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Assessment of Evertor Strength Following Inferior Extensor Retinaculum Flap Ligamentoplasty in Patients With Chronic Lateral Ankle Instability

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ABSTRACT

The primary aim of our study was to evaluate the strength of ankle evertor muscles in patients who have undergone a lateral ankle ligamentoplasty (which combined tensioning of the primary ligament group and reinforcing it with a pediculated extensor retinaculum flap), using 2 measurement systems (isokinetic and the functional weightbearing test [MyoLux). Our hypothesis was the strength of evertor muscles on the treated side was comparable to that of the contralateral healthy side. This prospective study included 23 patients who had chronic ankle instability and underwent an inferior extensor retinaculum flap ligamentoplasty. Clinical and functional results were assessed using the American Orthopaedic Foot & Ankle Society and Karlsson scores. The evertor muscle strength was analyzed, in both treated and healthy contralateral ankles, using isokinetic testing (gold standard) – an open kinetic chain test and a functional closed kinetic chain test (MyoLux). Data were interpreted using the Stata 14.0 software. The American Orthopaedic Foot & Ankle Society score was 88.1 ± 4.5, and the Karlsson score was 89.6 ± 4.0. Isokinetic tests did not show any significant difference between the treated ankles and the healthy one. Functional tests measuring inversion control at the ankle did not demonstrate any functional differences between the 2 ankles. As confirmed by good functional scores and the lack of difference in evertor muscle strength, this study reports that the inferior extensor retinaculum flap ligamentoplasty is a satisfactory treatment of chronic ankle instability. In addition, the MyoLux is a reliable and effective test to properly assess proprioception at the ankle.

Lateral ankle sprain is one of the most common musculoskeletal lesions in the world, with 6000 daily occurrences in France and >23,000 in the United States (1,2). This is equivalent to 1 episode per 10,000 population every day. In the sporting community, lateral ankle sprains represent 25% of all sports injuries (3).

One of the main complications of lateral ankle sprains is chronic ankle instability (CAI). This affects between 40% and 70% of patients (2,4,5). CAI has been described as a consequence of mechanical instability (ligamentous injury), functional instability (neuromuscular peroneal disorders), and postural deficits (6–12).

It is widely accepted that initial management should be nonoperative in all cases (4). In case of failure, however, surgical treatment may be considered (5). According to Tourné et al (8), CAI may result in long-term cartilage damage and arthritis. More than 80 different procedures that aim to restore mechanical ankle stability have been described (5). The surgical technique described in this study involves both retensioning the lateral collateral ligament (anterior talofibular ligament [ATFL] and calcaneofibular ligament [CFL]) and reinforcing it with a pediculated "neoligament" taken from the inferior extensor retinaculum. This technique was first described by Saragaglia et al (9) from the anatomic studies of Blanchet and Gould (5,9). Mabit et al (5) and Tourné et al (8) reported excellent long-term results, reducing the prevalence of arthritis and residual instability. Moreover, this technique stabilizes the subtalar joint without sacrificing the peroneus brevis muscle (5,8,9). Isokinetic eccentric muscular weakness has been considered an etiological factor for CAI by some (6,10,11).

To the best of our knowledge, there are no studies that investigate the proprioceptive and muscular results of inferior extensor retinaculum flap

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ligamentoplasty. Proprioceptive factors play a major role in the mechanism of CAI (10−14).

The eccentric performance of the ankle evertors is of primary interest as it plays a vital role in the active control of the sudden ankle inversion (8,11,14).

The main objective of this study was to determine, at short-term follow-up, proprioceptive and muscular recovery after inferior extensor retinaculum flap ligamentoplasty for chronic lateral ankle instability.

Our hypothesis was that the strength of evertor muscles on the treated side is comparable to that of the contralateral healthy side.

Materials and Methods

Patients

Twenty-three patients were included in this study prospectively. Inclusion criteria were patients age older than 18 years with total capacity, patient consent, clinical and imaging assessments with criteria of chronic ankle instability, restricted to ATFL and CFL lesions, surgery of only inferior extensor retinaculum flap ligamentoplasty performed by 1 senior surgeon, the MyoLux system was not used in postoperative rehabilitation, minimal follow-up of 1 year, no other ankle and/or foot disorders, no neurologic and/or vestibular diseases, healthy contralateral ankle was healthy, and no subjective apprehension during physical exercise.

