Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(4), 2616-2625 | ISSN:2251-6727

Impact of Preoperative CT on Surgical Planning in Posterior Malleolus Involvement of Trimalleolar Ankle Fractures: A Prospective Observational Study

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(Received: 16 June 2025 Revised: 20 July 2025 Accepted: 19 August 2025)

KEYWORDS

Posterior malleolus, CT imaging, trimalleolar ankle fracture, surgical planning, fixation strategy, Haraguchi classification

ABSTRACT:

Introduction: Posterior malleolar fractures, commonly seen in trimalleolar ankle injuries, pose significant challenges in surgical management due to their complex morphology. While conventional radiographs form the basis of initial planning, computed tomography (CT) offers enhanced visualization that may influence preoperative decision-making.

Objectives: To evaluate the impact of preoperative CT imaging on surgical planning for trimalleolar ankle fractures involving the posterior malleolus.

Methods: This prospective observational study was conducted at the Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Tamil Nadu, between August 2023 and February 2025. A total of 53 adult patients with trimalleolar ankle fractures underwent surgical treatment. Two preoperative surgical plans were formulated per patient: Plan A (based on X-ray) and Plan B (revised after CT review), by a panel of four senior orthopedic surgeons. These were compared with the actual intraoperative decisions regarding fixation method, surgical approach, and patient positioning. The posterior malleolus was classified using the Modified Haraguchi system, and inter-modality agreement was analyzed using Kappa statistics.

Results: CT imaging altered the fixation strategy in a significant number of cases. CC screw fixation increased from 41.5% (X-ray) to 50.9% (CT), while plate fixation increased from 24.5% to 30.2%. Intraoperative decisions showed strong agreement with CT-based plans (Kappa = 0.815 for CC screws; Kappa = 0.859 for plating; $p = 0.001$). The use of anterior-to-posterior screws increased from 34.0% (X-ray) to 43.4% (CT), and posterior-to-anterior screw plans showed perfect agreement (Kappa = 1.000). CT also influenced patient positioning, with Lazy Prone and Prone-to-Supine conversions employed more frequently post-CT. Type I Haraguchi fractures were most common (62.3%), but Type II and III required more complex fixation approaches

Conclusions: CT imaging significantly improves preoperative surgical planning for posterior malleolus fractures by providing better assessment of fragment morphology, influencing fixation method, approach, and patient positioning. CT-based strategies align more closely with intraoperative requirements than X-ray-based plans, supporting its routine use in managing complex ankle fractures.

1. Introduction

Ankle fractures are among the most common orthopedic injuries, with an annual incidence of 122–184 per 100,000 person-years (1,2). Posterior malleolar fractures account for 7% to 44% of these and are often associated with complex patterns requiring careful management (1,3). The posterior malleolus, described by Henderson as part of the weight-bearing tibial surface, contributes significantly to ankle joint stability and congruity. Its involvement is linked to long-term complications such as chronic instability and post-traumatic arthritis (1).

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JCHR (2025) 15(4), 2616-2625 | ISSN:2251-6727

Functionally, the posterior malleolus serves as the insertion point for the posteroinferior tibiofibular ligament (PITFL), and displacement of this fragment—particularly when involving >25% of the articular surface—can lead to increased joint pressure, incongruity, and adverse outcomes (1,4). A step-off >2 mm is associated with fibular subluxation and syndesmotic failure (1). Emerging evidence suggests that even smaller, unreduced fragments may destabilize the ankle, questioning the conventional fixation threshold of 25–33% (1).

Traditional classification systems (Lauge-Hansen, Danis-Weber) based on radiographs often underestimate fracture complexity. In contrast, CT-based classifications—especially the Haraguchi system—offer a clearer assessment of posterior fragment morphology and enhance surgical planning (5–7). The Haraguchi classification defines three distinct fracture types and has shown strong clinical reliability (5). CT has thus become the preferred preoperative imaging modality due to its superior accuracy in evaluating fragment configuration and guiding the choice of approach and fixation (6).

Marginal impaction, although first described in acetabular injuries, is now recognized in ankle fractures. Often missed on radiographs, this osteochondral depression is better visualized on CT, particularly in supination-adduction type II fractures, where it can influence surgical decision-making (8).

