Arthroscopic Repair of Chronic Plantar Plate Tears of the First Metatarsophalangeal Joint

A New Surgical Technique With Patient Outcomes

Elisabeth Ellingsen Husebye,*† MD, PhD and Are Haukåen Stødle,† MD, PhD

Investigation performed at Oslo University Hospital, Oslo, Norway

Background: Most plantar plate tears of the first metatarsophalangeal joint can be treated successfully by nonoperative means. Primary repair may be indicated to restore continuity of the plantar structures and joint stability. Inadequate or failed nonoperative treatment may cause persistent pain and disability and thereby represent a career-threatening injury to an athlete. The chronic plantar plate tears are difficult both to diagnose and to treat. When surgical treatment is indicated, traditionally a wide plantar or 2 parallel incisions are used. An arthroscopic approach allows for verification and visualization of the injury and, at the same time, repair of the injury.

Purpose: To describe findings of plantar plate tears, present a new arthroscopic procedure for plantar plate tear repair, and present the outcomes after surgery.

Study Design: Case series; Level of evidence, 4.

Methods: This was a retrospective study on the first 10 patients treated with the arthroscopic technique. The patients underwent surgery between June 2017 and January 2021. Patient data, clinical symptoms and findings, and operative details were obtained from the patient records. Patients were contacted via email to complete patient-reported outcome measures (Manchester Oxford Foot Questionnaire [MOxFQ] and Numeric Rating Scale [NRS] for pain).

Results: Four female and 6 male patients with a median age of 24 years (range, 12-44 years) were operated on at a median of 20 months (range, 2-38 months) after injury. Of the 10 patients, 8 had a hyperextension injury of the first metatarsophalangeal joint and 7 had a subtle valgus malalignment of the hallux; 8 patients were injured during sport activity. All patients reported plantar pain at pushoff. All but 1 patient returned to the same level of preinjury activity within 6 months. At a median of 29 months (range, 7-49 months) after surgery, the median MOxFQ score was 6 (range, 0-41) and the median NRS pain score was 0.

Conclusion: Arthroscopic plantar plate repair of chronic plantar plate tears resulted in a high rate of return to activity/sport and excellent outcome scores.

Keywords: plantar plate; turf toe; arthroscopic repair; first metatarsophalangeal joint; sport; hallux; metatarsophalangeal joint sprain

*Address correspondence to Elisabeth Ellingsen Husebye, MD, PhD, Division of Orthopaedic Surgery, Oslo University Hospital, Oslo, Norway (email uxngng@ous-hf.no, elis.e.husebye@gmail.com) (Twitter: @ElisabethEllin9).

†Division of Orthopaedic Surgery, Oslo University Hospital, Oslo, Norway.

Final revision submitted August 25, 2022; accepted August 30, 2022.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Oslo University Hospital (reference No. 18/11866).

The Orthopaedic Journal of Sports Medicine, 10(12), 23259671221137558
DOI: 10.1177/23259671221137558

The plantar plate of the first metatarsophalangeal joint (MTPJ-1) is a thickening of the plantar joint capsule and receives fibers from the flexor hallucis brevis tendons, the intermetatarsal ligament, the plantar fasciae, and the phalangeal sesamoid ligaments.[19,23,31] The plantar plate is designed to stabilize and resist hyperextension of the joint and stabilize the joint in the sagittal plane. Both the medial and the lateral sesamoids are embedded in the plantar plate. The most frequently reported mechanism of injury of the plantar plate of the MTPJ-1 is axial loading with hyperextension.[6,26] The term "turf toe" is often used to describe this hyperextension injury to the MTPJ-1.

Plantar plate injury can represent a significant injury to the MTPJ-1, with major impact on an athlete's career, and it requires a high index of suspicion.[9,21] If unrecognized, it can result in chronic problems including persistent pain,

reduced push-off strength, progressive deformity, and eventually joint degeneration.[2,18] The great majority of the MTPJ-1 plantar plate tears are successfully treated nonoperatively.[13,18,27] Primary repair could be indicated when a significant vertical or valgus instability is present, at diastasis of bipartite sesamoids or sesamoid fractures, at retraction of sesamoid(s), or by chondral injuries or loose bodies.[2,3,11,12,18,19] Surgical intervention can also be indicated in cases in which nonoperative treatment has failed, or by delayed diagnosed and inadequately treated injury with persistent symptoms.[18] These chronic injuries are difficult to diagnose and treat. Traditionally, in both acute and chronic situations, a wide plantar incision or a dual incision for medial and lateral access has been used for plantar plate repair of the MTPJ-1.[1,9,28]

