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Original Article

Epidemiological study and clinical-functional evaluation of patients undergoing surgical treatment of tibial pilon fractures

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Abstract

Objective: To describe the epidemiological profile of patients undergoing osteosynthesis for tibial pilon fractures and to perform a functional-clinical evaluation using the Foot and Ankle Outcome Score and the American Orthopaedic Foot and Ankle Society questionnaires.

Method: Retrospective and descriptive study based on the analysis of 35 patients diagnosed with tibial pilon fracture undergoing surgical treatment between January 1, 2019, and December 31, 2021. The parameters analyzed included: age, sex, profession, side affected, trauma mechanism, interval between surgeries, comorbidities, and postoperative complications.

Results: The sample consisted of 23 males (66%) and 12 females (34%), with a mean age of 47.6 years, with falls from height and automobile accidents being the main trauma mechanisms. The distribution of the affected side was balanced: 18 cases in the left ankle (51%) and 17 in the right (49%). According to the AO/OTA classification, fractures classified as AO 43C1 (28.6%) and 43C3 (25.7%) were the most frequent. It was observed that 88.8% of patients classified as 43C3 fractures experienced complications.

Conclusion: The development of complications in tibial pilon fractures is significantly associated with AO/OTA classification, which directly reflects poorer clinical-functional outcomes.

Level of Evidence III; Retrospective.

Keywords: Tibia fractures; Internal fixation of fractures; Treatment outcome.

Introduction

Tibial pilon fractures (TPF), originally described by French radiologist Étienne Destot in 1911, refer to intra-articular fractures that affect the distal third of the tibia with extension to the metaphysis. The term “pilon” (from the French *pilon*) was used to illustrate the mechanical function of the distal tibia, which acts as a pilon on the talus. These fractures are relatively rare, accounting for less than 1% of all lower-limb fractures and approximately 3% to 10% of tibial fractures[1-3].

Most TPFs result from high-energy trauma, such as falls from height and automobile accidents, and are characterized by axial impaction of the talus against the distal tibia. This mechanism produces complex injuries with variable patterns of comminution, joint misalignment, and, often, significant soft-tissue injury. Approximately 30% present as open fractures[4,5].

The epidemiology of TPFs reinforces their predominance among males aged 25-50 years, typically in occupational contexts or high-risk activities[6]. For diagnosis, simple radiographs (anteroposterior and lateral) are usually sufficient, and computed tomography is essential for proper evaluation and surgical planning[7].

Study performed at the Departamento de Ortopedia e Traumatologia do Hospital Santa Marcelina, São Paulo, SP, Brazil.

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Its classification can be performed using the traditional Rüedi-Allgöwer system, which categorizes injuries into three types (I to III) based on the degree of joint displacement and comminution. The AO/OTA system, widely used, provides a more detailed classification: Type A (extra-articular), Type B (partially articular), and Type C (fully articular), subdivided by degree of complexity. The most severe correspond to categories 43B3 and 43C3[3,8].

Its treatment is challenging, and the most widely accepted protocol, described by Sirkin et al.[9], recommends a two-step approach for high-energy fractures: initially, stabilization with an external fixator, followed by definitive osteosynthesis after adequate healing of soft tissues[9,10].

Long-term follow-up studies show that, even with adequate management, high-energy TPFs have a poor prognosis, with a high incidence of sequelae such as post-traumatic arthrosis, chronic pain, persistent edema and functional limitation. Socioeconomic factors also directly influence the functional recovery of patients[11].

Thus, TPFs are complex and multifactorial injuries, with a significant impact on joint function and quality of life. Clinical-functional evaluation using validated instruments, such as the Foot and Ankle Outcome Score (FAOS) and the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale, allows the objective quantification of functional recovery.

The objective of our study is to describe the epidemiological profile of patients undergoing osteosynthesis for tibial pilon fractures and to perform a functional-clinical evaluation using the FAOS and AOFAS questionnaires.

Methods

This study was conducted at a reference hospital in orthopedics and traumatology, with approval from the Institutional Review Board. All participants signed the Informed Consent Form in accordance with the current ethical guidelines.

