On the surgical treatment of chronic anterolateral ankle instability

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Chapter I

GENERAL INTRODUCTION
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Anatomy

The ankle joint is the most congruent joint of the human body. The stability of the joint is provided by the bony configuration of the ankle mortise and the talar dome and by the ankle ligaments. During ankle motions, both rotation and translation around and along the movement axes occur. Soft tissue stability is mainly provided by the ligaments; these are the tibio-fibular syndesmosis superiorly, the deltoid ligament on the medial side and on the lateral side, the anterior talo-fibular ligament, the calcaneo-fibular ligament and the posterior talo-fibular ligament (Figure 1).

The anterior talo-fibular ligament can be considered to be an intra-articular reinforcement of the anterolateral part of the rather weak ankle joint capsule. This ligament is rather long and thin and is the main stabilizer on the lateral aspect of the ankle. It is the most vulnerable to injuries. The orientation of the anterior talo-fibular ligament is in a plane parallel to the axis of movement (flexion-extension), provided the ankle is in a neutral position. Thus, the anterior talo-fibular ligament is a true collateral ligament when the foot is placed in plantar flexion. However, most ankle ligament injuries occur by internal rotation in equinus position with the foot in plantar flexion, when the narrowest part of the talus is placed in the ankle mortise and the ankle is thus rendered most lax. This is probably one important reason for the high incidence of injuries of the anterior talo-fibular ligament.

The extra-articular calcaneo-fibular ligament arises from the anterior part of the tip of the fibula. It runs obliquely downwards and backwards to be attached to the lateral surface of the calcaneus. There is a great variety in direction and in proximal attachement. Usually the main part attaches to the tip of the fibula, and in most cases, a bundle of fibres runs directly to the anterior talo-fibular ligament as well. In some cases, the calcaneo-fibular ligament attaches predominantly to the anterior talo-fibular ligament. In cross section the ligament is rounded and has a diameter of 6 to 8 mm. The length is about 20 mm. In contrast to the anterior talo-fibular ligament, this ligament is not part of the fibrous capsule, but is separated from it. It is intimately associated with the posteromedial part of the peroneal tendon sheath. It bridges the talocrural as well as the subtalar joint. The axis of rotation of the talocrural joint runs approximately through, or just below, the tip of the fibula. The insertion of the calcaneo-fibular as well as the anterior talo-fibular ligament at its axis of rotation point (distal fibula
Figure 1: The lateral ankle ligaments
tip) therefore allows flexion and extension movements in the talocrural joint. The connecting bundles that cross over from the anterior talo-fibular to the calcaneo-fibular provide an even lower ‘attachment point,’ possibly to obtain this centre of rotation position. This part of the ligament is known as the lateral talocalcaneal ligament.\textsuperscript{12} The calcaneo-fibular ligament should, considering its bi-articular characteristic, permit subtalar movement. Ligamentous attachment to the calcaneus in the area of the subtalar axis of motion is not anatomically possible. If the ligament runs parallel to this axis, the mobility of the subtalar joint is impeded as little as possible. However, due to the fact that the directional axis can vary enormously between individuals, a great individual difference can also be seen with regard to the ligamentous path. The long axis of the ligament angles posteriorly to the long axis of the fibula between $10^\circ$ and $80^\circ$.\textsuperscript{2-4} In the normal standing position the ligament is relaxed. In plantar flexion the ligament remains relaxed. Only in dorsiflexion and in inversion of the calcaneus is the ligament tensed.\textsuperscript{4}

The posterior talo-fibular ligament is a short and thick ligament. The posterior talo-fibular ligament is tight with the ankle in extension and lax in plantar flexion. Injuries to this ligament are infrequent, and the ligament is not used as a part of a reconstructive procedure. The anterior tibio-fibular ligament (a part of the anterior ankle syndesmosis) is a short, rather thick ligament, and has little impact of lateral ankle ligament function per se. The distal tibiofibular syndesmosis is essential for stability of the ankle mortise and thereby to weight transmission and walking. Experimentally, a combination of forced external rotation, dorsiflexion and axial loading of the ankle has demonstrated to cause a rupture of the anterior tibio-fibular ligament.\textsuperscript{4,5} This will often be accompanied by a (partial) rupture of the deltoid ligament. The main stabilizer on the medial side is the deep portion of the deltoid ligament, a fan-shaped, thick and strong ligament, which is infrequently injured.

Anatomic variations in shape, size, orientation and capsular relations of the lateral ankle ligaments are common; up to 75% of subjects show some variation, most commonly the calcaneo-fibular ligament. The anterior talo-fibular ligament is divided into two separate bundles in one-third of all patients.\textsuperscript{12} These anatomical variations should be born in mind when deciding upon treatment of ankle ligament injuries, especially surgical procedures.\textsuperscript{1}
Acute ligament injuries

In repeated studies, it has been shown that a sprained ankle is the most common sports-related injury, mainly in the younger age groups.\(^6\)\(^-\)\(^9\) Acute ankle ligament injuries are the single most common type of injuries seen by general practitioners and emergency departments. They involve about 25% of all injuries of the musculoskeletal system with over 20,000 patients in the U.S. each day.\(^10\)\(^-\)\(^12\) Inversion trauma constitutes a large percentage of these injuries. In about 10 to 15 percent of all inversion trauma, a rupture of the lateral ankle ligaments is present with involvement of the anterior talo-fibular ligament. It has been estimated that these injuries constitute approximately 25% of all time loss in sports participation, especially in sports that involve running and jumping, e.g., soccer, basketball and volleyball. Although many of these injuries are not serious per se, they are very costly to the society due to their high incidence.\(^13\)