The study population consisted of 11 men (48%) and 12 women (52%). Their mean age was 37 ± 10 years (age range 18 to 56 years). Their mean weight was 70.8 ± 9.5 kg (range 52 to 100 kg), and their mean height was 173.8 ± 6.6 cm (range 157 to 190 cm). Mean body mass index was 23.3 ± 2.4 kg/m^2 (range 17.8 to 28.7 kg/m^2). There were 10 right feet (43%) and 13 left feet (57%). Six patients were smokers (26%), and 17 (74%) practiced sports at “good” to “high” levels. Mean follow-up was 1.9 ± 0.4 years (range 1.2 to 3). This study was approved by our local ethic committee, and informed consent was obtained from all participants.

Tools for the Diagnosis of CAI

An exhaustive workup, described in previous studies (15,16), was performed to precisely locate the ligamentous injuries of the tibiofibulotalocalcaneal system and 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. First step is the clinical assessment with an accurate interview history about instability (first sprain, subsequent instability-related accidents, treatments), symptoms reported as feeling of insecurity at the ankle, giving a way, pains and blockage (5), and impact on occupational or sport activities. Clinical examination should be thorough and comparative, focused on foot morphotype (hindfoot varus, which is a factor for instability even in the absence of laxity), joint range of motion (lack of ankle dorsiflexion, subtalar joint stiffness), pain points, and legs pendant, in the various lateral and medial ligament bundles, sinus tarsi, joint lines, and tendon courses (especially retromalleolar and submalleolar peroneal tendons). Peroneal tendon dislocation under active and/or passive tension in eversion should also be screened. Ligament testing is a key step, assessing laxity on the collateral lateral ligaments (varus, talar anterior drawer), the medial ligament (Hinterman test), or the syndesmotic complex (squeeze test, external rotation in forced dorsiflexion of the ankle).

Clinical examination may or may not be sufficient to demonstrate laxity; it often fails to diagnose lesion location. It should be supplemented by complete, directed imaging assessment. Simple comparative anteroposterior and lateral weightbearing ankle radiography is systematic to screen for and analyze bone avulsion of ligament insertions, associated lesions (osteochondral talar dome lesion, tibiofibular diastasis, and tarsal synostosis), neglected fracture (nonunion of the lateral talar apophysis or fifth metatarsal styloid process), and signs of osteoarthritis. Méary or Djian hindfoot view with cerclage, Salzman view, or long axial view specifies hindfoot morphotype, often varus or valgus. Radiographs in forced position in the talocrural joint, although controversial, may help to confirm and quantify laxity and lesion location (autovarus, manual testing, or Telos device). Magnetic resonance imaging can confirm the presence of ligament lesions and sometimes determine their type (distention, tear, avulsion, etc.) and the number of bundles involved and analyzes adjacent tendons (peroneal in particular). Computed tomography-arthrography analyzes cartilage. Surgical procedures may be indicated based on the results of the preoperative assessment. We included in this study only the tibiofibular and subtalar ligament injuries, excluding any hindfoot malalignment, additional ligaments lesions, and lesions related to chronic laxity.

Operative Technique

This ligamentoplasty allows reinsertion of distended ligaments onto the lateral malleolus. In 1975, Blanchet used flap harvested from the extensor retinaculum to reinforce the anterior talofibular ligament, and the fibular sheath to strengthen the calcaneofibular ligament. This technique, also known as the extensor retinaculum ligamentoplasty, was reported by Saragaglia et al (9) (Fig. 1).

(A)

(B)