In this study, we present the symptoms and findings, the surgical procedure, and the results after a new arthroscopic procedure for plantar plate tear repair in patients with chronic plantar plate injury of the MTPJ-1. Our hypothesis was that arthroscopic repair of the MTPJ-1 plantar plate would result in a high return to preinjury level of activity.

METHODS

This study was approved by the data protector officer at Oslo University Hospital, and the patient or the patient's parent signed an informed consent. Included were patients who underwent arthroscopic repair of the MTPJ-1 plantar plate at a single institution between June 2017 and January 2021. Ten patients (4 female, 6 male; 6 left foot, 4 right foot) were eligible for inclusion. Patient data, clinical findings, and symptoms were obtained from the medical records. Weightbearing radiographs and magnetic resonance imaging (MRI) scans were available for all patients.

For the evaluation of vertical joint instability, the Lachman test was used. It was considered positive when a clear difference to the contralateral side was present. Reduced range of motion (ROM) was defined when the extension of MTPJ-1was $<45^{\circ}$. Subtle hallux valgus deformity was a clinical observation, defined as the first toe just touching the second toe at weightbearing and not doing so on the contralateral side. The subtle valgus finding was not verified on weightbearing radiographs.

The surgery was performed at a single center by surgeons with experience in foot and ankle arthroscopy. The indication we used for arthroscopic plantar plate surgery was patients with a history, symptoms, and findings compatible with late diagnosed or failed nonoperative treatment of plantar plate tear of the MTPJ-1.[3] Patients with an isolated medial collateral ligament injury or an injury to the abductor hallucis tendon were excluded.

Preparation for Surgery

The patients were operated on under general anesthesia. They were placed on the operating table in a supine position with a pneumatic tourniquet applied to the ipsilateral thigh. The injured foot was prepared with chlorhexidine ethanol solution (Klorhexidinsprit farget, 5 mg/mL; Fresenius Kabi Norge A/S). A cushion was placed under the ankle.

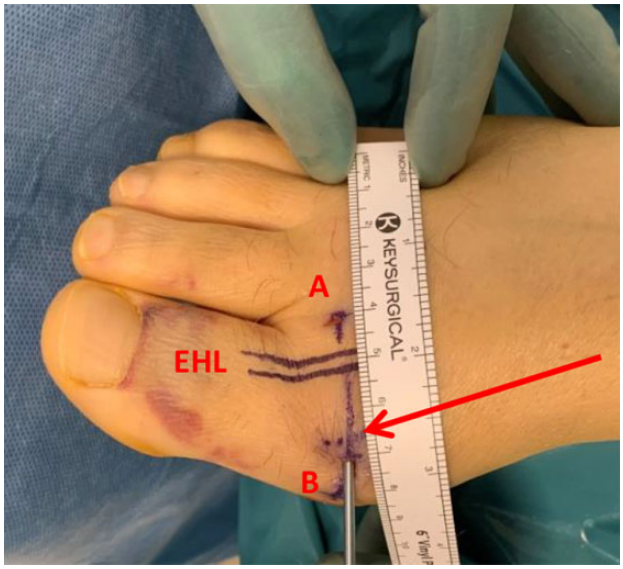

Figure 1. Placement of the portals related to the extensor halluces longus tendon (EHL) for arthroscopy of the right first metatarsophalangeal joint; the dorsolateral portal is *A*, and the dorsomedial portal is *B*. A branch of the peroneus superficialis nerve is marked on the dorsomedial aspect of the base of the great toe (arrow). The arthroscope enters the joint through the dorsomedial portal.

Surgical Technique

A dorsomedial and a dorsolateral portal were made 6 to 9 mm laterally and 15 to 20 mm medially to the extensor hallucis longus tendon at the joint level as shown in Figure 1. The 1.9-mm arthroscope (NanoScope; Arthrex, Inc) was introduced through the dorsomedial portal (Figure 1), carefully avoiding the medial cutaneal branch of the peroneus superficialis nerve. The nerve branch was palpated and marked before the skin incisions were made. In order to help locate the nerve, the end of a marker pen was carefully slid across the skin and the nerve could be felt rolling under the marker pen.