Despite the increasing use of CT, there is limited quantitative evidence on its actual impact in altering preoperative surgical plans for posterior malleolar fractures. This study aims to evaluate whether the inclusion of CT imaging significantly changes the operative strategy—particularly in terms of approach, fixation method, and patient positioning—in trimalleolar ankle fractures and fracture-dislocations.

2. Objectives

To evaluate the role of preoperative CT imaging in surgical planning of trimalleolar ankle fractures involving the posterior malleolus.

- To formulate and compare preoperative surgical plans based on plain radiographs (Plan A) and CT imaging (Plan B).
- To determine whether CT imaging influences surgical decision-making, including approach, fixation method, and patient positioning.

3. Methods

Study Design and Setting

This was a prospective, observational, descriptive study conducted in the Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Kattankulathur, Tamil Nadu.

Study Period

The study was carried out over a 2-year period from August 2023 to February 2025.

Study Population

Fifty-three adult patients with trimalleolar ankle fractures or fracture-dislocations who underwent operative treatment were included.

Inclusion Criteria

- Patients aged 18 years and above
- Trimalleolar ankle fractures and fracture dislocations

Exclusion Criteria

- Pilon fractures
- Age < 18 years
- Non-union fractures

Sample Size Calculation

The required sample size was calculated using the formula:

$$n \geq \frac{Z^2{}_{1-\alpha/2} \cdot P(1-P)}{d^2}$$

Where:

- Z_{1}–$\alpha/2$ = 1.96 (for 95% confidence interval)
- P = 0.166 (estimated prevalence of CT-based surgical change)
- d = 0.10 (precision)

$$n = \frac{(1.96)^2 \times 0.166 \times (1-0.166)}{(0.10)^2}$$

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$$n = \frac{3.84 \times 0.166 \times 0.834}{0.01}$$

$$n = \frac{5.3162}{0.01} = 53.16$$

Thus, the final sample size was approximated to 53 patients. The formula used is standard for estimating proportions in prevalence studies and is supported by Naing et al. (9).

Eligible patients were evaluated using:

- **Plain radiographs**, classified using the Lauge-Hansen system and assessed for percentage of articular surface involvement.
- **CT scans**, with posterior malleolus fragments classified according to the Modified Haraguchi classification.

A panel of four senior orthopedic surgeons independently developed:

- **Plan A**: based on X-ray findings alone
- **Plan B**: revised after reviewing CT findings

Each plan addressed:

- Patient positioning
- Surgical approach
- Sequence of fixation
- Mode of fixation

Intraoperative decisions were documented and compared with Plans A and B to evaluate the influence of CT imaging on surgical planning.

4. Results

A total of 53 patients with trimalleolar ankle fractures were included in the study. The demographic and injury-related characteristics are summarized in **Table/Fig 1.**

Demographic Characteristics

The majority of patients (26.4%) were in the 51–60 years age group, followed by those under 40 years (24.5%). Males constituted 67.9% of the study population (**Table/Fig 1**).

Occupational and Injury Profile

Most patients were business professionals (50.9%), followed by homemakers (26.4%) and employees (17%). The most common mode of injury was road traffic accidents (RTA), accounting for 73.6% of cases. Closed fractures were observed in 92.5% of cases, and only 3.8% had associated long bone injuries (**Table/Fig 2**).

Radiographic and CT-Based Classification

According to Lauge-Hansen classification, 62.3% of cases were Supination-External Rotation (SER) type, and the rest were Pronation-External Rotation (PER) (**Table/Fig 3**). Based on articular surface involvement, **75.5%** had less than 25% joint surface involvement.

Posterior malleolus fractures were classified using Modified Haraguchi classification on CT scans: Type I (posterolateral) in 62.3%, and Types II and III both in 18.9% each (**Table/Fig 4**).

