Strategies to minimize soft tissues and septic complications in staged management of high-energy proximal tibia fractures

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Accepted: 19 December 2019

Abstract

Background Soft tissues (wound dehiscence, skin necrosis) and septic (wound infection, osteomyelitis) complications have been historically recognized as the most frequent complications in surgical treatment of high-energy proximal tibia fractures (PTFs). Staged management with a temporary external fixator is a commonly accepted strategy to prevent these complications. Nonetheless, there is a lack of evidence about when and how definitive external or internal definitive fixation should be chosen, and which variables are more relevant in determining soft tissues and septic complications risk. The aim of the present study is to retrospectively evaluate at midterm follow-up the results of a staged management protocol applied in a single trauma center for selective PTFs.

Methods The study population included 24 cases of high-energy PTFs treated with spanning external fixation followed by delayed internal fixation. Severity of soft tissues damage and fracture type, timing of definitive treatment, clinical (ROM, knee stability, WOMAC and IOWA scores) and radiographic results as well as complications were recorded.

Results and conclusion Complex fracture patterns were prevalent (AO C3 58.3%, Schatzker V–VI 79.1%), with severe soft tissues damage in 50% of cases. Mean time to definitive internal fixation was 6 days, with double-plate fixation mostly chosen. Clinical results were highly satisfying, with mean WOMAC and IOWA scores as 21.3 and 82.5, respectively. Soft tissue complication incidence was very low, with a single case of wound superficial infection (4.3%) and no cases (0%) of deep infection, skin necrosis or osteomyelitis. Staged management of high-energy PTFs leads to satisfying clinical and radiographic results with few complications in selected patients.

Keywords High-energy fractures · Spanning external fixation · Damage control · Proximal tibia · Tibial plateau · Complications · Infection

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Background

Soft tissues (wound dehiscence, skin necrosis) and septic (wound infection, osteomyelitis) complications have been historically recognized as the most frequent complications in surgical treatment of high-energy proximal tibia fractures (PTFs). The reported incidence of these complications in the literature reaches up to 50–80% of cases [1–3]. In the past, the leading cause resided in the excessive soft tissues surgical damage used to obtain anatomic reduction and absolute stability even in complex cases. Long-term studies about high-energy PTFs demonstrate limb alignment, knee stability and absence of complications, which are significantly related to the functional outcome comparably to anatomic articular surface reduction [4]. Therefore, optimal results may be achieved with stable fixation of the fracture able to restore physiologic limb alignment while minimizing soft tissue damage [5]. Consequently, damage control strategies have been introduced in high-energy PTFs treatment in order to plan definitive treatment in an ideal soft tissues condition, as already proposed for tibial pilon fractures [6, 7]. Egol et al. [8] reported for the first time in 2005 the results of acute spanning external fixation of high-energy PTFs followed by delayed internal fixation, with surprisingly low soft tissues and septic complications. Thereafter, other authors reported the results of similar treatment strategies, with very heterogeneous indications, techniques and timing of treatment [9]. In particular, there is a lack of evidence about when and how external or internal definitive fixation should be chosen and which variables are more relevant in determining soft tissues and septic complications risk. The aim of the present study is to retrospectively evaluate at midterm follow-up the results of a staged management protocol applied in a single trauma center for high-energy PTFs, with special focus on soft tissues and septic complications.

Materials and methods

Patients presenting from January 2009 to December 2014 at the Emergency Department of the S. Martino Hospital of Genova (Italy) with high-energy PTFs were all considered for the present study. Exclusion criteria were definitive external fixation and clinical follow-up < 6 months.

A staged management protocol was applied to all patients (Fig. 1). The protocol consisted in knee spanning external fixator in the acute phase (first 24 h), together with soft tissue lesion treatment (open fractures debridement, fasciotomies for compartment syndrome and neurovascular lesions repair). In all cases of open fractures such as Gustilo 3B or 3C, compartment syndromes treated with fasciotomies, fractures with excessive meta-diaphyseal comminution (Fig. 2) and soft tissue lesions not resolving within 14 days, knee spanning fixation was converted to circular external fixation as definitive treatment. Therefore, according to the exclusion criteria, this group of patients was excluded from the study. Delayed open reduction internal fixation (ORIF) was carried out using single or double plating (Fig. 3) in all the remaining cases, which represented the final study population. Collected data included trauma modality and fracture