A 2.0-mm shaver was introduced through the dorsolateral portal. An accessory direct medial sesamoidal portal was established in the joint line, at a level just dorsal to the articulation of the medial sesamoid to the metatarsal head (Figure 2). A self-retaining retractor with pin guides was placed slightly plantar on the medial side, to avoid interference with the working portals (Figure 3). The joint was distracted.

Irrigation was obtained manually using a 50-mL syringe attached to an extension line. An endoscopic debridement was performed. The cartilage was inspected with regard to any cartilage injury or degeneration. The plantar plate tear was located (Figure 4). At the edge of the proximal phalanx, the footprint of the plantar plate was prepared with a shaver to facilitate the surface for reattachment. When the

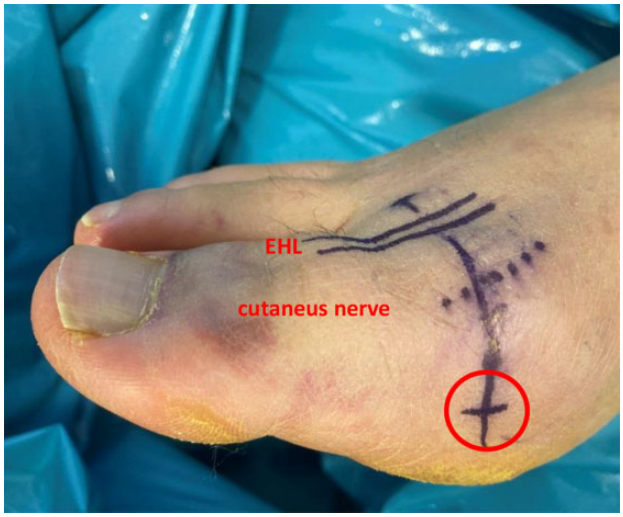

Figure 2. Location of the direct medial accessory portal (circle). EHL, extensor halluces longus tendon.

Figure 3. Placement of the self-retaining retractor with pin guides at the medial aspect of the right foot.

rupture involved the central part of the plantar plate, the flexor hallucis longus tendon could be visualized plantar to the plantar plate.

The procedure for placing the suture in the plantar plate is shown in Figure 5. A suture introducer, loaded with a loop wire (suture passing wire; Arthrex), was passed through the direct medial portal to puncture down and up in the plantar plate from medial to lateral (Figure 5A). Using a loop wire, (No. 0 FiberWire; Arthrex) we passed a suture through the plantar plate (Figure 5B). Care was taken not to injure or pass the suture through the flexor hallucis longus tendon. The suture ends were pulled out of the joint through the portals. At this point, the suture passed from the dorsolateral portal into the joint, through

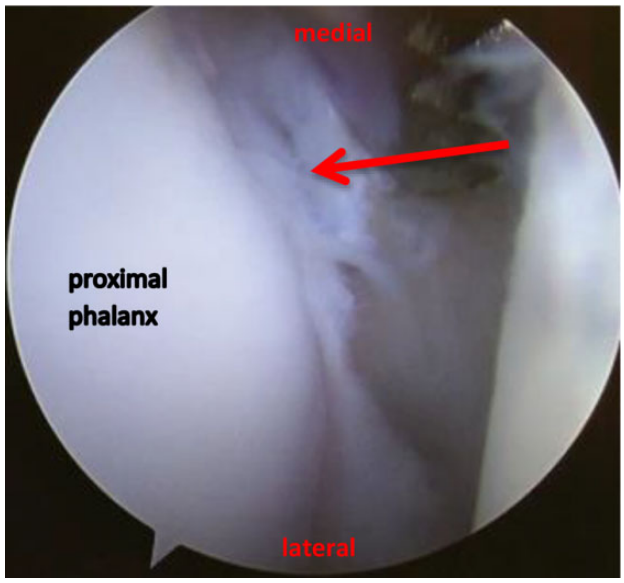

Figure 4. Dorsolateral view of the plantar plate tear (arrow) at the base of the proximal phalanx.

the plantar plate, and out of the joint again through the medial or dorsomedial portal (Figure 5C).

