Arthroscopy and Percutaneous Internal Fixation in Maisonneuve Fractures. Imaging Evaluation

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ABSTRACT

Introduction: Maisonneuve fracture (MF) is an injury characterized by the subcapital fracture of the fibula associated with a capsuloligamentous injury of the ankle. Treatment involves the restoration of normal bone and capsuloligamentous anatomy in order to reestablish physiological tibiotalar contact forces. This quality of reduction can be difficult to achieve, especially with percutaneous techniques. **Objective:** To evaluate the quality of reduction in Maisonneuve fractures reduced in a closed manner (under direct arthroscopic visualization) and fixed percutaneously. **Materials and Methods:** We analyzed comparative preoperative and postoperative radiographs and CT scans of the operated and healthy ankles. **Results:** 13 fractures were evaluated. Radiographic parameters of postoperative procedures (medial clear space, distal tibiofibular overlap, tibiofibular clear space) did not register differences except for the anterior tibiofibular space, which had increased in 1 case. Postoperative tomographic measurements of tibiofibular clear space and anterior tibiofibular space showed 100% satisfactory reductions. Two patients presented altered distal tibiofibular overlap values with a difference greater than 2 mm compared to the healthy ankle. **Conclusion:** We recommend arthroscopy for the management of MF as an intraoperative control tool for safer percutaneous fixation.

Keywords: Maisonneuve fracture; tibiofibular instability; syndesmotic injury; ankle arthroscopy; imaging evaluation.

Level of Evidence: IV

Asistencia artroscópica y fijación interna percutánea en fracturas de Maisonneuve. Evaluación por imágenes de los resultados

RESUMEN

Introducción: La fractura de Maisonneuve es una lesión caracterizada por la fractura subcapital del peroné asociada a una lesión capsuloligamentaria de tobillo. Su tratamiento supone la restauración de la anatomía ósea y capsuloligamentaria normal para restablecer las fuerzas de contacto tibioastragalinas fisiológicas. Esta calidad de reducción puede ser difícil de alcanzar, sobre todo, con técnicas percutáneas. **Objetivo:** Evaluar mediante imágenes la calidad de la reducción de fracturas de Maisonneuve reducidas en forma cerrada (bajo visualización directa artroscópica) y fijadas por vía percutánea. **Materiales y Métodos:** Se analizaron radiografías e imágenes de tomografía computarizada preoperatorias y posoperatorias, comparativas de los tobillos operado y sano. **Resultados:** Se evaluaron 13 fracturas. Los parámetros radiográficos posoperatorios (espacio claro medial, solapamiento tibioperoneo distal, espacio claro tibioperoneo) no registraron diferencias, excepto por el intervalo tibioperoneo anterior que aumentó en un caso. La medición tomográfica posoperatoria del solapamiento tibioperoneo distal y el intervalo tibioperoneo anterior reveló que todas las reducciones eran satisfactorias. Dos pacientes tenían valores alterados en la sindesmosis tibioperonea distal con diferencia >2 mm respecto del tobillo sano. **Conclusión:** Recomendamos la asistencia artroscópica para el manejo de la fractura de Maisonneuve como herramienta de control intraoperatorio para una fijación percutánea más segura.

Palabras clave: Fractura de Maisonneuve; inestabilidad tibioperonea; rotura sindesmal; artroscopia de tobillo; evaluación por imágenes.

Nivel de Evidencia: IV

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INTRODUCTION

In 1840, the French surgeon Jules Maisonneuve described an injury characterized by a subcapital fracture of the fibula associated with a distal tibiofibular syndesmosis (DTFS) injury and produced by a traumatic mechanism of external rotation.[1,2] Currently, the term Maisonneuve fracture (MF) is used ambiguously to refer to ankle injuries presenting a fibula fracture in its proximal third or fourth, associated with ankle capsuloligamentous involvement with joint displacement, produced by rotational forces.

MF requires the restoration of normal bone and capsuloligamentous anatomy. This ensures the restitution of physiologic tibiotalar contact forces, minimizing the risk of posttraumatic osteoarthritis.[3-12] Such anatomic reduction cannot be easily achieved given the complexity of the local anatomy and the low sensitivity of intraoperative fluoroscopy for detecting residual reduction defects.[13] It is known that fibular displacements of up to 6 mm in the sagittal plane are compatible with normal parameters (distal tibiofibular clear space [DTFCS], distal tibiofibular overlap) on the AP radiograph.[14] In a cadaveric study, it was demonstrated that there are no reliable radiographic parameters to assess the indemnity of the DTFS and its correct reduction, since reproducibility in the positioning of each ankle to be analyzed cannot be assured even under laboratory conditions. The technical difficulty in assessing the quality of reduction during surgery can be further interpreted if we consider that all reduction techniques, open or closed, have poor reduction rates of between 24% and 50%,[3,8,11,15,16] when assessed by computed tomography (CT). According to a recent article from a European Level 1 trauma center, 1.6% of all operated ankle fractures will require revision surgery due to failed osteosynthesis, with poor syndesmotic reduction being the leading cause (59%).[17]

Arthroscopic assistance in MF allows, in our opinion, to solve the technical difficulties of the condition. First, it enables a closed reduction of the DTFS under direct arthroscopic visualization; second, it allows the diagnosis and eventual treatment of chondral lesions, in general, associated with this type of lesions.

The objective of this study was to evaluate the reduction of DTFS in closed reduced MF (under direct arthroscopic visualization and percutaneously fixed) using imaging (correlating radiographs and CT).

