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ORIGINAL ARTICLE

Fibular fixation improves ankle functional outcomes and alignment in the intramedullary nailing of distal third tibiofibular diaphyseal fractures

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Abstract

Purpose The study aims to determine the effect of fibular fixation on alignment and fracture healing of tibia, and ankle functional outcomes in the treatment of distal third tibiofibular diaphyseal fractures.

Methods Consecutive 111 patients (33 females and 78 males) with distal third tibiofibular diaphyseal fracture who met the inclusion criteria were included in the study. Patients were divided into two groups as those who underwent fibular fixation with tibia intramedullary nailing (study group) and those who did not (control group). Groups were compared in terms of demographic features, trauma and fracture characteristics, functional and radiological outcomes.

Results No significant difference was observed between the groups in terms of demographic features, trauma characteristics, complications, and follow-up time ($p > 0.05$). Surgery time was significantly lower in the control group ($p = 0.001$). Ankle joint range of motion, AOFAS score, OMAS score, and full weight-bearing time were significantly better in the fibular fixation group ($p = 0.023$, $p = 0.001$, $p = 0.001$ and $p = 0.039$, respectively). Significantly better coronal alignment and sagittal alignment were found in the fibular fixation group ($p = 0.001$ and $p = 0.001$, respectively). Patients who underwent fibular fixation had significantly better radiological outcomes in terms of fibular rotation angle and ankle arthrosis ($p = 0.000$ and $p = 0.022$, respectively).

Conclusion Fibular fixation not only contributes to fracture union, early full weight-bearing, and alignment but also improves ankle functional outcomes in the distal third tibiofibular fractures treated with intramedullary nailing for tibia.

Level of evidence Level III, retrospective study.

Keywords Distal third tibiofibular diaphyseal fractures · Intramedullary nailing of the tibia · Fibular fixation · Ankle functional outcomes

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Introduction

Diaphyseal fractures of the tibia and fibula are the most common fractures of all long bones [1]. Distal tibia fractures account for 37.8% of all tibia fractures [2]. Fibula fractures accompany tibia fractures in approximately three-quarters of cases [3]. Intramedullary nailing is the preferred treatment for displaced tibial diaphyseal fractures (AO 42), due to its high biomechanical stability and minimally invasive application of surgery [4]. However, the anatomy of the distal tibia is responsible for reduced biomechanical stability and a higher complication rate in the treatment of distal tibiofibular fractures with intramedullary tibial nailing (IMTN) alone. Since the distal tibia has limited cortical bone support, the IMTN alone is less stable and prone to failure complications such as varus, valgus, and rotational deformities as well as nonunion [5]. Although IMTN of distal third tibia fractures is a well-established technique for reliable short- and long-term clinical outcomes, no consensus or clinical guidelines have been provided for the need for fixation or indications for associated distal fibular fractures [6, 7]. Biomechanical studies have highlighted the value of surgical fixation of the fibula as a complement to overall implant stability and as an aid to the reduction in IMTN [8, 9].

Previous studies have investigated whether fibular fixation is necessary for non-comminuted distal third tibia fractures [1, 2, 8, 10, 11]. However, no consensus is stated in the literature regarding the indications for fibular fixation in the treatment of combined fractures of the distal-third tibiofibular diaphyseal fractures [12]. Some surgeons argue that fixation of the fibula provides a stiffer structure and helps achieve a more anatomical reduction of the tibia and consequently prevents lower leg malalignment [13]. Several authors have recommended that comminuted fibula fracture and the same level fractures of the tibia and fibula may be relative indications of fibular fixation [9, 14]. In the literature, ankle functions have been evaluated in the distal metaphyseal tibia fractures (AO 43), which generally extend to the ankle joint [15]. Previous studies have generally focused on fracture healing and alignment of the tibia and ignored the ankle scores [1–3, 12, 13].

The present study aims to determine the effect of fibular fixation on alignment and fracture healing of tibia and ankle functional outcomes in the treatment of distal third tibiofibular diaphyseal fractures. Our hypothesis is that fibula fixation would also improve ankle functional outcomes while providing fracture healing and maintaining the alignment of the tibia.

Materials and methods

Patients who underwent surgery for distal third tibiofibular diaphyseal fracture between January 2009 and April 2016 were retrospectively screened after the approval of the local ethics committee (IRB approval ID: 2019–2014 and decision number: 2019/304). A distal tibia diaphyseal fracture (AO-42) was defined as a fracture distal to the isthmus of the diaphysis and extending through the flare of the distal tibia (Fig. 1) [12]. The patients with or without fibula fixation treated with intramedullary nailing for distal third tibia diaphyseal fractures were included in the study. Conservative treatment, patients under the age of 18 years, treatment with plate fixation or external fixators for the tibia fracture, revision surgery, ipsilateral femur fracture, bilateral tibia fractures, patients with vertebral and/or pelvic injuries that prevent mobilization, intraarticular tibia fractures, and fractures other than the distal third diaphysis of tibia and fibula were excluded from the study. Ipsilateral previous ankle trauma/problems such as fracture, clinically and radiologically proven ankle arthritis, talar osteochondral lesions, Achilles tendinopathy, chronic ankle injury, or instability were excluded. Besides, syndesmosis and other ligament injuries were excluded from the study to homogenize the injury pattern in the groups. 111 patients (33 females and 78 males) who met the inclusion criteria were included in the study. Patients were divided into two groups: those who underwent fibular fixation with tibia intramedullary nailing (study group, $n=54$) and those who did not (control group, $n=57$). Groups were compared in terms of demographic features, trauma and fracture characteristics, functional and radiological outcomes.

