Original Research

Decreasing the Abnormal Internally Rotated Talus After Lateral Ankle Stabilization Surgery

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Background: Increased internal rotation of the talus has been found in patients with mechanical ankle instability (MAI).

Purpose/Hypothesis: To evaluate and compare the talar rotation position before and after lateral ankle lateral stabilization surgery in patients with MAI. We hypothesized that the abnormal internal talus rotation in patients with MAI will decrease after surgery for ankle lateral instability and that there will be no significant difference in internal talus rotation between the ligament repair and reconstruction groups.

Study Design: Case-control study; Level of evidence, 3.

Methods: We retrospectively studied 56 patients with MAI who underwent ankle lateral stabilization surgery after arthroscopic evaluation (repair, 36 cases; reconstruction, 20 cases). Before and after the operation, magnetic resonance images of all the participants were reviewed. The rotated position of the talus was measured and calculated by the Malleolar Talus Index at the magnetic resonance axial plane.

Results: The internal rotation of the talus decreased significantly after ankle lateral stabilization surgery in patients with MAI as compared with before surgery (mean ± SD, 83.3° ± 3.3° vs 86.7° ± 3.9°; $P < .01$). However, there was no statistically significant difference between the ligament repair and reconstruction groups before or after the operation.

Conclusion: Abnormal internal rotation of the talus in patients with MAI was decreased after ankle lateral stabilization surgery.

Keywords: ankle; instability; operation; talus; rotation

Ankle sprains are among the most common sports injuries, and the risk factors thereof are both intrinsic and extrinsic.[8] Previous studies reported that specific anatomic variations have been associated with ankle instability, such as talus internal rotation and anterior subluxation, hindfoot varus, and varus tilt of the tibial plafond.[3,4,9,17,25,26] Therefore, restoration of native ankle joint alignment and normal geometry potentially mitigates ankle reinjury and osteoarthritis. Biomechanical studies have shown that deficiency of the anterior talofibular ligament (ATFL) increases internal rotation of the talus.[5,7,21] Caputo et al[4] found ATFL-deficient ankles demonstrated a statistically significant increase in internal rotation, anterior translation, and superior translation of the talus relative to the contralateral intact ankle. Moreover, abnormal internal rotation of the talus can increase the stresses on the medial portion. As a result, the incidence of cartilage lesions increases, particularly in the anteromedial portion of the talus.[21]

Previous research has indicated that ankle lateral stabilization surgery can provide satisfactory clinical outcomes.[16,18,27] However, few studies have evaluated the restoration of normal kinematics after surgery.

In 2017, Li et al[17] introduced a new index, the Malleolar Talus Index (MTI), to assess the talar rotation position at

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the axial plane on a magnetic resonance imaging (MRI) scan. They concluded that the MTI was reproducible and that it simplified the calculation of the talar rotation position on axial MRI. In their study, a larger MTI was found in patients with mechanical ankle instability (MAI), which indicated increased internal rotation of the talus. The purpose of the present study was to evaluate and compare the rotated talar position before and after ankle lateral stabilization surgery in patients with MAI. We hypothesized that abnormal internal talus rotation in patients with MAI would decrease after surgery for ankle lateral instability.

METHODS

From January 2016 to October 2018, a total of 56 patients were enrolled in this retrospective study. The inclusion criteria were as follows: history of ankle sprain with persistent symptoms (eg, giving way, pain, or swelling) of at least 12 months' duration, positive anterior drawer test, ATFL injury by MRI and arthroscopic evaluation, nonoperative treatment for at least 3 months, and MRI evaluation at final follow-up.

The exclusion criteria were as follows: history of ipsilateral lower extremity surgery or ankle fracture, deformity around the ankle joint (flat foot, high arch, varus heel, or inverting tibial plateau), age <16 or >60 years (to avoid the impact of immature bone or degenerative joint deformity on the measurement results), and posterior talofibular ligament tear. The study protocol received ethics committee approval, and informed consent was obtained from each participant.