MATERIALS AND METHODS

The inclusion criteria were: patients with Maisonneuve ankle fracture (fracture of the proximal third of the fibula associated with ligament injury at the DTFS and medial ligament injury or bony avulsion of the tibial malleolus), acute and subacute (less than 6 weeks of evolution), treated by reduction under direct arthroscopic visualization and percutaneous internal fixation.

Exclusion criteria were: patients with altered talocrural angle observed in the initial radiographs and that conditioned open reduction and internal fixation of the fibula, with previous degenerative ankle disease, history of hindfoot fracture in the treated or contralateral ankle, who refused to have a control postoperative CT scan, polytraumatized and with open fracture.

Surgical technique

The patient is placed in the supine position, under locoregional block and sedation. A hemostatic cuff inflated to 270 mmHg pressure is put on the inguinal region, and the glute homolateral to the injured limb is elevated. Conventional anterior arthroscopic portals are used and a systematic examination of the joint is carried out, evaluating ligamentous and chondral lesions and the presence of intra-articular free bodies. A 4 mm 30° Storz arthroscope is used for this purpose. After documenting the associated injuries, arthroscopic debridement of the DTFS and medial gutter is performed. The free bodies are removed, if applicable, and the synovitis is shaved, thus facilitating the correct visualization of the DTFS. The fibula is then reduced within the tibial notch under direct arthroscopic visualization. We consider that the reduction is adequate when the complete closure of the distal tibiofibular joint space is dynamically visualized by means of internal rotation and hindfoot inversion maneuvers. Secondly, the medial gutter is reduced, and the quality of the reduction in malleolar fractures and the complete closure of the articular space in pure ligament injuries are evaluated. We then proceed to the transitional fixation of the DTFS with a sharp-tipped clamp, followed by a second arthroscopic control to evaluate the preservation of the reduction in the DTFS (continuity of the articular cartilage of the anterior tibial lip with its corresponding one on the anterior aspect of the fibula) that could have been lost when closing the clamp (Figures 1 and 2).

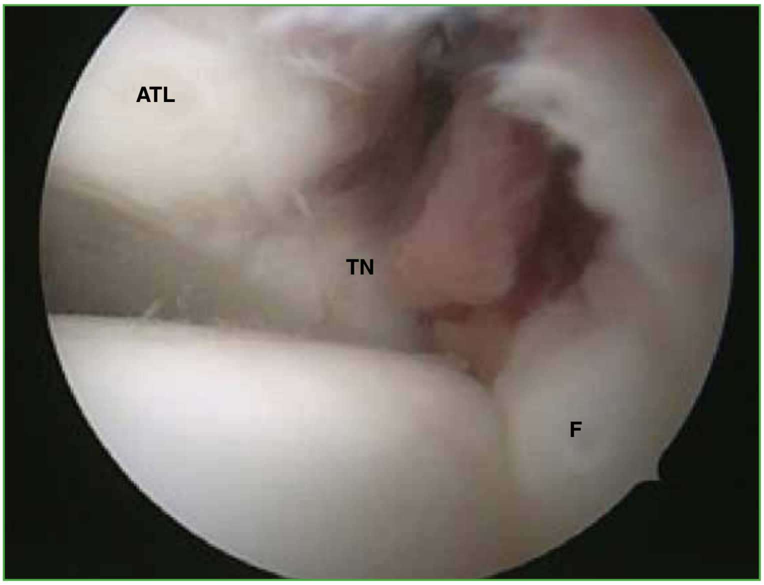

Figure 1. Open syndesmosis.
ATL = anterior tibia lip; TN = tibial notch; F = fibula.

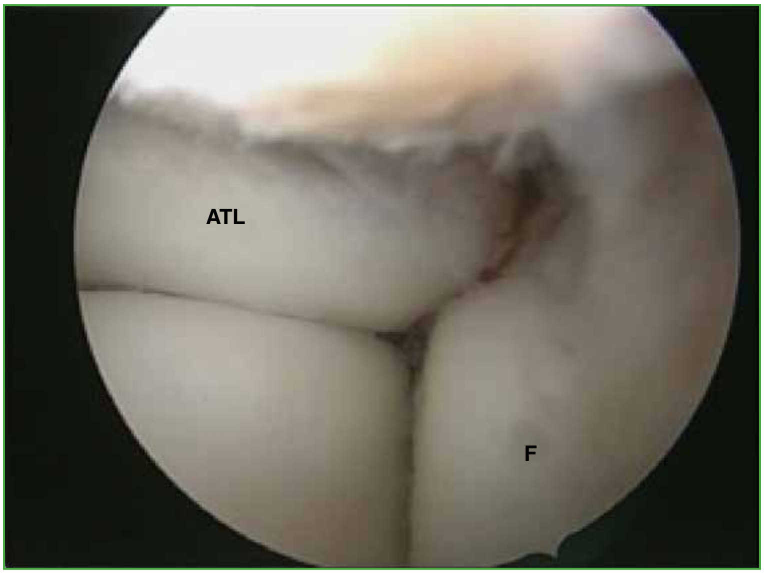

Figure 2. Closed syndesmosis.
ATL = anterior tibia lip; F = fibula.

Finally, percutaneous fixation is carried out with cannulated screws (cortical, fully threaded, 4 mm, proximal to the notch, number 1). Fluoroscopy is used to evaluate the quality of the reduction and osteosynthesis.

The patient is immobilized with a posterior plaster cast until healing (48-72 hours), after which the limb is transferred to an offloading walking boot for four weeks. At the beginning of the second week, the patient is instructed to remove the boot to perform ankle flexion-extension exercises. From the fourth week onwards, the walker boot is removed and partial weight-bearing (30%) begins until the implants are removed in the twelfth week.

