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Swollen Ankle Fractures: What Predicts Delays in Definitive Fixation?

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ABSTRACT

Objective: Delaying definitive fixation of ankle fractures helps reduce soft tissue complications, and estimating the timing to definitive fixation can aid in optimizing treatment plans. The purpose of this study was to compare pilon and malleolar fractures in terms of time to definitive treatment and to evaluate the correlation between timing and radiographic parameters measured on computed tomography (CT).

Materials and Methods: In this single-center retrospective observational study, adult patients with pilon or malleolar fractures treated with two-stage surgery for soft tissue swelling between 2022 and 2024 were analyzed. Fracture type (malleolar or pilon) was assessed using X-rays and CT. Syndesmotic distance, anterior distance, medial and lateral soft tissue distance, and bone/soft tissue ratio were measured on axial CT scans. The relationship between time to definitive surgery, fracture type, and CT measurements was analyzed. Soft tissue complications were recorded.

Results: Of 88 patients enrolled, 57 (64.8%) had malleolar fractures and 31 (35.2%) had pilon fractures. The median time to definitive fixation was 8 days [6–10] overall (7 days [6–10] for malleolar fractures vs. 8 days [6–11] for pilon fractures; p=0.336). Timing showed a negative correlation with anterior distance (p=0.003) and a positive correlation with bone/soft tissue ratio (p=0.041). Four patients developed wound complications; none required hardware removal.

Conclusion: In staged surgical treatment, the median time to swelling resolution was 8 days, similar for both fracture types. Longer times were associated with reduced soft tissue coverage, correlating negatively with anterior distance and positively with the bone/soft tissue ratio.

Keywords: Ankle fractures, computed tomography, external fixation, soft tissue, staged treatment.

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INTRODUCTION

Ankle fracture patterns vary depending on the mechanism of injury.[1,2] While tibial pilon fractures typically result from axial injuries, malleolar fractures are more often associated with rotational mechanisms.[1–3] Due to inadequate soft tissue support around the ankle, skin circulation may be compromised, and wound-related issues such as superficial or deep infection or wound dehiscence may occur at the time of initial presentation with any type of injury.[4–9] Therefore, definitive treatment of ankle fractures may be deferred to prevent secondary damage to the soft tissue envelope.[7,10] The wrinkle test or the resolution of blisters may help determine the appropriate timing. In most cases, immobilization in a short leg splint or temporary external fixation is employed for this purpose.[5,7,10,11]

Currently, two-stage treatment of tibial pilon fractures is considered the standard of care,[10,12,13] and staged treatment of malleolar fractures is also gaining acceptance, though it remains less common than for pilon fractures,[14–19] since pilon fractures are generally associated with greater soft tissue compromise than malleolar fractures. Although the transition to definitive treatment is most often guided by the wrinkle sign in both fracture types,[7,13,16,18] to our knowledge, the time to definitive treatment and the factors influencing it have not been compared between these fracture groups. In addition, while patient-related factors impacting soft tissue status have been identified,[7,12,14] the influence of radiographic characteristics, both of the fracture and the soft tissue envelope, on waiting time has not been clearly established.

The purpose of this study was to compare pilon and malleolar fractures and to evaluate the correlation between various radiographic parameters and the time to definitive fixation. Our hypothesis was that the waiting time for pilon fractures would be similar to that for malleolar fractures and that, regardless of fracture type, radiographic measurements could help estimate the optimal timing for definitive fixation.

KEY MESSAGES

- Predicting the waiting time to definitive fixation may benefit clinical workflow and patient care planning.
- Time to definitive fixation was similar for pilon and malleolar fractures.
- Anterior soft tissue distance and bone/soft tissue ratio, measured on axial CT, correlated with waiting time.

MATERIALS AND METHODS

This single-center, retrospective, observational study was approved by the Ankara Etlik City Hospital Ethics Committee (Decision No: BADEK-2024-803, dated 28.08.2024). Written informed consent was obtained from all patients, and the study was conducted in accordance with the Declaration of Helsinki.

Data from patients with ankle fractures who underwent surgery in the Orthopedics and Traumatology Clinic of our training and research hospital between December 2022 and February 2024 were retrospectively analyzed.

The inclusion criteria were:

- Age over 18 years
- Closed tibial pilon or malleolus fracture with Tscherne grades C1 or C2 soft tissue injury
- Staged treatment (temporary external fixation followed by open reduction and internal fixation when soft tissue conditions permitted) due to soft tissue swelling (negative wrinkle sign)
- Minimum follow-up of six months.

