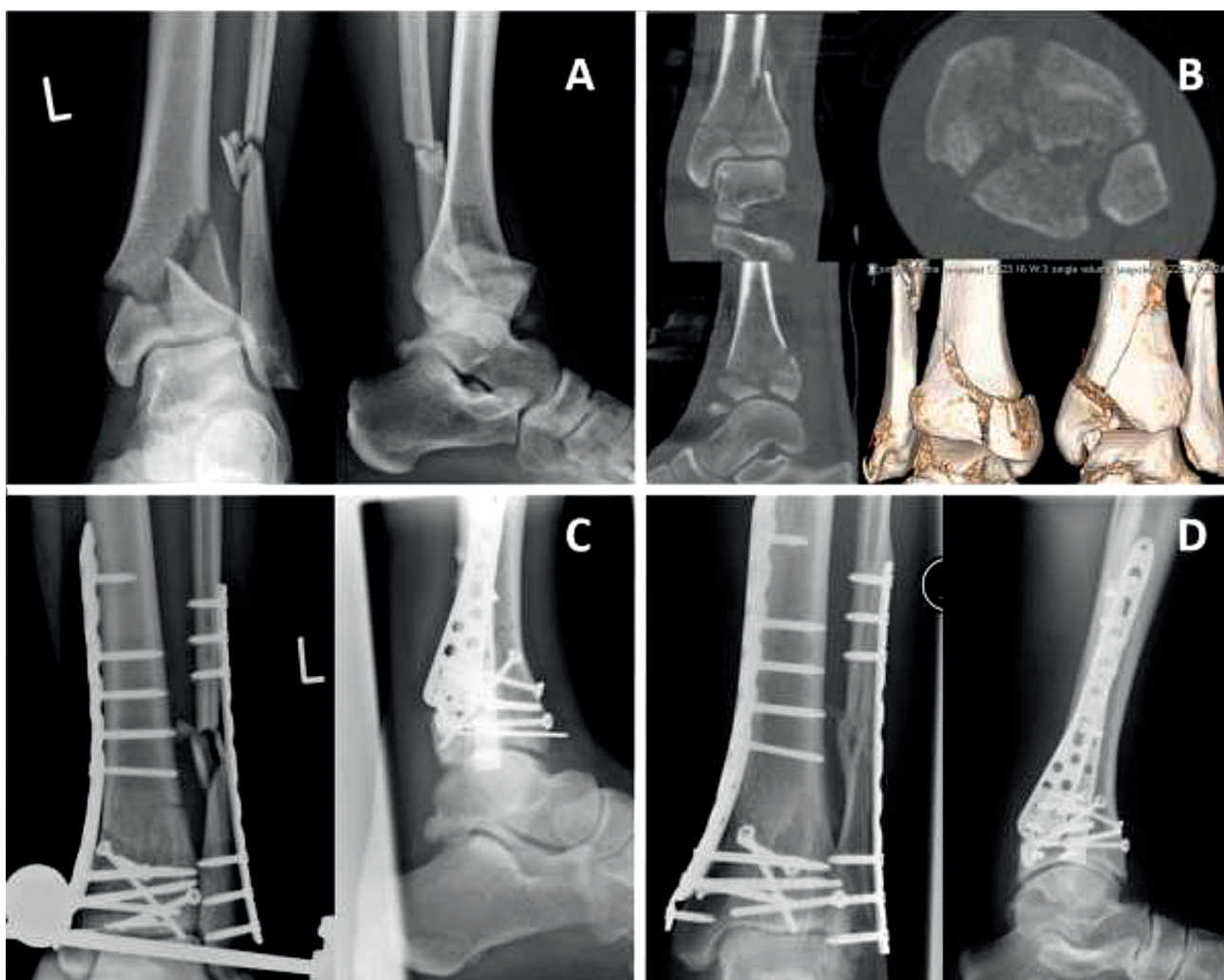


Fig. 2. 34-year-old male patient with a GII (Oestern and Tschern) closed pilon tibial fracture (AO 43C3) after a motor vehicle accident. A – preoperative radiographs; B – after closed reduction and external fixation CT-scan for the preoperative planning of the definitive osteosynthesis; C – open reduction and internal fixation after consolidation of the soft-tissues. The external fixator was left direct postoperatively in situ in order to minimize any soft-tissue complications; D – 8-year-follow-up with uneventful healing, and excellent radiographical and clinical outcome.

