Direct Cannulated Screw Fixation of Bartoníček-Rammelt Type 2 and Type 3 Posterior Malleolar Fractures

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ABSTRACT
Introduction: The importance of the posterior malleolus in ankle stability has been demonstrated in numerous studies, and most authors agree that surgical fixation is indicated when the fragment involves more than 25-30% of the articular surface. However, the optimal fixation method remains controversial. **Objective:** To evaluate the mid-term outcomes of isolated fixation of posterior malleolar fractures using cannulated screws, with particular emphasis on functional recovery, joint stability, and complication rates. **Materials and Methods:** A retrospective study was conducted between January 2018 and December 2022. Inclusion criteria were age >18 years, posterior malleolar fractures treated exclusively with cannulated screws, and a minimum follow-up of 24 months. Clinical and radiographic evaluations were performed preoperatively and postoperatively. **Results:** Fifty-eight patients were included. The mean fragment size was 28.4% of the articular surface. Anatomic reduction was achieved in 82.7% of cases, with a union rate of 100%. At follow-up, ankle dorsiflexion was reduced by 25% and plantar flexion by 20%. The *American Orthopaedic Foot & Ankle Society* (AOFAS) score improved from 58.4 to 88.6, while the Visual Analog Scale (VAS) pain score decreased from 7.1 to 2.8. The overall complication rate was 17.2%. **Conclusions:** Direct fixation of the posterior malleolus with cannulated screws is an effective strategy for the management of these fractures, achieving high rates of anatomic reduction and a complication profile comparable to that of other fixation methods.
Keywords: Fracture; posterior malleolus; ankle.
Level of Evidence: IV

Fijación directa con tornillos canulados de las fracturas tipos 2 y 3 de Bartoníček y Rammelt

RESUMEN
Introducción: En numerosos estudios, se ha demostrado la importancia del maléolo posterior en la estabilidad del tobillo, y la mayoría concuerda en que es necesaria la fijación quirúrgica cuando el fragmento representa >25-30% de la superficie articular. Sin embargo, el método de fijación ideal sigue siendo controvertido. **Objetivo:** Evaluar los resultados a mediano plazo de la fijación exclusiva de fracturas del maléolo posterior con tornillos canulados, especialmente la recuperación funcional, la estabilidad articular y las tasas de complicaciones. **Materiales y Métodos:** Estudio retrospectivo realizado entre enero de 2018 y diciembre de 2022. Los criterios de inclusión fueron: edad >18 años, fracturas fijadas exclusivamente con tornillos canulados y un seguimiento mínimo de 24 meses. Se llevaron a cabo evaluaciones clínicas y radiológicas pre y posoperatorias. **Resultados:** Se incluyó a 58 pacientes. El tamaño promedio del fragmento fue del 28,4%. Se logró una reducción anatómica en el 82,7% de los casos, con una tasa de consolidación del 100%. En el seguimiento, la dorsiflexión disminuyó un 25% y la flexión plantar, un 20%. El puntaje de la escala de la AOFAS mejoró de 58,4 a 88,6, mientras que el puntaje de la escala analógica visual para dolor disminuyó de 7,1 a 2,8. La tasa global de complicaciones fue del 17,2%. **Conclusiones:** La fijación directa del maléolo posterior con tornillos canulados representa una estrategia efectiva para el manejo de estas fracturas, con altas tasas de reducción anatómica y un perfil de complicaciones comparable con el de otros métodos de fijación.
Palabras clave: Fractura; maléolo posterior; tobillo.
Nivel de Evidencia: IV

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INTRODUCTION

Ankle fractures involving the posterior malleolus (PM) are associated with poorer clinical outcomes and a higher risk of osteoarthritis.[1-3] Numerous studies have demonstrated the importance of the PM in ankle stability, and most authors agree that surgical fixation is necessary when the fragment accounts for more than 25-30% of the articular surface.[4–8] Regardless of the size of the posterior malleolus, in recent years, greater attention has been paid to the anatomical restoration of the incisura and to the stability of the distal tibiofibular syndesmosis by directly reducing and fixing the posterior fragment.[9] There are various fixation options, such as anteroposterior or posteroanterior screws, buttress plates, or a combination of these techniques.[9–12] However, the ideal fixation method remains controversial.

