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Arthroscopic reconstruction of the lateral ankle ligaments: Radiological evaluation and short-term clinical outcome



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KEYWORDS

Radiography;
Lateral ankle ligaments;
Arthroscopic anatomical reconstruction;
Postoperative evaluation

Abstract

Purpose: The purpose of this study was to describe the positioning of bone tunnels of arthroscopic anatomical reconstruction of lateral ankle ligaments (AAR-LAL) and identify radiological measurements associated with short-term clinical outcome one year after surgery.

Materials and Methods: A total of 61 patients were included in this IRB-approved retrospective study. There were 52 men and 9 women, with a mean age of 36.3 ± 10.8 (SD) years. AAR-LAL was performed to treat chronic instability secondary to strain sequelae after failure of conservative treatment. Good short-term clinical outcome was defined by Karlsson-score ≥ 80 ($n = 40$) one year after surgery. Sixteen radiological measurements were studied to characterize the positionings of fibular, talar and calcaneal tunnels (FT, TT and CT, respectively). Feasibility and inter-observer agreement were calculated for each measurement. Receiver operating characteristic curves were used to identify optimal thresholds for measurements associated with outcome at univariate analysis. A binary logistic regression was used to identify independent predictors.

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Results: Two measurements were associated with good outcome: distance from the proximal FT entrance to the distal end of the fibula on anteroposterior (AP) view (called 'AP distal FT', $P=0.005$), and the ratio between the distance from TT entrance to the talo-navicular joint and the talus length on lateral view ($P=0.009$). Optimal thresholds were of >35 mm and <0.445 , respectively. At multivariate analysis, only 'AP distal FT' >35 mm remained independent predictor of good outcome ($P=0.002$).

Conclusion: Radiological evaluation of bone tunnels following AAR-LAL is feasible, reproducible, and helps predict short-term outcome after reconstruction of lateral ankle ligaments.

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Chronic ankle instability is extremely common, especially during sports activities. It mostly results from inversion injuries and affects the lateral ligament complex, including the anterior talo-fibular ligament (ATFL) and/or calcaneofibular ligament (CFL). The first step after an acute sprain is an intensive preservative functional treatment [1–3]. However, 20–40% of patients continue to suffer from pain and/or instability [4,5], which can be responsible for osteochondral lesions of the talar dome and ankle osteoarthritis. Therefore, surgical restabilization is required before irreversible damages [6].

Several surgical techniques have been described, including ligament repair (suture) and non-anatomical or anatomical reconstruction (replacement) [7]. Arthroscopic anatomical reconstruction of lateral ankle ligaments (AAR-LAL) is a promising and increasingly used technique that reproduces the anatomical orientation of both the ATFL and CFL with the help of three bone tunnels [8,9]. It better resists anterior displacement, internal rotation and talar tilt, without restricting subtalar joint motion. Long term results have been even more convincing than short term results [4], tending to replace non anatomical procedures. This technique has been recently improved by careful and precise positioning of tunnels and anchors at footprint sites of proximal and distal insertions, and by using arthroscopy [10–12].

While the surgical techniques are improving and have already proved their ability to restore good functional properties, little is known about their radiographic post-operative evaluation at short-, mid- and long-term. With arthroscopic techniques becoming widespread, both musculoskeletal radiologists and non-specialized radiologists may face postoperative radiographs of AAR-LAL. By analogy with the cruciate ligaments of the knee, there is a need for imaging criteria in order to improve postoperative radiographic assessment after an AAR-LAL and to help identify tunnel positionings at risk of pain and instability.

The purpose of this study was to describe the positioning of bone tunnels of AAR-LAL and identify radiological measurements associated with short-term clinical outcome one year after surgery.

Materials and methods

Study design and population

This single-center retrospective study was IRB approved (Université de Bordeaux, France, 33FR700-03-2016-8). A total of 87 consecutive mid-sport level patients with a history of one or more sprain injuries were initially included. They were seen at our institution for symptomatic chronic ankle instability, secondary to lateral sprain injuries, after failure of non-surgical functional treatment. None of them had prior ankle surgery. They all underwent AAR-LAL between January 2013 and December 2015.

Exclusion criteria were: age under 18 years old, pregnancy, neuromuscular disorder, previous history of ankle fracture, infections, diabetic foot syndrome, bony malalignment, preoperative radiographic osteoarthritis of the ankle and subtalar joints (which was a contraindication for surgery), intercurrent ankle surgery and non arthroscopic technique.

