FOOT & ANKLE INTERNATIONAL

DOI: 10.3113/FAI.2012.1079

Long-Term Follow-up of Lateral Reconstruction with Extensor Retinaculum Flap for Chronic Ankle Instability

Yves Tourné, MD, PhD[1]; Christian Mabit, MD[2]; Paul J. Moroney, MB, FRCSI (Tr & Orth)[3]; Christophe Chaussard, MD[4]; Dominique Saragaglia, MD[4]

Grenoble, France; Limoges, France

ABSTRACT

Background: **Chronic instability is a common complication of lateral ankle sprains. Furthermore, patients often have unrecognized associated lesions affecting the ankle and subtalar joints. Many stabilizing surgical techniques have been described, each with variable results. This article reports the long-term results of ligamentous retensioning combined with reinforcement using an extensor retinaculum flap.** ***Patients and Methods:*** **This is a retrospective, multicenter study. One hundred fifty cases were reviewed at a mean follow-up of 11 years. Functional results were assessed using the Karlsson score. Pre- and postoperative radiological assessment employed stress x-rays to measure varus tilt and anterior drawer and the Van Dijk classification to grade osteoarthrosis. The Stata 10 program was used for statistical analysis.** ***Results:*** **A thorough preoperative workup identified ligamentous lesions of the subtalar joint in 30% of cases. At review, 93% of patients were satisfied. Residual instability was present in only 4.8%. Radiographic analysis of both ankles revealed a differential in varus tilt of only 0.12° and in anterior drawer of 0.17 mm. There was no deterioration of the articular surfaces after 11 years of follow-up.** ***Conclusion:*** **To the authors' knowledge, this is the largest series reported with such a follow-up. This technique addressed both lateral ankle and subtalar instability without sacrificing the peroneal tendons. It protected against progression of posttraumatic arthrosis and provided superior results to other reported techniques in terms of patient satisfaction and residual instability.**

Level of Evidence: IV, Retrospective Case Series

Key Words: Ankle Instability; Extensor Retinaculum Flap; Lateral Collateral Ligament Laxity

INTRODUCTION

Chronic instability is a frequent complication of lateral ankle sprains with an estimated prevalence of 20% to 40%.[8] Clinical laxity resulting from mechanical ligamentous insufficiency can be treated surgically by ligament reconstruction. An impressive range of techniques, with generally favorable results, has been described to treat lateral ankle instability. The aims of any surgical reconstruction technique are to restore the capsuloligamentous structures, and thus articular stability, while preserving the mobility of the talocrural and subtalar joints and avoiding secondary arthrosis.[4]

The surgical technique reported in this article combined retensioning of the incompetent lateral collateral ligament with reinforcement by a neoligament harvested from the extensor retinaculum. Although the retensioning of the capsuloligamentous structures resembled the techniques described by Broström[9] or Duquennoy et al.,[14] the reinforcement using the extensor retinaculum, described by Saragaglia,[48] is different from that reported by Blanchet[7] or Gould et al.[20] The purpose of this study was to evaluate the long-term stability of 150 capsuloligamentous lateral ankle reconstructions, to identify the causes of failure and the preoperative factors predictive of success, and to assess the impact of surgery on the articular surfaces.

[1]Department of Foot and Ankle Surgery, Groupe Chirurgical République, Grenoble, France.

[2]Department of Orthopaedics and Traumatology, University Hospital, Limoges, France.

[3]Department of Foot and Ankle Surgery, Sports Surgery Clinic, Santry, Dublin 9, Ireland.

[4]Department of Orthopaedics and Traumatology, University Hospital, Grenoble, France.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Corresponding Author:
Yves Tourné, MD, PhD
Groupe Chirurgical République-Grenoble-France
Foot and Ankle Surgery
15 Rue de la République
Grenoble 38000
France
E-mail: ytme@me.com

METHODS

This was a retrospective, multicenter study from two university hospitals and one private institution and includes 150 cases of capsuloligamentous reconstruction of the lateral collateral ligament of the ankle. This study is part of a larger body of work performed for the SOFCOT symposium in 2008, comprising 310 cases of ligamentous reconstruction, with a mean follow-up of 13 years.[38] The 150 cases presented in this series represent 105 cases from that symposium and 45 additional cases that adhere to the same inclusion criteria: all ankles had physeal closure; no neuromuscular pathology, fractures, or surgical procedures on the ankle except for osteochondral lesions of the talar dome; cases reviewed at a mean follow-up of 11 years (range, 5 to 19 years); and an average age at follow-up of 39 years. To our knowledge, this is largest reported series with such a follow-up.

This study is characterized by an equal male/female ratio and a mean age at time of surgery of 28 (range, 14 to 56) years. Clinical features include recurrent "sprains" (a mean of 10) occurring on average for 96 months and affecting a majority of right ankles (54%). The etiology of these sprains was predominantly sports related (83%) as opposed to 11% accidents in the home and 6% in the workplace. The initial treatment of these sprains was primarily conservative (54% strapping or brace; 23% casting of variable duration). For 23% of patients, no treatment was performed or the sprain was completely neglected. Eighty-four percent of patients had undergone a course of physiotherapy before surgical intervention. "Chronicity" was defined as persistence of symptoms and signs (clinical and radiographic) of instability, despite adequate rehabilitation, at least 6 months after the initial acute injury. Clinically, all patients felt their ankles to be unstable, with 57% both unstable and painful. Laxity was confirmed by stress radiographs (6% manual; 94% Telos Stress Device) with opening in varus in 84% and positive anterior drawer in 83% of cases. The differential between the healthy and operated sides was 8° for varus and 2 mm for anterior drawer (Figure 1). Hindfoot morphotype was neutral in the great majority of cases (78%) or else in moderate varus. Plain radiographs demonstrated early preoperative arthrosis (grade 2 of Van Dijk) in only 3% of cases. Complementary investigations included computed tomography (CT) arthrogram (27%), CT scan (3%), magnetic resonance imaging (MRI) (2%), and ultrasound (1%). The subtalar joint, on the basis of published clinical and radiographic criteria,[54] was considered involved in the instability in 28% of cases.