Exclusion criteria were:

- Open fractures
- Additional injuries or comorbidities that could affect surgical timing
- Presentation later than 24 hours after trauma
- Additional fixation performed during external fixation
- Definitive treatment performed using a method other than plate-screw fixation
- Absence of computed tomography (CT) after external fixation. Study flowchart was shown in Figure 1.

Surgical Technique and Follow-Up

All patients underwent surgery within 24 hours of admission. Ceftriaxone (1 g) was administered 30 minutes before each procedure and continued for 48 hours postoperatively. Anesthesia (spinal or general) was selected according to the anesthesiologist's assessment in both surgical stages. All patients received enoxaparin for thrombosis prophylaxis during hospitalization, and nonsteroidal anti-inflammatory drugs were used for pain control.

The delta frame method was used for all external fixation procedures (Fig. 2). With the patient in the supine position, a 4-mm middle-portion threaded pin was inserted from the medial to lateral aspect of the calcaneus through the calcaneal tuberosity, using the previously defined safe zones as recommended in the AO Surgery Reference.[20] Two 4-mm threaded pins were then inserted into the tibial shaft, slightly medial to the anterior tibial crest, at a distance that would not interfere with incisions planned for definitive surgery and would not compromise stability.[21] After ligamentotaxis with the calcaneal pin, the pins on each side were connected separately with rods. Following fluoroscopic verification of fracture reduction and joint distraction, all clamps were tightened and the procedure was completed.

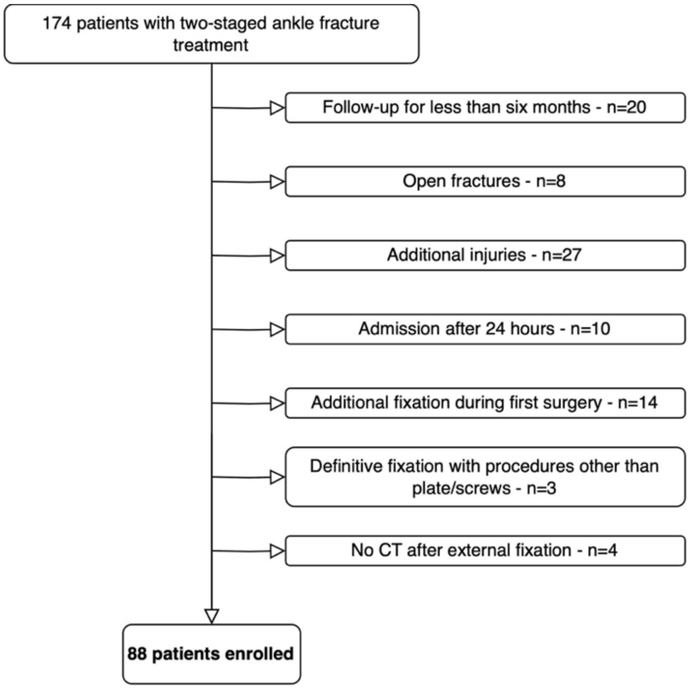

Figure 1. Study flowchart.

During hospitalization, patients underwent elevation and cold compression. Pin sites were dressed using a conventional method, and patients were evaluated daily. Those without skin problems, such as blister formation or erythema, and who exhibited a positive wrinkle test at the planned incision sites were scheduled for definitive surgery the following day. All definitive surgeries were performed in a single stage, with surgical approaches planned using CT scans obtained after external fixation.

A short leg splint was applied to patients after definitive surgery for pain control. Patients were discharged after at least two consecutive days without wound problems. Sutures were removed on postoperative day 15 in patients without wound complications, and splints were removed at one month. Wound status was assessed at follow-up visits at six weeks, three months, and six months, and patients were admitted as needed.

