On the surgical treatment of chronic anterolateral ankle instability

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Chapter IX

DISCUSSION & SUMMARY
DISCUSSION

Chronic anterolateral ankle instability develops in approximately 30-40% of patients after an acute lateral ligament rupture. It is defined as a situation in which a patient experiences recurrent episodes of giving-way with a duration of more than six months. It can be caused by either functional or mechanical ligament instability or a combination of both. Functional instability is a clinical syndrome which is characterised by a patient who complains that his or her foot tends to give way, but in whom physical examination and radiography reveal a stable ankle joint. Some pathological process other than mechanical instability causing functional instability could be present, such as:

- defect of proprioception
- peroneal muscle weakness
- tibiofibular sprain
- instability of the subtalar joint

Mechanical instability or ligament laxity is present when an abnormal displacement of the talus in relation to the ankle mortise can occur due to laxity of one or more of the lateral ankle ligaments. This ligament laxity does not always require surgical reconstruction. There is no absolute indication for surgical intervention, but relative indication for surgical treatment is recurrent giving-way in spite of well performed proprioceptive training. Non-surgical treatment is always recommended before operative management is considered.

In patients with mechanical instability there is an abnormal displacement of the talus relative to the ankle mortise which can be elicited by application of anterior drawer stress onto the talus. This anterior displacement of the talus relative to the tibia is considered to be straight forward. Our hypothesis was, however, that in case of chronic anterolateral 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. As Siegler et al. demonstrated, the ankle has coupled three-dimensional flexibility characteristics. In an experimental setup we determined the amount of rotation and the centre of rotation in case of an anterior drawer test. Our findings demonstrated that during application of anterior drawer stress and after sectioning the anterior talo-fibular ligament indeed an internal rotation of the talus occurs. After concomitant sectioning of the deltoid ligament, the rotational component of dissappeared. We conclude that the intact deltoid ligament is responsible for internal rotation
of the talus during application of an anterior drawer stress. The anterior talo-fibular ligament is regarded to be the most important stabilizer of the lateral ligament complex of the ankle joint. Investigation of its integrity after trauma or in a chronic condition, therefore, has priority. The findings of our study have implications for the method of testing the integrity of the anterior talo-fibular ligament. When the foot is pulled straight forward in relation to the lower leg, the intact deltoid ligament will resist an anterior translation of the talus out of the ankle mortise. This might result in a false negative anterior drawer test. Stress radiographs are reported to have a high percentage of false negative outcomes. This is especially true for the anterior drawer tests. The stress apparatus like the TELOS device do not take into account this rotational movement. In these test devices the foot is forced into a straight forward direction. This can easily explain the high percentage of false negative results. A testing technique which does not allow for internal rotation to occur, will reduce the predictive value of the anterior drawer test in detecting a lesion of the anterior talo-fibular ligament. Therefore, a technique in which the foot is pulled anteriorly and medially, using the deltoid ligament as a center of rotation should be applied. Only when performed in this manner, the anterior subluxation of the talus out of the ankle mortise can be fully appreciated. This is valid for clinical as well as for mechanical test situations.

More than 60 surgical procedures for the correction of chronic anterolateral instability of the ankle joint have been described. Basically, these procedures can be divided into two main groups: anatomical reconstruction and non-anatomical reconstruction. Most of the non-anatomical reconstructions are tenodeses using some of the tendons around the ankle, e.g., the Evans, Chrisman-Snook and Watson-Jones procedures or modifications of these. These procedures usually include a transfer of the peroneus longus or brevis tendon in such a way that the ankle joint and subtalar joint are bridged. Many studies report good short-term results. There have been few reports of long-term results, but Snook et al. reported satisfactory long-term results after using his Chrisman-Snook procedure. Other long-term studies, however, have shown that tenodeses do not prevent mechanical instability and may lead to subsequent degenerative changes, result in a restricted range of ankle motion and decrease the eversion strength.