This is a retrospective, longitudinal, and observational study, based on electronic medical records and clinical-functional evaluation of patients diagnosed with TPF who underwent surgical treatment between January 1, 2019, and December 31, 2021.

Population and sampling

Thirty-five medical records of patients diagnosed with TPF and surgically treated in that period were evaluated. The sample consisted of 23 males (66%) and 12 females (34%). The mean age was 47.6 years (range, 19-80 years).

Inclusion and exclusion criteria

Patients with TPF confirmed by radiography and undergoing surgical treatment in two stages were included: initially with external fixation for temporary stabilization, followed by open reduction and internal fixation (ORIF) after soft-tissue improvement.

Patients with open fractures, a history of previous ankle fractures, a lack of adequate radiographic documentation, a period of injury greater than 24 hours, the presence of neurological diseases or congenital deformities in the operated lower limb, and loss to outpatient follow-up were excluded from the sample.

Surgical procedures

The surgical treatment followed a two-stage approach. Initially, stabilization was performed with a uniplanar external fixator (medial delta assembly) as a matter of urgency. After regression of edema and soft-tissue improvement, ORIF was performed. Fibula reduction and fixation were performed sideways using a one-third tubular plate and 3.5 mm screws. The distal tibia was approached by an anteromedial approach, using an anatomical plate for the distal tibia.

In cases of metaphyseal comminution, the minimally invasive plate osteosynthesis (MIPO) technique was used, adhering to the principles of relative stability and preservation of the fracture hematoma. In fractures with joint comminution, open reduction and direct internal fixation of the joint surfaces were performed to achieve anatomical restoration.

Clinical-functional evaluation

Functional assessment was performed during outpatient follow-up, approximately 12 months after definitive surgery. Two validated instruments used were the AOFAS and FAOS questionnaires

Variables analyzed

The variables collected and analyzed were age and sex, affected side, trauma mechanism, interval between the first and second surgical interventions, comorbidities, and postoperative complications, including infection, wound dehiscence, and post-traumatic arthrosis.

Results

The sample consisted of 23 males (66%) and 12 females (34%). The mean age was 47.6 years (range, 19-80 years). The distribution of the affected side was balanced: 18 cases in the left ankle (51%) and 17 in the right (49%). The most frequently affected patients were retired (22.9%) and delivery workers (20%). The most prevalent trauma mechanisms were falls from height (34.3%) and automobile accidents (34.3%).

Regarding comorbidities, 17 patients (48.6%) reported no pre-existing diseases. Among the others, six had systemic arterial hypertension (SAH), six had diabetes mellitus (DM), and five had both conditions (SAH + DM).

Regarding postoperative complications, 16 (45.7%) patients had uneventful postoperative courses. Among the 19 cases with complications (54.3%), the most frequent were post-traumatic arthrosis (22.9%), surgical site infection (8.6%), and surgical wound dehiscence (8.6%). One patient had an infection associated with delayed consolidation, and another had only delayed bone consolidation.

Table 1 presents the frequency distribution of categorical variables: profession, trauma mechanism, comorbidities, and postoperative complications.

Table 2 details the quantitative variables: age, time to ORIF, and FAOS and AOFAS functional scores, stratified by fracture classifications (43B3, 43C1, 43C2, 43C3). Measures of central tendency and dispersion were reported: mean, median, standard deviation, minimum, and maximum values.

Regarding fracture distribution, eight patients (22.9%) had fractures classified as 43B3, ten (28.6%) as 43C1, eight (22.9%) as 43C2, and nine (25.7%) as 43C3.

To identify significant differences between fracture classification groups, analyses of variance (ANOVA) were conducted for the variables age, time to ORIF, FAOS, and AOFAS scores. The assumptions of normality and homogeneity of variances were previously tested and met.

