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Open Tibial Fracture Treatment in Argentina

Reoperation Rates Following Surgical Management

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Background: The purposes of the present study were (1) to characterize open tibial fractures and their treatment in trauma centers located across different regions of Argentina and (2) to evaluate the rates of and indications for reoperation after the surgical treatment of such fractures.

Methods: This retrospective multicenter study evaluated open tibial fractures in Argentina that were operatively treated by experienced orthopaedic trauma surgeon-members of the Argentine Association of Orthopedic Trauma (AATO) between January 2015 and June 2020. Data were collected from 13 hospital databases; 8 hospitals were designated as "interior," and 5 hospitals were designated as "exterior." The study included 701 skeletally mature patients, all of whom had a minimum of 12 months of follow-up. Information was collected on patient demographics, injury pattern and mechanism, fracture classification, treatment modality, reoperation rates, time between definitive fixation and reoperation, and indications for reoperation.

Results: Seventy-six percent of presenting injuries were the result of a high-energy mechanism. Intramedullary nailing represented the most common type of fixation (88%). One hundred and fifty patients (21%) required reoperation. Delayed union/nonunion was the most common indication for reoperation in patients who had been previously treated with intramedullary nail fixation (31%; 39 of 126), and infection was the most common indication for reoperation in patients who had been treated with plate fixation (43%; 3 of 7). The time between the injury and definitive fixation was significantly different between the interior and exterior trauma centers (13.8 versus 4.7 days; $p < 0.001$), as was the time between definitive fixation and reoperation (69.3 versus 25.2 days; $p = 0.004$). The reoperation rates for the interior and exterior trauma centers were similar (20% versus 24%; $p = 0.2$). Infection, delayed union/nonunion, and implant removal were the most common indications for reoperation across groups.

Conclusions: An improved understanding of the factors that influence treatment may help to guide future areas for improvement, establish educational goals, and create additional nationwide guidelines for open tibial fracture treatment.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Open tibial shaft fractures are common and problematic long-bone injuries[1]. The incidence of high-energy injuries and the limited soft-tissue coverage of the tibia contribute to complications such as nonunion, malunion, and infection. Such complications are particularly common in low and middle-income countries (LMICs), where open tibial fractures are the leading cause of musculoskeletal morbidity[2-5]. In Latin America, the number of open tibial fractures has been reported to be as high as 50,000 per year, with complication rates as high as 20%[6,7]. In certain cases, these complications require reoperation, which directly impacts patient quality of life and health-care costs.

In recent years, studies have identified predictors of complications and/or reoperations related to open tibial fracture etiology and treatment, including fracture type, fracture pattern, soft-tissue injury, and delay in treatment[8-10]. However, those studies were largely conducted in high-income countries (HICs), with limited representation from LMICs[11,12]. Although there have been

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†A list of the Study Group members is included in a note at the end of the article.

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studies on open tibial fractures based in Latin America, the focus has largely been on treatment patterns rather than complication or reoperation rates, likely because of the paucity of standard-of-care protocols and guidelines in many of those countries[13,14]. Currently, little is known about the true burden of open tibial fractures in Latin America and the associated complication rates[12]. Moreover, identifying patterns of incidence, management, and outcomes of open tibial fractures in Latin America is often complicated by regional disparities in health-care infrastructure, limiting the generalizability of study results. Indeed, in Argentina, there are 3 health-care sectors (public, social security, and private), resulting in a pluralistic and fragmented system with disparate allocation of resources throughout the country's 24 provinces. This health-care system (and its inherent disparities in coverage) is unlike health-care systems in many higher-resourced countries and further complicates Argentina's regional and economic differences[15,16].

The purposes of this multicenter retrospective observational study were (1) to characterize open tibial fractures and their management in trauma centers located across different regions of Argentina and (2) to evaluate the rates of and indications for reoperation after surgical treatment of such fractures.