Surgical Procedures

All patients underwent arthroscopic evaluation. The quality of the ATFL was evaluated. The ATFL remnants were divided into 2 grades.

Grade A: The ATFL was thick with adequate tension and indicated a good remnant.
Grade B: The ATFL was thin with extreme laxity and indicated a poor remnant.

If the ATFL remnant was insufficient for repair (grade B), ligament reconstruction was performed. After the arthroscopic evaluation, open lateral ankle ligament repair (modified Broström procedure) or anatomic reconstruction using auto- or allosemitendinosus tendon was performed by a senior surgeon (Y.H.H.).[10,11]

Rehabilitation and Clinical Evaluation

After the operation, the ankle was immobilized in a slightly everted position with a short-leg cast. The cast was removed 2 weeks postoperatively. After removal, passive dorsiflexion and plantar flexion were permitted. Partial weightbearing was started 4 weeks after the operation. No formal physical therapy was performed during this period. All patients had a minimum follow-up of 6 months. Before the operation and at the final follow-up, all patients were evaluated by the anterior drawer test, American Orthopaedic Foot and Ankle Society (AOFAS) score, and MRI.

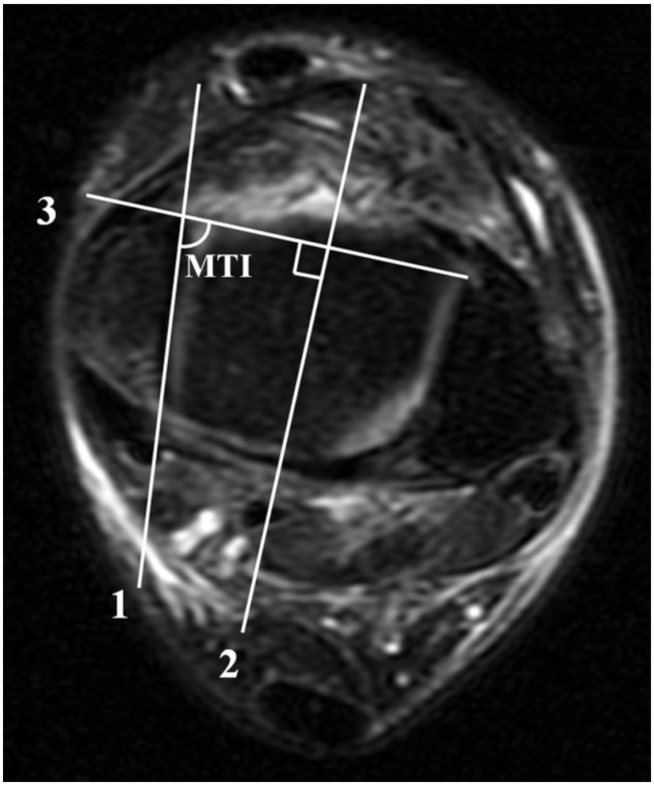

Figure 1. T2-weighted magnetic resonance imaging in the axial plane of the articular surface of the talus. Line 1 is parallel to the articular border of the medial malleolus. Line 2 is the bisected axis of talus. Line 3 is perpendicular to line 2 and passes through the anterior border of the medial malleolus. The Malleolar Talus Index is the angle formed between lines 1 and 3.

MRI Scan and Image Analysis

All MRI scans were evaluated with a 3.0-T scanner (MAGNETOM Verio A Tim System; Siemens) in a standardized fashion. Axial proton density–weighted fast spin echo images were taken at increments from the distal tibial diaphysis to the most inferior aspect of the calcaneus (repetition time/echo time, 2600-2800/24-30 ms; matrix, 512 × 320; slick thickness, 3 mm). The MTI was measured and calculated (Figure 1). The plane of the articular surface of the talus was determined, and line 1 was drawn, which paralleled the articular border of the medial malleolus. Line 2 was drawn, which bisected the talus axis. Line 3 was drawn, running perpendicular to the talar axis from the anterior border of the medial malleolus. The MTI was the angle formed between lines 1 and 3.[17] A larger MTI indicated increased internal rotation of the talus.

