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Anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a 2- to 10-year follow-up, multicenter study

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Abstract The clinical outcome of anatomical reconstruction or tenodesis in the treatment of chronic anterolateral ankle instability was assessed in a retrospective multicenter study. The anatomical reconstruction group (group A) consisted of 106 patients (mean age at operation 24 ± 8.4 years) and the tenodesis group (group B) of 110 patients (mean age at operation 26 ± 11.4 years). Patients were evaluated at a mean follow-up of 5.5 ± 2.8 years in group A and 5.2 ± 2.9 years in group B. The review protocol included patient characteristics, physical examination, two ankle scoring scales to evaluate the functional results, and standard anteroposterior and lateral radiographs to evaluate degenerative changes. Mechanical stability was evaluated using standardized stress radiographs. A larger number of reoperations was performed in group B ($P = 0.008$). At physical examination, more patients in group B had a smaller range of ankle motion than those in group A ($P = 0.009$). A larger proportion of patients in group B had medially located osteophytes, as seen on standard radiographs ($P = 0.04$). On stress radiographic examination, the mean talar tilt ($P = 0.001$) and mean anterior talar translation ($P < 0.001$) were seen to be significantly greater in group B than in group A. There were no differences in mean Karlsson score between the groups, but more patients in group A had an excellent result on the Good score ($P = 0.011$). Unlike anatomical reconstructions, tenodeses do 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.

Keywords Anatomical reconstruction · Ankle · Instability · Ligament · Tenodesis

Introduction

Chronic anterolateral instability of the ankle joint is defined as instability lasting longer than 6 months. Ligament laxity can be demonstrated by physical examination and stress radiographs. In patients with symptoms of giving-way but no signs of mechanical laxity on stress radiographic examination, several other causes may be present. These factors include: proprioceptive deficit, peroneal muscle weakness, tibiofibular sprain, and mechanical instability of the subtalar joint [25, 27, 45]. In some cases chronic ankle instability is associated with generalized joint hyperlaxity or the neglect of an acute injury to the lateral ankle ligaments [31]. In spite of adequate treatment for an acute lateral ankle ligament rupture, 10–20% of patients develop chronic symptoms of giving-way [9, 11, 16, 25, 27]. The instability can be disabling, especially in patients with high demands on ankle joint function [18, 31]. Surgical reconstruction is indicated when a rehabilitation program does not produce a satisfactory functional outcome, and when mechanical instability is present [29].

A variety of surgical methods have been described for the treatment of chronic anterolateral instability of the ankle joint. These can be divided into two main groups: nonanatomical reconstructions using tenodesis and anatomical reconstructions using direct repair or imbrication of the lateral ankle ligaments. In nonanatomical reconstruction the anterior talofibular ligament and the calcaneofibular ligament are reconstructed by means of an autologous graft, usually involving one of the peroneal tendons [1, 10, 11, 16–18, 37, 41, 48, 50]. In anatomical reconstruction the ends of the ruptured or elongated remnants of the lateral ankle ligaments are utilized [6, 9, 25, 27, 34, 38].

There are few comparative studies in literature. Hennrikus et al. [22] and Wallenböck et al. [49] reported superior functional results for anatomical reconstructions. 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 [3, 7, 33].

The aim of this retrospective multicenter study was to compare the results of anatomical reconstruction with those of tenodesis in a large series of patients with a 2- to 10-year follow-up. Furthermore, the results were analyzed to determine whether inferior mechanical stability leads to degenerative changes and a deterioration in functional results in the medium or long term.

Patients and methods

Five European centers participated in the study. Between 1987 and 1995 a total of 324 reconstructions were performed for chronic anterolateral instability of the ankle at these five centers. All patients had experienced complaints for at least 6 months and had undergone rehabilitation with range of motion and proprioceptive training before the operation. Preoperatively, mechanical stability was assessed by stress X-rays in both the frontal plane, talar tilt, and sagittal plane, anterior talar translation, according to the criteria of Lindstrand et al. [32]. The indication to perform an anatomical reconstruction or a tenodesis depended upon the surgeon and was independent of the type of instability and other patient characteristics.

Of the 324 patients 152 underwent anatomical reconstruction and 172 tenodesis. The following inclusion criteria were employed: (a) age at operation between 14 and 60 years, (b) an uninjured contralateral ankle, (c) no history of previous fractures of the affected ankle, (d) no prior surgery other than an anatomical reconstruction or tenodesis of the affected ankle, (e) no prior surgery of the contralateral ankle, (f) no history of bilateral hyperlaxitiy, (g) no history of subtalar instability, and (9) no generalized neuromuscular disorder.

