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Original Article

A Comparative Analysis of Three Fixation Techniques for Non-Articular Pediatric Distal Tibia Fractures

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ABSTRACT

Objective: To evaluate the relationship between the distance of pediatric distal tibial fractures to the physis and the fixation methods used, as well as their impact on weight-bearing times and complications.

Methods: This retrospective study included patients with open physes who underwent surgical treatment for pediatric distal tibial metaphyseal fractures in two centers between 2019 and 2024. Patients were grouped based on the fixation method used: K-wire, titanium elastic nails (TEN), or plate-screw fixation. Data collected included patient demographics, fracture distance to the physis, the ratio of fracture distance to metaphyseal width (DP/MW), weight-bearing times, and complications such as infection and reduction loss. Statistical analyses were performed using non-parametric tests, with a significance threshold of $p<0.05$.

Results: The study included 75 patients (52 males, 23 females) with a mean age of 9.7 years. Fixation methods included K-wire fixation (27 patients), TEN fixation (26 patients), and plate-screw fixation (22 patients). Pain-free weight-bearing was observed after a median of 8 weeks [7-9] in the K-wire fixation group, a median of 6 weeks [6-7] in the plate-screw fixation group, and a median of 6 weeks [5-6] in the TEN fixation group. The duration of pain-free weight-bearing was significantly longer in the K-wire group.A positive correlation was observed between the fracture's distance to the physis and earlier weight-bearing ($p=0.041$). Superficial infection developed in three patients (11.11%) who were fixed with K-wires and in one patient (4.55%) in the plate-screw fixation group. While loss of reduction was reported in one patient (3.70%) in the K-wire fixation group, no loss of reduction was observed in the other groups. No statistically significant differences in complications were observed between the groups.

Conclusion: The time to weight-bearing is longer in patients treated with K-wire fixation compared to TEN and plate-screw fixation. Additionally, fractures located farther from the physis allow for earlier weight-bearing. These findings underscore the critical role of fracture location and fixation method in informing treatment strategies. Further randomized controlled trials are essential to validate and strengthen these results.

INTRODUCTION

Tibia fractures are the third most common fractures of long bones in children.[1] Approximately 50–70% of pediatric tibial fractures occur in the distal third of the tibia, while 19–39% occur in the middle third of the tibia.[2,3] Although they are usually treated with closed reduction and casting, 100% translation, 1 cm shortening and coronal or sagittal deformity of up to 10° can be tolerated in children under 8 years of age, while 50% translation, 1 cm shortening and 5° coronal or sagittal deformity can only be tolerated in patients over 8 years of age.[4,5] In addition, surgical treatment should be considered in certain special cases (complex fractures with multi-trauma, soft tissue loss, vascular or nerve injuries).[6]

The type of fracture, the condition of the soft tissues, the degree of displacement of the fracture, the condition of the fibula and the weight of the child influence the treatment to be applied.[7,8] In addition, pediatric distal tibial metaphyseal fractures can often present as oblique, comminuted or transverse fractures.[9,10] Fixation methods

such as K-wire, plate screw, external fixator or titanium elastic nail (TEN) fixation are available for the fixation of fractures in this region.[3,6,11]

In the management of tibial shaft fractures, fixation using titanium elastic nails (TEN) may be considered even in children weighing more than 50 kg,[8,12] However, challenges can arise with TEN fixation due to the expansion of the medullary canal as it approaches the metaphyseal region. Although various fixation techniques have been described, the optimal treatment for pediatric distal tibial diaphyseal-metaphyseal junction fractures remains unclear in the current literature.

In this study, we evaluated distance from the midpoint of the fracture line to the physis, distance of fracture midline to physis/metaphysis width (DP/MW), weight-bearing times, and complications, including infection and loss of reduction, observed during the follow-up of patients treated with K-wires, TEN, and plate-screw fixation for fractures in this region.

MATERIALS AND METHODS

Ethics Committee Approval

The study was approved by the Ankara Etlik City Hospital Ethics Committee (Date: 10/07/2024, Decision No: AEŞH- BADEK-2024-457). Two different centers were included in our study: Ankara Etlik City Hospital between November 2022- March 2024 and Ankara Bilkent City Hospital Orthopedics and Traumatology Clinic between March 2019-March 2024.

