

Original Research Article

Functional outcomes following open reduction and internal fixation of closed bimalleolar ankle fractures: a prospective cohort study from a tertiary care centre in South India

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ABSTRACT

Background: Bimalleolar ankle fractures are unstable injuries that can cause persistent pain, restricted motion, gait disturbance, instability, and post-traumatic osteoarthritis if anatomical alignment is not restored. Open reduction and internal fixation (ORIF) is widely used for unstable ankle fractures, but prospective outcome data from Indian tertiary care centres remain limited. Objective was to evaluate functional outcomes after ORIF of closed bimalleolar ankle fractures using the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot score over 12 months.

Methods: A prospective observational cohort study was conducted between April 2024 and March 2026 at Siddhartha Medical College and Government General Hospital, Vijayawada, India. Thirty adult patients with closed bimalleolar ankle fractures underwent ORIF according to standard AO fixation principles. Functional outcomes were assessed at 6 weeks, 12 weeks, 6 months, 9 months, and 12 months using the AOFAS ankle-hindfoot score. Demographic characteristics, pain, walking ability, gait, ankle motion, stability, alignment, radiographic findings, and postoperative complications were assessed.

Results: All 30 patients completed the 12-month follow-up. The mean age was 45.4 ± 8.98 years, 60% were male, and road traffic accidents accounted for 66.7% of injuries. Pain, walking ability, gait, ankle motion, and functional scores improved progressively. At one year, 24 patients (80%) had excellent AOFAS outcomes, four (13.3%) had good outcomes, and two (6.7%) had fair outcomes; no patient had a poor outcome. Overall, 93.3% achieved good-to-excellent functional results.

Conclusions: ORIF was associated with progressive functional recovery over 12 months in this cohort of closed bimalleolar ankle fractures. Anatomical reduction, stable fixation, and structured rehabilitation were associated with favourable restoration of pain, mobility, gait, stability, and overall ankle function.

Keywords: Ankle fracture, AOFAS, Bimalleolar ankle fracture, Functional outcome, Open reduction and internal fixation; Orthopedic trauma, Prospective cohort

INTRODUCTION

Ankle fractures are among the most common lower-extremity fractures encountered in orthopaedic practice and account for approximately 9-10% of adult skeletal fractures.¹

Bimalleolar fractures involve the medial and lateral malleoli and represent unstable injuries in which disruption of ankle mortise congruity can lead to pain, malunion, restricted motion, instability, and post-traumatic osteoarthritis.²

The importance of anatomical reduction is illustrated by the finding of Ramsey and Hamilton that a 1 mm lateral

displacement of the talus reduced tibiotalar contact area by approximately 42%.³

For unstable ankle fractures, operative management aims to restore fibular length and rotation, achieve anatomical reduction, maintain mortise congruity, and provide stable fixation that permits rehabilitation; long-term evidence also indicates that functional results are influenced by reduction quality and other patient- and injury-related factors.⁴

The AOFAS ankle-hindfoot score was developed as a standardized clinical rating system incorporating pain, function, and alignment and is widely used in studies of ankle fracture outcomes.⁵

Previous clinical studies have demonstrated generally favourable recovery after operative treatment, although the magnitude and timing of recovery vary between populations and outcome measures.⁶⁻¹⁰

Prospective studies from Indian tertiary care institutions evaluating serial functional recovery after ORIF of closed bimalleolar fractures remain relatively limited. The present study therefore evaluated functional recovery over a 12-month period and compared the findings with previously published literature.

Aim

The aim of the study was to evaluate the functional outcome of open reduction and internal fixation in adult patients with closed bimalleolar ankle fractures.

Objectives

The study objectives were to assess serial functional outcomes using the AOFAS ankle-hindfoot score; to evaluate pain, gait, walking ability, ankle motion, stability, and alignment after ORIF; to document radiological union and postoperative complications; and to compare the observed functional outcomes with previously published studies.

METHODS

Study design

This prospective observational cohort study evaluated adults with closed bimalleolar ankle fractures treated surgically with ORIF. Patients were followed prospectively for 12 months with serial clinical and radiological assessments.

Study setting and duration

The study was conducted in the department of orthopaedics, Siddhartha Medical College and Government General Hospital, Vijayawada, Andhra Pradesh, India, a tertiary care teaching hospital serving

urban and rural populations. The study period extended from 1 April 2024 to 31 March 2026.

Ethical considerations

The study protocol was reviewed and approved by the institutional ethics committee of Siddhartha Medical College and Government General Hospital before recruitment. Written informed consent was obtained from all participants. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and patient information was anonymized for analysis.