At follow-up 2–10 years after the operation the following data were recorded: age, gender, profession, affected side, and preinjury Tegner activity level [43]. The review protocol consisted of a registration of postoperative complications, the number of reoperations and an assessment of the Tegner activity level. Functional outcome was graded using two ankle scores: the Karlsson score and scoring scale of Good et al. [29, 41]. Absence of symptoms was considered as an excellent result.

At physical examination the range of ankle motion was determined by measuring dorsiflexion and plantar flexion to the nearest 5° using a goniometer. A reduction of more than 5° in comparison with the contralateral ankle was considered as a restricted range of ankle motion. Also the presence of swelling and pain on palpation were determined.

Stability was tested by the anterior drawer test with the ankle in 15° of plantar flexion. This test was regarded as positive when there was considered to be a difference of more than 5 mm compared with the contralateral ankle. At follow-up all the centers performed standardized radiographic examinations consisting of anteroposterior and lateral radiographs of both ankles, and stress radiographs, including measurements of both talar tilt and anterior talar translation with the ankle in 15° of plantar flexion. Measurements were assessed according to the criteria established by Lindstrand et al. [32]. Talar tilt was regarded as positive when the tibiotalar angle was more than 10°, or when the difference between both ankles was more than 6°. Anterior talar translation was regarded as positive when the anterior displacement of the talus relative to the distal tibia was more than 4 mm, or the difference between both ankles was more than 3 mm. The standard load was 150 N using a Telos apparatus [27, 29, 32]. The development of degenerative changes was graded according to the scale suggested by Van Dijk et al. [47]. All the standard and stress radiographs were graded by one independent observer (R.K.).

Differences in baseline characteristics and final results between the centers and groups were analyzed (Table 1). Of the original 324 patients 30% were lost to follow-up: 47 were untraceable, 32 did not want to participate, 11 had moved away, 3 had died, and 4 were in prison. There was no significant difference between centers with regard to the number of patients lost to follow-up. After further analysis 3% of the patients had to be excluded: 4 did not meet the inclusion criteria and the radiographs for 7 were not available. As a result, 216 patients were included.

In terms of the anatomical reconstructions the following significant differences were identified between the centers: the left/right ratio (%) at one center was 66/34, while the overall ratio was 43/67 ($P = 0.034$). At two other centers the male/female ratio was 76/24 and 69/31, respectively, while the overall ratio was 53/47 ($P = 0.028$, $P = 0.041$). At one center there were seven cases of disturbed skin sensitivity at follow-up, corresponding to perioperative superficial peroneal nerve injury, while the overall number of direct postoperative complications was three ($P = 0.031$). With regard to the tenodeses, only one significant difference between the centers was identified: at one center the male/female ratio was 85/15, while the overall ratio was 56/44 ($P = 0.021$).

A total of 106 patients were included in the anatomical reconstruction group (group A) and 110 in the tenodesis group (group B). The baseline characteristics of the two groups are shown in Table 1. There were no significant differences in baseline characteristics between the two groups. The patients in group B were

Table 1 Anatomical reconstruction (group A) vs. tenodesis (group B): baseline characteristics

	Group A (n = 106)	Group B (n = 110)
Age (years)	24.3 ± 8.4	26.2 ± 11.4
Male/female ratio (%)	53/47	56/44
Left/right ratio (%)	43/57	37/63
Tegner preinjury (median)	6 (1–10)	5 (0–9)
Follow-up (years)	5.5 ± 2.8	5.2 ± 2.9

2 years older on average (mean age at operation 26 ± 11.4 years) than the patients in group A (mean age at operation 24 ± 8.4 years). There was a difference of 1 point on average in the median preinjury Tegner activity level, 6 (range 1–10) in group A compared with 5 (range 0–9) in group B ($P = 0.554$). The two groups were similar in terms of male/female ratio, left/right ratio, and the duration of follow-up. The mean follow-up period was 5.5 ± 2.8 years in group A and 5.2 ± 2.9 in group B ($P = 0.31$).

In group A 63 patients at two centers underwent imbrication with a regional periosteal flap and 43 at one center underwent a Broström procedure [9, 38]. Postoperatively, all patients had plaster cast for 6 weeks and range of motion and proprioceptive training. There were no significant differences in results between the procedures. In group B 35 patients were treated with an Evans procedure at one center, 43 with a modified Castaing procedure using a peroneus brevis hemitendon at two centers, 22 with a Viernstein procedure at one center, and 10 with a Watson-Jones procedure at one center [11, 14, 16, 18, 48, 50]. All procedures were performed with the foot in slight eversion. Postoperatively all patients received plaster cast for 6 weeks and thereafter range of motion and proprioceptive training. No significant differences in final results between the tenodesis procedures were observed.

