



Ankle arthrodesis through minimally-invasive transfibular approach: a new surgical technique

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Abstract

Purpose The purpose of our work was to demonstrate the surgical technique of ankle arthrodesis using the minimally-invasive transfibular (MITF) approach, which minimizes soft tissue damage and is advantageous for high-risk patients.

Methods In this prospective study, a total of 12 patients with end-stage varus ankle osteoarthritis, including high-risk individuals, underwent ankle arthrodesis using the MITF approach. The technique involves a unique osteotomy at the joint space level, minimizing soft tissue detachment from the fibula. The primary outcomes assessed included bony union, time to weight-bearing, correction of varus deformity, and functional outcomes measured by the American Orthopedic Foot and Ankle Society (AOFAS) hindfoot scale. However, the study's limitations encompass a small sample size and the absence of a control group.

Results At 6 months post-operation, all patients achieved bony union, with a mean time to union of 13.7 ± 5.2 weeks. The average time to initiate weight-bearing without additional support was 11.2 ± 3.8 weeks. Preoperative varus deformity (17.08 ± 8.36 degrees) and talar tilt (8.75 ± 4.33 degrees) were successfully corrected, with postoperative alignment within 0–5 degrees of valgus. Functional outcomes showed a significant improvement in AOFAS scores from 37.83 ± 7.79 points preoperatively to 77.42 ± 5.63 points one year after surgery ($p=0.002$). Minor complications occurred in two patients, both effectively treated with local therapy and antibiotics.

Conclusions The MITF approach for ankle arthrodesis demonstrates promising results in addressing end-stage varus ankle osteoarthritis, even in high-risk patients. However, the study's limitations highlight the need for a prospective comparative clinical trial with a larger sample size to ascertain the technique's effectiveness and safety definitively.

Keywords Ankle · Arthrodesis · Varus · Surgical approach · Osteoarthritis · Ankle arthritis

Introduction

The treatment of end-stage ankle osteoarthritis (OA) remains controversial due to the relatively high incidence of complications [1]. There are three main approaches to the treatment of this pathology: joint-preservation surgery, joint

replacement, and arthrodesis [2–4]. The joint-preservation approach is most effective in young patients at stages 2–3 OA and the initial stages of avascular necrosis, accompanied by moderate pain [1, 2]. However, the effectiveness of the method decreases as joint destruction progresses and bone quality decreases with age [5]. Joint replacement has not yet achieved dominance among the methods of treating ankle OA, in contrast to the knee and hip joints. This is associated with a higher rate of unsatisfactory outcomes due to potential risks of infection and instability [4, 5].

Ankle arthrodesis is one of the oldest methods of treating ankle joint OA and is still widely used [3, 6]. One of the main advantages of the method is rapid recovery and complete elimination of pain [7]. However, the disadvantages include the complete loss of function of the ankle joint and increased load on adjacent joints, accelerating their damage [8]. Additionally, special attention must be paid to reducing

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the risk of nonunion and infectious complications, with an incidence that can reach 26% [9]. The risk of complications is highest in patients with diabetes, obesity, and smokers [10]. Reducing the incidence of these complications forms the basis for choosing the optimal surgical approach and fixation method.

The choice of surgical approach and fixation method depends on the clinical situation and surgeon preference. Common surgical approaches for ankle arthrodesis include arthroscopic, lateral, medial, anterior, and posterior [3, 11–15]. Fixation methods encompass locked intramedullary nailing, cross-screw osteosynthesis, osteosynthesis with a plate, and the Ilizarov apparatus [16–19]. Arthroscopic and mini-open approaches are attractive options for ankle arthrodesis, especially for high-risk patients, however their usage is limited in case of deformity [11]. Anterior and posterior approaches are justified in the presence of fixators to be removed, deformity in the sagittal plane, and the presence of bone defects of the anterior or posterior edge of the tibia [12, 13]. The medial approach is indicated for valgus deformity, and the lateral approach for varus deformity [14, 15, 20].