Table 1. Frequency distribution of categorical variables

Variable	Categories	n	%
Profession	Retired	8	22.9%
	Delivery worker	7	20.0%
	Others	20	57.1%
Trauma mechanism	Fall from height	12	34.3%
	Automobile accidents	12	34.3%
	Others	11	31.4%
Comorbidities	None	17	48.6%
	SAH	6	17.1%
	DM	6	17.1%
	SAH + DM	5	14.3%
Complications	None	16	45.7%
	Post-traumatic arthrosis	8	22.9%
	Postoperative infection	3	8.6%
	Surgical wound dehiscence	3	8.6%
	Infection + delayed consolidation	1	2.9%
	Delayed consolidation	1	2.9%
	Others	3	8.6%

SAH: Systemic arterial hypertension; DM: Diabetes mellitus

Table 2. Sample characterization according to fracture classification

AO/OTA Classification	n	Age (years) Mean ± SD (min-max)	Time to ORIF (days) Mean ± SD (min-max)	FAOS score Mean ± SD (min-max)	AOFAS score Mean ± SD (min-max)
43B3	8	44.5 ± 12.3 (28-67)	4.1 ± 1.0 (3-6)	78.6 ± 8.2 (65-91)	85.3 ± 6.7 (72-95)
43C1	10	46.7 ± 11.9 (30-66)	4.7 ± 1.3 (3-7)	74.3 ± 9.0 (60-88)	81.4 ± 7.8 (68-93)
43C2	8	48.2 ± 13.5 (31-70)	5.7 ± 1.2 (4-8)	70.2 ± 7.5 (58-82)	78.9 ± 6.1 (68-89)
43C3	9	50.3 ± 10.7 (36-80)	5.3 ± 1.1 (4-7)	65.1 ± 8.7 (50-79)	74.6 ± 5.9 (63-84)

SD: Standard deviation; ORIF: Open reduction and internal fixation; FAOS: Foot and Ankle Outcome Score; AOFAS: American Orthopaedic Foot and Ankle Society.

ANOVA indicated a statistically significant difference in time to ORIF among fracture classifications ($p = 0.045$). Tukey's post-hoc test identified a significant difference between groups 43B3 and 43C2, with a mean time to ORIF 1.63 days greater in group 43C2.

Regarding the FAOS, a statistically significant difference was observed between the groups ($p = 0.002$). Tukey's test showed differences between classifications 43B3 vs. 43C3 and 43C1 vs. 43C3 (Table 3).

In addition, the correlations between time to ORIF and FAOS and AOFAS scores were evaluated; a moderate negative trend was observed, suggesting that longer intervals to ORIF may be associated with worse functional outcomes.

A Student's t-test for independent samples (significance level = 5%) was used to analyze associations between comorbidities and complications and FAOS and AOFAS scores. Analyses of the association between comorbidities and complications were also performed, as well as between fracture classification and complications, using the chi-square test. Statistically significant associations were identified between fractures classified as 43C3 and a higher occurrence of postoperative complications ($p < 0.05$).

In the first case (ratio between 43B3 and 43C3), the difference in mean scores is 21.61 points: the mean score for patients classified as 43B3 is 21.61 points higher than that for 43C3. In the second case (between 43C1 and 43C3), Tukey's test indicated that the mean FAOS for patients classified as 43C1 was 18.51 points higher than that for patients classified as 43C3 (Figure 1).

Table 4 shows significant differences between classifications 43B3 and 43C3, and between 43C1 and 43C3. In the first case, the difference between the means (43B3-43C3) is 19.31, indicating that the mean AOFAS score for classification 43B3 is 19.31 higher than that for classification 43C1. Regarding the differences between classifications 43C1 and 43C3, the difference in means is 15.16; that is, the mean AOFAS score for classification 43C1 is 15.16 points higher than for classification 43C3 (Figure 2).

To analyze the correlation between the AOFAS and FAOS scores and time to ORIF, a correlation matrix was generated and is presented in Table 5. Thus, all correlations were significant at the 5% level, with the correlation between

Table 3. Tukey's post-hoc test

Classification	Classification	Difference between means	SD	p-value
43B3	**43C1**	3.10	5.43	0.940
	43C2	10.37	5.72	0.287
	43C3	21.61	5.56	0.003*
43C1	**43C2**	7.28	5.43	0.546
	43C3	18.51	5.26	0.007*
43C2	**43C3**	11.24	5.56	0.203

SD: Standard deviation. *significant at the 5% level.