Two bone tunnels were made percutaneously in the proximal phalanx with a 1.8-mm Kirschner wire, from dorsomedial to plantomedial and dorsolateral to plantolateral (Figure 5D). The bone tunnels were made at a 30° to 40° angle to the proximal phalanx, perforating the cortex of the phalanx just distal to the cartilage of the MTPJ-1. At this point, it was important to precisely localize the plantar exit of the Kirschner wire, coinciding with the previously prepared footprint of the plantar plate. The correct placement of the bone tunnels is both difficult and crucial. The bone tunnel placements were controlled arthroscopically and fluoroscopically. A suture retriever funnel was introduced in the bone tunnels. A loop wire entered the joint through the funnel (Figure 5E) and was pulled out of the dorsomedial or direct medial portal, and the suture was passed through the loop of the wire and pulled out through the bone tunnel. The same procedure was performed for the lateral end of the suture (Figure 5F). The toe was reduced in a slightly plantarflexed position and the suture was tightened and tied over the bony bridge at the dorsal aspect of the phalanx. The stability of the first MTPJ-1 was tested. The wounds were closed, and a sterile dressing was applied.

Rehabilitation

The patients were advised to keep the foot elevated for 2 to 3 days after surgery to reduce pain and swelling. Thereafter, gentle passive and active dorsi- and plantarflexion exercises were recommended. Weightbearing was allowed in a surgical shoe or a walker boot for the first 6 to 8 weeks; no active toe-off was allowed. A silicone spacer was placed between the first and second toe for 12 weeks after surgery to avoid stress to the medial plantar structures of the

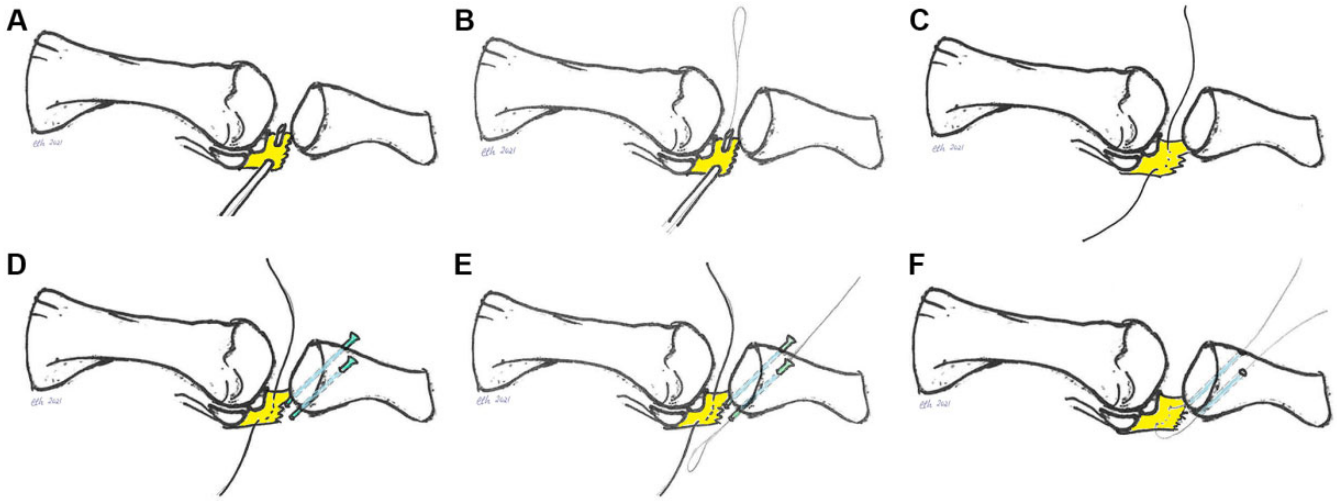

Figure 5. Illustrations of the suture passing through the plantar plate and the bone tunnels in the proximal phalanx. (A) The suture introducer enters the joint through the medial portal and passes through the plantar plate. (B) A loop wire passes through the suture introducer and is loaded with the suture. (C) The suture introducer is removed and leaves the suture in the plantar plate. (D) Bone tunnels are made in the proximal phalanx. (E) With a loop wire, the suture is led through the bone tunnels in the proximal phalanx. (F) The suture then passes through a bone tunnel in the proximal phalanx, through the plantar plate, and back through a second bone tunnel in the proximal phalanx.

