Dynamic and Stabilometric Analysis After Syndesmosis Injuries

A Comparative Study

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Background: Distal tibiofibular syndesmosis contributes to dynamic stability of the ankle joint and thereby affects gait cycle. The purpose of this study was to evaluate the grade of syndesmosis injury on plantar pressure distribution and dynamic parameters of the foot.

Methods: Grade of syndesmosis injury was determined by preoperative plain radiographic evaluation, intraoperative hook test, or external rotation stress test under fluoroscopic examination, and two groups were created: group 1, patients with grade III syndesmosis injury (n = 17); and group 2, patients with grade II syndesmosis injury (n = 10). At the last visit, radiologic and clinical assessment using the Foot and Ankle Outcome Score was performed. Dynamic and stabilometric analysis was carried out at least 1 year after surgery.

Results: The mean age of the patients was 48.9 years (range, 17–80 years), and the mean follow-up was 16 months (range, 12–24 months). No statistically significant difference was noted between two groups regarding Foot and Ankle Outcome Score. The comparison of stabilometric and dynamic analysis revealed no significant difference between grade II and grade III injuries ($P > .05$). However, comparison of the data of patients with grade III syndesmosis injury between injured and healthy feet showed a significant difference for dynamic maximum and mean pressures ($P = .035$ and $P = .49$, respectively).

Conclusions: Syndesmosis injury does not affect stance phase but affects the gait cycle by generating increased pressures on the uninjured foot and decreased pressures on the injured foot. With the help of pedobarography, processing suitable orthopedic insoles for the injured foot and interceptive measures for overloading of the normal foot may prevent later consequences of ankle trauma. (J Am Podiatr Med Assoc 110(4): 1-7, 2020)

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Distal tibiofibular syndesmosis injuries accompany 5% to 10% of all ankle sprains and 23% of all ankle fractures.[1,2] The most common mechanism of syndesmotic injury is excessive external rotation of the ankle with hyperdorsiflexion with or without abduction or adduction of the ankle. The distal fibular fragment is forced in the lateral direction by the posterior tubercle on the tibial incisura acting as a fulcrum. Currently, there is no universally accepted classification system for syndesmosis injuries, but according to the most accepted grading for these injuries, three types exist: grade I,

incomplete injury with a stable joint; grade II, complete anterior inferior tibiofibular ligament and interosseous ligament with a moderately stable joint; and grade III, complete injury of all lateral ligaments (including the posteroinferior tibiofibular ligament and transverse ligament) and deltoid avulsion with an unstable joint. Despite the number of publications, the best management of syndesmosis injuries is controversial, and most cases of supination and external rotation fracture associated with syndesmosis injuries are treated surgically. After placing a clamp with a neutral anatomical axis to reduce the syndesmosis, single or double screws, bioabsorbable screws, or suture-button implants are placed across the syndesmosis.

Distal tibiofibular syndesmosis contributes to dynamic stability of the ankle joint. An overlooked or mismanaged injury by malreduction of diastasis will alter ankle joint kinematics and lead to long-term dysfunction.[3-5] A comprehensive study by Sagi et al[6] examined functional consequences of chronic syndesmotic instability and found significantly worse functional scores in patients with malreduction. As at least two lateral ligaments and deltoid injury are necessary for obvious syndesmosis injury, the instability may remain in case of deltoid incompetence and talar subluxation despite a well-fixed fibular fracture.[7] If a misdiagnosed syndesmotic instability persists, it may result in late consequences such as stiffness, pain, and arthrosis of the ankle joint. To evaluate consequences of persistent syndesmosis instability, a prospective gait analysis study was performed on patients 1 year after ankle fracture. This study found less plantar flexion, decreased step/stride length and forefoot adduction in the swing phase, and a prolonged double-support phase.[8] This is the only study that evaluates gait after ankle fractures; however, the effect of syndesmosis injury on stabilometry or gait parameters after treatment has not been evaluated. The pedobarographic analysis is able to show the distribution of the pressure beneath the foot with simple dynamic analysis including stride length, walking speed, and cadence.