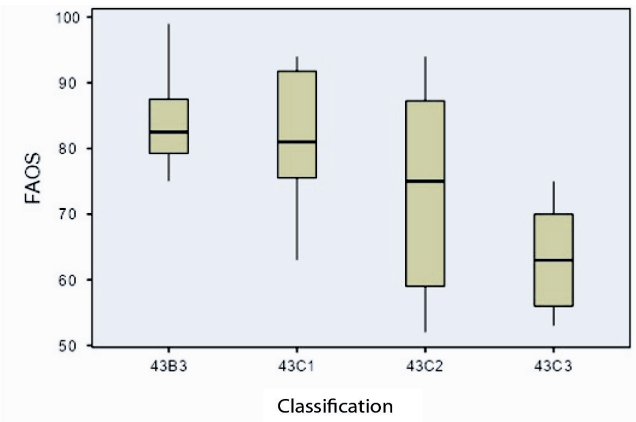

Figure 1. Boxplot of fracture classification according to the FAOS score.

Table 4. Tukey's post-hoc test

Classification	Classification	Difference between means	SD	p-value
43B3	43C1	4.15	4.54	0.798
	43C2	11.38	4.79	0.103
	43C3	19.31	4.65	0.001*
43C1	43C2	7.22	4.54	0.399
	43C3	15.16	4.40	0.009*
43C2	43C3	7.93	4.65	0.339

SD: Standard deviation. *significant at the 5% level.

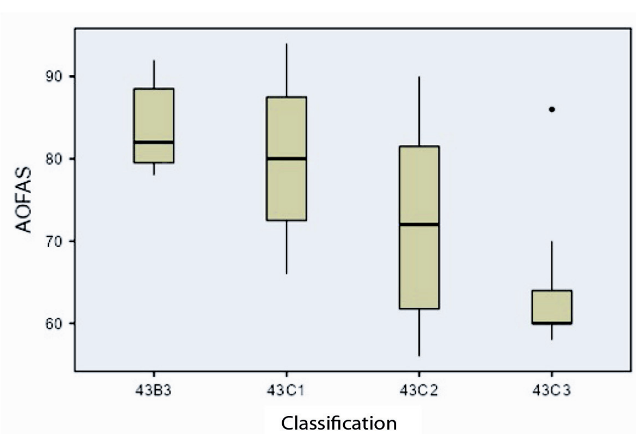

Figure 2. Boxplot of fracture classification according to the AOFAS score.

Table 5. Correlation matrix among FAOS, AOFAS, and time to ORIF

	Time to ORIF	FAOS	AOFAS
Time to ORIF	—		
FAOS	-0.44*	—	
AOFAS	-0.37*	0.93*	—

ORIF: Open reduction and internal fixation; FAOS: Foot and Ankle Outcome Score; AOFAS: American Orthopaedic Foot and Ankle Society. *significant at the 5% level.

FAOS and time to ORIF equal to -0.44, indicating a moderate negative association. That is, moderately low values of time to ORIF correspond to high values of the FAOS, or even indicate that, as the time for ORIF increases, the FAOS tends to decrease (moderately). However, because the correlation is statistically significant, it is plausible to assume a possible (inverse) relationship between the variables.

Similarly, the correlation between AOFAS and time to ORIF shows the same pattern, albeit with a weak correlation coefficient, which is significant at the 5% level. That is, in a weak but significant way, the shortest time to ORIF is associated with the highest AOFAS scores, suggesting that as time to ORIF increases, AOFAS scores are likely to decrease. Thus, whether the relationship between time to ORIF and FAOS or time to ORIF and AOFAS is examined, both cases demonstrate similar distributions of values.

When exploring the other variables, the relationships between the presence or absence of comorbidities and complications in patients, and the FAOS and AOFAS scores, were examined. For this purpose, a Student's t-test was applied to independent groups (Table 6). After applying the Student's t-test, Table 6 shows no significant differences in FAOS but significant differences in AOFAS scores between groups with and without comorbidities.

Based on the postoperative complication scores, there are significant differences between the two groups. In this sense, the mean FAOS and AOFAS *scores* are statistically higher among patients in the group that did not develop complications than among those with complications.

Table 7 presents the frequency distributions for patients with and without comorbidities and for those with and without surgical complications. Eleven patients with comorbidities developed complications; ten without comorbidities did not; and six with comorbidities did not. From these data, the chi-square test yielded p = 0.299, indicating no significant association between the variables under comparison.