Medical history and subjective symptoms of instability were systematically reported by the surgeon (with expertise in ankle surgery, founding member of the Ankle Instability Group) during a preoperative consultation. The surgeon also performed comparative physical examination to estimate ligaments functionality with the help of anterior drawer and varus tilt test.

Radiological evaluation consisted in classical comparative weight-bearing anteroposterior (AP), lateral and mortise views, Meary view for hind foot alignment (with a wire circling the back heel) and stress views performed with a Telos stress device including anterior drawer test and talar tilt test. Radiographic instability was defined by a talar tilt angle $>10^\circ$ or $>10^\circ$ difference with the other side, and/or an anterior drawer >8 mm or more than a 3 mm difference with the controlateral ankle. For all patients, ultrasound of the ankle was performed to investigate the state of ligaments and tendons damage, as well as a computed-tomography (CT) arthrography to identify cartilage injury. Lesion of the CFL was defined as an evidence of tears on ultrasound examination associated with an opacification of the fibular sheaths

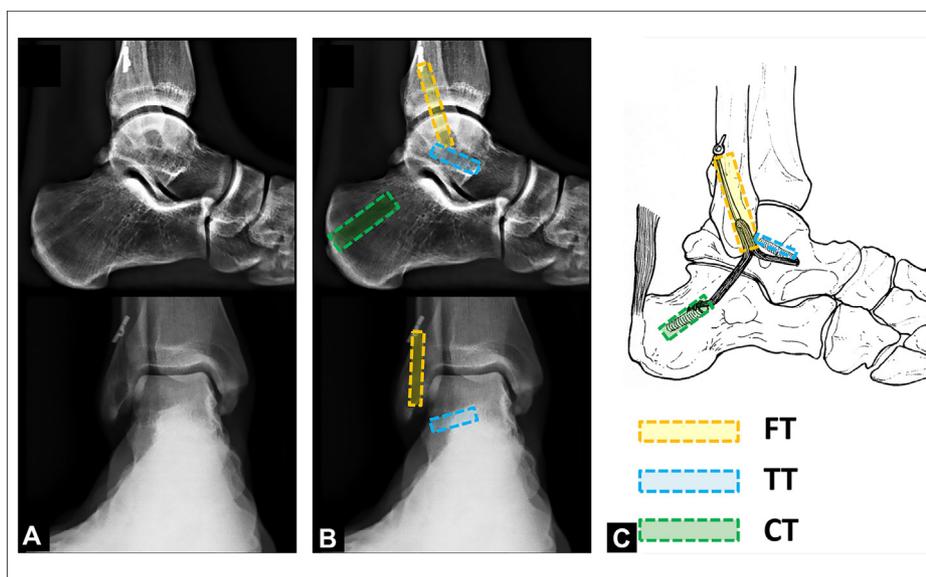


Figure 1. Tunnels positioning. The arthroscopic reconstruction of lateral ankle ligaments consists in the positioning of three tunnels: fibular tunnel (FT), talar tunnel (TT) and calcaneal tunnel (CT), which can be seen on lateral and anteroposterior views (A) and are highlighted in yellow, blue, and green, respectively (B). (C) corresponds to a scheme illustrating the tendon autograft that is fixed inside the TT and FT with the help of biointerference screws, and in the FT with a pin as a fixation device. The graft between the entrances of FT and TT reproduces the anterior talofibular ligament (ATFL). The graft between, and the entrances of, FT and CT reproduces the calcaneofibular ligament (CFL).

on CT-arthrography, demonstrating the communication with the tibio-talar joint.

Surgical technique

Surgeries were all performed by the same surgeon with more than 20 years of experience in ankle surgery, including 5 years of experience in arthroscopic ankle surgery and funding member of the Ankle Instability Group [12]. In brief, an autograft was prepared from the ipsilateral gracilis tendon to create a 1-cm-long doubled segment with two single strand limbs for the ATFL and CFL reconstructions. ATFL limb was 4 cm-long and CFL limb was 5.5 cm. The fibular tunnel (FT) was drilled with an approximate 10° axis, from distal to proximal, rotating anteriorly to the axis of the fibula. The fixation device was hooked on the posterolateral cortex of the fibula. The calcaneal tunnel (CT) was drilled through the calcaneus with a distal, posterior and medial direction, and crossed both cortices. The talar tunnel (TT) was drilled after exposing the talar insertion of the ATFL. It was a 20 mm deep tunnel with a slightly proximal direction, centred towards the middle of the talus. Of note, tunnels positioning was not assisted by radiographs during the surgical procedure. The technique simultaneously repairs ATFL lesions and eventually associated CFL lesions, consequently none of the patients had an additional CFL reconstruction. Fig. 1 illustrates the tunnels positioning.