Effect of CT on Fixation Method and Surgical Approach

The choice of fixation method changed significantly following CT evaluation. CC screw fixation increased from 41.5% based on plain radiographs to 50.9% after CT, and plate fixation rose from 24.5% to 30.2%. Intraoperative findings were largely consistent with CT-based decisions, indicating that CT scans provided a more reliable basis for preoperative planning. Kappa values reflected strong agreement between CT-based and intraoperative decisions for both screw and plate fixations (Kappa = 0.815 and 0.859, respectively), with all comparisons showing high statistical significance (p = 0.001) **(Table/Fig 5).** The comparison of fixation strategies based on X-ray, CT, and intraoperative decisions is illustrated in **Table/Fig 6**, following the corresponding data presented in Table/Fig 5.

CT imaging also had a notable impact on the surgical approach. The use of the percutaneous anterior-to-posterior CC screw approach increased from 34.0% (X-ray) to 43.4% (CT), and posterolateral plating saw a rise from 20.8% to 24.5%. Posterior-to-anterior fixation remained consistent across all stages, showing perfect agreement (Kappa = 1.000). Overall, CT guidance resulted in more tailored and consistent intraoperative decisions, with Kappa values indicating strong to perfect agreement across various approaches and all p-values remaining statistically significant **(Table/Fig 7).**

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JCHR (2025) 15(4), 2616-2625 | ISSN:2251-6727

Surgical Approach and Fixation Strategy

After CT evaluation, a notable shift toward the percutaneous anterior-to-posterior approach using CC screws (from 34% to 43.4%) was observed. Posterolateral plating was also used more frequently after CT imaging. Posterior-to-anterior fixation had perfect agreement across all stages (Kappa = 1.0) (**Table/Fig 8**).

Patient Positioning Based on Imaging

The surgical positioning plan changed post-CT in several cases. Supine positioning was most common (67.9% post-CT), followed by Lazy Prone and Prone-to-Supine conversions. Agreement across all three stages (X-ray, CT, and intraoperative) was **strong to very strong**, with statistically significant differences (**Table/Fig 9**).

5. Discussion

The present prospective observational study assessed the impact of computed tomography (CT) on preoperative surgical planning in trimalleolar ankle fractures, specifically focusing on posterior malleolus involvement. The findings underscore that CT imaging plays a pivotal role in enhancing the precision of surgical decision-making by influencing fixation strategies, surgical approach selection, and patient positioning, thereby aligning preoperative planning more closely with intraoperative execution.

In this cohort, CT-based evaluation resulted in a marked shift in the choice of fixation methods. CC screw fixation increased from 41.5% (X-ray-based plan) to 50.9% following CT review, while plate fixation rose from 24.5% to 30.2%. These decisions were closely mirrored intraoperatively, with Kappa values of 0.815 for CC screws and 0.859 for plate fixation, indicating strong agreement. This concordance supports the role of CT in offering detailed visualization of fracture morphology—including fragment size, orientation, and articular surface involvement—which is often underappreciated on plain radiographs alone (7,10). Literature suggests that posterior malleolus fractures involving more than 25% of the tibial plafond require anatomical reduction and fixation to restore tibiotalar congruity and reduce the risk of post-traumatic arthritis (11–13).

Surgical approach selection was similarly influenced by CT. Use of the percutaneous anterior-to-posterior screw technique increased from 34.0% to 43.4%, and posterolateral plating saw greater utilization. Posterior-to-anterior screw fixation maintained 100% agreement across planning and intraoperative phases (Kappa = 1.000), suggesting its role remains limited to specific, well-visualized fracture patterns. These findings align with evidence advocating individualized approaches based on posterior column involvement, syndesmotic stability, and fragment configuration (10,14).

CT imaging also allowed improved classification of fractures using the Haraguchi system, which provides superior clinical relevance compared to traditional systems like Lauge-Hansen. Type I (posterolateral) fractures were most common (62.3%), but it was the Type II (medial extension) and Type III (shell-type) patterns—better visualized on CT—that frequently required complex approaches like posteromedial or posterolateral plating. Prior study have shown that Type II fractures are associated with poorer outcomes and syndesmotic instability (15), while CT-derived classifications offer superior interobserver reliability and surgical guidance (16).

Beyond fixation and classification, CT imaging also guided intraoperative patient positioning. While supine remained the most common (67.9%), 17.0% of patients required Lazy Prone positioning, and 15.1% underwent prone-to-supine repositioning. Such tailored planning likely minimized intraoperative time, improved access, and reduced fluoroscopy exposure. Similar adaptations were reported by Donohoe et al., who observed changes in operative strategy in nearly half the cases after CT review (17).