MTPJ-1. After 6 to 8 weeks, the patients were allowed to gradually increase pushoff in a normal shoe, with a slightly more rigid sole, for another 6 to 8 weeks. Running activities were allowed from 8 to 12 weeks after surgery. The patients were to avoid contact sports and activities including axial load pushoff, pivoting, and loaded dorsiflexion for 3 to 4 months.

Outcome Measures

Outcome measures included the Norwegian version of the Manchester Oxford Foot Questionnaire (MOxFQ; range, 0 [best] to 100 [worst]). The MOxFQ has shown good reliability, validity, and responsiveness for various foot and ankle conditions.[10,20] Scores from the 3 MOxFQ subdomains (walking/standing, pain, and social interaction) as well as the total score were recorded. In addition, patients completed a Numeric Rating Scale (NRS) for pain (range, 0 [no pain] to 10 [worst pain imaginable]).[14] The MOxFQ and NRS were emailed to the patients.

Statistical Analysis

Data are presented as median values with ranges.

RESULTS

The median age of the 10 study patients was 24 years (range, 12-44 years). The median time from injury to operative treatment was 20 months (range, 2-38 months). The final physical follow-up examination was at a median of 12 months (range, 6-15 months) postoperatively, and the median follow-up time for patient-reported outcomes was 29 months (range, 7-49 months).

Preoperatively, all patients had plantar pain on palpation, push-off pain, and pain at passive maximal extension of MTPJ-1. Mechanisms of injury, sport/activity performed at the time of injury, and clinical findings and symptoms are presented in Table 1. None of the patients had an interphalangeal join flexion contracture with dorsal dislocation or subluxation. A comparison of the plantarflexion strength to the contralateral side was not performed in any of the patients.

None of the patients had proximal retracted sesamoids on radiographs. The MRI reports describe a plantar plate disruption in 5 of the 10 patients. Two of the MRI scan series had 1-mm slice thickness; the rest of the MRI scans had thicker slices.

All tears were medially or centromedially located. None of the patients had cartilage injuries, and all but 1 patient had synovitis in the area of the plantar plate tear. The duration of surgery was a median of 121 minutes (range, 75-170 minutes).

Between 3 and 6 months postoperatively, all except 1 patient returned to the same level of activity as before injury. At the final physical follow-up at 12 months after surgery, 1 patient had reduced skin sensation, 7 patients had minor reduced ROM of MTPJ-1 compared with the other foot, and the subtle valgus deformity was only corrected in 2 of the 7 patients. The median MOxFQ subscores at 29 months after surgery were as follows: walking/standing, 2 (range, 0-54); pain, 10 (range, 0-40), and social interaction, 0 (range, 0-38). The median MOxFQ total score was 6 (range, 0-41). The median NRS for pain was 0 (range, 0-2). The scores are presented in Table 2.

TABLE 1
Preoperative Patient and Injury Characteristics and Clinical Findings (N = 10 patients)[a]

	Patient No.									
	1	2	3	4	5	6	7	8	9	10
Sex	M	F	F	F	M	M	M	M	F	M
Age, y	26	12	44	17	23	28	25	26	15	28
Activity at injury	Soccer	Handball	Sprint	Soccer	Boat in high sea	Martial arts	Soccer	Motocross	Handball	Running
Injury mechanism	Valgus, HE	Multiple HE	Valgus, plantarflexion	HE	Unknown	HE, twisting, valgus	HE	HE	Valgus, HE	HE
Position of toe 1	Subtle valgus	Normal	Subtle valgus	Normal	Subtle valgus	Normal	Subtle valgus	Subtle valgus	Subtle valgus	Subtle valgus
ROM MTPJ	Reduced	Reduced	Reduced	Normal	Normal	Normal	Normal	NA	Reduced	Normal
Lachman, preop/relaxed[b]	+/+	–/+	+/+	–/+	–/+	+/+	–/–	–/–	–/–	+/+
Pain location	Plantomedial	Plantocentral	Plantomedial	Plantomedial	Plantomedial	Plantomedial	Plantomedial	Plantomedial	Plantomedial	Plantomedial
Pain										
At passive max extension	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
At rest	No	No	Yes	No	Yes	No	No	NA	Yes	No
Walking	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
At night	No	No	Yes	No	Yes	No	No	Yes	No	No
Running, activity	Yes	Unable	Unable	Yes	Unable	Yes	Yes	Yes	Unable	Yes
Pushoff	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Feeling of instability	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No