Differences in baseline characteristics and final results were calculated using the multianalysis of variance for comparison of mean values and the χ^2 test for proportions between the centers. Differences in baseline characteristics and final results between the two groups were calculated using the analysis of variance for a comparison of mean values and the χ^2 test for proportions. A P value of less than 0.05 was considered as statistically significant.

Results

The results at the final follow-up are presented in Table 2. In group A 8% of patients had postoperative complications; each of these cases involved disturbed skin sensitivity due to perioperative damage to the superficial peroneal nerve. In group B 15% of patients had postoperative complications: skin necrosis in seven patients, neuroma in seven, wound infection in two, and hypoanesthesia due to perioperative damage to the superficial peroneal nerve in one patient.

The number of reoperations was higher in group B: 17% versus in 5% group A ($P = 0.008$). In group B overly tight tenodesis led to reoperation in three patients who underwent an Evans tenodesis, one who underwent a modified Castaing procedure, two who underwent a Viernstein procedure, and two who underwent a Watson-Jones procedure. In these cases the tendon was released from its original sutures and reattached to the distal fibula. Furthermore the following patients in group B were reoperated on to remove bony spurs near the drillhole of the tenodesis: two who underwent an Evans procedure, three who underwent a Viernstein procedure, and four who underwent a modified Castaing procedure who complained of persisting pain located anteriorly near the lateral malleolus. In group A five patients were reoperated to release an overly tight reconstruction.

At physical examination, there was a significant difference in the number of patients with a restricted range of ankle motion between the two groups ($P = 0.009$). In group A 10% had a restricted range of ankle motion; 5 patients had a restricted dorsiflexion, 3 a restricted plantar flexion, and 3 both. In group B 33% had a restricted range of ankle motion; 19 had a restricted dorsiflexion, 4 a restricted plantar flexion, and 13 both. The number of patients with a positive anterior drawer test was similar in the two groups; 31% in group A and 33% in group B. In terms of the scale of Good et al. [41], there were significantly more patients who had an excellent result (i.e., free from symptoms) in group A; 58% compared with 36% in

Table 2 Anatomical reconstruction (group A) vs. tenodesis (group B): final results

	Group A (*n* = 106)	Group B (*n* = 110)	*P*
Postop. complications (%)	8	15	n.s.
Reoperations (%)	5	17	0.008[a]
Tegner, preinjury (median)	6 (range; 1–10)	5 (range; 0–9)	n.s.
Follow-up	6 (range; 1–10)	5 (range; 0–9)	n.s.
Difference	1 (range; -5–4)	1 (range; -4–3)	n.s.
Restricted ROM (%)	10	33	0.009[a]
Pain on palpation (%)	25	25	n.s.
Anterior drawer sign (%)	33	36	n.s.
Arthrosis (van Dijk; %)			
Grade 0	71	68	n.s.
Grade I	21	22	n.s.
Grade II	8	8	n.s.
Grade III	0	2	n.s.
Karlsson score (points)	92 ± 10.3	91 ± 10.8	n.s.
Good score (grade; %)			
Excellent	58	36	0.012[a]
Good	25	45	0.016[a]
Fair	12	15	n.s.
Poor	5	4	n.s.

[a] χ^2

Table 3 Anatomical reconstruction (group A) vs. tenodesis (group B): results of stress radiographic examination

	Group A (n = 106)	Group B (n = 110)	P
Positive stress X-rays (%)[a]	22	41	0.009[b]
Talar tilt			
Affected ankle (°)	4.5 ± 2.7	6.7 ± 2.1	0.001[c]
Unaffected ankle	4.0 ± 3.1	5.0 ± 4.6	n.s.
Difference	0.61 ± 2.6	1.8 ± 2.1	0.015[c]
Anterior talar translation			
Affected ankle (mm)	2.9 ± 2.2	4.7 ± 1.9	< 0.001[c]
Unaffeffected ankle	3.0 ± 1.2	3.7 ± 2.3	n.s.
Difference	–0.14 ± 2.1	1.0 ± 1.6	0.031[c]

[a] According to Lindstrand et al. [32]
[b] χ^2
[c] Analysis of variance

group B (P = 0.012). There were no significant differences between the groups in terms of the Tegner and Karlsson scores.

