

General

Lateral ligament reconstruction and additive medial ligament reconstruction in chronic ankle instability: a retrospective study

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Background

Ligamentous lesions of the ankle joint are common. Isolated medial ligament injuries are rare but are often associated with lateral ligament injuries, isolated medial ligament lesions are often overlooked. The present study aimed to evaluate the clinical and functional differences in the outcomes of isolated lateral and combined medial and lateral ligament reconstruction. The study is based on patient-reported outcome measurements and motion sensor technology to assess these outcomes.

Objective

The purpose of this study was to compare the clinical and functional outcomes of isolated lateral and combined lateral and medial ankle ligament reconstruction.

Methods

From December 2014 to August 2018, 111 patients underwent either isolated lateral ligament (LG) or medial and lateral ligament (MLG) reconstruction. Of the 104 patients meeting the inclusion criteria, 49 had LG and 55 had MLG reconstruction. Outcome measures included the Short Form-36 Health Survey SF-36, Foot and Ankle Outcome Score (FAOS), Foot and Ankle Ability Measure (FAAMG), Tegner Activity Scale, the European Foot and Ankle Society (EFAS), American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score, and the Karlsson Peterson Score. Mobility and stability were assessed using the Orteligent™ motion sensor for both healthy and treated ankles.

Results

While there were no significant differences in outcome scores between the groups, overall scores improved after treatment ($p > 0.00$). Notably LG showed improved movement, with better dorsal extension measured by the Sensor ($p \div 0.02$). The sensor's results correlated significantly with FAOS subscales for pain ($p \div 0.05$), stiffness ($p \div 0.01$), ADL ($p \div 0.02$), and sports ($p > 0.00$).

Conclusion

Postoperative results, regardless of LG or MLG, showed significant subjective well-being improvement. LG's advantages were highlighted by a significant improvement in dorsal extension, supported by correlated results from a portable motion sensor assessing ankle stability.

INTRODUCTION

Ligament lesions and ankle sprains are among the most common injuries, particularly in sporting activities.¹⁻⁶ Approximately one-fourth of these injuries occur during sports involving running or jumping, with 85 % of them associated with inversion trauma.⁷

The lateral ligament complex, consisting of the calcaneofibular ligament (CFL), the anterior talofibular ligament (AFTL), and the posterior talofibular ligament (PFTL), is most commonly affected by these injuries.⁸⁻¹³ The prevalence of lateral ligament injuries varies from 80 % to 90 %, depending on the conducted study.^{8,14}

Isolated medial ligament injuries are rare but are often accompanied with lateral ligament injuries.¹⁵⁻¹⁸ The prevalence of combined medial and lateral ligament lesions

ranges from 23 % to 40 %.¹⁹⁻²¹ Unfortunately, medial ligament lesions are frequently overlooked and misdiagnosed.^{15,16}

Primary nonoperative therapy involves six weeks of immobilization, ankle support and physiotherapy. If conservative treatment fails, surgery is preferred.²²⁻²⁴ About 20 % of patients require surgical treatment to prevent chronic instability or arthritis.²⁵⁻²⁹ Unlike primary instability, chronic ankle instability is not only involved in the AFTL but also in the CFL (65 %) and the medial ligament complex (40 %).^{7,30} Anatomic reconstruction using a ligament anchor is a commonly researched technique for ligament reconstruction.³¹ However, the existing literature is limited and the few existing studies reported positive outcomes of lateral ligament reconstruction (LG) compared to medial reconstruction.^{32,33}

Therefore, the objective of the present study aims to evaluate the clinical and functional differences in the outcomes of isolated LG and combined MLG. To the author's knowledge, this is the first clinical study comparing the clinical outcomes of isolated lateral with combined medial and lateral ligament reconstruction in chronic ankle instability by utilizing various outcome measurements as well as a motion sensor.

MATERIAL AND METHODS

The study was approved by the appropriate ethics committee (Ethics approval number: 8543_BO_S_2019), and all participants provided written consent to participate in the study.

