Chronic ankle instability. Which tests to assess the lesions? Which therapeutic options?

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Summary  This paper purpose is to suggest an in-depth approach to diagnose the causes and lesions associated with and consecutive to chronic ankle instability due to ankle collateral ligament laxity. The different therapeutic and medicosurgical options adapted to this diagnostic approach are identified. The diagnostic aim is to precisely locate the ligamentous injuries of the tibiofibular, subtalar, talar and calcanean system, to identify the predisposing factors such as the hindfoot morphology, and any lesions associated with chronicity: anterolateral impingement, fibular injury, osteochondral lesions of the talus dome and early osteoarthritis. Clinical tools are used in particular to identify areas of pain and for comparative analysis of mobility and laxity (ligament testing). There are also radiological tests, weight-bearing plain X-ray (stress X-ray), (alignment of the hind foot, with a Meary view [metal wire circling the heel], arthrosis), dynamic images to confirm and quantify laxity (manually, with a Telos device, with patient-controlled varus) and also more sophisticated techniques (ultrasound, CT arthrogramm, gadolinium enhanced MRI, MR arthrogramm) to identify ligament, tendon and cartilage damages. They are adapted to the lesions which have been identified in the diagnostic work-up: conservative first, to treat proprioceptive deficits (a new neuromuscular reprogramming technique which emphasizes muscle preactivation) and any static disorders (plantar orthotics); then surgical, to repair any collateral ligament (or sometimes subtalar) injury with three types of procedures: tightening the capsuloligamentous structures, ligament reconstruction with reinforcement (using the fibrous peristoeum, the frondiform ligament (of Retzius) or tendinous reconstruction with the plantaris muscle, the peroneus tertius or even the calcanean tendon) and tendon transfer procedures using all or part of the peroneus brevis (whole peroneus brevis and half peroneus brevis procedures). Any additional surgical procedures which may be indicated based on the results of the diagnostic work-up are performed at the same time as primary surgery when possible (medial complex repair, calcaneal realignment osteotomies, talus osteochondral injuries debridment or fixation, anterior and posterior

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Introduction

Ankle sprains are the most frequent and common injuries in athletes [1–3]. Although capsuloligamentary damage of the lateral compartment is one of the determining elements of chronic ankle instability, it cannot be dissociated from its subtalar component [4,5]. Moreover, other ligamentary lesions of the polyarticular complex of the ankle should not be ignored, in particular medial lesions (both the medial collateral ligament and the plantar calcaneonavicular [spring] ligament) or anterolateral lesions of the bifurcate ligament. These lesions, which are mainly determined by the mechanisms and intensity of injury, result in complex laxity of the ankle, which therefore goes beyond simple lateral laxity [6]. Finally, predisposing factors which may cause or maintain instability must also be considered, such as constitutional varus of the foot, or damage associated with chronicity such as osteochondral lesions of the talar dome, fissures of the fibular tendons or anterior or posterior impingement.

Thus, the therapeutic management of lateral laxity of the ankle is based on a precise description of lesions including any potential associated lesions. Treatment must also be adapted to these lesions and provide global medicosurgical management of this entity. Therefore, this paper provides an update on the diagnostic and therapeutic approach to chronic ankle stability; it was drafted during a symposium held at the Sofcot Congress in Paris in 2008 which included evaluation of the results of long term follow-up (average follow-up 13 years) in 310 cases of lateral capsuloligamentary ankle reconstruction.

Tools for the diagnosis of lesions

The aim of diagnosis is to identify all existing factors of instability, which are not merely limited to laxity. Ankle instability is potentially arthrogenic even if the incidence has not been precisely determined. In 1979, a study by Harrington [7] reported degenerative articular damage located especially in the medial compartment in 36 subjects, an average of 40 years old with a history of more than 10 years of chronic instability. In a radiological study of 209 patients, Rieck et al. [8] confirmed the importance of chronic lateral instability as an etiological factor of ankle arthrosis. Degenerative lesions were twice as frequent in cases of instability as in recent sprains in patients who were younger than 30 years old, and severe damage was five times more frequent. In the group between 30 and 40 years old, all patients with chronic instability had articular changes, and severe damage was 10 times greater than if the sprain was recent. More recently, Valderrabano et al. [9] confirmed the correlation between arthrosis and instability in a 30-year follow-up of progressive disease with talar varus misalignment in more than half the cases, and found that the aggravating factor was medial damage.