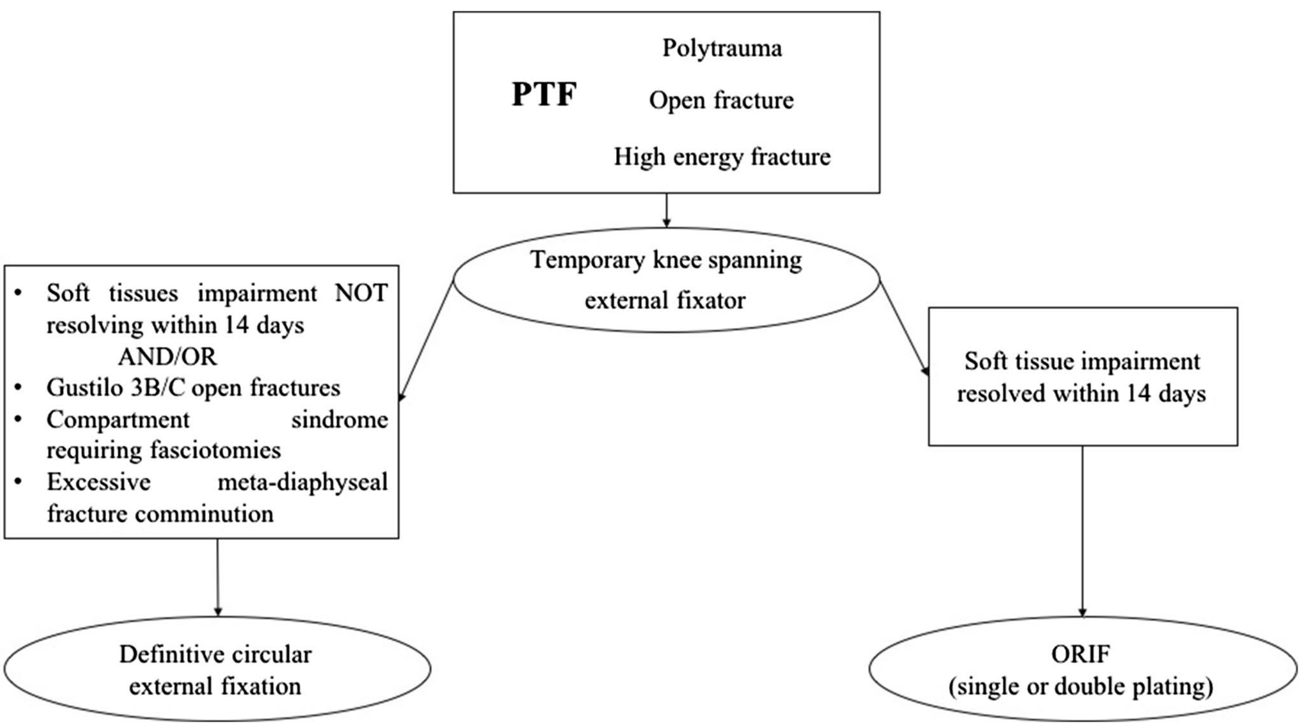

Fig. 1 The staged management protocol applied to the present study population is showed. All patients with high-energy PTFs underwent temporary knee spanning external fixator within the first 24 h. Soft tissue lesions treatment (open fractures debridement, fasciotomies for compartment syndrome and neurovascular lesions repair) was performed in the same procedure. Thereafter, according to the delineated exclusion criteria, conversion to definitive open reduction internal fixation (ORIF) with single or double plating was performed in selected patients

