

The Effect of Repairing the Integrity of the Calcaneofibular Ligament During Calcaneal Fracture Surgery on Postoperative Ankle Joint Function

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Background: Calcaneal fracture is a common fracture in clinical practice. Open reduction and internal fixation of the calcaneal plate inevitably require cutting or damaging the calcaneofibular ligament (CFL) beneath the sheath of the fibular muscle tendon. Hence, calcaneal fractures are mainly treated through the lateral L-shaped extension approach. However, there is still controversy over whether the integrity of CFL can be repaired during surgery. Thus, we aimed to explore the effect of repairing CFL during calcaneal fracture surgery on postoperative ankle joint function.

Methods: In this retrospective study, we analyzed the clinical data of 84 patients with Sanders type II and III calcaneal fractures admitted to Wuhan Fourth Hospital from March 2021 to May 2023. According to whether CFL was repaired during surgery, the patients were divided into a repair group (n=44) and non-repair group (n=40). These patients underwent surgery by the same surgeon. The perioperative conditions between the two groups were compared. After a one-year follow-up, the rates of excellent ankle function and incidence of complications was also compared.

Results: The duration of surgery and hospitalization in the repair group was longer than that in the non-repair group, and the intraoperative blood loss was greater than that in the non-repair group ($P < 0.05$). After surgery, the excellent and good rate of ankle function in the repair group (90.91%) was higher than that in the non-repair group (67.50%) ($P < 0.05$). The incidence of complications in the repair group (9.09%) was not significantly higher than that in the non-repair group (7.50%) ($P > 0.05$).

Conclusion: Although preserving CFL integrity during calcaneal fracture surgery increases the duration of surgery and hospitalization, the postoperative recovery of range of motion is good, the rate of excellent ankle function is significantly improved, and there is no significant increase in complications.

Keywords: calcaneal fracture, suture anchors, fibular ligament, repair, ankle stability

Introduction

Calcaneal fractures are common fractures in clinical practice¹ with an incidence rate of about 2% of the total incidence rate of systemic fractures and about 60% of the total incidence rate of tarsal fractures. They are usually caused by vertical violence injury and have a high disability rate.¹ The calcaneofibular ligament (CFL) originates from the tip of the lateral malleolus and inserts onto the lateral wall of the calcaneus. It plays a vital role in resisting talar tilt and inversion, acting synergistically with the anterior talofibular ligament to maintain both tibiotalar and subtalar joint stability.² However, because of the complex surrounding structure of calcaneal fractures and limited local soft tissue coverage, there are still

certain challenges in clinical treatment.³ If not treated promptly and effectively, patients may experience various types of sequelae, posing a huge threat to their daily activities and quality of life.^{3,4}

Surgery is an important method for the current clinical treatment of Sanders type II and III calcaneus fractures.⁵ There is currently no unified standard for the surgical approach for calcaneal fractures. The vast majority of orthopedic surgeons use the lateral L-shaped lengthening approach of the calcaneus.^{5,6} This approach can effectively expose the complete fracture of the lateral side of the calcaneus. However, during the surgical procedure, it is necessary to completely detach the peroneal tendon sheath and calcaneofibular ligament (CFL) from the lateral wall of the calcaneus. Furthermore, the posterior heel joint and fracture end are clearly exposed, causing iatrogenic damage to the integrity of the CFL.^{6,7} Nevertheless, it is necessary to cut open the support band and tendon sheath for repair and stretch the fibular tendon to suture the ligament.⁸ Reports have suggested that this surgery increases painful scars in the local soft tissue of the calcaneus, especially around the tendon sheath, affects joint mobility, and likely damages the motor nerves and sensory branches of the gastrocnemius nerve that passes through the skin at that location.^{9,10} Some scholars also believe that joint instability may occur after surgery without repairing the CFL.^{11,12} At present, there are few reports on whether iatrogenic injury to the CFL caused by incision exposure during calcaneal fracture surgery affects ankle joint stability during postoperative rehabilitation.

This study retrospectively analyzed the clinical data of patients with Sanders type II and III calcaneal fractures in our hospital. The aim of this study is to clarify whether repairing the CFL during calcaneal fracture surgery has an impact on postoperative ankle joint stability.

Materials and Methods

Patient Selection

We conducted a retrospective case-control study using medical records of patients with Sanders type II and III calcaneal fractures who underwent surgical treatment at Wuhan Fourth Hospital from March 2021 to May 2023. The study was approved by the Ethics Committee of Wuhan Fourth Hospital, and the need for informed consent was waived.

