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Original article

Do two distal locking screws in two planes offer the best option in the nailing of diaphyseal tibial fractures?

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ABSTRACT

Background: Although the intramedullary nail represents the treatment for most tibia diaphyseal fractures, there is no agreement on the configuration of the distal locking screws. Therefore, this study aimed to investigate the impact of the configuration of distal locking bolts on the healing of a tibial shaft fracture.
Methods: We retrospectively analyzed 170 closed fractures of the tibia diaphyseal operated consecutively between 2018 and 2021. Patients with postoperative unacceptable reduction (>5° in any plane or gap >4 mm), nail-canal ratio <0.78, and less than 12 months of follow-up were excluded. Using a univariate and multivariate analysis, we analyzed comorbidities (smoking, Body mass index >30, diabetes), fracture type (OTA/AO), the number (one, two, three distal locking screws), and configuration (uniplanar, biplanar, triplanar) of distal locking screws between patients with and without a bone union.
Results: One hundred and forty-two fractures were available for analysis. The bone union and non-union rates were 89.4 % (n = 127) and 10.6 % (n = 15), respectively. The multivariate analysis showed that type A fractures (OR 6.67, p = 0.010) and using two distal locking screws with a biplanar configuration (OR 3.63, p = 0.036) were independent variables related to bone union. In contrast, smoking habit (OR 0.12, p = 0.041), fractures type B (OR 0.22, p = 0.013), and uniplanar fixation (OR 0.51, p = 0.003) were related to non-union.
Conclusion: The findings of this study suggest that using two distal locking screws (anteroposterior + mediolateral) in the nailing of closed tibial diaphyseal fracture represents the optimal configuration, offering a higher likelihood of healing compared to other locking options.

1. Introduction

Tibial diaphyseal fractures are one of the most prevalent long-bone fractures.[1] Among the various fixation strategies used for these injuries, intramedullary nailing is the approach for most of them.[2,3]

An essential aspect of the biomechanical principles underlying nailing is the use of distal locking screws.[4,5] In recent years, the advent of multiplanar configuration for distal looking has sparked numerous clinical and biomechanical trials, highlighting its importance in treating distal tibial fractures.[6–10] However, concerning tibial shaft fractures, the literature is still being determined regarding the optimal number and configuration of distal locking bolts.[10] While some advocate for the adequacy of a single distal locking bolt is sufficient,[9] others highlight the traditional configuration of two mediolateral distal locking bolts.[10] Alternatively, others prefer to use two or more distal locking bolts in two or more planes.[11] Hence, this study aimed to investigate the impact of the configuration of distal locking screws on tibial diaphyseal fracture healing. We hypothesized that increasing the number of planes and distal locking screws in a tibial diaphyseal fracture would enhance the likelihood of bone union.

2. Methods

After the respective institutional ethics committee approval (protocol number 9524), we retrospectively reviewed all consecutive patients treated for a closed tibial diaphyseal fracture (OTA/AO 42) with a

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reamed intramedullary nail between June 2018 and November 2021 at two orthopedic trauma referral centers.

Patients older than 18 years with acute tibial shaft fractures who filled a follow-up longer than 12 months were included in this study. Exclusion criteria were patients with pathologic fractures, concomitant long bone fractures, fractures with intra-articular extension, unacceptable postoperative reduction (>5° in any plane or gap >4 mm), and those who presented with surgical site infection after nailing. Due to the reported effect of nail diameter concerning the medullary canal in the union of the tibial diaphyseal fractures, patients with a nail-canal ratio (NCR) < 0.78 were also excluded.[12]

Of a total of 172 closed tibial diaphyseal fractures treated in the period mentioned above, 28 were excluded (one pathological fracture, three concomitant fractures, 8 for articular extension, 4 for unacceptable reduction, 4 for postoperative infection, 3 for not fulfilling the minimum follow-up, and 7 with an NCR <0.78).

2.1. Highlights of the surgical technique

All surgeries were performed by five surgeons with more than ten years of experience in orthopedic trauma. The surgical approach, number, and configuration of the distal locking screws were selected according to the preference of the attending surgeon. Reaming was performed progressively, increasing the size of the drills every 0.5 mm until two reams reached cortical contact, and a nail 1 mm narrower than the last reamer size was implanted. The nails were statically locked in all cases using two mediolateral proximal bolts, one implanted in the oblong hole.

All patients were allowed partial weight-bearing with crutches as tolerated and ankle and knee mobility exercises were commenced on the first postoperative day.