Materials and Methods

This multicenter study retrospectively evaluated open tibial fractures in Argentina that were operatively treated by experienced orthopaedic trauma surgeon-members of the Argentine Association of Orthopedic Trauma (AATO) between January 2015 and June 2020. A total of 19 AATO-affiliated trauma centers in Argentina were invited to participate in the study, of which 13 joined the Study Group from the provinces of Buenos Aires, Chubut, Córdoba, La Rioja, Mendoza, Neuquén, Santa Fe, and Tucumán (Fig. 1). The study followed a consecutive case series design. Eight hospitals were designated as "interior," and 5 hospitals were designated as "exterior." The interior group represents trauma centers that are located outside of the Buenos Aires province. Due to Argentina's economic and social inequalities and decentralized health system, the interior provinces have fewer trauma centers, fewer personnel, poorer infrastructure (underdeveloped information systems), and less access to resources, including fixation hardware, instruments, and supplies[16,17]. In contrast, the exterior group represents trauma centers in the Buenos Aires province, an urban region where the capital city is located. Exterior hospitals, as defined in this study, generally have more resources than interior hospitals[17-19]. Underscoring this discrepancy in resources, a recent study measured Argentinians' use of health-care services and determined that there is greater use of services by those with higher levels of per capita income[17]. Furthermore, more than one-third (36%) of patients in the interior group have no insurance and rely on government-related health-care insurance and personal resources[20], which can delay the ability to acquire necessary implants for surgery.

The inclusion criteria were skeletal maturity, a nonarticular open tibial fracture, and a minimum of 12 months of follow-up. Sixty-eight patients were excluded because of insufficient follow-up clinical data. A surgeon from each trauma center was invited to complete the 15-question electronic survey for each patient in the study, using data collected from the hospital databases. Demographic information, injury pattern and mechanism, fracture classification, treatment modality, reoperation rates, time between definitive fixation and reoperation, and indications for reoperation were collected. These same measures were stratified by trauma centers in the interior and exterior regions. Fractures were categorized with use of the Gustilo-Anderson (GA)[32] and AO/OTA[33] classification systems as available in the medical records. Treatment was categorized as early definitive or staged fixation; the latter involved initial external stabilization, early prophylactic antibiotics (48 hours of cefazolin for GA type-I and II fractures and gentamicin for GA type-IIIA fractures), irrigation and debridement, and subsequent internal fixation.

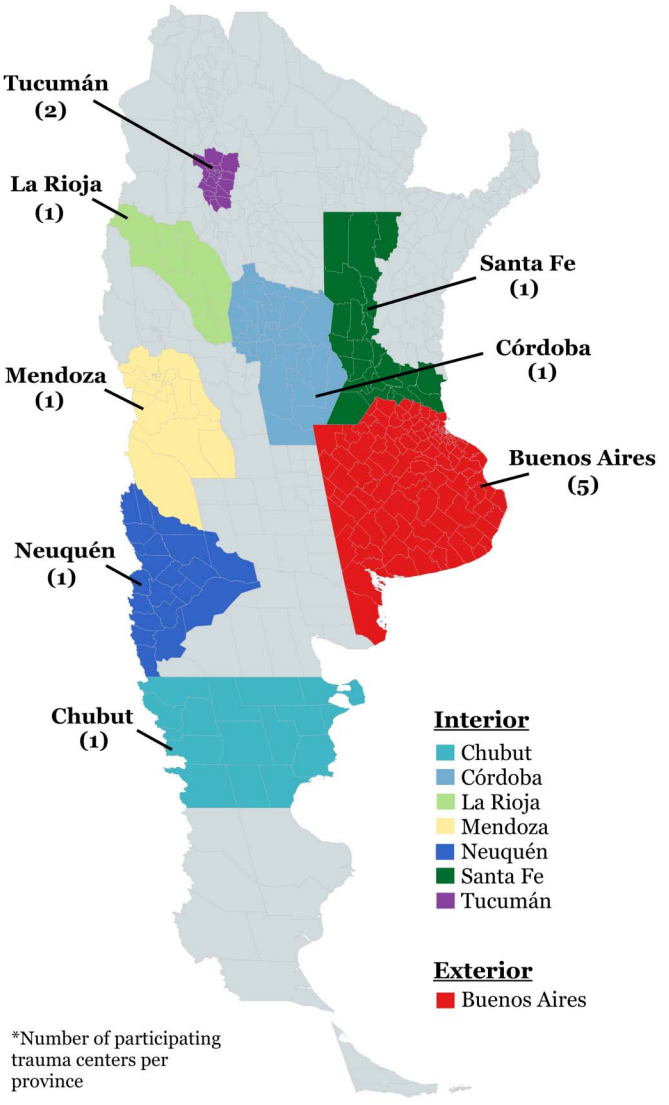

Fig. 1
Map of 13 participating trauma centers by province in Argentina.

TABLE I Surgeon Characteristics Stratified by Interior and Exterior Trauma Centers*

	Interior Trauma Centers	Exterior Trauma Centers	P Value†
Total	16 (100%)	25 (100%)	
Fellowship in musculoskeletal trauma			0.65
Yes	6 (38%)	8 (32%)	
No	10 (63%)	17 (68%)	
Years of practice			0.66
<5	0 (0%)	0 (0%)	
5-10	2 (13%)	4 (16%)	
>10	14 (88%)	21 (84%)	

*The values are given as the number of surgeons, with the percentage in parentheses. †Fisher exact test or chi-square test.