Ligament injuries to the ankle are divided into: (a) acute and (b) chronic. In most cases the lateral ligament injury occur with the foot rotating inwards in plantar flexion when the tibia is simultaneously rotating outwards, giving rise to anterolateral rotational movement. The medial malleolus acts as a fulcrum when the ankle moves into increased inversion, losing its stabilizing function and increasing the strain on the lateral side. The anterior talo-fibular ligament and the calcaneo-fibular ligament act synergistically through the whole range of motion.

Ankle ligament injuries are often classified as Grade I (mild), Grade II (moderate) and Grade III (severe).\(^14\) Grade I injuries include stretching of the ligament without macroscopic rupture. There is a minor swelling and tenderness and not an increased laxity. The loss of function is minimal and the recovery is usually quick. In Grade II injuries there is a partial macroscopic rupture of the ligaments, with moderate swelling, tenderness and pain. There is a mild to moderate increment of laxity, some loss of motion and moderate functional disability. Grade III injuries always include a complete rupture of the ligaments and the joint capsule, with severe bruising, swelling and pain. There is a major loss of function, reduction of motion and increased laxity due to the ligament rupture. The injured subject is often unable to bear weight because of pain. Radiographs are often needed to rule out a fracture. The value of this classification is doubtful, since for Grade II and Grade III injuries, the therapeutic consequences are the same. After a supination it is important to distinguish a simple sprain from an acute lateral ankle ligament lesion which can be a capsular lesion, partial rupture or
complete rupture. The exact extent of the ligament lesion has in this context no direct consequences and is therefore not important to know.\textsuperscript{15,16}

It is well known from several previous studies that the anterior talo-fibular ligament is the most vulnerable of the lateral ankle ligaments.\textsuperscript{4,9,10,17,19} Further, it has been shown that rupture of the anterior talo-fibular ligament occurs as an isolated injury in approximately two-thirds of all ankle ligament injuries. With an increasing force, the calcaneo-fibular ligament is also damaged. A rupture of both the anterior talo-fibular ligament and the calcaneo-fibular ligament occurs in 15-25\%. Isolated rupture of the calcaneo-fibular ligament happens in approximately 1\% and injury to the posterior talo-fibular ligament is extremely rare.\textsuperscript{4}

Individuals with generalised hypermobility of the joints or a previous history of ankle ligament injury are at greater risk of ankle injuries.\textsuperscript{20-22}

Isolated ligament injuries of the deltoid ligament are infrequent. The frequency has been estimated to approximately 2.5\% of all ankle ligament injuries.\textsuperscript{5} The injury mechanism is an excessive eversion, i.e., an outward rotation of the foot during simultaneous inwards rotation of the tibia. This type of injury usually takes several weeks to heal, and more often gives rise to chronic antero-medial pain rather than recurrent medial instability. Pain and swelling are present for a longer period of time than for a corresponding injury on the lateral side.

Injury of the ankle syndesmosis is often seen in soccer players after external rotation of the foot, in dancers after forced dorsiflexion of the foot or in alpine skiers after combined external rotation, axial compression and forced dorsiflexion.\textsuperscript{24-26} The differential diagnosis is especially important in this injury. When this injury is suspected, a complete radiographic examination of the lower leg should be performed to rule out a fracture of the proximal fibula. Disruption of the ankle syndesmosis is painful, and often heals slowly, but residual disability with recurrent instability episodes is not frequent. It is believed that a rupture of the anterior tibio-fibular ligament without any associated bony injury is a common feature of ankle sprains.\textsuperscript{27-29} A rupture of the anterior tibio-fibular ligament alone does usually neither cause symptoms nor degenerative changes at long-term follow-up. It is concluded that this rupture of the anterior tibio-fibular ligament does occur in 1 - 5\% of the patients after severe inversion trauma of the ankle.\textsuperscript{28} Physical examination cannot discriminate between an isolated lateral ankle ligament rupture or a lateral ankle ligament rupture accompanied by a syndesmotic
ligament rupture. Treatment of the lateral ankle ligament rupture is sufficient for the natural healing of the concomittant syndesmotic ligament rupture.\textsuperscript{30}

A supination trauma is associated with a distraction force on the lateral side and compression force on the medial side of the joint. Apart from anterolateral pain and swelling, 60\% of the patients experience pain on palpation of the anteromedial ankle joint structures.\textsuperscript{31} Damage to the cartilage rim covering the anterior distal tibia, the anterior part of the medial malleolus and the medial talar facet is known to occur in the majority of patients who sustain a supination trauma. Depending on the degree of damage, a repair reaction with cartilage proliferation, scar tissue formation and calcification will follow. Additional damage due to recurrent instability or forced ankle movement, especially forced dorsiflexion, will enhance this process. Recurrent microtrauma to this anteriorly located cartilage rim could be another important factor. Especially in cases where macroscopic cartilage damage is already present, due to supination or direct trauma, repetitive ball kicking can explain the development of the so called "footballer's ankle." It has been shown that in patients with anteromedial osteophytes, 75\% had a history of supination trauma or had participated in soccer.\textsuperscript{32,33} Presence of osteophytes is not always associated with serious complaints. Asymptomatic ankle osteophytes have been reported in over 50\% of athletes. Removal of these spurs is important to create normal movement and prevent reoccurrence of the impingement. Arthroscopic removal of these osteophytes produces good or excellent results in over 90\% of cases.\textsuperscript{34,35} Grading the degree of osteoarthritis in patients with an anterior impingement syndrome is important for the judgement of the prognosis.\textsuperscript{35}