Radiographic Evaluation and Outcomes

All radiographs and CT scans were reviewed by two investigators. Fractures were classified as pilon or malleolar, further categorized according to the 2018 Orthopaedic Trauma Association/AO Foundation (OTA/AO) Fracture and Dislocation Classification.[22] Malleolar fractures were also subclassified according to the Lauge-Hansen classification, while intra-articular fragments in tibial pilon fractures were

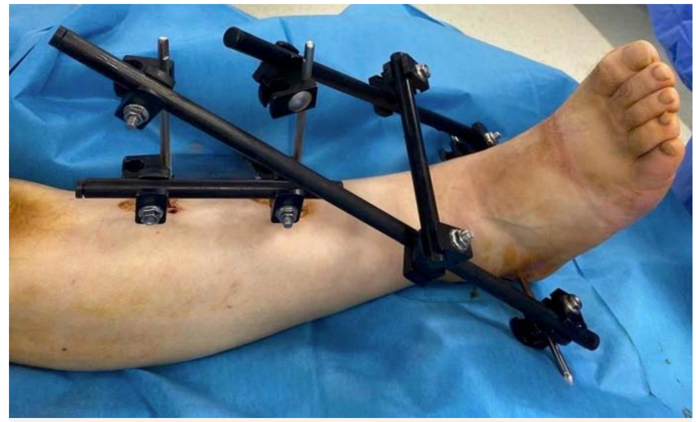

Figure 2. Delta frame external fixation.

counted on CT scans. In cases of disagreement, radiographs were reviewed jointly to reach a consensus.

After collection of clinical data, early CT images (obtained immediately after temporary stabilization) were evaluated twice at six-week intervals by two additional observers blinded to the clinical data. The syndesmosis distance was measured as the shortest distance between the lateral cortex of the tibia and the medial cortex of the fibula on axial sections taken 10 mm proximal to the joint (Fig. 3a).[23] On sections taken 5 mm proximal to the joint, a line was drawn between the medial cortex of the tibia and the lateral cortex of the lateral malleolus, dividing the medulla of both bones into two equal parts. The perpendicular distance from this line to the most anterior point of the skin was defined as the anterior distance. The distance from each end of this line to the medial and lateral skin were defined as the medial and lateral soft tissue distances, respectively. The ratio of the length of this line to the length between its projections on the skin was defined as the bone/soft tissue ratio (Fig. 3b).

The relationship between fracture type and classification, syndesmosis distance, anterior distance, medial and lateral soft tissue distance, bone/soft tissue ratio, and time to definitive surgery on CT imaging was analyzed. Details of patients who developed soft tissue complications during postoperative follow-up were recorded.

Statistical Analysis

Statistical analyses were performed using SPSS 20.0 (SPSS Inc., Chicago, Illinois). Inter- and intra-rater reliability of numerical measurements was assessed using intraclass correlation coefficients (ICC), presented as mean ICC values. The Kolmogorov-Smirnov test was used to assess whether the data conformed to a normal distribution. Descriptive and outcome data were reported as mean ± standard deviation

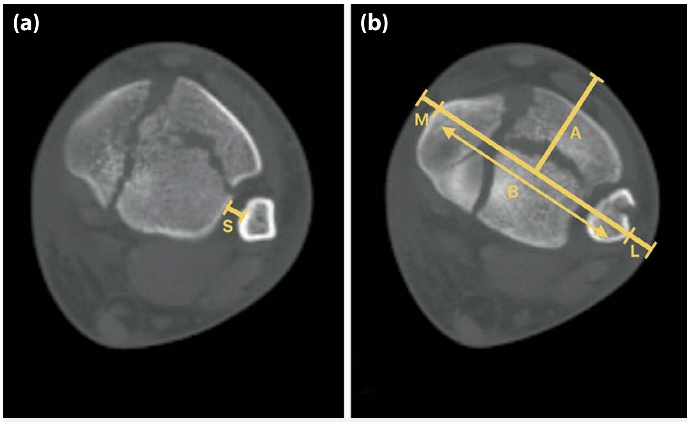

Figure 3. Axial computed tomography images of a 33-year-old male with a tibial pilon fracture; time to definitive fixation was 12 days. **(a)** Syndesmotic distance (S), measured on a slice 10 mm proximal to the joint line, defined as the shortest distance between the lateral cortex of the tibia and the medial cortex of the fibula.[7] **(b)** Anterior distance (A), measured on a slice 5 mm proximal to the joint line, defined as the distance from the skin to the midpoint of the line dividing the medullae of both bones (B). Medial (M) and lateral (L) soft tissue distances represent the distances from the medial and lateral skin to line B. The bone/soft tissue ratio is calculated as B / (B + M + L).

or as median with first and third quartiles, where appropriate, and as frequency and percentage for categorical data. Differences between numerical variables were analyzed using the independent samples t-test or Mann-Whitney U test, while categorical variables were analyzed using the chi-square test. Correlations between numerical data were assessed using Spearman's rho test. Multiple linear regression analysis for time to definitive fixation was conducted using the ordinary least squares (OLS) estimation method. Post-hoc power analysis, based on the most significant observed correlation, was performed using G*Power version 3.1.9.6 (Franz Paul, Kiel, Germany). P values <0.05 were considered statistically significant.