Radiographic evaluation

For this study, preoperative (non-weight-bearing) and long-term postoperative comparative radiographs of the operated ankle and the healthy contralateral (weight-bearing) ankle were obtained during control. On AP radiographs, the following parameters were evaluated: medial clear space (MCS) (the distance from the lateral edge of the medial malleolus to the medial edge of the talus, measured at the level of the talar dome), DTFCS (the distance between the lateral edge of the posterior tibial tubercle and the medial edge of the fibula, measured 1 cm proximal to the tibial plafond), and tibiofibular overlap (overlap of the fibula with the anterior tubercle of the tibia, measured 1 cm proximal to the plafond). The reduction was considered satisfactory if the difference between the operated ankle and the healthy ankle did not exceed plus or minus 2 mm for any of the aforementioned parameters.

A medial injury was considered to be present if, on initial radiographs, an MCS >4 mm or a fracture of the tibial malleolus was observed. The talocrural angle was also evaluated as a measure of fibula shortening, which was considered abnormal if it differed by more than 2° with respect to the non-operated ankle.

In the lateral radiographs, the anterior tibiofibular interval (ATFI) (distance between the anterior border of the tibia and the anterior border of the fibula) was evaluated. The contralateral healthy ankle was taken as the normal reference value. The reduction was considered satisfactory if the difference between the operated ankle and the healthy ankle did not exceed 2 mm for the aforementioned parameter.

The original full leg radiographs were examined, as well as the characteristics of the proximal fibula fracture, such as if it affected the fibular head, if it was a high subcapital fracture, a low subcapital fracture, or if it was comminuted.

Tomographic evaluation

Preoperative CT images of the injured side and postoperative comparative CT images of both ankles taken in the control were evaluated for this study. Standardized cuts parallel to the tibial plafond in neutral position were used. The vertical axis of the tibia and the horizontal axis of the tibial plafond were used to confirm such parallelism, and the neutral position was defined as the bimalleolar axis, a line tangential to the anterior process of the medial and lateral malleolus. The axial section performed 10 mm proximal to the tibial plafond was evaluated in all cases. Axial tibiofibular relationships and measurements were analogous to those evaluated on plain radiographs. The distal tibiofibular joint was evaluated by seven measurements (Figure 3): A) the distance between the most anterior point of the notch, and the closest and most anterior point of the fibula; B) the distance between the tibia and the fibula at the middle of the notch; C) the distance between the most posterior point of the notch, and the closest and most posterior point of the fibula; D) the DTFCS defined as the distance between the medial edge of the fibula and the tip of the lateral edge of the posterolateral tibial tubercle; E) the DTFS defined as the maximum overlap between the anterolateral tibia and the medial fibula measured in mm; F) the ATFI, defined as the distance between the anterior edge of the tibia and the anterior edge of the fibula; G) the angle of rotation: angle between a line join-

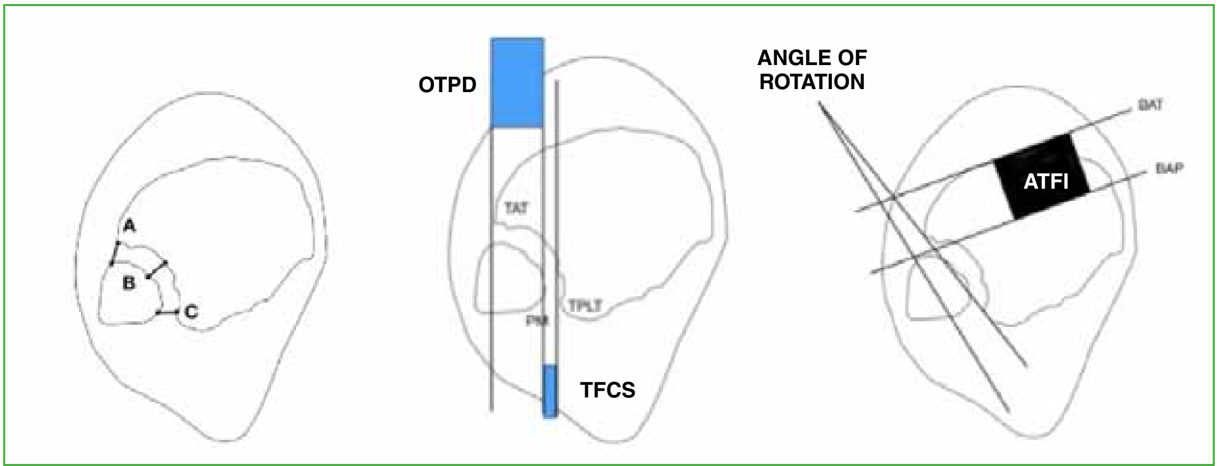

Figure 3. Evaluation of the distal tibiofibular joint using seven measurements.
DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis; ATFI = anterior tibiofibular interval. ATT = anterior tibial tuberosity; MF = medial edge of the fibula; PLTT = posterolateral tibial tubercle; AT = anterior edge of the tibia; AF = anterior edge of the fibula.

ing the anterior and posterior point of the notch and another line joining the anterior and posterior tubercle of the fibula. The measurements taken on the contralateral healthy ankle were taken as the normal reference value. The reduction was considered satisfactory if the discrepancy between the operated ankle and the healthy ankle was no more (open DTFS) or less (closed DTFS) than 2 mm.

All radiographic and tomographic measurements were performed independently by two senior physicians from the Imaging Department. For this, they were asked to evaluate CT scans and radiographs of both ankles and upload the results blindly, in a spreadsheet.