This study included patients with open physes who underwent surgical treatment for pediatric distal tibial metaphyseal fractures not involving the physis. Eligibility criteria required patients to have a minimum of six months of postoperative follow-up and complete preoperative and postoperative radiological and clinical data. Exclusion criteria encompassed fractures extending to the physis, open fractures, pathological fractures, fractures involving multiple extremities, and cases managed conservatively with casting.

The fracture was defined as a distal metaphyseal fracture according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) - Pediatric Comprehensive Classification of Long Bone Fractures (PCCF) classification system.[13]

Data were collected on patient demographics, including gender, age at the time of fracture, weight and the affected side. Additional variables included the distance from the midpoint of the fracture line to the physis, the ratio of the fracture midline-to-physis distance to the metaphyseal width (DP/MW) (Fig. 1), the fixation method used, and the presence of an associated fibular fracture. The measurements were made by single surgeons and the choice of fixation method is surgical preference. For all patients with displaced fibular fractures, intramedullary K-wire fixation was performed. Follow-up assessments recorded the time to weight-bearing, loss of reduction, the necessity for re-

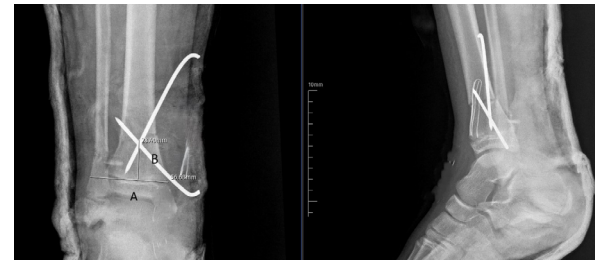

Figure 1. Distal tibia fracture fixed with K-wire, **(a)** metaphyseal width, **(b)** the distance from the midpoint of the fracture line to the physis.

Figure 2. Distal tibia fracture fixed with TEN, **(a)** Preoperative anteroposterior radiograph, **(b)** Preoperative lateral radiograph, **(c)** Postoperative anteroposterior radiograph, **(d)** Postoperative lateral radiograph.

operation, and the presence of infection. After union was seen on the radiograph, the patients were asked to bear weight. The periods mentioned in the study are the weeks during which the patients were able to bear weight without pain. Loss of reduction was defined as an angulation exceeding 5 degrees or a shortening greater than 1 cm.[14]

Postoperative protocols were tailored according to the treatment method employed. In the K-wire fixation group, a short leg splint was applied for one month postoperatively, whereas the TEN fixation group utilized a splint for two weeks (Fig. 2). No splinting was required for patients in the plate and screw fixation group (Fig. 3). All patients were allowed partial weight-bearing after the first postoperative month. All patients received cefazolin as preoperative prophylaxis, followed by three additional doses within the first 24 hours postoperatively. Routine follow-up evaluations were conducted at the second, fourth, sixth, seventh, and eighth weeks. Weight-bearing was permitted

Figure 3. Distal tibia fracture fixed with TEN, **(a)** Preoperative anteroposterior radiograph, **(b)** Preoperative lateral radiograph, **(c)** Postoperative anteroposterior radiograph, **(d)** Postoperative lateral radiograph.

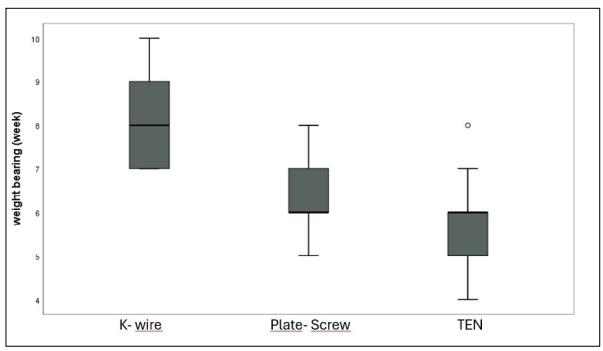

Figure 4. Weight-bearing timelines based on fixation types, TEN, titanium elastik nail.

once callus formation was observed in three planes on radiographs. K-wires were removed following radiographic confirmation of union. In contrast, no standardized timeline was established for the removal of TEN or plate implants. Instead, implant removal for these groups was planned collaboratively with the patient after achieving radiographic union, with a second procedure scheduled at an appropriate time.