Fixation of the PM with posterior screws allows for anatomical reduction and absolute stability, which are fundamental factors for adequate treatment.[13] Nevertheless, its effectiveness in terms of functional outcomes remains an active area of research.[14,15] The biomechanical stability of screw fixation has been questioned in comparison with other fixation methods, which motivated the present study.

The objective of this study was to evaluate the mid-term outcomes of treatment using cannulated screws alone for PM fractures. Through clinical and imaging evaluations, we sought to analyze key aspects, such as functional recovery, joint stability, and the occurrence of complications, as well as to identify predictors of therapeutic success. The analysis of these results may contribute to a better understanding of the indications and limitations of this treatment strategy for PM fractures.

MATERIALS AND METHODS

After obtaining approval from our hospital's Ethics Committee (protocol number 9,273), we conducted a retrospective analysis of the department's database to identify all patients who underwent surgery for a trimalleolar ankle fracture between January 2018 and December 2022.

We included patients older than 18 years with acute unilateral ankle fractures (<15 days from injury) involving the PM, treated exclusively with screw fixation through a posterior approach, who underwent pre- and postoperative computed tomography (CT) and had a minimum follow-up of 24 months.

Patients were excluded if they had comorbidities that contraindicated surgery (poorly controlled diabetes mellitus, severe peripheral vascular disease), pre-existing pathology of the affected ankle, open fractures, avulsion fractures, or non-displaced fractures (<2 mm) in which the PM was not fixed.

Variables Analyzed

After reviewing the medical records, the following variables were recorded: sex, age, affected side, and associated comorbidities (body mass index, diabetes mellitus, smoking, peripheral vascular disease, among others).

All patients had standard ankle radiographs and pre- and postoperative computed tomography (CT) scans available for evaluation.

Preoperative CT images were used to determine the size of the PM fragment (%) and the presence of a third fragment. The axial slice with the largest measurable diameter, on which the contour of the intact tibial articular surface could be assessed, was used as the reference.[16] The Bartoníček-Rammelt classification was used to define the different types of PM fractures.[17]

The time from injury to surgery, operative time, and the surgical approach used (posteromedial or posterolateral) were documented.

Based on the immediate postoperative radiographs, the fixation construct was classified as follows: one buttress screw plus one compression screw, one buttress screw plus two compression screws, or one buttress screw plus one positional screw (Figure 1). The fixation construct was selected intraoperatively according to fragment size and whether the intercalary fragment was resected. In addition, the need for supplementary syndesmotic stabilization with a transsyndesmotic screw was recorded.

All measurements were performed by a single examiner (the operating surgeon and study author). Synapse Radiology PACS® software (version 5.7.000 AI, FUJIFILM Healthcare Americas Corporation, USA) was used for all measurements.

The quality of PM reduction was assessed on immediate postoperative axial and sagittal CT images and classified as anatomical (<1 mm articular gap/step-off), satisfactory (1-2 mm), or unsatisfactory (>2 mm).[18–20]

The timing of weight-bearing initiation and the time to fracture union were recorded, with union defined as disappearance of the fracture line in the PM fragment.[21]

Figure 1. Fixation constructs used. **A.** One buttress screw plus two compression screws. **B.** One buttress screw plus one compression screw. **C.** One buttress screw plus one positional screw.

At the final follow-up, a clinical examination was performed to assess ankle range of motion in comparison with the contralateral side.[13] Outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score and the visual analog scale (VAS) for pain.

Finally, treatment-related complications were recorded, including the development of mid-term degenerative changes. The degree of post-traumatic osteoarthritis was graded at final follow-up according to the radiographic classification of Bargon.[22]

Surgical Technique

All patients underwent surgery under spinal or general anesthesia in the prone position with a pneumatic thigh tourniquet. In 49 patients, a standard posterolateral approach was used between the flexor hallucis longus tendon and the peroneal tendons, with identification and protection of the sural nerve. In the remaining nine cases, a modified posteromedial approach was used to access displaced posteromedial fragments between the flexor hallucis longus tendon and the posterior tibial neurovascular bundle.