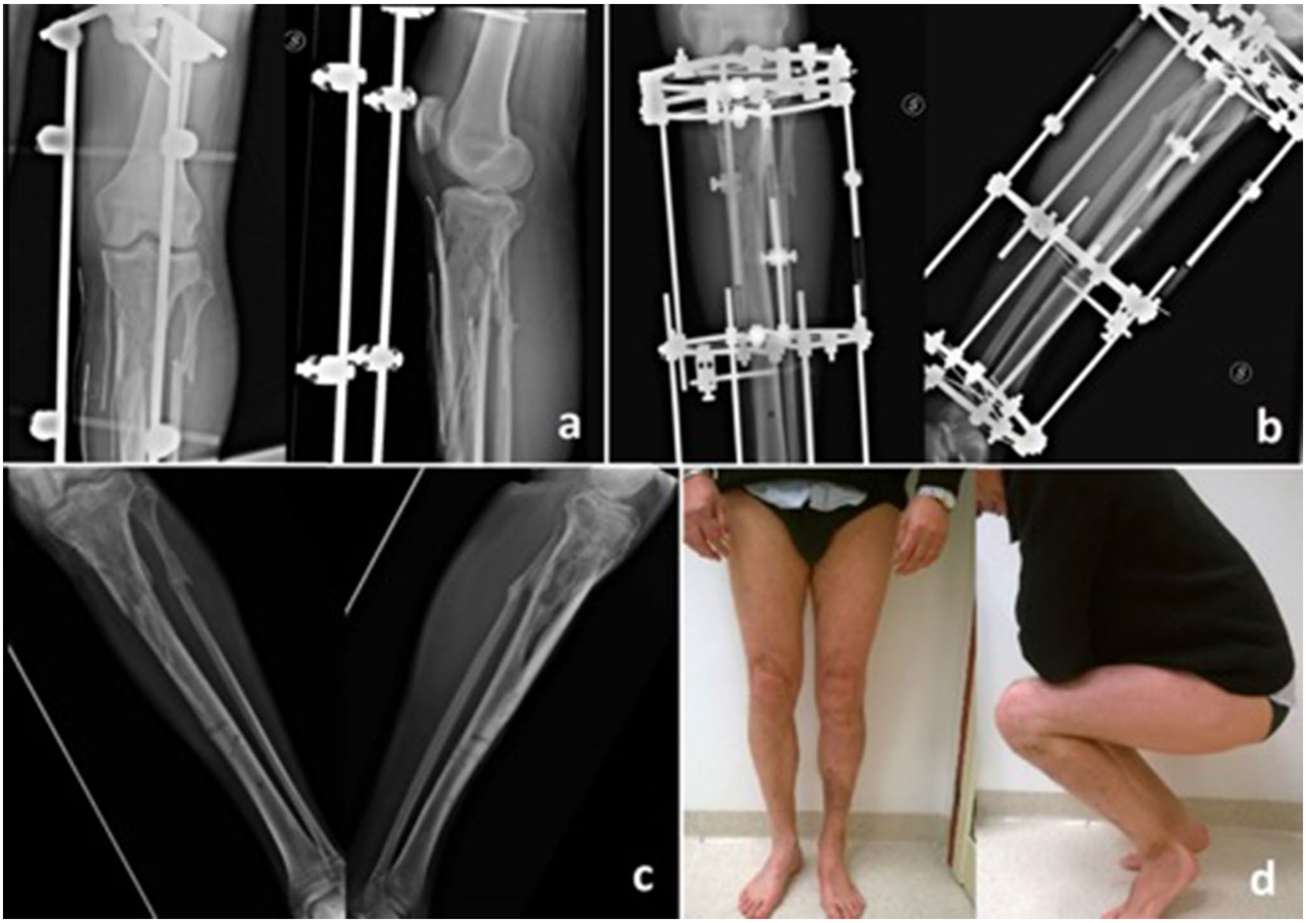

Fig. 2 A 54-year-old man reporting a AO41C2/42C3 fracture, closed TIII, with excessive meta-diaphyseal comminution after a motor vehicle accident. **a** Bridge stabilization with external fixation (EF), anterior–posterior (AP) and lateral (LL) views. **b** Circular hybrid EF, AP and LL views, using olive wires for articular surface reduction and fixation. **c** Radiographic control, AP and LL views, 8 months after trauma (3 months after frame removal). **d** Clinical result at 32 months

type according to Schatzker [10] and Arbeitsgemeinschaft für Osteosynthesefragen (AO) [11] classifications, defined on postoperative radiographic and CT scan images obtained after spanning external fixation. Soft tissue lesions were also recorded, using Tscherne [12] classification for closed fractures and Gustilo–Anderson [13] classification for open fractures. Associated lesions were also recorded, including proximal fibula fractures, neurovascular lesions and systemic associated lesions. Time to definitive treatment after acute spanning fixation was recorded, together with surgical approach (anterolateral, posteromedial or combined) and internal fixation technique. Surgical time of definitive treatment was also registered. Early postoperative complications, both related to spanning external fixation and definitive internal fixation, were recorded, especially focusing on soft tissues and septic complications. Radiographic retrospective evaluation was undertaken, detecting time to union and cases of nonunion if any. Clinical evaluation at follow-up included range of motion (ROM), knee stability, Western Ontario and McMaster University (WOMAC) [14] and Iowa [15] knee scores. Results were statistically analyzed in order to find correlations within subgroups and compared to the literature.

Statistical analysis

Statistical data evaluation was undertaken with two-tailed parametric tests with significance level set at 5%. Baseline and follow-up comparison of data couples were carried out using the *t* test for paired data (in case of measurement repeated in time) and with the heteroskedastic *t* test for non-paired data. The analysis of variance (ANOVA, according to Tukey) test was used to compare the groups. Correlation between scalar variables was performed through the linear regression. Event frequency comparison between groups was made with the two-tailed Fisher's exact test for minimal frequency < 5 events or with the two-tailed Chi-square test for