Sample size

The required sample size was estimated using Epi Info version 7.2.5 based on the prevalence obtained from the institutional pilot study. Using the formula $n = Z^2pq/d^2$, with $p=1.5\%$, a 95% confidence level, and a 5% margin of error, the calculated minimum sample size was approximately 23 patients. To allow for possible loss to follow-up, 30 consecutive eligible patients were included.

Patient selection

All consecutive patients presenting during the study period with closed bimalleolar ankle fractures were screened. Patients were eligible if they were aged 18 years or older, had a radiographically confirmed closed bimalleolar fracture, were medically fit for surgery, and provided informed consent. Patients were excluded if they were younger than 18 years, had an open fracture, trimalleolar fracture, fracture-dislocation, previous ankle arthrodesis, distal neurovascular injury, active infection or skin disease at the operative site, severe medical comorbidity precluding surgery, or refusal to participate.

Preoperative evaluation

A standardized clinical assessment included history, mechanism of injury, demographic characteristics, associated medical illnesses, local examination, and neurovascular examination. Anteroposterior, lateral, and mortise radiographs were obtained for all patients. Routine pre-anesthetic investigations included complete blood count, renal function tests, blood glucose estimation, coagulation profile, electrocardiography, and chest radiography when indicated. Medical comorbidities were optimized before surgery.

Surgical technique

All procedures were performed under spinal anesthesia with the patient supine and under tourniquet control. Intravenous prophylactic antibiotics were administered approximately 30 minutes before skin incision. Fixation followed AO principles, emphasizing anatomical reduction, restoration of fibular length and rotation, stable fixation, and preservation of ankle mortise congruity. The lateral malleolus was approached through a standard

lateral incision and was fixed according to fracture configuration using a one-third tubular plate, semitubular plate, cannulated cancellous screw, or Kirschner wires where indicated. The medial malleolus was exposed through a standard medial approach and fixed using partially threaded cancellous screws, malleolar screws, tension-band wiring, or Kirschner wires according to fragment size and fracture morphology. Fluoroscopy in anteroposterior, lateral, and mortise views was used to confirm reduction and implant position before wound closure.

Postoperative protocol

Postoperative management consisted of intravenous antibiotics for five days followed by oral antibiotics for three days, limb elevation and edema control, and a below-knee plaster slab for four weeks. Sutures were removed at 12-14 days. Active ankle range-of-motion exercises were started after slab removal. Partial weight-bearing was initiated at four weeks, followed by gradual progression to full weight-bearing after radiological evidence of fracture union. Patients were advised regular supervised physiotherapy throughout rehabilitation.

Outcome assessment

Patients were assessed at 6 weeks, 12 weeks, 6 months, 9 months, and 12 months. The primary outcome measure was the 100-point AOFAS ankle-hindfoot score, comprising pain (40 points), function (50 points), and alignment (10 points). Scores of 90-100 were classified as excellent, 80-89 as good, 70-79 as fair, and below 70 as poor.

Table 1: Interpretation of AOFAS ankle-hindfoot score.

Scores	Interpretation
90-100	Excellent
80-89	Good
70-79	Fair
<70	Poor

Secondary outcomes included pain severity, walking distance, ability to walk on uneven surfaces, activity limitation, gait, hindfoot motion, sagittal ankle motion, ankle stability, alignment, radiographic union, and postoperative complications.

Radiological assessment

Serial anteroposterior, lateral, and mortise radiographs were obtained at follow-up. Radiological union was defined by bridging trabeculae across at least three cortices on orthogonal radiographs, absence of fracture-line tenderness, and the ability to bear weight without significant pain. Reduction quality was assessed on standard ankle radiographs.

Statistical analysis

Data were entered into Microsoft Excel 2019 and analysed using Epi Info version 7.2.5. Continuous variables were expressed as mean±standard deviation, while categorical variables were summarized as frequency and percentage. Chi-square or Fisher's exact test was planned for categorical comparisons and Student's t-test for normally distributed continuous variables. A p value below 0.05 was considered statistically significant. Secondary outcomes included pain severity, walking distance, ability to walk on uneven surfaces, activity limitation, gait, hindfoot motion, sagittal ankle motion, ankle stability, alignment, radiographic union, and postoperative complications.

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RESULTS

Patient characteristics

Thirty consecutive patients were enrolled, and all completed the scheduled 12-month follow-up. The mean age was 45.4±8.98 years (range, 31-60 years); 18 patients (60%) were male and 12 (40%) were female. Road traffic accidents were the predominant mechanism of injury, accounting for 20 cases (66.7%), while falls accounted for 10 cases (33.3%).

Table 2: Baseline demographic characteristics.

Variables	Value (%)
Number of patients	30
Mean age (years)	45.4±8.98
Age range	31-60 years
Male	18 (60)
Female	12 (40)
Road traffic accident	20 (66.7)
Fall	10 (33.3)

Table 3: Pain progression during follow-up.