Finally, the association between fracture classification and the development of complications was evaluated. The chi-square test was applied to the values (Figure 3). The test shows a significant association between fracture classification and the development (or not) of complications.

Figure 3 shows that the development of complications is directly associated with the fracture classification. In this case, patients with classification 43B3 fractures did not experience complications. On the other hand, 88.8% of patients with classification 43C3 fractures developed complications. Classifications 43C1 and 43C2 showed that 60% and 62.5% of patients, respectively, had complications. Thus, an ordering of susceptibility to postoperative complications can be inferred, such that classifications 43B3, 43C1, 43C2, and 43C3, in this order, indicate increasing susceptibility.

Discussion

It is widely recognized that initial trauma triggers a complex inflammatory cascade, the magnitude of which is modulated

Table 6. Comparison of FAOS and AOFAS scores according to the presence of comorbidities and development of postoperative complications

Comorbidities		N	Mean	Median	SD	Difference between means	p-value
FAOS	Without	18	79.89	82.50	14.58	8.65	0.063
	With	17	71.24	75.00	11.82		
AOFAS	Without	18	78.78	80.00	11.90	7.78	0.049
	With	17	71.00	70.00	10.57		
Complication		**N**	**Mean**	**Median**	**SD**	**Difference between means**	**p-value**
FAOS	Without	16	85.50	85.00	7.63	18.08	< 0.001*
	With	19	67.42	63.00	12.46		
AOFAS	Without	16	84.13	82.00	5.39	16.81	< 0.002*
	With	19	67.32	64.00	10.10		

SD: Standard deviation; FAOS: Foot and Ankle Outcome Score; AOFAS: American Orthopaedic Foot and Ankle Society. *significant at the 5% level.

Table 7. Relationship between the presence of comorbidities and postoperative complications

	Without comorbidities	With comorbidities	Total
Without complications	10	6	16
With Complications	8	11	19
Total	18	17	35

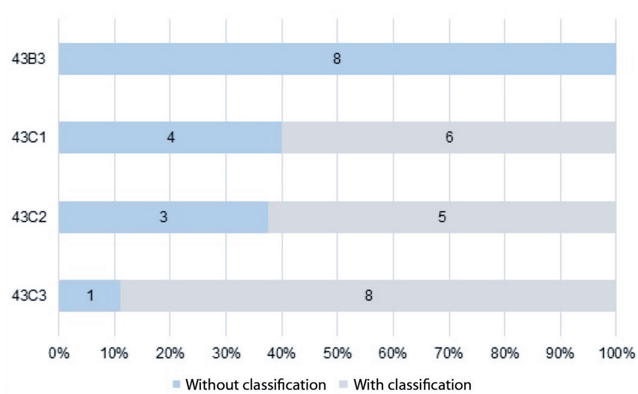

Figure 3. Association between fracture classification and the development of postoperative complications.

by both the extent of the injury and individual genetic factors, and may culminate in Systemic Inflammatory Response Syndrome (SIRS)[12]. During the recovery period, patients may experience complications related to osteosynthesis or to the definitive treatment of fractures themselves.

In this context, it is essential to minimize the initial inflammatory response and ensure an adequate interval for restoring homeostasis. For this, it is recommended to adopt damage-control measures, including postponement of definitive fixation[13].

We evaluated 35 clinical records of patients with TPF who initially underwent temporary external fixation as a damage control strategy, followed by definitive osteosynthesis. External fixation is an effective method for both closed and open fractures, with a low complication rate when used appropriately[14].

Tomás-Hernández[15] points out that, due to the high-energy mechanism involved, most TPFs exhibit significant fragmentation, with external fixation being the initial treatment of choice for damage control. This measure should be instituted early to allow adequate realignment and restoration of limb length and to facilitate subsequent anatomical reduction. The importance of positioning the pins outside the fracture zone is emphasized to avoid interference with definitive fixation and potential surgical approach routes.

As an essential therapeutic tool in the treatment of high-energy TPFs, external fixation should be applied early in all injuries involving loss of joint alignment or a risk of amputation, thereby promoting initial restoration of limb alignment[16].