RESULTS

Between May 2013 and January 2019, 16 fractures were treated in 16 patients, 13 met the inclusion criteria. The mean postoperative follow-up was 31 months (range 14-84). The sample included 12 men and one woman, with a mean age of 39.1 years (range 18-69). The affected side was the right in seven patients, and the left in six. All reported external rotation trauma with the foot fixed to the ground, nine suffered the fracture during sports practice. Twelve medial injuries were recorded, 10 of them ligament injuries (76.9%), two tibial malleolus fractures (15.38%), one patient (7.69%) had no medial injury. Eight (61.5%) had posterior malleolus involvement, it was not fixed in any case. The proximal fibula fracture was classified as high subcapital in five cases (38.4%), low subcapital in five (38.4%), comminuted subcapital in two (15.3%), and capital in one (7.6%). For internal fixation, two 4-mm fully threaded quadricortical screws were used in 10 cases (76.9%) and one 4-mm fully threaded quadricortical screw in three cases (23.1%). Screw breakage was recorded in two patients. In one case, it was a single screw and, in the remaining case, it was one of two screws (Table 1).

Radiographic outcomes

There were no differences in MCS, DTFCS or DTFS with respect to the healthy side. The ATFI increased in one case and the talocrural angle decreased in one patient (Table 1).

Table 1. Radiographic outcomes

Evaluator 1

	MCS	DTFCS	DTFS	ATFI
Patient 1	0.1 mm	1.7 mm	-0.3 mm	0.2 mm
Patient 2	0.9 mm	-0.9 mm	-0.4 mm	-1.5 mm
Patient 3	0.3 mm	0.6 mm	-1 mm	-0.3 mm
Patient 4	0.2 mm	0.5 mm	-0.6 mm	0.4 mm
Patient 5	0 mm	0.1 mm	0.9 mm	1.6 mm
Patient 6	0.1 mm	1.7 mm	0 mm	2.5 mm
Patient 7	0.2 mm	0.7 mm	-0.2 mm	-1.5 mm
Patient 8	0.2 mm	0.5 mm	-0.5 mm	-0.2 mm
Patient 9	0 mm	0.2 mm	-1.7 mm	1.5 mm
Patient 10	0.9 mm	-1 mm	-0.1 mm	1.6 mm
Patient 11	0.3 mm	0.3 mm	-1 mm	0.6 mm
Patient 12	0.4 mm	0.1 mm	-0.5 mm	0 mm
Patient 13	0.1 mm	1.8 mm	0.6 mm	1 mm

Evaluator 2

	MCS	DTFCS	DTFS	ATFI
Patient 1	-0.1 mm	0.6 mm	-0.1 mm	0.9 mm
Patient 2	0 mm	0.1 mm	0.7 mm	0 mm
Patient 3	0.1 mm	0.4 mm	-1.7 mm	1.7 mm
Patient 4	0 mm	0.1 mm	-0.4 mm	0 mm
Patient 5	-0.1 mm	0.4 mm	0 mm	0.4 mm
Patient 6	-0.2 mm	-0.8 mm	0.4 mm	2.5 mm
Patient 7	0.1 mm	-1 mm	0.8 mm	-1 mm
Patient 8	0.1 mm	0.6 mm	0 mm	-0.5 mm
Patient 9	-0.1 mm	-0.7 mm	-1.2 mm	1.5 mm
Patient 10	0 mm	-1 mm	0 mm	1.8 mm
Patient 11	0 mm	0.9 mm	0 mm	1.6 mm
Patient 12	0.4 mm	0.3 mm	-0.2 mm	0.2 mm
Patient 13	0 mm	0.6 mm	1 mm	1.5 mm

MCS = medial clear space; DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis; ATFI = anterior tibiofibular interval.

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Tomographic outcomes

Preoperative tomographic evaluation showed deviations of up to 4 mm in ATFI, 3 mm in DTFCS, and DTFS, 4.7° in rotation angle and 4 mm in A and B measurements. No abnormal values were recorded in the measurement of C. Postoperative tomographic measurement of DTFCS and ATFI revealed that all reductions were satisfactory. Two patients had DTFS values with a difference >2 mm from the contralateral healthy ankle, the maximum difference was 3 mm. Three patients (23.1%) with an abnormal preoperative A value continued with altered measurements. One had a difference of 2 mm in B on the preoperative CT and a postoperative B value of 3 mm. Regarding the comparative angle measurement, the angle had increased in three patients in the postoperative controls (Table 2).

Table 2. Tomographic outcomes

Evaluator 1

	ATFI	DTFCS	DTFS	Rotation angle	Anterior	Medial	Posterior
Patient 1	- 2 mm	0 mm	-2 mm	-0.5°	2 mm	1 mm	-1 mm
Patient 2	1 mm	2 mm	0 mm	3°	4 mm	2 mm	2 mm
Patient 3	0 mm	2 mm	-1 mm	0.4°	0 mm	2 mm	1 mm
Patient 4	1 mm	3 mm	-3 mm	-0.8°	3 mm	1 mm	0 mm
Patient 5	1 mm	-1 mm	- 1.5 mm	2°	1.4 mm	0 mm	-1 mm
Patient 6	4 mm	0 mm	0 mm	4.7°	4 mm	1 mm	0 mm
Patient 7	- 2 mm	- 2 mm	0 mm	0.1°	2 mm	1 mm	1 mm
Patient 8	2 mm	0 mm	2 mm	-0.1°	-1 mm	-1 mm	0 mm
Patient 9	0 mm	0 mm	2 mm	1.4°	0 mm	1 mm	-1 mm
Patient 10	1 mm	-2 mm	0 mm	-1.3°	0 mm	1 mm	-2 mm
Patient 11	2 mm	0.5 mm	1 mm	2°	1.6 mm	-0.5 mm	-1 mm
Patient 12	0 mm	1 mm	-2 mm	-1°	1 mm	0 mm	1 mm
Patient 13	1 mm	0 mm	0 mm	0°	1 mm	0 mm	2 mm