Anatomical reconstruction is defined as the restoration of normal anatomic ligamentous proportions leading to the original biomechanical situation of the lateral ligament complex of the ankle joint. Anatomical reconstruction of the anterior talo-fibular ligament is technically
possible since this ligament with its insertion points does not show much interindividual variety. The insertion sites at the anterior tip of the fibula and the talar neck are all well defined. However, the anterior talo-fibular ligament can be divided into two parallel oriented separate bundles in approximately 10-30% of cases. The calcaneo-fibular ligament originates from the anterior tip of the fibula. The original insertion of the calcaneo-fibular ligament at the calcaneus is much more difficult to identify and shows significantly more interindividual variety. Furthermore, 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. It is therefore questionable if an anatomical reconstruction of the calcaneo-fibular ligament can be obtained when the original anatomy has been destroyed after a traumatic rupture. This remains an important issue since several authors have found that results improved when both ligaments are routinely reconstructed. In these procedures the remnants of the calcaneo-fibular ligament are taken of the fibula and after shortening, sutured back to the anterior tip of the fibula (its anatomical position). Therefore, it remains unknown if the insertion at the calcaneus and thus the direction of the shortened ligament is correct. This depends on the position in which this ligament healed after its initial rupture.

In recent literature, anatomical reconstruction has acquired increasing popularity. These procedures make use of the ruptured or elongated remnants of the ligaments to restore normal ligament stability. Karlsson et al. noted that the anterior talo-fibular ligament and calcaneo-fibular ligament were usually elongated and scarred rather than disrupted and recommended shortening the ligaments and reattaching them to the fibula at their anatomical origins. These authors reported a success rate after two to 12 years after the operation of 88%. A problem arises in anatomical reconstruction when the local ligament tissue is severely damaged. In these cases, reinforcement with local tissues, like periosteal flaps or the inferior extensor retinaculum, may be necessary. Gould et al. described a modification of the Broström technique using repair of the lateral talo-calcaneal ligament and reefing of the lateral ankle retinaculum to the fibula in addition to the repair of the anterior talo-fibular ligament and calcaneo-fibular ligament. The problem of attenuated ligamentous tissue could thus be overcome. A similar modification has been described by Liu et al. with 92% satisfactory results at a mean of five years after the operation. Another option is anatomical reconstruction using an autograft e.g. the plantaris tendon, fascia lata or achilles tendon. Satisfactory results have been reported after reconstruction of
the anterior talo-fibular and calcaneo-fibular ligament with a plantaris tendon plasty.\textsuperscript{73} The use of allografts for reconstruction of the lateral ankle ligaments has been found to produce satisfactory results in only one study.\textsuperscript{75} More studies are needed to evaluate the value of the use of allografts for anatomical reconstruction of the lateral ankle ligaments.

From the literature it can be concluded that anatomical reconstruction leads to a high percentage of good and excellent results at short-, mid- and long-term follow-up. Biomechanical studies suggest that an anatomical reconstruction provides adequate stability and does not cause a limitation in the range of motion.\textsuperscript{47,68,69}

There are few studies in literature that compare tenodesis with anatomical reconstruction. These studies report superior functional results for anatomical reconstructions. Unfortunately they include only short-term follow-up. The long-term effects of both anatomical reconstruction and tenodesis are therefore relatively unknown.

The clinical studies presented in this thesis are performed to compare the results of anatomical reconstruction with those of tenodesis according to a standard protocol. Several aspects were studied including: mechanical stability evaluated with the anterior drawer test at physical examination and standardized stress radiographs; ankle joint function with standardized assessment of the range of ankle joint motion; the detection of degenerative changes in the ankle joint by using standardized radiographs of both ankles; and evaluation of patient satisfaction including assessment of functional stability using standardized scoring systems.