Inclusion Criteria

Patients who 1) met the diagnostic criteria for calcaneal fractures;¹ 2) had Sanders classification II–III type fracture; 3) had unilateral fracture; 4) had closed fracture; 5) had clear history of injury; 6) were operated by the same surgeon; 7) had complete clinical data and had been followed-up for one year.

Exclusion Criteria

Patients with 1) pathological fractures; 2) severe osteoporosis; 3) muscle bonds, nerve damage, and severe damage to surrounding soft tissues; 4) combined anterior talofibular ligament rupture; 5) bilateral ankle ligament injuries; 6) history of foot or ankle injuries or surgeries.

Methods

Preoperative Preparation

After admission, all patients were given intermittent cold therapy with limb elevation and heel compression using a cold compress machine. After the swelling and pain reduced, patients were treated with anticoagulant drugs. Preoperative blood routine, biochemical and coagulation indicators, and infection tests were performed. Furthermore, electrocardiogram, echocardiogram, lower limb venous ultrasound, lateral and axial digital radiography (DR) of the calcaneus, and computed tomography (CT) of the calcaneus were also carried out. Surgical treatment could only be performed when the soft tissue conditions in the heel area were favorable. The reparability of the CFL was decided based on whether the integrity of the calcaneofibular ligament is damaged or the tendon tissue is thinned or torn during intraoperative exploration.

Operative Method

The locking and compression titanium plate internal fixation surgery approach was adopted. With the patient lying on their side and the affected side facing upwards, lumbar epidural anesthesia was induced, and a tourniquet was applied to

the affected limb (pressure of the tourniquet adjusted to 400 mmHg). An enlarged “L”-shaped incision was made on the outer side of the calcaneus, with the vertical part of the incision avoiding the sural nerve as much as possible and the horizontal part located about 1 cm above the intersection of the plantar skin and dorsum skin. The turning point of the incision was rounded and blunt to avoid affecting the blood supply of the skin flap. The subcutaneous tissue was slowly separated to expose the long and short tendons of the fibula, as well as the sural nerve and CFL. The CFL was cut from the insertion point of the lateral wall of the calcaneus. The supporting band of the peroneal muscle, the interosseous ligament of the calcaneus, and the capsule of the calcaneus joint were cut in sequence, and the long and short tendons of the fibula were carefully retracted dorsally to expose the subtalar joint. Using a periosteal dissector to bluntly separate deep tissue from the lateral wall of the calcaneus, the subtalar joint and the lateral wall of the calcaneus were clearly exposed. The hook was replaced with multiple Kirschner needles to fix the dice bone, talus, and fibular bone. Then, the lateral wall of the calcaneus, calcaneal joint, articular surface, and talofibular joint were exposed. After prying and repositioning, reduction of the medial wall and tarsal process were first implemented; then, the Gissane angle and the Bohler angle of the calcaneus were restored. Assisted by C-arm X-ray machine fluoroscopy, the alignment and recovery status of the calcaneal fracture were determined. If the bone defect was >1 cm, allogeneic bone repair materials were implanted and titanium plates were placed. If repairing the CFL, the residual CFL tissue was freed from the tip of the fibula at the proximal end of the fibula (Figure 1). Then a 2.0mm Kirschner wire was used to drill a hole at the calcaneal insertion point of the CFL, and a 3.5mm diameter anchor with wire was implanted in the bone hole (Figure 2). The CFL severed end was then sutured with the suture provided by the anchor with the ankle slightly dorsiflexed and everted, tightened and knotted to fix it (Figure 3), and then the subextensor retinaculum was sutured to the periosteum. Finally, the Kirschner wire was removed and the tourniquet loosened, to effectively stop bleeding. After placing the appropriate drainage, the incision was closed. Following fracture fixation, the peroneal tendon sheath was routinely sutured to its anatomical position to reduce the risk of postoperative tendon subluxation. Repair was performed when intraoperative findings revealed complete rupture, significant thinning of the CFL fibers, or avulsion at the insertion site. These criteria were consistently applied by the same surgeon throughout all cases.