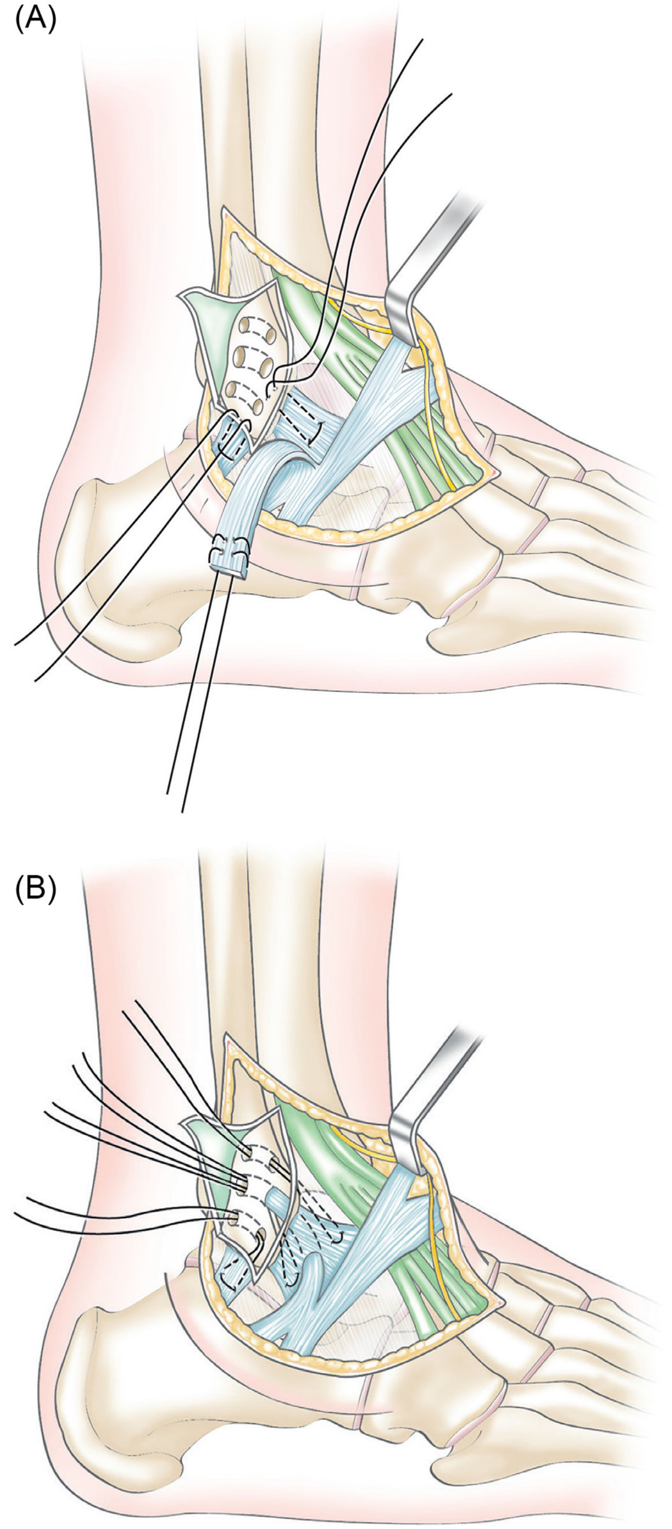

Fig. 1. **(A)** ATFL and CFL prior to reinsertion, with a periosteal flap harvested from the inferior extensor retinaculum (IER). **(B)** The periosteal flap is the bisector of the angle constructed by the ATFL and CFL axis.

The patient is secured in a lateral decubitus position, with use of a thigh tourniquet, and the lower limb is internally rotated. The skin incision is curvilinear and centered on the lateral malleolus. It runs over the sinus tarsi to the dorsal midfoot. A periosteal flap is developed posteriorly toward the sulcus for the peroneal tendons. It will reinforce the capsular shift at the end stage of the procedure. An L-shaped arthrotomy is then performed along the course of the peroneus tertius, creating a residual capsuloligamentous flap, attached to the neck of the talus and the lateral border of the calcaneus. The residual anterior talofibular and calcaneofibular ligaments are located, and their condition is assessed. This arthrotomy allows inspection of the talar dome cartilage and the anterior edge of the tibia and talar neck. Two 3×14-mm Biocomposite SutureTak anchors (Arthrex, Naples, FL) are inserted to allow for reinsertion at a later stage of the procedure: 1 anchor for the capsule and the ATFL (1 needle each) at the upper anterior part of the lateral malleolus, lateral to the fibular insertion of the talofibular ligament, and 1 medial to the tip of the lateral malleolus for the CFL and inferior part of the ATFL when present (1 needle per ligament). Subcutaneous release isolates the inferior extensor retinaculum (IER), from which a rectangular flap, about 1 cm $\times$ 3 to 4 cm, is harvested from the superior bundle. Care is taken to protect the superficial branches of the peroneal and sural nerves. The flap remains inserted on the calcaneus at the entry to the sinus tarsi.

