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Comparing Multipin Clamps With Outriggers With Standard Clamps for Lower Extremity Periarticular External Fixation: Similar Radiographic and Clinical Outcomes

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ABSTRACT

Introduction: Staged treatment of high-energy periarticular tibia fractures involves temporization with closed reduction and external fixation, aiming to provide early reduction and stabilization while mitigating soft-tissue complications. Various external fixator configurations exist, including those that use a “multipin” clamp capable of holding multiple pins but limiting pin placement to a single plane. The purpose of this study was to compare clinical and radiographic outcomes and associated costs of standard and multipin outrigger clamp constructs in tibial plateau and pilon fractures treated with temporary external fixation. We hypothesized that use of the multipin clamp may be associated with poorly aligned reductions and increased complication rates.

Methods: A retrospective review of 100 patients with periarticular tibial plateau (AO/OTA: 41B/C) or pilon (43B/C) fracture at a Level 1 trauma center from 2014 to 2023 was conducted. Patient, injury, and complication characteristics were collected. Patients were categorized based on the external fixator clamp used: multipin (MP) or standard (S). Clinical outcomes and complication rates were assessed. Radiographic alignment was evaluated by the change in anterior and lateral distal tibial angles, and sagittal plane translation for pilon fractures, and medial and posterior proximal tibial angles for plateau fractures.

Results: 70 patients underwent standard (25 pilon, 45 plateau) and 30 multipin (10 pilon, 20 plateau) external fixation. MP and S groups showed no notable differences in demographics or injury characteristics. Both groups demonstrated comparable complication rates and radiological alignment outcomes, with no notable differences observed. MP constructs were more costly than standard systems.

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Conclusion: In this retrospective study of 100 patients, there was no difference in radiographic or clinical outcomes between the standard frame and multipin frame groups. Typical costs for the multipin frame constructs were $635 to $1249 more than the standard frame constructs.

In the setting of high-energy tibial plateau and pilon fractures, adopting a staged approach with provisional stabilization has emerged as a promising strategy. This approach allows early reduction and stabilization while limiting infections and soft-tissue complications, thereby improving overall outcomes.[1,2] One method of temporary stabilization for periarticular fractures of the tibia involves closed reduction and joint-spanning external fixation, before definitive anatomic reduction and internal fixation when tissue conditions allow. This treatment strategy for tibial plateau[3,4] and pilon fractures[5,6] has resulted in improved outcomes, particularly regarding soft-tissue and infective complications, without compromising fracture reduction or functional outcomes.[1] However, external fixators (EFs) still need to be applied in a well-constructed stable configuration, and to a reduced fracture, for the benefits of staged fixation to be realized.

EFs aid in providing fracture stability and maintaining length and alignment until definitive fixation can be accomplished.[7] Various geometric configurations of EFs exist, including unilateral, bilateral, triangular, delta, quadrilateral, or circular designs, with Schanz pins which are attached to pin-to-bar clamps that can be positioned in either a uniplanar or multiplanar fashion.[8] The use of a "standard" combination or adjustable EF clamp facilitates pin placement in different planes, enabling the creation of triangular or delta frames, which establish a multiplanar construct. In addition, these clamps allow for direct attachment of the EF rod and pins, promoting versatility in construct design. Certain EF systems use a "multipin" clamp capable of holding multiple pins but restricting their placement to a single plane and limited spread. These multipin clamps are used in combination with outrigger posts for rod placement.

Poorly executed external fixation can compromise the outcomes of definitive surgery. However, to our knowledge, no studies have compared outcomes between external fixation using the standard and multipin EF clamps. The aim of this study was to compare clinical outcomes and radiographic alignment in patients with periarticular tibial plateau and pilon fractures who underwent temporary external fixation with a multipin outrigger construct versus those treated with external fixation using a standard clamp. The secondary aim was to compare costs between the 2 constructs.

We hypothesized that EF systems incorporating multipin clamps with outrigger posts may overly constrain constructs early in the closed reduction/external fixation procedure and be associated with inferior fracture alignment after temporization and definitive fixation. We also hypothesized that the use of a multipin outrigger construct would increase complication rates and cost.