Postoperative controls were performed at two weeks for wound inspection, then at 1, 2, 4, 6, and 12 months, continuing yearly.

2.1.1. Data collection

The clinical and x-ray records were reviewed to obtain the following data: fracture type according to the OTA/AO classification, surgical approach, number, and configuration of the distal interlocking screws implanted. The latter was classified as uniplanar, biplanar, or triplanar fixation. The bone union and non-union rates were also analyzed.

2.1.2. Definitions

Uniplanar: distal locking screw in a single plane.

Biplanar: anteroposterior (AP) and mediolateral (ML) distal locking bolts (with two or three screws).

Triplanar: AP, ML, and oblique screws using three or more screws.

Fracture Union: Bone bridging in three of the four cortices on anteroposterior (AP) and lateral (L) radiographs and the absence of pain at the fracture site on weight-bearing. Non-union: absence of fracture callus after nine months after nailing, with no healing progression in three consecutive months on follow-up radiographs.[13]

2.2. Statistical analysis

The variables were expressed as the median and interquartile range (IQR) or as frequency and percentage according to their nature. We evaluated the differences in the variables analyzed between the group that evolved with the bone union and those that did not, using a Student's t-test, Chi-square, or Fischer's exact test. We performed a multivariate regression analysis with the significant variables to identify the independent variables related to bone union. A value of $p < 0.05$ was considered statistically significant. All data were entered in an Excel spreadsheet, and statistical calculations were performed with SPSS version 23 software (Chicago, Illinois, USA).

3. Results

The study population involved 142 patients with 142 fractures, of whom 112 (78.9 %) were male, and the median age was 34 (range 26–42) years. Regarding comorbidities, 6 (4.2 %) had diabetes mellitus (DM), 18 (12.7 %) were smokers, and 25 (17.6 %) had a body mass index (BMI) > 30.

The most frequently treated fracture was type A (73.9 %), and the most frequently used surgical approach was the para-patellar (45.8 %). Two distal bolts with biplanar configuration were the most frequently used (56.3 %) (Table 1; Fig. 1). The bone union and non-union rates were 89.4 % (n = 127) and 10.6 % (n = 15), respectively. The median time between nailing and the bone union was 9 (6–21) weeks. The median follow-up was 27 (range 12–34) months.

3.1. Comparative analyses

When comparatively analyzing patients with and without a bone union, we observed that smoking, the type of OTA/AO fracture, distal locking planes, and configuration were significantly related to fracture union (Table 2).

3.2. Multivariate analyses

The final adjusted model showed that type A fractures and two bolts in the biplanar configuration were independent variables related to fracture union. Conversely, smoking, type B fractures, and uniplanar fixation were shown to be independent variables with inverse effects on bone union (Table 3).

4. Discussion

The main finding of this study was that using two distal screws in two planes (AP + MD) is an independent predictor of the bone union after nailing a diaphyseal tibia fracture. It shows us that using two locking screws in a biplanar configuration was better than using one or two in a single plane.

The theory underlying fracture stability after a reamed nail tibial fracture is that bone-to-implant contact is critical.[10–14] Thus, in contrast to distal tibial fractures, where bone-to-implant contact is impossible anatomically, scant focus has been directed toward the configuration of

Table 1
Fracture type, surgical approach, and distal locking.

Variables	Overall population (n = 142)
OTA/AO fracture type	
A	101 (71.1)
B	33 (23.2)
C	8 (5.6)
Surgical approach	
Trans-tendon	43 (30.2)
Para-patellar	65 (45.8)
Supra-patellar	34 (23.9)
Distal locking planes	
Uniplanar	33 (23.2)
Biplanar	101 (71.1)
Triplanar	8 (5.6)
Distal Locking bolts	
1	8 (5.6)
2	105 (73.9)
3	29 (20.4)
Configuration	
1 bolt 1 plane	8 (5.6)
2 bolts 1 plane	25 (17.6)
2 bolts 2 plane	80 (56.3)
3 bolts 2 plane	21 (14.7)
3 bolts 3 plane	8 (5.6)