This analysis therefore may contribute to understanding of consequences of such injuries and thereby may shorten the recovery period by use of suitable orthopedic insoles. Our hypothesis was that syndesmosis injury would maintain evenly distributed loading compared with the uninjured foot and patients without syndesmosis injuries after the recovery period. Secondarily, we hypothesized that a well-fixed syndesmosis would have good functional outcomes.

Materials and Methods

Institutional review board approval was given by the ethics committee of the hospital (decision number 312/2016). This retrospective study evaluated patients with grade II or III syndesmosis injuries (n = 27) that were treated surgically between May of 2015 and February of 2016. Patients with grade II to III syndesmosis injuries, older than 16 years, with a minimum 12 months of follow-up, and who agreed to participate were included. Exclusion criteria were concomitant fractures other than the same ankle, obvious angular deformity at the contralateral ankle, previous ipsilateral and/or contralateral extremity trauma that could influence the pedobarographic evaluation, psychiatric diseases, and malign obesity. Patients were advised to participate in the study by telephone interview, and written informed consent was obtained.

Preoperative radiographic parameters including increased tibiofibular clear space (>6 mm), decreased tibiofibular overlap (<1 mm), and/or increased medial clear space (greater than superior clear space) were sufficient to diagnose unstable (grade III) injuries, and clinical signs (positive external rotation and squeeze tests) were performed to diagnose grade II injuries where radiographs were normal. All preoperative radiographs or intraoperative fluoroscopic examinations were performed on a nonweightbearing basis. Intraoperative hook test or lateral translation and external rotation stress test under fluoroscopic examination was also performed for determination of syndesmosis stability in all patients. Preoperative radiologic examination revealed 15 grade III injuries, and intraoperative examination revealed an additional two grade III injuries. Thus, two groups were created: group 1, patients with syndesmosis instability (n = 17); and group 2, patients with moderately stable syndesmosis (n = 10). All fractures were classified according to Lauge-Hansen and Weber.[9]

A direct lateral access route to the fibular fracture was used, and angle-stable locking fibular plate osteosynthesis (aap Implantate AG, Berlin, Germany) was performed in all cases. Medial malleolar fractures were fixed after anatomical reduction of the fracture by two cannulated 4.0-mm screws. Early functional range-of-motion exercises were begun in both groups. Routine postoperative follow-up was performed in both groups, including toe-touch ambulation for the first 4 weeks and

Table 1. Patient Demographics

Characteristic	Group 1	Group 2	Total
No. of patients	17	10	
Age (years)			
Mean	15	47	
Range	17–80	21–71	
BMI (kg/m^2)			
Mean	30.53	32.4	
Range	26–40	27–36	
Side			
Right	6	7	13
Left	11	3	14
Gender			
Male	9	5	14
Female	8	5	13
Weber			
A	—	2	2
B	2	5	20
C	15	3	5
Lauge-Hansen			
SER	15	5	20
SAD	—	2	2
PAD	1	1	2
PER	1	2	3

Abbreviations: BMI, body mass index; PAD, pronation adduction; PER, pronation external rotation; SAD, supination adduction; SER, supination external rotation.

graduated weightbearing thereafter depending on pain tolerance. Patients were advised to visit the outpatient clinic before the pedobarographic examination, and their full hospital charts including preoperative radiographs and operative notes were obtained. Current radiologic and clinical assessment of the ankle was performed, and the Foot and Ankle Outcome Score (FOAS) questionnaire was handed out. Pedobarographic analysis was carried out at least 1 year postoperatively.

Pedobarography

Dynamic pedobarography was carried out in an area measuring 4 m long and 1 m wide, controlling a resolution of 262,144 sensors, allowed by the surface analysis of the platform composed of seven sensors per square centimeter (Modular Clinical Electronic Baropodometer; Diasu Company, Rome, Italy). The subjects were allowed five trial attempts. The average walking speed was measured from these attempts, and single pressure evaluation, which did not deviate more than 10% from the average walking speed, was used to prevent the effect of walking speed on evaluation. Maximum and mean foot pressures and differences between center of force (gravity) and center of maximum pressure, forefoot and hindfoot areas, and forefoot and hindfoot loading were analyzed. At least 4 months had elapsed since surgery before analysis was performed, according to Dattani et al.[10]

Questionnaire

The FAOS is a patient-administered 42-item questionnaire and has been used to evaluate patient-relevant outcomes after ankle reconstruction for lateral ankle instability.[11] It consists of five subscales including pain, other symptoms, function in daily living, function in sport and recreation, and foot and ankle–related quality of life. Total scores of each subscale are summed and divided by the maximum score for the subscale. Zero to 100 points are possible; 100 indicates no problem and 0 indicates an extreme problem.