The transfibular approach for ankle arthrodesis was first described by Horwitz in 1942 [21]. This approach allows the correction of ankle varus with the closed-wedge method. Access to the ankle joint is through the fibula, and therefore various techniques of fibular osteotomy or resection are employed [14, 22–27]. These techniques involve substantial soft tissue dissection, potentially elevating the risks of infection and nonunion—especially pertinent in high-risk patients such as those with obesity, diabetes, smoking habits, or rheumatoid arthritis [10, 20].

In our work, we present a minimally-invasive transfibular (MITF) approach for tibiotalar arthrodesis in varus ankle osteoarthritis. This technique avoids excessive dissection of soft tissues, provides excellent access to the ankle joint, and has great potential for correcting varus deformity. The

described approach allows the preservation of the shape of the ankle joint. The use of this approach is also justified when performing total hindfoot arthrodesis with a retrograde intramedullary nail.

Materials and methods

Patient characteristics

For the period from September 1, 2020, to September 1, 2022, twelve patients (8 men, 4 women) with an average age of 59.58 ± 9.12 years (range: 46–73 years) underwent surgery. Surgery was indicated for varus ankle osteoarthritis at stages 3B and 4, according to the Takakura-Tanaka classification [28]. Patients with secondary ankle osteoarthritis due to inflammatory joint disease were not included in current study.

Given the availability of effective alternative treatment methods, such as joint-preservation procedures (ankle distraction arthroplasty, supramalleolar osteotomy), and ankle arthroplasty, the decision in favor of arthrodesis was made individually in each specific case after discussing all the advantages and disadvantages of the described methods. Factors such as age over 60 years, smoking, diabetes mellitus, and obesity (BMI > 30) were the primary considerations influencing patients to undergo arthrodesis through the MITF approach. Patients with subtalar osteoarthritis, for whom total hindfoot arthrodesis was indicated, were not included in the current study (Table 1).

In all cases, tibio-talar arthrodesis was performed using 6.5 headless compression screws or 7.3 cannulated screws, along with a 3.5 mm locked reconstructive plate. All surgeries were conducted by the same orthopedic surgeon. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Hospital

Table 1 Patient characteristics

N	Age	Gender	Stage of OA*	Etiology	Smoking	Comorbidities
1	46	M	3B	Post-traumatic	Yes	HIV, hepatitis C
2	71	M	3B	Primary	No	
3	65	F	4	Primary	No	Obesity
4	52	M	4	Post-traumatic	Yes	Type 2 DM
5	73	F	3B	Primary	No	
6	48	F	4	Post-traumatic	Yes	
7	66	M	3B	Post-traumatic	No	Obesity, type 2 DM
8	57	M	3B	Post-traumatic	Yes	
9	60	M	4	Post-traumatic	Yes	
10	54	M	3B	Primary	No	Obesity, hypothyroidism
11	69	M	4	Post-traumatic	Yes	
12	54	F	3B	Post-traumatic	No	Obesity, type 2 DM

* - Stage by Takakura-Tanaka Classification

Local Ethical Committee (12.08.2020/№ A21-C0820). Written informed consent was obtained from all patients.

Radiographic and clinical outcome measurement

A preoperative and postoperative observation protocol was established prior to the inclusion of patients in the study. All 12 patients were prospectively enrolled and followed until the final 12-month postoperative follow-up. Serial ankle plain radiographs in the mortise and lateral positions were obtained preoperatively, 1 day, 6, 10, 14 weeks, and 6, 12 months after the operation. The stage of ankle and subtalar joint osteoarthritis, as well as the degree of varus deformity of the distal tibia and talar tilt, were assessed preoperatively. The correct hindfoot position was evaluated clinically and through postoperative x-rays. The goal for arthrodesis was a slight valgus ($0\text{--}5^\circ$), neutral dorsiflexion, and slight external rotation [3]. Bony union was assessed in serial postoperative radiographs, confirmed radiographically by observing the presence of trabecular lines at the tibio-talar junction, the disappearance of the radiolucent line, and the absence of pain at the ankle joint during full weight-bearing. Functional outcomes were evaluated using the American Orthopedic Foot and Ankle Society (AOFAS) hindfoot scale preoperatively and 12 months after surgery.