Postoperative clinical evaluation

Postoperative clinical evaluation was made by the same surgeon. Patients were asked to answer the widely used and validated functional Karlsson-score. It is made of 8

categories and 100 points. It combines subjective ankle instability (25 points), pain (20 points), swelling (10 points), stiffness (5 points), need for support (5 points), and symptoms associated with stair climbing (10 points), running (10 points) and work activities (15 points) [13]. Patients were then classified in two groups: good clinical outcome (Karlsson-score $\geq 80/100$) and poor clinical outcome (Karlsson-score $< 80/100$). Short-term evaluation was defined as the evaluation performed one year after surgery (± 28 days).

The AOFAS ankle and Hindfoot Scale was also collected during postoperative consultations, in order to assess gait, ankle range of motion in flexion/extension, hindfoot mobility and malalignment. Patients were finally asked to rate their subjective satisfaction according to a ten-points scale, from 1 (unacceptable) to 10 (fully satisfied). All these scores were collected within 2 days after the postoperative radiographs, and at each clinical evaluation. Of note, none of the patients had other surgeries during the follow-up.

Radiological postoperative evaluation

All the radiographs were classical weight-bearing strict AP, lateral and Meary views. Measurements were independently performed by 2 radiologists blind to clinical data: a senior and a junior musculoskeletal radiologists with 9 and 2 years of experience in musculoskeletal imaging, respectively. Data were analyzed on a picture archiving and communication system (Entreprise Imaging, Agfa). Fig. 2 shows how the radiological measurements were evaluated.