Once the fracture had been exposed, displaced intercalary fragments were resected when they impeded reduction (n = 12). Reduction was achieved under direct visualization using reduction forceps and confirmed by intraoperative fluoroscopy. A fully threaded cannulated screw with a washer was then placed at the proximal apex of the fragment to function as a buttress screw. Finally, depending on fragment size and morphology, one or two 4.0-mm cannulated screws were inserted to provide interfragmentary compression or, when the intercalary fragment had been resected, positional fixation (Figure 2). Syndesmotic stability was assessed intraoperatively using a fluoroscopic stress test, and a transsyndesmotic screw was inserted when instability persisted (43.1% of cases).

Technical Considerations and Pitfalls

Fixation using cannulated screws alone is a reproducible technique; however, it requires careful attention to several critical points that, in our experience, make the difference between a satisfactory outcome and an inadequate reduction.

First, accurate identification of the fracture fragment may be challenging in the presence of metaphyseal comminution or intercalary fragments. Preoperative CT evaluation with axial and sagittal reconstructions is essential for planning the size and number of screws.

Second, the decision to resect an intercalary fragment should be individualized. When its presence prevents anatomical reduction of the main posterior fragment, we recommend fragment resection followed by PM fixation using a buttress screw and a positional screw.

Third, the buttress screw with a washer should be placed at the proximal apex of the fragment and oriented perpendicular to the fracture line. Improper orientation may result in axial migration of the fragment and loss of reduction. Compression screws should be checked on lateral fluoroscopic views to ensure that they do not penetrate the tibiotalar joint.

A common pitfall is underestimating residual syndesmotic instability. Even after anatomical fixation of the PM, intraoperative stress testing may reveal persistent syndesmotic instability, as occurred in 43.1% of our series. Failure to perform this assessment may compromise the functional outcome.