Surgical procedure, postoperative care and follow-up

The surgical procedure was performed under general anesthesia or spinal anesthesia in the supine position on the radiolucent table. All patients were operated on by the same surgical team. Preoperative 1 g cefazolin was applied to the patients. In the control group, fibula fixation was not performed after IMTN (Figs. 2 and 3). In the study group, fibular fixation was firstly performed using a locked anatomic distal fibular plate with a lateral approach. In this way, it was aimed to provide the length and alignment of the fibula for easy reduction of the tibia fracture. Then, IMTN was applied for the tibia fracture (Figs. 4 and 5). All tibia fractures were fixed with IMTN after closed reduction in both groups. IMTN was locked statically and dynamization was not needed for any patient during follow-up. All patients were evaluated

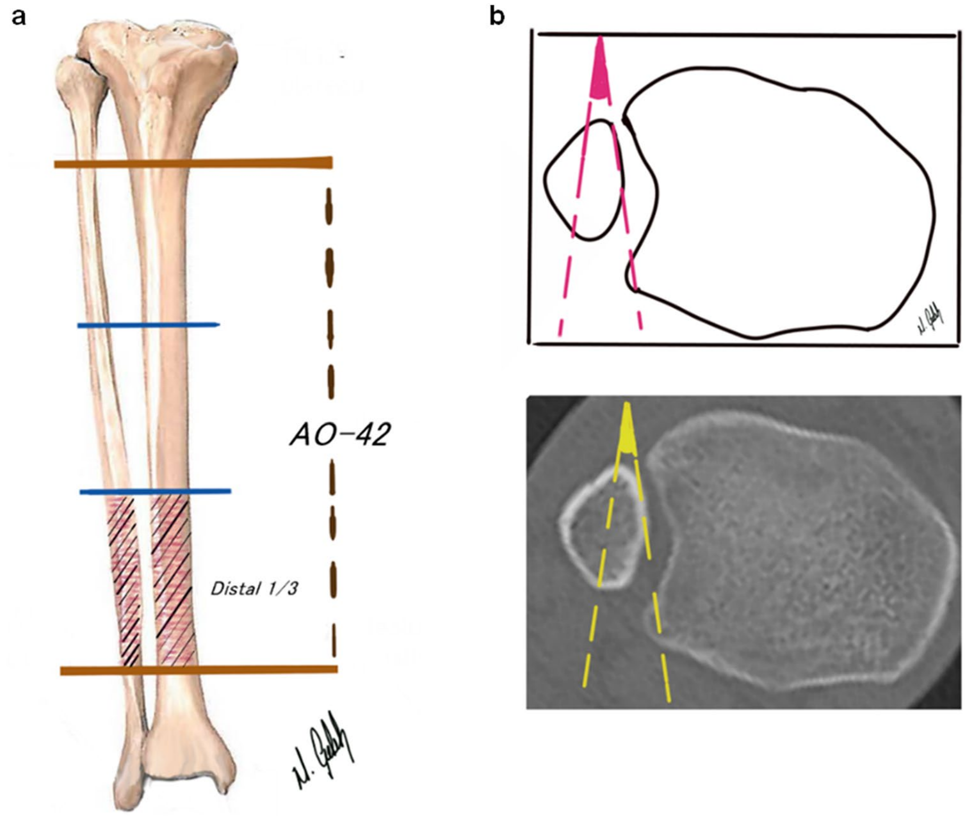


Fig. 1 Illustration of **a** distal third tibial diaphyseal region and **b** measurement of the fibular rotation angle

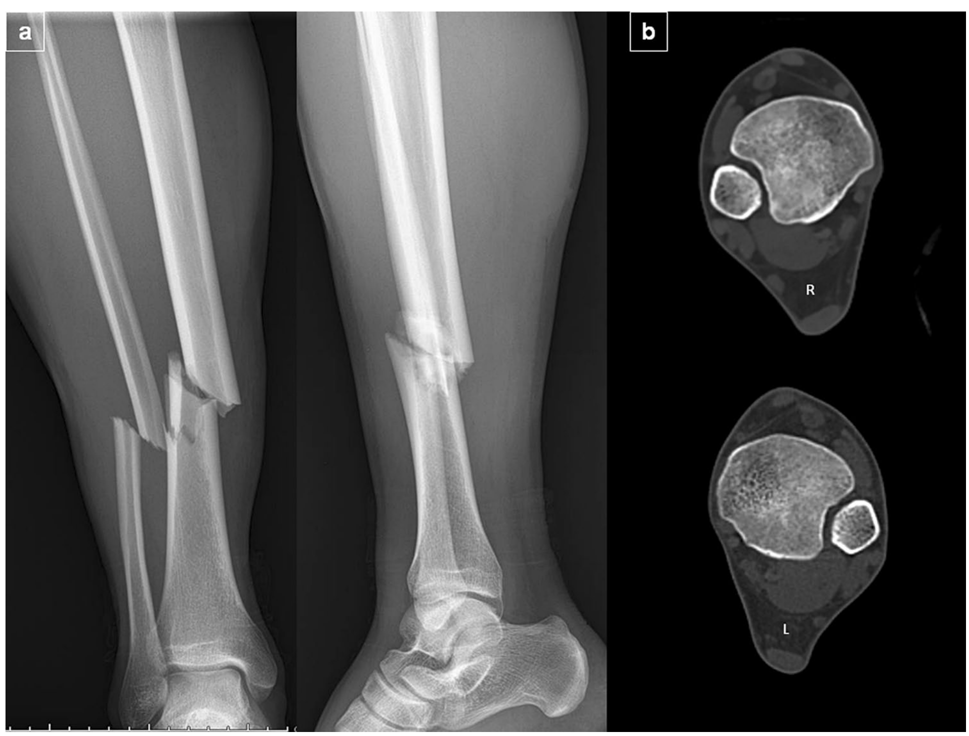


Fig. 2 41-year-old female patient admitted after motor vehicle accident **a** displaced type I open fracture of the distal third of right tibiofibular shaft **b** axial CT images of the distal tibiofibular joint of right and left ankles