Statistical analysis

In this study, we utilized SPSS Statistics 19.0 software (IBM SPSS, Chicago, IL, USA) to conduct a comprehensive statistical analysis of key variables. The homogeneity of variance for age, the degree of varus deformity of the distal tibia and talar tilt, time to union, and time to unassisted walking was expressed as mean \pm standard deviation.

A comparative analysis between preoperative and postoperative function, assessed through the AOFAS score, was performed using the Wilcoxon signed-rank test. Categorical variables, such as gender and etiology, were presented in absolute values and percentages. The 5% significance level was uniformly applied to all statistical tests ($P < 0.05$).

Surgical technique

The surgical technique for accessing the ankle joint was consistent across all patients. However, the technique of osteosynthesis underwent refinements as experience increased. Below is the final version of the proposed technique for ankle joint arthrodesis through a MITF approach.

Minimally-invasive transfibular (MITF) approach

Under spinal anesthesia, the patient was positioned supine, and skin preparation and draping were carried out. The pneumatic tourniquet was inflated just before the operation commenced. The lateral malleolus was palpated, and a single longitudinal incision of approximately 3–4 cm was made, centered over the ankle joint. Two reference K-wires were inserted, one proximally from the fibula perpendicular to the anatomical axis of the tibia towards the base of the medial malleolus, and the other distally from the fibula parallel and 2 mm distally to the talus articular surface (Fig. 1a). In cases of significant talus tilt, the distal wire was placed parallel to the first wire towards the lateral margin of the talus articular surface (Fig. 1b).

Following careful dissection of the fibula between the reference K-wires, two Hofman retractors are positioned anteriorly and posteriorly. Using an oscillating saw, the bone wedge from the fibula is resected (Fig. 2a). This resected fragment can later serve as a bone autograft. Subsequent

Fig. 1 The position of reference K-wires in varus ankle without (a) and with b talus tilt

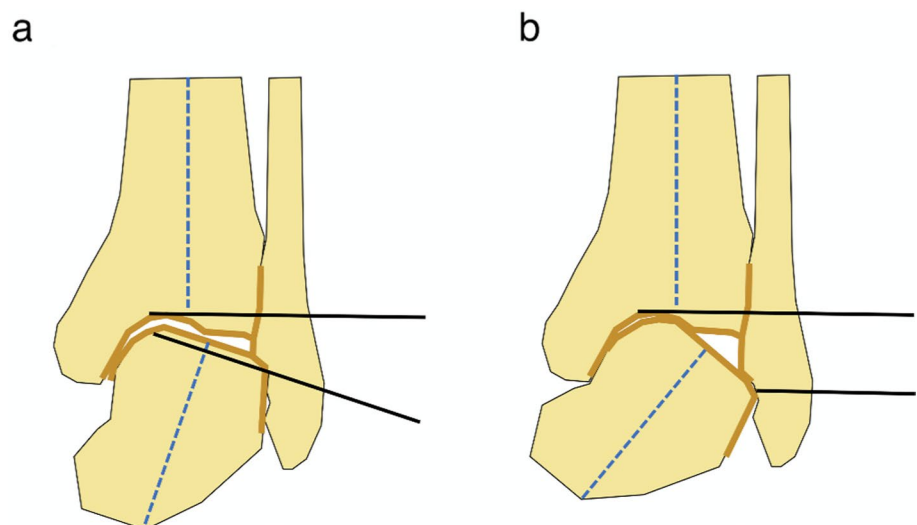
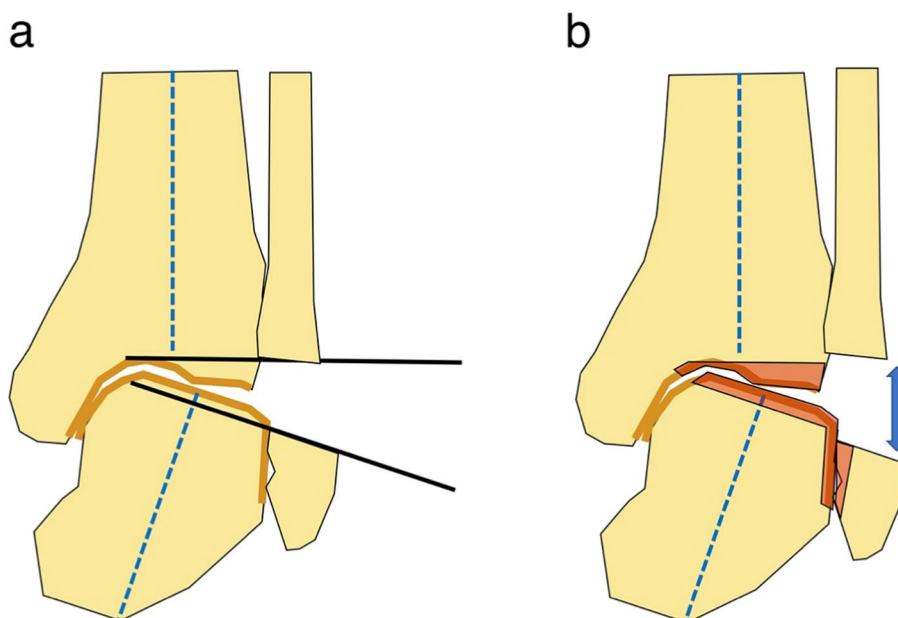