Angle measurements were made with a picture archiving and communication system (PACS Version 11.0; Carestream

TABLE 1
Participant Characteristic Data[a]

Variable	Repair Group (n = 36)	Reconstruction Group (n = 20)	P
Sex, male:female, No.	31:5	18:2	.513
Age, y	28.4 ± 7.3	30.6 ± 9.4	.407
Height, mm	171.2 ± 7.1	168.8 ± 8.7	.532
Weight, kg	73.3 ± 11.3	73.1 ± 11.4	.723
Body mass index, kg/m^2	25.0 ± 4.2	25.9 ± 4.5	.683
Follow-up time, mo	14.7 ± 9.1	15.5 ± 9.2	.731

[a]Data are reported as mean ± SD unless otherwise indicated.

Health). The values were accurate to 1 decimal place. An independent observer (H.Y.L.) measured all index values on MRI scans. Each measurement was repeated 3 times for intraobserver analysis and calculation of mean values. The interval between measurements was at least 1 week. To test interobserver reliability, 30 MRI scans were measured independently by 2 orthopaedic surgeons (H.Y.L. and H.L.).

Statistical Analysis

All values were reported as means and standard deviations. Intra- and interobserver reliability of measurements was analyzed with the intraclass correlation coefficient (ICC). An ICC <0.4 was considered poor; between 0.4 and 0.7, moderate; and >0.7, excellent. A reliability analysis of scale was used to calculate the ICC values. After the normal distribution of variables by Kolmogorov-Smirnov test was checked, MTI values before and after the operation were compared by a paired-samples *t* test. MTI values between the repair and reconstruction groups were compared by an independent *t* test. All statistical analyses were performed with SPSS Version 19.0 (IBM). Differences were considered statistically significant at $P < .05$. Post hoc analysis was performed to calculate statistical power. As the calculated effect size was 0.7, the sample size was 48, and the α level was .05, the calculated power was 1.0.

RESULTS

Participants' characteristic data are presented in Table 1. No significant difference was found in age, sex, height, weight, or body mass index between the ligament repair and reconstruction groups. The intra- and interobserver ICCs for the MTI measurements were 0.874 and 0.835, respectively, indicating excellent reliability.

Before the operation, the mean MTI in the patients with MAI was 86.7° ± 3.9° (95% CI, 86.6°-86.8°) and varied from 79.8° to 97.6° with a range of 17.8°. After the operation, the mean MTI was 83.3° ± 3.3° (95% CI, 83.2°-83.4°) and varied from 74.3° to 90.5° with a range of 16.2°. There was a statistically significant difference in MTI before and after the operation ($P < .01$). The mean MTI decreased 3.4° ± 4.7° (95% CI, 3.6°-3.2°) after surgery.

No significant difference was found between the ligament repair and reconstruction groups before the operation (86.8° ± 3.9° vs 86.5° ± 3.9°; $P = .804$) or after (83.0° ± 3.1° vs 83.8° ± 3.7°; $P = .342$) (Table 2). AOFAS scores significantly increased after the operation (68.5 ± 5.3 vs 90.2 ± 5.3; $P < .01$). However, there was no significant difference in AOFAS scores between the repair and reconstruction groups after surgery (90.5 ± 5.6 vs 89.3 ± 5.5; $P = .336$). The anterior drawer test was negative in all participants after the operation.

TABLE 2
Results of MTI and AOFAS Scores[a]

	Repair Group	Reconstruction Group
MTI		
Preoperative	86.8° ± 3.9° (86.7°-87.0°)	86.5° ± 3.9° (86.4°-86.9°)
Postoperative	83.0° ± 3.1° (82.9°-83.2°)	83.8° ± 3.7° (83.7°-84.2°)
P	≤.001	.023
AOFAS score		
Preoperative	69.1 ± 5.2 (68.9-69.4)	67.3 ± 5.4 (67.1-67.8)
Postoperative	90.5 ± 5.6 (90.3-90.8)	89.3 ± 5.5 (89.1-89.4)
P	≤.001	≤.001

[a]Data are reported as mean ± SD (95% CI). AOFAS, American Orthopaedic Foot and Ankle Society; MTI, Malleolar Talus Index.