**Mechanical stability**

The ankle joint is the most congruent joint of the human body.\textsuperscript{76} Its bony configuration provides a large intrinsic stability during standing and walking. Extrinsic stability is provided by the muscles, capsular tissues surrounding the joint and mainly by the lateral ankle ligaments. When the lateral ligaments are ruptured or insufficient, as in chronic anterolateral ankle instability, the ankle joint loses its extrinsic stability leading to recurrent giving-way and persisting mechanical instability. Reconstructive procedures, like anatomical reconstruction or tenodesis are aimed at restoration of this mechanical instability. Both anatomical reconstruction and tenodesis have been the subject of experimental studies. Some experimental studies report that tenodeses have a negative effect on the kinematic coupling of the ankle joint and thus do not prevent mechanical instability. Most of these studies report that a tenodesis procedure prevents neither anterior talar translation nor talar tilt.\textsuperscript{46-50} Our data are in accordance with these experimental findings. Stress radiographic
examination detected inferior mechanical stability, i.e. significantly higher number of positive stress radiographs and larger mean values for talar tilt and anterior talar translation, for patients who had undergone a tenodesis procedure. The inferior mechanical stability provided by the tenodesis becomes more obvious in the long term, as we found more patients 10 to 15 years after the operation to have a positive anterior drawer test at physical examination. Even 15 to 30 years after Evans tenodesis, we found, in comparison with anatomical reconstruction, higher mean values of anterior talar translation and talar tilt at stress radiographic examination. This is explained by the fact that the Evans tenodesis neither reconstructs the anterior talo-fibular ligament nor the calcaneo-fibular ligament, but is expected to act as a resultant of both. The question is if this really happens. In any case, this type of reconstruction does not prevent mechanical laxity sufficiently.

Ankle joint function

In the short-term, we found a large number of patients after tenodesis with a restricted range of dorsi- or plantarflexion. This can be explained by the non-anatomical position in which the transferred tendon replaces the anterior talo-fibular ligament. Also when the reconstruction is too tight, this can restrict dorsi- or plantarflexion and simultaneously may not prevent tilt and anterior translation of the talus. Although this phenomenon has also been found in several cadaver studies, the exact explanation for the simultaneous finding of restriction of the physiological range of ankle motion and increased mechanical laxity after a tenodesis reconstruction remains unclear. Not only the range of motion of the ankle joint can be limited, but of the subtalar joint as well. The calcaneo-fibular ligament has a bi-articular characteristic by crossing the ankle and subtalar joint. Non-anatomical reconstruction of this ligament can result in a restricted range of motion (i.e. inversion) of the subtalar joint. From several experimental studies it is known that the Evans and Chrisman-Snook tenodeses, which both reconstruct the calcaneo-fibular ligament, restrict subtalar motion. A restricted range of subtalar motion presents a problem for stabilizing the ankle/foot complex when walking on uneven ground. This is not only disturbing for performing sport activities but is also disabling in performing daily activities. When left uncorrected, this will lead to subtalar degeneration. What started as a problem of the ankle joint, now is a problem of both the ankle and subtalar joint. Pain from subtalar joint degeneration can only be solved by an arthrodesis of the subtalar joint. This will subsequently place more load onto the ankle joint with subsequent development of more degenerative changes in this joint. Furthermore, tenodeses are often performed with the foot placed in mild eversion. In this way
the lateral side of the ankle joint can easily become overtightened, leading to a restricted range of subtalar motion.\textsuperscript{33,46-48,50}

We found on the short-term a significant larger number of patients with limitation in range of ankle motion after tenodesis. This significant difference in limitation in range of ankle motion, however, resolved on the longer term. A possible explanation is that due to the insufficient mechanical stability provided by the tenodesis recurrent sprains and giving-way will occur. These events will stretch the tenodesis out and subsequently the restriction in the range of ankle motion subsequently disappears. This can explain why 10 to 15 years after the index operation we did not find more patients with a limited range of ankle motion after tenodesis than after anatomical reconstruction, while mechanical and functional stability had severely deteriorated.

Limitation of the range of ankle motion is not only caused by the non-anatomical position of the transferred tendon but, especially in the long-term, it can also be caused by anterior bony spurs. Persistent mechanical instability will lead to recurrent sprains and microtrauma. As a result, osteophytes form and additional soft tissue impediments may be present. Tol et al. concluded that the cause of pain is not the osteophyte but the occurrence of a soft tissue impingement between the osteophytes.\textsuperscript{51} During dorsiflexion hypertrophic synovial tissue impinges between the osteophytes leading to a limited range of ankle motion.