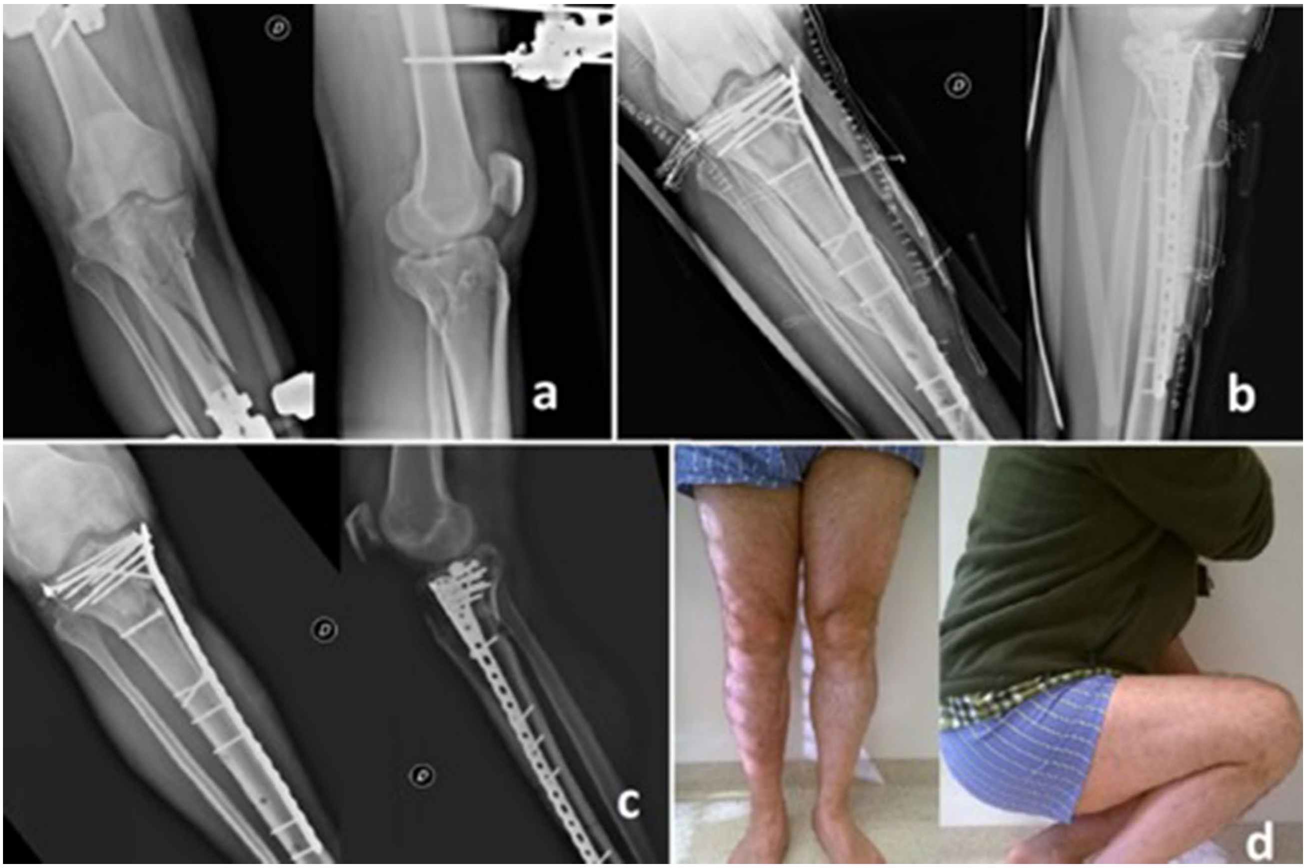

Fig. 3 A 44-year-old man reporting a high-energy proximal tibia trauma after motor vehicle accident. **a** Radiographic examination of the fracture (AO41C3/42B1), AP and LL views, after bridging external fixation. **b** ORIF carried out 3 days after trauma. Postop radiographic result, AP and LL views. **c** Radiographic result, AP and LL views, at 2-year follow-up. **d** Clinical result at 27 months

minimal frequency > 5. The Statistical Package for Social Science 11.0 software (SPSS Inc., Chicago, IL) was used for data calculation.

Results

Applying exclusion criteria, the final study population counted 24 cases in 23 patients, 16 males and 7 females, with mean age at trauma 45 years (range 17–61). Mean follow-up was 29 months (range 8–55). Trauma modality was motorcycle accident in 18 cases, fall from height in 3 cases and sports-related (skiing) trauma in one case. Complex fracture patterns were prevalent (AO C3 58.3%, Schatzker V–VI 79.1%), with severe soft tissue damage in 50% of cases (Table 1). Associated lesions were present in 79.2% of cases, and five (20.8%) cases were polytrauma patients. Mean time to definitive treatment was 6 days (range 2–13) (Table 1). No complications related to spanning external fixator were noted.