Tibial fractures are often associated with significant soft-tissue edema, which justifies prolonged hospitalization and postponement of definitive internal fixation until swelling regression[17]. In general, surgical treatment of TPFs has high rates of complications, including wound dehiscence, infection, delayed consolidation, non-union, and even amputations[18]. Historically, these complications were attributed to early internal fixation in cases of significant soft-tissue impairment, prompting a change in the therapeutic algorithm to adopt a two-stage protocol: initial external fixation followed by definitive internal fixation after resolution of edema[6].

According to Ben Bouzid et al.[19], TPF surgical treatment should prioritize the restoration of alignment, limb length, and joint anatomy, preferably by minimally invasive techniques to reduce the risk of infection and pseudarthrosis.

In this study, fractures classified as AO 43B3 and 43C3 predominated among male patients, consistent with the findings of Mair et al.[20], who report a higher incidence of these injuries in men, usually around 45 years of age. In addition, fractures with intact fibula tend to be more frequent in type B than in type C of the AO classification.

The main causes of TPF identified were automobile accidents and falls from height (both with 12 cases), corroborating epidemiological findings in the literature that point to high-energy traumas, such as falls from great heights and automobile accidents, as the main etiological mechanisms[21].

Sakata et al. [22] also found that most victims were of working age, which implies significant socioeconomic consequences.

These losses are estimated to reach 1% of GDP in low-income countries and up to 2% in high-income countries. In 2021, DATASUS reported an increase in the proportion of hospitalizations due to traffic accidents, with a rate of 6.1 hospitalizations per 10,000 inhabitants[23].

Regarding comorbidities, as observed by Moulin [24], there was no significant association between their presence and the development of complications. Approximately 48.6% of patients in this study had no associated pathology, whereas the remainder reported SAH and DM more frequently; both were present in five patients simultaneously. Although Saad et al.[21] pointed out that comorbidities such as DM and smoking substantially increase the risk of complications and the need for surgical revisions, this association was not confirmed in our sample.

In this study, postoperative complications were strongly associated with fracture type according to the AO/OTA classification. Fractures classified as 43B3 did not present complications, whereas most classified as 43C3 developed complications, indicating greater severity and complexity[25]. The main complication identified was post-traumatic arthrosis (11 cases), especially in type 43C fractures, which is in line with the literature that reports the development of this condition within two years after trauma. According to a study by Moulin[24], joint stiffness was the most prevalent complication (70% of cases).

Borges et al.[26] also identified post-traumatic arthrosis as a late complication of 43C fractures, although without significant correlation between the AOFAS score and the degree of mild or severe arthrosis, indicating that this condition may not be decisive in the functional outcome.

Wei et al.[27] state that high-energy fractures are often associated with complex soft-tissue injuries, vascular injuries, and bone loss, which contribute to complications such as infection, nonunion, and post-traumatic arthritis.

The FAOS and AOFAS scores were also relevant: patients without complications had significantly higher scores. In contrast, patients with more severe fractures (43B3, 43C1, 43C2, and 43C3) had progressively lower scores, indicating that fracture severity was associated with poorer clinical outcomes.

A systematic review and meta-analysis published in 2022 showed that, even with appropriate soft-tissue care, the risk of deep infection in TPFs remains above 9%[28]. In a pilot study, O'Toole et al.[29] observed a nonstatistically significant reduction in infections with preoperative supplemental oxygen. In another randomized, multicenter study, the same authors investigated the use of local vancomycin during the intraoperative period to reduce infections[30].

Conclusion

This study indicates that the development of complications in tibial pilon fractures is significantly associated with AO/OTA classification, which directly reflects poorer clinical-functional outcomes.

Author's contribution: Each author contributed individually and significantly to the development of this article: **SDSP *(**https://orcid.org/0000-0002-8677-3981**)** Conceived and planned the activities that led to the study, performed the surgeries, and wrote the article; SMM *(https://orcid.org/0000-0001-6039-4599) Interpreted the results of the study and participated in the review process; MAGR *(https://orcid.org/0000-0002-7424-9074) Performed the surgeries and data collection; RPL *(https://orcid.org/0009-0002-4246-5538) and PAMF *(https://orcid.org/0009-0005-6076-9713) Performed the surgeries, data collection, and wrote the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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