Statistical Analysis

SPSS version 11.5 (SPSS Inc, Chicago, Illinois) was used for data analysis. Median and range for metric variables, and frequency and percent for categorical variables were given as descriptive statistics. The FAOS and pressure measurements between the two groups were compared with the Pearson χ^2 test, the Mann-Whitney U test, and the Wilcoxon signed ranks test where appropriate. The significance level was set at 5% ($\alpha = 0.05$).

Results

Table 1 presents baseline characteristics and demographics of the two treatment groups. No statistically significant differences between the two groups regarding age, body mass index, gender, or fracture classification were noted. The mean age of the patients was 48.9 years (range, 17–80 years) and the mean follow-up was 16 months (range, 12–24 months). Open reduction and internal fixation of the syndesmosis was performed by a single 3.5-mm cortical screw purchasing either three ($n = 9$) or four ($n = 8$) cortices leveling 2 to 5 cm above the ankle joint. Nonunion, deep infection, or neurovascular complication was not seen among patients. Preoperative skeletal traction from calcaneus was applied to two patients because of severe preoperative fracture instability, and serial debridement to the lateral side was performed on one because of wound dehiscence. Implant removal was performed in only two patients for skin irritation at 4 months postoperatively, and screw breakage was seen in six of eight patients where four cortices were pur-

Table 2. Comparison of the Two Groups Regarding FOAS

FOAS Subscale	Group 1	Group 2	*P* Value
Pain	80.083	85.643	.563
Symptom	78.417	85.5	.467
ADL	79.125	84.286	.633
Sports	61.250	62.857	.912
QOL	72.5	85.5	.307

Abbreviations: ADL, activities of daily living; FOAS, Foot and Ankle Outcome Score; QOL, quality of life.

chased. No statistically significant difference was noted between the two groups regarding FAOS (Table 2). Although nominal values of the sport subscale of their FAOS between the two groups were almost equal, pain, symptom, activities of daily living, and quality-of-life subscales were slightly higher in group 1.

The mean time from injury to pedobarographic evaluation was 14 months (range, 13–17 months). Stabilometric and dynamic findings of the two groups are shown in Table 3. The comparison of stabilometric data and dynamic analysis revealed no statistically significant difference between the two groups. However, comparison of the data of patients with syndesmosis injury between injured and healthy feet showed significant differences for dynamic maximum and mean pressures ($P = .035$ and $P = .049$, respectively) (Fig. 1 and Table 4).

Discussion

Syndesmosis injury results in disruption of anterior inferior syndesmotic ligaments that are essential for creation of the ankle mortise.[11] Acute ankle instability caused by syndesmotic diastasis or lateral ligamentous complex injury that may or may not be accompanied by a fracture not only alters ankle mechanics but also impairs ankle joint position sense by damaging mechanoreceptors, ligaments, and capsule, leading to proprioceptive deficit.[12] Subsequent functional instability after lateral ligamentous disruption, which alters force transfer from foot to the floor, has been evaluated extensively in the literature. However, peak force transfer changes after treatment of a syndesmotic injury have not been evaluated before. This study was designed to compare pressure changes in patients with unstable syndesmosis injury with their healthy foot and also compare them with moderately stable syndesmosis injuries. We found that patients with unstable syndesmosis injuries demonstrated similar patient-relevant outcomes but alterations in loading of the whole foot, especially a decrease in loading of the hindfoot in the stance phase of gait.