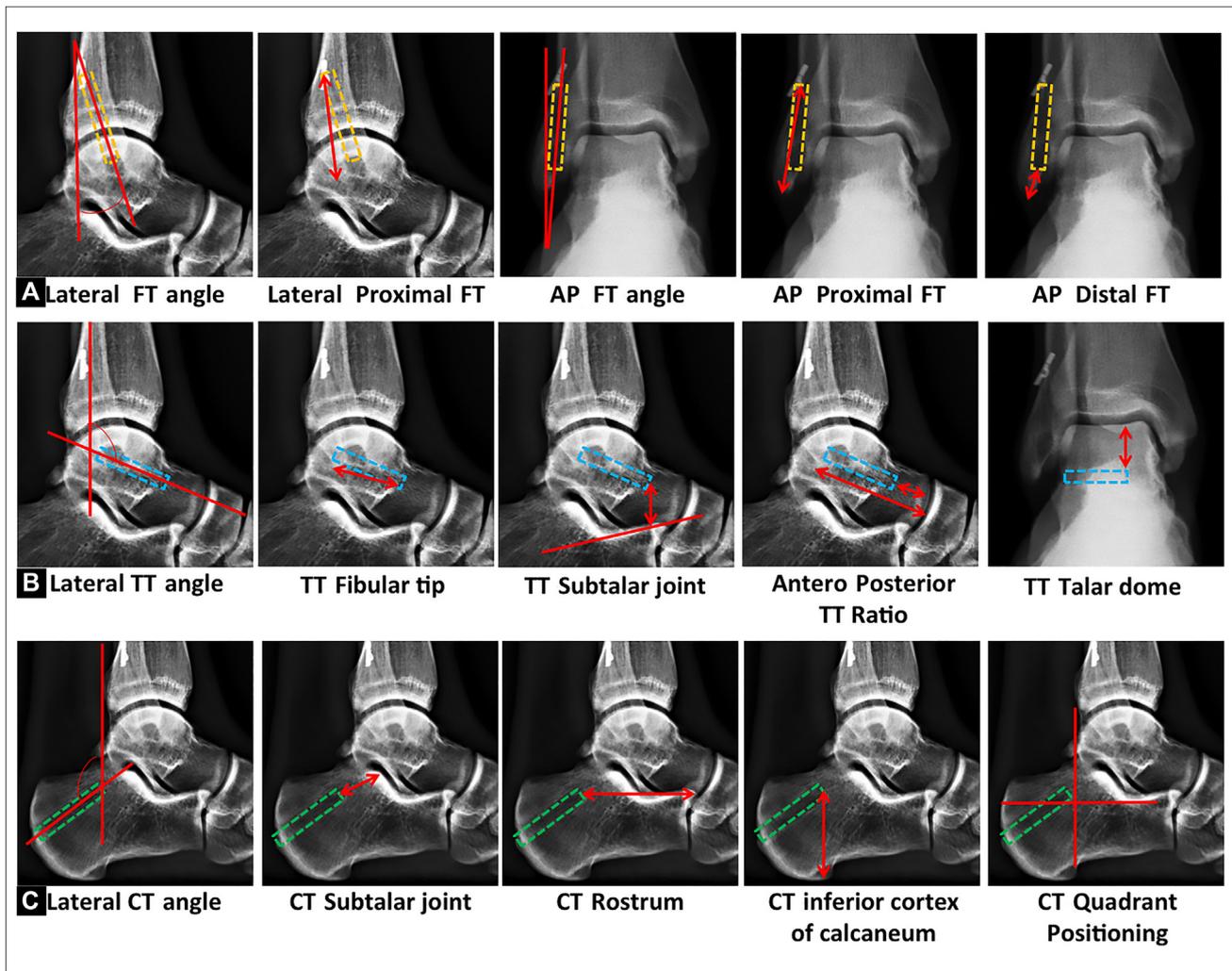


Figure 2. Radiographs show all radiographic measurements. A. Panel shows the five measurements that were performed to evaluate the FT positioning. B. Panel shows the five measurements to evaluate the TT. C. Panel shows the five measurements to evaluate the CT. Of note, the FT orientation on AP view, called ‘AP FT orientation,’ is not represented.

Fibular tunnel

Placement of FT was assessed by 6 measurements (Fig. 2A): i), the angle between the FT and the posterior cortex of the fibula on lateral view (called ‘Lateral FT angle’); ii), the distance between the center of the proximal FT entrance and the distal end of the fibula on lateral view (called ‘Lateral proximal FT’); iii), the angle between FT and the lateral cortex of the fibula on AP view (called ‘AP FT angle’); iv), the distance between the center of the proximal FT entrance and the distal end of the fibula on AP view (called ‘AP proximal FT’); v), the distance between the center of the distal FT entrance and the distal end of the fibula AP view (called ‘AP distal FT’); vi), FT orientation was reported on AP view: medial or lateral or vertical (called ‘AP FT orientation’).

Talar tunnel

Positioning of TT was assessed by 5 measurements (Fig. 2B): i), the distance between the centre of the TT entrance and

the distal end of the fibula on lateral view (called ‘Lateral TT fibula’); ii) the distance between the center of TT entrance and a line passing through the subtalar joint on lateral view (called ‘Lateral TT subtalar joint’); iii) the ratio between the distance from the TT entrance to the talo-navicular joint and the maximal length of the talus on lateral view (called ‘Lateral TT ratio’); iv) the angle between =TT and a vertical line on AP view (called ‘AP TT angle’); v) the distance between the center of =TT entrance and the talar dome on AP view (called ‘AP TT talar dome’).

Calcaneal tunnel

Placement of CT was assessed by 5 measurements, all on lateral view (Fig. 2C): i), the angle between CT and the posterior cortex of the fibula (called ‘Lateral CT angle’); ii), the distance between the subtalar joint and the center of CT entrance (called ‘Lateral CT subtalar joint’); iii), the distance between the calcanean rostrum and the center of CT entrance (called ‘Lateral CT rostrum’); iv), the

distance between the inferior cortex of the calcaneus and the center of CT entrance (called 'Lateral CT inferior calcaneus'); v), 'Lateral CT-quadrant positioning': the entrance of CT was projected within a quadrant defined by a vertical line (tangent to the posterior convexity of the talus) and horizontal line (going through the deepest concavity of the tarsal sinus).

Additional measurements

The relationship between the posterior opening of CT and the distal insertion of the calcaneal tendon was considered at risk of tendon injury if the distal extremity of the CT opened at the upper half of distal tendon enthesis. Hindfoot malalignment was also investigated on Meary view.

Statistical analysis

Statistical analysis was based on the lecture of the senior radiologist. Feasibility of a radiological measurement was defined as the percentage of patients in which the measurement could be made with certainty. We defined a measurement as 'feasible' if it was measurable in > 2/3 (67%) of patients. Inter-observer agreements were assessed using interclass correlation coefficient (ICC) for continuous values (with two-way mixed model). The Cohen's Kappa (κ) test for pairwise agreement was used for categorical variables. The agreement for ICC was defined as good (> 0.75), moderate (0.5–0.75) or poor (< 0.5). The agreement for classical κ was defined as slight (0–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.8–0.99).