Methods

After obtaining institutional review board approval, a retrospective review of all patients with periarticular tibia fractures who underwent staged treatment with an EF followed by definitive fixation at a Level 1 trauma center over a 10-year period between 2014 and 2023 was conducted. Inclusion criteria encompassed patients aged 18 and older with AO/OTA 41B or 41C tibial plateau fractures and AO/OTA 43B or 43C tibial pilon fractures. Assessment of computed tomography images and radiographs was undertaken to ensure that these inclusion criteria were met. Patients were required to have adequate imaging of the fracture site in 3 instances: (1) in external fixation, (2) after definitive fixation, and (3) imaging of the contralateral limb. Exclusion criteria comprised patients with bilateral lower limb fractures or those lacking contralateral imaging of the uninjured limb. Patients who did not undergo definitive fixation at our institution were also excluded.

Dr. Saizserves or an immediate family member as a board member, owner, officer, or AAOS, ORS, OTA. Dr. Soles or an immediate family member serves as a paid consultant to Depuy Synthes and Johnson & Johnson; as a board member, owner, officer, or OTA. Dr. Lee or an immediate family member has received royalties from Globus Medical; is a member of a speakers' bureau or has made paid presentations on behalf of Depuy Synthes and Johnson & Johnson; serves as a paid consultant to Osteocentric/SMV, Depuy Synthes, and Johnson & Johnson; has stock or stock options held in Osteocentric; as a board member, owner, officer, or AO foundation. Dr. Campbell or an immediate family member is a member is a speakers' bureau or has made paid presentations on behalf of Depuy Synthes, Johnson & Johnson, and Smith & Nephew; serves as a paid consultant to Depuy Synthes and Johnson & Johnson; has stock or stock options held in NSITE Medical; has received research or institutional support from Takeda Pharmaceuticals; serves as a board member, owner, officer, or committee member of AAOS and OTA. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Tse, Dr. Saade, Dr. Ikwuezunma, Mr. Walters, Dr. Simister, and Dr. Fitzpatrick.

Patients were categorized into multipin (MP) and standard (S) groups based on the EF clamp used on the tibia (Figure 1), during their temporization external fixation procedure, which was reviewed through surgical notes. The DePuy Synthes Large External Fixator system (Westchester, PA) was used for all patients, with an 11-mm Outrigger Post used in the MP group. Knee-spanning and ankle-spanning EFs were placed for tibial plateau and pilon fractures, respectively, using the technique described previously for the standard technique group.[9,10] Note that this technique involves a reduction before placing all the Schanz pins. In the multipin group, the MP clamp was typically used to hold 2 pins in the tibia for pilon fractures and 2 pins in the tibia and 2 pins in the femur for plateau fractures; often, all pins were placed before the closed reduction. The typical multipin and standard constructs of knee-spanning external fixation are shown in Figure 2, A and B, respectively. The typical multipin and standard constructs of ankle-spanning external fixation are shown in Figure 3, A and B, respectively.

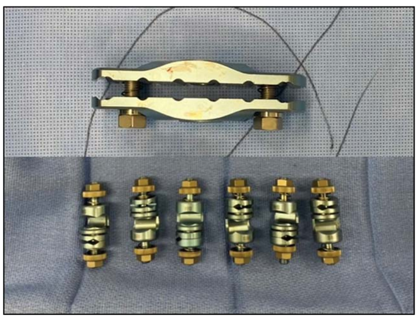
Patient demographics including age at injury, sex, body mass index, and history of smoking and diabetes were collected. Injury details comprised the Injury Severity Score (ISS), AO/OTA fracture classification, Gustilo-Anderson open fracture classification, and polytrauma status, defined as an ISS greater than 15. Surgical characteristics including the type of EF clamp used, duration between temporization and definitive fixation, and details of early partial fixation if performed during initial external fixation were recorded. Patient clinical outcomes were analyzed among those with a minimum follow-up duration of 3 months, including pin site infection after definitive fixation, nonunion, deep infection requiring revision surgery, and need for revision surgery after definitive fixation. Pin site loosening and pin site infection in the period between external fixation and definitive fixation was also recorded for all patients. Pin site infection was defined as an infection at the sites of pin insertion that required antibiotic treatment, and deep infection was defined as an infection with positive tissue or fluid cultures that required revision surgery.