flap was necessary in order to close the soft-tissue defect. In the case of the I° open fracture, a secondary wound closure could be achieved. Two patients, both with C-type pilon fractures underwent a primary dermato-fasciotomy because of compartment syndrome. Infections were only seen in patients with C-type fractures. Four patients (14.8%) underwent revision surgery because of deep infection. Due to persisting osteitis in combination of fracture non-union, a below knee amputation (BKA) could not be prevented in one of these cases. All other patients attained uneventful fracture healing.

Overall, the patients scored 82.1 ± 20 points (range 30–100 points) in AOFAS hindfoot score, which represents a good clinical outcome. The patients were further subdivided into different groups; patients with B-type fractures scored significantly better than those with C-type fractures (B-type: 91.5 ± 12 points, range 68–100 points vs. C-type: 75.3 ± 22 points, range 30–100 points; $p = 0.02$). Patients with closed pilon tibial fractures

reached significantly higher values in the AOFAS hindfoot score than those with open pilon fractures (88.9 ± 18 points, range 30–100 points vs. 66.7 ± 16 points, range 46–91 points; $p = 0.035$). Those patients, who sustained an additional fracture of the ipsilateral hindfoot scored significantly lower on AOFAS hindfoot score compared to patients with a monotrauma (69.8 ± 23 points, range 30–97 points vs. 87.0 ± 17 points, range 46–100 points; $p = 0.013$). No difference was observed in terms of functional outcome as evaluated with the AOFAS hindfoot score, as far as age (patients younger and older than 50 years) (83.8 ± 15 points, range 56–100 points vs. 79.4 ± 27 points, range 30–100 points; $p = 0.45$) or gender are concerned (male vs. female: 78.6 ± 20 points, range 30–100 points vs. 91.5 ± 17 points, range 55–100 points; $p = 0.07$).

Total ankle range of motion was $41^\circ \pm 10^\circ$ for B-type fractures (range 20° – 55° ; dorsalextension: $10^\circ \pm 4^\circ$, range 5° – 15° , plantarflexion: $30^\circ \pm 8^\circ$, range 15° – 40°) and $35^\circ \pm 17^\circ$ (range 0° – 60° ; dorsalextension: $7^\circ \pm 6^\circ$,

range 0°–20°, plantarflexion: $28^\circ \pm 12^\circ$, range 0°–45°) for C-type fractures respectively. No statistical difference was found in total range of motion between B- and C-type pilon fractures.

Besides the two patients (primary hindfoot fusion and secondary BKA respectively), 17 patients (17/25; 68%) had developed posttraumatic osteoarthritis (Kellgren classification $\geq \text{II}^\circ$) of the ankle at the time of final follow-up (5/11 patients with B-type fracture, 12/14 patients with C-type fracture; $p = 0.08$). However, only five of them reached higher scores in Kellgren classification system and presented a more severe osteoarthritis than Grade II° (III° 2/17 (11.8%) patients, IV° 3/17 (17.7%) patients). In one patient, a B3.1 fracture with comminuted ventral plafond evolved an osteonecrosis and subsequent arthritis, which was treated with total ankle replacement. No further ankle fusion or joint replacement has to be undertaken so far.

DISCUSSION

Within the last decades, the therapeutic algorithm of pilon fractures underwent a paradigm shift (22, 28). Whereas 50 years ago pilon fractures underwent primary osteosynthesis and a single-stage surgical algorithm was advocated (30), a two-stage protocol has prevailed today (3, 17, 31, 34). The present study confirms the fact that meticulous planning, respect of the soft-tissues and choice of the optimal time-point for the definitive osteosynthesis and overall treatment according to standardized protocols can optimize the outcome of this severe injury. In comparison to previous studies, particularly to those that have advocated a primary osteosynthesis, we were able to show significantly better functional results and lower complication rates (4, 9, 10, 27, 33).