Statistical analysis

The calculation and statistical analysis of the study data were performed using IBM SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA). The normality of the distribution for continuous variables was assessed using the Kolmogorov-Smirnov test, which revealed that none of the continuous variables followed a normal distribution. Consequently, continuous variables were summarized using median, minimum, and maximum values. Categorical variables were presented as frequencies (n) and percentages (%). For comparisons of continuous variables between groups, the Kruskal-Wallis test and Mann-Whitney U test were applied for non-normally distributed data. The relationship between two continuous variables was evaluated using Spearman's rho correlation coefficient. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 75 patients, comprising 52 males (69.3%) and 23 females (30.6%), were included in the study. Of these patients, 42 (56%) underwent surgery on the right distal tibia, while 33 (44%) were treated on the left side. Fixation methods included K-wire fixation in 27 patients (36%), TEN fixation in 26 patients (34.6%), and plate-screw fixation in 22 patients (29.3%) (Table 1). No significant differences were observed between the groups in terms of age or weight.

Reduction loss was observed in one patient (3.7%) treated with K-wire fixation, necessitating conversion to plate-screw fixation. Distal fibular fractures accompanying distal tibial fractures were present in 4 patients (14.8%) in the K-wire group, 5 patients (22.7%) in the plate-screw group, and 5 patients (19.2%) in the TEN group. Superficial infections occurred in 3 patients treated with K-wire fixation and 1 patient treated with plate-screw fixation, all of which were successfully managed with oral antibiotic therapy. Due to the limited number of cases with reduction loss, concomitant fibular fractures, and superficial infections, a statistically reliable evaluation could not be performed (Table 1).

No significant differences were observed between the three groups in terms of the distance from the fracture midline to the physis (p=0.474) and the ratio of the fracture midline-to-physis distance to the metaphyseal width (p=0.615). Pain-free weight-bearing was observed after a median of 8 weeks [7-9] in the K-wire fixation group, a median of 6 weeks [6-7] in the plate-screw fixation group, and a median of 6 weeks [5-6] in the TEN fixation group. Pairwise post-hoc comparisons revealed significantly longer weight-bearing times in the K-wire group compared with both the TEN group ($p=6.0\times10^{-9}$) and the plate-screw group ($p=1.44\times10^{-6}$). The duration of pain-free weight-bearing was significantly longer in the K-wire group (Table 2).

Analyzing the relationship between the distance to the physis and the union and weight-bearing times, it was found that as the distance from the physis increased, weight-bearing could be initiated earlier. (p=0.041)

DISCUSSION

The most significant finding of our study is that the time to weight-bearing was longer in patients treated with K-wire fixation, while fractures located farther from the ph-

Table 1. Demographic data and informative data about surgery

	K -Wire		Plate and Screw		Titanium Elastic Nail	
	n	%	n	%	n	%
Gender						
Male	21	77.78	13	59.09	18	69.23
Female	6	22.22	9	40.91	8	30.77
Side						
Left	16	59.26	6	27.27	11	42.31
Right	11	40.74	16	72.73	15	57.69
Loss of Reduction						
No	26	96.30	22	100.00	26	100.00
Yes	1	3.70	0	0.00	0	0.00
Fibula Fracture						
No	23	85.19	17	77.27	21	80.77
Yes	4	14.81	5	22.73	5	19.23
Infection						
No	24	88.89	21	95.45	26	100.00
Superficial	3	11.11	1	4.55	0	0.00

Table 2. Relationship between fixation methods and variables

	K-Wire	Plate and Screw	Titanium Elastic Nail	p
Age	12 [10–14]	12 [11–14]	12 [10–13]	0.750
Distance of fracture midline to physis (cm)	2.40 [2.15–2.65]	2.50 [1.93–3.08]	2.45 [2.23–2.60]	0.474
Distance of fracture midline to physis/metaphysis width (DP/MW)	0.43 [0.35–0.50]	0.36 [0.31–0.55]	0.44 [0.33–0.55]	0.615
Weight (kg)	27 [20-36]	28 [18-40]	27[18-42]	0.612
Weight bearing time (week)	8.0 [7–9]	6.0 [6–7]	6.0 [5–6]	0.000*

*:Kruskal Wallis test, p<0.05.

ysis allowed for earlier weight-bearing. Although the small number of cases with reduction loss precludes statistically significant conclusions, we believe it is crucial to ensure the stability of fixation in patients undergoing K-wire fixation to minimize the risk of reduction loss.