Surgical technique

The surgical technique was described by Saragaglia et al.[48] and is depicted in Figure 2. The patient was placed in a lateral decubitus position, with a thigh-level pneumatic tourniquet and the lower limb in internal rotation. The skin incision was anterolateral, curvilinear, and centered on the lateral malleolus. Subcutaneous dissection, avoiding the sensory branches of the superficial peroneal and sural nerves, permitted identification of lateral collateral ligament remnants and the inferior extensor retinaculum. At this point, a rectangular retinacular flap (approximately 1 cm wide and 3 to 4 cm long) was elevated and remained attached to the calcaneus at the entrance to the sinus tarsi. A resorbable core suture secured the flap. An L-shaped arthrotomy was then performed along the course of the peroneus tertius, thereby creating two flaps: one residual capsuloligamentous flap, attached to the neck of the talus and the lateral border of the calcaneus, and a periosteal flap that was developed posteriorly toward the sulcus for the peroneal tendons. This arthrotomy also allowed access to the cartilage of the dome of the talus as well as the anterior margin of the tibia and the neck of the talus. Further synovial, bony, and osteochondral procedures were performed as required, guided by the preoperative workup.

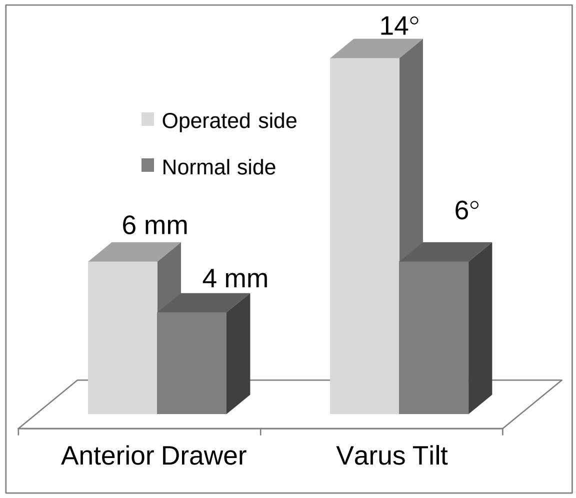

Fig. 1: Comparison of mean preoperative radiological results in terms of anterior drawer and varus between the normal and operated sides.

For reinsertion of the lateral collateral ligament remnant and its retinacular reinforcement in the anterior part of the lateral malleolus, three tunnels, spaced ∼1 cm apart, were created using a 2-mm drill bit. The middle tunnel was enlarged to 4.5 mm to allow reinsertion of the retinacular flap while permitting unhindered sliding of this flap. The orientation of this middle tunnel corresponded to the bisector of the angle formed by the anterior and middle bundles of the lateral collateral ligament (the anterior talofibular and calcaneofibular ligaments).

The anterior and middle bundles of the capsuloligamentous lateral collateral ligament remnant were then secured with core sutures and reinserted into the two remaining 2-mm tunnels (an alternative technique used suture anchors instead of tunnels in 25 cases). The tissues were tensioned with the foot in a neutral position.

Supplementary procedures associated with the ligamentoplasty were performed in 24% of cases (Table 1). Calcaneal osteotomy, mosaicplasty, or chondrocyte grafts were not