Evaluator 2

	ATFI	DTFCS	DTFS	Rotation angle	Anterior	Medial	Posterior
Patient 1	-2 mm	-1.8 mm	-2 mm	-0.27°	2 mm	1 mm	-1 mm
Patient 2	2 mm	2 mm	2 mm	-0.1°	5 mm	3 mm	1 mm
Patient 3	1 mm	-1 mm	0 mm	1.25°	2 mm	1 mm	0 mm
Patient 4	0.7 mm	-0.5 mm	-2.5 mm	-1°	2.3 mm	1.3 mm	0 mm
Patient 5	2 mm	-0.5 mm	1.5 mm	0.1°	2 mm	0.2 mm	-1.5 mm
Patient 6	2 mm	0 mm	-3 mm	-2°	5 mm	1 mm	0 mm
Patient 7	0 mm	0 mm	-1 mm	0°	1 mm	0 mm	0 mm
Patient 8	1 mm	0 mm	2 mm	0°	-1 mm	0 mm	0 mm
Patient 9	0 mm	0 mm	0 mm	1°	1 mm	0 mm	-1 mm
Patient 10	0 mm	0 mm	0 mm	-0.3°	-1 mm	0 mm	0 mm
Patient 11	0 mm	0 mm	0 mm	0°	1 mm	0 mm	0 mm
Patient 12	0 mm	1 mm	-2 mm	-0.5°	1 mm	0 mm	0 mm
Patient 13	0 mm	1 mm	-1 mm	0.5°	1 mm	1 mm	2 mm

ATFI = anterior tibiofibular interval; DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis.

DISCUSSION

We use the term MF ambiguously to refer to fractures of the proximal third or fourth of the fibula associated with capsuloligamentous involvement of the ankle, produced by external rotation trauma. The classic conception of this injury is that the position of the rearfoot in pronation would initially affect the medial structures (fracture by avulsion of the tibial malleolus or involvement of the superficial and deep bundles of the deltoid ligament); and that the force acting in external rotation would produce ligament injury in the DTFS and injury to the interosseous membrane that should extend to the fracture line.[2] However, publications that have attempted to corroborate this pathophysiology are inconclusive.[3,18-20] One of the controversial points is the level of involvement of the interosseous membrane. Several studies have analyzed this structure using magnetic resonance imaging. Nielson et al.[13] demonstrated that the height of the fibula fracture does not necessarily correlate with the level of the interosseous membrane tear. Manyi et al.[14] studied 12 patients, and found a membrane lesion in all, but in no case more proximal than 112 mm from the joint line. Morris et al. found the lesion in only four of the five patients evaluated by magnetic resonance imaging.[19]

Bartoníček et al. published the largest series of this condition and redescribed the fracture based on imaging analysis and intraoperative findings in 54 patients. They found that only the distal anterior tibiofibular ligament and the interosseous ligament were constant lesions, that the interosseous membrane was almost always affected, but only in its distal third and exceptionally the lesion reached the level of the fracture line, and that up to 80% of the patients had a fracture of the posterior malleolus. Regarding the specific medial injury, they recorded 50% ligament injuries, 37% tibial malleolus fractures and, in 13.6% (7 cases), no medial injuries were detected. In our series, the most frequent medial injury was ligamentous and represented 76.9% of the cases, there were 15.3% of malleolar fractures and a medial injury in one case. The absence of medial injuries recorded in both series cannot explain pronation and external rotation as the mechanisms of injury. According to Bartoníček et al.,[15] MFs could be produced both by a pronation and external rotation mechanism and by one in supination and external rotation. In the first case, the medial lesion is a constant and represents the initial point of injury according to the classic Lauge-Hansen interpretation for these lesions. For cases without medial injury, Bartoníček et al. considered that they could be the consequence of supination and external rotation trauma that had not reached the final stage of medial injury, but had affected the anterior and posterior DTFS.

Regarding gender distribution, our sample included 12 males and one female. Sproule et al. also reported this higher incidence in the male sex (12 males, 2 females).[20] However, this finding is significant given that the rest of the published series report a similar sex distribution.[7,18,20]

To treat MFs, normal bone and capsuloligamentous anatomy must be restored, as well as physiological tibiotalar contact forces, to reduce the possibility of post-traumatic osteoarthritis.[3-9] It is difficult to evaluate the reduction's correctness intraoperatively. A cadaveric study demonstrated that there are no reliable radiographic parameters to assess the indemnity of the DTFS, because even in laboratory conditions, reproducibility in the positioning of the ankle to be analyzed cannot be assured.[5] It is also known that fibular displacements of up to 6 mm in the sagittal plane are compatible with normal parameters in the anteroposterior radiograph.[13] Finally, rotation of the fibula within the notch is even more difficult to evaluate with radiographs, because it is a two-plane deformity and radiographs can only evaluate uniplanar displacements. Arthroscopy is then proposed as a solution to the problem. Takao et al. compared the sensitivity of radiography and arthroscopy in diagnosing syndesmosis injuries in 52 treated patients. In comparison to arthroscopy, the sensitivity and specificity for anteroposterior radiographs were 44.1% and 100%, respectively, and 58.3% and 100% for the mortise view; thus, they concluded that arthroscopic examination of syndesmotic reduction should be a standard procedure.[21]

The syndesmotic radiographic parameters were normal in 12 of our patients. The remaining case presented an increased ATFI. This was a patient with a posterior malleolus fracture that had not been fixed, which facilitated displacement of the fibula in the sagittal plane. The talocrural angle was altered in one case. This patient had a shortening of the fibula visible on AP radiographs, but the syndesmotic parameters measured by radiography and CT were normal. Consequently, we consider that radiographic assessment of the talocrural angle should never be omitted, nor can it be replaced by tomographic evaluation.