Radiographic alignment was evaluated for all patients using plain radiographs of both the uninjured contralateral limb and the injured side at 2 time points: (1) in external fixation after initial temporization and (2) after definitive fixation. The difference between the injured and contralateral uninjured side was subsequently calculated to measure the change in native anatomical alignment for all measurements. For tibial plateau fractures, measurements included the medial proximal tibial angle on coronal imaging (Figure 4A) and the posterior proximal tibial angle on sagittal imaging (Figure 4B). For pilon fractures, measurements included the lateral distal tibial angle on coronal imaging (Figure 5A), anterior distal tibial angle on sagittal imaging (Figure 5B), and sagittal plane percentage translation as ascertained by the tibial shaft anatomic axis intersection in relation to the talus (Figure 5C).

For statistical analyses, radiographic outcomes for tibial plateau and pilon fractures were considered independently and clinical outcomes were compared for plateau and pilon fractures separately and overall between the MP and S groups. Chi-square and Fisher exact tests were used to analyze categorical data, and *t*-tests analyzed continuous outcomes. A post hoc power analysis was also conducted.

The cost for each construct was estimated by summating the price of each component required to build a typical frame used in each EF method (Figures 2 and 3), based on our institution's contracted rates with DePuy Synthes.

Figure 1

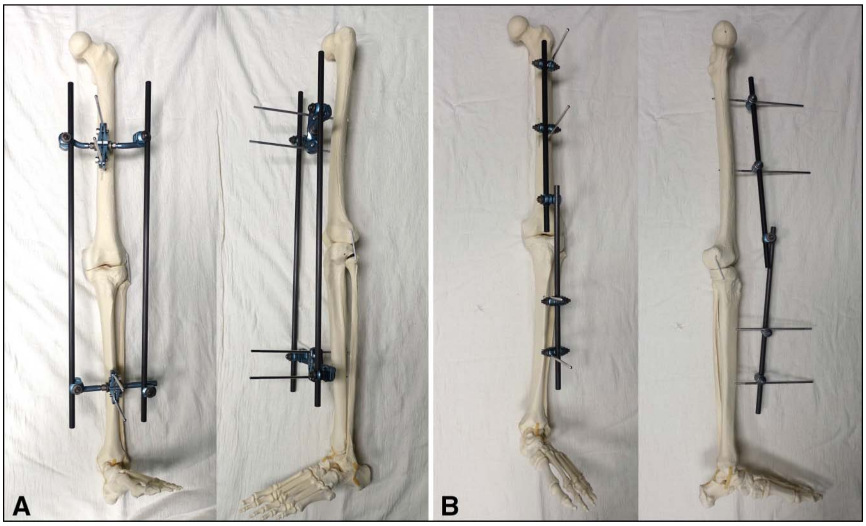


Images demonstrating the multipin external fixator clamp (top) and standard external fixator clamp (bottom).

Results

Of 161 patients with periarticular tibia fractures who underwent temporary external fixation followed by definitive fixation, a total of 100 met the inclusion criteria: 65 tibial plateau and 35 pilon fractures. 30% of patients underwent external fixation with the MP clamp (20 tibial plateau, 10 pilon) while 70% of patients underwent external fixation using standard (S) clamps (45 tibial plateau, 25 pilon). 12 different orthopaedic trauma surgeons performed the procedures, with some

Figure 2



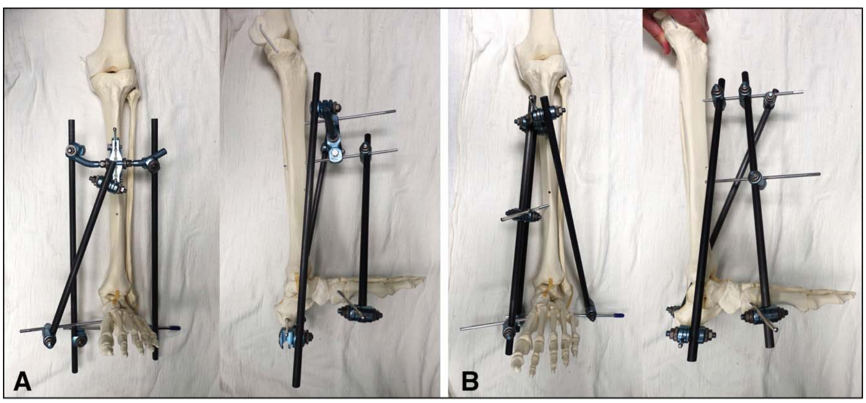
Images of the model demonstrating knee-spanning external fixation constructs: (**A**) multipin and (**B**) standard.