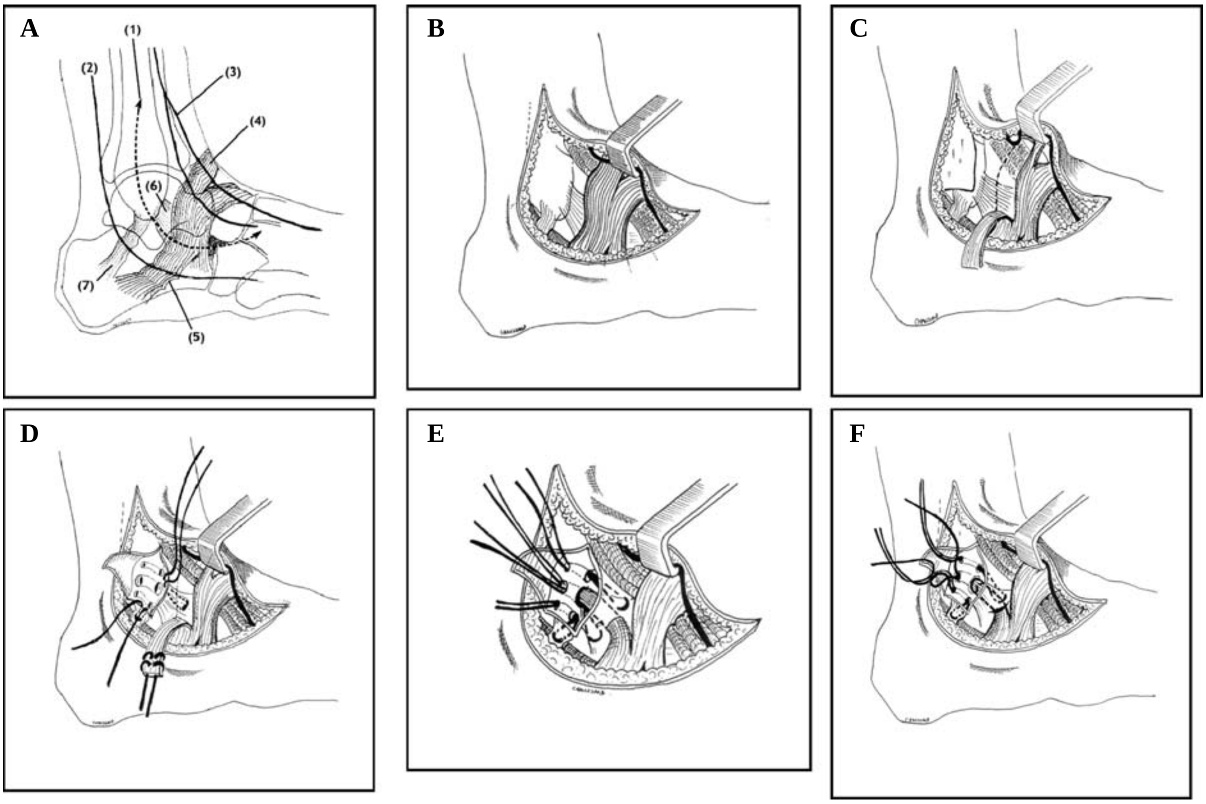

Fig. 2: Surgical technique of extensor retinaculum flap. (**a**) Basic anatomy: (1) surgical approach, (2) course of peroneus brevis, (3) sensory branches of superficial peroneal nerve, (4) extensor retinaculum, (5) peroneal tendon sheath, (6) anterior bundle of lateral collateral ligament (anterior talofibular ligament), (7) middle bundle of lateral collateral ligament (calcaneofibular ligament). (**b**) Exposure of retinaculum. (**c**) Elevation of retinaculum flap. (**d**) Drilling of malleolar tunnels and suturing of each flap. (**e**) Passage of sutures in the tunnels (verification of sliding of the retinaculum flap in the central tunnel). (**f**) Tensioning and suture fixation of the flaps with the foot and ankle in neutral position.

Table 1: Rate of Surgical Procedures Associated with Ligamentoplasty

Associated procedures	Rate
Resection of bony avulsion	11.5%
Resection of soft tissue impingement	17%
Suture of fissured peroneal tendons	3%
Resection of peroneal tenosynovitis	1%
Resection of cartilaginous lesion	7.6%
Osteochondral graft	1%

performed in any case. The mean duration of postoperative immobilization was 6 weeks, while weight bearing was recommenced at an average of 2 weeks. Postoperative proprioceptive physiotherapy was routinely prescribed and completed in all cases.

Assessment methods

Assessment parameters were chosen on the basis of published literature and were collated in a single study database. Epidemiological data included age at surgery, gender, level of activity according to the Tegner score,[38] state of the contralateral ankle, etiology of the initial sprain, sprain-to-surgery interval, and reason for surgery. Functional results were measured using the Karlsson[27] and Good–Jones–Livingstone[19] scores. Radiographic outcomes were evaluated in terms of stability and arthrosis.

The Karlsson score takes account of several parameters: pain, swelling, subjective instability, stiffness, ability on stairs, running, work, sporting activities, and the need to wear a brace. A score was given for each parameter, resulting in a total score between 0 and 100; results were considered poor for scores below 50, moderate for 50 to 79, good for 80 to 94, and excellent for 95 to 100.

The radiographic examination of the operated and contralateral ankles comprised anteroposterior (in 20° internal rotation) and lateral views, a weight-bearing hindfoot alignment view (Meary), and stress views in forced varus and anterior drawer. These films were performed according to the protocols of each individual center, either by passive manual force, with the aid of the Telos Stress Device, or by active "autovarus."[13] This assessment allowed evaluation of level of arthrosis according to the classification of Van Dijk[59] (Table 2), residual laxity (quantified by both the degree of

Table 2: Van Dijk Radiological Classification

Grade	Tibiotalar joint line
G0	Normal joint or subchondral sclerosis
G1	Osteophytes without joint space narrowing
G2	Joint space narrowing with or without osteophytes
G3	(Sub)total disappearance or deformation of the joint space

lateral opening on forced varus radiographs and anterior translation on the anterior drawer view), and the morphotype of the hindfoot on the Meary view.

Statistical analysis was performed using Stata 10 software for OS X. We used values and frequencies for qualitative variables and mean plus standard deviation for continuous variables. Statistical significance was assumed at p .05. For continuous variables, paired means were compared with the Student *t*-test and multiple means by analysis of variance. Pairwise correlations were assessed using the Spearman coefficient. Multivariate analysis by logistic regression was used to identify positive prognostic factors for the Karlsson score.

RESULTS

Intraoperative observations

In addition to the classical damage to the anterior and/or middle bundles of the lateral collateral ligament, macroscopic lesions to the ligaments of the subtalar joint (interosseous ligament, cervical ligament) were noted in 30% of cases.