Definitive internal fixation was carried out with combined anterolateral and posteromedial approaches in 45.8% of cases. Angular stable plates eventually combined with free screws were used in all cases, with minimally invasive plate osteosynthesis (MIPO) technique applied to all anterolateral plates for diaphyseal fixation. No bone grafting was used. Mean surgical time was 142.5 min (range 45–270). In only one case (4.3%), a superficial wound dehiscence was noted, which is successfully treated with advanced medications. This complication occurred at the posteromedial wound in a combined AL and PM approach case. Neither deep infections nor skin necrosis were registered (0%). Mean radiographic follow-up was 14.8 months. There was no case of nonunion, with mean union time of 5.2 months (range 2–12 months). Clinical evaluation was not undertaken in one case due to lower limbs paraplegia, caused by T12 myelic fracture reported at the time of trauma. In the remaining 23 cases, mean ROM was – 0.2° (range – 5°/0°) in extension and 130.4° (range 100° – 160°) in flexion. Anteromedial knee instability at follow-up was found in three cases (13%), associated with valgus instability in one case.

Mean WOMAC score was 21.3 points (range 1–62), with 91.3% of patients reaching excellent (0–19 pts) or good

Table 1 Detailed comprehensive description of follow-up, fracture classification, associated lesions and time to definitive internal fixation (GA = Gustilo–Anderson, T = Tscherne, AL = antero-lateral, PM = posteromedial) for each patient is provided

Patient	Follow-up (months)	Schatzker classification	AO classification	Open/closed fracture classification	Associated lesions	Time to definitive treatment (days)	Surgical approach	Surgical time (min)	ROM	WOMAC total	IOWA
Case 1	55	II	41B3	GA IIIA	Floating knee	11	AL	235	0/100	22	85
Case 2	21	V	41C3	T II	–	5	AL + PM	225	0/110	62	53
Case 3	37	VI	41C2	T I	Multiple injuries of extremities Head trauma	6	AL	120	0/130	21	86
Case 4	16	V	41C1	T I	–	4	AL + PM	170	0/110	36	61
Case 5	20	IV	41C3	T I	Multiple injuries of extremities	3	AL + PM	120	0/135	8	92
Case 6	23	V	41C3	GA I	Thoracic trauma	3	AL	90	− 5/150	11	94
Case 7	33	V	41C1	T II	Floating knee Thoracic trauma Abdominal trauma	9	AL + PM	270	0/140	36	55
Case 8	36	–	41A3	GA II	–	4	AL	115	0/160	8	91
Case 9	34	V	41C3	T III	Thoracic trauma	13	AL + PM	120	0/100	26	82
Case 10	16	V	41C1	T II	–	8	AL	95	0/150	34	70
Case 11	8	IV	41C3	T I	–	2	PM	185	0/110	10	88
Case 12	20	V	41C2	T II	Multiple injuries of extremities Thoracic trauma Myelic spinal fracture	7	AL + PM	155	–	–	–
Case 13	13	VI	41C3/42B1	T II	Multiple injuries of extremities	11	AL	45	5/100	46	67
Case 14	27	VI	41C3/42B1	T I	Multiple injuries of extremities	3	PM	165	0/145	19	80
Case 15	39	IV	41C3	T I	–	5	PM	120	5/130	31	68
Case 16	50	VI	41C3/42B1	T I	–	7	AL + PM	110	− 5/140	21	93
Case 17	49	VI	41C3/42B2	T I	–	3	AL	165	0/100	6	94
Case 18	52	VI	41C3	T I	Multiple injuries of extremities	3	AL + PM	140	0/150	21	81
Case 19 (patient 19 right knee)	31	VI	41C1	GA IIIA	Multiple injuries of extremities Common peroneal nerve lesion	7	AL	170	0/160	13	91
Case 20 (patient 19 left knee)	31	–	41A3	GA I	Multiple injuries of extremities	7	AL	170	0/160	1	99
Case 21	10	VI	41C3	T I	–	2	AL + PM	135	− 5/130	10	91

Table 1 (continued)

Patient	Follow-up (months)	Schatzker classification	AO classification	Open/closed fracture classification	Associated lesions	Time to definitive treatment (days)	Surgical approach	Surgical time (min)	ROM	WOMAC total	IOWA
Case 22	16	V	41C3	T I	–	6	AL + PM	75	0/100	21	92
Case 23	28	II	41B3	GA IIIA	Multiple injuries of extremities Thoracic trauma Spinal fracture	8	AL	105	0/140	19	88
Case 24	27	VI	41C3	T I	Multiple injuries of extremities Thoracic trauma	7	AL + PM	120	0/150	8	97

(20–39 pts) results. Mean IOWA knee score was 82.5/100 (range 53–99) (Table 1).