For feasible and at least moderately reproducible variables, we continued the analysis and investigated association with short-term outcome defined as 'good outcome' if Karlsson-score was ≥ 80 and 'poor outcome' if Karlsson-score was < 80. Normal distribution of continuous variable was assessed by Shapiro–Wilk normality test. Continuous variables were analyzed with unpaired Student *t*-test

(or non-parametric Wilcoxon-test, depending on normality test), and qualitative variables with Fisher-test (or Chi² test). For significant epidemiological data and radiological measurements, receiver operating characteristic (ROC) curves were built in order to determine the optimal thresholds to discriminate patients with good and poor outcomes, that is, that satisfied the Youden index *J* (defined as $J = \text{sensitivity} + \text{specificity} - 1$). These measurements were dichotomized accordingly, and analysed with a binary logistic regression to estimate multivariate OR with their 95% confidence interval (CI). Patients with missing value were excluded from the multivariate analysis. All tests were two-tailed. Statistical analyses were done using the SPSS statistical package (IBM, version 21.0, Chicago, IL). A *P* value < 0.05 was deemed significant. Results were expressed as mean, standard deviation (SD) and ranges.

Results

Patient population

Eighty-seven caucasian patients were initially enrolled. There were 26 patients excluded because of incomplete imaging ($n=20$) or clinical evaluations ($n=6$), leading to 61 patients (52 men and 9 women), with a mean age of 36.3 ± 10.8 (SD) years. Karlsson-score, AOFAS and subjective satisfaction scores for the whole population were $77.6/100 \pm 17.4$ (SD), $82.1/100 \pm 20$ (SD) and $7.5/10 \pm 2.2$ (SD), respectively. Forty (65.5%) patients had a good short-term outcome and 21 (34.4%) a poor outcome. Baseline characteristics (age, gender, operated side, coexisting lesions of CFL and preexisting focal chondropathy) were not significantly different between the two groups (Table 1).

Radiological evaluation

Table 2 summarizes the reproducibility and the feasibility of all the radiological measurements. Some measurements were hardly feasible, such as 'Lateral FT angle', 'Frontal TT angle', 'AP TT talar dome' (42.6%, 29% and 29%,

Table 1 Patients characteristics.

Variables	All patients ($n=61$)	Good outcome ($n=40$)	Poor outcome ($n=21$)	<i>P</i> value
Age	36.3 ± 10.8	36.3 ± 11.3	36.3 ± 10.0	0.987
Gender				0.253
Women	52 (85.2%)	36 (90%)	16 (76.2%)	
Men	9 (14.8%)	4 (10%)	5 (23.8%)	
Side				> 0.999
Right	29 (47.5%)	19 (47.5%)	10 (47.6%)	
Left	32 (52.5%)	21 (52.5%)	11 (52.4%)	
Associated CFL injury	34 (55.7%)	20 (50%)	14 (66.7%)	0.281
Chondropathy grade \geq III	4 (6.6%)	2 (5%)	2 (9.5%)	0.602
AOFAS score	82.1 ± 20	88.0 ± 18.2	68.9 ± 17.9	< 0.0001
Overall satisfaction score	7.5 ± 2.2	8.5 ± 1.1	5.6 ± 2.5	< 0.0001

Data are number of patients with percentage in parentheses. CFL: calcaneo-fibular ligament; AOFAS: American Orthopedic Foot and Ankle Society hind foot score.

Table 2 Inter-observer agreements and feasibility of the radiological measurements.

Measurements	Inter-observer agreement	Feasibility (%)
Fibular tunnel		
Lateral FT angle	0.975 [0.940–0.990] ^a	26 (42.6)
Lateral proximal FT	0.950 [0.841–0.944] ^a	56 (91.8)
AP FT-angle	0.898 [0.819–0.912] ^a	48 (78.7)
AP proximal-FT	0.915 [0.857–0.950] ^a	59 (96.7)
AP distal-FT	0.990 [0.984–0.994] ^a	52 (85.2)
AP FT orientation	0.345 [0.241–0.449] ^b	48 (78.7)
Talar tunnel		
Lateral TT-fibula	0.632 [0.290–0.810] ^a	42 (69)
Lateral TT-subtalar joint	0.733 [0.475–0.865] ^a	42 (68.8)
Lateral TT ratio	0.717 [0.468–0.850] ^a	43 (70.5)
AP TT angle	0.832 [0.515–0.943] ^a	17 (27.9)
AP TT talar dome	0.874 [0.786–0.927] ^a	17 (28)
Calcaneal tunnel		
Lateral CT-angle	0.922 [0.862–0.956] ^a	47 (77)
Lateral CT-subtalar joint	0.853 [0.747–0.915] ^a	54 (89)
Lateral CT-rostrum	0.874 [0.791–0.925] ^a	54 (89)
Lateral CT inferior calcaneus	0.926 [0.868–0.959] ^a	54 (89)
Lateral CT quadrant positioning	0.359 [0.287–0.431] ^b	49 (80.3)