Furthermore, the tenodesis procedure requires the sacrifice of a part or all of the peroneus brevis tendon, involves a long scar and extensive soft-tissue dissection, prolonged immobilization and weakening of the peroneal tendons. For athletes or professionals (such as ballet dancers or soccer players) who require extensive ankle balance or kinesthetic sense, these procedures may be career-ending. In our study, almost 50% of the athletes had a reduced activity level at follow-up, 2-10 years after a tenodesis.

\textbf{Degenerative changes}

Instability has been associated with the development of degenerative changes as seen on standard radiographs.\textsuperscript{52,53} Anterior cruciate ligament reconstruction has gained popularity due to the fact that a reconstruction prevents the development of degenerative changes in the knee.\textsuperscript{71} Chronic instability of the knee due to anterior cruciate ligament insufficiency has been shown to lead to progressive degenerative changes in the joint.\textsuperscript{72} For the ankle joint the same negative influence of chronic instability can be expected. It has been demonstrated that, in supination trauma, cartilage damage occurs in 65% of patients in the medial aspect of the
ankle joint. In a supination trauma, the talus rotates out of the ankle mortise and, in this subluxated, supinated position, the weight causes axial compression through the medial malleolus and the medial talar facet. This impact force explains the initial cartilage damage on the anteromedial side of the ankle joint. Especially in case of recurrent instability, every episode will add damage to the joint cartilage. This will successively lead to the development of degenerative changes. This phenomenon has been found by Harrington, who performed arthroscopic surgeries on 12 of 36 patients with chronic ankle instability; in all 12 cases, degenerative changes were seen in the medial compartment of the ankle joint. Any ligamentous reconstruction for chronic anterolateral ankle instability is thought to protect the cartilage of the ankle joint from further damage from micro-movements and recurrent sprains. However, Rosenbaum et al. reported a high incidence of anterior tibial and talar osteophyte formation and osteoarthrosis after Evans tenodesis. Since a tenodesis results in greater laxity when compared with anatomical reconstructions, the risk for development of degenerative changes must be larger after tenodesis than after anatomic reconstruction. Our results confirm increased mechanical laxity for the tenodesis group, as well as a larger number of patients with degenerative changes. After tenodesis a larger number of patients displayed medially located osteophytes compared with patients who had undergone an anatomical reconstruction. On the basis of these two observations, we concluded that there is a correlation between the increase in mechanical laxity and the development of medially located degenerative changes in the ankle joint. Anatomical reconstruction resulted in a higher percentage of satisfactory results at long-term follow-up. At 15 to 30 years of follow-up 87% of these patients still has a mechanically stable ankle. Nevertheless 59% had developed degenerative changes. We conclude that the cartilage damage must have been present already at the time of reconstruction. The reconstruction itself does, therefore, not prevent the further development of degenerative changes in the ankle joint.

The initial inversion trauma is the onset for the development of degenerative changes in the ankle joint on the long run. Our results show that subsequent deterioration of the functional result in the long-term, cannot be prevented even by an anatomical reconstruction.

**Patient satisfaction**

Most short-term studies report satisfactory subjective results after either anatomical reconstruction or tenodesis, the results of long-term studies are, however, less unequivocal. Sugimoto et al. reported on the long-term outcome of a Watson-Jones procedure in 36 patients. According to the rating system of Good et al. excellent and good results were found.
in 90% of patients 14 years after the operation. Van der Rijt and Evans, on the other hand, reported unsatisfactory results after a Watson-Jones tenodesis. In their series of nine patients, who were followed up for a mean of twenty-two years, the previously, favourable results were found to have deteriorated seven to ten years after the operation. Also Karlsson et al. observed that the results of tenodesis procedures had a tendency to deteriorate over time. In their series of 42 patients 50% had an excellent or good subjective result according to the rating system of Good et al., 14 years after the operation, while of 12 patients with a satisfactory early result, the outcome had deteriorated after three to six years. Several studies in the literature report on inferior functional results for tenodesis when compared with anatomical reconstruction. A prospective study by Hennrikus et al. shows that the modified Broström procedure results in significantly higher scores according to the scale of Good et al. than the Chrisman-Snook tenodesis. In 1993, Wallenböck et al. compared the results of the Evans and Watson-Jones tenodesis with those of periosteal plasty in 45 patients. They found superior functional results for anatomical reconstruction. We performed a systematic review in Medline and Embase, but we did not find any comparative studies evaluating the long-term (i.e. more than 10 years) results of both anatomical reconstructions and tenodeses. A recent comparative study of Mabit et al. revealed good or excellent results according to the rating system of Good et al. in 54% of patients who underwent a tenodesis and in 91% of patients who underwent an anatomical reconstruction. However, this study included only a short-term follow-up (on average 3 to 5.5 years after the operation).