Statistical analysis of retrieved data revealed a significant correlation between severe soft tissues compromise (Tscherne type II and III fractures and open fractures) and longer time to definitive fixation compared to Tscherne I cases (4.25 vs 7.75 days, $p = 0.03$). No other statistically significant correlation was found. Table 2 resumes data comparisons with related statistical analysis (Table 2).

Discussion

Complex high-energy trauma PTFs represent a very difficult injury to treat properly [8]. The principal aim of surgical treatment is anatomic reduction and stable fixation of the fracture to allow early mobilization. Moreover, the absence of complications has been demonstrated to be strictly related to clinical results, with soft tissue complications as wound dehiscence and infection being the most relevant [5, 16]. Nonetheless, historical experiences with single incision and compression plating techniques, performed few hours or days after trauma, were associated with a complications rate of 73–87.5% of cases, especially deep infection and wound-related problems [1, 17].

Different strategies to preserve soft tissues and bone blood supply while obtaining fixation goals were introduced in the last years. The latter included circular or hybrid definitive external fixation and spanning external fixation followed by delayed internal fixation with angular stable plates. Literature reports good results and a significant reduction in complications with both strategies. When choosing internal fixation as a definitive treatment, temporary spanning external fixation becomes paramount [4, 8, 18, 19]. In this scenario, the advantages of angular stable plates and MIPO techniques with respect to bone vascularity and soft tissues preservation also seem to play a role [20]. However, the specific factors associated with functional outcome and both septic and soft tissue complications risk in the staged management of high-energy tibial plateau factors still have to be determined. Notably, spanning external fixation has been advocated by some authors as a possible source of additional complications. However, both the results of the present and many other studies report against this statement [5, 21]. Time to definitive surgery also represents a controversial topic. Depending on the severity of soft tissues compromise, the time of temporary external fixation needed to allow for definitive osteosynthesis may vary considerably. In the literature, the mean time to definitive surgery is reported to be 5–20 days, with reports from 2 days up to 111 days [8, 9, 22]. In the present paper, the mean time to definitive surgery was 6 days (range 2–13), which compares

Table 2 Non-paired group analysis using Student's *t* test to compare different variables (first column) with two groups according to soft tissues compromise (second column), or the knee instability at follow-up (third column)

Dependent variables	Soft tissues compromise (independent variables)	Mean	*p* value	Knee instability (independent variables)	Mean	*p* value
WOMAC pain	T I	3.00	0.53	No	2.70	0.20
	T II-T III-Open	4.00		Yes	8.67	
WOMAC stiffness	T I	1.75	0.12	No	2.00	0.10
	T II-T III-Open	2.91		Yes	4.33	
WOMAC function	T I	12.92	0.24	No	13.95	0.29
	T II-T III-Open	18.36		Yes	26.00	
WOMAC total	T I	17.67	0.23	No	18.65	0.24
	T II-T III-Open	25.27		Yes	39.00	
Iowa knee score	T I	85.25	0.33	No	84.80	0.24
	T II-T III-Open	79.55		Yes	67.33	
Time to definitive fixation	T I	4.25	**0.03**			
	T II-T III-Open	7.75				
ROM flexion	T I	127.50	0.52	No	132.00	0.36
	T II-T III-Open	133.64		Yes	120.00	
Flexion gap	T I	17.08	0.92	No	14.75	0.92
	T II-T III-Open	16.36		Yes	30.00	
ROM extension	T I	−0.42	0.68	No	−0.25	0.66
	T II-T III-Open	0.00		Yes	0.00	
Extension gap	T I	0.83	0.92	No	1.00	0.42
	T II-T III-Open	0.91		Yes	0.00	

T Tscherne

favorably with other literature reports. Soft tissues compromise severity was demonstrated to be significantly associated with a longer time of spanning fixation (7.75 vs 4.25 days, $p = 0.03$). Nonetheless, patient selection for the present study leaded to exclusion of cases exceeding 15 days of spanning fixation, which were considered for definitive external fixation according to the staged management protocol described. The reason for this choice resides in the theoretical augmented risk of infection after prolonged temporary external fixation. According to some authors, waiting up to 3 weeks for soft tissues healing may be considered acceptable in case proper alignment, axis and rotation are maintained by the fixator [5, 8]. Nonetheless, there is evidence that after 2 weeks the risk of pin-site contamination raises significantly, thus causing a theoretical augmented infection risk, although often not clinically relevant [23]. Moreover, based on the latter consideration, beneath 15 days fixator pins can be maintained in the surgical field to be used for reduction and distraction [22], which has been proven to be a very useful surgical trick in both our author and other authors' experience (Fig. 4) [24]. Definitive ORIF surgical technique was planned in the present paper population based on fracture characteristics, especially regarding medial plateau fracture morphology. Indeed, whereas isolated medial or lateral plateau fractures treatment indications are usually straightforward, the choice between single lateral or double plating is debated [25, 26] (Fig. 5).