**Diagnosis of acute ligament injuries**

Although ruptures of the ankle ligaments are very common, treatment selection remains controversial. In a systematic review of orthopaedic literature, it was found that treatment with too short duration or that did not include sufficient support of the ankle joint tended to result in more residual symptoms. It was concluded that a "no-treatment" strategy for ruptures of the lateral ankle ligaments led to more residual symptoms.\textsuperscript{10,17,36,37} After a supination trauma it is therefore important to distinguish a simple distorsion from an acute ankle ligament rupture since adequate treatment is associated with a better prognosis.\textsuperscript{16} Because of the often reported poor reliability of physical examination of ligament ruptures after inversion trauma of the ankle, stress radiography, arthrography, MRI and ultrasonography are often performed simultaneously.\textsuperscript{38} However, these methods are expensive and their reliability is
also debated. The reliability of physical examination can be enhanced when the investigation is repeated a few days after the trauma. The accuracy of physical examination has been determined in a series of 160 patients, who all underwent arthrography, comparing physical examination within 48 hours of the injury and 5 days after the injury. The specificity and sensitivity of delayed physical examination for the presence or absence of a lateral ankle ligament rupture were 84% and 96% respectively. The most important features of physical examination are swelling, haematoma discoloration, pain on palpation and the anterior drawer test. Physical examination is unreliable in the acute situation, since the anterior drawer test cannot be performed due to pain. A few days after the trauma, the swelling and pain have subsided and it becomes obvious if the cause of swelling was edema or haematoma. The pain on palpation has become more localized and the anterior drawer test can now be performed. The site of pain on palpation is important. If there is no pain on palpation over the anterior talo-fibular ligament, there is no acute lateral ligament rupture. Pain on palpation over the anterior talo-fibular ligament itself cannot distinguish between a rupture or a distorsion. Pain on palpation in combination with a haematoma discoloration has, however, a 90% chance of acute lateral ligament rupture. A positive anterior drawer test has a sensitivity of 73% and a specificity of 97%. A positive anterior drawer test in combination with pain on palpation over the anterior talo-fibular ligament and haematoma discoloration has a sensitivity of 100% and a specificity of 77%. Delayed physical examination provides a diagnostic modality with a high sensitivity and specificity.\textsuperscript{12,39}

**Treatment of acute ligament injuries**

Repeated studies have shown that simple sprains can safely be treated non-surgically. Functional treatment with a very short period of rest, cooling (ice), compression, and elevation to reduce the edema (the RICE principle) during the first 1-3 days, depending upon the amount of swelling, bruising and pain should always be recommended. Early weight-bearing without crutches, if possible, is encouraged. Active range of motion training should be started after the acute phase treatment is completed, followed by neuro-muscular coordination training using balance boards and peroneal strengthening exercises.\textsuperscript{13,19,40,41}

The injured ligaments should be protected from new injuries during the healing phase by using external support (ankle tape or a brace) to control the range of motion and to reduce the symptoms of functional instability. Both ankle tape and ankle braces, e.g. the air-stirrup, are easy to apply, versatile and effective in stimulating the proprioceptive system. The results of
functional treatment of ankle sprains are satisfactory in the majority of cases, and most athletes are able to return to sporting activities within 1-2 weeks. It has been shown that costs are significantly lower and ankle function is significantly better following early functional treatment (supervised rehabilitation program) or air-stirrup brace (Figure 2) than immobilization in a plaster cast.²¹,⁴²-⁴⁷
There is still a controversy as to whether ligament ruptures should be treated non-surgically by active functional treatment and early mobilization, or by primary surgical repair followed by immobilization using a plaster cast or a brace. There are only a few prospective, randomised and controlled studies found in the literature. These studies have mostly shown that the medium- and long-term results are satisfactory in the majority of these patients regardless of the primary choice of treatment, i.e. surgical repair, cast immobilization alone for 3-6 weeks, or functional treatment based on the principle of early immobilization. In a prospective, randomised trial, comparing early mobilization with plaster cast immobilization, it was shown that these treatment modalities prevented late residual symptoms and persistent ankle instability equally well, but patients treated with early mobilization had significantly less pain at three weeks and were more likely to be back at work after one week. Taken together, at least 80-90% of patients with lateral ankle ligament ruptures will regain satisfactory functional stability after non-surgical treatment. This is, however, not uncontroversial and a recent metaanalysis concluded that surgical treatment leads to superior results in the short- and mid-term follow-up, in terms of giving-way and residual pain. Also, a large randomised prospective trial of surgical and functional treatment of lateral ankle ligament ruptures with 6-11 years of follow-up revealed that operative treatment leads to less residual pain and giving-way than functional treatment.