Due to the high remodeling potential in pediatric tibial fractures, conservative treatment plays a significant role. Surgical intervention is planned when acceptable limits are not achieved.[4] In tibial shaft fractures, fixation with titanium elastic nails (TEN) is generally considered the appropriate surgical method for children. Depending on the child's weight and age, plate and screws may occasionally be used for fixation. However, as the fracture approaches the metaphyseal region, the widening of the medullary canal can make achieving and maintaining reduction with TEN more challenging.[15] In fact, some studies have suggested the potential use of additional K-wire fixation or external fixators in combination to enhance fixation in fractures in this area.[16,17] In a study by Heinrich et al.[18] on distal tibial shaft fractures, no significant difference in the time to weight-bearing was found between patients treated with TEN and those treated with plate-screw fixation.[18] Masquijo's study reported union times between 8 and 10 weeks for fractures fixed with minimally invasive plates.[11] Shen et al.[15] noted that most of their patients with distal tibial fractures treated with TEN achieved union at an average of 9.6 weeks. While our findings align with the literature, to the best of our knowledge, no studies have compared K-wire fixation in this context. It is hypothesized that the delayed weight-bearing observed with K-wire fixation may be related to greater micro-movement at the fracture site compared to the other two fixation methods.

In approximately 30% of distal tibial fractures, an associated ipsilateral fibular fracture is observed.[17] The presence of a displaced fibular fracture can complicate closed reduction. Moreover, in cases where the fibular fracture is not fixed, there is an increased risk of valgus deformity.[17] In distal tibial fractures where tibial fixation is challenging, attention should be paid to the fibular fracture to prevent

shortening and deformity of the fibula. In our study, similar rates of fibular fractures were observed across the groups. Furthermore, the low number of patients with fibular fractures in our cohort and the use of intramedullary fixation with K-wires in all cases might explain the absence of deformity in our results.

In patients treated with K-wire fixation, the removal of the K-wires in an outpatient setting provides a distinct advantage over other patient groups, where implant removal typically requires a second surgical procedure. However, the risk of pin-site infections is higher in the K-wire group, and these patients often require longer follow-up with a short-leg splint. The delayed weight-bearing observed in the K-wire group may be attributed to this prolonged immobilization. In the group treated with titanium elastic nails (TEN), Shen et al.[15] reported no cases of infection or skin irritation. However, in a study by Sankar et al.,[19] 26% of patients reported pain at the TEN entry site.[19] We believe that bending and cutting the elastic nail as close as possible to the cortex at the entry site may prevent patient complaints associated with the procedure.

There were different splinting durations for the three fixation methods used in this study. Because the stability provided by each fixation technique differs, various splinting approaches were applied, and the literature also remains inconclusive on this issue.[6,20] Plate and screw fixation provides stable fixation, and follow-up with splinting has been reported to be unnecessary.[11] The splinting protocols used in our study are consistent with those reported in the literature, and the timing of partial weight-bearing was similar among the groups. However, it is thought that differences in the duration of immobilization may have influenced the time to achieve pain-free full weight-bearing.

This study has several limitations. The retrospective design and the relatively small sample size are notable constraints. The lack of information regarding the thickness of the K-wires used in the patients represents another limitation. Different splinting protocols differed among groups, which may have confounded the results regarding weight-bearing times. Additionaly, the small number of complications precluded robust statistical evaluation. However, conducting the study in two separate centers, including three separate groups, and evaluating the fixation methods according to their distance from the physis could make a significant contribution to the literature. Nevertheless, randomized controlled trials are required to achieve more accurate and robust conclusions.

CONCLUSION

The most significant findings of our study are that the time to weight-bearing is longer in the K-wire fixation group compared to the TEN and plate-screw groups, and that earlier weight-bearing is possible as the fracture's distance from the physis increases.

Ethics Committee Approval

The study was approved by the Ankara Etlik City Hospital Ethics Committee (Date: 10.07.2024, Decision No: AEŞH-BADEK-2024-457).