Postoperative Management and Follow-up

Antibiotics were used for one day after surgery to prevent infection. The affected limb was continued to be elevated after surgery, and toe movement could be attempted once the effect of anesthesia wore off. Symptomatic treatment was provided with anti-inflammatory, analgesic, and anticoagulant drugs. The dressing was changed in a timely manner, and active and passive ankle flexion and extension activities were performed on the second day after surgery. The thread was removed in about 2 weeks. Regular follow-up was conducted after discharge to guide functional exercise and maintain patients' postoperative follow-up data. After 6 weeks, the affected limb could bear some weight. Axial DR of the

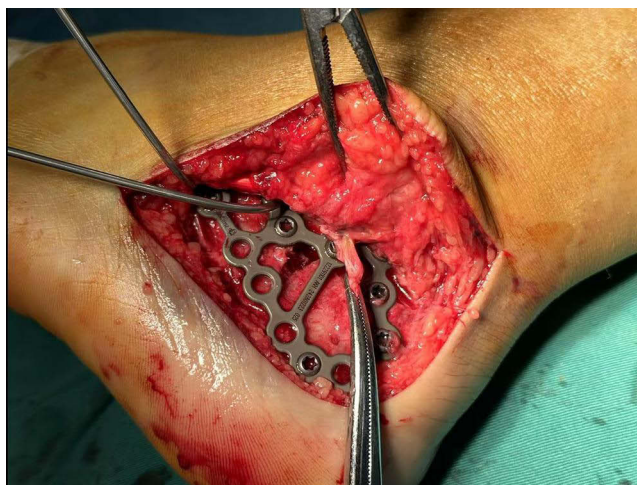


Figure 1 Residual CFL tissue was freed from the tip of the fibula at the proximal end of the fibula.

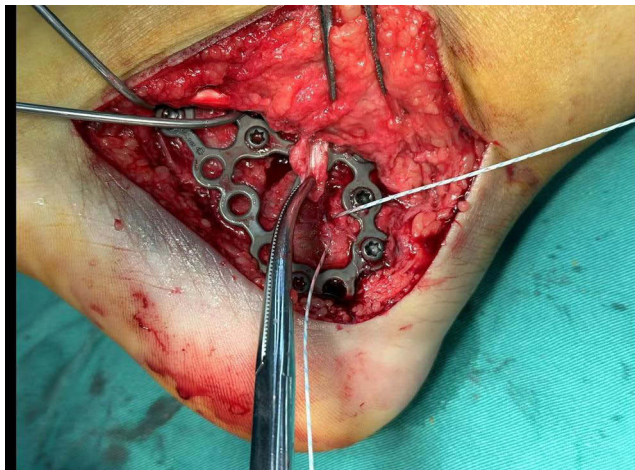


Figure 2 A bone groove was made.

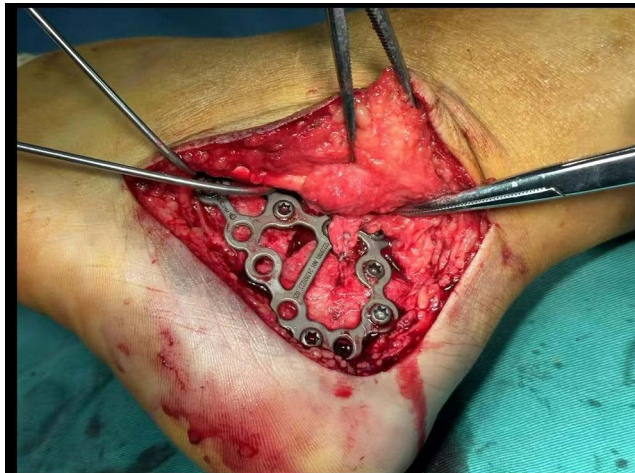


Figure 3 Suture of the severed end of CFL.

operated segment was reevaluated in 10 weeks. Complete weight-bearing exercise could be performed based on the healing condition of the fracture. Patients were followed-up for 1–12 months after discharge, with regular check-ups and guidance on functional exercise.

Outcome Measures

1) Perioperative conditions, including surgical duration, intraoperative blood loss, and length of hospital stay. 2) Excellent rate of ankle function according to the assessment of the American Orthopedic Ankle Association (AOFAS), with a total score of 100 points, wherein a score ≥ 90 was excellent, 80–89 was good, 70–79 was fair, and ≤ 69 was poor. Excellent and good rate = $(\text{excellent} + \text{good}) / \text{total cases} \times 100\%$. 3) Follow-up on the occurrence of complications within one year, including nerve damage, infection, hematoma, and joint stiffness.