Nevertheless, the initial severity of the fracture in terms of initial absorbed energy, bony comminution and soft-tissue trauma still affects the outcome. On the other hand, age and gender did not affect the outcome in our population, in contrast to fracture severity. In patients with type C fractures according to the AO classification higher infection and arthritis rates were observed compared with patients with type B fractures. Additionally, type B fractures showed better functional results in the AOFAS, compared with type C fractures, even if no significant differences were observed between the two groups in terms of ROM.

Moreover, the necessity for bone grafting, as an indirect measurement of bone comminution and bone defects, resulted in higher degrees of osteoarthritis in the final follow-up. Higher initial soft-tissue injury either in open or closed fractures also had an impact on the functional outcome of the patients, as patients with closed fractures scored better in AOFAS at the final follow-up. On the contrary, open fractures needed in almost all cases plastic surgery, in order to address soft-tissue defects.

In order to counteract these risk factors and to reduce complications that define the outcome of these severe injuries, clearly defined surgical principles and stan-

dardized treatment protocols are needed (7, 15). During the initial management of pilon tibial fractures the closed reduction and external fixation is in most cases the first step of treatment, as the fractures are too unstable and the soft-tissues are compromised for retention in plaster (18). An extra Steinmann-nail in the calcaneus is commonly needed for the retention of length (23). The proximal pins in the tibia should be placed proximal enough, in order not to intervene with the definitive osteosynthesis, while the whole structure of the external fixator should be not in the „region of interest“ for the minimization of metal artefacts during later CT diagnostic (25). Several authors advocate also at this time point the primary osteosynthesis of the fibula, in order to achieve through ligamentotaxis better reduction of the antero- and posterolateral tibial fragments (36). Nevertheless, this step should be performed even in cases of simple fibular fractures with caution, as it implies that the choice of the surgical approach for the definitive osteosynthesis can be made at this time-point already. Additionally, one should look for signs of compartment syndrome, which has been reported in up to 12% of the cases (6). In this case a dermatofasciotomy should be performed.

In the case of open pilon fractures (up to 1/3 of the cases) (5, 16) tissue probes should be sent for microbiological examination and thorough debridement and jet-lavage should be performed, while broad-spectrum antibiotics should be administered, at least till the definitive antibiogram. Open wounds should not be closed primarily and should be covered with synthetic skin, while second-look surgery should be planned for the next 24–48 hours. Concomitant vascular or neurological injuries should be also addressed at this time-point. If soft-tissue defects remain after repetitive debridement, one should consider plastic surgery at an early time-point.

Immobilization in plaster is a rarity in tibial pilon fractures. Only minimally displaced partially articular fractures (for instance AO-43-B1) with insignificant soft-tissue injuries may be immobilized in a lower-leg-plaster. Even in such cases one should remain vigilant, as secondary swelling can occur, which could compromise the soft-tissues; in this case one should switch to external fixator. In our treatment algorithm plaster-splinting is an absolute rarity, as it does not really permit the monitoring of the soft-tissues, which is of utmost importance for the selection of the optimal time-point for definitive surgery.

Adjuvant measurements, like manual lymph drainage, kryotherapy or AV-pulsation may be implemented, so that the swelling subsides. In most cases 5–10 days are needed, till the soft-tissues present with no tension and the skin can wrinkle again.

Before the definitive osteosynthesis and after the primary reduction and external fixation a pre-operative planning CT-scan is obligatory, after the principle “span-scan-plan”. 2D- and 3D-CT-reconstructions are of great assistance in the comprehension of the personality of the fracture and the meticulous surgical planning (surgical approaches, osteosynthesis technique and type

of implants). There are six typical fragments that can be identified (35, 37):

1. medial malleolus fragment,
2. anterolateral fragment,
3. posterolateral fragment,
4. ventral tibial fragment,
5. dorsal tibial fragment,
6. central pilon-fragment („die-punch fragment“).