Functional and clinical results

The majority of patients were satisfied with the result of surgery (93%), with 6.7% disappointed and 0.3% dissatisfied. The mean overall Karlsson score was 94.8 (range, 40 to 100), with 93.3% good or very good results. For the criteria of stability and pain, the results were satisfactory, with a stability score (out of 25 points) of 95.2% and a pain score (out of 20 points) of 96.2% (15). The Karlsson score was correlated with the subjective outcome (very satisfied patients have a better functional score than disappointed patients).

These results appear to be stable over time because the Karlsson score did not vary with increased follow-up. More advanced pre- and postoperative degenerative lesions, as measured by the Van Dijk score, were significantly associated with poorer clinical outcomes (Table 3). Postoperative complications were also associated with a poorer result.

Talocrural dorsiflexion was normal in 95% of cases, as was plantarflexion in 99% of cases. Global varus and valgus mobility of the hindfoot (talocrural and subtalar joints) was reduced in 20% of cases, but without any effect on functional stability.

Table 3: Contingency Table Comparing Preoperative Articular Degeneration (as Measured by the Van Dijk Classification) with Postoperative Clinical Outcome (as Measured by the Karlsson Score)

	Preoperative Van Dijk grade		
Karlsson score	G0/G1	G2/G3	Total
Good/excellent (score: 80–100)	139	1	140
Poor/moderate (score: <80)	6	4	10
Total	145	5	150

NOTE: $p < .0001$; odds ratio, 92.6; 95% confidence interval, 9 to 961 (Fisher exact test).

Radiographic results

The results of stress x-rays (manual force 1%, Telos Stress Device 97%, and autovarus 2%) at review demonstrated a clear improvement in laxity with a discrepancy in anterior drawer of 0.17 mm (±2 mm) and in varus of 0.12° (±5°). This corresponds to a near normalization of stability. Radiographic follow-up failed to demonstrate any significant progression of degenerative articular lesions, with a majority classified as G0 or G1 (97%); stability of G2 lesions (3%), and no G3 lesions (0%) (Table 4).

Finally, concerning the Meary hindfoot alignment views, few patients had a varus hindfoot (6%), so no relationship was proven between a varus hindfoot and poor clinical or radiographic outcomes.

Prognostic factors

The preoperative factors of gender, age at surgery, side operated on, contralateral ankle status, and occupation had no impact on results. A link was found between the functional result and residual radiological laxity measured by stress radiographs because patients who remained clinically unstable at review were radiologically more lax than patients without residual clinical instability. A similar relationship was found concerning residual pain. There were significantly

Table 4: Postoperative Progression of Radiological Lesions According to Van Dijk Classification

Grade	Preoperative	Postoperative
G0	77%	72%
G1	20%	25%
G2	3%	3%
G3	0%	0%

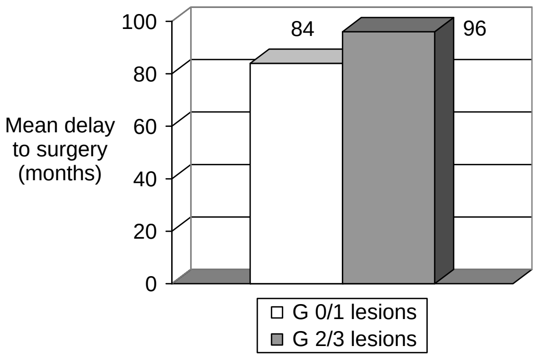

Fig. 3: The severity of preoperative articular degeneration is linked to mean delay to surgery; $p = .002$ (Mann–Whitney U test).

more signs of arthrosis or osteochondral lesions preoperatively if the delay to intervention was longer (Figure 3), because in these cases clinical results were poorer, although this was not statistically significant. Patients with instability and pain had worse clinical outcomes ($p < .024$) and more arthrosis ($p < .01$) than those with instability alone, even if preoperative laxity was essentially identical in both cases. Patients injured through workplace accidents only represented 6% of patients in this study. Although it is difficult, therefore, to prove statistically, workplace injuries were associated with a poorer functional result, with one in two such patients having an unsatisfactory outcome ($p = .018$).

Four principal prognostic factors were identified:

- Etiology of the laxity: The likelihood of having a good result was increased by a factor of 4.4 in cases resulting from sports or domestic injuries, compared with accidents in the workplace.
- The longer the delay to surgery, the more advanced were the degenerative changes in the ankle joint (Figure 3).
- The more severe the degenerative changes were pre- and postoperatively, the poorer was the clinical outcome (Table 3).
- Postoperative complications: The absence of complications, especially neurological, increased the probability of a good outcome by a factor of 10.

Complications occurred in 16% of cases (Table 5); the two most frequent were neurological (dysesthesias and neuromas) (7.6%) and complex regional pain syndrome, type I (3.8%)—both significantly related to poorer outcomes. Other complications included hematoma (1.8%) and superficial skin necrosis (2.8%). No deep infection or thromboembolic events were reported in this series.

Table 5: Types and Rates of Complications

Types of complications	Rate
Hematoma	1.8%
Superficial skin necrosis	2.8%
Neuromata & dysesthesiae	7.6%
Complex regional pain syndrome, type I	3.8%

DISCUSSION

There is a wealth of literature concerning instability of the ankle. However, when a follow-up of at least 5 years is specified, the number of articles falls to about 30, including the recent SOFCOT 2008 series[8] with 310 cases of lateral ankle stabilization with 13 years mean follow-up. In this study, clinical outcomes and improvements in radiological stability were superior in the 105 cases treated using an extensor retinaculum flap to those treated using other techniques ($p < .01$). Studies using the Broström and Duquennoy techniques[6,22,41,52] report between 81% and 96% good or very good results. Using these techniques, a correlation has been proven between preoperative varus and final outcome: the higher the preoperative varus, the greater the radiological laxity at follow-up. One must therefore be prudent when considering an isolated capsuloligamentous retensioning to treat a major preoperative laxity that most certainly involves the subtalar joint.[38] The simultaneous capsuloligamentous retensioning and reinforcement with the extensor retinaculum flap used in our technique avoids these pitfalls.