using both types of constructs. 5 surgeons (41.7%) used the MP EF, and 10 surgeons (83.3%) used the S construct. The mean duration between external fixation and definitive fixation was 11.5 days for the MP group (12.0 days for tibial plateau, 14.4 days for pilon) and 12.9 days for the S group (10.6 days for tibial plateau, 13.3 days for pilon) (*P* = 0.33). 53% had left-sided injuries. The mean age was 43.7 ± 15.7 years, 63% were male, the mean body mass index was 30.6 ± 8.2, 34% were smokers, and 10% were diabetic. No statistically significant differences were found between the groups regarding these patient demographics (Table 1).

The mean ISS was 8.4 in the MP group and 12.3 in the S group (*P* = 0.09). No significant difference was observed in the distribution of polytrauma patients between groups (13.3% in MP vs. 18.6% in S, *P* = 0.77). 3 patients (10%) in the MP group (1 tibial plateau, 2 pilon) and 18 patients (25.7%) in the S group (7 tibial plateau, 11 pilon) sustained open fractures (*P* = 0.08). Of the patients with tibial plateau fractures, all had AO/OTA 41C-type fractures. Of the patients with pilon fracture, 2 (5.7%) had AO/OTA 43B-type and 33 had 43C-type fractures. Distributions of both Gustilo-Anderson classification and AO/OTA fracture classification between the MP and S groups were also not markedly different, as summarized in Table 2.

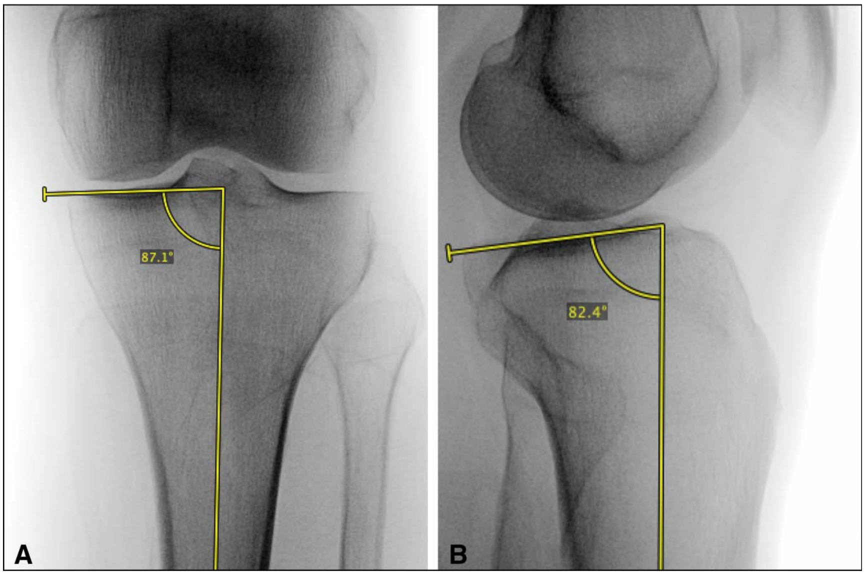
2 patients (6.7%) in the MP group (1 plateau, 1 pilon) compared with 3 patients (4.3%) in the S group (3 plateau) experienced pin site infection that required antibiotics in the period between external fixation and

Figure 3



Images of the model demonstrating ankle-spanning external fixation constructs: (**A**) multipin and (**B**) standard.