FT: fibular tunnel; AP: anteroposterior; TT: talar tunnel; CT: calcaneal tunnel.

^a Indicates ICC with their 95% confidence interval.

^b Indicates kappa values with their 95% confidence interval. Feasibility is defined as the percentage of patients (in parentheses) for whom the radiological measurement was easy to perform and given with certainty. Nonfeasible measurements were due to ill-defined anatomical structures and/or tunnels on radiographs.

respectively). All the inter-observer agreements were at least moderate except ‘AP FT orientation’ ($\kappa=0.345$) and ‘Lateral CT quadrant positioning’ ($\kappa=0.359$). These 5 measurements were consequently removed from the following analysis.

Association between radiological measurements and clinical outcome

At univariate analysis, ‘AP proximal FT’ was significantly greater in patients with good clinical outcome (40.3 ± 12.5 [SD] mm) than in those with poor clinical outcome (31.6 ± 6.6 [SD] mm) ($P=0.005$). ‘Lateral TT ratio’ was significantly lower in patients with good clinical outcome (0.409 ± 0.050 [SD]) than in those with poor clinical outcome (0.458 ± 0.068 [SD]) ($P=0.009$) (Table 3). Measurements related to calcaneal tunnel positioning were not statistically different between the two groups.

ROC curves analysis provided an area under the curve (AUROC) of 0.783 (95%CI: 0.657; 0.909) for ‘AP proximal FT’, and of 0.727 (95%CI: 0.565; 0.889) for ‘Lateral TT ratio’, with best threshold of 34 mm and 0.445, respectively (Fig. 3). After dichotomization according to these thresholds, the diagnostic value of each of these two variables were calculated (Table 4) and they were entered into multivariate analysis. Only ‘AP proximal FT > 35mm’ remained an independent predictor of good short-term clinical outcome (OR = 11.98; 95%CI: 2.43–59.06) ($P=0.002$) (Table 5).

Neither infection, nor neuralgia was reported during the follow-up. Four patients suffered from talagia. Radiographs of these 4 patients demonstrated a projection of the

calcaneal tunnel on calcaneal tendon entheses. However, this was also present in other 14 asymptomatic patients (24.6%). No differences in prevalence of post-operative calcaneal pain were found between the groups ($P=0.607$).

Discussion

This study evaluated several radiographic measurements in order to identify accurate, reproducible and useful criteria associated with favorable short-term clinical outcome one year after surgery, defined as Karlsson-score ≥ 80 . Of the 16 proposed measurements, 5 were excluded because of technical difficulties to visualize and estimate them. AP proximal FT and Lateral TT ratio were associated with good outcome and AP proximal FT > 34 mm was an independent predictor of good clinical outcome. Despite the lack of significant association between the other radiological measurements and outcome, this does not mean that these measurements do not matter, on contrary, it suggests that the surgeon correctly placed all of them. In addition, since AP proximal FT > 34 mm’ was the sole independent predictor in our study, we believe that in any case, the surgeon should try to place the FT at least 34 mm above the distal end of the fibula.

Further anatomical and biomechanical studies on cadaver should be performed to understand why AP proximal FT > 34 mm’ could improve clinical outcome. The explanation could be that verticalization of the graft increases its tensile force. Lateral TT-ratio was significantly lower in the group with good outcome than in the group with poor outcome. However this measurement appears more difficult

Table 3 Association between radiological measurements and short-term clinical outcome at univariate analysis.