The study was approved by the Argentinian institutional review boards at each participating site: Hospital Sirio Libanes, Hospital Británico, Hospital Regional Comodoro Rivadavia Dr. Victor Sanguinetti, Hospital Mariano Etchegaray, Clínica María Auxiliadora, Hospital Enrique Vera Barros, Hospital Provincial de Neuquén, Hospital Central de Mendoza, Hospital Privado de la Comunidad, Sanatorio Allende, Sanatorio Modelo Tucumán, Sanatorio Padre Rio, and Sanatorio Regional Tucumán.

Statistical Analysis

A descriptive analysis of the collected data was performed using StataSE version 15.0 (StataCorp). Two-sample t-tests and Fisher exact tests with equal variances were performed to compare groups.

Source of Funding

No external funding was used for this study.

Results

Demographics, Mechanism, and Injury Classification

Seven hundred and one patients with open tibial fractures met the inclusion criteria. The mean age was 37 years, and most patients (76%) were male. The characteristics of the surgeons' orthopaedic trauma fellowship training and experience were similar between the interior and exterior groups (Table I). Seventy-six percent of presenting injuries were the result of a high-energy mechanism, 22% of the injuries were the result of a low-energy mechanism, and 2% were the result of a gunshot injury. GA classifications were documented for 307 patients, with type-II open tibial fractures being the most common open fracture type (n = 121; 39%). The most common AO/OTA fracture classification was 42-B2 (n = 138; 20%) (Table II).

Treatment

Twenty-eight percent of injuries were treated initially with staged fixation. The mean time between the injury and definitive fixation was 10.4 days (median, 4 days; range, 0 to 145 days). Intramedullary nailing represented the most common type of fixation overall (88%) (Table III) and for all GA and AO/OTA fracture

TABLE II Mechanism of Injury and Fracture Classification*

Mechanism of injury	
Total	701 (100%)
High-energy	530 (76%)
Low-energy	157 (22%)
Gunshot	14 (2%)
Gustilo-Anderson fracture classification†	
Total	307 (100%)
I	75 (24%)
II	121 (39%)
IIIA	61 (20%)
IIIB	34 (11%)
IIIC	16 (5%)
AO/OTA open tibial fracture classification	
Total	701 (100%)
Proximal	
41-A1	9 (1%)
41-A2	16 (2%)
41-A3	10 (1%)
Diaphyseal	
42-A1	104 (15%)
42-A2	115 (16%)
42-A3	101 (14%)
42-B2	138 (20%)
42-B3	73 (10%)
42-C2	30 (4%)
42-C3	39 (6%)
Distal	
43-A1	43 (6%)
43-A2	10 (1%)
43-A3	13 (2%)

*The values are given as the number of patients, with the percentage in parentheses. †Data not reported for all respondents.

TABLE III Definitive Fixation and Reoperation

Fixation	
Total	701 (100%)
Treatment timing	
Definitive	508 (72%)
Staged	193 (28%)
Time between injury and definitive fixation *(d)*	
Mean	10.4
Median	4
Range	0-145
Type of fixation	
Intramedullary nail	615 (88%)
Plate	61 (9%)
External fixator	23 (3%)
Cannulated screws	2 (0%)
Reoperation	
Reoperation rate	21% (150 of 701)
Time between definitive fixation and reoperation *(d)*	
Mean	55.1
Median	9
Range	2-770
Indications for reoperation (n = 150)	
Infection	42 (28%)
Delayed union/nonunion	41 (27%)
Hardware removal	30 (20%)
Malunion	7 (5%)
Other	30 (20%)

types except for metaphyseal multifragmentary tibial injuries (41-A3), which were most frequently treated with plate fixation.

Reoperation

Of the 701 fractures, 150 (21%) required reoperation. The mean time between definitive fixation and reoperation for all indications was 55.1 days (median, 9 days; range, 2 to 770 days). Overall, the most common reason for reoperation was infection (28%; 42 of 150) (Table III). The most common reason for reoperation among patients who had been managed with intramedullary nail fixation was delayed union/nonunion, and the most common reason among those who had been managed with plate fixation was infection. Malunion was the least commonly cited reason for reoperation (Table IV).

Comparing Interior and Exterior Trauma Centers

Intramedullary nailing remained the most common method of fracture fixation across interior and exterior trauma centers. The mean time between injury and definitive fixation for all indications was 13.8 days at interior trauma centers and 4.7 days at exterior centers; this difference was significant ($p < 0.001$).