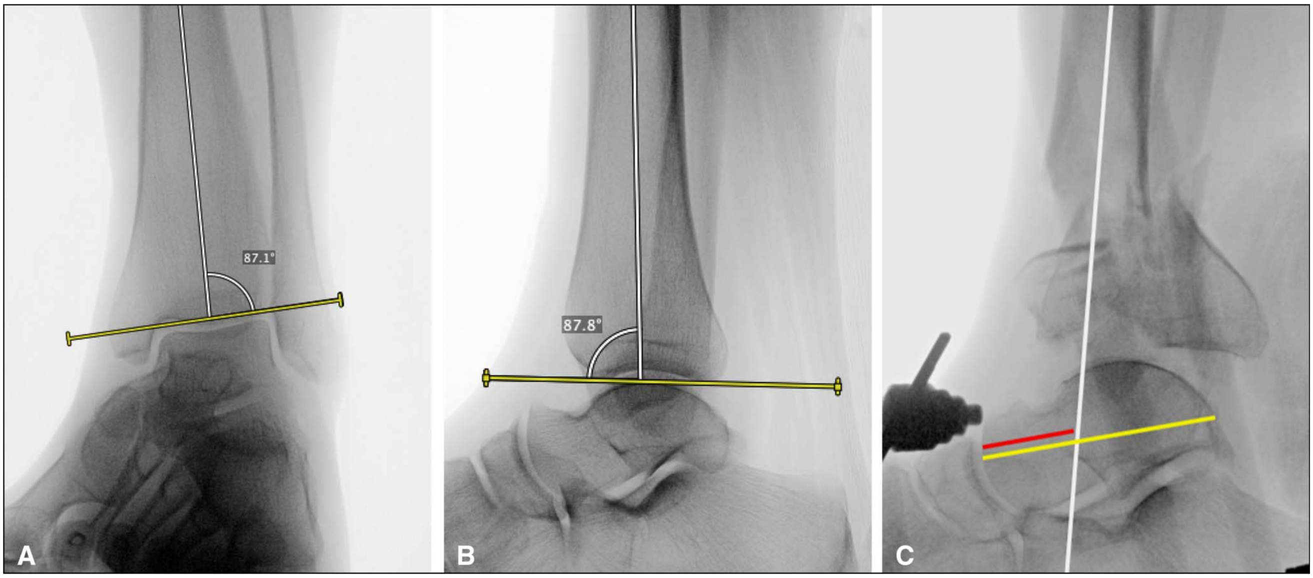
Figure 4



Radiographs with tibial plateau fracture measurements: (**A**) medial proximal tibial angle (MPTA) and (**B**) posterior proximal tibial angle (PPTA).

definitive fixation (*P* = 0.63). Only 1 patient who received the multipin EF for a tibial plateau fracture had pin site loosening after external fixation overall. 49 patients with tibial plateau fracture (14 MP, 35 S) and 29 patients with pilon fracture (8 MP, 21 S) had at least 3 months of follow-up, with a mean follow-up duration of 418.7 days ± 340.5 (IQR = 157 to 461). All other clinical outcomes including pin site infection after definitive fixation, need for revision surgery after definitive fixation, nonunion, and deep infection were compared in this cohort of patients (Table 3). No statistically significant differences were found in overall rates of pin site infection (0% vs. 3.6%), nonunion (16.1% vs. 4.6%), deep infection requiring revision

Figure 5



Radiographs with pilon fracture measurements: (**A**) lateral distal tibial angle (LDTA); (**B**) anterior distal tibial angle (ADTA); and (**C**) sagittal plane translation, reported as a ratio of the length of the anterior talar head to the tibial axis (red line) to the length of the anterior talar head to the posterior talar body (yellow line).

Table 1. Summary of Patient Demographics

Factor or Variable	Overall			Pilon			Plateau		
	Standard	Multipin	*P*	Standard	Multipin	*P*	Standard	Multipin	*P*
Age, mean ± SD	43.4 ± 16.4	44.5 ± 14.3	0.74	41.1 ± 17.9	43 ± 10.4	0.75	44.7 ± 15.5	45.3 ± 16.1	0.88
Male sex, n (%)	44 (62.9)	19 (63.3)	1	16 (64.0)	7 (70.0)	1	28 (62.2)	12 (60.0)	1
BMI, mean	30.7 ± 8.5	30.5 ± 7.5	0.89	30.9 ± 9.1	32.1 ± 7.7	0.72	30.6 ± 8.3	29.7 ± 7.4	0.67
Smokers, n (%)	25 (35.7)	11 (36.7)	1	7 (28.0)	5 (50.0)	0.26	18 (40.0)	6 (30.0)	0.58
Diabetic, n (%)	7 (10.0)	3 (10.0)	1	4 (16.0)	1 (10.0)	1	3 (12.0)	2 (10.0)	1

BMI = body mass index, SD = standard deviation

surgery (23.2% vs. 22.7%), and rates of revision surgery (32.1% vs. 45.5%) between the MP and S groups. Overall, 10 of 18 patients with open fractures (55.6%) experienced a postoperative deep infection, compared with a 12.9% infection rate in patients with closed fractures ($P < 0.01$). All 10 patients who went on to nonunion had AO/OTA C-type fractures (30% 41C3, 60% 43C3, 10% 43C2).