Functional treatment includes a short period of relative immobilization using an ankle tape, elastic bandage or ankle brace. Absolute immobilization using a plaster cast does not appear to be advantageous. Training of the range of motion, peroneal muscle strength, and coordination is started as soon as pain and swelling have subsided. Weight bearing should be encouraged as soon as possible. The aim of this program is to minimize recovery time, and allow for an earlier return to demanding sports activities and heavy labour. The functional treatment does not increase the risk of residual laxity and complications are less frequent than with surgical repair followed by cast immobilization. It should also be born in mind that secondary reconstructive procedures usually produce satisfactory results, though not being postponed too long (i.e. within 6 months). Also, the cost and the length of sick-leave have been shown to be lower after functional treatment. This factor is, of course, of great importance, especially when resources are limited.

Still, an unsolved problem is how the approximately 30-40% of patients who will develop chronic functional instability in spite of adequate primary treatment and may need surgical
reconstruction at a later stage, can be identified. Neither the degree of ligament injury nor the degree of radiographic laxity as measured by stress radiographs are reliable predictors.\textsuperscript{54,55} Therefore, this question still remains unanswered.

**Ankle joint instability**

Functional instability is the most common residual disability after acute, lateral ligament ruptures and is a description of the subjective symptoms of the patient, e.g., repeated giving-way, in some cases combined with pain. Laxity, on the other hand refers to an objective measurement, e.g. standardized stress radiographs, or clinical measurement of anterior drawer sign.\textsuperscript{56}

Functional instability is a complex syndrome, in which mechanical, neurological, muscular and constitutional factors interact. The etiological factors are not exactly known and in several cases there is a combination of factors. Elongation of the ruptured ligaments, i.e. increased laxity, proprioceptive deficit, peroneal muscle weakness and subtalar instability are all documented etiological factors of functional instability, either alone or in combination. In some studies a correlation between functional instability and increased laxity using standardized stress radiographs, has been shown.\textsuperscript{56,57} Although these radiographic stress tests may be useful, the reliability of these test is rather low and there is no definite correlation between functional instability and increased laxity.

Correlation between functional instability and isometric peroneal muscle weakness has been shown, using a Cybex II Dynamometer. Correlation between functional instability and decreased postural control has also been shown using stabilometric measurements, indicating a proprioceptive deficit after ligament injury.\textsuperscript{14,21,58} In these studies, however, no correlation has been found between functional instability and increased laxity.

Freeman and co-workers introduced the term *functional instability* more than 30 years ago as a description of the patient’s subjective complaint of “giving-way.” These authors found that the majority of their patients developed functional instability following acute ligament ruptures.\textsuperscript{19} A proprioceptive deficit was the most important factor behind the development of functional instability. Increased laxity was less important. In another study it was shown that the passive position sense was impaired by an anesthetic block of the ankle joint.\textsuperscript{59} Active position sense was, however, preserved. Afferent input from the calf muscles, mainly the
peroneus muscles, appeared to be responsible for the dynamic ankle protection against sudden inversion. Normal afferent input from the calf muscles is probably a prerequisite for stable, single-leg stance. This explains why co-ordination exercises and strength training of the peroneal muscles can restore the functional stability of the injured ankle. Due to this reason the peroneal tendons should possibly be preserved when choosing a surgical procedure to restore mechanical stability.

The reaction time of the peroneal muscles, measured during sudden inversion using EMG, has been shown to be significantly longer in unstable ankles than in stable ones.\textsuperscript{58,59} This difference in the reaction time is due to the time that elapses between the start of the inversion of the ankle and the stimulation of the mechanoreceptors in the ligaments and the joint capsule. Delayed proprioceptive response to a sudden angular displacement of the ankle may be one of the most important causes of functional instability of the ankle joint.

It can be concluded that functional instability is caused by increased laxity, inhibition of proprioceptive function, peroneal muscle weakness or a combination of these factors. The cause of functional instability has to be analysed individually.

**Chronic anterolateral ankle instability**

Chronic anterolateral ankle instability develops in approximately 30-40% of patients after acute ligament rupture.\textsuperscript{12,17,22} Ligament laxity does not always require surgical reconstruction. The indication for surgical intervention is recurrent giving-way in spite of proprioceptive training. Non-surgical treatment is always recommended before surgical treatment should be considered. Surgical reconstruction is probably more often needed in athletes with high demands of ankle function.\textsuperscript{9,13,22,60}

**Diagnosis of chronic anterolateral ankle instability**

Clinical tests for acute and chronic ankle instability can be divided into the talar tilt test and anterior drawer test. The talar tilt test is clinically impracticable and most often unreliable.\textsuperscript{12,15,16} The anterior talo-fibular ligament is the most important stabilisator of the ankle joint. It is the first ligament to rupture during an inversion trauma. Therefore, the anterior drawer test is the most important test for detection of acute and chronic ankle instability.\textsuperscript{12,16} Increased anterior translation of the talus in the talo-crural joint can occur when the anterior talo-fibular ligament is ruptured or elongated. There are several ways of performing an anterior drawer test.\textsuperscript{12} In most test situations the foot is moved anteriorly relative to the tibia. The ankle thereby is
placed in 10° to 20° of plantar flexion. It has been postulated that the anterior drawer test does not produce a straight forward translation of the talus in relation to the tibia, but that it is rather a rotatory movement (comparable to the anterolateral rotatory instability of the knee in case of an anterior cruciate ligament rupture).\(^\text{12}\) This rotation is caused by the intact deltoid ligament which prevents the talus to move forward on the medial side. This, however, has never been proven, neither experimentally nor clinically.