Diagnostic aims

The following must be determined:

- ligament injuries for the entire tibiofibular, talar, calcanean and subtalar system;
- predisposing factors such as morphology of the hind foot;
- associated lesions caused by chronic disease: anterolateral impingement, anterior and posterior impingement, fibular injuries, osteochondral injuries and even early osteoarthritis.

Clinical tools

Questioning

First, the patient is asked to describe the clinical history of the first sprain, treatments received, the types of sports practiced and the level. The reasons for consulting may include a feeling of insecurity, recurrent sprains and permanent pain or may only associate with acute episodes, edema and sometimes symptoms of mechanical intra-articular disturbance (locking, sticking). Finally, how long instability has existed and the functional effects are also identified: frequency, conditions under which symptoms occur and socioprofessional consequences.

Clinical examination

A complete comparative clinical examination of both ankles should be performed:

- articular mobility during dorsal and plantar flexion is rarely limited. Gastrocnemius muscle retraction (limitation of dorsal flexion of the ankle with the knee extended, while mobility of the bent knee is normal) should be looked for, as well as any dislocation of the fibular tendons. Mobility of the hind foot can be evaluated with the patient in the ventral decubitus position by applying a goniometer to the lateral side of fibula and calcaneum, and by manually placing pressure to cause ankle varus (Fig. 1);
- painful areas are looked for in the different ligament bundles (anterior talofibular, fibulocalcanean, and posterior tibiofibular bundle) as well as in the tarsal sinus (cervical ligament), the medial collateral ligament and joint spaces and along the tendon paths (in particular the retro- and submalleolar fibular tendons);
- ligament testing is a central part of the clinical examination. Anterior drawer of the talus and talar tilt in varus
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Figure 1  Evaluation of varus mobility of the hind foot in the decubitus ventral position.

are investigated. The goal is to identify the degree of laxity. This test should always be comparative to eliminate constitutional hyperlaxity. Laxity in varus is investigated with the patient in the decubitus ventral position: this can be evaluated globally while at the same time trying to obtain more precise information, by placing the hand on the ankle, on the talocrural area (Fig. 2a), then by testing subtalar mobility (Fig. 2b). Anterior drawer is evaluated with the knee flexed, legs hanging, classically during medial rotation to test the anterior talofibular ligament (Fig. 3a). This must also be investigated during lateral rotation (Fig. 3b) to test medial laxity as suggested by Hintermann, and in this case it is frequently associated with anteromedial pain [10,11];

- the morphology of the foot should be evaluated, in particular to determine the presence of hind foot varus (Fig. 4), which is a factor of ankle instability even without laxity.

Radiological tools

Although the clinical examination may provide a diagnosis in certain cases, it may be insufficient to define laxity and even more to provide a topographic diagnosis. A negative
Figure 5  Weight bearing X-rays of the ankle (Meary-view). Drawing of a parallelogram including the width of the talar dome and the large tuberosity of the calcaneus. Two vertical lines are then drawn, one beginning from the middle of the width of the talar dome and perpendicular to the subtalar base; the other from the middle of the width of the talar dome and joining the middle of the subtalar base. The angle between these two vertical lines defines the valgus (or varus) of the hind foot (measurement defined by Djian, with opaque metal markers straight above the malleoliL'angle). Normally, the tibial axis passes through the union of the 1/3 medial/2/3 lateral of the subtalar base (measurement defined by Meary, by circling the heel with a metal wire).

Clinical examination does not necessarily eliminate chronic instability. Thus, in most cases, complementary radiological tests are precious for identifying lesions in the diagnostic work-up.

Weight-bearing X-rays
Comparative weight-bearing X-rays of both ankles (anterior-posterior and profile) are systematically performed to evaluate and investigate:

- morphology of the hind foot: varus can be more precisely quantified with a Meary view (with a wire circling the back heel) (Fig. 5);
- ligament avulsion fractures: a sign of prior sprains;
- associated lesions: osteochondral lesions of the talar dome, tibiofibular diastasis and tarsal synostosis.

Misdiagnosed fractures: fracture of the lateral apophysis of the talus, pseudarthrosis of the styloid of the fifth metatarsal.

Signs of early osteoarthritis: periarticular changes and early articular narrowing.

Stress views
The purpose is to confirm and quantify laxity and the topography of injuries.