In an ankle fracture, the fibula may shorten or rotate on itself, or shift coronally, rotationally or sagittally within the notch. Therefore, the exact assessment of syndesmotic reduction cannot be determined with two-dimensional studies and CT appears as the logical solution. Again, there is no consensus on what to measure in CT, or how to measure it. We took these seven tomographic parameters as sufficient to evaluate a poor reduction with all its possible displacements. Also noteworthy is the considerable interindividual variation in DTFS morphology[22,23] as well as the minimal differences between the two ankles of an individual.[13] Therefore, the contralateral uninjured ankle should be the parameter of normality when we analyze the outcomes.[24] In our sample, there were three cases with poor CT-assessed outcomes, all associated with a fracture of the posterior malleolus. In one, the posterior malleolus fracture (Rammelt type 2) consolidated in an elevated way and displaced medially, generating a posterior displacement of the fibula in the sagittal plane, associated with external rotation and coronal translation with widening of the syndesmosis (Figure 4).

The second patient also had a type 2 posterior malleolus fracture, but without displacement. In this case, the posterior malleolus consolidated anatomically, but the fibula remained in external rotation and displaced in the coronal plane (Figure 5).

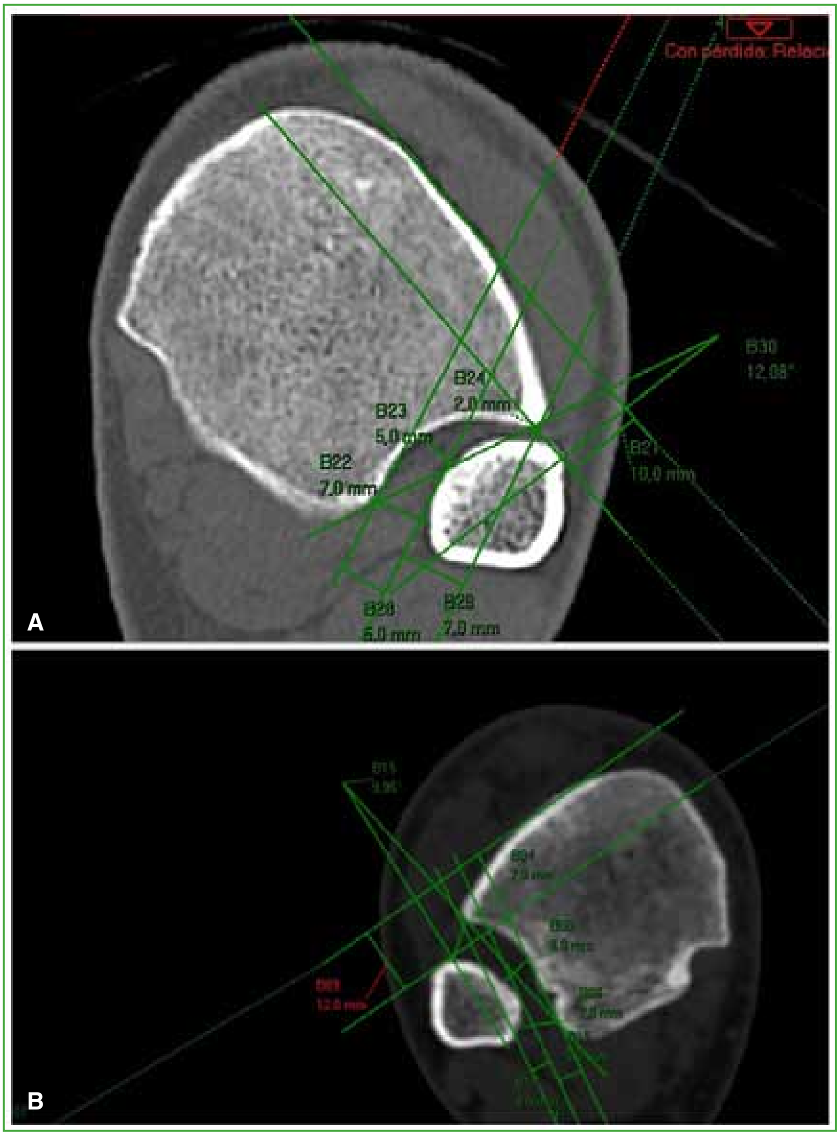

Figure 4. A. Normal parameters in the contralateral healthy ankle. **B.** Morphological alteration in the tibial notch due to malunion of the posterior malleolus associated with a posterior, lateral and externally rotated translation of the fibula.