Notably, the 2017 review of Shao et al. [27] considers the number of incisions and the number of plates as important risk factors for SSI after PTFs. In this scenario, spanning temporary fixation was demonstrated to have the advantage of allowing internal definitive fixation in optimal soft tissue conditions, leaving the surgeon to freely choose double or single approach depending on fracture morphology only. In the present paper, according to the latter consideration, double plating was performed in 10 of the 19 bicondylar fractures with no differences in complications rate compared to single plating. At mean 14.8-month radiographic follow-up, fracture union was achieved in all cases (100%), with mean union time of 5.2 months. These data results are in line with other literature reports, where mean union rate appears to range from 96 to 100% and mean union time from 4 to 6 months [8, 21, 25]. Clinical results of the present paper population in terms of WOMAC (mean 21.2, excellent/good 91.6%) and IOWA (mean 82.5/100) scores and ROM were meanly very good. Comparison of these data with the literature results to be quite difficult, because of the few studies reporting clinical results of high-energy PTFs and of the heterogeneous methods used for evaluation. Nonetheless, they seem to be in line

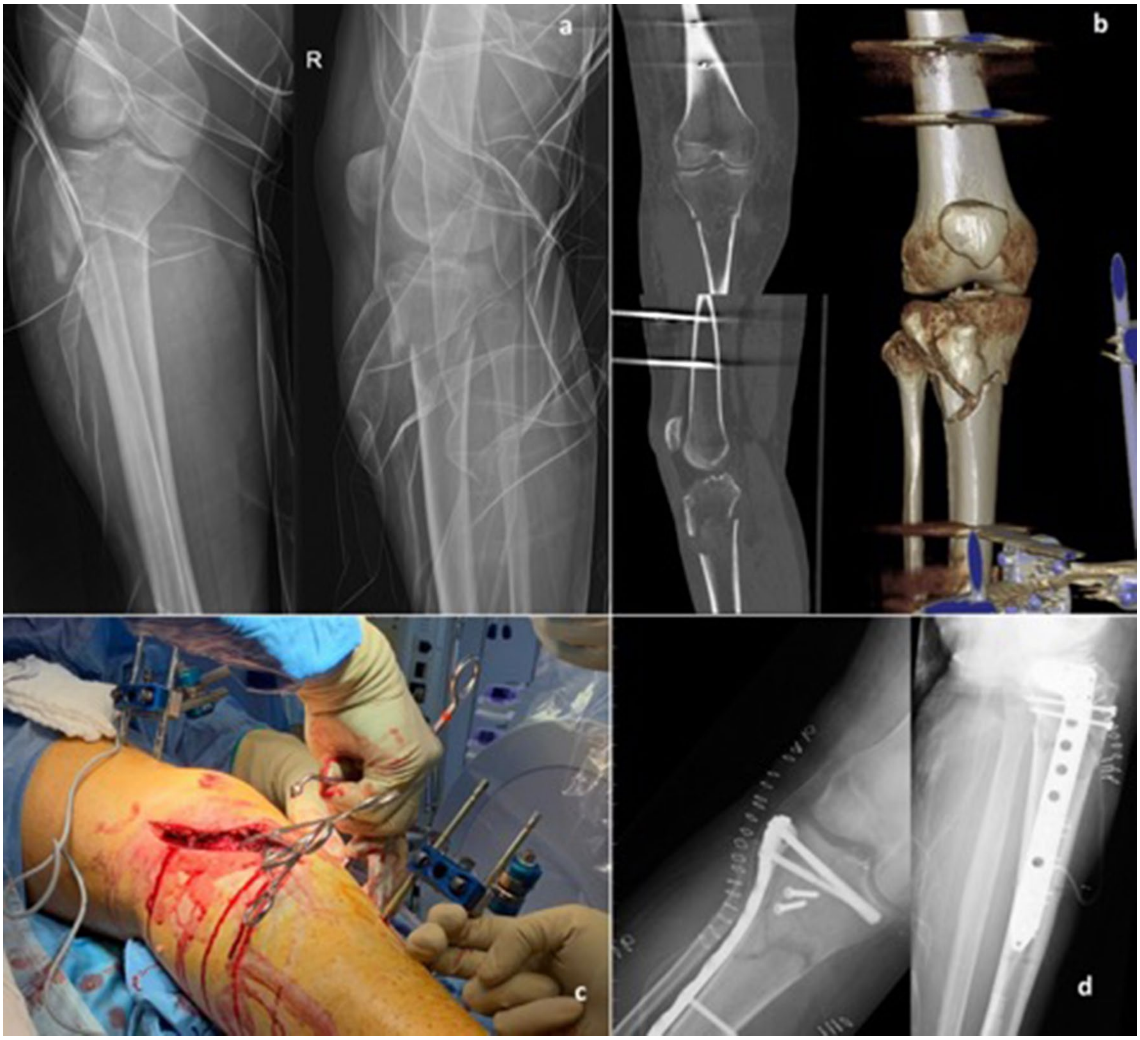

Fig. 4 A 61-year-old woman reporting a high-energy proximal tibia trauma. **a** Radiographic examination of the fracture, AP and LL views, classified as AO41C2. **b** Computed tomography (CT) scan, coronal, sagittal and 3D views after spanning EF. **c** Surgical picture showing the use of pins maintained in the surgical field for reduction and distraction. **d** ORIF carried out 5 days after spanning EF. Postop radiographic result, AP and LL views

with other literature reports with similar follow-up [8, 21]. In the present paper population, there was no statistically significant association of any single factor with clinical results, possibly due to the relatively small sample size. However, a trend toward worse clinical result in terms of subjective stiffness (WOMAC stiffness subscale) was found in the severely compromised soft tissues group (Table 2). More interestingly, a trend toward worse clinical result both at WOMAC (total score, pain and function subscales) and at IOWA score was found for the unstable knees group (Table 2), which are in line with previous literature reports that demonstrated knee instability to be a major determinant of clinical outcome [4]. As far as complications are concerned, there was only one case (4.3%) of superficial infection and no case of skin necrosis, deep infection or other major soft tissue complications. These data compare very favorably not only with historical reports but also with the most recent literature about high-energy PTFs. Recently, Unno et al. [28] reported their experience (101 non-consecutive patients) about early ORIF of tibial plateau fractures in selected cases. They reported complications needing surgical treatment within 12 months in 15.7% of cases. Other authors reported an infection rate of 3–18% of cases [8]. In a recent meta-analysis [28], the cumulative incidence of SSI after ORIF of tibial plateau fracture was 9.9%. Literature concerning other staged management protocols showed better results, more similar to what reported in the present study. Egol et al. [8] reported in a multicentric study on 57 cases treated with spanning fixation in all cases followed by internal fixation in 91% of cases an infection rate of 5%, decreasing to 3% if only closed fractures were included. Over the clear advantages demonstrated by staged treatment experiences, the single factors influencing infection risk are still a matter of