The unsatisfactory subjective results after tenodesis can be explained; in the short-term, the non-anatomical tenodesis can easily lead to a restricted range of ankle motion. Especially athletes need a full range of ankle motion in order to perform their sports activities. Reoperations may be necessary to release the tenodesis or even a new reconstructive procedure has to be performed. The results of our study in an athletic population showed that after tenodesis 48% of patients had to reduce their activity level. This was caused by either a restricted range of ankle motion or reduced push-off power due to sacrifice of the peroneal tendon(s).

The inferior mechanical stability provided by the tenodesis can become symptomatic. The patient complains about recurrent sprains and giving-way. In our study this increased from 18% of patients 2 to 10 years after tenodesis, to 68% of patients 10 to 15 years after tenodesis and 72% 15 to 30 years after tenodesis. Recurrent sprains stretch the tendon out and mechanical instability becomes worse with the occurrence of each sprain.

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Long-standing instability leads to cartilage damage in the ankle joint and the formation of talar and tibial osteophytes. When these osteophytes lead to impingement of the soft tissues, symptoms of an anterior impingement syndrome occur. The patient has chronic ankle pain with pain on palpation, as well as limited and painful dorsiflexion. Arthroscopic removal of the osteophytes is often necessary in these patients.17,51,52,58

Conclusion
We conclude that, unlike anatomical reconstruction, tenodesis does not restore the normal anatomy of the lateral ankle ligaments. These procedures result in a restricted range of ankle motion, a higher number of reoperations, impairment of athletic performance and unsatisfactory functional results. Furthermore, we conclude that tenodesis does not entirely prevent mechanical laxity, thereby leading to subsequent degenerative changes on the medial side of the ankle joint.

Due to the elongation or loosening of the tendon in the long-term, the restriction in the range of ankle motion will resolve and mechanical instability will be more persistent. This will lead to the development of more severe degenerative changes in the ankle joint. Subsequently, the risk of the development of osteophytic formation and the need for a reoperative procedure to remove these osteophytes increases over time.

Nowadays, anatomical reconstruction of the lateral ankle ligaments can be regarded as the surgical treatment of choice in patients with chronic anterolateral ankle instability. Even when the original ligament ends are absent or too weak in order to perform a sufficient reconstruction, alternative procedures such as reinforcement with local tissues or the augmentation of autografts have been developed to overcome this problem.

There are, however, some remaining issues concerning anatomical reconstruction. Since the insertion of the calcaneo-fibular ligament at the calcaneus shows a high interindividual variety, it is doubtful whether reconstruction of this ligament is truly anatomical. Several studies report that reconstruction of both the anterior talo-fibular ligament and calcaneo-fibular ligament improve the results. When we would be able to identify the original calcaneal insertion of the calcaneo-fibular ligament, we would theoretically be able to restore the original direction of this ligament and thus not disturb isometricity. More experimental and clinical studies are needed to solve this issue.

The role of the subtalar joint in the etiology of chronic anterolateral ankle instability remains unclear. Pathologic instability of the subtalar joint is not clearly defined and probably difficult to objectify. Most studies dealing with the subject of chronic anterolateral ankle instability
aim at outcome measures concerning the function and state of the ankle joint. A reconstructive procedure, especially when it includes reconstruction of the calcaneo-fibular ligament, will inevitably have its influence on the subtalar joint as well. This, however, remains somewhat neglected in literature and needs further clarification.