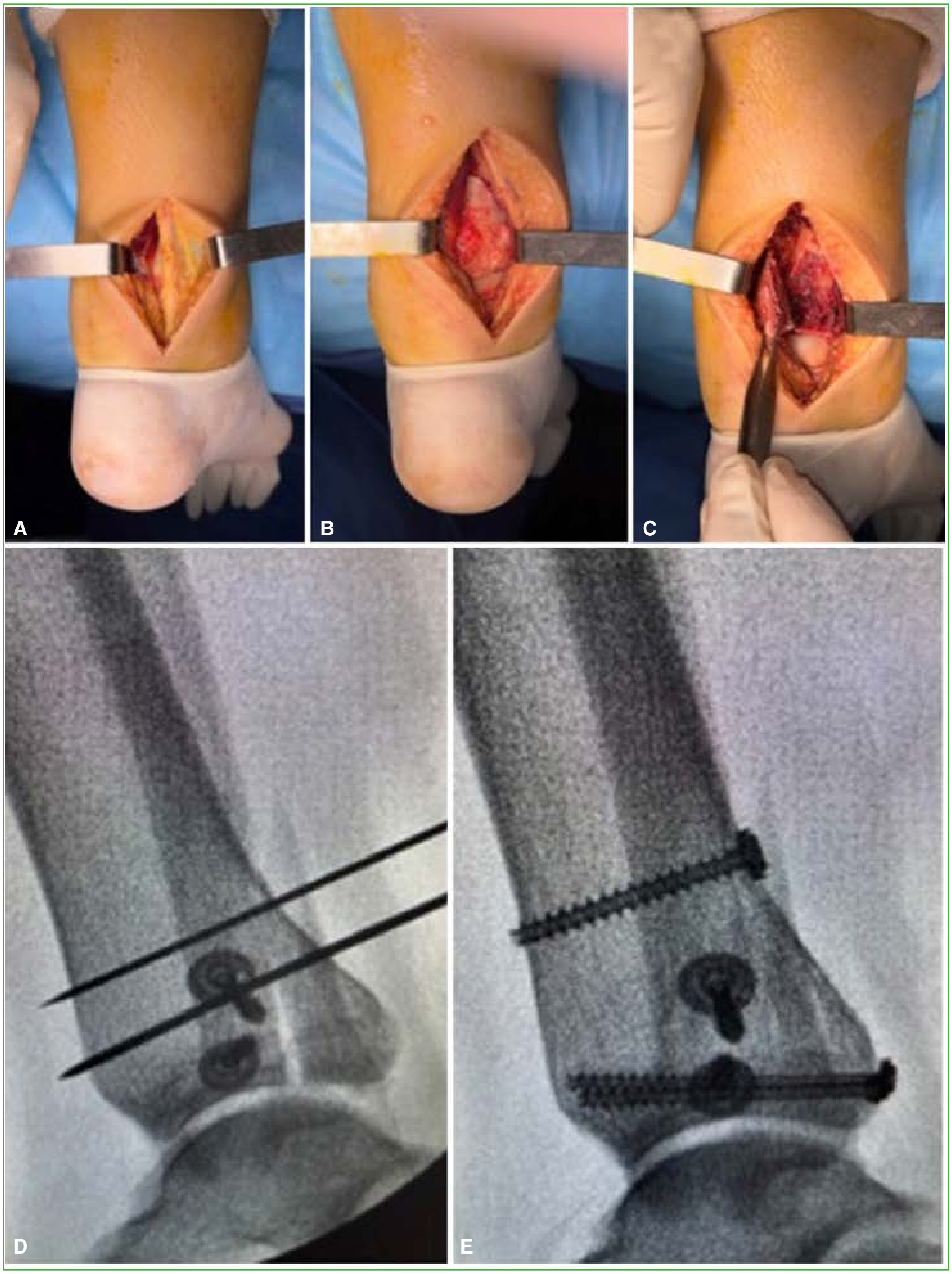

Figure 2. Surgical sequence for the posteromedial approach. **A.** Patient positioned prone with a posteromedial approach between the flexor hallucis longus tendon and the posterior tibial neurovascular bundle. **B.** Exposure and direct visualization of the posterior malleolus through the posteromedial approach. **C.** Mobilization of the posterior fragment under direct visualization to allow anatomical reduction. **D and E.** Intraoperative fluoroscopic images showing placement of the buttress screw with a washer at the proximal apex of the fragment to prevent shear displacement, followed by transfracture compression screws inserted through the posterior cortex to minimize tendon irritation.

Finally, posterior approaches allow the fixation construct to be tailored to the fracture pattern rather than forcing the fracture to conform to the fixation construct, as is often the case with posterior plating. The different screw configurations available, together with the possibility of countersinking the screws within the posterior cortex, facilitate anatomical reduction while minimizing the risk of irritation of the posterior tendons by the fixation hardware.

Statistical Analysis

Continuous variables are presented as mean and standard deviation or median and interquartile range, according to their distribution, whereas categorical variables are expressed as frequencies and percentages.

Continuous and categorical variables were compared using Student's *t* test and the χ^2 test (or Fisher's exact test, when appropriate), respectively. A p value <0.05 was considered statistically significant.

The collected data were entered into an Excel spreadsheet (Redmond, WA, USA), and statistical analyses were performed using GraphPad Prism version 8.0 (La Jolla, CA, USA).

RESULTS

Between January 2018 and December 2022, 223 patients were treated for ankle fractures involving the posterior malleolus (PM).

Ninety-eight patients were excluded because the PM was not fixed for various reasons (most had nondisplaced Bartoníček-Rammelt type 1 or type 2 fractures), 27 because fixation was performed with a buttress plate, 21 because preoperative or postoperative CT scans were unavailable, 9 because of open fractures, and 10 because of insufficient follow-up.

The final series comprised 58 patients with PM fractures treated exclusively with cannulated screw fixation and a mean follow-up of 32.5 ± 7.7 months. Demographic characteristics are summarized in Table 1.

Table 1. Characteristics of the patients included in the series (n = 58).

Gender, n (%)	
Female	37 (63.8)
Male	21 (36.2)
Age (mean, SD)	44.6 ± 16.4
Side, n (%)	
Right	26 (44)
Left	32 (56)
Comorbidities	
BMI (mean, SD)	26.9 ± 4.2
Diabetes, n (%)	5 (8.6)
Smoking, n (%)	4 (6.9)
Vascular, n (%)	2 (3.5)

SD = standard deviation; BMI = body mass index.

The mean PM fragment size was 28.4 ± 7.0% (range, 20–38%) of the tibiotalar articular surface. Twelve fractures (20.7%) were associated with an intercalary fragment.

Thirty-three of the 58 PM fractures (57%) were Bartoníček-Rammelt type 2 and 25 (43%) were type 3. No type 4 fractures were treated with screw fixation alone.