Figure 6  Comparative dynamic X-rays of two ankles: reference measures.

Figure 7  Dynamic X-rays of two ankles: patient-controlled varus technique (autovarus).

Dynamic X-rays of the talocrural joint (Fig. 6) can be performed either manually or with a Telos stress device (at 150N), or even actively by patient-controlled varus (autovarus) [12] (Fig. 7). These dynamic films to measure anterior drawer and varus laxity are, in chronic lesions, not or barely disturbed by muscular defense reactions. However, the methods are different depending on the series and one meta-analysis concluded that the significant variability made results difficult to exploit [13]. Nevertheless, the results are still interesting if a differential value is used to evaluate them. Their reproducibility varies: the values obtained with the Telos stress device will be lower than those obtained manually, while patient controlled varus will provide results that are 30% higher than passive varus testing [12]. Based on a prospective radiological-surgical compar-
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ison, Faure et al. [14] found perfect specificity (100%) for dynamic X-rays in the diagnosis of anterior talofibular ligament injuries. The sensitivity was much lower: 65%, for equinovarus (positive if \( \geq 10^{\circ} \)), 52% for anterior drawer (positive if \( \geq 8 \) mm) and 74% when both techniques were associated. False negatives occurred with the anterior talofibular ligament was simply pulled. Dynamic X-rays only have diagnostic value if they are positive.

Subtalar laxity is difficult to evaluate. Numerous radiological techniques have been proposed [15–22] mainly during stress and depending on specific views. In 1979, Moyen [23,24] described a dynamic radiological protocol, which showed the two-talocural and subtalar joint spaces. Although it cannot be used in everyday practice (complex device, possible difficulty in reading the films), this protocol had the advantage of showing subtalar laxity: in the anterior-posterior view, it appears as medial translation of the calcaneum under the talus, which is a sign of real rotational instability. Kato [25] described a procedure for evaluating talocalcaneal drawer on a dynamic X-ray of the foot in profile: it reached 5 mm in certain patients in the group with subtalar instability compared to 2 mm in the group with isolated talocrural instability. Thus, subtalar laxity is not a simple articular gap, but an increase in translation-rotation. Dynamic X-rays with patient-controlled varus can also be used to evaluate talocrural and subtalar elements.

Complementary tests

Complementary radiological tests include: ultrasound, CT arthrography, MRI and its technical variants (gadoldium enhanced MRI, MR arthrography). The aim of these tests is to confirm the number of injured ligament bundles, identify if necessary the type of lesion (pull, tear, detachment…) and study the tendon structures (in particular fibular tendons) and the cartilage.

- Ultrasound can be used to evaluate ligament and tendon structures [26] but cannot be used to evaluate bone or cartilage and is operator-dependent. It can be useful for the diagnosis of anterolateral impingement [27]. Its main interest is the dynamic evaluation of the lateral collateral ligament and the fibular tendons (Fig. 8);
- CT arthrography (Fig. 9) can be used to identify different types of injury to the anterior talofibular ligament, and indirectly identify calcaneofibular ligament tears by uptake in the fibular sheath, anterolateral capsulovascular adhesions, subtalar ligament lesions and fibrosis of the tarsal sinus. It is especially useful in diagnosing or confirming bone or cartilage injuries that are not or are poorly visible on plain X-ray: lateral apophysis of the talus, anteromedial apophysis of the calcaneum, early arthrosis. It is the best imaging technique to identify the degree, the location, and the open or closed nature of an osteochondral lesion of the talus [14];
- MRI is especially useful for investigating the ligament complex, the tarsal sinus, and lesions particularly associated with the fibular tendons [28–34]. In one of the first studies, Beltram et al. [28] identified the anterior talofibular ligament in 100% of cases, the calcaneofibular in 80% (in a coronal view), the cervical ligament in 88% and the talocalcanean in 56% (saggital view). In a study of chronic instability with unenhanced MRI, Chandnani et al. [35] found a sensitivity of 50% and a specificity of 100% for the study of the anterior talofibular ligament, and a sensitivity of 50% and a specificity of 83% for the study of the fibulocalcanean ligament. Results of unenhanced MRI do not seem to be significantly better than dynamic X-ray. Gadolinium enhanced MRI (Fig. 10) is better than unenhanced MRI. It provides perfect images of the different lesions of the anterior talofibular bundle, anterolateral impingement, fibular lesions, any posterolateral impingement as well as spring-ligament lesions. Images of ligament tears are easier to read on MR arthrography (Fig. 11) and this technique is better than gadolinium MRI for visualising cartilage but less effective for evaluating pulled ligaments and synovial impingement. [36].