Statistical Analysis

The data were input into Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). The Shapiro–Wilk test was used to evaluate data normality. Normally distributed data were represented by mean \pm standard deviation; independent sample *t*-test was used for intergroup comparison, and paired *t*-test was used for intragroup comparison before and after. Non-normally distributed data were represented by median and interquartile range. Mann–Whitney *U*-test was used for intergroup comparisons, and Wilcoxon signed rank test was used for

intragroup comparisons. The count data were represented by the number of cases, and chi-square test was used for comparison. $P < 0.05$ indicates a statistically significant difference.

Results

We identified 95 patients with Sanders type II and III calcaneal fractures who underwent surgical treatment at Wuhan Fourth Hospital between March 2021 and May 2023. 11 patients were excluded, including two cases of pathological fractures, two of severe osteoporosis; two of muscle and nerve injuries, with severe damage to surrounding soft tissues; two of anterior fibular ligament rupture; and three cases were lost to follow-up. The number of eligible patients was 84, of whom 44 underwent talofibular ligament repair (repair group) and the remaining 40 did not (non-repair group) (Figure 4). There was no significant difference ($P > 0.05$) in general information such as sex, age, affected side, fracture-to-surgery interval, body mass index (BMI), and Sanders classification between the two groups of patients (Table 1).

Comparison of Perioperative Conditions Between Two Groups

The duration of surgery, hospitalization, and intraoperative blood loss in the repair group were significantly higher than those in the non-repair group ($P < 0.05$) (Table 2).

Comparison of Excellent and Good Ankle Function Rates Between the Two Groups

The functional outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score. Scores ≥ 90 were considered excellent, 80–89 good, 70–79 fair, and ≤ 69 poor. The excellent and good rate of ankle function in the repair group (90.91%) was significantly higher than that in the non-unrepair group (67.50%) ($P < 0.05$) (Table 3).