Regarding radiographic alignment, no statistically significant differences were found in changes compared with native alignment for both tibial plateau and pilon fractures at all time points and measurements (Table 4).

The total costs for the multipin constructs were higher than those for the standard constructs. Specifically, the cost of an MP knee-spanning EF (Figure 2A) was $5404.80, compared with $4155.60 for a standard knee-spanning EF (Figure 2B). Similarly, the cost of an MP ankle-spanning EF (Figure 3A) was $6057.60, whereas the cost of a standard ankle-spanning EF (Figure 3B) was $5422.80.

Discussion

In this retrospective study comparing outcomes between multipin and standard EF clamps in a cohort of patients with periarticular tibia fractures who underwent initial external fixation followed by definitive fixation, we found no difference between the 2 groups. MP EFs were more costly than standard constructs.

Clamps serve as anchoring components within EF frames, facilitating the connection of pins to posts and rods while providing flexibility in their configuration.[11,12] Multipin clamps, such as those used in the MP group of this study, enable the attachment of multiple pins within a single clamp, which can then be connected to an outrigger post. Biomechanical studies have shown

Table 2. Summary of Injury Characteristics

Factor or Variable	Overall			Pilon			Plateau		
	Standard	Multipin	*P*	Standard	Multipin	*P*	Standard	Multipin	*P*
ISS, mean ± SD	12.3 ± 11.5	8.4 ± 8.2	0.09	16.0 ± 14.3	10.5 ± 9.3	0.28	10.2 ± 9.2	7.3 ± 7.5	0.22
GA classification, n									
I	1	0	0.24	0	0	0.69	0	1	0.38
II	1	5		2	1		3	0	
IIIA	1	7		5	1		2	0	
IIIB	0	5		4	0		1	0	
IIIC	0	1		0	0		1	0	
AO/OTA classification,[a] n									
B				1	1	0.16	0	0	0.11
C1				0	0		3	0	
C2				1	2		4	5	
C3				23	7		38	15	

GA = Gustilo-Anderson, ISS = Injury Severity Score
[a]AO/OTA 41 for tibial plateau fractures and AO/OTA 43 for pilon fractures.

Table 3. Clinical Outcomes of Standard Versus Multipin Groups

Factor or Variable	Overall			Pilon			Plateau		
	Standard	Multipin	P^a	Standard	Multipin	P^a	Standard	Multipin	P^a
Pin site infection after definitive fixation, n (%)	2 (3.6)	0 (0)	1	1 (4.8)	0 (0)	1	1 (2.9)	0	1
Revision surgery after definitive fixation, n (%)	18 (32.1)	10 (45.5)	0.30	9 (42.9)	3 (37.5)	1	9 (25.7)	7 (50)	0.18
Nonunion, n (%)	9 (16.1)	1 (4.55)	0.27	7 (33.3)	0 (0)	0.14	2 (5.71)	1 (7.14)	1
Deep infection, n (%)	13 (23.2)	5 (22.7)	1	7 (33.3)	1 (12.5)	0.38	6 (17.1)	4 (28.6)	0.79

[a]Fisher exact test.

that a higher pin-per-clamp ratio enhances overall construct stiffness, and that clamps that attach pins to outriggers are more stiff than the standard “near-far” configuration.[11,13] However, this design feature may compromise fixation rigidity if the holding strength is distributed unevenly across the multiple pins within the clamp or if pins are positioned asymmetrically.[12] In addition, the loosening of 1 pin may affect the entire pin-clamp unit, potentially leading to the loosening of other pins as well.[11]