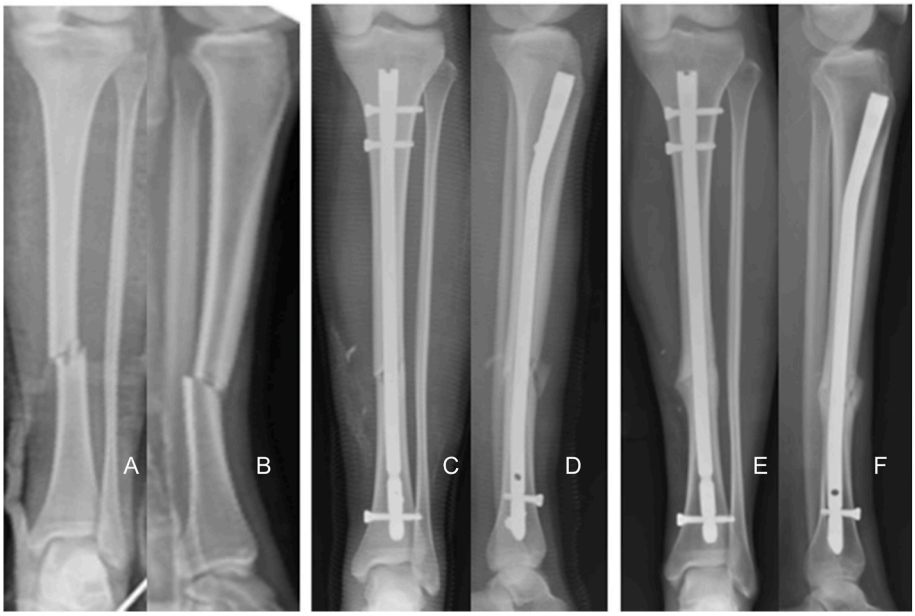

Fig. 1. AB: AP – L radiographs of type A (OTA/AO)fracture. **CD:** Immediate postoperative AP and L radiographs showing the use of two distal locking screws in biplanar configuration (anteroposterior + mediolateral). **EF:** AP and L radiographs at six postoperative months showing bone healing.

Table 2
Comparative analyses, between union and non-union patients.

	Non-union (n = 15)	Union (n = 127)	*p value*
Male gender	9 (60.0)	103 (81.1)	0.34
Age	34.5 (26.5–39.7)	34.0 (26.0–43.0)	0.74
DM	1 (6.6)	5 (3.9)	0.61
Smokers	5 (33.3)	13 (10.2)	0.018
BMI >30	2 (13.3)	23 (18.11)	0.64
OTA/AO Type			
A	6 (40.0)	95 (74.8)	0.015
B	7 (46.7)	26 (20.5)	
C	2 (13.3)	6 (4.7)	
Fibula fracture	5 (33.3)	46 (36.2)	0.82
Surgical approach			
Trans-tendon	6 (40.0)	37 (29.1)	0.23
Para-patellar	6 (40.0)	59 (46.4)	
Supra-patellar	3 (21.4)	31 (24.4)	
Distal Locking planes			
Uniplanar	8 (53.3)	25 (19.7)	0.012
Biplanar	6 (40.0)	95 (74.8)	
Triplanar	1 (6.6)	7 (5.5)	
Distal Locking bolts			
1	2 (13.3)	6 (4.7)	0.26
2	11 (73.3)	94 (74.1)	
3	2 (13.3)	27 (21.2)	
Configuration			
Uniplanar 1 bolt	2–13.3	6–4.7	0.028
Uniplanar 2 bolts	6–40.0	19–14.9	
Biplanar 2 bolts	5–33.3	75–59.0	
Biplanar 3 bolts	1–6.6	20–15.8	
Triplanar 3 bolts	1–6.6	7–5.5	

DM: diabetes mellitus; **BMI:** Body Mass Index.

Table 3
Multivariate analyses.

	OR	CI 95 %	*p* value
Smoker	0.12	0.07–0.94	**0.041**
OTA/AO type			
A	6.67	1.96–13.83	**0.010**
B	0.22	0.07–0.72	**0.013**
C	0.26	0.12–2.26	0.227
Locking planes			
Uniplanar	0.51	0.37–0.58	**0.003**
Biplanar	13.95	1.51–25.94	**0.006**
Triplanar	0.7	0.08–6.24	0.749
Configuration			
Uniplanar 1 bolt	1.19	0.16–7.46	0.231
Uniplanar 2 bolts	3.10	0.91–10.48	0.062
Biplanar 2 bolts	3.63	1.09–12.10	**0.036**
Biplanar 3 bolts	0.38	0.16–3.11	0.361
Triplanar 3 bolts	1.16	0.11–11.49	0.897

OR: odds ratio; CI 95 %; confidence interval 95 %.

distal bolts as a predictor of the union in diaphyseal fractures.[10] In our current analysis, after excluding patients with an NCR <0.78 to avoid its confounding effect, we found a significant 3.63-fold increase in the probability of fracture union with biplanar distal fixation employing two screws.