Fig. 2 Wedge resection from a fibula (a) and preparation of the articular surfaces (b)



to fibular wedge resection, a laminar spreader is introduced to provide clear visualization of the tibiotalar joint. Depending on the deformity, cartilage and the necessary bone for deformity correction from the talar and distal tibial regions are removed using osteotomes or an oscillating saw (Fig. 2b).

The achieved reduction is assessed under the image intensifier, and additional joint preparation is performed if necessary. The fibulo-talar and fibulo-tibial joints are prepared using an oscillating saw and osteotomes. The fibula is then reduced with a Weber clamp, and two provisional 2.8 mm threaded wires are placed through the tibiotalar joint (Fig. 3a, b).

Before osteosynthesis, the position of the tibiotalar joint is checked on the lateral view. Fibula fixation is accomplished with a 3–4 hole 3.5 mm reconstructive plate. Initially, a long fibulo-talar 3.5 mm cortical screw is placed in a distal hole, creating fibulo-talar compression. The fibula is drilled with a 3.5 mm drill bit, and the talus with a 2.5 mm drill bit. The second 4.0 mm fully-threaded cancellous or 3.5 cortical fibulo-tibial screw is placed in a dynamic (eccentric proximal) part of the hole. Screw tensioning creates compression at the osteotomy and arthrodesis site, with the fibula acting as a biologic plate. The third fibulo-tibial screw is placed in the proximal hole (Fig. 4a). An alternative method for fibulo-talar compression involves using a large Weber

Fig. 3 The prepared articular surfaces (a). Reduction of arthrodesis site with a Weber clamp and provisional fixation with two 2.8 mm threaded wires (b)