Between December 2014 and August 2018, 111 patients received isolated anatomical reconstruction of the LG or anatomical reconstruction of the MLG ligaments, diagnosed by clinical examination, MRI and arthroscopy. 104 of these patients fulfilled the inclusion and exclusion criteria (see [Table 1](#)). They were divided into two groups: Those who had LG only, and those who received MLG (see [Figure 1](#)). All patients were sent two questionnaires to compare the results before and after the operative treatment and both questionnaires contained the following scores: 36-Item Short Form Survey (SF 36), Foot and Ankle Outcome Score (FAOS), Foot and Ankle Ability Measure (FAAMG), Tegner Activity Scale, and European Foot and Ankle Society (EFAS). All participants were invited for at least one year of follow-up examination.

The **SF 36** measures the health status of patients in a 36-item self-reported questionnaire to evaluate the cost efficiency of health treatment. The score consists of eight sections (vitality, physical functioning, pain, general health, psychological functioning, emotional functioning, social functioning and mental health). The total outcome ranges from 0 to 100, with every score worth the sum of their questions.³⁴

The **FAOS** is a 42-items patient-reported questionnaire measuring functional limitations and symptoms of the foot and ankle on five subscales (pain, stiffness, sport, activity of daily living, and quality of life). Answers were given on a 1 -5 Likert scale. The total and subscale scores were calcu-

lated by summing the items and the final score is given on a scale of 0 to 100, where 100 is the equivalent of no symptoms at all.^{35,36}

FAAMG is a self-reported outcome scale for physical functioning related to the foot. It has two scales: the activity of daily living (ADL) with 21 items and the sports scale with 8 items. The individual items are scored from no difficulty to complete inability to perform (0-4 points). The ADL subscale ranges from 0 to 84 and the sports subscale ranges from 0 to 32.³⁷

The **Tegner Activity Scale** is a list of ADL and sports. The score varies from 0 to 10, where a score of 10 correlates with participation in sports at an elite level, and a score below 6 corresponds to competitive sports. It is used to grade work and sports activities in daily life.³⁸

The **EFAS** covers pain and physical functioning and consists of six questions with a maximum score of 24 and a minimum score of 0. Each question was scored from 0 to 4.³⁹

In addition to the clinical examination of the foot, the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score and Karlsson Peterson Score were used.

The **AOFAS hindfoot score** is a clinically reported score that consists of three categories with nine questions each for pain (40 points), function (50 points), and alignment (10 points), with a total of 100 points. This score was utilized to assess patients with foot and ankle disorders.

The **Karlsson-Peterson** score was used to evaluate ankle joint stability.⁴⁰ It consists of eight items (pain, swelling, instability, stiffness, stair climbing, running, work activities, and support), each worth between 0 and 25 points. The total score was calculated by summing and dividing by the number of items.

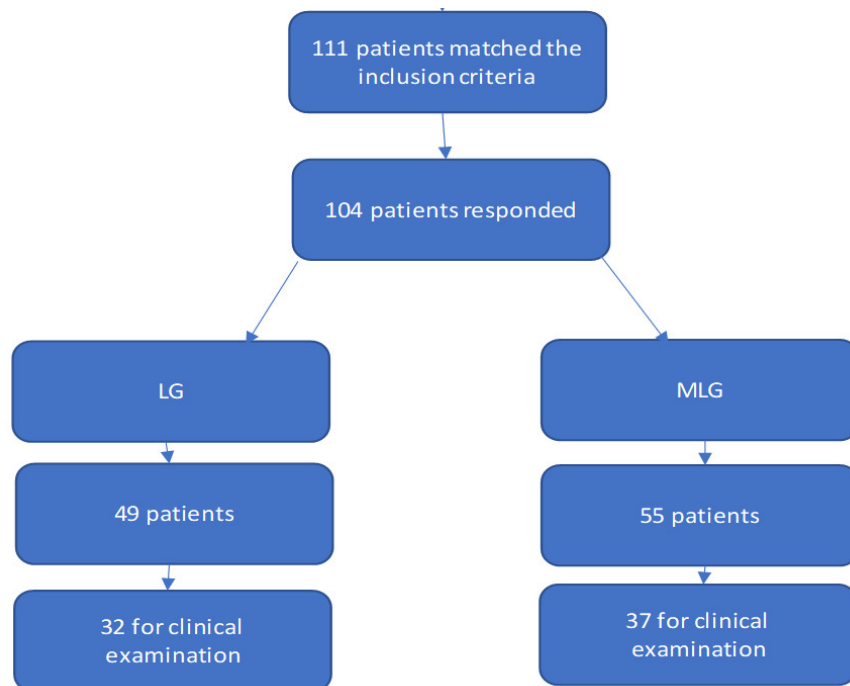
Additionally, the patient's ankle mobility and stability were measured using the **Orthelligent Sensor™** from OPED (Medizinpark 1, 83626 Valley, Germany), comparing both ankles in three exercises: one-legged stand ([figure 2a](#)), dorsal extension ([figure 2b and 2c](#)), and one-legged squat ([figure 2d and 2e](#)). The sensor is attached to the ventral side of the tibia right underneath the knee. It is able to sensor/evaluate/demonstrate the range of motion, help with coordination, or determine strength and speed. The patients were instructed by a video explanation given by the application through exercise. The sensor recorded the lateral deviation of the leg in a single-leg stance in mm and the mobility in the ankle joint (°) in the other two clinical tests using motion recognition software. The results were then sent to the application of the chosen device. To evaluate and present these results, the sensor uses the Limb Symmetry Index (LSI). LSI compares an affected limb to an unaffected limb and is often used in rehabilitation. It was calculated by dividing the affected limb by the unaffected limb and multiplying the result by 100. These results were used to compare the operated and healthy ankles as well as comparing between the groups.