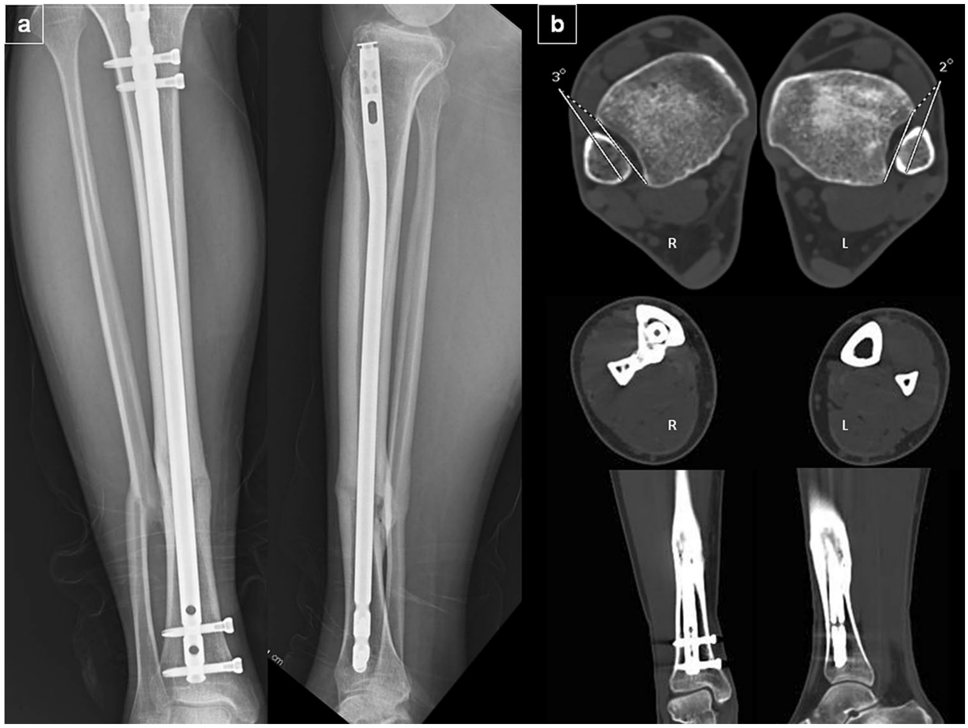
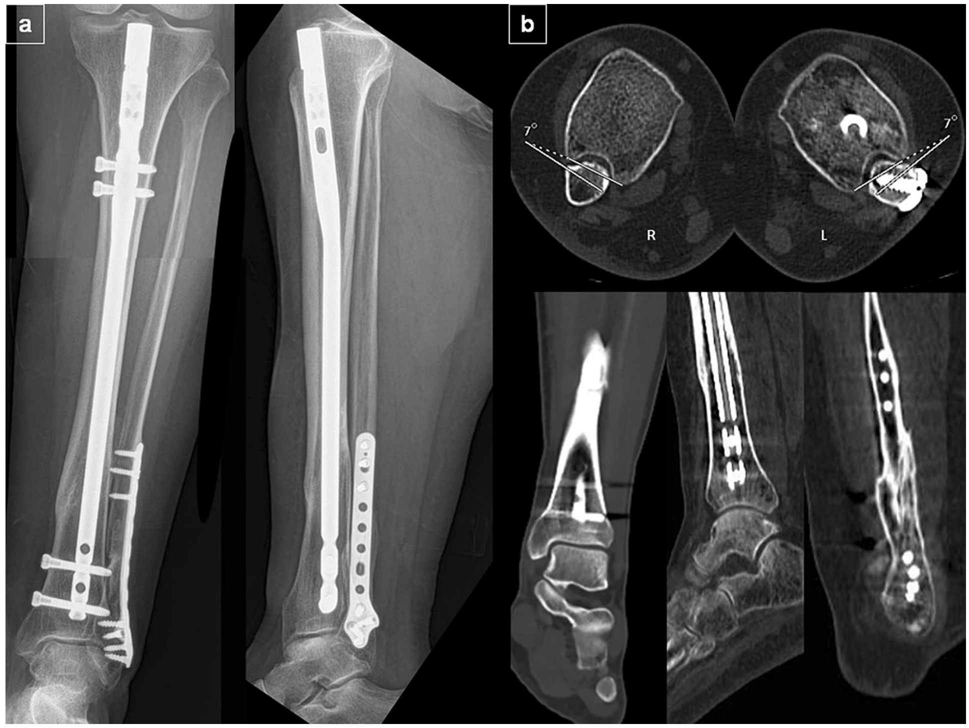


Fig. 3 86th month after the surgical treatment **a** intramedullary nailing of the distal third tibia shaft without fixation of fibula **b** measurement of the fibular rotation angle on axial CT images shows the difference between right and left ankle. Axial CT images of both ankles show the distal tibiofibular synostosis of the operated side

Fig. 4 37-year-old male patient admitted after the pedestrian-vehicle accident **a** displaced type II open fracture of the distal third of left tibiofibular shaft **b** axial CT images of the distal tibiofibular joint of right and left ankles

clinically every 2 weeks within the first 3 months and radiologically every 4 weeks within the first 12 months postoperatively. Follow-up after the first year was carried out with an interval of 6 months, and an annual follow-up after 2 years. All patients underwent hip, knee, and ankle joint motion rehabilitation as far as they can tolerate in the early postoperative period. Partial weight-bearing was allowed to the patients when callus formation was observed radiographically. Johner and Wruhs criteria [16], Olerud–Molander Ankle Score (OMAS) [17],

Fig. 5 91st month after the surgical treatment **a** intramedullary nailing of the distal third tibia shaft with plate fixation of fibula **b** measurement of the fibular rotation angle axial CT images shows the similarity between right and left ankle



American Orthopaedic Foot and Ankle Society (AOFAS) score [19], full weight-bearing time, union time, ankle range of motion, and rotational alignment were used for the functional outcomes at the final postoperative follow-up.