Another problem is that the development of degenerative changes is not prevented by anatomical reconstruction. Therefore, a short interval (i.e. < 6 months) between the onset of symptomatic instability and the reconstructive procedure as possible is recommended.

As any open surgical procedure anatomical reconstruction is correlated with the risk of infection, haematoma, nerve damage and postoperative dystrophy. The role of minimally invasive procedures like arthroscopic stapling repair and thermal capsular shrinkage in the treatment of chronic ankle instability have yet to be established.
SUMMARY
The aim of this thesis was to analyze the results of surgical treatment of chronic anterolateral ankle instability. This was carried out by means of clinical multi-centre studies. Furthermore, the movements of the talus in case of anterolateral ankle instability were analysed in an experimental study.

In chapter II, the experimental study, movements of the talus were followed in three planes after subsequent sectioning of the lateral ankle ligaments. The aim of this experimental study was to determine the amount and centre of rotation that occurs when performing an anterior drawer test on a stable and unstable ankle joint.

The anterior drawer test was evaluated in 15 fresh human ankle specimens by computed tomography. The specimens were held in a specially-designed testing apparatus in which an anterior translation force of 150 N could be applied in a controlled manner. Testing was done with intact ligaments and was repeated after sectioning of the anterior talo-fibular ligament and after sectioning of the deltoid ligament.

Both anterior translation and internal rotation of the talus relative to the tibia increased significantly after sectioning of the anterior talo-fibular ligament. After application of an anterior translation force to the intact ankle we found a mean (SEM) internal rotation of the talar body of \(2.03° (0.94)\) \((p=0.048)\). When the anterior talo-fibular ligament was sectioned, internal rotation of the talar body increased to a mean value (SEM) of \(14.2° (1.4)\) \((p<0.001)\). When the deltoid ligament was sectioned, internal rotation of the talar body decreased to a mean value (SEM) of \(0.40° (1.4)\) \((p<0.001)\). The centre of rotation was located at the deltoid ligament/medial malleolus in all separate experiments. Sectioning of the deltoid ligament caused the internal rotational component to disappear.

It was concluded 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. When performing an anterior drawer test this has to be taken into account, since the technique in which the foot is pulled straight forward will result in a high percentage of false negative results.

In chapter III, the different methods for anatomical reconstruction of the lateral ankle ligaments are discussed. Anatomical reconstruction for chronic anterolateral ankle instability is successful in approximately 85-95% of patients, both on the short- and long-term. When compared with the classic tenodesis procedures, anatomical reconstruction leads to superior functional results, mechanical laxity is more effectively restored and subsequently the risk for
development of degenerative changes in the ankle joint is reduced. Therefore, anatomical reconstruction of the lateral ankle ligaments is nowadays considered to be the surgical treatment of choice. In some patients direct suturing of the anterior talo-fibular and calcaneo-fibular ligament is possible. But, in contrast with Broström’s findings, many authors do not find well preserved torn ligaments which can be directly repaired. More frequently the original torn ligament ends are difficult to identify. In most patients with chronic ankle instability the ligaments are attenuated or elongated. For these cases, several modified anatomical reconstructive procedures based on Broström’s original concept have been developed. The ligaments can be shortened and reinserted and reinforcement with local tissue or structures, such as peristosteum or inferior extensor retinaculum. These procedures lead to similar or superior functional results when compared with the original Broström procedure. When the ligaments are absent, a plantaris tendon plastic may be indicated.

The role of procedures like arthroscopic stapling repair and thermal capsular shrinkage in the treatment of chronic ankle instability have yet to be established.

In chapter IV the clinical outcome of anatomical reconstruction or tenodesis in the treatment of chronic anterolateral ankle instability was assessed in a retrospective multicentre study. The anatomical reconstruction group consisted of 106 patients and the tenodesis group of 110 patients. Patients were evaluated at a mean follow-up of approximately 5.5 years.

The review protocol included patient characteristics, physical examination, two ankle scoring scales to evaluate the functional results, as well as standard AP and lateral radiographs to evaluate degenerative changes. Mechanical stability was evaluated using standardized stress radiographs.