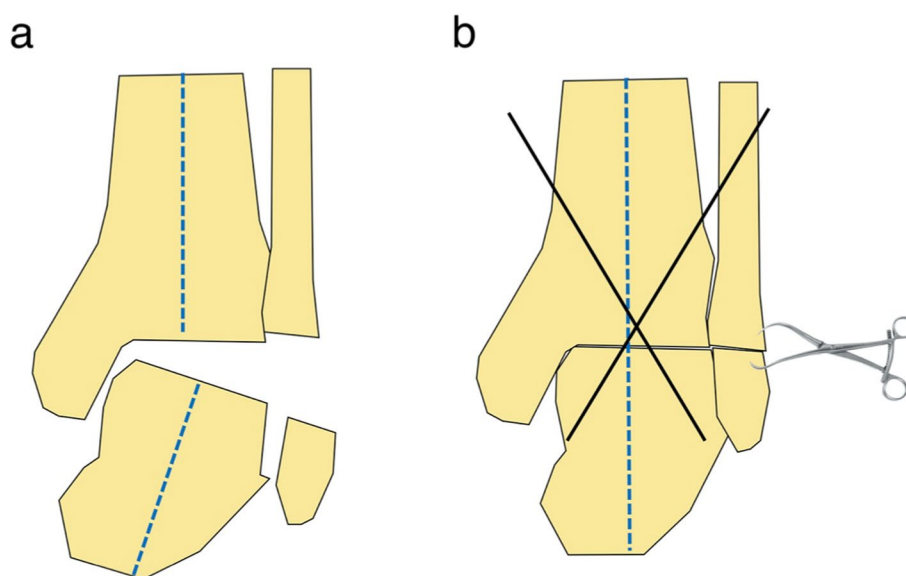
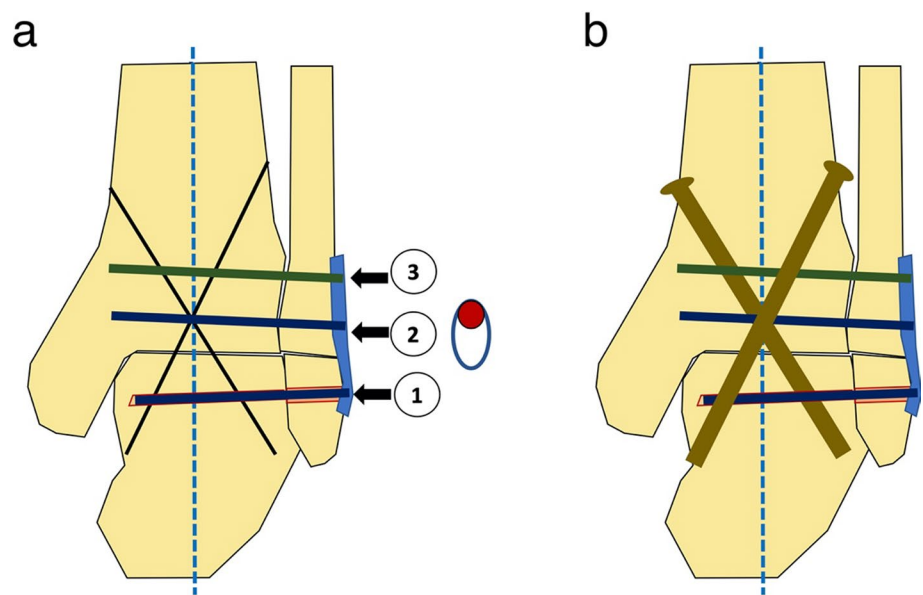


Fig. 4 The osteosynthesis with a reconstructive LCP plate (a) and two compression screws (b)



clamp. In this case, the plate is fixed in a distal hole with a locking screw.

The ankle arthrodesis is completed with two 6.5 headless compression or 7.3 cannulated screws (Fig. 4b). Our preference is to use the first partially threaded screw for compression and the second full-threaded screw for more rigid fixation.

In Fig. 5, preoperative fluoroscopic images (5a), an intraoperative picture of the surgical approach (5b), and a postoperative fluoroscopic image (5c) of a 57-year-old male with Takakura-Tanaka stage 3B varus ankle osteoarthritis are presented.

Postoperative treatment

Given the predominantly high-risk patients included in the current study, postoperative antibacterial prophylaxis was administered for 3–5 days. Aspiration drain was not employed. In uncomplicated cases, sutures were removed two weeks after surgery. A Stirrup splint was used postoperatively, and it was replaced with a short walking cast after suture removal. Nonweightbearing was recommended for the six weeks after the operation. Partial weightbearing was permitted at 6 weeks, and full weightbearing was allowed at 10 weeks.