Radiological evaluation

Radiological evaluation was performed by two orthopedic specialists blinded to the study. Standard plain radiographs, preoperative and postoperative final control computed tomography (CT) were used in the radiological evaluations of the patients. Evaluation of coronal and sagittal alignment was determined from the last postoperative AP and lateral radiographs by using Johner and Wruhs criteria [18] and categorized according to the methods described by Prasad et al. [1]. The previously defined canal fit ratio was used to evaluate the compliance of the nail to the tibial fracture site [19]. The measurement of the canal fit ratio is obtained by dividing the diameter of the tibia at the fracture level by the diameter of the nail. Fibular rotation measurement was performed as described by Futamura in axial sections of postoperative final control CT (Fig. 1) [20]. Distal tibiofibular synostosis was detected by postoperative final control radiographs and CT. Osteoarthritic changes were analyzed and classified with Van Dijk score [21].

Statistical analysis

NCSS (Number Cruncher Statistical System) Statistical Software (Utah, USA) program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, median, frequency, ratio), Shapiro–Wilk test, and box plot graphics were used for statistical analysis. The Student's *t* test was used for the comparison of normally distributed variables and the Mann–Whitney *U* test was used for the comparison of variables that did not show normal distribution. In the comparison of qualitative data, the Pearson Chi-Square test, Fisher's exact test, and Fisher–Freeman–Halton test were used. Statistical significance was evaluated at the $p < 0.05$ level. In the calculation of post-hoc sample size, the power of the study with a 0.05 alpha value was found over 80%. The standard effect size for quantitative data was set at 0.63% and the power of the study was 92%.

Results

The demographic characteristics of the patients were presented in Table 1. There was no significant difference between the groups in terms of age, gender, body mass index (BMI), fracture side, trauma mechanism, fracture side, time to surgery, hospitalization, complications, and follow-up time ($p > 0.05$). Surgery time was significantly lower in the control group ($p = 0.001$). No significant difference was

Table 1 Comparison of demographic characteristics of patients in groups

	Fibular fixation ($n=54$) n (%)	Control ($n=57$) n (%)	Total ($n=111$) n (%)	p
Age (years)				
Min–max (median)	20–56 (37.50)	19–56 (38)	19–56 (38)	[a]0.814
Mean ± SD	37.2 ± 9.2	36.8 ± 9.4	37.3 ± 9.3	
Gender				
Female	16 (29.6)	17 (29.8)	33 (29.7)	[c]1.000
Male	38 (70.4)	40 (70.2)	78 (70.3)	
BMI (kg/m^2)				
Min–max (median)	20–33 (24)	19–34 (26)	19–34 (25)	[a]0.301
Mean ± SD	24.8 ± 3.2	26.5 ± 3.6	25.1 ± 3.4	
Fractured side				
Left	21 (38.9)	23 (40.4)	44 (39.6)	[c]1.000
Right	33 (61.1)	34 (59.6)	67 (60.4)	
Trauma mechanism				
Simple fall	18 (33.3)	21 (36.8)	39 (35.1)	[e]0.758
Pedestrian accident	12 (22.2)	15 (26.3)	27 (24.3)	
Motor vehicle accident	13 (24.1)	10 (17.5)	23 (20.7)	
Bike accident	7 (13)	6 (10.5)	13 (11.7)	
Sports injury	4 (7.4)	5 (8.8)	9 (8.1)	
Risk factor for bone healing				
No	26 (48.1)	30 (52.6)	56 (50.5)	[d]0.730
Smoking	19 (35.2)	16 (28.1)	35 (31.5)	
Diabetes	4 (7.4)	3 (5.3)	7 (6.3)	
Open fracture	9 (16.7)	12 (21.1)	21 (18.9)	
Time to surgery (h)				
Min–max (median)	4–72 (11.50)	3–72 (11)	3–72 (11)	[b]0.516
Mean ± SD	17.1 ± 13.4	16.1 ± 13.8	16.6 ± 13.5	
Surgery duration (min)				
Min–max (median)	58–89 (68)	45–74 (56)	45–89 (63)	[a]**0.001***
Mean ± SD	68.4 ± 6.9	56.8 ± 8.4	62.4 ± 9.7	
ASA score				
I	39 (72.2)	38 (66.7)	77 (69.4)	[e]0.913
II	11 (20.4)	14 (24.6)	25 (22.5)	
III	3 (5.6)	3 (5.3)	6 (5.4)	
IV	1 (1.9)	2 (3.5)	3 (2.7)	
Hospitalization (days)				
Min–max (median)	2–7 (3)	2–6 (3)	2–7 (3)	[b]0.472
Mean ± SD	3.3 ± 1.4	3.1 ± 1.2	3.2 ± 1.3	
Complication				
No	49 (90.7)	45 (78.9)	94 (84.7)	[d]0.085
Yes	5 (9.3)	12 (21.1)	17 (15.3)	
Follow-up (months)				
Min–max (median)	41–96 (52)	40–94 (52)	40–96 (52)	[b]0.359
Mean ± SD	55.5 ± 11.0	56.6 ± 10.9	56.1 ± 10.9	