Informed Consent

The requirement for informed consent was waived due to the retrospective nature of the study.

Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept: Y.E., S.G.; Design: Y.E., S.G., A.S.N.; Supervision: Y.E., H.A.; Fundings: K.S., S.G.; Materials: K.S.; Data collection &/or processing: A.S.N., K.S., H.A.; Analysis and/or interpretation: Y.E., H.A.; Literature search: K.S., S.G.; Writing: Y.E., H.A.; Critical review: Y.E., S.G., A.S.N., K.S., H.A.

Conflict of Interest

None declared.

REFERENCES

1. Galano GJ, Vitale MA, Kessler MW, Hyman JE, Vitale MG. The most frequent traumatic orthopaedic injuries from a national pediatric inpatient population. J Pediatr Orthop 2005;25:39–44. [CrossRef]
2. Heo J, Oh CW, Park KH, Kim JW, Kim HJ, Lee JC, et al. Elastic nailing of tibia shaft fractures in young children up to 10 years of age. Injury 2016;47:832–6. [CrossRef]
3. Hong P, Rai S, Liu X, Tang X, Liu R, Li J. Which is the better choice for open tibial shaft fracture in overweight adolescent with open physis: A comparative study of external fixator plus elastic stable intramedullary nail versus external fixator alone. Injury 2021;52:3161–5. [CrossRef]
4. Sheffer BW, Villarreal ED, Ochsner MG 3rd, Sawyer JR, Spence DD, Kelly DM. Concurrent ipsilateral tibial shaft and distal tibial fractures in pediatric patients: Risk factors, frequency, and risk of missed diagnosis. J Pediatr Orthop 2020;40:e1–5. [CrossRef]
5. Mashru RP, Herman MJ, Pizzutillo PD. Tibial shaft fractures in children and adolescents. J Am Acad Orthop Surg 2005;13:345–52. [CrossRef]
6. Harly E, Angelliaume A, Lalioui A, Pfirrmann C, Harper L, Lefevre Y. Divergent intramedullary nailing (DIN): A modified intramedullary nailing technique to treat paediatric distal tibial fractures. J Pediatr Orthop 2019;39:e773–6. [CrossRef]
7. Rickert KD, Hosseinzadeh P, Edmonds EW. What's new in pediatric orthopaedic trauma: The lower extremity. J Pediatr Orthop 2018;38:e434–9. [CrossRef]
8. Andreacchio A, Alberghina F, Marengo L, Canavese F. Pediatric tibia and femur fractures in patients weighing more than 50 kg (110 lb): Mini-review on current treatment options and outcome. Musculoskelet Surg 2019;103:23–30. [CrossRef]
9. Slongo T, Audigé L, Lutz N, Frick S, Schmittenbecher P, Hunter J, et al. Documentation of fracture severity with the AO classification of pediatric long-bone fractures. Acta Orthop 2007;78:247–53. [CrossRef]
10. Slongo TF, Audige L, Group AOPC. Fracture and dislocation classification compendium for children: The AO pediatric comprehensive classification of long bone fractures (PCCF). J Orthop Trauma 2007;21:S135–60. [CrossRef]
11. Masquijo JJ. Percutaneous plating of distal tibial fractures in children and adolescents. J Pediatr Orthop B 2014;23:207–11. [CrossRef]