Traditional radiographic classifications like Lauge-Hansen, while informative in understanding injury mechanism, proved inadequate for guiding management in posterior malleolus injuries. Although over 75% of cases had <25% articular involvement by X-ray, CT revealed structural complexities necessitating fixation—highlighting the diagnostic superiority of CT (18).

A growing body of literature supports the integration of CT in routine preoperative planning. Sheikh et al. found that CT altered posterior fixation decisions in 25.6% of cases (19). Furthermore, CT better quantifies posterior fragment size and reveals marginal impaction—key indicators for fixation—that are frequently missed on plain radiographs (20,21). Outcome-oriented studies affirm that CT-guided surgical planning improves long-term functional scores and reduces the incidence of post-traumatic arthritis, particularly in cases involving posteromedial fragments (22).

Despite its strengths, this study has limitations. The single-center design and moderate sample size may limit the generalizability of findings. Moreover, the study did not assess postoperative functional outcomes or complication rates. Future studies incorporating longitudinal follow-up are warranted to evaluate the clinical benefits of CT-based surgical planning, particularly its role in preserving ankle joint function and preventing degenerative changes.

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Table/Fig 1: Demographic characteristics including age and sex distribution.

AGE GROUP	NO. OF CASES	PERCENTAGE
< 40	13	24.5%
41-50	11	20.8%
51-60	14	26.4%
61-70	11	20.8%
> 70	4	7.5%
Total	53	100.0%

Table/Fig 2: Occupation, mode of injury, fracture type, and associated injuries.

OCCUPATION	NO. OF CASES	PERCENTAGE
Business	27	50.9%
Doctor	1	1.9%
Employee	9	17.0%
Farmer	2	3.8%
Homemaker	14	26.4%
Total	53	100.0%

Table/Fig 3: Radiographic Classification Based on Lauge-Hansen Mechanism and Articular Surface Involvement (n = 53)

CLASSIFICATION TYPE	SUB-CATEGORY	NO. OF CASES	PERCENTAGE (%)

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Lauge-Hansen Type	Supination External Rotation (SER)	33	62.3%
	Pronation External Rotation (PER)	20	37.7%
Articular Surface Involvement	< 25% of articular surface	40	75.5%
	> 25% of articular surface	13	24.5%

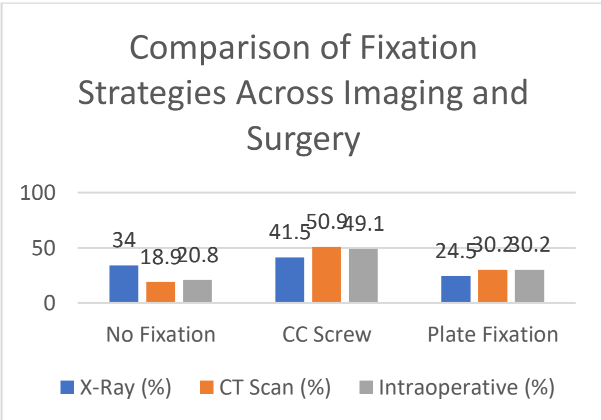
Table/Fig 4: Distribution of posterior malleolus fractures based on Haraguchi classification.

SL.NO.	TYPE	NO. OF CASES	PERCENTAGE
1	PL	33	62.3%
2	PL+PM	10	18.9%
3	SS	10	18.9%

Table/Fig 5: Comparison of Fixation Methods for Posterior Malleolus Based on Imaging Modality and Intraoperative Findings (n = 53)

SL. NO.	TYPE OF FIXATION	X-RAY (N, %)	CT SCAN (N, %)	INTRAOPERATIVE (N, %)	KAPPA	P-VALUE
1	No Fixation	18 (34.0%)	10 (18.9%)	11 (20.8%)	0.625	0.001
2	CC Screw	22 (41.5%)	27 (50.9%)	26 (49.1%)	0.815	0.001
3	Plate Fixation	13 (24.5%)	16 (30.2%)	16 (30.2%)	0.859	0.001

Table/Fig 6: Bar chart comparing fixation strategies across X-ray, CT scan, and intraoperative assessment