The statistically significant parameters are in bold

BMI body mass index, *ASA* The American Society of Anesthesiologists

*$p < 0.01$

[a]Student *t* test

[b]Mann–Whitney *U* test

[c]Fisher's exact test

[d]Pearson Chi-square test

[e]Fisher–Freeman–Halton test

Table 2 Comparison of fracture characteristics of patients in groups

	Fibular fixation ($n=54$) n (%)	Control ($n=57$) n (%)	Total ($n=111$) n (%)	p
AO classification				
42-A	33 (61.1)	30 (52.6)	63 (56.8)	[d]0.664
42-B	15 (27.8)	19 (33.3)	34 (30.6)	
42-C	6 (11.1)	8 (14)	14 (12.6)	
Gustilo Anderson classification				
Closed	45 (83.3)	45 (78.9)	90 (81.1)	[e]0.947
Type I open	3 (5.6)	5 (8.8)	8 (7.2)	
Type II open	4 (7.4)	4 (7)	8 (7.2)	
Type III open	2 (3.7)	3 (5.3)	5 (4.5)	
Type of tibia fracture				
Simple	27 (50)	27 (47.4)	54 (48.6)	[d]0.908
Wedge	20 (37)	21 (36.8)	41 (36.9)	
Complex	7 (13)	9 (15.8)	16 (14.4)	
Type of fibula fracture				
Transverse	12 (22.2)	11 (19.3)	23 (20.7)	[d]0.930
Oblique	23 (42.6)	25 (43.9)	48 (43.2)	
Comminuted	19 (35.2)	21 (36.8)	40 (36)	
Distance from ankle joint (cm)				
Min–max (median)	5–12 (8)	5–13 (8)	5–13 (8)	[a]0.721
Mean ± SD	8.3 ± 1.9	8.4 ± 2.2	8.4 ± 2.1	
Location of fibula fracture				
Same level as tibia fracture	15 (27.8)	14 (24.6)	29 (26.1)	[d]0.928
Proximal to tibia fracture	20 (37)	22 (38.6)	42 (37.8)	
Distal to tibia fracture	19 (35.2)	21 (36.8)	40 (36)	

[a]Student *t* test

[d]Pearson Chi-square test

[e]Fisher–Freeman–Halton test

observed between the groups in terms of AO fracture classification, Gustilo Anderson fractures classification, tibia, and fibula fracture types, the distance of the tibia fracture from the ankle, and the location of the fibula fracture ($p > 0.05$) (Table 2).

Johner–Wruhs score, rotational alignment, and duration of union did not differ between the groups in the functional evaluation ($p > 0.05$). However, ankle joint range of motion, AOFAS score, OMAS score, and full weight-bearing time were significantly better in the fibular fixation group ($p=0.023$, $p=0.001$, $p=0.001$ and $p=0.039$, respectively). Besides, the distributions of AOFAS and OMAS scores (as excellent, good, and fair) were significantly better in the fibular fixation group ($p=0.006$ and $p=0.002$, respectively) (Table 3).

In the radiological evaluation, canal fit ratio and distal tibiofibular synostosis did not differ between the groups ($p > 0.05$). However, varus/valgus angulation and anterior/posterior angulation were significantly higher in the control group ($p=0.034$ and $p=0.001$, respectively). Significantly better coronal alignment and sagittal alignment were observed in the fibular fixation group ($p=0.001$ and $p=0.001$, respectively). Patients who underwent fibular fixation had significantly better radiological outcomes in terms of fibular rotation angle and ankle arthrosis ($p=0.000$ and $p=0.022$, respectively) (Table 4).

Discussion

The most important findings of the present study are that fibular fixation in distal tibiofibular fractures where IMTN is performed for tibia fracture improves functional and radiological results, is related to better ankle clinical scores, and maintains the axial, coronal, and sagittal alignment. Fibular fixation has theoretical advantages such as better control over the length and rotation of the limb and the possibility of better anatomical alignment. However, some studies have shown that fibular fixation can prevent tibial fracture reduction and make fixation too stiff which prevents cyclic loading

Table 3 Comparison of functional outcomes of the patients in groups

	Fibular fixation ($n=54$) n (%)	Control ($n=57$) n (%)	Total ($n=111$) n (%)	p
Johner–Wruhs score				
Excellent	43 (79.6)	42 (73.7)	85 (76.6)	[c]0.577
Good	11 (20.4)	13 (22.8)	24 (21.6)	
Fair	0 (0)	2 (3.5)	2 (1.8)	
Rotational alignment				
Excellent	45 (83.3)	41 (71.9)	86 (77.5)	[c]0.381
Good	8 (14.8)	12 (21.1)	20 (18)	
Fair	1 (1.9)	3 (5.3)	4 (3.6)	
Poor	0 (0)	1 (1.8)	1 (0.9)	
Ankle range of motion				
Excellent	45 (83.3)	35 (61.4)	80 (72.1)	**[d]0.023***
Good	7 (13)	18 (31.6)	25 (22.5)	
Fair	2 (3.7)	2 (3.5)	4 (3.6)	
Poor	0 (0)	2 (3.5)	2 (1.8)	
AOFAS score				
Min–max (median)	72–100 (90)	70–100 (80)	70–100 (83)	**[b]0.001****
Mean ± SD	86.7 ± 5.8	83.0 ± 5.9	84.8 ± 6.1	
Excellent	31 (57.4)	16 (28.1)	47 (42.3)	**[c]0.006****
Good	20 (37)	37 (64.9)	57 (51.4)	
Fair	3 (5.6)	4 (7)	7 (6.3)	
OMAS score				
Min–max (median)	70–100 (95)	65–100 (80)	65–100 (85)	**[b]0.001****
Mean ± SD	88.9 ± 8.3	82.4 ± 9.4	85.6 ± 9.5	
Excellent	31 (57.4)	16 (28.1)	47 (42.3)	**[c]0.002****
Good	23 (42.6)	41 (71.9)	64 (57.7)	
Full weight-bearing (weeks)				
Min–max (median)	12–24 (13)	12–27 (14)	12–27 (14)	**[b]0.039***
Mean ± SD	14.0 ± 2.6	15.2 ± 3.6	14.6 ± 3.1	
Union time (weeks)				
Min–max (median)	11–22 (13)	11–24 (13)	11–24 (13)	[b]0.387
Mean ± SD	13.3 ± 2.3	13.7 ± 2.7	13.5 ± 2.5	