The results of these different techniques have been analysed by comparing surgical/gadolinium-MRI/MR arthrography results [37,38]. The results of gadolinium MRI and MR arthrography are excellent and similar for visualizing ligaments (lateral collateral, tibiofibular syndesmotic, tarsal sinus and medial collateral) and tendons. Gadolinium MRI provides more complete visualisation of the ligaments than CT arthrography, and is better for direct evaluation of the fibular tendons. It is the reference technique for evaluating chronic ankle instability; CT arthrography may be more appropriate in the presence of an associated osteochondral lesion or early arthrosis.

Although dynamic MRI may be the technique of the future, existing results in the literature are still experimental [39–42]. Mabit et al. [33] have proposed static MRI with the foot in inversion (the position is maintained by an elastic strap), which improves sensitivity for the visualisation of the anterolateral bundles, in particular the cervical ligament, by creating stress (Fig. 12).

Compared to these other tests, we do not feel that ankle arthroscopy, which was proposed by Hintermann et al. [43–46], should play a role in the usual diagnostic work-up.

In summary, the diagnostic work-up (working diagnosis?) is based on a detailed clinical investigation which determines the necessary additional tests with the goal of evaluating lesions as thoroughly as possible to define the best therapeutic strategy (Tables 1 and 2). Brantigan et al. [47] showed that the risk of recurrent sprain (evaluated at 10%) after surgery may be linked to undiagnosed subtalar instability.

Therapeutic options

Medical treatment

Medical treatment is always proposed first. This medical treatment has two goals, which are usually associated: correcting static deficiencies and rehabilitation.

Correction of static deficiencies

Static disorders are identified during the clinical examination and confirmed with radiological tests, in particular imaging techniques (weight-bearing "stress") X-ray, Meary's
Figure 8  Dynamic ultrasound of the ankle: a: fibular tendons in place; b: during inversion: the tendons are dislocated.

Figure 9  CT scan of the ankle: a: complete tear of the anterior talofibular ligament and lateral capsulosynovial adhesions; b: calcaneofibular ligament tear; c: medial osteochondral lesion of the talus.

Figure 10  Gadolinium MRI of the ankle: a: anterolateral and anterior inferior tibiofibular ligament impingement; b: stage 4 fissure of the peroneus brevis; c: posteromedial impingement; d: damaged plantar calcaneonavicular ligament.

Figure 11  MR arthrography of the ankle: a: detachment of the anterior talofibular ligament; b: calcaneofibular ligament tear; c: lateram osteochondral fracture of the talus.
### Table 1  Results of different tests for the diagnosis of laxity and ligament damage.

<table>
<thead>
<tr>
<th></th>
<th>Laxity</th>
<th>LCL Fx LTFA</th>
<th>LCL Fx LCF</th>
<th>S/T Cervical Inter-osseous</th>
<th>LCM spring ligament</th>
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<tbody>
<tr>
<td>Clinical</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>±</td>
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<tr>
<td>Rx simple</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rx DYN</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>0</td>
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<tr>
<td>CT arthrography</td>
<td>0</td>
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<td>+</td>
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<tr>
<td>MR arthrography</td>
<td>0</td>
<td>+</td>
<td>+</td>
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<td>+</td>
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<tr>
<td>Gadolinium MRI</td>
<td>0</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Ultrasound</td>
<td>+</td>
<td>+</td>
<td>±</td>
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</table>

### Table 2  Results of different tests for evaluation of hind foot alignment and to diagnose anterolateral synovitis, fibular tendon and cartilage damage.

<table>
<thead>
<tr>
<th></th>
<th>Hind foot alignment</th>
<th>Lateral synovitis</th>
<th>Fibular tendons</th>
<th>Cartilage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical</td>
<td>+</td>
<td>±</td>
<td>+</td>
<td>0</td>
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<tr>
<td>Rx simple</td>
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<td>+</td>
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<tr>
<td>Rx DYN</td>
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<td>CT arthrography</td>
<td>±</td>
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<td>MR arthrography</td>
<td>0</td>
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<td>Gadolinium MRI</td>
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<td>Ultrasound</td>
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Hindfoot varus is the most frequent static deficiency. It favors traumatic inversion and also plays a role in the gradual weakening of fibular tendons resulting in an alteration of proprioceptive control. The use of a plantar orthotic with a corner or a band for pronation control can help stabilize the ankle. Flat foot valgus can also contribute to ankle instability, in particular if it is due to talocalcaneal or calcaneonavicular synostosis. A plantar orthotic with an ankle shell that "blocks" the calcaneus on the inside of the shoe is sometimes indicated in these cases.