Table/Fig 7: Comparison of Surgical Approaches for Posterior Malleolus Fixation Based on Imaging and Intraoperative Findings (n = 53)

SL. NO.	SURGICAL APPROACH	X-RAY (N, %)	CT SCAN (N, %)	INTRAOPERATIVE (N, %)	KAPPA	P-VALUE
1	No Fixation	18 (34.0%)	10 (18.9%)	11 (20.8%)	0.625	0.001

2	Percutaneous and CC Screw – Anterior to Posterior	18 (34.0%)	23 (43.4%)	22 (41.5%)	0.805	0.001
3	Percutaneous and CC Screw – Posterior to Anterior	4 (7.5%)	4 (7.5%)	4 (7.5%)	1.000	0.001
4	Posterolateral with Plate	11 (20.8%)	13 (24.5%)	13 (24.5%)	0.893	0.001
5	Posteromedial with Plate	2 (3.8%)	3 (5.7%)	3 (5.7%)	0.791	0.001

Table/Fig 8: Surgical Approaches Used for Posterior Malleolus Fixation Based on X-Ray, CT Scan, and Intraoperative Assessment (n = 53)

SL.NO.	**APPROACH**	**AFTER XRAY**	**AFTER XRAY**	**AFTER CT**	**AFTER CT**	**INTRA OPERATIVE**	**INTRA OPERATIVE**	**KAPPA**	**P-VALUE**
1	No Fixation	18	34.0%	10	18.9%	11	20.8%	0.625	0.001
2	Percutaneous and CC Screw- Anterior to Posterior	18	34.0%	23	43.4%	22	41.5%	0.805	0.001
	Posterior to Anterior	4	7.5%	4	7.5%	4	7.5%	1.000	0.001
3	Posterolateral with Plate	11	20.8%	13	24.5%	13	24.5%	0.893	0.001
4	Posteromedial with Plate	2	3.8%	3	5.7%	3	5.7%	0.791	0.001

Table/Fig 9: Distribution of patient positioning based on imaging stage.

SL. NO.	**PATIENT POSITION**	**AFTER XRAY**	**AFTER XRAY**	**AFTER CT**	**AFTER CT**	**INTRA OPERATIVE**	**INTRA OPERATIVE**	**KAPPA**	**P-VALUE**
1	Supine Position	39	73.6%	36	67.9%	36	67.9%	0.805	0.001
2	Lazy Prone	7	13.2%	9	17.0%	9	17.0%	0.876	0.001
3	Prone first and changed to Supine	7	13.2%	8	15.1%	8	15.1%	0.889	0.001

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JCHR (2025) 15(4), 2616-2625 | ISSN:2251-6727

Illustrative Cases Demonstrating CT-Guided Alterations in Surgical Planning

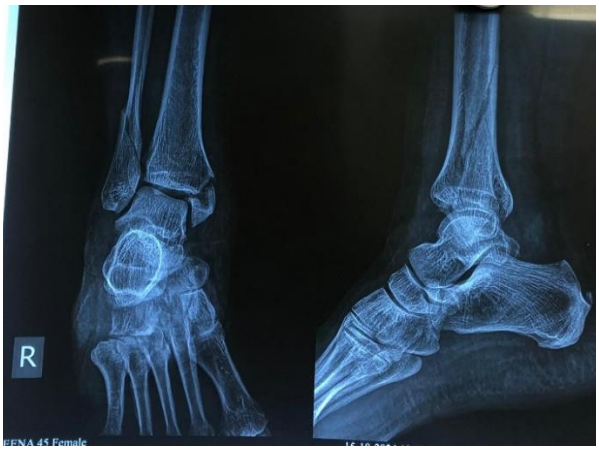
Case Illustration 1: CT-Guided Surgical Modification in a Type 2A Posterior Malleolus Fracture

A 45-year-old female from the study cohort presented with a right-sided trimalleolar ankle fracture following a fall. Initial evaluation with plain radiographs classified the injury as Supination-External Rotation (SER) type based on the Lauge-Hansen classification (**Table/Fig 10**). The preliminary surgical plan (Plan A), formulated using only plain radiographs, proposed prone-to-supine positioning with a posterolateral approach and plating of the posterior malleolus.