A larger number of reoperations was performed in the tenodesis group (p=0.008). After tenodesis more patients had a restricted range of ankle motion compared with anatomical reconstruction (p=0.009). A larger number of patients in the tenodesis group had medially located osteophytes, as seen on standard radiographs (p=0.04). Using stress radiographic examination, the mean talar tilt (p=0.001) and mean anterior talar translation (p<0.001) were significantly increased in the tenodesis group as compared with the anatomical reconstruction group. There were no differences in the mean Karlsson score between the groups, but after anatomical reconstruction significantly more patients had an excellent result when the Good score was applied (p=0.011).

It was concluded that, unlike anatomical reconstructions, a tenodesis procedure does not restore the normal anatomy of the lateral ankle ligaments. This results in restricted range of
ankle motion, reduced long-term stability, an increased risk of medially located degenerative changes, a larger number of reoperations and less satisfactory overall results.

In chapter V, the long-term clinical outcome after anatomical reconstruction and tenodesis was assessed in a retrospective multicentre study. The anatomical reconstruction group consisted of 25 patients and the tenodesis group of 29 patients. For both groups, the mean follow-up period was 12.3 yrs. At physical examination, there were significantly more patients in the tenodesis group (n=18) with a positive anterior drawer sign as compared with the anatomical reconstruction group (n=7) (p=0.02). Medially located osteophytes in the ankle joint as seen on standard radiographs were seen more often in the tenodesis group (n=7) than in the anatomical reconstruction group (n=1) (p=0.03). The mean talar tilt, 4.7° in the anatomical reconstruction group vs 6.9° in the tenodesis group, (p=0.02) and anterior talar translation, 2.9 mm in the anatomical reconstruction group vs 4.3 mm in the tenodesis group, (p=0.04) were significantly higher in the tenodesis group at radiographic stress examination. According to the rating system developed by Good et al. (1975), significantly fewer patients in the tenodesis group (n=8) had an excellent result as compared with the anatomical reconstruction group (n=15) (p=0.03) and more patients in the tenodesis group (n=9) had a fair or poor result (p=0.04) as compared with the anatomical reconstruction group (n=2). From the findings of this study it was concluded that a tenodesis procedure does not restore the normal anatomy of the lateral ankle ligaments. When compared with anatomical reconstruction, a tenodesis leads to inferior results in terms of functional and mechanical stability, as well as overall satisfaction at long-term follow-up.

In chapter VI, functional stability and ligament laxity, as well as degenerative changes in the ankle joint, were retrospectively assessed in 99 patients who had undergone a reconstruction of the lateral ankle ligaments for chronic anterolateral ankle instability 15 to 30 years earlier. The mean duration of follow-up was more than 20 years. In the literature there are no studies reported with such a long-term follow-up yet. The study population was divided into patients who underwent anatomic reconstruction (n=54) and patients who underwent Evans tenodesis (n=45). The mean follow-up period was approximately 21 years (range; 15-30). During the follow-up period, seven patients in the anatomical reconstruction group were reoperated on, while 17 patients after Evans tenodesis required a reoperation (p=0.004). At the follow-up, physical examination revealed significantly more patients (n=15) with limited dorsiflexion after Evans tenodesis than after
anatomical reconstruction (n=6, p=0.007). Seven patients had a positive anterior drawer test after anatomical reconstruction compared with 18 after Evans tenodesis (p=0.002). Fifteen patients had chronic ankle pain after anatomical reconstruction while the corresponding value was 27 after Evans tenodesis (p=0.001). Stress radiographic evaluation demonstrated 30 unstable ankles in the tenodesis group compared with 13 in the anatomical reconstruction group (p<0.001). Four patients had developed severe osteoarthrosis after Evans tenodesis compared with none after anatomical reconstruction (p=0.025). Functional stability was assessed by the Karlsson score and the rating system developed by Good et al. Both scoring systems revealed superior results for anatomical reconstruction 15 to 30 years after the index operation.