STATISTICAL ANALYSIS

Normal distribution was tested using the Kolmogorov Smirnov test. As the data were mainly non normally distrib-

Table 1. General Study and Patients data

General Study and Patients Data		
1.1 Including criterias	Lateral ligament plasty of the ankle joint Lateral and medial ligament plasty of the ankle joint	
Excluding criterias	Age < 18 Wheelchair Previous cartilage therapy of the ankle joint Medial malleolus osteotomy	
1. Demographic characteristics n= 109	Lateral n=49	Lateral/Medial n=55
	Median [IQR]	Median [IQR]
Male	14	16
Female	35	39
Age	46.00 (30-57)	40.00(26-52)
BMI kg/m ²	25.56(22-30)	26.64(23-32)
Follow-up (months)	45.00 (34-61)	26.00(17-41)

**Figure 1. Showing the process of recruiting and including patients for the study.**

uted, non-parametric tests such as the Mann Whitney-U, and the Wilcoxon test were applied, with a level of significance of 5%. Furthermore, the correlation between FAOS and the sensor results was analyzed. For this purpose, we used Spearman's rho test.

Because we showed non-normal distribution of data, we had to adapt for possible statistical outliers. To ensure reliable results, we chose to present our data with median and interquartile range to make use of the robustness of the median.

RESULTS

49 patients underwent LG, comprising 14 males and 35 females with a median age of 46 years and a mean Body-Mass-Index (BMI) of 25.5. The median follow-up time for this group was 45 months. 55 patients received MLG, comprising 16 males, 35 females. The median age was 40 years, the mean BMI was 26.6 and the median follow-up time was 26 months (see [Table 1](#)). There were no statistically significant differences in patient characteristics between the two groups, despite the difference in the median follow-up time of 19 months. Additionally, there were no significant differ-



Figures 2a-e. Showing the exercises of the study.

ences between groups regarding pre-existing illnesses, drug usage, patient frequency, and postoperative complications.

The FAOS showed no significant difference between groups for all pain subscales. The intra-individual comparison showed a significant difference in all subscales of the FAOS between the pre- and post-operative states (see [Table 2](#)).

The SF 36 demonstrated/highlighted improvement in the median of both groups in terms of the physical sum scale (PCS) after treatment. It increased from 45 to 60 in the LG and from 41 to 64 in the MLG. The mental sum scale (MCS) score remained at 80 for the LG and slightly improved from 77 to 78 in the MLG. Comparing both groups, there were no significant difference either before or after treatment (see [Table 2](#)). The FAAMG also indicated an improvement in ADL and sports in both groups (see [Table 2](#)). In the LG group, the median improvement before and after treatment for ADL and sports was 58 and 87, and 31 and 69, respectively. In the MLG group, the median before and after treatment for ADL and sports was 61 and 82, and 33 and 63, respectively. However, no significant differences were observed between the groups after treatment.

We were able to demonstrate an improvement in the median of one point of the EFAS ([Table 2](#)) in both groups from 2 to 3 points after the treatment.

The median AOFAS score (see [Table 2](#)) for the LG group was 86, and 78 for the MLG group, indicating a tendency towards the lateral group concerning the AOFAS score. There were no statistically significant differences in the Tegner Activity Scale before or after treatment. This also applies to the Karlson scores.