**Figure 12**  "Stress" MRI: (a) maintaining the foot in inversion with an elastic strap. Visualisation (arrow) of the cervical ligament; (b) sagittal view; (c) frontal view; (d) tear (arrow).

**Rehabilitation**

Rehabilitation has several goals:

- fight against a short Achilles tendon [48,49]: this should be identified because it may be the cause of dynamic instability from equinus ankle which is determined during walking or running. Stretching exercises several times a day and eccentric exercises are proposed in these cases;
- neuromuscular reprogramming [50–52]: the ligament and tendon system of the ankle, weakened by repeated injury due to instability, is used less and less, resulting in postural regression which perpetuates chronic instability. This proprioceptive deficit can be increased, aggravated and maintained by possible fibular tendon injuries, hind foot varus or pulling of the periarticular nerve branches. The work by Freeman et al. [53] resulted in the development of proprioceptive training based on muscular biofeedback: this method mainly stimulates the vestibular system by head movements and results in uncontrolled "tetanisation" of the ankle muscles because it is very rapid. Thonnard et al. [54] then Forestier and Toschi [55] showed that a feedforward phenomena of anticipation could be developed which is still called muscular preactivation (pretension). This is a new approach to neuromuscular reprogramming of the ankle, which should now be included in rehabilitation protocols for instability both in the pre- or postoperative period. [56–59].

The rehabilitation protocol is organised in 9 weeks of training:

- the goal for the first 3 weeks is to develop unconscious proprioception with exercises for stability and articular protection according to the principle of achieving "two goals". There is a destabilising element, a ball, an elas-
tic, turning the head, manual exercises with a stick or a weight and a target element which is ankle instability. This method is effective but limited, because the work on the ankle remains static;
- the next 3 weeks are used to develop dynamic biofeedback with motor coordination exercises that can be correctly performed with the new Hubert™ technology: this is an electronic device with a dynamic motorized platform that will gradually stress the joint, according to the same "two goal" principle. This dynamic reprogramming is partial because there is little stimulation of muscular anticipation mechanisms which are essential for preventing recurrence;
- the goal for the last 3 weeks (which can be extended if necessary) is to recover anticipation mechanisms, in particular thanks to physical therapy devices such as Myolux™ (Fig. 13) which provide specific reinforcement during eccentric-concentric work. These devices selectively work the short fibular the long fibular or the anterior tibial structures and strongly solicit muscular anticipation mechanisms, which are the real mechanisms of protection against instability.

Surgical treatment

This is the second pillar in the medicosurgical management of chronic ankle laxity.

Surgical procedures for the lateral collateral ligament of the ankle [60–63]
The 80 different surgical interventions and variants found in the literature to treat this entity are a sign of the lack of consensus for technical management. The goal of all interventions is to restore stability: short and intermediate term results are good or very good in between 80 and 95% of cases. There are very few long-term results evaluating stability and its articular effects in the literature. Based on the evaluation of lesions and depending on the anatomical goals for repair on one hand, and the structures used for ligament reconstruction on the other hand, three main types of surgical procedures can be identified: tightening of the ligament and capsular tissue, tightening associated with reconstruction and tendon grafts using all or part of the tendon (mainly the peroneus brevis).

The position of the patient and the surgical approach. The position of the patient and the surgical approach is generally the same whatever the surgical procedure. A popliteal block with or without a stimulating catheter is often performed for pain. This patient is placed in the decubitus dorsal position with the leg supported in medial rotation. The surgical approach is centered on the lateral malleolus, curving more or less towards the front depending on the surgical procedure. The immediate danger of these ligamentoplasty procedures are both cutaneous, to avoid extensive subcutaneous detachment (which is why it is important to conserve the inframalleolar fat pad) and neurological because of possible injury to the superficial terminal branches of the sural nerve and the superficial fibular nerve.