The reconstruction of the joint surface and the respect of the soft-tissues affect the outcome of pilon tibial fractures to a great extent (29, 30, 32). The choice of the surgical approaches is important, in order to allow for adequate view of the fragments and positioning of the implants without further compromising the already damaged soft-tissues. As a rule, a minimal distance of 5–7 cm between two skin incisions should be preserved in order to avoid further skin necrosis. Several surgical approaches can be chosen (anteromedial, anterolateral, medial, posteromedial, lateral and posterolateral) (21). Each approach, or each combination of those, offers certain advantages and bears certain limitations that must be kept in mind in terms of reduction potential, implant placement and iatrogenic soft-tissue injury. Therefore, thorough planning and individualized choice should be preoperatively made (1, 12, 14).

If possible, one should go for a minimally invasive plate osteosynthesis (MIPO), in order to minimize the soft-tissue trauma, but without compromising the quality of anatomical reduction (2). Ideal fractures for MIPO-technique are non- or minimally displaced fractures. As an alternative, MIPO-techniques can be also used in cases of extreme soft-tissue injury. In cases of implementation of MIPO-technique, the osteosynthetic fixation of the fibula is the first step, as it allows through ligamentotaxis the initial reduction of the tibial components that can be then furtherly reduced anatomically, with the use of K-wires (joystick-technique) or percutaneous reduction-clamps, or even arthroscopic assistance (19). Percutaneous lag screws and locking bridging plates are used most commonly for the fixation of the fracture.

In cases that do not allow MIPO-technique, the open reduction and internal fixation with screws and plate osteosynthesis remains the gold standard. The principles that were published 50 years ago by Rüedi et al. can be considered still relevant: osteosynthesis of the fibula, reconstruction of the tibial joint surface, bone-grafting for bone defects and medial osteosynthetic support (30).

Simple fibular fractures should be initially addressed, in order to achieve reduction of the tibial components through ligamentotaxis. However, in cases of complex fibular and simple tibial fractures, one should start with the tibia (36). In order to assist the view of the tibial joint surface a spreader can be used. The anterolateral and medial fragments must be mobilized in order to identify the exact fragments, as well as, to inspect the joint surface of the talus. The fracture is then cleared from the hematoma, which can be preserved and repositioned in areas of small cancellous defects. The reduction begins in most cases with the posterolateral

fragment, followed by the reduction of the central and medial fragment, which can be temporarily held by K-wires. Especially complex B- and C-type fractures need an additional fixation with a bridging-plate that holds the joint-block with the diaphysis of the tibia. The anterolateral or medial plate is introduced from distal to proximal, either in a submuscular or subcutaneous manner and is also temporarily fixed with K-wires after radiological control of reduction. The distal plate screws are placed initially, so that the whole joint surface is fixated. The plate should be fixated proximally with 3–4 bicortical locking screws, especially in osteoporotic bone. After completion of the osteosynthesis, the external fixator can be left in situ if needed (calcaneus pin can be removed at this point), in order to support soft-tissue consolidation. Salvage procedures, like Ilizarov-fixateur or primary arthrodesis should be performed only in cases of massive bone comminution with extreme soft-tissue injuries (34).

CONCLUSIONS

The limitations of the present study were the relatively low number of cases due to loss of follow-up, as well as, its retrospective design. Additionally, in some patients the outcome scores might be influenced by concomitant injuries. Nevertheless, as pilon tibial fractures are often caused by high impact traumata, concomitant injuries are common and thus the presented data reflect the outcome of this patient group more realistic.

Conclusively, the present data support the fact that a standardized, two-staged and differentiated treatment protocol is important, in order to achieve a satisfactory outcome of this complex injury and reduce the risk of postoperative complications.

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