The data from the OPED Sensor showed a significant difference in the execution of the dorsal extension using the operated foot between the two groups, favoring the LG with

a median of 26°. The other two exercises showed no significant difference in the operated foot (see [Table 3](#)). Specifically, the one-leg stand as a parameter for lateral stability did not indicate a significant difference between the two groups (see [Table 3](#)). When comparing the operated foot with the non-operated foot, regardless of the group (see [Table 3](#)), we were able to show a significant difference in the dorsal extension towards the healthy foot with a median of 29 compared to 21 in the operated side. Our correlation analysis showed a positive correlation between two of the three exercises of the operated foot and the FAOS subscales (see [Table 3](#)). There was no correlation between the FAOS and one leg-squat. For the one-leg stand we were able to show a correlation between subscale stiffness, QOL, and a tendency for subscale pain. Dorsal extension correlated significantly with the stiffness, ADL and sport subscales.

DISCUSSION

This study aimed to assess the outcomes of anatomical ligament reconstruction in chronic ankle joint instability by comparing the clinical outcomes of isolated lateral ligament reconstruction with combined medial and lateral reconstruction after surgical treatment. The postoperative scores and function between both groups were found to be comparable. We showed that in both cases, surgical treatment leads to a significant improvement in function and stability.

Our study revealed that there was no significant difference between the isolated LG or combined MLG. Despite the existing controversy in the literature regarding the implementation of surgical treatment for chronic instability of the ankle joint, our findings emphasized the positive effects of ligament reconstruction in addressing this condi-

Table 2. Overview of the Patient reported outcome measurements (PROM) and clinical Scores.

2.1 FAOS n=104	Lateral n=49			Lateral/Medial n=55			Comparison between groups	
	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative
	Median[IQR]	Median[IQR]	p-value	Median[IQR]	Median[IQR]	p-value	p-value	p-value
Pain	50[44-69]	86[52-94]	<0.00	50[36-63]	86[58-97]	<0.00	0.24	0.49
Stiffness	50[35-71]	75[50-89]	<0.00	53[35-64]	75[57-85]	<0.00	0.73	0.80
ADL	75[57-86]	92[70-100]	<0.00	75[54-85]	92[75-100]	<0.00	0.86	0.66
Sport	40[15-55]	75[40-90]	<0.00	30[15-45]	70[45-95]	<0.00	0.17	0.79
QOL	37[25-50]	50[37-75]	<0.00	31[18-43]	56[31-75]	<0.00	0.24	0.84
2.2 SF 36 n=104	Lateral n=49			Lateral/Medial n=55			Comparison between groups	
	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative
	Median[IQR]	Median[IQR]	p-value	Median[IQR]	Median[IQR]	p-value	p-value	p-value
PCS	45[35-52]	60[44-68]	<0.00	41[30-55]	64[48-72]	<0.00	0.45	0.35
MCS	80[63-86]	80[65-84]	0.9	77[65-84]	78[65-84]	0.3	0.58	0.72
2.3 FAAMG n=104	Lateral n=49			Lateral/Medial n=55			Comparison between groups	
	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative
	Median[IQR]	Median[IQR]	p-value	Median[IQR]	Median[IQR]	p-value	p-value	p-value
ADL	58[43-70]	87[55-94]	<0.00	61[42-71]	82[70-98]	<0.00	0.96	0.50
Sport	31[25-41]	69[38-91]	<0.00	33[22-41]	63[41-92]	<0.00	0.58	0.93
2.5 EFAS n=104	Lateral n=49			Lateral/Medial n=55			Comparison between groups	
	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative	Pre- vs. Postoperative	Preoperative	Postoperative
	Median[IQR]	Median[IQR]	p-value	Median[IQR]	Median[IQR]	p-value	p-value	p-value
Result	2[2-3]	3[2-3]	<0.0	2[1-3]	3[1-3]	<0.0	0.12	0.65
2.6 AOFAS n=69	Lateral n=32			Lateral/Medial n=37			Comparison between groups	
	Postoperative			Postoperative			Postoperative	
	Median[IQR]			Median[IQR]			p-value	
Result	86[80-90]			78[69-95]			0,11	