It was concluded that, in contrast with an anatomical reconstruction, the non-anatomical Evans tenodesis does not prevent laxity in a large number of patients. Subsequently, the functional result of the index operation deteriorates more rapidly after Evans tenodesis than after anatomical reconstruction.

In chapter VII, 285 patients at 2 to 30 years after anatomical reconstruction for chronic anterolateral ankle instability were reviewed. Results were analysed for three follow-up cohorts: 2-10 years (n=106), 10-20 years (n=55) and 20-30 years (n=24). The question was whether functional, clinical and radiological results deteriorated with the passage of time. Recurrent sprains occurred in 7.5% of patients in the 2-10 years follow-up group, in 17% in the 10-20 years follow-up group and in 12.5% in the 20-30 years follow-up group. After 2-10 years, 5% of patients had been reoperated on due to residual complaints. After 10-20 years this percentage was 9% and after 20-30 years 17%. At physical examination, the anterior drawer test was positive in 18% of patients in the 2-10 years follow-up group, 20% of patients in the 10-20 years follow-up group and 17% of patients in the 20-30 years follow-up group. The development of degenerative changes in the ankle joint as seen on standard radiographs were detected in 29% of patients 2-10 years after the operation. After 10-20 years this percentage increased to 56% and after 20-30 years to 67%. Assessment of ankle joint function using the Karlsson scoring scale revealed a mean (SD) value of 92 (10.3) points after 2-10 years, and 87 (8.2) and 81 (11.9) points after 10-20 and 20-30 years, respectively. The Good score showed that approximately 85% of patients had good or excellent results until 20 years after the operation. After more than 20 years, approximately 70% of patients had good or excellent results. The stress radiographs revealed a decrease of the mean value of talar tilt from 4.5° (2.7) in the 2-10 years follow-up group to 3.4° (3.8) in the 10-20 years follow-up
group and 2.7° (3.7) in the 20-30 years follow-up group. The mean value for anterior talar translation increased over time; 2.9 mm (2.2) in the 2-10 years follow-up group, to 3.0 mm (2.2) in the 10-20 years follow-up group and to 3.8 mm (2.3) in the 20-30 years follow-up group.

From this survey it was concluded that anatomical reconstruction preserves mechanical stability at a long-term. However, anatomical reconstruction does not reduce the risk for the development of degenerative changes of the ankle joint and subsequent reoperations.

In a further comparison of anatomical reconstruction with tenodesis, the objective of the retrospective multicentre study, described in chapter VIII, was to see which method produces better results in terms of maintenance of sports activity level, restoration of laxity, degenerative changes and patient satisfaction.

Only athletes with a preinjury of Tegner activity level ≥7 were included. At follow-up, pre- and postoperative data and the present Tegner activity level were assessed. Standard and stress radiographs of both ankles were taken. The study population was divided into anatomical reconstructions and tenodeses. A total of 41 anatomical reconstructions and 36 tenodeses were included. The median preinjury Tegner activity level for both groups was 9 (range 7-10). At the follow-up, 2-10 years after the operation, the median Tegner activity level for both groups was 8 (range 4-10). However, 17 patients in the tenodesis group had a lower Tegner activity level than before the operation due to the current status of their operated ankle. The corresponding number in the anatomical reconstruction group was four patients (p<0.001). Significantly more patients in the tenodesis group (n=15) had limited ankle dorsiflexion than in the anatomical reconstruction group (n=3, p<0.001). At radiographic examination, 11 patients in the tenodesis group displayed medially located osteophytes compared with two patients in the anatomical group (p=0.02). The stress radiographic examination revealed that more patients in the anatomical group (n=38) had normal laxity values than in the tenodesis group (n=28, p=0.06). According to the rating system developed by Good et al., 36 patients in the anatomical reconstruction group had a good or excellent result compared with 21 patients in the tenodesis group (p=0.003).

It was concluded that a tenodesis leads to a reduction in activity level due to the loss of ankle function, increased mechanical laxity and degenerative changes in the medial compartment of the ankle joint. Anatomical reconstruction was found to be superior to tenodesis in all the above mentioned outcome measures in a highly active athletic population.
References