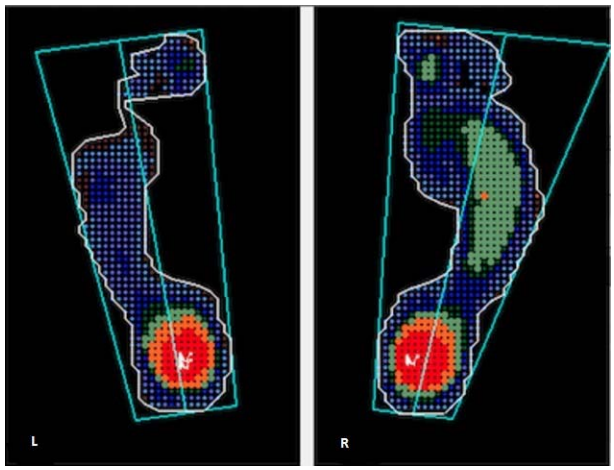


Figure 1. Dynamic analysis of a 19-year-old man with a body mass index of 32 kg/m^2. The patient had sustained a supination external rotation injury of his left foot; bimalleolar and syndesmosis fixation was performed, and the syndesmosis screw was removed at the end of the third month. This figure depicts apparent hyperloading of the healthy foot after 13 months postoperatively.

Gigi et al[13] analyzed spatiotemporal gait parameters in patients with chronic ankle instability caused by lateral ligamentous complex injury and found significant differences in gait velocity, cadence, step length, stride length, single-limb support, and double-limb support. Similarly, Nyska et al[14] examined dynamic force distribution in patients with chronic ankle instability. They focused primarily on the pattern of walking and stated that similar distribution of plantar foot pressure changes in patients with chronic instability and in healthy controls might be explained by altered central control. As is well known, plantar flexion of the foot at the end of the stance phase puts the foot in a less stable position, leading to a longer contact time and increased loading of the lateral foot. Our dynamic pedobarographic analysis showed that after surgical fixation of syndesmosis, there would be no change in hindfoot axis or foot angle, which signifies evenly distributed loading of the foot. However, static analysis demonstrated significant pressure changes between the healthy foot and the injured foot up to 14 months postoperatively. Patients hesitated to load the hindfoot; midfoot and forefoot loading was increased with respect to the hindfoot.

In addition to the radiographic and clinical assessment of surgical treatment of syndesmosis

Table 3. Comparison of Stabilometric Data and Dynamic Analysis of the Two Groups

Characteristic	Group 1	Group 2	*P* Value
LFF (%)			.414
Right			
Median	47	46.6	
Range	35.1–66.8	42.2–51.3	
Left			
Median	44.52	47.1	
Range	25.7–52.2	40–48.9	
LHF (%)			.47
Right			
Median	53	53.4	
Range	33.3–64.9	48.7–57.8	
Left			
Median	53.5	52.9	
Range	47.8–74.3	51.1–60	
TA (cm^2)			.132
Right			
Median	132	136.6	
Range	85.8–186.5	123–176.5	
Left			
Median	122.5	124.4	
Range	93.5–175.3	100.5–153	
DTA (cm^2)			.744
Right			
Median	114.3	120.3	
Range	85.3–159.8	102.8–163	
Left			
Median	104.5	113.1	
Range	76.5–155	11.75–129.5	
DLHF (kg)			.422
Right			
Median	55.2	56	
Range	35.8–67.3	43.9–65.4	
Left			
Median	56.2	53.9	
Range	26.5–65.1	43.6–72.4	
DLHF (kg)			.407
Right			
Median	43.6	42.2	
Range	31.7–62.4	33.5–54.3	
Left			
Median	42	45.1	
Range	32.8–71	26.9–53.2	
DPMax (g/cm^2)			.514
Right			
Median	1145.4	1277.6	
Range	938.4–1867.3	944.2–1610.1	
Left			
Median	1269.6	1451.1	
Range	893.6–2145.5	238.5–1737	
DPMean (g/cm)			.482
Right			
Median	678.7	742.3	
Range	579.1–1061	539.2–8722.7	
Left			
Median	765.6	786.5	
Range	514.6–1018.3	619.2–1113	
CoFCoP (mm)			.091
Right			
Median	19	23	
Range	5–31	14–30	
Left			
Median	21	21.5	
Range	11–27	16–32	

Abbreviations: CoFCoP, difference between center of force and center of pressure; DLFF, dynamic loading forefoot; DLHF, dynamic loading hindfoot; LFF, loading forefoot; LHF, loading hindfoot; DTA, dynamic total area; DPMax, dynamic maximum pressure; DPMean, dynamic mean pressure; TA, total area.