Follow-ups	No pain (%)	Mild (%)	Moderate (%)	Severe (%)
6 weeks	0	7 (23.3)	16 (53.3)	7 (23.3)
12 weeks	5 (16.7)	12 (40)	13 (43.3)	0
6 months	18 (60)	10 (33.3)	2 (6.7)	0
9 months	22 (73.3)	8 (26.7)	0	0
12 months	24 (80)	6 (20)	0	0

Table 4: Clinical recovery at final follow-up.

Functional parameters	Recovery at 12 months
No pain	80%
Walking without difficulty	90%
Walking >6 blocks	86.7%
No activity limitation	80%
None/slight gait abnormality	93.3%
Normal hindfoot motion	93.3%
Normal sagittal motion	86.7%
Stable ankle	100%
Good alignment	100%

Pain and functional recovery

Pain improved progressively throughout follow-up. At 6 months, 60% of patients were pain free, increasing to 80%

at 12 months; no patient reported severe pain after 12 weeks.

At 12 months, 90% of patients could walk comfortably on uneven surfaces, 86.7% could walk more than six blocks, and 80% had no activity limitation. None or only a slight gait abnormality was present in 93.3% of patients. Normal hindfoot motion was present in 93.3% and normal sagittal ankle motion in 86.7%. All patients had a stable ankle and good alignment at final follow-up.

AOFAS functional outcome

A progressive shift toward higher AOFAS categories was observed at each follow-up assessment. At 12 months, 24 patients (80%) had excellent outcomes, four (13.3%) had good outcomes, and two (6.7%) had fair outcomes; no patient had a poor outcome. Thus, 93.3% achieved good-to-excellent functional outcomes.

Table 5: Functional outcome according to AOFAS score.

Follow-ups	Excellent (%)	Good (%)	Fair (%)	Poor (%)
6 weeks	0	2 (6.7)	10 (33.3)	18 (60)
12 weeks	2 (6.7)	8 (26.7)	12 (40)	8 (26.7)
6 months	8 (26.7)	12 (40)	8 (26.7)	2 (6.7)
9 months	16 (53.3)	10 (33.3)	4 (13.3)	0
12 months	24 (80)	4 (13.3)	2 (6.7)	0

DISCUSSION

The present prospective cohort study evaluated 30 adults with closed bimalleolar ankle fractures treated with ORIF and followed for 12 months. The principal finding was progressive improvement across pain, walking ability, gait, ankle motion, stability, alignment, and AOFAS functional category, with 93.3% of patients achieving good-to-excellent outcomes at one year.

Age, sex and mechanism of injury

The mean age in the present study was 45.4 years, with all patients between 31 and 60 years. This distribution is compatible with the economically active age group commonly represented in operative ankle-fracture series. Hemanth et al reported a broader age range of 17-73 years in a prospective series of 90 surgically treated ankle fractures, while their cohort also showed a male predominance and road traffic accidents as the commonest

mechanism. In the present study, males constituted 60% and road traffic accidents accounted for 66.7%, indicating a similar demographic and injury pattern. Age and comorbidity are relevant prognostic variables in operative ankle-fracture cohorts; Egol et al reported better short-term functional recovery among younger patients and better one-year recovery in men and in patients without diabetes or major systemic disease.^{8,10}

Overall functional outcome

The present study demonstrated a 93.3% good-to-excellent AOFAS outcome at 12 months, with 80% of patients achieving an excellent score. This compares favourably with the 2020 tertiary-care study by Dwivedi et al, in which the mean final AOFAS score was 89.86±7.95 and 86.2% of patients achieved excellent-to-good results. In a prospective series of surgically treated ankle fractures, Hemanth et al reported improvement in functional parameters between three and six months, with a mean

Olerud-Molander score of 81.7 ± 16.2 at six months. A larger prospective study by Egol et al reported that 90% of patients achieved at least 90% functional recovery at one year. The favourable one-year outcome in the present cohort is therefore consistent with the broader literature, although direct comparison is limited by differences in fracture composition, scoring systems, sample size, and rehabilitation protocols.^{7,8,10}

Pain

Pain showed a clear time-dependent improvement, with the proportion of pain-free patients increasing from none at six weeks to 80% at one year. This pattern is comparable with the prospective study of Egol et al, in which 88% of patients reported no or mild pain at one year after operative treatment. Hemanth et al, likewise demonstrated significant improvement in pain between three and six months. The progressive reduction in pain in the present cohort supports the expected benefit of stable fixation followed by rehabilitation, although pain outcomes remain influenced by age, comorbidity, injury severity, and postoperative complications.^{6,8,10}