RESULTS

A total of 88 patients were included in the study (mean age: 47.8±18.2 years; 49 males). Of these, 57 patients (64.8%) had malleolar fractures and 31 (35.2%) had pilon fractures. The median time to definitive fixation was 8 days [6–10] for all patients, 7 days [6–10] for malleolar fractures, and 8 days [6–11] for pilon fractures. No significant difference was found between the groups (p=0.336) (Table 1). There was also no significant relationship between time to definitive fixation and age (rho=0.197, p=0.069) or sex (p=0.571).

Medial malleolar fracture subtypes included supination-external rotation in 46 patients (73%), pronation-external rotation in 14 patients (22.2%), and pronation-abduction in three patients (4.8%). No significant difference in time to definitive fixation was observed between these subtypes (p=0.523). For tibial plafond fractures, the median intra-articular fragment count was 3 [2–3] (Table 1), with no significant correlation between fragment count and time to definitive fixation (rho=0.055, p=0.768).

Mean measurements were as follows: syndesmotic distance, 5±3.6 mm; medial soft tissue distance, 8.7±4 mm; lateral soft tissue distance, 8.8±3.2 mm; anterior distance, 15.4±4.2 mm; and bone/soft tissue ratio, 0.76±0.06. The mean ICC for measurements was 0.94. Correlation analysis showed a significant negative correlation between time to definitive fixation and anterior distance (rho=-0.316, p=0.003) and a significant positive correlation between time to definitive fixation and bone/soft tissue distance (rho=0.218, p=0.041). No other parameters demonstrated a significant correlation with time to definitive fixation (Table 2).

Multiple linear regression analysis was conducted to predict time to definitive fixation based on the measurements. The overall regression model was not significant (F (4,83)=2.158, R^2=0.094, p=0.081). However, the coefficient for anterior distance was significant (coefficient=-0.2329, 95% CI: -0.429 to -0.037, t=-2.365, p=0.020) (Table 3). Post-hoc power analysis for the correlation between time to definitive fixation and anterior distance, with a significance level (alpha) of 0.05, revealed a power of 82.8%.

Superficial wound complications occurred in four patients (4.5%), two with malleolar fractures and two with tibial pilon fractures. None of these patients required removal of plates and screws. No patients developed pin site infections. Characteristics of patients with wound complications are presented in Table 4.

DISCUSSION

The results of this study indicate that, in delayed treatment of malleolar fractures, the waiting time for definitive fixation was similar to that of tibial pilon fractures. Furthermore, the amount of soft tissue around the bone (particularly anterior distance and the bone/soft tissue ratio) was associated with a shorter time to soft tissue readiness. These findings suggest that the quantity of soft tissue covering the bone is more important for soft tissue recovery than the fracture type itself.

Soft tissue problems are one of the most common complications after ankle fracture surgery.[5,8,9] Due to the poor soft tissue coverage of the distal tibia, injuries in this region are especially

Table 1. Patient demographics, measurement results, and analysis of differences between fracture types

	All patients (n=88)	Malleolar fractures (n=57)	Pilon fractures (n=31)	p
Age	47.8±18.2	46.7±19.9	49.9±14.6	0.438
Sex (male)	49 (55.7%)	26 (45.6%)	23 (74.2%)	**0.010**
OTA/AO classification				
43B1			5 (16.1%)	
43B2			3 (9.7%)	
43B3			6 (19.4%)	
43C1			7 (22.6%)	
43C2			3 (9.7%)	
43C3			7 (22.6%)	
44A		2 (3.5%)		
44B		38 (66.7%)		
44C		17 (39.8%)		
Lauge-Hansen classification (for malleolar fractures)				
SER		46 (73%)		
PER		14 (22.2%)		
PAB		3 (4.8%)		
Intra-articular fragment count (for pilon fractures)			3 [2-3]	
Syndesmotic distance (mm)	5±3.6	5.2±4.2	4.5±2.2	0.395
Medial soft tissue distance (mm)	8.7±4	8.8±3.9	8.4±4.1	0.612
Lateral soft tissue distance (mm)	8.8±3.2	8.6±2.9	9±3.8	0.613
Anterior distance (mm)	15.4±4.2	16.3±3.5	13.8±5	**0.009**
Bone/soft tissue ratio	0.76±0.06	0.76±0.06	0.77±0.06	0.507
Time to definitive fixation	8 (6–10)	7 (6–10)	8 (6–11)	0.336