DISCUSSION

The most important finding of the present study was that increased internally rotated talus in patients with MAI was decreased after surgery for ankle lateral instability. Previous biomechanical studies reported that ankle lateral ligaments provide resistance to the internal rotation of the talus.[7,19] Abnormal internal rotation of the talus was found in patients with chronic ankle instability (CAI).[4,5,17] Moreover, altered cartilage loading in the medial position of the ankle joint[1] and early development of medial osteoarthritis were both determined to be caused by an internally rotated talus.[13] Thus, restoration of normal joint alignment is an important goal of surgery. Several biomechanical studies noted that lateral stabilization surgery can restore the kinematics of the ankle, especially an abnormal internally rotated talus.[2,6,21] It is undoubtedly more important to evaluate such a kinematic situation in vivo than in cadaver specimens. However, few clinical studies have evaluated the correction of abnormal geometry changes after surgery. In a clinical research study, Wainright et al[28] demonstrated that modified Broström-Gould repair significantly decreased internal rotation of the talus at 75% (2.6° ± 0.8°) and 100% (2.7° ± 0.8°) body weight. However, they used a difficult technique to evaluate the abnormal position of the talus. Moreover, their study was limited by its small sample size (only 7 patients). In the current study, we used a relatively simple and reproducible way to evaluate the rotation of the talus and employed a large sample size (N = 56) to achieve similar results, whereby internal rotation of the talus decreased 3.4° ± 4.7° after the operation.

Previous authors used different techniques to evaluate in vivo the changes in kinematics of the ankle joint. Bischof et al,[1] Caputo et al,[4] and Wainright et al[28] used MRI and biplanar fluoroscopy to measure tibiotalar kinematics. Sheehan et al[23] and Siegler et al[24] used 3-dimensional MRI to evaluate movement of the ankle and subtalar joint in vivo. Imai et al[12] and Park et al[20] used 3-dimensional computed tomography to quantify the motion of the tibiotalar joint in vivo. Although the techniques used in all of these reports are precise and reliable, their major disadvantage is that they are difficult to apply in clinical practice. In 2017, Li et al[17] introduced a new method to evaluate the rotating position of the talus on MRI. In their research, 3 lines were identified on the magnetic resonance axial plane. Line 1 was parallel to the articular border of the medial malleolus; line 2 was the bisected axis of the talus; and line 3 was perpendicular to line 2 and passed through the anterior border of the medial malleolus (Figure 1). MTI was the angle formed between lines 1 and 3, which indicates the rotated position of the talus. A larger MTI indicates increased internal rotated talus. In the study, 105 participants were measured by the MTI, whereby intra- and interobserver reliabilities were 0.994 and 0.887, respectively. The authors reported that patients with MAI have a more internally rotated talus, and they concluded that MTI is a reproducible and easy technique for evaluation of the talus position. In the current study, we used MTI to evaluate the restoration of the internally rotated talus after lateral ankle ligament reconstruction. We also found this to be a reproducible and easy technique to evaluate the talus position, which produced intra- and interobserver reliabilities of 0.874 and 0.835, respectively.

Numerous surgical techniques have been introduced to treat chronic lateral ankle instability, including nonanatomic reconstruction, anatomic repair, and anatomic reconstruction. Although nonanatomic reconstruction techniques have resulted in a high degree of patient satisfaction, these techniques are prone to numerous complications after surgery, such as alterations in ankle and hindfoot kinematics and development of osteoarthritis over the longer term.[14,15] Other studies have demonstrated that nonanatomic lateral ligament reconstruction techniques can restore talus varus stability. However, such techniques cannot properly restore the rotational stability.[20,22] Therefore, nonanatomic tenodesis should not be used for the treatment of CAI. In the current study, we found that anatomic repair and reconstruction techniques provided satisfactory clinical outcomes and decreased abnormal talus internal rotation.