This neoligament is reinforced using a 2-0 nonabsorbable looped suture: Fiberloop (Arthrex). Its size is checked. Due to its attachment to the calcaneus, this flap stabilizes the subtalar joint. A 2.4-mm wire is inserted between the 2 anchors, from the anterior margin of the lateral malleolus to its posterior border. A retractor protects the peroneal tendons. The orientation is 45° to the plantar aspect of the foot. The wire is overdrilled according to the previous sizing of the neoligament (diameter between 4.5 and 5.0 mm). The flap is passed through a short gap into the capsule and then into the tunnel, using a Nitinol suture passing wire. The smooth sliding of this flap is checked before final fixation. First the CFL, then the ATFL, and finally the capsule are secured to the previously placed anchors and thus reinserted onto the anterior part of the lateral malleolus. The sutures are tied with the ankle in neutral position. The extensor retinaculum flap is fixed with use of a biotenodesis interference screw of 4.75 mm. Its tension is checked. The periosteal flap is repositioned on the lateral side of the lateral malleolus, reinforcing the reconstruction. Further sutures, placed over the extensor digitorum brevis muscle completely close the sinus tarsi entry and reinforce the subtalar joint ligaments. Subcutaneous and skin closures are performed. The ankle is immobilized for 3 weeks in a nonweightbearing below-knee cast, followed, for 3 weeks, by a removable weightbearing boot to allow early rehabilitation. Postoperative proprioceptive physiotherapy is routinely prescribed and completed (9).

Clinical Evaluation

Functional outcome was evaluated using the Karlsson (17) and American Orthopaedic Foot and Ankle Society (AOFAS) scores (18). In the AOFAS score, outcomes were classified as excellent (95 to 100), good (80 to 94), average (50 to 79), or poor (<50).

Isokinetic Evaluation of Ankle Eversion/Inversion Strength

Measurements were made using a Contrex isokinetic dynamometer, developed by Physiomed (Schnaittach, Germany). The subject's installation was standaridzed according to the apparatus recommendations (Fig. 2) (1,19,20).

The subject was in lying supine, with the knee bent at 55° on the tested side, and the contralateral lower leg in a horizontal position with the thigh strapped to the table. The dynamometer axis was aligned with the axis of eversion- inversion motion of the joint: passing through the heel, the talocalcaneal joint, and the center of the axis between the lateral and the medial malleolus. Straps stabilized the foot, leg, and pelvis. Handles were set on both sides to hold on to, in order for the subject to perform better (11−13).

The testing sequence was inspired from studies by Willemse et al (12) and Harstsell et al (13). The healthy ankle was tested first, followed by the treated side. One-minute recovery time was given between each series, and 5-minute recovery between testing of each side. Evertor muscle eccentric strength was tested in 2 steps. The eccentric mode was chosen due to its close relation with the sprain protection mechanism (1,10). The test was performed at low velocity (i.e., 30°/s) as in previous studies (11−13,19,20). The subject performed 3 warm-up series of 4 repetitions, followed by 1 measurement series. The second measure was done at high velocity (120°/s) (11−13,19,20). It consisted of 2 series of 4 repetitions; the first was a warm-up, and the second was for measurement purposes. Subjects were given verbal encouragement throughout.

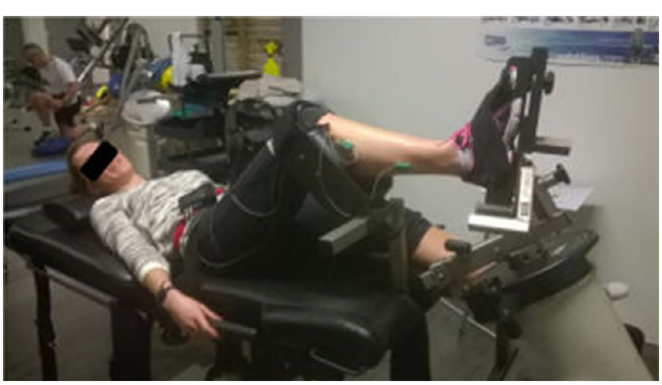

Fig. 2. Patient demonstrating the starting position for isokinetic tests.

Fig. 3. Rear-foot articulator and inertial unit (white box on orange base).