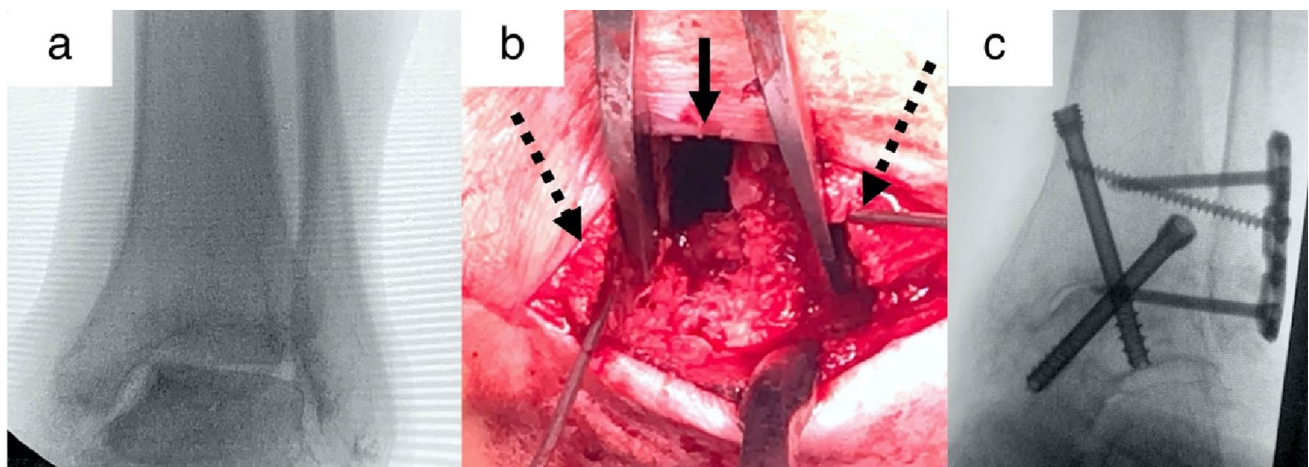


Fig. 5 The intraoperative pictures: a—AP view before arthrodesis, b—intraoperative picture of a surgical approach with a laminar spreader is placed between two fibular fragments (dashed arrows) to visualize an ankle joint (solid arrow), c—AP view after internal fixation of arthrodesis

Results

At 6 months post-operation, bony union was achieved in all 12 patients, with a mean time to union of 13.7 ± 5.2 weeks. The average time to initiate walking without additional support was 11.2 ± 3.8 weeks. Preoperatively, the mean varus of the distal tibia was 17.08 ± 8.36 degrees, and the talar tilt was 8.75 ± 4.33 degrees. Postoperatively, alignment at the coronal plane ranged between 0–5 degrees of valgus in all patients.

Functional outcome data demonstrated a significant increase in the AOFAS score, rising from 37.83 ± 7.79 points preoperatively to 77.42 ± 5.63 points one year after surgery ($p = 0.002$).

Two patients experienced minor complications: a 52-year-old male smoker with type 2 diabetes mellitus had wound edge necrosis, and a 54-year-old female with class II obesity (BMI = 36.7) and hypothyroidism had a superficial wound infection. Both cases were successfully treated with local therapy and a course of systemic antibiotics.

Discussion

Despite the advancement of arthroplasty and the widespread promotion of joint-preservation procedures, the indications for arthrodesis in ankle joint osteoarthritis remain extensive, often serving as the primary treatment option [29].

The lateral transfibular approach, being one of the most popular, offers exceptional visualization of the ankle joint. Primarily indicated in cases of varus ankle, this approach allows for deformity correction using closed-wedge joint surface resection. Access to the ankle joint is gained through the fibula, employing various osteotomy or resection techniques [14, 16, 20, 21].

Resection of the distal fibula provides excellent access to the ankle joint, however necessitates its complete dissection from soft tissues, including muscles, joint capsule and ligaments. This extensive surgical dissection increases the risk of infectious complications. This approach is accompanied by change in the shape of the ankle joint, causing discomfort in some patients.