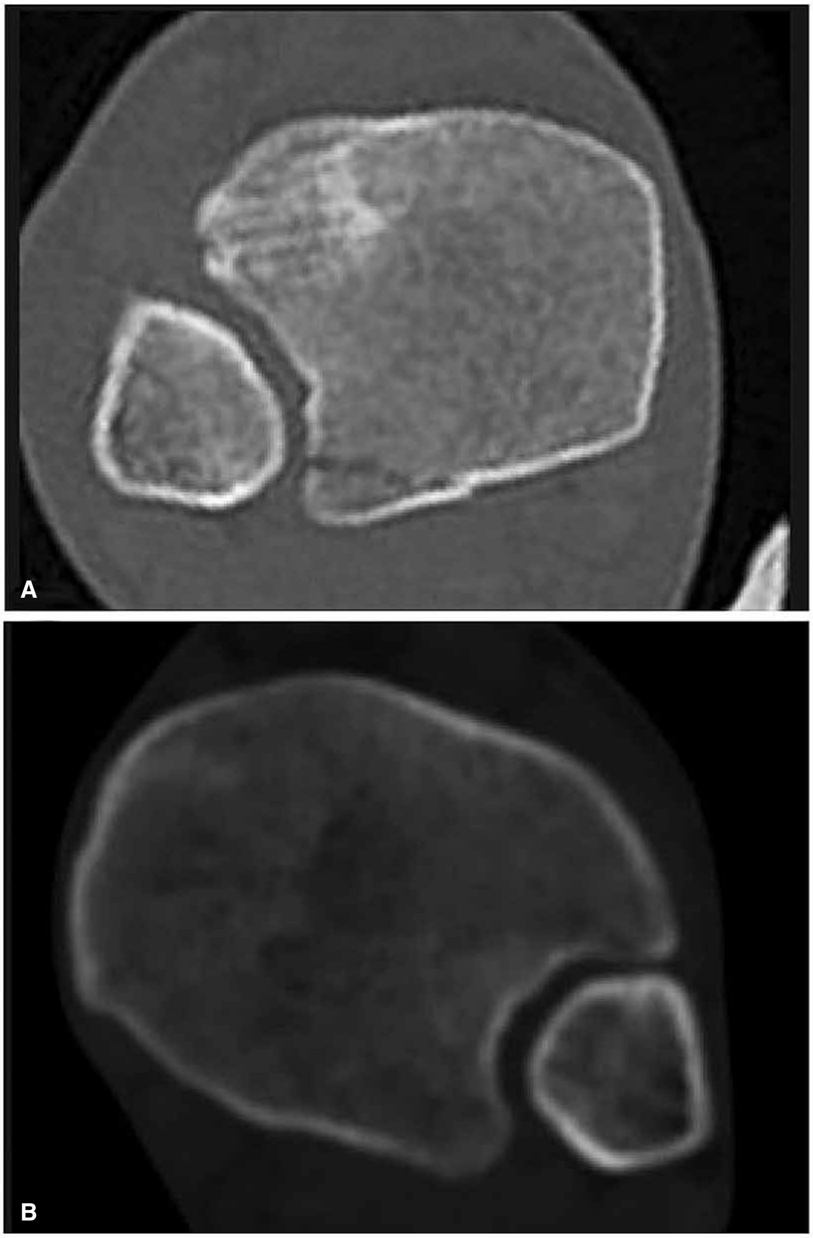

Figure 5. A. Poor reduction in external rotation of the fibula. **B.** Healthy contralateral ankle.

The third malreduction was associated with a type 1 posterior malleolus fracture and the abnormal displacement occurred in the coronal plane, without a rotational deficit in the fibula. Only the first patient had poor clinical evolution; in the other two, the unsatisfactory reduction had no functional implications.

It is striking that two of the three poor reductions record an externally rotated fibula within the notch. Anterior arthroscopic visualization of the syndesmosis should avoid the problem. Several publications have warned about the effect that the depth and version of the notch can have on correct syndesmotic reduction.[14,17,22] Cherney et al. were able to establish a relationship between the depth of the notch and reduction defects in external rotation and posterior translation of the fibula.[23] The authors consider that, when placing a reduction clamp and closing the syndesmosis, the patient's anatomy could predispose to a poor coronal or rotational reduction. If the patient has a flat notch, the pressure exerted by the forceps will produce an anterior or posterior translation of the fibula. In turn, in a deep notch, the prominent anterior and posterior tibial tuberosities do not allow anterior translation of the fibula. In this case, the force exerted by the clamp will produce a posterior or rotational displacement. Ideally, the force exerted by the clamp should be perpendicular to the axis of the tibial notch, thus limiting the rotation and lateral translation that could be generated by the clamp when closing.

In our study, the rate of poor results was 23% (assessed by CT), close to the values obtained with open reductions and far from the high rates of poor reductions (assessed by CT) of percutaneous techniques. Miller et al.[24] compared the results obtained in 25 patients treated with percutaneous reduction with those of 149 patients treated prospectively but with an open reduction protocol using a posterolateral approach and subsequent fixation of the syndesmosis. In the direct visualization group, the rate of poor outcomes was 16% compared to 52% in the percutaneous technique group, all evaluated by CT. In a similar study, Pelton et al.[25] recorded a statistically significant difference when treating fractures with an open reduction. The authors concluded that percutaneous reduction has unacceptably poor reduction rates, so they discontinued its use. Furthermore, they caution that the requirement for a second approach at the syndesmotic level or to prolong the one employed for fibula reduction and fixation increases the procedure's risk of complications.

CONCLUSIONS

Arthroscopic assistance for the treatment of MFs has allowed us to obtain reasonably low rates of poor reductions, as measured by CT. The low sensitivity of radiographs to measure reduction deficits during surgery, as well as the lack of a CT scanner in our setting, make arthroscopy a vital tool for the treatment of this condition. We recommend arthroscopic assistance for safer percutaneous fixation and because it provides the same favorable outcomes with fewer complications.