Variables	Good outcome	Poor outcome	P value
Fibulartunnel			
Lateral proximal FT	46.1 ± 16.1 [28; 89]	38.4 ± 10 [17; 64]	0.091
AP FT angle	7 ± 4.1 [0; 20]	9 ± 4.3 [0; 20]	0.133
AP proximal FT	40.3 ± 12.5 [14; 67]	31.6 ± 6.6 [17; 50]	0.005
AP distal FT	6.3 ± 3.9 [1; 16]	5.3 ± 3.3 [0; 11]	0.250
Talar tunnel			
Lateral TT fibula	30.9 ± 8.3 [8; 47]	30.8 ± 7 [14; 41]	0.940
Lateral TT subtalar joint	20.5 ± 4.7 [2; 32]	22.7 ± 3.2 [15; 32]	0.109
AP TT ratio	0.409 ± 0.050 [0.20; 0.58]	0.458 ± 0.068 [0.38; 0.6]	0.009
Calcaneal tunnel			
Lateral CT angle	129 ± 12.5 [115; 148]	128 ± 10.9 [110; 153]	0.919
Lateral CT subtalar joint	13.5 ± 5.6 [6; 34]	14.9 ± 6.2 [6; 28]	0.378
Lateral CT rostrum	53.6 ± 10 [34; 79]	58.3 ± 9.1 [37; 83]	0.077
Lateral CT Inferior calcaneus	55.7 ± 9.7 [37; 79]	57.5 ± 12.3 [34; 83]	0.201

Numbers are expressed as mean ± SD. Numbers in brackets are ranges. FT: fibular tunnel; AP: anteroposterior; TT: talar tunnel; CT: calcaneal tunnel. Results are expressed as mean ± standard deviation. Angles are expressed in degree, ratios do not have units, measurements are expressed in mm. Only measurements combining acceptable feasibility and at least moderate reproducibility are shown.

Table 4 Diagnostic value of radiological measurements associated with good short-term clinical outcome.

	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV
AP proximal FT (> 34 mm)	28	15	5	9	76% (28/37)	75% (15/20)	85% (28/32)	62% (15/24)
Lateral TT ratio (< 0.445)	23	11	7	5	82% (23/28)	61% (11/18)	77% (23/30)	69% (11/16)

TP: true positive; TN: true negative; FP: false positive; FN: false negative; PPV: positive predictive value; NPV: negative predictive value; AP: anteroposterior; FT: fibular tunnel; TT: talar tunnel. Data for TP, TN, FP and FN are numbers of patients. Data for sensitivity, specificity, PPV and PPN are percentages with proportions in parentheses.

Table 5 Results of univariate and multivariate analyses of radiological measurements associated with good short-term clinical outcome.

Measurements	Univariate analysis		Multivariate analysis	
	OR	P value	OR	P value
AP proximal-FT (> 34 mm)	9.33 [2.62–31.12]	0.001	11.98 [2.43–59.06]	0.002
Lateral TT-ratio (< 0.445)	7.23 [1.97–17.99]	0.004	3.37 [0.68–16.74]	0.168

OR: odds ratio; AP: anteroposterior; FT: fibular tunnel; TT: talar tunnel. Numbers in brackets are 95% confidence interval.

to perform with moderate ICC. One could hypothesize that too proximal an entrance of TT would lead to laxity of the graft and to possible subluxation of the talus when the foot is plantar-flexed. Indeed, Karlsson et al. showed that such laxity is correlated with poor clinical outcome [14].

Some additional measurements could have been studied. The fibular tubercle is a surgically useful landmark, located at the postero-superior side of the peroneal trochlea, which is easily palpable and helpful for peroperative location of the calcaneal insertion [15]. This tubercle is classically located 20 mm posteriorly to the calcaneal tunnel. However, despite being clinically relevant, this landmark is hardly detected on radiographs.

We can also question which imaging modality could evaluate at best the quality of the surgery. CT with multiplanar and volume-rendering reconstructions would better estimate the tunnels positionings. This study was retrospective, performed in a daily clinical routine, but further studies should explore the performance of CT in this indication. In addition, peroperative imaging and computer assistance is a growing field in orthopedic surgery that could overcome the issue of sub-optimal visualization, especially in ankle radiographs, and therefore improve tunnels positioning [16]. Indeed, 5 radiological measurements were removed from the analysis because they were considered as 'hardly feasible' in more than one third of patients. The lack of feasibility