This study has some limitations. First, the MRI scans were obtained from patients in a supine and nonweightbearing position. However, because the participants were scanned under the same conditions, the results were comparable. Further studies are needed to evaluate the alignment of the weightbearing ankle. Second, we evaluated only the rotation changes in the talus of patients with CAI and not the changes in the subtalar joint. Further study will be needed to evaluate the in vivo alignment changes in the subtalar joint in patients with CAI during walking. Third, we did not measure the angle in the contralateral asymptomatic ankle as a control. However, as insufficiency problems may be appearing in the contralateral ankle after the occurrence of unilateral ankle instability, we felt it inappropriate to use the contralateral ankle as a control.[17]

Abnormal internal rotation of the talus could cause medial cartilage damage. In clinical practice, this abnormal alignment should be corrected as soon as possible. In this study, ankle lateral stabilization surgery decreased the internal rotation of the talus, indicating that anatomic ligament repair and reconstruction techniques can partially rectify the abnormal alignment of the ankle joint. Thus, restoration of normal joint alignment is an important goal of surgery. Future studies should evaluate the capability of surgical stabilization to restore ankle and subtalar joint biomechanics during walking.

CONCLUSION

This study demonstrated that abnormal internal rotation of the talus in patients with MAI was decreased after ankle lateral stabilization surgery. No significant difference was found in internal rotation of the talus between patients undergoing ligament repair and ligament reconstruction.

REFERENCES

1. Bischof JE, Spritzer CE, Caputo AM, et al. In vivo cartilage contact strains in patients with lateral ankle instability. *J Biomech*. 2010; 43(13):2561-2566.
2. Boey H, Verfaillie S, Natsakis T, Vander Sloten J, Jonkers I. Augmented ligament reconstruction partially restores hindfoot and midfoot kinematics after lateral ligament ruptures. *Am J Sports Med*. 2019;47(8):1921-1930.
3. Bozkurt M, Doral MN. Anatomic factors and biomechanics in ankle instability. *Foot Ankle Clin*. 2006;11(3):451-463.
4. Caputo AM, Lee JY, Spritzer CE, et al. In vivo kinematics of the tibiotalar joint after lateral ankle instability. *Am J Sports Med*. 2009;37(11): 2241-2248.
5. Fujii T, Kitaoka HB, Watanabe K, Luo ZP, An KN. Ankle stability in simulated lateral ankle ligament injuries. *Foot Ankle Int*. 2010;31(6): 531-537.
6. Fujii T, Kitaoka HB, Watanabe K, Luo ZP, An KN. Comparison of modified Broström and Evans procedures in simulated lateral ankle injury. *Med Sci Sports Exerc*. 2006;38(6):1025-1031.
7. Guerra-Pinto F, Côrte-Real N, Mota Gomes T, et al. Rotational instability after anterior talofibular and calcaneofibular ligament section: the experimental basis for the ankle pivot test. *J Foot Ankle Surg*. 2018;57(6):1087-1091.
8. Herzog MM, Kerr ZY, Marshall SW, Wikstrom EA. Epidemiology of ankle sprains and chronic ankle instability. *J Athl Train*. 2019;54(6): 603-610.
9. Hintermann B. Biomechanics of the unstable ankle joint and clinical implications. *Med Sci Sports Exerc*. 1999;31(7):S459-S469.
10. Hua Y, Chen S, Jin Y, Zhang B, Li Y, Li H. Anatomical reconstruction of the lateral ligaments of the ankle with semitendinosus allograft. *Int Orthop*. 2012;36(10):2027-2031.
11. Hua Y, Chen S, Li Y, Chen J, Li H. Combination of modified Brostrom procedure with ankle arthroscopy for chronic ankle instability accompanied by intra-articular symptoms. *Arthroscopy*. 2010;26(4): 524-528.
12. Imai K, Tokunaga D, Takatori R, et al. In vivo three-dimensional analysis of hindfoot kinematics. *Foot Ankle Int*. 2009;30(11):1094-1100.
13. Kim JB, Yi Y, Kim JY, et al. Weight-bearing computed tomography findings in varus ankle osteoarthritis: abnormal internal rotation of the talus in the axial plane. *Skeletal Radiol*. 2017;46(8):1071-1080.