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

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REFERENCES

1. Maisonneuve JG. Recherches sur la fracture du peroné. *Arch Gen Med* 1840;7:165-87, 433-73.
2. Lauge-Hansen N. Fractures of the ankle. II. Combined experimental-surgical and experimental-roentgenologic investigations. *Arch Surg (1920)* 1950;60(5):957-85. PMID: 15411319
3. Sagi HC, Shah AR, Sanders RW. The functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. *J Orthop Trauma* 2012;26(7):439-43. https://doi/org/10.1097/BOT.0b013e31822a526a
4. Beumer A, van Hemert WL, Niesing R, Entius CA, Ginai AZ, Mulder PGH, et al. Radiographic measurement of the distal tibiofibular syndesmosis has limited use. *Clin Orthop Relat Res* 2004;(423):227-34. https://doi.org/10.1097/01.blo.0000129152.81015.ad
5. Tunturi T, Kemppainen K, Pätiälä H, Suokas M, Tamminen O, Rokkanen P. Importance of anatomical reduction for subjective recovery after ankle fracture. *Acta Orthop Scand* 1983;54(4):641-7. https://doi.org/10.3109/17453678308992903
6. Yde J, Kristensen KD. Ankle fractures: supination-eversion fractures of stage IV. Primary and late results of operative and non-operative treatment. *Acta Orthop Scand* 1980;51(6):981-90. https://doi.org/10.3109/17453678008990904
7. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreduction of the tibiofibular syndesmosis in ankle fractures. *Foot Ankle Int* 2006;27(10):788-92. https://doi.org/10.1177/107110070602701005

8. Cornu O, Manon J, Tribak K, Putineanu D. Traumatic injuries of the distal tibiofibular syndesmosis. *Orthop Traumatol Surg Res* 2021;107(1S):102778. https://doi.org/10.1016/j.otsr.2020.102778
9. Close JR. Some applications of the functional anatomy of the ankle joint. *J Bone Joint Surg Am* 1956;38-A(4):761-81. PMID: 13331972
10. Burns WC 2nd, Prakash K, Adelaar R, Beaudoin A, Krause W. Tibiotalar joint dynamics: indications for the syndesmotic screw--a cadaver study. *Foot Ankle* 1993;14(3):153-8. https://doi.org/10.1177/107110079301400308
11. Ramsey PL, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Joint Surg Am* 1976;58(3):356-7. PMID: 1262367
12. Dikos GD, Heisler J, Choplin RH, Weber TG. Normal tibiofibular relationships at the syndesmosis on axial CT imaging. *J Orthop Trauma* 2012;26(7):433-8. https://doi.org/10.1097/BOT.0b013e3182535f30
13. Nielson JH, Sallis JG, Potter HG, Helfet DL, Lorich DG. Correlation of interosseous membrane tears to the level of the fibular fracture. *J Orthop Trauma* 2004;18(2):68-74. https://doi.org/10.1097/00005131-200402000-00002
14. Manyi W, Guowei R, Shengsong Y, Chunyan J. A sample of Chinese literature MRI diagnosis of interosseous membrane injury in Maisonneuve fractures of the fibula. *Injury* 2000;31(Suppl 3):C107-10. https://doi.org/10.1016/s0020-1383(00)80038-8. 2014;38(1):83-8.
15. Bartoníček J, Rammelt S, Kašper Š, Malík J, Tuček M. Pathoanatomy of Maisonneuve fracture based on radiologic and CT examination. *Arch Orthop Trauma Surg* 2019;139(4):497-506. https://doi.org/10.1007/s00402-018-3099-2
16. Merrill KD. The Maisonneuve fracture of the fibula. *Clin Orthop Relat Res* 1993;(287):218-23. PMID: 8448946
17. Duchesneau S, Fallat LM. The Maisonneuve fracture. *J Foot Ankle Surg* 1995;34(5):422-8. https://doi.org/10.1016/S1067-2516(09)80016-1
18. Pankovich AM. Maisonneuve fracture of the fibula. *J Bone Joint Surg Am* 1976;58(3):337-42. PMID: 816799
19. Morris JR, Lee J, Thordarson D, Terk MR, Brustein M. Magnetic resonance imaging of acute Maisonneuve fractures. *Foot Ankle Int* 1996;17(5):259-63. https://doi.org/10.1177/107110079601700504
20. Sproule JA, Khalid M, O'Sullivan M, McCabe JP. Outcome after surgery for Maisonneuve fracture of the fibula. *Injury* 2004;35(8):791-8. https://doi.org/10.1016/S0020-1383(03)00155-4
21. Takao M, Ochi M, Oae K, Naito K, Uchio Y. Diagnosis of a tear of the tibiofibular syndesmosis. The role of arthroscopy of the ankle. *J Bone Joint Surg Br* 2003;85(3):324-9. https://doi.org/10.1302/0301-620x.85b3.13174
22. Summers HD, Sinclair MK, Stover MD. A reliable method for intraoperative evaluation of syndesmotic reduction. *J Orthop Trauma* 2013;27(4):196-200. https://doi.org/10.1097/BOT.0b013e3182694766
23. Cherney SM, Spraggs-Hughes AG, McAndrew CM, Ricci WM, Gardner MJ. Incisura morphology as a risk factor for syndesmotic malreduction. *Foot Ankle Int* 2016;37(7):748-54. https://doi.org/10.1177/1071100716637709
24. Miller AN, Carroll EA, Parker RJ, Boraiah S, Helfet DL, Lorich DG. Direct visualization for syndesmotic stabilization of ankle fractures. *Foot Ankle Int* 2009;30(5):419-26. https://doi.org/10.3113/FAI-2009-0419
25. Pelton K, Thordarson DB, Barnwell J. Open versus closed treatment of the fibula in Maissoneuve injuries. *Foot Ankle Int* 2010;31(7):604-8. https://doi.org/10.3113/FAI.2010.0604