The reoperation rate was not significantly different between interior and exterior centers (20% versus 24%; $p = 0.2$). The 3 most common indications for reoperation in interior trauma centers were infection (26%), delayed union/nonunion (21%), and implant removal (21%). Similarly, the 3 most common indications for exterior trauma centers were delayed union/nonunion (37%), infection (29%), and implant removal (19%). The time between injury and initial treatment was <24 hours for 85 of 260 patients from the exterior group and 132 of 438 patients from the interior group. A significant difference was observed in the time to definitive fixation and reoperation between interior and exterior trauma centers, with interior hospitals reporting a mean of 69.3 days and exterior hospitals reporting a mean of 25.2 days ($p = 0.004$) (Table V).

Discussion

Open tibial fractures often require additional procedures or revision surgery for the treatment of complications[21]. Evaluating the characteristics of these injuries associated with complications in Latin America is particularly relevant as this region has the highest rates of road traffic fatalities per capita worldwide[22]. Providing insight into the indications for reoperation following these injuries, specifically within a country with regional disparities such as Argentina, could be useful for determining patient prognosis, optimizing patient outcomes, and creating standard protocols for open tibial fracture management. The indications for and rates of reoperation (primarily infection, delayed union/nonunion, and implant removal) were similar between the interior and exterior trauma centers, potentially secondary to comparable surgeon expertise and experience in both groups. While formal treatment guidelines largely do not exist in Latin America, including Argentina, the present study

TABLE IV Indications for Reoperation According to Implant Type

Indication for Reoperation	External Fixator (N = 17)	Intramedullary Nail (N = 126)	Plate (N = 7)	Cannulated Screws (N = 0)	Total
Infection	3 (18%)	36 (29%)	3 (43%)	0 (0%)	42
Implant removal	0 (0%)	28 (22%)	2 (29%)	0 (0%)	30
Delayed union/nonunion	2 (12%)	39 (31%)	0 (0%)	0 (0%)	41
Malunion	1 (6%)	6 (5%)	0 (0%)	0 (0%)	7
Other	11 (65%)	17 (13%)	2 (29%)	0 (0%)	30

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TABLE V Comparison Between Interior and Exterior Trauma Centers*

	Interior Trauma Centers	Exterior Trauma Centers	P Value†
Total *(no. of patients)*	438 (100%)	260 (100%)	
Treatment timing *(no. of patients)*			1.00
Definitive	317 (72%)	189 (73%)	
Staged	121 (28%)	71 (27%)	
Mean time from injury to definitive fixation *(d)*	13.8	4.7	<0.001‡
Time from injury to initial treatment *(no. of patients)*			0.49
≤24 hr	132 (30%)	85 (33%)	
>24 hr	306 (70%)	175 (67%)	
Type of fixation *(no. of patients)*			0.001‡
Intramedullary nail	373 (85%)	240 (92%)	
Plate	44 (10%)	16 (6%)	
External fixator	21 (5%)	2 (1%)	
Cannulated screws	0 (0%)	2 (1%)	
Mechanism *(no. of patients)*			0.045‡
High-energy	326 (74%)	203 (78%)	
Low-energy	97 (22%)	56 (22%)	
Gunshot	15 (3%)	1 (1%)	
Gustilo-Anderson classification *(no. of patients)**			0.075
Type I	35 (19%) of 182	39 (32%) of 122	
Type II	75 (41%) of 182	45 (37%) of 122	
Type IIIA	42 (23%) of 182	19 (16%) of 122	
Type IIIB	19 (10%) of 182	15 (12%) of 122	
Type IIIC	11 (6%) of 182	4 (3%) of 122	
Reoperation			
Total no. of reoperations	87 (20%)	62 (24%)	0.20
Mean time from definitive fixation to reoperation *(d)*	69.3	25.2	0.004‡
Indication for reoperation *(no. of patients)*			0.08
Implant removal	18 (21%) of 87	12 (19%) of 62	
Infection	23 (26%) of 87	18 (29%) of 62	
Malunion	5 (6%) of 87	2 (3%) of 62	
Delayed union/nonunion	18 (21%) of 87	23 (37%) of 62	
Other	23 (26%) of 87	7 (11%) of 62	

*Data not reported for all respondents. †Fisher exact test or t test. ‡Significant.

demonstrated consistencies in open tibial fracture management across the regions of this country.