The number of patients with degenerative changes as seen on standard AP and lateral radiographs were similar in the two groups. Two patients in group B had developed severe osteoarthrosis (grade III). In group B 17% of patients demonstrated medially located osteophytes, compared with 7% in group A (P = 0.04). In the stress radiographic examination, the mean talar tilt (P = 0.001) and the anterior talar translation (P < 0.011) were significantly higher in group B. According to the criteria of Lindstrand et al. [32] 22% in group A had positive stress radiographs and 41% in group B (P = 0.009; Table 3).

Discussion

More than 60 surgical procedures for the correction of chronic anterolateral instability of the ankle joint have been described [4, 6]. Most of these procedures involve nonanatomical reconstruction. In most procedures the peroneus brevis tendon or a part of it is used to establish a tenodesis between the distal fibula and the calcaneus, the talus, or the base of the fifth metatarsal. Other authors have recommended tendon transfer in which replacement of the lateral ankle ligaments is performed in a more anatomical fashion, for example, by using a split peroneus brevis tendon. This reduces the risk of losing eversion strength [14]. There are several classic tenodeses such as the Elmslie, Evans, Chrisman-Snook, and Watson-Jones procedures [11, 15, 16, 31, 37, 41, 42, 48, 50]. These procedures usually include the reconstruction of the anterior talofibular and calcaneofibular ligaments to correct instability in the talocrural and subtalar joints [11]. The clinical outcomes of tenodeses reported in the literature vary. Many studies report good short-term results [11, 16, 18, 31]. There have been few reports of long-term results, but Snook et al. [42] reported satisfactory long-term results after using the Chrisman-Snook procedure. On the other hand, some long-term studies 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 eversion strength [5–8, 24, 26].

The recent literature shows that anatomical reconstruction has acquired increasing popularity [19, 20, 27, 28, 34, 35]. These procedures make use of the ruptured or elongated remnants of the ligaments to restore normal ligament stability [9]. A problem arises in anatomical reconstruction when the local ligament tissue is severely damaged. In these cases augmentation with an autograft may be necessary [28]. To reinforce the ligaments, autografts with mechanical properties similar to those of the normal ligaments are most frequently used. These include periosteal flaps or the inferior extensor retinaculum [40]. Some authors advocate the use of the fascia lata or free sections of the Achilles or plantaris tendon to reconstruct the anterior talofibular ligament [2]. Nachtkamp et al. [36] investigated the histological changes in periosteal flaps in patients with chronic anterolateral ankle instability. They noted structural alignment of the collagenous fibers in the periosteal flap into a ligamentlike structure 8–12 weeks after the operation. Anatomical reconstructions have been reported to produce satisfactory long-term results in a large proportion of patients [19, 25, 27, 40].

Both anatomical reconstruction and tenodesis have been the subject of experimental studies. Most of these studies report that a tendon transfer procedure limits the range of ankle motion and prevents neither anterior talar translation nor talar tilt [3, 23, 30, 33, 44]. Liu et al. [33] found similar results in a cadaver model, i.e., that the Watson-Jones and Evans tenodesis provide less mechanical stability than the modified Broström procedure. In terms of these experimental results it is evident that a tenodesis has a negative effect on the kinematic coupling of the ankle joint complex [6]. Our data are in accordance with these experimental findings. Stress radiographic examinations have revealed that patients receiving anatomical reconstruction have significantly less talar tilt and anterior talar translation. Instability has been associated with the development of degenerative changes as seen on standard radiographs [21]. As the results of stress radiographic examinations in our series demonstrated inferior mechanical stability for the tenodesis group, a larger number of patients with degenerative changes could be expected. More patients in the tenodesis group displayed medially located osteophytes than in the anatomical reconstruction group (Fig. 1).

On the basis of these two observations we feel that there is a correlation between the decrease in mechanical stability and the development of medially located degenerative changes in the ankle joint. The same phenomenon has been found by Harrington [21], who performed arthroscopy in 12 of 36 patients with chronic ankle instability; in all 12