In articles that study retensioning with reinforcement,[1,12,24,32,33,35,36,37,40,46] such as the modified Broström–Gould technique using the peroneus tertius and periosteum, 82% to 85% good or very good results have been reported. Conversely, for reconstructions relying on the plantaris tendon,[1,12] analysis of both series reveals widely contrasting results with 67% good or very good outcomes in one study versus 100% in the other.

Procedures using a split stabilizing tendon,[39,50,52] such as the Chrisman–Snook and hemi-Castaing, have 90% to 93% good or very good results.

Transfer of a complete tendon, such as in the Castaing technique,[25] produces 80% good or very good results, whereas the Evans technique gives variable results ranging from 50% to 93% good or very good results, with an average of 75%.[3,26,30,43] Meanwhile, the Watson–Jones technique produces an average of only 50% good or very good results.[5,21,51,58]

Surgical techniques that use all of the peroneus brevis[15,25] give poorer results than those that use only half the tendon.[39,50,52] In their articles, Krips et al.[31–34] compared techniques considered “anatomic” (Broström–Gould and periosteal) with “nonanatomic” techniques (hemi-Castaing, Watson–Jones, Evans). They confirmed that the outcomes from anatomic techniques are significantly superior ($p < .005$). It should be remembered that the definitions of good, very good, and excellent results are diverse or absent in this large group of publications, which hinders their direct comparison.

The two most frequent individual complications in our series were neurological (7.6%) and complex regional pain syndrome, type I (3.8%). These rates remain below those in the literature (11% and 6%, respectively).[39,50,53] Notably, although infectious complications occur in 4% to 6% of cases in most reported series, we had none in our study.

It would appear that overall the clinical outcomes in the published literature are generally favorable, with results ranging from 70% to 90% good or very good results. However, when one focuses on a subjective criterion such as residual instability, positive results are not as frequent, with a residual instability rate of 15% to 26%, depending on the technique, with a mean of 20%. Our technique left only 4.8% of cases residually unstable (Karlsson subscore, instability). In addition, our technique had similar rates of good to very good results (93.3%) and patient satisfaction (93%), as well as correction of laxity and normalization of varus and anterior drawer (measured objectively by stress radiographs).

The subtalar joint has been previously studied in the literature. Few studies have used it as a patient selection criterion. In the series of Thermann et al.[52] and Jarde et al.,[25] all patients had subtalar instability following lateral ankle stabilization with the Castaing technique. Conversely, other authors have made subtalar instability an exclusion criterion, even though the proposed technique crosses the subtalar joint and has a tenodesing effect.[22−29,32] In our series, 30% of patients had complex subtalar lesions (diagnosed clinically, radiologically, or by intraoperative observation). Because of the anatomic attachment of the extensor retinaculum to the calcaneus, our technique allowed stabilization of not only the talocrural joint but also the subtalar joint. In view of our results, and its ability to preserve proprioception, reconstruction with an extensor retinaculum flap has now become our technique of choice for stabilization of the subtalar joint.

Radiological comparison is difficult, given the paucity of publications reporting any radiographic analysis. Where available, the rates of radiological change according to the classification of Van Dijk are variable at 18% to 65%.[12,21,32,33,43,51] Tibiotalar osteoarthrosis is mainly post-traumatic and is secondary to tibiotalar instability in 15% of cases.[10,47] According to Valderrabano et al.,[56] the mean interval between injury and the onset of osteoarthrosis is 34 years. In our series, the rate of G2 lesions remained constant (Table 4). These rates confirm the protective effect of this ligamentoplasty against the onset of tibiotalar osteoarthrosis.

Several risk factors may lead to chronicity.[8] Insufficient initial treatment is a major predisposing factor. Therefore, there is a need for thorough investigation, even at the time of the acute injury. Morphological factors exist that vary from individual to individual, such as the arc of curvature of the talar dome and the presence of varus malalignment of the hindfoot. Furthermore, insufficient recovery of proprioceptive control is an important issue. Neuromuscular reprogramming focusing on preactivation must replace "classical" rehabilitation according to the principles of Freeman.[18,22−30]

Finally, chronic instability causes secondary lesions that are often responsible for pain. These may comprise fissuring of the peroneal tendons, anterior or posterior osteophytes, interposition of anterior soft tissue (impingement syndrome), and especially osteochondral lesions of the talar dome that are the precursors of ankle osteoarthrosis.