Likely because of the efforts by the AATO to promote national standards of care, numerous similarities in treatment were identified between the interior and exterior trauma centers. The most common method of surgical fixation across all GA and AO/OTA classification types was intramedullary nailing, except for AO/OTA 41-A3. Plating was identified as the most common treatment for the latter (metaphyseal multifragmentary tibial fractures). Consistent with other studies, intramedullary nailing is often the preferred fixation method for low and high-energy open tibial fractures because of its cost-effectiveness, improved function, and shorter length of hospitalization relative to other modalities[9,23-28]. However, the use of intramedullary nails for open tibial fractures has been associated with reoperation rates as high as 44%[29]. In the present study, delayed union/nonunion was the most common cause of reoperation following intramedullary nailing (31%), with evidence from other studies supporting a strong association between nonunion and reoperation, potentially because of the lack of cortical continuity[8,30,31]. Examining the cost and availability of implants in Argentina could provide further insight into the extent to which these factors may influence the type of fracture fixation utilized.

To close regional gaps in care, there has been a concerted effort over the past decade to educate and provide consistent

training on the treatment of traumatic musculoskeletal conditions throughout the AATO network. In Argentina, a greater percentage of the population in the interior provinces has a lower socioeconomic status and lacks health-care insurance[18,19]. Additionally, interior-region medical centers have fewer specialists[17]; these documented disparities include orthopaedic surgeons. The difficulty in procuring implants not only results in delayed care but also affects the type of surgery performed. As an example, the initial treatment of open tibial fractures is more frequently performed with use of skeletal traction rather than external fixation for patients with poorer insurance options. In contrast, the majority of patients in the exterior region have private health insurance, with a larger number of potential treatment facilities, and fewer delays in the authorization and more frequent acquisition of implants within 48 to 72 hours. Given that the training and care standards have been established by national organizations, including the AATO, these findings highlight that resource allocation is likely to be a major contributor to delays in patient care. The time to definitive fixation following acute fracture management and the time to reoperation were notably different between interior and exterior trauma centers. Overall, these findings support that there are significantly greater patient-care delays in the lesser-resourced regions.

The present study had several limitations. Because of the retrospective nature of this investigation, the available data were limited to what had been documented at the time of care, inherently affecting the level of evidence. For example, GA classifications were only available for approximately half of the patients, and the documentation of time from injury to hospital presentation and initial antibiotic administration was not available, making complication causality distinctions challenging. The discrepancy in documentation standards for open tibial fractures highlights a potential area for improvement. Additionally, the 13 trauma centers included in the study do not necessarily represent all trauma centers in Argentina. By design, these 13 centers were selectively chosen for the orthopaedic trauma surgeons' affiliation with the AATO and for their uniform experience and treatment standards. Overall, the data documenting the total number of health-care facilities per province relative to the number represented in the study were not available. However, the participating centers, located in provinces throughout the country, are geographically diverse. Finally, patient outcomes (e.g., pain, mobility, functional results) and risk factors associated with reoperation (e.g., soft-tissue management, patient-related metabolic considerations, behavioral factors) were outside the scope of the study and were therefore not evaluated.

In summary, this study characterizes open tibial fracture treatment, complications, and reoperation rates in Argentina. While there were similarities in the indications for and rates of reoperation in patients treated at interior and exterior hospitals, differences were identified in the time from injury to definitive fixation and from definitive fixation to reoperation. These findings suggest that there are more substantial patient-care delays in the lesser-resourced regions. Further improvements in health-system organization are warranted in order to reduce complication rates. An improved understanding of the factors that influence management may help to guide future areas for improvement, establish educational goals, and create additional nationwide guidelines for open tibial fracture treatment. ■

Note: The Study Group includes: Damian Arroquy, MD (Clínica María Auxiliadora, Olavarria); Federico Arroquy, MD (Hospital Privado de la Comunidad, Mar del Plata); Juan M. Barrios, MD (Hospital Mariano Etchegaray, Gran Lamadrid); Carolina Dominguez, MD (Hospital Provincial de Neuquén Dr. Castro Rendon, Neuquén); Ignacio Gabrielli, MD (Hospital Central de Mendoza, Mendoza); Martin Mangupli, MD (Sanatorio Allende, Cordoba); Nicolas A. Robador, MD (Hospital Enrique Vera Barros, La Rioja); Sergio A. Sandrigo, MD (Sanatorio Padre Rio, Santa Fe); Harold Simesen de Bielke, MD (Sanatorio Model, Tucumán); and Adrian D. Villaroel Schvemer, MD (Hospital Regional Comodoro Rivadavia Dr. Victor Manuel Sanguinetti, Chubut).

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