The statistically significant parameters are in bold

AOFAS American Orthopaedic Foot and Ankle Society, *OMAS* The Olerud–Molander Ankle Score

[b]Mann–Whitney *U* test

[c]Fisher's exact test

[d]Pearson's Chi-square test

*$p < 0.05$, **$p < 0.01$

in the tibial fracture site, thereby facilitating higher rates of delayed union and nonunion in distal tibia fractures treated with IMN [2, 6, 22]. The present study has been established due to the controversies in the literature regarding the necessity and benefit of fibular fixation. We aimed to determine the effect of fibular fixation on fracture union, alignment, and functional outcomes of distal tibiofibular fractures treated with IMTN. Besides, nonunion was not observed in any of the patients in our study. Although delayed union developed in three patients in the fibula fixation group and five patients in the control group, it was not statistically significant ($p > 0.05$).

Fixation of the fibula maintains the length of the lateral column. When fibula fixation is performed prior to IMTN, it provides to restore the alignment of the proximal and distal tibial fragments [1]. De Giacomo and Tornetta [19] emphasized that the presence or level of the fibula fracture did not affect the surgical alignment or its change in alignment during the union. However, Berlusconi et al. [12] have recommended fibular fixation for the treatment of distal tibiofibular shaft fractures when both fractures lie on the same plane and

Table 4 Comparison of radiological outcomes of patients in groups

	Fibular fixation ($n=54$) n (%)	Control ($n=57$) n (%)	Total ($n=111$) n (%)	p
Canal fit ratio				
Min–max (median)	1.73–2.55 (2)	1.77–2.58 (2)	1.73–2.58 (2)	[b]0.305
Mean ± SD	1.98 ± 0.15	2.01 ± 0.16	1.99 ± 0.16	
Valgus/varus angulation				
Min–max (median)	0–5 (1)	0–10 (1)	0–10 (1)	**[b]0.034***
Mean ± SD	1.3 ± 1.6	2.3 ± 2.7	1.8 ± 2.3	
Coronal alignment				
Excellent	48 (88.9)	33 (57.9)	81 (73)	**[e]0.001****
Good	6 (11.1)	20 (35.1)	26 (23.4)	
Fair	0 (0)	4 (7)	4 (3.6)	
Anterior/posterior angulation				
Min–max (median)	0–8 (1)	0–10 (1)	0–10 (1)	**[b]0.001****
Mean ± SD	1.4 ± 2.0	2.8 ± 2.9	2.1 ± 2.6	
Sagittal alignment				
Excellent	44 (81.5)	29 (50.9)	73 (65.8)	**[e]0.001****
Good	9 (16.7)	22 (38.6)	31 (27.9)	
Fair	1 (1.9)	6 (10.5)	7 (6.3)	
Distal tibiofibular synostosis				
No	52 (96.3)	54 (94.7)	106 (95.5)	[c]1.000
Yes	2 (3.7)	3 (5.3)	5 (4.5)	
Fibular rotation angle				
Min–max (median)	0–4 (0)	0–13 (4)	0–13 (1)	**[b]0.000***
Mean ± SD	0.5 ± 0.8	4.6 ± 3.7	2.6 ± 3.4	
Ankle arthrosis				
Grade 0	49 (90.7)	41 (71.9)	90 (81.1)	**[e]0.022***
Grade I	5 (9.3)	14 (24.6)	19 (17.1)	
Grade II	0 (0)	2 (3.5)	2 (1.8)	