A thorough investigation of the causes and effects of chronic instability is fundamentally important to identify ligamentous insufficiency (in particular subtalar), calcaneal morphotype, and the secondary lesions listed above. The goal is to avoid revision surgery and to optimize the global outcome. For laxity, clinical examination and stress x-rays are of most value. Gadolinium-enhanced MRI and MR arthrogram are most useful to assess the subtalar joint, ligamentous, and tendinous lesions. Hindfoot alignment is easily evaluated clinically and with Meary view radiographs, while ultrasound demonstrates lateral synovitis and peroneal tendon fissuring. Finally, isolated osteochondral lesions and more generalized arthrosis are best identified using weight-bearing x-rays and, in particular, CT arthrogram. This is a retrospective study with a mean of 11 years of follow-up and our practice has developed over this time period. It is for this reason that only a minority of our patients have had all the aforementioned investigations performed. It is now our protocol to perform stress x-rays, a Meary hindfoot alignment view, and MRI and CT arthrogram, in addition to standard weight-bearing x-rays for all instability patients. With such a preoperative workup, we seldom encounter any unexpected pathology and are prepared in advance to address associated tendinous or cartilaginous lesions. The variability in the number of preoperative investigations performed in each patient in this study unfortunately does not allow a correlation with clinical outcomes that might confirm the value of our current practice.

Despite advances in nonsurgical management, a surgical strategy must often be adopted to effectively deal with all the different lesions that may be associated with the lateral laxity of an unstable ankle. Our results strongly support use of an extensor retinaculum flap for stabilization of both isolated lateral collateral ligament injuries and associated lesions of the subtalar joint, where its peripheral location stabilizes both the ankle and subtalar joints. For complex lesions, guided by exhaustive preoperative investigations, it may be necessary to consider a medial ligament repair[23] associated with that on the lateral side, a realignment osteotomy for any hindfoot deformity (varus is most common[2,57,60]), or even an arthroscopy before definitive surgery when osteochondral lesions or impingement are present. Ignoring these associated lesions puts the entire operation at risk of failure.

CONCLUSION

Our results demonstrated that the longer a patient has chronic instability, the greater is the risk of osteochondral lesions and arthrosis, and the poorer are the clinical outcomes following surgery. Thus we believe that unnecessary delay to surgery should be avoided in patients with chronic ankle instability. Ligamentoplasty combining capsuloligamentous retensioning and reinforcement with an extensor retinaculum flap afforded long-term protection against degenerative tibiotalar arthrosis. There was a correlation between correction of laxity and the functional result. Nevertheless, rendering an ankle "nonlax" does not necessarily mean that it is stable and painless. The role of proprioception must always be considered. It is essential also to remember the importance of the subtalar joint and to routinely look for varus malalignment of the hindfoot. We believe that complementary examinations, such as CT arthrogram and MRI, allow surgeons to identify preoperatively multiple ligamentous injuries (lateral and medial, talocrural and subtalar), associated lesions (osteochondral lesions of the talus, anterior and posterior impingement), and the morphotype of the hindfoot, which could require calcaneal realignment osteotomy.