Tightening the capsuloligamentary complex. These are the simplest procedures [64]. In 1964, Broström [65–67] described suturing of the anterior and medial lateral collateral ligament bundles. In 1980, Duquennoy et al. [68] published his procedure for transosseous tightening and repair of the anterior and medium capsuloligamentous flap (Fig. 14). However, in certain cases, the poor anatomical quality of residual bundles requires reconstructive reinforcement as well as tightening [68,69].

Ligament reconstruction for augmentation. Reconstruction may be fibrous: the periosistal flap developed by Küner [70] provides anatomical repair of the lateral collateral ligament bundles of the ankle, while Roy-Camille developed a single or double bundle variant depending on the diagnosis of lesions [71,72] (Fig. 15). However, the periosistum of the fibular malleolus is not always very resistant and this procedure is not indicated in growing children (to avoid postoperative ossification). The extensor retinaculum (frondiform ligament) was proposed by Gould et al. [73] to modify and reinforce repair by the Broström procedure. Blanchet [74], then Saragagalia et al. [75] suggested creating a neoligament from this retinaculum. The position is non-anatomical because it is at the bisector of the anterior and medium bundle of the lateral collateral ligament. In this procedure calcaneal insertion, besides providing reinforcement of the capsule, also provides peripheral stabilisation.
Figure 15  Tightening of the capsuloligamentary complex and reinforcement with the frondiform ligament (Saragaglia technique): a: approach; b: harvesting of the ligament graft; c: transmalleolar insertion of the capsuloligament graft.

Figure 16  Tightening of capsuloligamentary complex with periosteal reinforcement (Roy-Camille procedure): a: single bundle; b: double bundle; c: passage into the tunnel drilled in the talar neck.

of the subtalar joint by reinforcing the cervical ligament (Fig. 16).

Reconstruction may be tendinous: the plantaris muscle can be used to perform a real ligamentoplasty, which is anatomical for the anterior and medium bundle but does not stabilize the subtalar joint in the original procedure [76,77].

In 1996, Mabit et al. [78,79] described ligament reconstruction using the peroneus tertius tendon which was anatomical for the anterior bundle and the cervical ligament, thus providing true peripheral stabilisation of the subtalar joint when necessary (Fig. 17).

Finally, Storen [80] has proposed anatomical reconstruction of the anterior bundle, the cervical ligament and the subtalar joint with the Achilles tendon, which is non-anatomical and only functional for the medium bundle.

Tendon grafts. These are the third group of procedures. The use of the peroneus brevis is the most common. This active ankle stabiliser is turned from its original path to compensate for the ligament deficit, without taking an anatomical path, while having a tenodesic effect on the subtalus The peroneus brevis tendon remains inserted on the styloid of the fifth metatarsal and, depending on the procedure, usually represents a functional compromise for the anterior and medium bundles of the lateral collateral ligament of the ankle and the subtalar ligaments.

Among the numerous variants described in the literature, we can mention Watson-Jones [81] in 1952, who replaced the anterior bundle, Evans [82,83] in 1953, then Elmslie [84], Chrisman and Snook [85,86,87] and Vidal et al. [88] who proposed peripheral lateral support. But in France, the
most well known procedure is that of Castaing et al. [89]: with its triangular structure, this non-anatomical ligamentoplasty provides functional relief by creating a bisector between the anterior and the medial bundle that truly locks the subtalar articulation (Fig. 18). Its tenodesic effect remains controversial in the literature from a biomechanical point of view [90], especially if there is no subtalar injury and in young athletes. To preserve this active inversion stabilizer, which is essential for correct proprioception, the "half-Castaing" procedure only takes the anterior part of the peroneus brevis. The use of all or part of the peroneus brevis imposes certain technical obligations: avoiding too much "tightening" in valgus to prevent subtalar ankylosis; identifying the exact position of the transmalleolar tunnel while respecting the oblique direction and height in relation to the apex of the fibular malleolus, thus defining a "pseudo-isometry" for this ligamentoplasty in relation to the peroneus brevis.

It is important for the surgeons to be aware of these different procedures so that they can make the best choice based on pre- as well as peroperative results.

Innovations have been proposed. For example tendon allografts which require an extensive tissue bank and the possibility of using the peroneus brevis, the fascia lata or the calcaneal tendon. The interest of these procedures is that anatomical ligamentoplasty is possible while the patient’s peroneus brevis remains intact [91].