We initially hypothesized that MP clamps would result in inferior outcomes due to several technical limitations our authors have experienced with their use. The MP clamp imposes constraints on pin spread, limiting the distance between pins and potentially compromising the overall alignment. By contrast, the standard framing technique typically involves placing 1 tibial Schanz pin before closed reduction, followed by 2 pins in either the femur or foot (for plateau and pilon fractures, respectively). After the “gross” closed reduction, the second tibial pin is inserted, allowing for fine-tuning of the reduction, particularly regarding translation. With the use of the MP clamp, 2 pins are used in the tibia during the initial phase of closed reduction, restricting the ability of the tibia shaft to translate, as it becomes fixed in space at 2 locations, which can lead to poorer in-frame alignment. However, in this retrospective comparative study of 100 patients with tibial plateau and pilon fractures, the use of the multipin EF clamp for temporary stabilization of periarticular tibial plateau and pilon fractures did not result in a higher rate of complications or worse radiographic alignment, disproving our initial hypothesis. Both multipin and standard EF clamps were comparably effective in providing temporary stabilization for these fractures, and complication rates were not markedly different. Deep infection rates for both groups were similar to rates described in the current literature for patients treated with temporary external fixation.[14,15] Regarding tibial plateau fractures, there were minimal changes in medial proximal tibial angle and posterior proximal tibial angle in both groups, suggesting good radiological alignment was maintained both in the external fixation and after definitive fixation. Although statistically significant differences in radiographic alignment for pilon fractures were not observed, the trend toward increased changes in anterior distal tibial angle, lateral distal tibial angle, and sagittal plane translation in the MP group at all time points suggests that there may be potential challenges in achieving and maintaining optimal alignment with multipin configurations. Future investigation with larger cohorts and prospective study designs is warranted to confirm these trends and elucidate the underlying mechanisms in these differences.

Our investigation found that standard EF constructs were less expensive than MP constructs. A previous study demonstrated that, although surgeons agree that cost should be a key factor in selecting medical devices, their knowledge of implant costs is generally low.[16] Another study highlighted that savings can be achieved simply by informing surgeons of implant prices because they are more likely to voluntarily choose lower cost constructs.[17] Given the lower cost of standard EF systems, along with comparable clinical and radiographical outcomes, this may encourage surgeons to opt for these systems without compromising the quality of patient care.

This study has several limitations that should be acknowledged. The retrospective design introduces inherent biases, and the relatively small sample size affects the statistical power of our analyses and limits the generalizability of our findings. A post hoc power analysis concluded that only the sagittal plane translation variable reached 80% power in our study. Radiographic alignment assessment relied on measurements made by residents, which introduces the possibility of measurement error, particularly when assessing complex fractures. The

Table 4. **Radiographic Outcomes of Standard Versus Multipin Groups**

Factor or Variable	Pilon			Plateau		
	Standard	Multipin	*P*	Standard	Multipin	*P*
LDTA[a]						
External fixation (°)	2.19	2.32	0.95			
Definitive fixation (°)	0.28	10.93	0.06			
ADTA[a]						
External fixation (°)	1.93	3.76	0.43			
Definitive fixation (°)	1.75	4.94	0.12			
Sagittal plane translation[a]						
External fixation (%)	4.42	9.21	0.22			
Definitive fixation (%)	0.93	3.67	0.36			
MPTA[a]						
External fixation (°)				1.60	0.65	0.31
Definitive fixation (°)				0.10	0.73	0.28
PPTA[a]						
External fixation (°)				1.50	1.86	0.80
Definitive fixation (°)				0.10	0.48	0.70

ADTA = anterior distal tibial angle, LDTA = lateral distal tibial angle, MPTA = medial proximal tibial angle, PPTA = posterior proximal tibial angle
[a]Change in the radiographic alignment to the uninjured limb

surgical procedures were also performed by different surgeons, each with their own techniques and preferences, which may have introduced variability in the application of EFs and subsequent clinical outcomes. Surgeons may have selected their methods based on routine practice or familiarity, and owing to the retrospective nature of the study, we were unable to account for these differences. As a result, the effectiveness of each technique in a new learner's application could not be properly evaluated. In addition, various factors, including but not limited to fracture type and open fracture status, may have influenced clinical outcomes in our cohort, beyond just the choice of EF clamp type. The soft-tissue envelope for closed injuries could not be assessed because of the study's retrospective nature. However, our study mitigated some of these confounding factors, as evidenced by the lack of statistically significant differences in the distribution of demographics and injury characteristics between the MP and S groups.

Conclusion

We found no difference in clinical or radiographic outcomes between patients who underwent temporization of tibial plateau or pilon fractures using either standard pin-bar clamps or multipin clamps. Despite the potential technical limitations associated with the use of multipin clamps, our findings indicate that these challenges did not translate into inferior clinical or radiological outcomes compared with standard clamps. Additional investigation with larger cohorts is warranted to corroborate these findings. Given that standard constructs are more cost-effective than multipin systems, surgeons may take this into consideration when selecting the type of EFs.

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