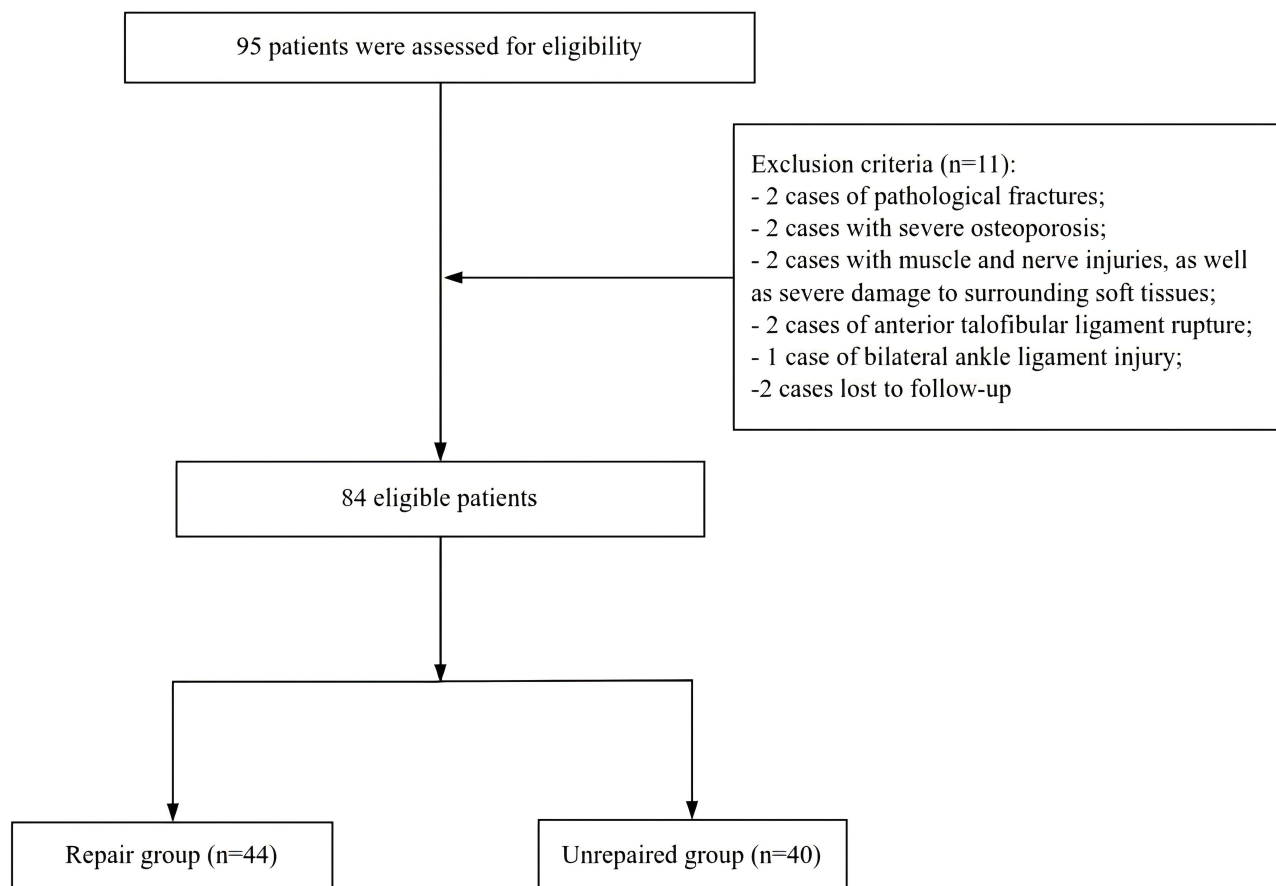


Figure 4 Patient screening process.

Table 1 Comparison of Baseline Characteristics Between Two Groups

Characteristics	Repair Group (n=44)	Unrepaired Group (n=40)	χ^2/t	P
Male (yes), n (%)	33 (75.0)	35 (87.5)	2.123	0.145
Age (years), median (Q1, Q3)	49.05±12.00	46.73±9.75	0.967	0.336
Affected side (left/right), n (%)	22 (50.0)/22 (50.0)	23 (57.7)/17 (42.5)	0.474	0.491
Interval between fracture and surgery (hours), Mean±SD	13.86±3.68	12.53±3.20	1.770	0.081
BMI (kg/m ²), Mean±SD	23.47±2.44	23.97±3.03	-0.839	0.404
Sanders staging (II/III), n(%)	27 (61.4)/17 (38.6)	23 (57.5)/17 (42.5)	0.130	0.719

Abbreviations: BMI, body mass index; Q1, the first quartile; Q3, the third quartile; SD, standard deviation.

Table 2 Comparison of Perioperative Conditions Between Two Groups

Group	n	Surgical Duration (Minute)	Intraoperative Blood Loss (mL)	Hospitalization (Day)
Repair group	44	86 (78.5–95.5)	36 (28–46)	19 (15.5–21)
Unrepaired group	40	76 (69–84.5)	32 (26–37.5)	13 (11.5–15)
Z		-3.623	-2.346	-5.565
P		<0.001	0.019	<0.001

Table 3 Comparison of Excellent and Good Ankle Function Rates Between Two Groups

Group	n	Excellent	Good	Fair	Poor	Excellent and Good Rate
Repaired group	44	25 (56.82)	15 (34.09)	2 (4.55)	2 (4.55)	40 (90.91)
Unrepaired group	40	13 (32.50)	14 (35.00)	7 (17.50)	6 (15.00)	27 (67.50)
χ^2						7.113
P						0.008

Table 4 Comparison of Incidence of Complications Between Two Groups

Group	n	Nerve Injury	Infection	Hematoma	Joint Stiffness	Total Incidence Rate
Repaired group	44	2 (0.00)	1 (1.52)	1 (1.52)	0 (0.00)	4 (9.09)
Unrepaired group	40	1 (1.72)	1 (1.72)	0 (0.00)	1 (0.00)	3 (7.50)
χ^2						0.069
P						0.792

Comparison of Incidence of Complications Between the Two Groups

During the follow-up period, there were two cases of nerve injury, one of infection, and one of hematoma in the repair group. In the non-repair group, there was one case of nerve injury, one of infection, and one of joint stiffness. There was no significant difference in the incidence of complications between the two groups ($P>0.05$) (Table 4).