Certain procedures, in particular the half-peroneus brevis, can be performed with a minimally invasive variation such as the Chrisman-Snook or the half-Castaing [92].

Arthroscopic thermal shrinkage uses the properties of thermal denaturation of collagen at 70° resulting in tissue retraction and cicatricial hypertrophy [93,94]. This technique is indicated for isolated lesions, especially incomplete lesions of the anterior bundle of the lateral collateral ligament, thus providing a "pseudo-isometry" for this ligamentoplasty in relation to the peroneus brevis.

It is important for the surgeons to be aware of these different procedures so that they can make the best choice based on pre- as well as peroperative results.

Additional surgical procedures
After the complete diagnostic work-up of lesions has determined whether the lateral laxity of the ankle is isolated or complex, additional surgical procedures may be necessary and performed when possible during the primary operation.

Subtalar articular lesions. Biomechanical and anatomical studies have shown that lesions of the cervical ligament and sometimes of the interosseous talocalcaneal ligament may be isolated or associated with those of the lateral collateral ligament of the ankle [95,96]. A certain number of surgical procedures that reinforce the lateral collateral ligament of the ankle can also, depending on the variant, provide peripheral stabilisation of the subtalar joint. We have already seen that ligamentoplasty with the extensor retinaculum flap (frondiform ligament), the peroneus tertius or even the periosteal flap can play this role. As Keefe et Haddad [96] reported, several procedures for stabilisation have been described that take into account the subtalar joint usually using the peroneus brevis [97–99]; these techniques seem to be much more invasive that those mentioned above.

Complex instabilities. They include lateral laxity, medial laxity and morphostatic disorganisation of the hindfoot. Medial lesions require reconstructions that may include medial collateral ligament suture, spring ligament suture or even reinforcement with the posterior tibial muscle tendon [100]. The severity of these lesions may cause secondary hind foot valgus, requiring corrective variation osteotomy of the calcaneus to protect the repair of the medial structures. On the other hand, primary varus of the hind foot is treated by valgisation osteotomy of the calcaneus [6,101,102] to prevent recurrent instability (Fig. 19). Depending on the results of the in-depth preoperative evaluation of lateral laxity, any one of these surgical procedures may be proposed usually in the same operation. Lesions associated with chronic disease may require ankle arthroscopy (possibly associated with traditional reconstructive surgery) for osteochondral lesions of the talar dome, for anterior or posterior bone impingement or soft tissue interposition, or even tenoscopy or direct repair of tenosynovites fibular tendon fissures. [103,104].
Chronic ankle instability - diagnostic tools and therapeutic options

Multicentric French Series (SOFCOT 2008)

This is a multicentric retrospective study of 310 cases of lateral reconstruction of the ankle followed up for an average of 13 years with a minimum follow-up of 5 years. Most patients were men (53%) and sports injuries predominated (78%); the average duration of instability was 92 months for an average age at surgery of 28. The subtalar joint played a role in instability in 28% of cases. Four technical classes (C) were identified:

- **C1** (isolated capsuloligamentous tightening);
- **C2** (tightening associated with reinforcement);
- **C3** (reconstruction using part of a stabilising-eversion tendon; for example the peroneus brevis);
- **C4** (ligamentoplasty using an entire stabilising-eversion tendon).

The clinical and functional evaluation was based on the Karlsson and Good-Jones-Livingstone scores; the radiographic evaluation included AP and profile views, Meary view (view with a wire circling the heel) and dynamic X-rays (manual techniques, Telos® or patient-controlled) for residual laxity.

Most results were satisfactory (92%). The average Karlsson score was 90 [19—100] or 87% of good and very good results; it was correlated with the subjective results and did not change over time. Postoperative complications (20%), in particular nerve complications, were correlated to less satisfactory results. Although follow-up X-rays confirmed that the progression of arthrosis was limited (2%) and stability improved (88% of stabilized ankle at the time of follow-up), there was no correlation between the functional results and residual radiographic laxity. Results were less successful in unstable and painful ankles and there was more secondary arthrosis. Depending on the procedure used the analytical evaluation showed that results were significantly poorer in type C4 reconstructions and follow-up X-ray results for laxity were less good in type C1 tightening procedures.