After fibular resection, osteosynthesis is performed with a plate or screws [22–24]. For plate osteosynthesis, a bed for the plate fixation to the lateral surface of the tibia and talus is required. Braly et al. reported a union rate of 95% (18 out of 19 patients) with a mean time to union of 18 weeks, with no observed infectious complications [22]. It's essential to note that two potential factors increasing infection risk in this technique are the presence

of a massive subcutaneous plate in an environment of a postoperative hematoma resulting from traumatic dissection and resection of the articular surfaces. Techniques for total hindfoot arthrodesis through a lateral approach with fibular resection and fixation with a plate or intramedullary nail have also been described.

Suo et al. described a modified technique using a resected fibula fragment as a biological plate. After preparing the articular surface, the fibula is fixed to the talus and tibia with screws, resulting in 100% union observed in all 28 arthrodeses within 22 patients, with an average union time of 15 weeks. One patient experienced a superficial infection successfully treated by local therapy [30]. It is important to note that this technique does not reduce the traumatic nature of the operation concerning the surrounding soft tissues. The limitations of above-mentioned studies are retrospective design, small sample size, unclear inclusion criteria and no control group. These limitations in study design make it challenging to assess the true safety and efficacy of the techniques, especially in high-risk patients.

Modified approaches involving preserving the soft tissue connection to the fibula have been explored. After preparing the articular surface, the fibular flap is used as a biological plate, and the ankle joint is fixed with screws or an intramedullary nail in the case of total hindfoot arthrodesis [14, 26, 27]. These techniques include the formation of a bone flap, which is retracted anteriorly or posteriorly, resulting in significantly less aggressive soft tissue dissection. Colman et al. reported a 96% union rate in 48 patients, estimating a 93% union rate in 15 high-risk patients with a mean union time of 83 days (12 weeks). Complications were observed in 16.7% of cases, including nonunion in 2 patients, superficial infection in 3 patients, and pain in 3 patients [20]. Balaji et al. reported a 100% union rate with a mean union time of 3.8 months in 29 patients. Soft tissue complications were observed in 20.7% of cases, including superficial infection in 4 cases and non-infectious wound healing problems in 2 cases. Notably, out of 29 patients, 7 with an increased risk of complications (2 with rheumatoid arthritis, 5 with tuberculous arthritis) accounted for 4 of the 6 described complications [14]. The absence of a large subcutaneous implant after extensive soft tissue dissection is certainly a positive factor that may reduce the rate of infectious complications.

Table 2 provides a concise overview of the outcomes of tibiotalar arthrodesis conducted via the lateral approach as reported in a predominant portion of existing literature. Emphasis is placed on several notable limitations, including the limited sample sizes, the lack of a control group, and the retrospective nature of the studies in the overwhelming majority of instances. In the vast majority of cases, the inclusion criteria typically do not encompass high-risk patients, nor do they adequately consider the presence of deformity as a factor that may modify the outcomes. Consequently, it

Table 2 Overview of publications reporting the outcomes of tibiotalar arthrodesis conducted via the lateral approach