Surgery was performed at a mean of 8.9 ± 4.6 days after injury. Mean operative time was 93.3 ± 40.6 minutes. A posterolateral approach was used in 49 patients (84.5%) and a modified posteromedial approach in the remaining 9 (15.5%).

In 39 patients (67.3%), fixation consisted of a full-threaded cannulated buttress screw with a washer placed at the apex of the fracture, supplemented by two transfracture compression screws. In 12 patients (20.7%), fixation consisted of a buttress screw plus one compression screw, whereas in the remaining 7 (12%), a buttress screw plus one positional screw was used. In these latter cases, this construct was selected because displaced intercalary fragments had been resected to achieve anatomical reduction of the PM.

Despite direct fixation of the PM, additional syndesmotic stabilization with a transsyndesmotic screw was required in 25 cases (43.1%).

According to postoperative CT scans, 48 patients (82.7%) achieved an anatomical reduction of the PM, 9 (15.5%) a satisfactory reduction, and 1 (1.8%) an unsatisfactory reduction (Figures 3–5).

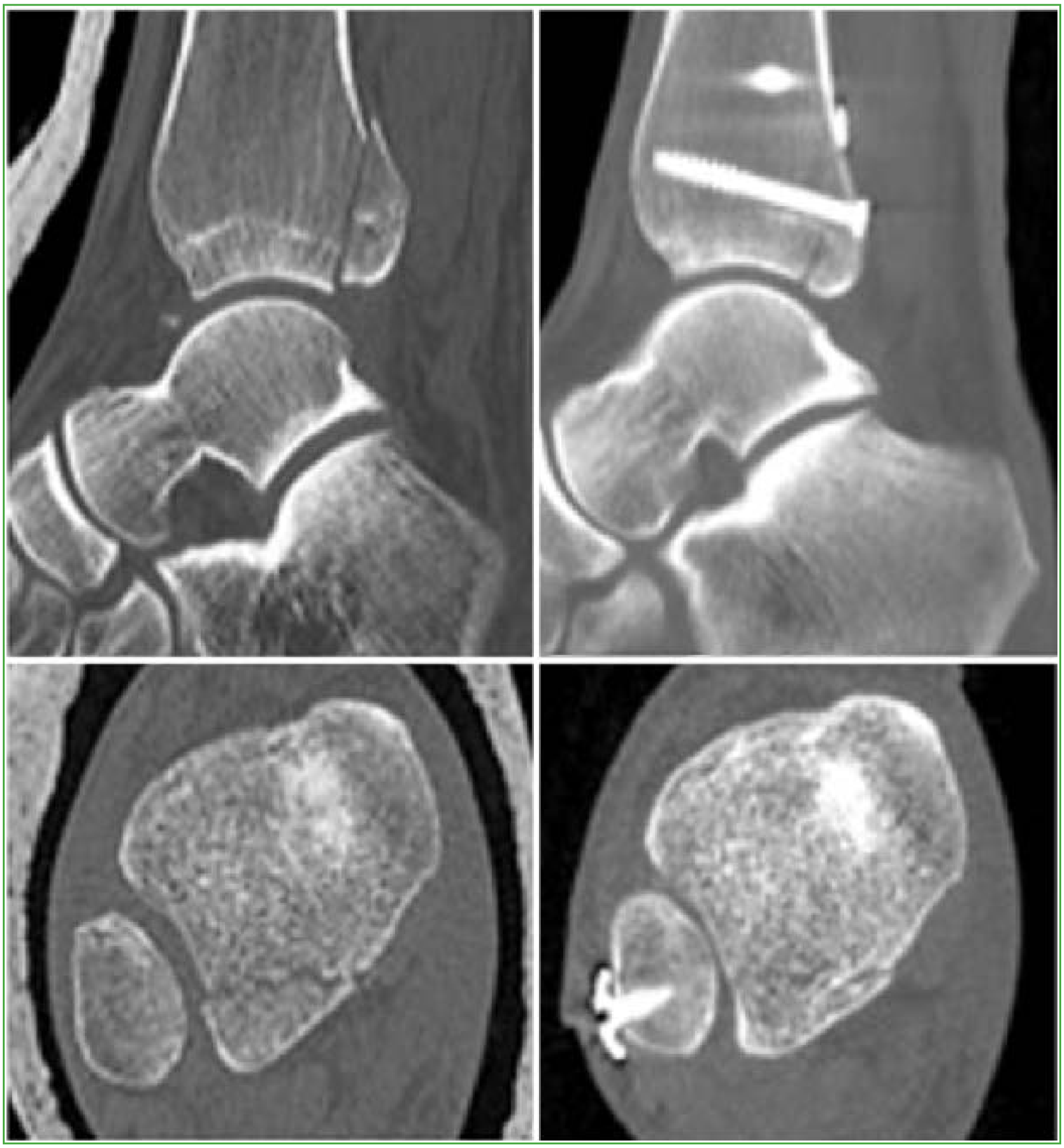

Figure 3. Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: anatomical reduction. No displacement is observed.

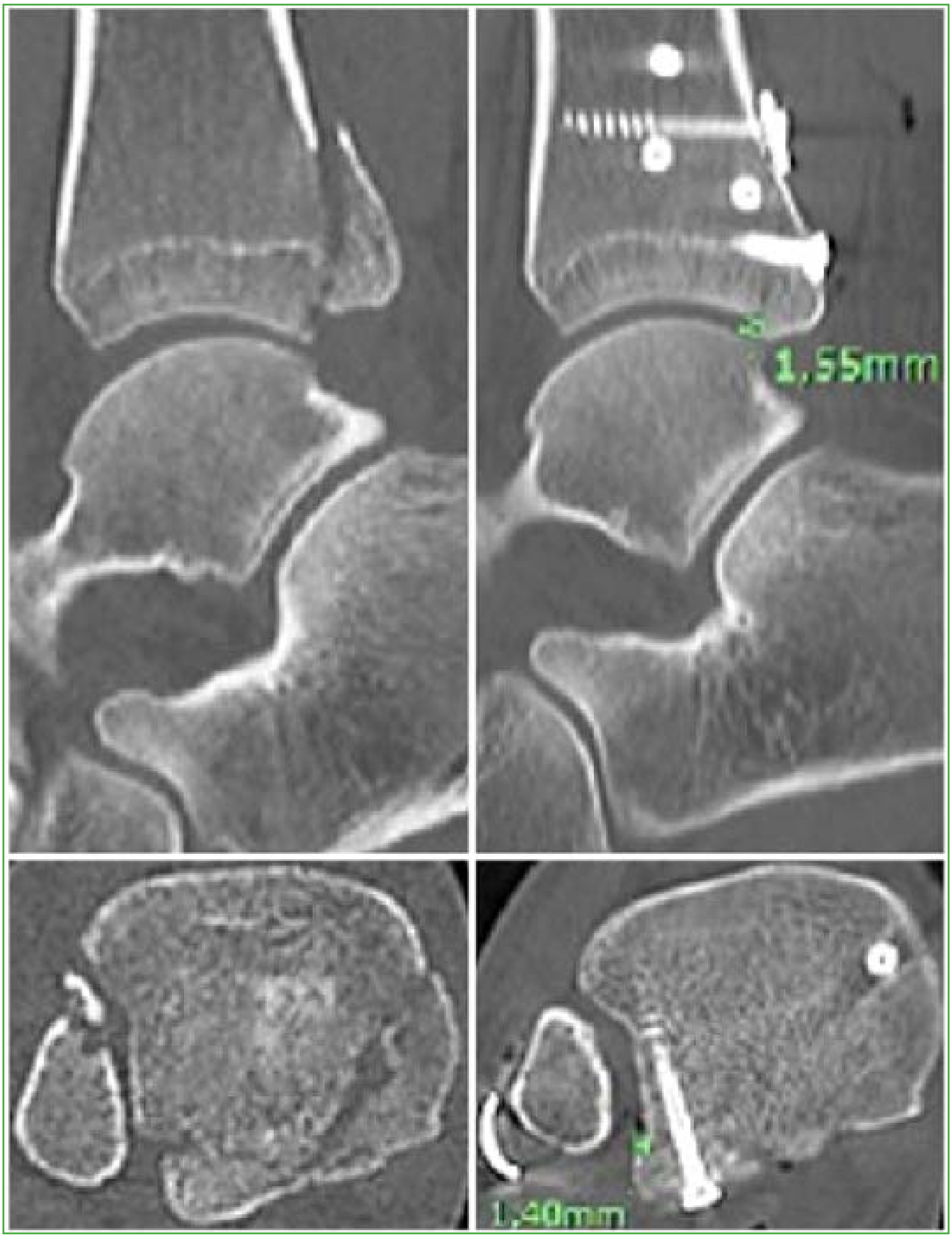

Figure 4. Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: satisfactory reduction. Residual displacement between 1 and 2 mm is observed.