Discussion

The ankle lateral ligament is composed of the anterior talofibular ligament, the CFL and the posterior talofibular ligament, which are crucial for maintaining the stability of the ankle joint and maintaining daily activities of the human body.¹³ The CFL starts from the tip of the lateral malleolus, runs obliquely backwards and downwards, and ends on the outer surface of the calcaneus; it is located deep in the tendon sheath of the peroneal muscle and is closely connected to it.^{7,13} CFL is mainly used to prevent foot inversion and limit the tilt of the talus. It works together with the talar ligament to maintain the stability of the subtalar joint and is an important structure to counteract the stress of tibial and talus eversion.^{14–16} When the CFL is cut off, positive stress radiography can show mild inclination of the talus, while the external rotation of the talus can increase by 2.9°.^{16,17} The repair team implanted a 3.5-mm diameter suture anchor

with its own suture anchors to suture the CFL stump during surgery. The ankle was gently stretched back and turned outward, tightened and knotted for fixation, and then the extensor support band was sutured to the periosteum. This ensures the functional integrity of the CFL and further enhances lateral ankle stability. Our intraoperative experience suggests that CFL injury is common in both tongue-type and depression-type fractures due to rotational displacement of the posterior tuberosity fragment. Although specific prevalence rates are lacking in the literature, this observation supports the relevance of CFL repair.

The results of this study showed that the excellent rate of OFAS score in the repair group (90.91%) was significantly higher than that in the non-repair group (67.50%). This indicates that performing CFL repair during surgery is highly beneficial to patients' postoperative recovery. Vega et al¹⁸ treated 24 patients with chronic ankle instability and anterior talofibular ligament (ATFL) and CFL tears. After non-surgical treatment failed, arthroscopic repair of ATFL and CFL was performed, and the median AOFAS score increased from 65 points before surgery to 97 points at the final follow-up. This is consistent with the results of this study. Ligaments are of oligovascular structure, with poor blood supply and nutrition. After cutting, the severed end retracts, making repair difficult. Scar tissue often self-heals. Cutting the CFL will also damage the ligament proprioceptors. Thompson et al¹⁹ found that after the loss of ligament proprioceptors, functional imbalance occurs in the joint capsule and ligaments of the injured joint due to afferent nerve block, which affects joint stability.

After one year of postoperative follow-up, there were two cases of nerve injury, one of infection, and one of hematoma in the repair group. In the non-repair group, there was one case each of nerve injury, infection, and joint stiffness. There was no significant difference in the incidence of complications between the two groups. It can be seen that repairing CFL with suture anchors is easy to perform, and the tissue compatibility between rivets and threads is good, making it less prone to complications such as wounds after local tissue irritation.²⁰ However, the repair group showed a significant increase in surgical duration, intraoperative bleeding, and hospital stay compared to the non-repair group. The CFL is relatively thick and difficult to repair due to the coverage of the fibular tendon sheath and the obstruction of steel plate screws, thus resulting in prolonged surgical time, increased volume of bleeding, and greater trauma to the body. This is why some scholars do not recommend intraoperative repair. Ko et al²¹ also showed that additional CFL repair did not bring significant advantages in any measurement results at 3 years. D'Hooghe et al²² evaluated the effects of ATFL and CFL on ankle stability in a biomechanical cadaver model. Compared with single ATFL repair, the stiffness increase after ATFL/CFL combined repair was not statistically significant. However, based on the results of this study, repairing CFL during surgery can bring benefits to patients' postoperative recovery.

This study has some limitations. First, this is a single center retrospective analysis, and the two groups of patients were not randomly assigned, which limits our ability to establish causal relationships. Second, given the retrospective nature of the research, we relied on medical records, and whether a patient had a previous ankle sprain was based on their self-reported medical history, which may have recall bias. Third, subgroup analysis could not be conducted owing to the sample size. Therefore, we cannot further understand the effectiveness of these procedures in specific patient populations. Fourth, our follow-up period was not long-term; therefore, we could not evaluate the impact of intraoperative repair of CFL on the long-term functional recovery of patients. Last, the rehabilitation compliance of patients may have significantly affected the study results. High-quality prospective randomized controlled trials are needed in the future with extended follow-up times to validate the value of repairing the CFL. Additionally, our study did not include direct biomechanical or radiological measures of ankle joint stability. This was primarily due to the retrospective nature of the study and ethical considerations limiting further imaging beyond standard care. Postoperative function was thus assessed through clinical examination and the AOFAS scoring system, which may not fully capture mechanical stability. Future studies with objective stability measurements are warranted.

Conclusion

The use of suture anchors to repair CFL combined with locked compression titanium plates for the treatment of calcaneal fractures increases the length of surgery and hospitalization. However, there was a significant effect in improving the rate of excellent ankle function along with no significant increase in the incidence of complications.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and the Helsinki Declaration (as revised in 2013). The requirement for informed consent was waived by the ethics committee due to the observational and retrospective nature of the study. This study was approved by the ethics committee of Wuhan Fourth Hospital (KY2024-163-01).

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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