Knowledge of the laxity of the ankle joint ligaments in both the sagittal and the frontal planes can give valuable pattern of information during the diagnostic assessment of chronic functional instability. Radiographic measurements of ankle joint stability are often used before deciding upon the operative treatment of chronic anterolateral ankle instability.\(^\text{55, 68}\) Contrast arthrography and tenography of the peroneal tendons can give very concise information on the extent of ligament and tendon injury after acute ruptures, but these diagnostic tools are hardly necessary and very little used today.\(^\text{69}\) Standardized stress radiographs can be used in both differential diagnostic evaluation and assessment of therapy. Their main drawback is the limited correlation between functional stability and increased laxity.

The two radiographic tests which are used are the lateral instability/laxity test (talar tilt) and the anterior instability/laxity test (anterio r talar translation). Increased laxity can be defined either as a single value of anterior talar translation > 10 mm or talar tilt > 9 degrees. Another way of defining increased laxity is a difference of anterior talar translation > 3 mm, i.e. the difference in anterior talar translation between the functionally unstable ankle and the contralateral ankle and/or talar tilt > 3 degrees in patients with unilateral instability.\(^\text{55, 68}\) A good correlation between functional and mechanical instability has been shown in some studies, but this correlation is highly variable, since several factors other than mechanical instability can be responsible for the development of functional instability. Several studies have questioned the reliability of stress radiographs, especially the measurements of talar tilt, and it must be born in mind that radiographs alone can never be used to establish the indication of surgery.\(^\text{54, 55, 57}\)

Ultrasonography (US), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) have been used to delineate injuries of the ankle ligaments. CT and MRI can provide useful information in patients with chronic pain after ligament injury to the ankle, especially
when the cause seems to be intra-articular. US can be useful as a screening modality, especially when there is a discrepancy between clinical and radiological examinations after trauma. US is cheap and non-invasive.\textsuperscript{38,39} However, like CT and MRI, US is unable to demonstrate ligament laxity. Both these modalities are probably rather little used in patients with chronic anterolateral ankle instability and pain after ligamentous injury, partly due to the increased use of ankle arthroscopy.

**Treatment of chronic anterolateral ankle instability**

Less than 10% of all subjects who have sustained acute ligament injuries will need stabilizing surgery at a later stage.\textsuperscript{60} Before deciding upon surgical treatment in a patient with chronic ligament insufficiency, a supervised rehabilitation program based on peroneal muscle strengthening and co-ordination training should always be carried through. More than half of these patients will regain satisfactory functional stability after 12 weeks on such a program.\textsuperscript{45-49} The goals of the program are to strengthen the peroneal muscles, to regain normal proprioceptive function, and to re-establish normal protective reflexes. Patients with high-grade mechanical laxity have less favourable prospects in regaining satisfactory function by physiotherapy. In these patients surgical treatment should be considered at an earlier stage.

More than 60 different surgical procedures to stabilize the unstable ankle have been described in literature. These procedures can be divided into two main groups:

- A. non-anatomical reconstruction and
- B. anatomical reconstruction

Ad. A. Non-anatomical reconstructions are the most widely procedures used in the past. Especially tenodesis is a well known principle of surgical reconstruction. The three classic tenodeses – Evans, Watson-Jones and Chrisman-Snook – are all well documented, and the short- and long-term results are well reported. The Evans tenodesis is technically the least demanding of these tenodeses. However, the Evans tenodesis neither reconstructs the anterior talo-fibular ligament nor the calcaneo-fibular ligament biomechanically, as the tenodesis is positioned in a plane between these two ligaments. Several authors have reported good short-term results after this reconstruction and its modifications, but the long-term results have varied. Many patients with satisfactory early results have deteriorated after a few years, resulting in unsatisfactory function in the long run. In one study it was shown that less than 50% of subjects had satisfactory results after a mean follow-up period of 14 years.\textsuperscript{73}
Watson-Jones tenodesis reconstructs the anterior talofibular ligament, but not the calcaneofibular ligament. Several good short-term results have been reported, but long-term follow-up studies have shown disappointing functional results in approximately two-thirds of the patients. Late deterioration is common, with increased laxity and reduction of ankle function, as well as pain. The Chrisman-Snook tenodesis restores both the anterior talo-fibular and the calcaneo-fibular ligament, and is probably the most widely used non-anatomical reconstruction today (Figure 3).

Figure 3: The Chrisman-Snook tenodesis
The peroneus brevis tendon is split longitudinally, and half of the tendon is used to reconstruct both ligaments. Satisfactory results have been reported in 94% of patients in one study.\(^7\) Stress provocation has also shown less residual laxity after the Chrisman-Snook reconstruction than after the Evans reconstruction. This procedure is technically more demanding than the other tenodeses.