Maximum peak torque was recorded in NewtoN·meter (N·m) during each attempt and at each velocity. Low velocity (30°/s) measured muscular strength, and high velocity (120°/s) evaluated muscle power. The range of these values measured in inversion was verified and validated (21). We normalized torque values with weight (N·m/kg) (13), because it is more relevant as ankle inversion moments usually occur in a closed kinetic chain and, thus, against body weight.

Functional Test: Eccentric Weightbearing Ankle Inversion Control

This functional test has previously been described in several studies (10,11,22,23). It involves measuring the angular velocity during inversion. This test was carried out using a customized MyoLux device (MyoLux Medik e-volution II, CEVRES; Santé, France). This piece of equipment is equipped with a rear-foot articulator that mimics inversion/eversion movements along the physiological subtalar axis (Fig. 3) (10,11,22,23). When the patient weightbears onto the tested leg, the ankle is automatically inverted, thus requiring eccentric eversion to control this movement. Through this, a closed kinetic chain testing is therefore possible (10,11,22,23). The articulator was equipped with an Inertial Measurement Unit (Shimmer3, Dublin, Ireland) (Fig. 3), which measured the integrated gyroscope angular velocity. The sampling frequency of each signal was standardized at 51.2 Hz. Signals were then analyzed with the use of custom software developed using Shimmer capture (Shimmer sensing, Dublin, Ireland), which converted measurements of angular velocity into degrees/s. Data analysis was done with Excel software (Microsoft).

Patients were positioned standing up with their leg fully extending at the knee, facing a wall. They balanced themselves using a light touch of 2 fingers against the wall (22). Assessors monitored that patients did not heavily lean on the wall. Patients stood on 1 leg, onto the tested ankle, which was equipped with the MyoLux^{TM} Medik E-volution device in position 3. They then lifted their forefoot so that only the heel was weightbearing. The test involved inverting the foot so that the fifth toe would touch the floor, then returning to a neutral position (Fig. 4). Patients were asked to slow down the inversion movements as much as possible. This enabled the measurement of inversion movement velocity (in °/s): the lower the angular velocity; the better was the eccentric evertor muscle activation. One repetition of 6 series was needed for subjects to understand the movement and to collect valid data (22).

Regarding the functional test, angular velocity peaks were automatically determined for each trial. Peak values were selected for analysis rather than angular average values, because a neuromuscular deficit of ankle evertors is known to be related to a sudden incapacity to control weightbearing ankle inversion (10).

Protocols

The starting order of experimental measurements (eccentric isokinetism and functional testing) was randomly distributed between subjects.

Statistical Analysis

The Shapiro-Wilk test was used to show that data were not normally distributed. The Wilcoxon signed-rank test was used to compare data obtained from healthy ankles and treated ankles. The significance level was set at $p \leq .05$. The effect size was also calculated. This is an important parameter in behavioral studies such as the current one (24). It was calculated using Cohen d (25). According to Cohen, if $d < .2$, the effect is interpreted as small; when it is .2 to .8, it represents a moderate effect size; when it is >.8, the effect is considered to be large. Data analysis was done using the Stata 14.0 software (Stata Corporation, College Station, TX).