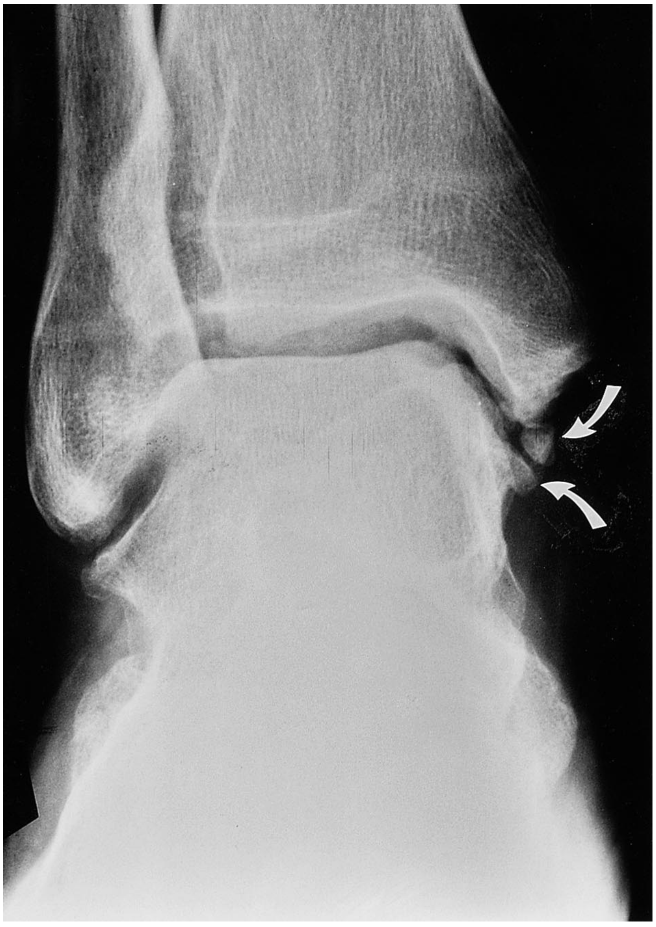

Fig. 1 Anteroposterior radiograph of a patient's ankle 9 years after a Watson-Jones tenodesis. Note particularly osteophyte formation at the medial talar facet and ossicle just below the medial malleolus

cases degenerative changes were seen in the medial compartment of the ankle joint. It has been demonstrated that in supination trauma cartilage damage occurs in 65% at the medial talar facet and tip of the medial malleolus [46]. In a trauma of this kind, the talus rotates out of the ankle mortice, and in this subluxated, supinated position the weight causes axial compression through the medial malleolus and the medial talar facet. This impaction force explains the cartilage damage which can subsequently lead to degenerative changes [3, 12, 23, 30, 33, 39, 44, 46].

We found that a larger number of patients in the tenodesis group had a restricted range of dorsi- or plantar flexion. This may appear in conflict with our finding of decreased mechanical laxity provided by the tenodesis. As the transferred tendon is placed in a nonanatomical position or when the reconstruction is too tight, this can restrict dorsi- or plantar flexion and simultaneously may not prevent tilt and anterior translation of the talus. Although this phenomenon has also been found by 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 [3, 23, 30, 33, 40].

As many tenodeses are performed with the foot placed in mild eversion, the lateral side of the ankle joint can easily become overtightened. Significantly more patients required the release of an overly tight reconstruction after tenodesis than after anatomical reconstruction. Another problem that has been reported in conjunction with tenodesis procedures is the development of symptomatic anterolateral bony spurs. The tendon, which is routed through a drill hole in the narrow lateral malleolus, may perforate the external cortex, leading to the development of symptomatic bony spurs [4]. Our results revealed that a significant number of patients in the tenodesis group required a second operation to remove symptomatic bony spurs.

When comparing the two groups with regard to functional stability using the scale of Good et al. [41], we found that significantly more patients in the anatomical reconstruction group had an excellent result. Significantly more patients were therefore free from symptoms of giving-way. This finding is supported by a prospective study by Hennrikus et al. [22] which showed that the modified Broström procedure resulted in significantly higher scores according to the scale of Good et al. than the Chrisman-Snook tenodesis. Wallenböck et al. [49] also found better functional results for anatomical reconstructions than with the Evans and Watson-Jones tenodeses.

All the participating centers in this multicenter study used the same standard protocol to review their patients and assess clinical outcome. A large series of 216 patients was reexamined at a medium- or long-term follow-up (2–10 years). All the radiographs were assessed by one independent observer. The limitations of the present study include inhomogeneous male/female and left/right ratios for comparisons between the centers. However, we are not aware of any study that reports that differences in male/female or left/right ratio influence the results of the surgical treatment of chronic anterolateral ankle instability. At one center there was a significantly larger number of postoperative complications than at the others. However, this included in all cases minor damage to the superficial peroneal nerve.

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 and less satisfactory functional results. Furthermore, we conclude that tenodesis does not prevent mechanical laxity after 2–10 years, thereby leading to subsequent degenerative changes on the medial side of the ankle joint.

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