One of the major drawbacks is that all non-anatomical reconstructions sacrifice normal, and in most cases, well-functioning anatomical structures around the ankle joint, either the peroneus brevis or peroneus longus tendons. This results in altered kinematics, often limitation of joint motion and gradual deterioration of the reconstructed ligament function. The consequence could be the development of degenerative changes of the ankle in the long run. All of these procedures also restrict the subtalar motion. Biomechanical analysis of non-anatomical reconstructions have shown that ligamentous isometricity is lacking and that normal ankle biomechanics are not restored.\(^72\)

Complications after using a non-anatomical reconstruction procedure have been reported. The majority of the complications are related to the long skin incision needed for harvesting the peroneus brevis tendon. Problems with delayed wound healing and sural nerve injuries have also been described.\(^78,79\)

Ad. B. The second main principle of stabilization of the unstable ankle is the anatomical reconstruction. The basic principle of anatomical reconstruction is to restore the normal anatomical ligamentous proportions which should lead to the original biomechanical situation of the lateral ligament complex of the ankle joint. For the anterior talo-fibular ligament anatomical reconstruction this is relatively simple. The insertion at the tip of the fibula and the talus is uniform. Most anatomical textbooks describe the existence of a single anterior talo-fibular ligament. In a certain percentage (approximately 10-30%), anatomically as well as functionally, an upper and a lower part of the ligament may be distinguished.\(^12\) The insertion of the calcaneo-fibular at the tip of the fibula is also uniform. It arises from the anterior part of the fibula. It runs obliquely downwards and backwards to be attached to the lateral surface of the calcaneus. This insertion point is less unambiguous. In the plantigrade foot there is interindividual direction of the calcaneo-fibular ligament, which lies between 10° to 80° posteriorly. There is also a considerable interindividual variety in the length of the calcaneo-fibular ligament.\(^4,12\) After a rupture of this ligament it is, therefore, difficult to identify its original insertion at the calcaneus. It is, therefore doubtful whether anatomical reconstruction
of the calcaneo-fibular ligament is at all possible. An anatomical reconstruction is a reconstruction in which a ligament is restored to its original insertions.

Anatomical reconstructions can be classified into four categories:

1. anatomical reconstruction using the original ligament remnants;
2. anatomical reconstruction using the original ligament ends with reinforcement of local tissues like periostium, inferior extensor retinaculum etc.;
3. anatomical reconstruction using an autograft;
4. anatomical reconstruction using an allograft.

Ad 1. Broström who described this procedure in detail, found that direct suture (repair) of the ruptured and elongated ligaments was possible, even several years after the primary injury. The combination of shortening, imbrication and reinsertion to the bony attachment of the injured ligaments has been successful. Satisfactory functional results after anatomical reconstruction of the lateral ankle ligaments have been described in several studies. The surgical technique is simple and easily performed. The damaged and/or elongated remnants of the anterior talo-fibular ligament and calcaneo-fibular ligament are divided, shortened 3-5 millimeters, imbricated and reinserted into bone (Figure 4). Satisfactory functional results have been reported in approximately 90% of patients, with radiographic evidence of less residual laxity. The results are, however, less satisfactory in patients with generalized hypermobility of the joints, very long standing ligamentous insufficiency (over 10 years) and in patients who have undergone previous ankle joint ligament surgery.

Anatomical reconstruction using the original ligament ends has been found to be technically simple giving rise to few complications, producing satisfactory functional results in both the short- and the long-run. However, as with tenodeses, no long-term results in athletes with very high demands on ankle stability have been found.
Figure 4: Shortening, imbrication and reinsertion of the anterior talo-fibular ligament and calcaneo-fibular ligament
Ad 2. In some cases the original ligament ends are too weak or too damaged in order to perform a sufficient reconstruction. In these cases local structures can be used for reinforcement. These modifications include using a periosteal flap from the lateral aspect of the fibula and the inferior extensor retinaculum and reinforcement of the calcaneo-fibular ligament repair with the lateral talo-calcaneal ligament. Also, tensioning of the lateral ankle ligaments and capsular tissue has been described. Experimental studies report that the use of these structures do not disturb normal joint kinematics.

Ad 3. Another principle of anatomical reconstruction is reconstruction using an autograft. In 1968, Weber described a procedure in which the anterior talo-fibular ligament is reconstructed using the plantaris tendon. The plantaris tendon can be detached with a stripper. Holes are drilled on the original insertions of the anterior talo-fibular ligament at the fibula and the talus. The graft is then pulled through these holes in a figure-of-eight loop. It thereby somewhat mimics the situation in patients with an anterior talo-fibular ligament which is built up out of two separate bundles. Segesser described a modification of the Weber procedure by which both the anterior talo-fibular and calcaneo-fibular ligament are reconstructed. Other examples of autografts for anatomical reconstruction are the Achilles tendon, as in the Solheim procedure, and the use free fascia lata described by Elmslie already in 1934. These procedures, in which fascia lata or the achilles tendon is used to restore the damaged ligaments, are very little used today.

Ad 4. The use of fresh frozen allografts in the reconstruction of the lateral ankle ligaments has also been reported to give satisfactory results in one study. Neither immunological rejections nor complaints of late instability were reported. As no normal tissues are sacrificed, this procedure can be considered as an alternative to anatomical reconstructions if the quality of the ligamentous tissue is poor.