There are very few studies in the literature with more than 5 years of follow-up. The different procedures were grouped together according to the symposium classification described above (C1; C2; C3; C4). We analysed results for each group, compared the groups and those of the symposium. Comparison of so-called “anatomical” procedures (Broström-Gould and perioseal) and “non anatomical” procedures (Half-Castaing, Watson-Jones, Evans) confirms that the results of anatomical procedures are statistically better [105—108]. Finally, the results of reconstruction with the entire tendon [109—117] tend to be less successful while those with a partial tendon provide the best results [118,119,86,120].

Classification of the therapeutic options

Based on the results of the symposium and the literature, a certain number of observations can be made.

**Classification of surgical procedures.** The distinction between an anatomical reconstruction and a tendoëdes reconstruction no longer seems appropriate. If the surgical procedures are divided into four classes based on the types of reconstruction, they can be used for comparative studies which reflect the real anatomical and functional results provided by the ligamentoplasty, and which reinforce the notion of subtalar articular stabilisation. **Comparison and evaluation of results.** The longer the laxity lasts, the more the arthrogenic risk increases due to the development of osteochondral injury to the talar dome. This suggests that early surgery should be recommended in patients with laxity and instability. Medial ligament injuries are clearly arthrogenic [24], confirming the necessity of a thorough preoperative evaluation of lesions that may be associated with lateral collateral lesions. Neurological complications (nerve branch lesions) significantly increase the risk of poor results. Unfortunately, although there is very little residual postoperative laxity, this is not always correlated with clinical results, probably due to persistent proprioceptive deficiencies, and sometimes because of morphological disorders such as hind foot varus. When laxity is found to be significant in the preoperative work-up this determines the choice of surgical procedure and makes simple tightening insufficient, because these laxities usually involve the subtalar joint (which cannot be stabilised by simple tightening).

**The choice of the surgical procedure.** It appears that the choice of the surgical procedure can be based on the presence or absence of subtalar laxity.

When there is no injury to the subtalar joint, logically the peroneus brevis can be preserved to maintain subtalar joint adaption mechanisms which are indispensable to athletes and to proprioception. Lesions of the anterior tibiofibular and calcaneofibular bundle should be treated by reinforcement when necessary and with the procedure of choice: frondiform, perioseum, peroneus tertius, plantarus [69—72]. Eclecticism should remain the rule.

When the subtalar joint is injured, part rather than all of the peroneus brevis should be used [73,74]; however, it can also not be used and the subtalar joint can be stabilised with appropriate reconstruction procedures (frondiform, peroneus tertius...).

In complex lesions, based on the results of the detailed preoperative diagnostic evaluation the indication for medial ligament reconstruction may be considered [75] associated with lateral reconstruction, osteotomy for realignment of any hindfoot deformity (usually varus) [76]), or even arthroscopy before surgery in the presence of osteochondral lesions or if impingement is diagnosed [77].

**Conclusion**

A true surgical strategy should be established for global management of the different lesions associated with ankle instability. This strategy is based on a precise evaluation of lesions with the goal of avoiding revision surgery and obtaining the best overall results. Clinical examinations and the most up to date dynamic X-ray techniques can be used to quantify laxity. Anterior talofibular bundle laxity can be evaluated with: CT scan, gadolinium enhanced MRI, MR arthrography; the calcaneofibular bundle and subtalar ligaments with: gadolinium MRI and MR arthrography; and medial ligament lesions with: gadolinium MRI. Hindfoot alignment can be evaluated by clinical examination and Meary view X-rays, lateral synovitis by gadolinium MRI and ultrasound, and fibular structures by gadolinium MRI.
The cartilage can be evaluated by weight-bearing X-rays, MR arthrography and especially CT arthrography.

Restoring proprioception is fundamental to recover function. Procedures to repair laxity should be reproducible and adaptable during surgery based on the lesions identified. The idea of a follow-up of more than 5 years is essential especially to evaluate laxity over time and to protect against osteoarthritis, which is the major risk in these chronic sprains. The results of our series and those in the literature confirm the role of lateral ligamentoplasty for the treatment of ankle instability and to protect against the risk of secondary osteoarthritis, as well as the importance of a precise diagnosis of injuries (CT scan MRI) to adapt the surgical procedure to ligamentous and any associated lesions.

Conflict of interest

None.

References

[36] Chou MC, Yeh LR, Chen CK, Pan HB, Chou YJ, Liang HL. Comparison of plain MRI and MR arthrography in the evaluation