Fig. 5 Clinical case of a 57-year-old woman reporting **a** AO41C3 fracture after a fall, AP and LL views. **b** Bridging EF, AP and LL views. **c** ORIF with single plate carried out 11 days after trauma, AP and LL views. **d** Radiographic result at 18-month follow-up, AP and LL views

debate. Indeed, beneath well-known factors as the presence of open fracture, many other aspects should be considered. Colman et al. found that every extra hour of operative time after the first 3 h increased the risk of SSI by approximately 78% [27], while surgical approach did not result to be correlated with infection. Conversely, Morris et al. [19] evaluated 302 cases of bicondylar tibial plateau fracture (of which 81.4% treated with a staged management) treated with internal fixation, recording a significant correlation between infection and smoke, open fracture, compartment syndrome and double plating. The 2017 review of Shao et al. reported open fracture, operative time, tobacco use and compartment syndrome as relevant risk factors for the development of SSI [27]. The latter data sustain the choice of the authors of the present paper to reserve definitive external fixation for cases presenting with compartment syndrome and severe open fractures. Moreover, a staged management protocol allows the fracture to be properly studied in order to plan definitive surgery in detail and reserve the more complex cases to senior trauma surgeons, thus limiting the surgical time. Indeed, in the present paper the mean surgical time was 142.5 min, including also treatment of associated lesions in many cases. These data should be compared with what reported by Colman et al. [29] who registered a mean 2.2-h surgical time in cases not complicated by infection versus 2.8 h in other cases. Moreover, whereas surgical time is still not clearly considered as a risk factor for infection in trauma surgery, hip and knee replacement-related research was able to demonstrate a significant association [30]. Limits of the study are the retrospective design, the absence of a control group and the relatively brief follow-up. Strength of this study are the limited drop-off and the relatively large sample size with respect to the type of fracture analyzed and the single-center experience.

Conclusions

Recognizing a high-energy trauma mechanism and signs of soft tissue compromise is a key factor to correctly manage PTFs. A staged management protocol consisting in acute spanning external fixation in all cases and delayed internal fixation in selected cases is associated with highly satisfying clinical results with very low septic and other complication rates. Surgeon experience and comprehensive evaluation of risk factors for septic complications seem to play a determinant role.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest Authors Gianluca Canton, Luigi Murena, Antonio Moretti, Emmanuele Santolini, Marco Stella, Michele Francesco Surace declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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