injuries, dynamic and static pedobarographic evaluation was performed to provide additional information on foot pressure changes in this study. Our results agree with those of previous studies that have shown that plantar pressure changes appear after ankle trauma. Çolak et al[15] have performed pedobarographic pressure analysis after talar neck fractures and found results similar to those of our report (ie, the mean maximum force in the hindfoot decreases significantly[15]). Correspondingly, pedobarographic analysis of the foot after calcaneal fractures showed that maximum pressures in the forefoot and medial hindfoot significantly decrease with lateralization of the gait line.[16-18]

In this study, we did not intend to debate the pros and cons of operative treatment for syndesmosis injuries. However, we found that FAOS scores showed significant improvements in both groups. The FOAS has been reported to be useful for the

Table 4. Subgroup Comparative Analysis Regarding Grade III Syndesmosis Injury with Healthy Foot

Characteristic	Fixed	Healthy	*P* Value
CoFCoP	19.8 ± 5.58	22.8 ± 5.62	.897
DPMean	757.9 ± 151.6	1156.1 ± 1346.5	.049[a]
DPMax	1337.5 ± 319.3	1367.5 ± 234.3	.035 [a]
DTA	113.7 ± 21.5	113.6 ± 26.7	.062
DLHF	45.1 ± 9.1	43.4 ± 7.54	.653
DLFF	53.2 ± 9.3	55.06 ± 7.8	.887
TA	124.7 ± 24.5	135.6 ± 19.5	.193
LHF	54.5 ± 6.7	53.6 ± 3.1	.21
LFF	45.5 ± 6.7	46.4 ± 3.1	.215

Abbreviations: CoFCoP, difference between center of force and center of pressure; DPMax, dynamic maximum pressure; DPMean, dynamic mean pressure; DLFF, dynamic loading forefoot; DLHF, dynamic loading hindfoot; DTA, dynamic total area; LFF, loading forefoot; LHF, loading hindfoot; TA, total area.

[a]Statistically significant.

evaluation of patient-relevant outcomes related to ankle reconstruction. The comparison of outcome data showed a statistically insignificant difference between the two groups, but quantitative comparison showed higher scores in group 2. This is probably attributable to the severity of initial trauma.

Chissel and Jones[19] recommended fixation of the syndesmosis when the fracture is greater than 3.5 cm above the joint line and the deltoid ligament is ruptured or when a bimalleolar fracture is incurred, with a fibular fracture greater than 15 cm above the joint line. Fixation can be carried out with metal screws or suture-button implants. The most accurate way of determining exact reduction is intraoperative computed tomography, but the most feasible method is intraoperative direct visualization or fluoroscopic examination of the tibiofibular line.[2-20]

This study is not without limitations that must be taken into consideration. First, our retrospective study seems to include a relatively small number of cases. However, a post hoc power analysis revealed that a sample size of 17 in group 1 including injured and healthy feet provided 80.9% power at a two-sided alpha level of 0.035 to detect a significant difference at foot pressures with an effect size of 0.8. Second, the accurate reduction of the syndesmosis, which has been shown to affect the final outcome substantially, was not evaluated. Although we performed an open reduction that made it possible to carry out anatomical reduction of the syndesmosis, Sagi et al[6] reported a malreduction rate of 15% with open assessment versus 44% with fluoroscopic assessment. A more comprehensive study comparing pedobarographic measurements in patients with malreduction and anatomical reduction should be performed. Third, we are unaware of any study that used the modular Clinical Electronic Baropodometer system. Currently, the most commonly used system is the emed-a50 system, which differs in sensor numbers and having different platform features that may have an impact on pressure measurements.

Conclusions

In conclusion, syndesmosis injury does not affect stance phase but affects the gait cycle by generating increased pressures on the uninjured foot and decreased pressures on the injured foot. During the early stance and midstance phases of the gait cycle, the foot dorsiflexes and the talus pronates, leading to stress on the tibiofibular ligament. This may elucidate decreased pressures on the whole foot arguably caused by hesitation of the patient to loading. With the help of pedobarography processing, suitable orthopedic insoles for the injured foot and interceptive measures for overloading of the normal foot may prevent later consequences of ankle trauma.

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