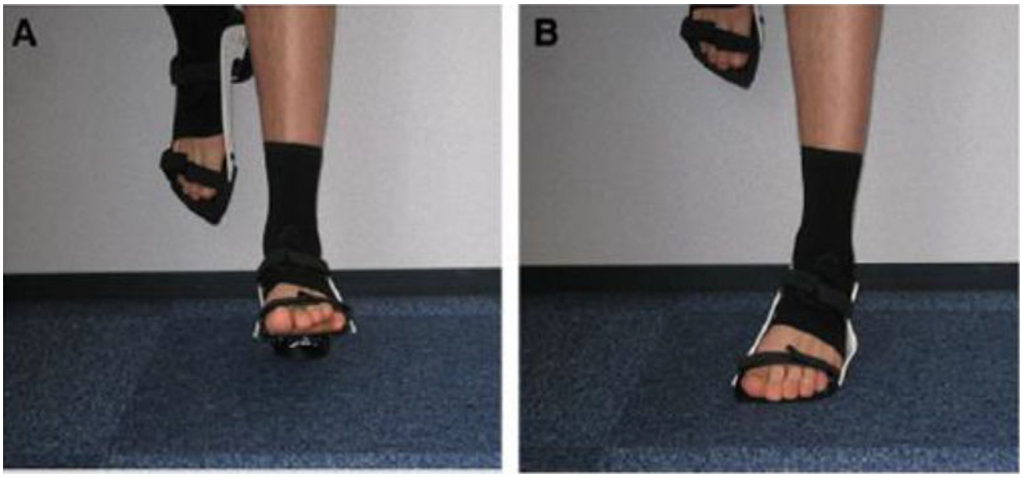

Fig. 4. Eccentric testing with MyoLux Medik E-volution II^{TM}.

Table 1
Main results for 4 eccentric parameters and the functional test

	Parameters	Healthy Ankle	Operated Ankle	*p* Value	Cohen Coefficient
Eccentric isokinetic test	Evertors peak torque (N•m) at 30°/s	33.4 (11.9)	28.6 (8.4)	.09	.7
	Evertors peak torque (N•m) at 120°/s (N•m)	31.5 (10.7)	28.2 (7.7)	.08	.7
	Normalized evertors peak torque (N•m/kg) at 30°/s	0.22 (0.1)	0.17 (0.08)	.06	.7
	Normalized evertors peak torque (N•m/kg) at 120°/s	0.17 (0.05)	0.16 (0.06)	.8	.7
Eccentric weightbearing ankle inversion control test	Angular velocity peak (°/s)	65.9 (37.5)	68.9 (21.5)	.83	.8

Ethics

This study was approved by the French National Commission for Data Processing and Liberty (CNIL). It was also endorsed by a people's protection group. Each patient was given information in accordance with national and international recommendations. Informed and uncoerced written consent was obtained and recorded.

Results

Results are summarized in Table 1. It is important to note that the peak torque values for isokinetic testing indicates the best performance in that test. Conversely, the peak angular velocity value corresponds to the worst performance in functional testing.

Clinical Evaluation

There were no post-operative complications, and no further ankle sprains.

On examination, the treated ankle was stable with negative anterior drawer test and no varus tilt. The healthy ankle had similar examination findings (this was an inclusion criterion). Mean plantarflexion on the treated ankle was 37° ± 8.01°, compared with 39° ± 6.87° on the healthy side ($p > .05$). Mean dorsiflexion was 12° ± 4.64° for the treated ankle and 14° ± 3.23° for the healthy ankle ($p > .05$).

The mean AOFAS was 88.1 ± 4.7, with 5 "excellent" scores (22%), 15 "good" scores (65%), and 3 "fair" scores (13%). The Karlsson score was 89.6 ± 4.0.

Isokinetic Testing of Evertor Muscle Strength

When testing eccentric strength at 30°/s, results do not demonstrate a significant difference between the healthy ankle (peak torque 33.4 ± 11.9 N·m) and the treated ankle (28.6 ± 8.4 N·m) ($p = .09$). At 120°/s, the difference was not significant between the healthy (31.5 ± 10.7 N·m) and the treated ankle (28.2 ± 7.7 N·m) ($p = .08$).

Interestingly, when evertor peak torque is indexed to weight, there are no significant differences between the healthy ankle and the treated ankle. At 30°/s, the mean value for the healthy ankle was 0.22 ± 0.1 N·m/kg; for the treated ankle, it was 0.17 ± 0.08 N·m/kg ($p = .06$). At 120°/s, it was 0.17 ± 0.05 N·m/kg for the healthy ankle and 0.16 ± 0.8 N·m/kg ($p = .08$) for the treated ankle ($p = .08$).

The effect sizes were moderate for all values ($d = .7$).

Functional Testing of Evertor Muscle Strength Using the MyoLux System

The angular velocity peak was 65.9 ± 22.7°/s for the healthy ankle and 68.9 ± 26.8°/s in the treated ankle. This difference was not significant ($p = .83$), and the effect size was moderate ($d = .8$).

Discussion

Data Interpretation

The main finding of our study is the absence of evertor muscle deficit after inferior extensor retinaculum flap ligamentoplasty.

In terms of functional outcome, the results from this study are similar to those from a literature review by Mabit et al (5). The Karlsson score for the latter review was 89.8%, compared with 89.6% in this study. Using the AOFAS scoring system, we collected a total of 87% "excellent" and "good" scores, compared with 79% in a study by Maffulli et al (26).