Figure 5. Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: unsatisfactory reduction. Residual displacement >2 mm is observed.

Progressive weight-bearing was initiated at a mean of 5.3 ± 0.8 weeks, and PM union was achieved at a mean of 16.3 ± 3.8 weeks. The union rate at final follow-up was 100%.

Comparative assessment of ankle range of motion showed a 25% reduction in dorsiflexion and a 20% reduction in plantarflexion in the operated ankle (Table 2).

Table 2. Range of motion of the injured/uninjured ankle at the end of follow-up.

Ankle range of motion	Operated	Uninjured	%
Dorsiflexion (°)	13.7	18.3	75
Plantar flexion (°)	36.4	45.3	80

The percentages were obtained by dividing the range of motion of the operated ankle by the range of motion of the uninjured ankle.

The mean AOFAS score improved from 58.4 ± 5.1 preoperatively to 88.6 ± 5.6 at final follow-up. Mean pain scores on the visual analog scale improved from 7.1 ± 1.2 preoperatively to 2.8 ± 0.7 postoperatively.

The overall complication rate was 17.2% (n = 10). Two patients (3.45%) developed surgical site infections requiring surgical debridement and culture-directed antibiotic therapy. Three patients (5.17%) underwent implant removal one year after surgery because of implant-related pain. Finally, five patients (8.62%) developed grade 2 or grade 3 post-traumatic osteoarthritis according to the Bargon classification. None required revision surgery at the time of the study.

No cases of loss of reduction or implant failure were observed at final follow-up.

DISCUSSION

Ankle fractures involving the posterior malleolus (PM) have consistently been associated with poorer clinical outcomes.[1,3,8] Appropriate treatment, surgical indications, and the optimal method of PM fixation remain subjects of debate.[7,10,11,13,23] Although buttress plating appears to be the preferred method for many authors, the findings of our study demonstrate that fixation with cannulated screws alone provides satisfactory mid-term clinical and radiographic outcomes comparable to those achieved with buttress plates.

Fractures involving more than 25% of the articular surface should be treated surgically.[16,18,24,25] For smaller fragments, the decision depends on fragment displacement, involvement of the incisura, and the presence of displaced intercalary fragments. Recent studies have suggested that fixation of these smaller fragments may also improve joint stability.[4,21,24] In our series, the mean PM fragment size was 28.4 ± 7.0%, similar to that reported by Zhang et al.[13] in which the mean fragment size was 30.9% in the screw fixation group and 31.7% in the plate fixation group.

The choice of surgical approach is based on the Bartoníček-Rammelt fracture classification, as well as the surgeon's preference and experience.[26] Erdem et al.[15] treated all PM fractures through a posterolateral approach. Similarly, Forberger et al.[27] used the same approach with excellent results. In our series, a posterolateral approach was used in 49 patients (84.5%), whereas a modified posteromedial approach was selected in the remaining 9 cases (15.5%) to reduce and fix displaced posteromedial fragments.

The literature generally recommends buttress plates rather than screws for PM fixation.[28] This recommendation is based on the belief that plates better prevent axial fragment migration by maintaining reduction,[14] a factor considered critical for successful fixation of these fractures.

In contrast, several recent studies have demonstrated that direct screw fixation provides functional and radiographic outcomes equivalent to those obtained with buttress plating while offering three distinct advantages: (1) less soft-tissue dissection, because it does not require the extensive exposure of the posterior tibial surface needed for plate application; (2) shorter operative time (Zhang et al. reported 78.5 vs. 98.2 minutes) and reduced intraoperative blood loss;[13,15,21] and (3) greater versatility of the fixation construct, allowing adaptation to fragment size and the presence or absence of intercalary fragments by using two or three 4.0-mm screws (Figure 6).