Author (year)	N. of cases	% of high-risk patients	Mean age	Etiology (primary/secondary)	Deformity	Approach details	Type of arthrodesis	Fixation method	Follow-up (months)	Union rate	Time to union (weeks)	Wound complications
Wang (1993) [31]	11	Unknown	41.2	unknown	Unknown	Fibular resection	Tibiotalar	Plate and screws	Not clear (mean – 41 month)	90.9%	11.8	1
Braly (1994) [22]	19	Unknown	54	0/19	Unknown	Fibular resection	Tibiotalar	Plate and screws	6–59	95%	18	0
Flückiger (2005) [26]	20	Unknown	52	Not clear	Unknown	Posterior fibular flap, combined with medial approach	Tibiotalar – 16, total—4	4.5 mm or 6.5 mm lag screws, fibula as a biologic plate	12–69	100%	Not clear	2
Colman (2007) [20]	48	16 smokers, 15 high risk	48	0/48	50%	Fibular resection	Tibiotalar	Three 6.5 mm screws, fibula as a biologic plate	Not clear (mean –36 months)	96% (93% for high risk)	11.7	3
Nielsen (2008) [32]	48	Unknown	51	10/38	Unknown	Fibular resection	Tibiotalar	Two 7.0 mm screws	12	84%	Not clear	4
Akra (2010) [33]	26	Unknown	56	3/23	Unknown	Posterior fibular flap	Tibiotalar	Two-four 7.3 screws, fibula as a biologic plate	12–36	100%	19.3	3
Napiontek (2015) [34]	23	Unknown	46	2/21	18—deformity	Posterior fibular flap	Tibiotalar	Two 6.3 or 7.0 mm screws	12–69	95.7%	Not clear	0
Schmidt (2017) [35]	35	6/35	57.1	Not clear	54% varus > 5°	Tranfibular (no details)	Tibiotalar	Not clear	> 12	97%	Not clear	Not clear
Balaji (2017) [14]	29	Unknown	50	0/29	Unknown	Posterior fibular flap, combined with medial approach	Tibiotalar	Two 6.5 mm screws, fibula as a biologic plate	> 12	100%	16.3	4
Kim (2018) [24]	22	Unknown	62.4	19/3	Unknown	Fibular resection	Tibiotalar	Two 7.0 mm screws, fibula as a biologic plate	Not clear	95.5%	11.8	0

Table 2 (continued)

Author (year)	N. of cases	% of high-risk patients	Mean age	Etiology (primary/secondary)	Deformity	Approach details	Type of arthrodesis	Fixation method	Follow-up (months)	Union rate	Time to union (weeks)	Wound complications
Suo (2020) [30]	28	Unknown	56.9	10/18	Unknown	Fibular resection	Tibiotalar	Two 7.3 mm screws, fibula as a biologic plate	12–54	100%	14.83	1
Lee (2020) [27]	27	Unknown	68.5	7/20	Unknown	Resection of anterior half of the fibula	Tibiotalar	Three 6.5 mm screws, fibula as a biologic plate	12–32	100%	Not clear	0
Kumar (2023) [36]	39	Unknown	40.36	0/39	Unknown	Fibular resection	Tibiotalar	Three/four 6.5 mm and 4.5 mm screws	24–65	91.7%	21.8	4

is imperative to exercise caution in the interpretation of the available data. A comprehensive literature review highlights that despite a considerable number of publications on ankle joint arthrodesis through the transfibular approach, an unequivocal assessment of its safety and effectiveness remains challenging, particularly for high-risk patients. Most publications have small sample sizes, retrospective designs, lack of control groups, and not stratification of enrolled patients by risk factors. Importantly, none of the previously described techniques can be considered minimally invasive, given the extensive soft tissue dissection involved.

Unlike other techniques, the proposed minimally-invasive transfibular approach does not require significant detachment of soft tissues from the fibula. The osteotomy is performed at the level of the joint space, providing the most direct view of the articular surfaces in the same plane as the osteotomy. In cases of varus arthritis, resection of the fibular wedge improves joint visualization and allows deformity correction. Osteosynthesis of the fibula with a short plate creates compression at the osteotomy and arthrodesis site, providing mechanically favorable fixation for early union. The arthrodesis through the described MITF approach demonstrated excellent results, even in high-risk patients. The small sample size, however, limits definitive statements regarding its effectiveness and safety compared to other techniques.

Conclusion

The described technique of the minimally-invasive transfibular approach for ankle arthrodesis has demonstrated promising results, particularly in addressing end-stage ankle osteoarthritis with varus deformity, especially in high-risk patients. However, it's important to acknowledge the main limitations of the current study, including the small sample size and the absence of a control group. To comprehensively assess the effectiveness and safety of the proposed technique, there is a critical need for a prospective comparative clinical trial with a larger patient cohort. Such a study would provide more robust evidence to guide the recommendation and widespread adoption of this approach in clinical practice.

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Declarations

Conflict of interest The author(s) declare that they have no competing interests.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Specialized Orthopedic University Hospital “Prof. B. Boychev” (12.08.2020/№ A21-C0820).

Informed consent Informed consent was obtained from all individual participants included in the study.

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