Comparing the performance of the treated ankle with the healthy ankle, the strength and power of evertor muscles appear better on the healthy ankle but is not significantly different. When the parameters were corrected for weight, there difference between both tested ankles was even smaller. The normalization of isokinetic torque values against body weight facilitates the statistical comparison of muscle performance in subjects with different morphologies (12,13). Normalized torque values are also more relevant because inversion moment generated at the ankle usually takes place in a closed kinetic chain, against body weight (10−12). Patients included in this study seem to have identical eccentric evertor strength and power on the healthy side and the treated side. This theory is reinforced by the moderate effect size (d = .7).

The peak torque values obtained in isokinetic eccentric testing were similar to those found in current literature for healthy ankles. Indeed, in Willems et al (12) evertor peak torque values were about 25N·m in patients with CAI and about 30 N·m in healthy subjects, when tested at 30°/s and 120°/s. In this study, at 30°/s and 120°/s, peak torque values were 28.6 and 28.2 N·m, respectively, for operated ankles and 33.1 and 31.5 N·m, respectively, in healthy ankles. These results are also comparable to those obtained by Harstell and Spaulding (13), who measured peak torque at 34 N·m in healthy ankles and 25 N·m in ankles with chronic instability. It appears that the surgery was beneficial since the results are better for the ankles operated than CAI.

Terrier et al (10,11) demonstrated significant evertor weakness in patients with CAI (27 N·m), compared with healthy subjects (36 N·m).

Terrier et al (10,11) reported a normal angular velocity <75.5°/s. In this study, peak angular velocity for the healthy ankle was 65.9°/s, and for the treated ankle, 68.9°/s. There was no significant difference between the 2 ankles, and the effect size was moderate (d = .8). When compared with available data (11), there was no strength deficit in operated ankles. Terrier et al (11) found the most angular velocity peak at 100.2°/s for CAI.

Results from functional testing also confirm the results from isokinetic testing and suggest that there is no difference in strength between the healthy ankle and the treated ankle. The increased sensitivity of functional testing is likely due to the fact that it analyzes the ankle in a closed kinetic chain, so the evertor muscles are tested in 'normal' physiological conditions.

Isokinetic testing is considered the gold standard to assess muscular strength (12−14,27). However, it has many limitations − open kinetic chain test, high equipment cost, need for specific training, and not easily transportable. Physiotherapists would like to have alternative tests. One such alternative is the MyoLux system. It resolves the above limitations and recent studies conclude the functional system has good reliability (10,11,22,23).

Furthermore, when comparing isokinetic testing with the MyoLux system, Terrier et al (12) found that isokinetic testing may not be as sensitive when evertor strength is indexed for weight (N·m/kg). That study included 12 healthy patients and 12 patients with CAI. Isokinetic testing failed to demonstrate a difference in strength between the 2 groups. On the contrary, the MyoLux test did discriminate between healthy and CAI.

Therefore, the MyoLux test is a reliable functional test of neuromuscular function. It is also less expensive, more easily transported, and easier to use than isokinetic tests. It has the added advantage of being a closed kinetic chain test, because the patient is weightbearing when tested.

Study Strengths and Limitations

The strong point of this study lies in the use of 2 different measuring systems to measure evertor strength. In addition, both tests concluded that there was no difference in ankle evertor muscle strength between the treated ankle and the healthy ankle.

This study was randomised and prospective, which limits bias in measurements. However, there were 2 main limitations. First, no preoperative data were collected. This would have indicated if patients had a preoperative strength deficit. It would have then showed the degree of improvement following surgical intervention. It would have also helped to determine if there was a regression in strength for the healthy ankle during rehabilitation. The second limitation was the small sample size analyzed, even if effect size was moderate.

In conclusion, this original study shows that this ligamentoplasty, using a flap from the IER is an effective treatment in chronic ankle instability. Postoperative functional and isokinetic testing showed no difference between the treated ankle and the contralateral healthy ankle. However, the study did not show a significant difference between the 2 measuring tests used − isokineticism and MyoLux. This could support the use of MyoLux functional testing in future works, as it is reliable, inexpensive, simpler to use, and more easily transported.

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