OTA/AO: Orthopaedic trauma association/AO foundation; SER: Supination-external rotation; PER: Pronation-external rotation; PAB: Pronation-abduction.

prone to wound-related complications.[11,13] In addition, soft tissue swelling disrupts the microvasculature and increases susceptibility to wound complications.[24] Therefore, delayed definitive surgery is a viable option for ankle fractures with soft tissue compromise. For this reason, staged surgical treatment (temporary external fixation followed by internal fixation when the soft tissue condition is suitable) is considered almost the standard of care for tibial pilon fractures[13] and has been reported to be preferable to splinting.[25] A similar two-stage approach for malleolar fractures has also been advocated by some authors.[16–19,26]

In this study, the median waiting time was eight days, and no significant correlation was found between fracture type (pilon or malleolar) and waiting time. This duration is consistent with other reports.[8,16,18,27–30] However, most of these studies compared outcomes of early versus delayed surgery, and no clear consensus exists. While some studies have reported that early surgery is more likely to result in wound problems,[5,24] others have found that delays are associated with infection and poorer functional scores,[31–35] that waiting with external fixation offers no additional benefit,[36] or that initial treatment with external fixation is itself a risk factor for wound complications.[9] It is important to note that in studies linking longer waiting times or external fixation to poorer outcomes, patients often presented with worse soft tissue conditions at baseline.[19] Because waiting time was not a modifiable parameter in this study's design, a direct comparison with studies evaluating the relationship between waiting time and outcomes was not possible. Nevertheless, the low rate of wound complications observed in this study, consistent with the literature, suggests that delayed treatment is an appropriate approach.

Table 2. Correlation analysis between measured radiological parameters and time to definitive fixation

	Spearman's Rho	p
Syndesmotic distance	-0.030	0.784
Medial soft tissue distance	-0.046	0.671
Lateral soft tissue distance	-0.185	0.085
Anterior distance	**-0.316**	**0.003**
Bone/soft tissue ratio	**0.218**	**0.041**

In all patients, a negative wrinkle sign was the main criterion for delaying treatment.[7,16,27,28,37,38] The conventional opinion is that early definitive fixation is possible within the first 6–8 hours for these fractures,[25,37,39] but it is not always feasible to prepare the patient for surgery within this period. The soft tissue status of the fracture can be assessed using a classification such as the Ostern-Tscherne grading system;[25] however, this system may not be suitable for follow-up purposes due to its relatively low interobserver reliability.[31] It should be recognized that soft tissue tension may be present across all grades, from 0 to 3. Therefore, the most effective way to evaluate the potential complications of definitive surgery is by monitoring the wrinkle sign during physical examination. Using this approach, and in agreement with the literature,[5,7–9,16,17,19,24,29,30,32–34,36,40] wound problems were observed in 4 of 88 patients (4.5%), and no patient required implant removal that could compromise fracture healing.

CT is the gold standard for surgical planning of ankle fractures.[13] However, it can also provide valuable information on soft tissue status, and it was hypothesized that it could be used to assess soft tissue condition in these injuries. Existing studies have not compared complications and time to definitive fixation with parameters measurable on CT. In this study several distances were defined to assess soft tissue on CT (Fig. 3b). These measurements were taken 5 mm proximal to the joint because all surgical incisions were located within this area. Correlation analysis revealed a significant negative correlation between time to definitive fixation and anterior distance, and a significant positive correlation between time to fixation and bone/soft tissue ratio. In other words, decreased soft tissue coverage was associated with a longer

Table 3. Multiple linear regression analysis for predicting time to definitive fixation

Variable	Coefficient (95% CI)	Standard error	t	p
Syndesmotic distance	-0.0221 (-0.244, 0.199)	0.111	-0.199	0.843
Medial soft tissue distance	-0.0077 (-0.213, 0.197)	0.103	-0.074	0.941
Lateral soft tissue distance	-0.1446 (-0.4, 0.11)	0.128	-1.128	0.263
Anterior distance	**-0.2329 (-0.429, -0.037)**	**0.098**	**-2.365**	**0.020**
Intercept	13.6818 (9.892, 17.472)	1.906	7.18	

CI: Confidence interval. The overall regression model was not statistically significant ($F(4,83)=2.158$; $R^2=0.094$; $P=0.081$).