The statistically significant parameters are in bold

*$p < 0.05$, **$p < 0.01$

[b]Mann–Whitney U test

[c]Fisher's exact test

[e]Fisher–Freeman–Halton test

the tibial fracture is relatively stabilized. In our study, prior fibula fixation facilitated tibia reduction and IMTN application and helped to achieve anatomical alignment regardless of the level of tibia and fibula fractures. However, fibula fixation prolonged the duration of surgery due to the additional lateral approach ($p=0.001$). On the other hand, fibular malalignment which affected especially the coronal alignment of the tibia fracture was detected in patients who did not undergo fibular fixation, during a mean follow-up of 5 years. Distal tibiofibular fractures undergoing fibula stabilization have a lower risk of late malalignment compared to those without fibula stabilization [10]. In distal tibia fractures treated with IMTN without fibula fixation, 2% malalignment and 3% malunion have been reported previously [19]. A significant difference was observed between the groups in terms of coronal and sagittal plane malalignment in our study ($p=0.001$ and $p=0.001$, respectively). Radiological outcomes of the present study stated that fibula fixation significantly decreased the malalignment and malunion rates. A previous study reported that fibula fixation did not improve treatment outcomes in the distal third of tibial diaphyseal fractures [3]. Rouhani et al. [3] also found that there was no advantage in using fibular fixation to treat the fractures of the distal tibial diaphysis. Prasad et al. [1] found a better ankle assessment score (AER) in the fibula fixation group while ankle range of motion and tibial union were similar between both groups. They also reported that the outcomes of the Johner and Wruhs criteria were similar between patients with and without fibula fixation. Although the Johner and Wruhs score were similar between the groups, the ankle range of motion, AOFAS score, and OMAS score were significantly better in those with fibular fixation in the present study ($p = 0.023$, $p = 0.006$, and $p = 0.002$, respectively). We think that fibula fixation improves the ankle scores by increasing the stabilization of the ankle mortise and contributing to the reduction of the distal tibial diaphyseal fracture. De Giacomo and Tornetta [19] stated that 80% of the patients gain full weight-bearing at 3 months and 95% of them gain full weight-bearing at 6 months. In the present study, we observed that fibula fixation significantly provided early full weight-bearing ($p = 0.039$).

Berlusconi et al. [12] have also reported a statistically significant higher incidence of external malrotation and valgus deformity in patients without fibular fixation. Besides, additional fibular plate fixation with IMTN for distal tibiofibular fractures has been shown to improve initial rotational stability compared to tibial IMTN alone [23]. In contrast to those papers, the rotational alignment in those who underwent fibula fixation was statistically similar to the control group in our study. In both groups, over 90% excellent and good results were obtained in terms of rotational alignment. This issue can be explained by the reduction that will provide appropriate rotational alignment of the tibia before IMTN. Van Maele et al. [24] reported that low tibiofibular fracture is an indication for fibula fixation although they could not prove the value of additional fibula fixation to prevent reduction loss in IMTN. Previous cadaveric studies stated that fibular plate fixation improved rotational and axial stability in patients with distal tibiofibular fracture and may reduce the risk of malunion with valgus deformity [11, 23]. Taylor et al. [7] emphasized that additional fibular fixation does not affect the maintenance of the alignment in the early postoperative period or short-term follow-up. In addition, they did not observe any statistically proven effect of fibular fixation in preventing late loss of coronal or sagittal alignment. In our study, the fibular rotation angle was significantly lower in those who undergo fibula fixation, and fibular fixation ensures the alignment and rotation of the fibula. Fibula fixation not only provides resistance to varus/valgus deforming forces and prevents the late loss of coronal or sagittal alignment, but also improves ankle functional outcomes as it maintains normal fibular alignment and rotation.

The increased rate of complications after open reduction and internal fixation of the fibula has been previously shown [2]. Superficial wound infection of the fibular approach site has been found comparatively higher in the patients treated with fixation of fibula than those without [1]. In the fibular fixation group, deep infection was observed in two patients, superficial infection in three patients, and massive soft tissue swelling in four patients. Superficial infection was observed in three patients, deep infection in three patients, and massive soft tissue swelling in six patients in the control group. Infections were treated with antibiotics and massive soft tissue swelling was treated with a cold pack and iv colloid fluid therapy. Debridement was not required for the superficial or deep infection in any of the patients. None of the patients required fasciotomy due to massive soft tissue swelling. Skin irritation was observed in four patients in the fibula osteosynthesis group, due to the distal fibular locking screw heads of the hardware. However, only the screws causing irritation were removed in those patients. There was no case in which the whole osteosynthesis hardware had to be removed. No significant difference was observed between the groups in terms of complications. One of the noticeable outcomes of the present study is that ankle arthritis was found to be significantly lower in patients with fibula fixation. However, the exclusion of previous ankle problems on the injured side of the patients was based solely on preoperative CT and patient anamnesis. Therefore, it may not be eligible to associate fibula fixation with reduced ankle arthritis. The follow-up period should be adequate to evaluate the complication rates such as osteoarthritis and functional disability in the ankle. In many studies in the literature, the functional outcomes of the ankle are not mentioned in the surgical treatment of distal tibiofibular diaphyseal fractures or the follow-up periods are short in terms of determination of ankle osteoarthritis. In the present study, the patients were followed for a long time to observe both ankle osteoarthritis and functional disability. Our study has some limitations such as retrospective design, a relatively small number of patients, and lack of randomization. In addition, the patients without previous ipsilateral ankle problems were included in the study, but the baseline AOFAS score was not evaluated before the injury. Although concomitant ankle bony injuries were excluded using CT, accompanying ankle ligament injuries or occult chondral injuries could not be evaluated with magnetic resonance imaging. Adequate power of the study, mid-term follow-up (average 56 months) to evaluate ankle instability and arthritis, detailed radiological evaluation, and use of multiple clinical evaluation scores are the strengths of the present study. Since there are very few studies evaluating the ankle functional outcomes in distal third tibia diaphyseal fractures, the present study would make a significant contribution to the literature.

In conclusion, fibular fixation not only contributes to fracture union, early full weight-bearing, and alignment but also improves ankle functional outcomes in the distal third tibiofibular fractures treated with IMTN. Although additional fibular fixation increases the surgery duration, it can be preferred for better alignment and better ankle functional outcomes in patients with distal third tibiofibular fracture.

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statistical analysis, performed measurements), 3. AB, MD (contribution: statistical analysis, performed measurements), 4. NZ, MD (contribution: study design, performed measurements, language editing), 5. MGB, Professor, MD (contribution: manuscript preparation, performed measurements), 6. CK, Professor, MD (contribution: statistical analysis, critical revision).