However, CT imaging revealed a Haraguchi Type 2A fracture pattern with posteromedial extension (**Table/Fig 11**), prompting a revision in Plan B to include additional fixation using a cannulated cancellous (CC) screw in addition to the plate. This revised strategy was adopted intraoperatively.

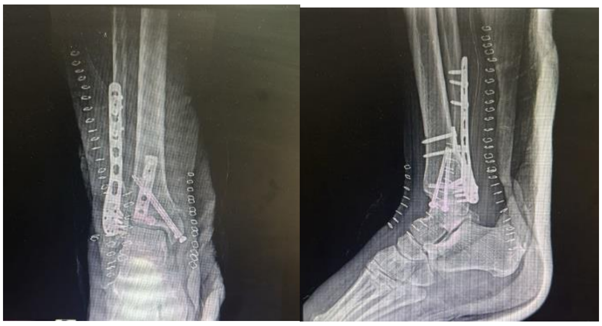
The final surgical procedure involved open reduction and internal fixation (ORIF) with lateral malleolar plating, combined plate and CC screw fixation for the posterior malleolus, and CC screw fixation for the medial malleolus. The postoperative outcome confirmed the modified approach (**Table/Fig 12**). This case underscores how CT imaging enabled enhanced surgical planning by revealing posterior fracture morphology not fully appreciated on plain radiographs.

Table/Fig 10: Preoperative plain radiograph (anteroposterior and lateral views) showing trimalleolar ankle fracture – Supination-External Rotation type.



Table/Fig 11: Axial and sagittal CT images demonstrating Haraguchi Type 2A posterior malleolar fracture with posteromedial extension.

Table/Fig 12: Postoperative radiograph showing ORIF with lateral plate, posterior plate, and medial CC screw fixation.



Case Illustration 2: CT-Driven De-escalation of Posterior Malleolus Fixation in a Type 3 Fracture

A 52-year-old female patient with a right-sided trimalleolar ankle fracture was evaluated. Plain radiographs initially suggested a Supination-External Rotation (SER) mechanism under the Lauge-Hansen classification (**Table/Fig 13**). Based on radiographs alone (Plan A), the surgical plan involved prone-to-supine positioning and percutaneous cannulated cancellous (CC) screw fixation for the posterior malleolus.

However, preoperative CT imaging revealed a Haraguchi Type 3 posterior malleolar fracture—characterized by a thin shell fragment with minimal articular involvement and no significant displacement (**Table/Fig 14**). The CT-based plan (Plan B) therefore recommended no fixation

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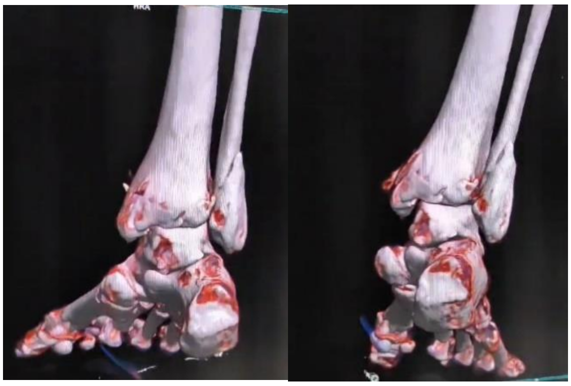
for the posterior malleolus and allowed the surgery to be performed entirely in the supine position.

This change was accepted and executed intraoperatively. The final procedure included open reduction and internal fixation (ORIF) with plating for the lateral malleolus and CC screw fixation for the medial malleolus, while no fixation was applied to the posterior fragment (**Table/Fig 15**). This case demonstrates how CT imaging can prevent unnecessary surgical intervention by accurately identifying non-fixation indications in thin, nondisplaced posterior fragments.

Table/Fig 13: Preoperative plain radiograph (anteroposterior and lateral views) showing trimalleolar ankle fracture – Supination-External Rotation type.

Table/Fig 14: Axial and sagittal CT views depicting Haraguchi Type 3 posterior malleolar fracture with shell-like morphology.



Table/Fig 15: Postoperative radiograph showing lateral and medial fixation, with no fixation applied to the posterior malleolus.