Table 3. Motion Sensore Measurements

3.1 Interindividual comparison	Lateral			Lateral/Medial			Comparison between groups	
	Operated side	Not operated side	n	Operated side	Not operated side	n	Operated side	Not operated side
	Median[IQR]	Median[IQR]		Median[IQR]	Median[IQR]		p-value	p-value
One-leg stand (mm)	2[1.5-3.8]	2[1-2]	29	3.0[2-3.8]	2.4[1.5-3.8]	34	0.10	0.46
One-leg squat (°)	0.5[0-3.2]	1[0-3]	18	0.5[0-1.8]	0.5[0-1.4]	13	0.64	0.39
Dorsal extension (°)	26[17-31]	30[23-34]	29	19.0[14-25]	28[24-32]	33	0.02	0.58
3.2 Intraindividual comparison	Operated side			Not operated side			n	Operated vs not operated
	Median[IQR]			Median[IQR]				
One-leg stand (mm)	2.6[1.6-3.8]			2.3[1.5-3.2]			63	0.57
One-leg squat (°)	0.5[0-2.8]			1.0[0-2.2]			31	0.65
Dorsal extension (°)	21.0[15.0-27.0]			29.0[24.0-33.3]			62	<0.001
	One leg stand (OP)			One leg squat (OP)			Dorsal extension (OP)	
3.3 Correlation	Correlation Coefficient r (p)			Correlation Coefficient r (p)			Correlation Coefficient r (p)	
FAOS Pain	0.3 (0.12)			0.1 (0.46)			0.2 (0.05)	
FAOS Stiffness	0.3 (>0.00)			0.1 (0.37)			0.2 (0.01)	
FAOS ADL	0.2 (0.06)			0.1 (0.48)			0.2 (0.02)	
FAOS Sport	0.2 (0.81)			0.1 (0.51)			0.3 (>0.00)	
FAOS QOL	0.2 (0.04)			0.1 (0.53)			0.2 (0.07)	

tion. Our results demonstrated a significant improvement in all subscales of the FAOS, which was proven to be reliant on the outcome of ankle joint reconstruction,^{35,41} an improvement in PCS as part of physical improvement after treatment, as well as all other scores in the intra-individual comparison.

Our study highlights the potential of surgical treatment, in contrast to the findings of Kamper and Grootjans (2012), who reported no difference between non-surgical and surgical treatment.⁴² Other studies observed persistent complaints after conservative treatments,^{1,43,44} which our results do not support. We demonstrated that patients who underwent combined medial and lateral ligament reconstruction experienced either fewer or equivalent complications compared to those with isolated lateral ligament reconstruction. Any postoperative infections observed were mild and successfully treated with antibiotics. Furthermore, no revision surgeries were required. These findings are further supported by similar results reported in the existing literature.^{45,46}

Since our results did not show a significant difference between LG and MLG reconstruction for either the primary or any other scores, it might lead to the conclusion that there was no difference in the outcomes for both procedures. This is also alluded to when examining the unaltered outcome of the Tegner Activity scale. A possible explanation for this is that the preoperative status is recalled by the patients and not directly collected before treatment. Moreover, our patients were not professional athletes. On the one hand, this might be interpreted as no positive change after treatment. On the other hand, the patients were able to perform their individual sports at the same level as before the surgical treatment, which may be interpreted as a full recovery.

If we postulate that there is no difference between the isolated LG and combined MLG reconstruction, the isolated reconstruction may be preferred since it reduces operation time and postoperative stiffness. Isolated reconstruction also reduces surgical associated trauma, which might reduce the time spent in hospital. However, it is known that medial ligament injuries are often associated with lateral ligament injuries or even overlooked.^{15,16} Recent studies stress that medial ligament lesions are an important factor in the development of ankle joint instability⁴⁷ and require MRI or arthroscopy for correct diagnosis. Studies have described the prevalence of combined injuries between 23 % and 40 %.¹⁹⁻²¹ An MRI Study was able to show medial ligament traumas in 50 % of distortions.^{48,49} Furthermore, about 77 % of patients with medial instability also have lateral instability.²⁰ Therefore, reconstruction of both ligaments seems only useful if a medial ligament lesion is diagnosed combined by clinical complaints, MRI or arthroscopy, especially since the isolated clinical determination of medial instability provides poor sensitivity.⁵⁰ In cases of difficulties concerning the diagnosis of medial ligament lesions, combined reconstruction should be used permissively. The question of whether a surgical approach should be used more frequently or whether it is more beneficial for patients should be answered in further prospective studies.