Few previous studies assessed the configuration of distal locking screws in diaphyseal tibial fractures, reporting mixed outcomes.[9,10,12] Happa et al.[9] in a series of 57 patients with non-complex closed or grade I open tibia diaphyseal fractures, concluding that a single distal locking screw is safe and does not compromise union rates. Ramos et al.,[10] in their study involving 86 tibia diaphyseal fractures treated with non-reamed nails, they reported no difference in the bone union between those treated with uniplanar or biplanar configuration using two screws. Unlike our series, these authors included open fractures. They did not discriminate the reduction quality, the nail-to-canal ratio, or the proximal block (dynamic or static), representing potential confounders that could have impaired their results.

In a cadaveric study Chen et al.,[8] found no additional advantages of the biplanar configuration over the traditional uniplanar mediolateral fixation. In contrast to the studies above, our analysis shows that biplanar fixation increases the likelihood of fracture union and also identified a significant detrimental effect on healing associated with the uniplanar configuration (OR 0.51; p 0.003).

Finally, Kadir et al.[11] found that adding a third screw in the anterior-posterior direction to a classical mediolateral distal configuration with two screws contributes to improving bone union. Our study is

partially in line with these results. Although we found that biplanar fixation is associated with better union rates than uniplanar fixation, adding a third screw in biplanar fixation did not improve the union rates.

Like in many other studies,[15,16] we found that smoking is an independent predictor for fracture non-union (OR 0.12; p = 0.041), emphasizing the importance of notifying patients of this and the need to stop smoking.

We also found that Type-A fractures have a higher probability of fracture union than Type-B and Type-C. These results align with Giannoudis et al.,[16] who found a higher risk of non-union for complex patterns (type B and C) after nailing tibia fractures than for simple patterns. In simple shaft fractures (type A), the nail behaves in a load-sharing mode, and distal locking screws mostly neutralize rotational forces. However, in more complex fractures, the nail behaves as a load-bearing device demanding the distal locking screws to counteract forces in all planes because of the lack of isthmic contact.[17]

The clinical implication of this study is that it would help to clarify the lack of consensus on the use of distal locking screws in the nailing of a diaphyseal tibial fracture. Finally, we acknowledge some limitations of the study. Firstly, those inherent to its retrospective design are susceptible to different biases. However, the multivariate analysis enables us to address the influence of potential confounders. Secondly, as in previous similar studies, we did not assess the height of the fracture at the diaphysis. Third, time to union was not assessed. Although adding a third blocking screw was not associated with higher consolidation rates, it might have influenced time to union.[10,11] Fourth, the functional outcomes were not assessed. A few strengths of the study are worth mentioning. It is the most extensive series of closed tibial diaphyseal fractures in which the configuration of distal locking screws is assessed in a clinical setting after reamed tibial nailing. It also avoids the confusing effect of the nail-canal ratio, highlighting the impact of the distal locks on the fracture union. Finally, it addresses an issue that is too usual in daily practice and has been scarcely reported.

5. Conclusion

The results of this study suggest that in the nailing of tibial diaphyseal fractures, using two distal locking screws in two planes (anteroposterior + mediolateral) is a strategy that increases the likelihood of healing compared with other locking options.

CRediT authorship contribution statement

Sebastian Pereira: Data curation, Project administration, Writing – review & editing. **Germán Garabano:** Conceptualization, Data curation, Investigation, Methodology, Visualization, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Leonel Perez Alamino:** Formal analysis, Investigation, Software, Visualization, Writing – review & editing. **Fernando Bidolegui:** Writing – review & editing. **Cesar Angel Pesciallo:** Validation, Writing – review & editing.