REFERENCES

1. **Anderson, ME:** Reconstruction of the lateral ligaments of the ankle using the plantaris tendon. J Bone Joint Surg. **67**:930–934, 1985.
2. **Baker, JM; Ouzounian, TJ:** Complex ankle instability. Foot Ankle Clin. **5**:887–896, 2000.
3. **Baltopoulos, P; Tzagarakis, GP; Kaseta, MA:** Midterm results of a modified Evans repair for chronic lateral ankle instability. Clin Orthop Relat Res. **422**:180–185, 2004. http://dx.doi.org/10.1097/01.blo.0000128645.84131.af
4. **Baumhauer, JF; O'Brien, T:** Surgical considerations in the treatment of ankle instability. J Athl Train. **37**:458–462, 2002.
5. **Becker, HP; Rosenbaum, D; Zeithammel, G; et al.:** Tenodesis versus carbon fiber repair of ankle ligaments. Clin Orthop Relat Res. **325**:194–202, 1996. http://dx.doi.org/10.1097/00003086-199604000-00023
6. **Bell, SJ; Mologne, ST; Sitler, DF; et al.:** Twenty-six-year results after Broström procedure for chronic lateral ankle instability. Am J Sports Med. **34(6)**: 975–978, 2006. http://dx.doi.org/10.1177/0363546505282616
7. **Blanchet, A:** La réfection capsuloligamentaire dans les instabilités chroniques de la tibiotarsienne. Rev Chir Orthop. **61(suppl II)**:175–176, 1975.
8. **Bonnel, F; Toullec, E; Mabit, C; Tourné, Y:** Chronic ankle instability: biomechanics and pathomechanics of ligaments injury and associated lesions. Orthop Traumatol Surg Res. **96**:424–432, 2010. http://dx.doi.org/10.1016/j.otsr.2010.04.003
9. **Broström, L:** Sprained ankles. V. Treatment and prognosis in recent ligament ruptures. Acta Chir Scand. **132**:537–550, 1966.
10. **Daniels, T; Thomas, R:** Etiology and biomechanics of ankle arthritis. Foot Ankle Clin North Am. **13**:341–352,2008. http://dx.doi.org/10.1016/j.fcl.2008.05.002
11. **Delahunt, E; Monaghan, K; Caufield, B:** Altered neuromuscular control and ankle joint kinematics during walking in subjects with functional instability of the ankle joint. Am J Sports Med. **34**:1970–1976, 2006. http://dx.doi.org/10.1177/0363546506290989
12. **De Vries, J; Struijs, PA; Raaymakers, EL; et al.:** Long-term results of the Weber operation for chronic ankle instability: 37 patients followed for 20–30 years. Acta Orthop. **76**:89–98, 2005. http://dx.doi.org/10.1080/17453670510045552
13. **Dubrana, F; et al.:** Instabilité chronique autour de la cheville (table ronde SOO). Rev Chir Orthop. **92(suppl 1)**:11–40, 2006. http://dx.doi.org/10.1016/S0035-1040(06)78369-6
14. **Duquennoy, A; Letendard, J; Loock, P:** Remise en tension ligamentaire externe dans les instabilités chroniques de la cheville. À propos de 22 cas. Rev Chir Orthop. **66**:311–316, 1980.
15. **Elmslie, RC:** Recurrent subluxation of the ankle joint. Ann Surg. **100**:364–367, 1934. http://dx.doi.org/10.1097/00000658-193408000-00012
16. **Fayolle, D:** Rééducation neuromusculaire sur instabilité de la cheville chez le sportif. KS. **467**:48–51, 2006.
17. **Forestier, N; Toschi, P:** The effect of ankle destabilization device on muscular activity while walking. Int J Sports Med. **6**:464–470, 2005. http://dx.doi.org/10.1055/s-2004-830336
18. **Freeman, MA; Dean, MR; Hamham, IW:** The etiology and prevention of functional instabilities of the foot. J Bone Joint Surg Br. **47**:678–685, 1965.
19. **Good, CJ; Jones, MA; Livingstone, BN:** Reconstruction of the lateral ligament of the ankle. Injury. **7**:63–65, 1975. http://dx.doi.org/10.1016/0020-1383(75)90065-0
20. **Gould, N; Seligson, D; Gassman, J:** Early and late repair of the lateral ligament of the ankle. Foot Ankle. **1**:354–358, 1980.
21. **Hamido, F; Ibrahim, SA; Abo-El-Noor, T; et al.:** Evaluation of the results of Watson-Jones tenodesis in chronic lateral instability of the ankle. Foot Ankle Surg. **13**:56–62, 2007. http://dx.doi.org/10.1016/j.fas.2006.10.005
22. **Hamilton, WG; Thompson, FM; Snow, SW:** The modified Bröstrom procedure for lateral ankle instability. Foot Ankle. **14**:1–7, 1993.
23. **Hintermann, B; Knupp, M; Pagenstert, GI:** Deltoid ligament injuries: diagnosis and management. Foot Ankle Clin. **11**:625–637, 2006. http://dx.doi.org/10.1016/j.fcl.2006.08.001
24. **Jarde, O; Bouzigues, P; Trinquier-Lautard, J.-L; et al.:** Laxité externe chronique de cheville: traitement chirurgical par une ligamentoplastie au périoste avec remise en tension capsulo-ligamentaire: a propos de 34 cas. Rev Chir Orthop. **85(1)**:51–57, 1999.
25. **Jarde, O; Duboille, G; Abi-Raad, G; et al.:** Instabilité de cheville avec lésion de l'articulation sous talienne demontrée par l'IRM. Résultats de l'intervention de Castaing dans une série de 46 cas. Acta Orthop Belg. **68**:515–528, 2002.
26. **Karlsson, J; Bergsten, T; Lansinger, O; et al.:** Reconstruction of the lateral ligaments of the ankle for chronic lateral instability. J Bone Joint Surg Am. **70**:581–588, 1988.
27. **Karlsson, J; Peterson, L:** Evaluation of ankle joint function: the use of a scoring scale. Foot Ankle Int. **1**:15–19, 1991.
28. **Konradsen, L:** Factors contributing to chronic ankle instabilty: kinesthesia and joint position sense. J Athl Train. **37**:381–385, 2002.
29. **Konradsen, L; Voigt, M; Hodsgaard, C:** Ankle inversion injuries. The role of the dynamic defense mechanism. Am J Sports Med. **25**:54–58, 1997. http://dx.doi.org/10.1177/036354659702500110
30. **Korkala, O; Transkanen, P; Makijarvi, J; et al.:** Long-term results of the Evans procedure for lateral instability of the ankle. J Bone Joint Surg Br. **73**:96–99, 1991.
31. **Krips, R; Brandsson, S; Swensson, C; et al.:** Anatomical reconstruction and Evans tenodesis of the lateral ligaments of the ankle: clinical and radiological findings after follow up for 15 to 30 years. J Bone Joint Surg Am. **84**:232–236, 2002. http://dx.doi.org/10.1302/0301-620X.84B2.12143
32. **Krips, R; Van Dijk, CN; Halasi, PT; et al.:** Long-term outcome of anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a multicenter study. Foot Ankle Int. **22(5)**:415–421, 2001.