Figure 6. A 56-year-old patient with a fracture involving a large portion of the posterior malleolus. **A and B.** Preoperative ankle computed tomography, axial and sagittal views. The large posterior fragment involves 40% of the posterior malleolus. **C and D.** Anteroposterior and lateral ankle radiographs obtained one year after surgery. The reduction achieved with a construct consisting of one buttress screw plus two compression screws inserted through the posterior cortex is demonstrated. Stable fixation with complete union and no sagittal displacement was achieved.

These advantages, together with the lower cost of screws compared with precontoured plates, make this technique particularly attractive for resource-limited centers and for surgeons experienced in posterior approaches.

In our series, three different cannulated screw constructs were used, all incorporating a buttress screw with a washer. Mean operative time was 93.3 ± 40.6 minutes, and fracture union was achieved in all patients without loss of reduction at a mean of 16.3 ± 3.8 weeks.

In ankle fractures associated with syndesmotic injury, rotational forces predominate, and disruption or avulsion of the posterior inferior tibiofibular ligament is frequently accompanied by injury to the anterior inferior tibiofibular and interosseous ligaments.[28] Therefore, fixation of the PM alone does not guarantee complete syndesmotic stability or accurate rotational reduction of the fibula within the incisura.

Accordingly, despite direct fixation of the PM, additional syndesmotic stabilization with a suprasyndesmotic screw was required in 25 cases (43.1%).

Failure to restore articular congruity is associated with poorer postoperative functional outcomes compared with anatomical reduction.[18–20] The incidence of osteoarthritis increases when the articular step-off exceeds 2 mm.[30] Both articular congruity and stability are independent prognostic factors that determine surgical success.[13,31,32] In our study, anatomical reduction was achieved in 48 patients (82.7%) and satisfactory reduction in 9 (15.5%). Kang et al.[22] reported similar findings, with 94% of screw-fixed PM fractures showing an articular step-off <2 mm. In a comparative study of 40 patients, Erdem et al.[15] reported one patient with a 3-mm step-off in the screw fixation group and one patient with a 2-mm step-off in the plate fixation group.

In our series, the mean AOFAS score improved from 58.4 to 88.6, while the mean visual analog scale pain score decreased from 7.1 to 2.8 at final follow-up. These findings are consistent with those reported in previous studies of PM fixation. In a retrospective study of 32 patients, Roukun et al. reported a mean AOFAS score of 92 points at final follow-up. Likewise, Forberger et al., in a series of 45 patients treated with buttress plate fixation, reported a mean postoperative AOFAS score of 93 points.

Conservative treatment of ankle fractures has been associated with a statistically significant reduction in ankle range of motion compared with surgical treatment.[20,31] Therefore, we consider anatomical reduction and stable internal fixation essential, as they allow early mobilization exercises, which are fundamental for rapid recovery.[31]

In our series, dorsiflexion of the operated ankle was reduced by 25% and plantarflexion by 20% compared with the contralateral ankle. These findings are consistent with previous reports. Zhang et al.[13] observed reductions of 22.5% in dorsiflexion and 15.1% in plantarflexion in the screw fixation group, compared with the uninjured ankle, whereas the corresponding values in the plate fixation group were 15.5% and 12.2%, respectively.

Despite the favorable mid-term outcomes, postoperative complications, particularly the development of osteoarthritis, remain an important concern. This underscores the importance of meticulous preoperative evaluation and appropriate surgical technique, as anatomical reduction and stable internal fixation are essential for minimizing these risks. The complication rate observed in our study is comparable to those reported in the literature. Five patients (8.6%) developed post-traumatic osteoarthritis by the end of follow-up. Similarly,

Zhang et al.[13] identified five cases (10.4%) of severe osteoarthritis.

CONCLUSIONS

This study has limitations inherent to its retrospective design, including the lack of randomization and the relatively small sample size. Prospective studies with larger cohorts and longer follow-up are needed to validate our findings and further evaluate the effectiveness of different fixation techniques.

In our series, anatomical or satisfactory reduction of the PM was achieved in 98% of patients, with no loss of reduction during follow-up and a complication rate comparable to those reported for other fixation methods.

Direct fixation of posterior malleolar fractures with cannulated screws represents an effective strategy for the management of these injuries.

Conflicts of interest: The authors declare no conflicts of interest.

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