Ethics

This retrospective chart review study, involving human participants, was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments. The Bioethics Committee of the British Hospital of Buenos Aires approved this study (Protocol number 9524).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Availability of data and material

All data generated and analyzed during this study are included in this published article and are available from the corresponding author on reasonable request.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Ross KA, O'Halloran K, Castillo RC, et al. Prediction of tibial nonunion at the 6-week time point. *Injury*. 2018;49(11):2075–2082. http://doi:101016/j.injury.2018.07.033.
2. Bhandari M, Guyatt G, Tornetta P, et al. Study to prospectively evaluate reamed intramedullary nails in patients with tibial fractures (SPRINT) investigators: randomized trial of reamed and unreamed intramedullary nailing of tibial shaft fractures. *J Bone Joint Surg Am*. 2008;90:2567–2578. https://doi.org/10.2106/JBJS.G.01694.
3. Donegan DJ, Akinleye S, Taylor RM, Baldwin K, Metha S. Intramedullary nailing of tibial shaft fractures: size matters. *J Orthop Trauma*. 2016;30(7):377–380. https://doi.org/10.1097/BOT.0000000000000555.
4. Manon J, Detrembleur C, Van de Veyver S, Tribak K, Cornu O, Putineanu D. Predictors of mechanical complications after intramedullary nailing of tibial fractures. *Orthop Traumatol Surg Res*. 2019;105(3):523–527. https://doi.org/10.1016/j.otsr.2019.01.015.
5. Zelle BA, Boni G. Safe surgical technique: intramedullary nail fixation of tibial shaft fractures. *Patient Saf Surg*. 2015;9:40. https://doi.org/10.1186/s13037-015-0086-1.
6. Gong FL, Wang KZ, Dang XQ, Wang CS, Shi ZB. Effect of one versus two distal locking bolts on the biomechanics of tibial interlocking nail: a comparative study using new model. *Di Yi Jun Yi Da Xue Xue Bao*. 2005;25(5):488–492.
7. Chan DS, Nayak AN, Blaisdell G, et al. Effect of distal interlocking screw number and position after intramedullary nailing of distal tibial fractures: a biomechanical study simulating immediate weight-bearing. *J Orthop Trauma*. 2015;29(2):98–104. https://doi.org/10.1097/BOT0000000000000195.
8. Schaffer NE, Wilson JL, Yee MA, Hake ME. Intramedullary nail for a distal tibia fracture. *J Orthop Trauma*. 2020;34(Suppl2):S37–S38. https://doi.org/10.1097/BOT/0000000000001837.
9. Happa O, Muratli HH, Yuksel HY, Celebi L, Dogruyol D, Bicimoglu A. Single or double distal locking in intramedullary nailing of tibial shaft fractures: a prospective randomized study. *ULUS travma Acil Cerrahi Derg*. 2020;16(1):33–37.
10. Ramos L, Bertrand ML, Benitez-Parejo N, Guerado E. How many distal bolts should be used in unreamed intramedullary nailing for diaphyseal tibial fractures? *Injury*. 2012;43(Suppl2):S59–S62. https://doi.org/10.1016/S0020-1383(13)70181-5.
11. Alemdaroglu KB, Iltar S, Ozturk A, Yucens M, Aydogan NH. The role of biplanar distal locking in intramedullary nailing of tibial shaft fractures. *Arch Bone Jt Surg*. 2019;7(1):33–37.
12. Garabano G, Pereira S, Perez Alamino L, Erns G, Pesciallo CA, Bidolegui F. The relevance of the number of distal locking planes and nail to canal ratio in bone healing after intramedullary nailing in tibial shaft fractures. *Eur J Orthop Traumatol*. 2023;33(5):2111–2119. https://doi.org/10.1007/s00590-022-03401-0.
13. Gorczyca JT. Tibial shaft fractures. In: Brinker MR, ed. *Review of Orthopedics Trauma*. Philadelphia: Saunders; 2001.
14. Penzkofer R, Maier M, Nolte A, et al. Influence of intramedullary nail diameter and locking mode on the stability of tibial shaft fracture fixation. *Arch Orthop Trauma Surg*. 2009;129(4):525–531. http://doi:10.1007/s00402-008-0700-0.
15. Stavrou Petros Z, Ciriello Vincenzo, Theocharakis Stylianos, et al. Prevalence and risk factors for re-interventions following reamed intramedullary tibia nailing. *Injury*. 2016;47(Suppl 7):S49–S52. http://doi:10.1016/S0020-1383(16)30855-5.
16. Fong Katie, Victoria Truong, Foote Clary J, et al. Predictors of nonunion and reoperation in patients with fractures of the tibia: an observational study. *BMC Muscoskel Disord*. 2013;14:103. http://doi:10.1186/1471-2474-14-103.
17. Vincenzo Filardi. The healing stages of an intramedullary implanted tibia: a stress strain comparative analysis of the calcification process. *J Orthop*. 2015;12(Suppl 1):S51–S61. http://doi:10.1016/j.jor.2015.01.016.