12. Hanf-Osetek D, Bilski P, Labadz D, Snela S. Tibial shaft fractures in children: Flexible intramedullary nailing in growing children especially weighing 50 kg (110 lbs) or more. J Pediatr Orthop B 2023;32:253–9. [CrossRef]
13. AO Pediatric Comprehensive Classification of Long Bone Fractures (PCCF). J Orthop Trauma 2018;32:S117–40. [CrossRef]
14. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: A multicenter study of early results with analysis of complications. J Pediatr Orthop 2001;21:4–8. [CrossRef]
15. Shen K, Cai H, Wang Z, Xu Y. Elastic stable intramedullary nailing for severely displaced distal tibial fractures in children. Medicine (Baltimore) 2016;95:e4980. [CrossRef]
16. Atef A, El Tantawy A. Open unstable metaphyseo-diaphyseal fractures of the tibia in adolescents: Treatment by flexible intramedullary nails augmented by external fixator. Int Orthop 2015;39:921–6. [CrossRef]
17. Liu Y, Ding S, Yang Y. Elastic stable intramedullary nail combined with Kirschner wire (E-K) technique for treating pediatric distal tibial diaphyseal metaphyseal junction (DTDMJ) fractures. Front Pediatr 2024;12:1333652. [CrossRef]
18. McGraw-Heinrich JA, Ezeokoli EU, Mitchell P, Silverstein RS, Smith BG. Pediatric distal third tibial shaft fractures: A comparison of surgical fixation methods and incidence of concomitant physeal fractures. J Pediatr Orthop B 2023;32:393–400. [CrossRef]
19. Sankar WN, Jones KJ, Horn BD, Wells L. Titanium elastic nails for pediatric tibial shaft fractures. J Child Orthop 2007;1:281–6. [CrossRef]
20. Maciejewski M, Klincewicz J, Janusz P. Treatment of unstable tibia shaft fractures in children with elastic stable intramedullary nails or minimally invasive plate osteosynthesis: Comparative study on 2 treatment options. J Pediatr Orthop 2025;46(1):1–5. [CrossRef]

Non-Artiküler Pediatrik Distal Tibia Kırıkları için Üç Fiksasyon Tekniğinin Karşılaştırmalı Analizi

Amaç: Pediatrik distal tibia kırıklarının fizise uzaklığı ile kullanılan fiksasyon yöntemleri arasındaki ilişkiyi ve bunların ağırlık verme süreleri ve komplikasyonlar üzerindeki etkisini değerlendirmek.

Gereç ve Yöntem: Bu retrospektif çalışmada, 2019-2024 yılları arasında iki farklı merkezde pediatrik distal tibia metafiz kırıkları nedeniyle cerrahi tedavi uygulanan açık fizisli hastalar incelendi. Hastalar kullanılan fiksasyon yöntemine göre K-teli, titanyum elastik çivi (TEN) veya plak-vida fiksasyonu olmak üzere gruplara ayrıldı. Toplanan veriler arasında hasta demografisi, kırığın fizise uzaklığı, kırık-fizis mesafesinin metafiz genişliğine oranı (DP/MW), ağırlık verme süreleri ve enfeksiyon ile redüksiyon kaybı gibi komplikasyonlar yer aldı. İstatistiksel analizler parametrik olmayan testler kullanılarak yapıldı ve anlamlılık sınırı $p<0.05$ olarak belirlendi.

Bulgular: Çalışmaya yaş ortalaması 9.7 yıl olan 75 hasta (52 erkek, 23 kadın) dahil edildi. Fiksasyon yöntemleri K-teli ile fiksasyon (27 hasta), TEN fiksasyonu (26 hasta) ve plak-vida fiksasyonu (22 hasta) olarak belirlendi. Ağırlık verme, K-teli grubunda ortalama 8. haftada başlatıldı ve bu süre TEN ve plak-vida gruplarına kıyasla anlamlı derecede uzundu (ortalama 6 hafta, $p<0.05$). Kırığın fizise uzaklığı ile daha erken ağırlık verme arasında pozitif bir korelasyon gözlendi ($p=0.041$). Yüzeyel enfeksiyonlar 4 hastada görülürken, 1 hastada redüksiyon kaybı rapor edildi. Gruplar arasında komplikasyonlar açısından istatistiksel olarak anlamlı bir fark bulunamadı.

Sonuç: K-teli ile fiksasyon yapılan hastalarda ağırlık verme süresi, TEN ve plak-vida fiksasyonu yapılan hastalara göre daha uzun bulundu. Ayrıca, fizisten daha uzak konumlanan kırıklar daha erken ağırlık vermeye olanak sağlamaktadır. Bu bulgular, kırık lokalizasyonunun ve fiksasyon yönteminin tedavi stratejilerinin belirlenmesindeki kritik rolünü vurgulamaktadır. Bu sonuçların doğrulanması ve güçlendirilmesi için daha fazla randomize kontrollü çalışmaya ihtiyaç vardır.

Anahtar Sözcükler: Ağırlık verme; kırık fiksasyonu; pediatrik; tibia.