Arthroscopic ligament stabilization has been reported to be an alternative to open reconstructions. The anterior talo-fibular ligament is shortened and reinserted by the use of a percutaneous staple. Only a few reports on this technique are found in the literature and it is probably very little used today. There might be a specific indication for this technique in children in order to avoid damage to the growth plate of the fibula. A drawback of the arthroscopic stabilization is that this technique makes it possible to reconstruct only the
anterior talo-fibular ligament. The arthroscopic technique for lateral ankle ligament stabilization is demanding, and the procedure should be performed only by surgeons with extensive experience in ankle arthroscopy.

Prevention

Two different methods for preventing ligament injuries of the ankle are found. These are coordination training and the application of an external ankle support. Proprioceptive training improves both postural control and functional stability. Balance board training can reduce the incidence of ankle ligament injuries among athletes with a history of previous injury, as well as in those with previously uninjured ankles. External ankle support theoretically reduces the ligamentous laxity. Both ankle taping and semirigid braces are frequently used to prevent ankle ligament injuries, both during the rehabilitation phase after injury and prophylactically to prevent the previously injured ankle joint from further injury. The mechanism behind the function of ankle tape is not fully understood.

There are three possible theories:

a. reduction of the joint laxity,

b. limitation of the extremes of ankle motion, and

c. shortening of the reaction time of the peroneal muscles by affecting the proprioceptive function of the ligaments and joint capsule around the ankle joint and the lower-leg muscles.

Laxity both in the sagittal plane (ATT) and the frontal plane (TT) has been shown in several studies to be reduced by the use of ankle tape. The frontal plane (TT) laxity is more effectively controlled than sagittal laxity. A significant reduction of TT has been shown after ankle taping. The highest degree of protection is found in ankles with the highest degree of laxity. In contrast to this, some authors have found insignificant reduction of laxity using ankle tape, analysed as ATT and TT measured with standardized stress radiographs. The reduction of laxity is thus debated.

Ankle tape does significantly affect the pattern of ankle motion. Tape effectively limits the extreme ranges of ankle motion. In spite of the fact that tape becomes looser after exercise, the partial reduction of laxity gained by limiting the extremes of ankle motion is probably a major factor behind the function of ankle tape.
Shortening of the reaction time of the peroneus brevis and longus muscles by enhancing the proprioceptive function of the ankle ligaments and joint capsule might explain the mechanism behind the function of ankle tape. Ankle tape has in some studies been found to have a stimulating effect on the peroneus brevis muscle in unstable ankles, measured using EMG and stop-action films. A significantly slower reaction time of both the peroneus longus and peroneus brevis muscles has been found in unstable ankles than in stable ones using a trap-door mechanism and EMG measurements of the reaction time. These changes were, however, only found in ankle with increased laxity as a sign of residual ligament injury. The reaction time of the peroneal muscles in stable ankles was not shortened using ankle tape.

Subtalar instability

Subtalar instability lacks a well-established clinical and scientific definition. In spite of this, ligament insufficiency of the subtalar joints can be regarded as one of the factors behind the development of chronic functional instability. The ligaments of the subtalar joint consist of three layers within the sinus and canalis tarsi and the lateral aspect of the subtalar joint. The incidence of subtalar instability is still unknown. The majority of these injuries occur in combination with injuries of the lateral ankle ligaments. Subtalar instability has an estimated prevalence of 10% in patients with chronic lateral ankle instability, but is not well scientifically proven. Using subtalar arthrography, injuries to the subtalar joints have been found in a high proportion of patients, who have sustained acute lateral ligament injuries. The clinical diagnosis of subtalar instability is difficult and unreliable. The diagnosis can be supported by using subtalar arthrography, subtalar stress radiographs or stress tomography. The value of MRI, CT and Ultrasonography in the diagnostic evaluation of subtalar instability is still unknown and there are only a few studies in the literature concerning both diagnostic assessment and therapeutic methods. Analysis of the degree of disability related to subtalar instability is still lacking.

In patients with chronic instability of subtalar joints not responding to supervised rehabilitation program, anatomical reconstruction is recommended. In order to bridge the subtalar joint, the superficial layer of the inferior extensor retinaculum can be utilized. The short-term results of these procedures are promising, but further studies are needed to evaluate the long-lasting function by objective measurements. Another option is a tenodesis procedure which bridges the subtalar joint. These procedures, however, are non-anatomical
and lead to limitation of the subtalar joint motion. No comparative studies are found, which implies that the optimal treatment is still unknown.

**Ankle arthroscopy**

Ankle arthroscopy has rapidly evolved as a valuable tool in the diagnosis and treatment of various intra-articular ankle disorders. Direct visualization of intraarticular pathology without arthrotomy is possible, thus reducing the risk of surgical complications that is associated with open surgery. Indications for ankle arthroscopy are osteochondral fractures, chondral lesions, soft-tissue impingement, bony impingement, posttraumatic osteoarthritis and loose bodies. Chronic pain at the anterior aspect of the ankle joint is rather frequent in athletes, e.g., soccer players and is often referred to as “footballer’s ankle”.\(^{32,33}\) This pain syndrome is sometimes present in combination with chronic instability of the ankle. The patient complains of anterior ankle pain during movement, especially dorsiflexion (hyperextension), with a sense of catching, locking and a feeling of functional instability. Several pathological changes have been reported in patients with anterior ankle pain such as intraarticular adhesions, “meniscoid”-type lesions, and impingement osteophytes. The meniscoid lesion and the anterior tibial and talar spurs are probably the most frequent of these changes. Several recent reports have shown satisfactory results after arthroscopic resection of soft tissue or bony impingement for the anterior ankle pain syndrome.\(^{34,35}\)