14. Krips R, Van Dijk CN, Halasi T, et al. Anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a 2- to 10-year follow-up, multicenter study. *Knee Surg Sports Traumatol Arthrosc*. 2000;8(3):173-179.
15. Krips R, Van Dijk CN, Halasi T, et al. Long-term outcome of anatomical reconstruction versus tenodesis for the treatment of chronic anterolateral instability of the ankle joint: a multicenter study. *Foot Ankle Int*. 2001;22(5):415-421.
16. Li H, Hua Y, Li H, Chen S. Anatomical reconstruction produced similarly favorable outcomes as repair procedures for the treatment of chronic lateral ankle instability at long-term follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(10):3324-3329.
17. Li HY, Zhou RS, Hua YH, Chen SY. MRI Identification of the fibular and talus position in patients with mechanical ankle instability. *Int J Sports Med*. 2017;38(7):546-550.
18. Matheny LM, Johnson NS, Liechti DJ. Activity level and function after lateral ankle ligament repair versus reconstruction. *Am J Sports Med*. 2016;44(5):1301-1308.
19. Omori G, Kawakami K, Sakamoto M, Hara T, Koga Y. The effect of an ankle brace on the 3-dimensional kinematics and tibio-talar contact condition for lateral ankle sprains. *Knee Surg Sports Traumatol Arthrosc*. 2004;12(5):457-462.
20. Park SJ, Jeong HJ, Shin HK, et al. Rotational and varus instability in chronic lateral ankle instability: in vivo 3D biomechanical analysis. *Acta Med Okayama*. 2018;72(6):583-589.
21. Prisk VR, Imhauser CW, O'Loughlin PF, Kennedy JG. Lateral ligament repair and reconstruction restore neither contact mechanics of the ankle joint nor motion patterns of the hindfoot. *J Bone Joint Surg Am*. 2010;92(14):2375-2386.
22. Sammarco VJ. Complications of lateral ankle ligament reconstruction. *Clin Orthop Relat Res*. 2001;391:123-132.
23. Sheehan FT, Seisler AR, Siegel KL. In vivo talocrural and subtalar kinematics: a non-invasive 3D dynamic MRI study. *Foot Ankle Int*. 2007;28(3):323-335.
24. Siegler S, Udupa JK, Ringleb SI, et al. Mechanics of the ankle and subtalar joints revealed through a 3D quasi-static stress MRI technique. *J Biomech*. 2005;38(3):567-578.
25. Sugimoto K, Samoto N, Takakura Y, Tamai S. Varus tilt of the tibial plafond as a factor in chronic ligament instability of the ankle. *Foot Ankle Int*. 1997;18(7):402-405.
26. Van Bergeyk AB, Younger A, Carson B. CT analysis of hindfoot alignment in chronic lateral ankle instability. *Foot Ankle Int*. 2002;23(1):37-42.
27. Vuurberg G, Pereira H, Blankevoort L, van Dijk CN. Anatomic stabilization techniques provide superior results in terms of functional outcome in patients suffering from chronic ankle instability compared to non-anatomic techniques. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(7):2183-2195.
28. Wainright WB, Spritzer CE, Lee JY, et al. The effect of modified Broström-Gould repair for lateral ankle instability on in vivo tibiotalar kinematics. *Am J Sports Med*. 2012;40(9):2099-2104.