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The ethical approval of the present study was obtained from the local ethics committee (Approval ID 2019-304).

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References

1. Prasad M, Yadav S, Sud A, Arora NC, Kumar N, Singh S. Assessment of the role of fibular fixation in distal-third tibia fibula fractures and its significance in decreasing malrotation and malalignment. Injury. 2013;44(12):1885–91.
2. Javdan M, Tahririan MA, Nouri M. The role of fibular fixation in the treatment of combined distal tibia and fibula fracture: a randomized, control trial. Adv Biomed Res. 2017;6:48.
3. Rouhani A, Elmi A, Aghdam HA, Panahi F, Ghafari YD. The role of fibular fixation in the treatment of tibia diaphysis distal third fractures. Orthop Traumatol Surg Res. 2012;98(8):868–72.
4. Mao Z, Wang G, Zhang L, Zhang L, Chen S, Du H, et al. Intramedullary nailing versus plating for distal tibia fractures without articular involvement: a meta-analysis. J Orthop Surg Res. 2015;10(1):95.
5. Wähnert D, Stolarczyk Y, Hoffmeier KL, Raschke MJ, Hofmann GO, Mückley T. Long-term stability of angle-stable versus conventional locked intramedullary nails in distal tibia fractures. BMC Musculoskelet Disord. 2013;14(1):1–8.
6. Vallier HA, Cureton BA, Patterson BM. Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. J Orthop Trauma. 2011;25(12):736–41.
7. Taylor BC, Hartley BR, Formaini N, Bramwell TJ. Necessity for fibular fixation associated with distal tibia fractures. Injury. 2015;46(12):2438–42.
8. Strauss EJ, Alfonso D, Kummer FJ, Egol KA, Tejwani NC. The effect of concurrent fibular fracture on the fixation of distal tibia fractures: a laboratory comparison of intramedullary nails with locked plates. J Orthop Trauma. 2007;21:172–7.
9. Bonnevialle P, Lafosse JM, Pidhorz L, Poichotte A, Asencio G, Dujardin F. Distal leg fractures: how critical is the fibular fractures and its fixation? Orthop Traumatol Surg Res. 2010;96:667–73.
10. Egol KA, Weisz R, Hiebert R, Tejwani NC, Koval KJ, Sanders RW. Does fibular plating improve alignment after intramedullary nailing of distal metaphyseal tibia fractures? J Orthop Trauma. 2006;20:94–103.
11. Morin PM, Reindl R, Harvey EJ, Beckman L, Steffen T. Fibular fixation as an adjuvant to tibial intramedullary nailing in the treatment of combined distal third tibia and fibula fractures: a biomechanical investigation. Can J Surg. 2008;51(1):45–50.
12. Berlusconi M, Busnelli L, Chiodini F, Portinaro N. To fix or not to fix? The role of fibular fixation in distal shaft fractures of the leg. Injury. 2014;45(2):408–11.
13. Francesco P, Paolo S, Filippo C, Francesco C, Enrico V. When is indicated fibular fixation in extra-articular fractures of the distal tibia? Acta Biomed. 2018;89(4):558–63.
14. Ehlinger M, Adam P, Gabrion A, Jeunet L, Dujardin F, Asencio G, et al. Distal quarter leg fractures fixation: the intramedullary nailing alone option. Orthop Traumatol Surg Res. 2010;96(6):674–82.
15. van den Berg J, Monteban P, Roobroeck M, Smeets B, Nijs S, Hoekstra H. Functional outcome and general health status after treatment of AO type 43 distal tibial fractures. Injury. 2016;47(7):1519–24.
16. Johner R, Wruhs O. Classification of tibial shaft fractures and correlation with results after rigid internal fixation. Clin Orthop Relat Res. 1983;178:7–25.
17. Turhan E, Demirel M, Daylak A, Huri G, Doral MN, Çelik D. Translation, cross-cultural adaptation, reliability and validity of the Turkish version of the Olerud–Molander Ankle Score (OMAS). Acta Orthop Traumatol Turc. 2017;51(1):60–4.
18. Akbaba YA, Celik D, Ogut RT. Translation, cross-cultural adaptation, reliability, and validity of Turkish version of the American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale. J Foot Ankle Surg. 2016;55(6):1139–42.
19. De Giacomo AF, Tornetta P III. Alignment after intramedullary nailing of distal tibia fractures without fibula fixation. J Orthop Trauma. 2016;30(10):561–7.
20. Futamura K, Baba T, Mogami A, Morohashi I, Kanda A, Obayashi O, et al. Malreduction of syndesmosis injury associated with malleolar ankle fracture can be avoided using Weber's three indexes in the mortise view. Injury. 2017;48(4):954–9.
21. Arnold H. Posttraumatic impingement syndrome of the ankle—indication and results of arthroscopic therapy. Foot Ankle Surg. 2011;17(2):85–8.
22. Kruppa CG, Hoffmann MF, Sietsema DL, Mulder MB, Jones CB. Outcomes after intramedullary nailing of distal tibial fractures. J Orthop Trauma. 2015;29:309–15.
23. Kumar A, Charlebois SJ, Cain LE, Smith RA, Daniels AU, Crates JM. Effect of fibular plate fixation on rotational stability of simulated distal tibial fractures treated with intramedullary nailing. J Bone Jt Surg Am. 2003;85(4):604–8.
24. van Maele M, Molenaers B, Geusens E, Nijs S, Hoekstra H. Intramedullary tibial nailing of distal tibiofibular fractures: additional fibular fixation or not? Eur J Trauma Emerg Surg. 2018;44(3):433–41.