33. **Krips, R.; Van Dijk, CN; Halasi, T; et al.:** Anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a 2 to 10 year follow up, multicenter study. Knee Surg Sports Traumatol Arthrosc. **8**:173–179, 2000. http://dx.doi.org/10.1007/s001670050210
34. **Krips, R; Van Dijk, CN; Lehtonen, H; et al.:** Sports activity level after surgical treatment for chronic anterolateral ankle instability. A multicenter study. Am J Sports Med. **30**:13–19, 2002.
35. **Kuner, EH:** Der gestielte perioszügel als möglichkeit de aubenbandersatzes. Hefte Unfallheilkd. **133**:191–193, 1978.
36. **Mabit, C; Chaudruc, JM; Fiorenza, F; et al.:** Lateral ligament reconstruction of the ankle: comparative study of peroneus brevis tenodesis versus periostal ligamentoplasty. Foot Ankle Surg. **4**:71–76, 1998. http://dx.doi.org/10.1046/j.1460-9584.1998.00090.x
37. **Mabit, C; Setton, D; Charissoux, JL; Pecout, C; Arnaud, JP:** La ligamentoplastie au périoste dans les instabilités chroniques de la cheville chez le sportif. J Traumatol Sport. **10**:102–105, 1993.
38. **Mabit, C; Tourné, Y; Besse, J-L; et al.:** Chronic lateral ankle instability surgical repairs: the long-term prospective. Orthop Traumatol Surg Res. **96**:417–423, 2010. http://dx.doi.org/10.1016/j.otsr.2010.04.004
39. **Marsh, JS; Daigneault, JP; Polzhofer, GK:** Treatment of ankle instability in children and adolescents with a modified Chrisman-Snook repair: a clinical and patient-based outcome study. Pediatr Orthop. **26(1)**:94–99, 2006. http://dx.doi.org/10.1097/01.bpo.0000189009.73444.a8
40. **Mascard, E; Christel, P; Witvoet, J:** Traitement des instabilités tibiotarsiennes chroniques par remise en tension ligamentaire externe transosseuse. J Traumatol Sport. **11**:1–8, 1994.
41. **Muijs, SP; Dijkstra, PD; Bos, CF:** Clinical outcome after anatomical reconstruction of the lateral ankle ligaments using the Duquennoy technique in chronic lateral instability of the ankle: a long-term follow-up study. J Bone Joint Surg. **90(1)**:50–56, 2008. http://dx.doi.org/10.1302/0301-620X.90B1.19210
42. **Nieuwenhuijzen, PHJA; Duyssens, J:** Proactive and reactive mechanisms play a role in stepping on inverting surfaces during gait. J Neurophysiol. **98**:2266–2273, 2007. http://dx.doi.org/10.1152/jn.01226.2006
43. **Nimon, GA; Dobson, PJ; Angel, KR; Lewis, PL; Stevenson, TM:** A long-term review of a modified Evans procedure. A 5- to 15-year follow-up of 111 ankles. J Bone Joint Surg Br. **83**:14–18, 2001. http://dx.doi.org/10.1302/0301-620X.83B1.10834
44. **Pisani, G:** Chronic laxity of the subtalar joint. Orthopedics. **19**:431–437, 1996.
45. **Riva, D:** La régression fonctionnelle du contrôle postural chez les athlètes de haut niveau. SFMKS. **437**:15–19, 2003.
46. **Roy-Camille, R; Saillant, G; Gagna, G; et al.:** Les laxités externes chroniques de chevile cure chirurgicale par une ligamentoplastie au périoste. Rev Chir Orthop. **72**:121–126, 1986.
47. **Salzman, CL; Salamon, ML; Blanchard, M; et al.:** Epidemiology of ankle arthritis: report of consecutive series of 369 patients. Iowa Orthop J. **25**:44–45, 2005.
48. **Saragaglia, D; Fontanel, F; Montbarbon, E; et al.:** Reconstruction for the lateral ankle ligaments using an inferior extensor retinaculum flap. Foot Ankle Int. **18**:723–725, 1997.
49. **Schon, IC; Clanton, TO; Baxter, DE:** Reconstruction for subtalar instability: a review. Foot Ankle. **11**:319–325, 1991.
50. **Snook, GA; Chrisman, OD; Wilson, TC:** Long term results of the Chrisman-Snook operation for reconstruction of the lateral ligaments of the ankle. J Bone Joint Surg Am. **67**:1–7, 1985.
51. **Sugimoto, K; Takakakura, Y; Akiyama, K; et al.:** Long-term results of Watson-Jones tenodesis of the ankle. Clinical and radiographic findings after ten to eighteen years of follow-up. J Bone Joint Surg. **80**:1587–1596, 1998.
52. **Thermann, H; Zwipp, H; Tscherne, H.:** Treatment algorithm of chronic ankle and subtalar instability. Foot Ankle Int. **18**:163–169, 1997.
53. **Thonnard, JL; Plaghki, L; Willems, P; et al.:** Pathogenesis of ankle sprain: testing of a hypothesis. Acta Belg Med Phys. **9**:141–145, 1986.
54. **Tourné, Y; Besse, JL; Mabit, C:** Chronic ankle instability. Which tests to assess the lesions? Which therapeutic options? Orthop Traumatol Surg Res. **96**:433–446, 2010. http://dx.doi.org/10.1016/j.otsr.2010.04.005
55. **Tropp, H:** Commentary: functional ankle instability revisited. J Athl Train. **37**:512–515, 2002.
56. **Valderrabano, V; Hinterman, B; Horisberger, M; et al.:** Ligamentous posttraumatic ankle osteoarthritis. Am J Sport Med. **34**:612–620, 2006. http://dx.doi.org/10.1177/0363546505281813
57. **Van Bergeyk, AB; Younger, A; Carson, B:** CT analysis of hindfoot alignment in chronic lateral ankle instability. Foot Ankle Int. **23**:37–42, 2002.
58. **Van der Rijt, A; Evans, GA:** The long term results of Watson Jones tenodesis. J Bone Joint Surg Br. **66**:371–375, 1984.
59. **Van Dijk, CN; Tol, JL; Verheyen, CC:** A prospective study of prognostic factors concerning the outcome of arthroscopic surgery for anterior ankle impingement. Am J Sports Med. **25**:737–745, 1997. http://dx.doi.org/10.1177/036354659702500603
60. **Vienne, P; Schoniger, R; Helmy, N; et al.:** Hindfoot instability in cavovarus deformity: static and dynamic balancing. Foot Ankle Int. **28**:96–102, 2007. http://dx.doi.org/10.3113/FAI.2007.0018