Patients with recurrent ankle pain, chondral and osteochondral lesions, anterior tibial spurs and soft-tissue pathology such as synovitis and meniscoid lesion are those who are most often in need of arthroscopic intervention.\(^{32}\)

**Outline of this thesis**

The anterior talo-fibular ligament is the most vulnerable of the lateral ankle ligaments and is injured in two-thirds of all ankle ligament injuries, followed by a combined rupture of the anterior talo-fibular and calcaneo-fibular ligament. After a supination trauma it is important to distinguish a simple distorsion from an acute ligament lesion since adequate treatment is associated with a better prognosis.\(^{10}\)

Delayed physical examination provides a diagnostic modality with a high sensitivity and specificity and is therefore the diagnostic strategy of choice.\(^{15,16}\) The anterior drawer test is the most important test for detection of acute and chronic ankle instability. It has been postulated
that the anterior drawer test does not give a straight forward translation of the talus in relation to the tibia, but that it is instead a rotatory movement (comparable to the anterolateral rotatory instability of the knee in case of an anterior cruciate ligament rupture).\textsuperscript{12} This rotation is caused by the intact deltoid ligament which prevents the talus to move forward on the medial side. The hypothesis of this study is that in case of chronic ankle instability, the anterior displacement of the talus relative to the tibia is a rotational displacement whereby the deltoid ligament represents the axis of rotation. The experimental study presented in this thesis (chapter 2) is performed to investigate the type of instability which occurs after an injury to the anterior talo-fibular ligament. If the anterior drawer, indeed, is a rotational test, this has implications for the method of testing.

Chronic anterolateral ankle instability develops in approximately 30-40\% of patients after an acute ligament rupture.\textsuperscript{12,17,22} If conservative treatment fails, surgical stabilization of the ankle joint may be indicated. Several different surgical procedures have been described to correct chronic anterolateral ankle instability. These surgical procedures can be classified as either non-anatomical, using some of the tendons around the ankle joint (e.g. Watson-Jones, Evans and Chrisman-Snook tenodeses), or anatomical reconstruction, with either direct suture of the torn ligaments, or imbrication and reinsertion to bone, and in some instances reinforcement with local tissue, such as the inferior extensor retinaculum (Gould’s modification of the Broström procedure) or a local periosteal flap. In Chapter 3 a literature overview is given of the different methods of anatomical reconstruction, their advantages and disadvantages and their results.

There are only a few studies the in literature comparing anatomical and non-anatomical reconstruction or tenodesis. Hennrikus et al. and Wallenböck et al. reported superior functional results for anatomical reconstructions.\textsuperscript{89,90} Some experimental studies report that tenodeses have a negative effect on the kinematic coupling of the ankle joint and thus do not prevent instability. In addition, they restrict range of ankle motion.\textsuperscript{91-94} We set up a number of studies to compare the outcome of anatomical reconstruction and tenodesis. Chapter 4 describes the results of anatomical reconstruction compared with those after tenodesis in a large series of patients with a 2–10-year follow-up. The hypothesis is that the results of tenodeses are inferior to anatomical reconstructions in terms of mechanical stability and preservation of normal ankle joint function.
In chapter 5 the long-term (i.e. 10-15 years) subjective and objective outcomes of anatomical reconstruction and tenodesis are assessed and compared. Long-standing instability is associated with the development of degenerative changes in the ankle joint. Several studies have shown that after a reconstructive procedure, the severity of the degenerative changes appears to be proportional to the degree of instability. In this context, our hypothesis was to find a larger number of patients with degenerative changes in the tenodesis group than in the anatomical reconstruction group, because of inferior mechanical stability provided by tenodesis. We analysed the location of the development of degenerative changes in the ankle joint.

Few studies in the literature indicate that the results after tenodesis deteriorate in the long-term. The aim of the study described in chapter 6 was to determine whether the results of tenodesis deteriorate further in the long-term (i.e. 15 to 30 years) and whether the results of anatomical reconstruction showed the same tendency to deteriorate as tenodeses have shown in previous studies. Specific emphasis was put on the need for reoperations and the eventual subjective result after the index operation.

In chapter 7, the results after anatomical reconstruction of the lateral ankle ligaments in three follow-up groups are described: 2-10, 10-20 and 20-30 years after the index operation. The hypothesis was that an anatomical reconstruction of the lateral ankle ligaments cannot stop the process of the development of degenerative changes in the ankle joint, since cartilage damage is the result of the initial injury.

Most studies that report on the outcome of anatomical reconstruction or tenodesis are based on a mixed population. For the outcome of the treatment, the patient activity level is, however, of importance. The functional demands imposed on the ankle joint of athletic individuals are substantially higher when compared with non-athletic patients. The aim of the study presented in chapter 8 is to compare the outcome of anatomical reconstruction and tenodesis in an athletic population. The principal outcome measures were; maintenance of activity level, mechanical laxity, degenerative changes in the ankle joint and functional stability. The hypothesis was that, in an athletic population, tenodesis produces inferior results in terms of function and the restoration of laxity in this specific population of high-level athletes.
References

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