Table 4. Characteristics of patients with wound complications

Protocol	Age	Sex	Fracture type	Time to definitive fixation (days)	Onset of wound problem after definitive fixation (days)	Wound management	Duration of wound problem (days)
21	53	Male	Pilon (3 intra-articular fragments)	18	8	Vacuum-assisted wound closure and skin grafting	20
25	24	Female	Malleolar (PER)	9	3	Superficial debridement and empirical antibiotics	24
47	78	Female	Malleolar (PAB)	10	5	Antibiotics (Pseudomonas in wound swab culture)	6
67	42	Male	Pilon (3 intra-articular fragments)	7	14	Superficial debridement and empirical antibiotics	12

PER: Pronation-external rotation; PAB: Pronation-abduction.

waiting time. While previous studies have primarily examined the relationship between waiting time and risk factors related to patient-specific clinical parameters (such as comorbidities or mechanisms of injury).[6,23,24,27,28,35,36,39,40] the use of CT measurements to predict this interval may provide additional guidance for treatment planning.

For standardization purposes, only patients who had undergone two-stage surgery (external fixation for temporary stabilization) were included in the study. There is no consensus regarding the use of temporary external fixation for follow-up in malleolar fractures. Tanoglu et al.[16] found that the functional scores of two-stage treatment were lower than those of single-stage treatment, although the difference was not statistically significant. Gonzalez-Morgado et al.[19] reported fewer complications after follow-up with temporary external fixation than with splinting, again without statistical significance, despite a worse baseline. A common feature of these studies is that they reported on the follow-up of patients with ankle fracture dislocation but did not provide a consistent definition of "fracture dislocation." Nevertheless, both emphasized that external fixation helps prevent redislocation in such fractures, and both noted that patients treated with a fixator had worse baseline soft tissue conditions.[16,19] In the present study, all fractures that did not extend into the tibiotalar plafond were classified as "malleolar fractures," without assessing dislocation status. Wawrose et al.[17] reported skin necrosis and wound dehiscence in patients treated with splinting, while no such complications occurred in those treated with a fixator; however, redislocation occurred in 50% of the splint group. Jiang et al.[18] compared external fixation with calcaneal traction in malleolar fractures and found lower pain scores in the external fixation group, although there was no difference in long-term outcomes.

Limitations of this study include its retrospective design, the unavailability of an a priori power analysis, and a relatively small sample size, which may limit the ability to detect significant differences. Additionally, standardized clinical data for analyzing additional parameters, such as comorbidities, were lacking. The decision regarding surgical approach and wrinkle test positivity was made on a case-by-case basis by surgeons not included in the analysis, resulting in non-standardization of incision-related parameters (such as approach and wound length), the definitive fixation method, and factors affecting the likelihood of wound complications, such as operative time. The lack of a standardized assessment of reduction quality after temporary external fixation may also be considered a limitation. However, these considerations increase the likelihood that the results can be generalized. In addition, because this study did not compare patients who did not undergo staged surgical treatment, we were unable to make a definitive statement regarding the superiority of the staged treatment approach. Finally, the lack of postoperative functional score analysis was another limitation; however, considering that functional outcome assessment was beyond the scope of the study and that many additional factors could influence these scores, it was reasonable not to perform this analysis.

CONCLUSION

The median time to resolution of swelling and wrinkle sign positivity for patients who underwent delayed surgical treatment due to soft tissue compromise was eight days, similar for both malleolar and pilon fractures. This time was longer in cases with less soft tissue coverage. Time to definitive fixation was significantly negatively correlated with anterior distance and positively correlated with the bone/soft tissue ratio measured on axial slices 5 mm proximal to the joint line on CT.

Ethics Committee Approval: The Ankara Etlik City Hospital Clinical Research Ethics Committee granted approval for this study (date: 28.08.2024, number: AEŞH-BADEK-2024-803).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Conflict of Interest: The authors have no conflict of interest to declare.

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