Walking ability and activity

At one year, 90% of patients walked comfortably on uneven surfaces, 86.7% could walk more than six blocks, and 80% had no activity limitation. Egol et al reported that 90% of their surgically treated cohort had no limitations or only recreational limitations at one year, closely paralleling the present findings. Hemanth et al also documented significant improvement in walking and activity between three and six months. These observations suggest that functional gains continue during the later

rehabilitation period even after early postoperative pain and mobility restrictions have subsided.^{8,10}

Gait and range of motion

At final follow-up, 93.3% of patients had none or only a slight gait abnormality, while 93.3% had normal hindfoot motion and 86.7% had normal sagittal ankle motion. Segal et al. demonstrated that patients with bimalleolar fractures may have measurable gait impairment and asymmetry during the early weight-bearing phase, particularly when compared with healthy controls. The higher level of gait recovery observed at 12 months in the present study is compatible with progressive rehabilitation but should not be interpreted as complete normalization in every patient. Similarly, Salas-Gómez et al reported persistent dorsiflexion and balance deficits at 12 months despite good clinical recovery after ORIF, emphasizing that patient-reported function and objective biomechanical recovery may not be identical.^{9,11}

Ankle stability and alignment

All patients in the present cohort had a stable ankle and good alignment at final follow-up. These findings are clinically important because restoration of fibular length, rotation, and mortise congruity is central to maintaining normal ankle biomechanics. The biomechanical work of Ramsey and Hamilton demonstrated a marked reduction in tibiotalar contact area with even minimal lateral talar displacement, supporting the emphasis placed on anatomical reduction in the present study. Long-term systematic review evidence also indicates that anatomical reduction is important for durable functional outcomes, while post-traumatic degenerative changes may become apparent only after longer follow-up.^{3,4}

Table 6: Comparison of functional outcomes with previous studies.

Studies	Sample / follow-up	Outcome measure	Reported result
Dwivedi et al, 2020 ⁷	29; final follow-up	AOFAS	Mean 89.86 ± 7.95 ; 86.2% excellent/good
Hemanth et al, 2016 ⁸	90; 6 months	Olerud-Molander	Mean 81.7 ± 16.2 ; significant improvement from 3 to 6 months
Salas-Gómez et al, 2022 ⁹	21 completed; 12 months	AOFAS/OMAS	AOFAS 84.4 ± 12.4 at 12 months
Egol et al, 2006 ¹⁰	198 complete follow-up; 1 year	AOFAS/SMFA	90% achieved $\geq 90\%$ functional recovery
Present study	30; 12 months	AOFAS	93.3% good/excellent; 80% excellent

Comparison with previous literature

The main comparative studies relevant to the present cohort are summarized in Table 6. The present good-to-excellent rate of 93.3% is numerically higher than that reported by Dwivedi et al (86.2%), while the AOFAS value reported by Salas-Gómez et al at 12 months was 84.4 ± 12.4 . Egol et al reported 90% of patients achieving at least 90% functional recovery at one year. These differences should be interpreted cautiously because the

studies differed in sample size, fracture spectrum, outcome instruments, follow-up methodology, and rehabilitation protocols.

Clinical implications

The findings support the importance of anatomical reduction, stable internal fixation, and structured rehabilitation in the management of unstable closed bimalleolar ankle fractures. The progressive recovery

observed through one year suggests that functional assessment should extend beyond the early postoperative period. Because the present study had no non-operative or alternative-fixation comparison group, the findings demonstrate outcomes within a surgically treated cohort rather than comparative treatment superiority.

Strengths of the study include its prospective design, standardized operative and rehabilitation protocols, complete 12-month follow-up, serial functional assessment, and real-world data from a tertiary care teaching hospital.

The study has several limitations. The sample size was small and the study was conducted at a single centre, limiting statistical power and external validity. There was no comparison group managed non-operatively or with alternative fixation techniques. Functional assessment relied primarily on the AOFAS score, and incorporation of an additional patient-reported outcome measure such as the Olerud-Molander Ankle Score would have strengthened the assessment.¹²

Finally, one year of follow-up may be insufficient to determine the incidence of post-traumatic osteoarthritis or late implant-related problems. Long-term multicentre studies with larger samples and comparative groups are warranted.¹²

CONCLUSION

In this prospective cohort of 30 adults with closed bimalleolar ankle fractures, ORIF was associated with progressive improvement in pain, walking ability, gait, ankle motion, stability, alignment, and AOFAS functional category over 12 months. At final follow-up, 93.3% of patients achieved good-to-excellent functional outcomes and 80% achieved excellent outcomes. The results support ORIF, when combined with anatomical reduction, stable fixation, and structured rehabilitation, as an effective treatment strategy for unstable closed bimalleolar ankle fractures. Larger multicentre studies with longer follow-up and comparative treatment groups are needed to determine the durability of these outcomes and the development of late post-traumatic degenerative changes.

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