Our results show that the PCS of the SF-36 improved after treatment, whereas the MSC did not, as MCS was initially high and remained high. This can be explained by the fact that the patients in our study were physically, but not mentally, impaired. Other studies also have concluded that after surgical treatment, the physical subscales of the SF-36 improve, in contrast to a small effect on the mental status of patients.⁴²

The numbers of the MRI study underline the necessity of a tool to measure stability objectively. The stability of a healthy ankle is expected to be comparable to that of a normally distributed population. This is also shown in our data by the inability of the sensor to quantify a significant difference between healthy ankles.

We used the Sensor to evaluate the stability of the operated and non-operated ankle of patients using three exercises. There is no significant difference in the one-leg stand between the operated and non-operated sides, regardless of the performed surgery (see [Table 3](#)). Because the one-leg stand causes considerable pressure on both the lateral and medial ligament complex, it represents lateral and postural stability. Since we were not able to show a significant difference between the operated and healthy ankles, this might lead to the conclusion that ligament reconstruction can restore stability equal to that of a healthy ankle. More importantly, this might offer the opportunity to measure the lateral and postural stability objectively after surgical treatment.

Furthermore, a positive correlation was demonstrated between the FAOS, dorsal extension, and one-leg stand (see [Table 3](#)). However, the correlation coefficient was not significant, whereas a significant correlation between the one-leg stand and the subscale stiffness and the dorsal extension and stiffness, sports and ADL could be outlined. The results for the one-leg pistol squat exercise did not show a significant difference or positive correlation. This can be attributed to the challenging nature of the exercise, as nearly all patients were unable to perform it adequately for motion measurement by the sensor. Nonetheless, our analysis suggests that the Sensor may prove to be a reliable tool in the future for quantifying and measuring lateral, medial, and postural stability of the ankle joint.

Additionally, a significant difference favoring the LG group was observed regarding dorsal extension (see [Table 3](#)). This suggests that ligament reconstruction induces stability at the expense of mobility, as the LG exhibited greater mobility compared to the combined medial and lateral group (MLG). Even though mobility was better for LG, we were not able to show any influence or change in the other parameters. Overall, our results support the benefits of ligament reconstruction in enhancing the ankle joint stability. These results are consistent with other studies,^{15,32,33,51} although other studies reported a reduction in the range of motion post-surgery.⁴⁸ The incidence of arthrosis in instability of the ankle ranges from 13 % and 78 %, ^{26,49,52} while the occurrence of ankle impingement after surgery is low.⁵³

Several limitations were present in our study due to its retrospective design. Patients had to rely on their memory to recall the preoperative situation, and the sample size

was relatively small with a short observation period. Furthermore, there was a significant difference in the median follow-up time between the groups, with a longer follow-up time potentially affecting healing and adaptation. Thus, our data should be interpreted carefully, as differences in follow-up time may influence the outcomes. Although our sample size was sufficient to highlight the positive correlation, a longitudinal analysis was not conducted. Therefore, future studies are needed to examine the limitations and appropriate utilization.

CONCLUSION

In summary, our study revealed comparable outcomes for isolated lateral ligament reconstruction (LG) and combined reconstruction of the medial and lateral ligament (MLG), indicating similar effectiveness of both treatment approaches. Consequently, isolated, anatomical ligament reconstruction should be the preferred surgical treatment for ankle instability since it reduces intraoperative trauma while providing comparable results after surgery. Combined reconstruction may be considered in cases of debatable trauma involving the medial ligament complex or definite diagnosis of combined medial and lateral ligament destruction. Regardless of the specific methods investigated, our study underlines the benefits of surgical ligament reconstruction in managing chronic ankle instability.

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COMPETING INTERESTS

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of the Medizinische Hochschule Hannover (Ethics approval number: 8543_BO_S_2019).

INFORMED CONSENT

Informed consent was obtained from all participants in the study.

AUTOR / COAUTHOR CONTRIBUTIONS

Moritz Kleinevoß Preparation and execution of examinations

Preparation of the data

Evaluation of the results

Writing and correction of the manuscript

Daiwei Yao Evaluation of the results

Correction of the manuscript

Project planning

Review of the progress of the project

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