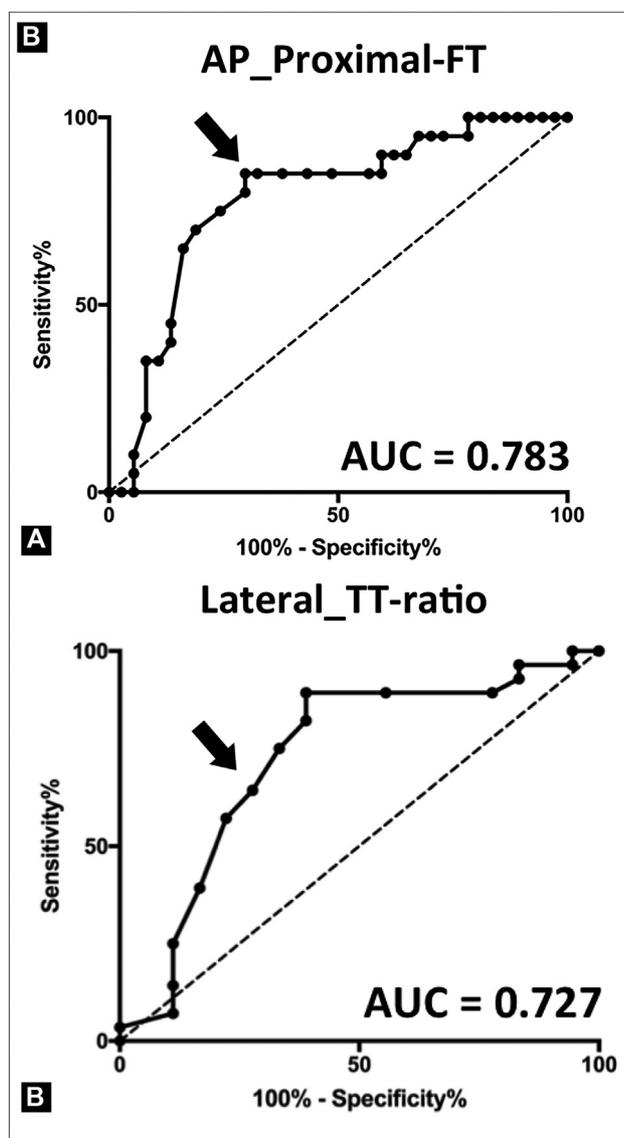


Figure 3. ROC curves of the two radiological measurements associated with good clinical outcome: 'AP Proximal FT' (A) and 'Lateral TT ratio' (B). Black arrows indicate the optimal thresholds providing highest Youden index (0.553 for AP proximal FT and 0.504 for Lateral TT ratio).

reflected difficulties for the radiologists to clearly distinguish the bone tunnel from the normal ankle anatomy and the risk of misinterpreting the radiographs. This could have been due to the poor contrast between the small-size tunnels and the adjacent structures on classical radiographs, the lack of experience in this recent field of musculoskeletal imaging, or soft-tissue swelling. In addition, failure of the reconstruction may also be secondary to poor quality or alterations of the autograft, independently of the tunnel positionings. Ultrasound could help verify the integrity of the graft. Magnetic resonance imaging (MRI) and MR-arthrography could enable to evaluate simultaneously the tunnel positionings, the autograft, but also the occurrence of chondropathy and new lesions to regional structures. The diagnostic strategy in case of poor clinical outcome should include these alternative imaging modalities and further

studies could investigate their added value as compared to classical radiographs.

Our study has limitations. The first relates to inclusion bias due to performance in a tertiary orthopedic center by a single surgeon with a strong expertise in ankle surgery and who participated in the elaboration of the technique, thus possibly underestimates the actual prevalence of complications. A second limitation is due to possible evaluation bias since the same surgeon performed the preoperative clinical evaluation, the surgery and the postoperative clinical evaluation. In a research setting, clinical evaluations should be done by a different person, blinded to clinical, radiological and surgical data. It should be noted that there is a lack of consensus regarding the best score to evaluate clinical outcome for ankle surgery [13,17]. Nevertheless, Karlsson et al. demonstrated that their score was correlated with both subjective and objective signs [13]. We also reported the AOFAS score and it showed good correlation with Karlsson-score. Finally, this study did not take into account inter-patient variability. The morphology of musculoskeletal structures depends on gender, height, activity or origins and this might lead to confusion bias in significance of the radiographic measurements. However, we did not find statistical difference between the two groups regarding epidemiological data that were available in patients' medical records.

In conclusion, we propose several radiological measurements from classical lateral and AP views and assessed their reproducibility, feasibility and association with short-term clinical outcome, one year after surgery. If further multicentric studies including long-term follow-up are required, our results could help radiologists to improve their evaluation of postoperative radiographs after an arthroscopic reconstruction of the CFL and ATFL.

Disclosure of interest

The authors declare that they have no competing interest.

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