[a]–, negative Lachman test; +, positive Lachman test; F, female; HE, hyperextension; M, male; max, maximum; NA, not available (no registration exists); preop, preoperative; ROM MTPJ, range of motion of first metatarsophalangeal joint.
[b]Stability of the first metatarsophalangeal joint was evaluated at the outpatient clinic and also after general anesthesia on the operating table.

TABLE 2
MOxFQ and NRS Scores[a]

	Patient No.										
	1	2	3	4	5	6	7	8	9	10	Median
MOxFQ											
Walking/standing	0	0	21	29	4	0	0	4	0	54	2
Pain	10	0	40	20	5	10	5	20	5	25	10
Social interaction	25	0	19	13	0	0	0	0	0	38	0
Total	9	0	27	22	3	3	2	8	2	41	6
NRS for pain	2	0	1	1	0	0	0	0	0	2	0

[a]MOxFQ, Manchester Oxford Foot Questionnaire; NRS, Numeric Rating Scale.

DISCUSSION

The chronic plantar plate tears of the MTPJ-1 are difficult to diagnose and treat. The arthroscopic approach to the MTPJ-1 allows both verification and treatment of the injury. This is the first report of arthroscopic partial plantar plate tear reconstruction of the MTPJ-1. The most important findings were a high rate of return to preinjury level of activity and excellent MOxFQ and NRS pain scores at 29 months after surgery.

In cases of open surgery, traditionally a plantar J-incision that begins medially and curves laterally along the flexor crease at the base of the hallux, an L-shaped incision, or a 2-incision technique has been used. These incisions allow extensive exposure of the plantar aspect of the joint.[1,8,18,19,24] Limited information regarding soft tissue complications or problems related to plantar scar tissues has been reported. However, wound healing problems, infection, transient neuritis and neuroma of the plantomedial nerve, and stiffness of the MTPJ-1 are described.[1] It is not uncommon that the patients experience persistent swelling and residual symptoms for months, even after seemingly successful open surgery.[4-7,21]

At MTPJ-1 arthroscopy, 3 portal incisions are used—none of these at the plantar aspect of the foot. Both size and location of incisions by the arthroscopic technique indicate surgery with a gentler approach than open surgery. Additionally, the arthroscopic approach offers the opportunity to inspect the MTPJ-1 and detect any other intra-articular pathology. The plantar plate tear was located medially or centromedially in all patients in the present study. No cartilage defects or loose bodies were found.

MTPJ-1 traction is needed for the arthroscopic procedure. Different techniques have been described to achieve traction; these include transphalangeal Kirschner wire, finger traps, or a distraction apparatus attatched to Ioban wrapped around the hallux.[15,17,22] In the first patients, we used manual traction. The present method for traction is a self-retaining retractor with a pin guide, placed slightly plantar on the medial side, to avoid interference with the working portals for arthroscopy.

A 2.7-mm arthroscope and a 3.5-mm shaver were used for the first 5 patients. Currently, we use a 1.9-mm

arthroscope and a 2.0-mm shaver. For irrigation, we use a 50-mL syringe, which in our hands works better than gravity-driven inflow or arthroscopic pumps.

There are several devices available to facilitate suture passing through the plantar plate. The Viper, MiniScorpion, and curved Pigtail (Arthrex, Inc) suture introducers all need some space to move around and rotate the instruments inside the joint. This, however, is difficult in the MTPJ-1. Our preferred technique uses a 70° microsuture introducer (Arthrex, Inc), with the entrance of the joint through the direct medial portal. The passing of the suture introducer through the plantar plate and obtaining a good purchase of the plantar plate are the most challenging steps of the endoscopic repair. The median operation time of 121 minutes also reflects the complexity of this procedure.

The patients included in this study can be classified as having either grade 2 or incompletely healed grade 3 injuries according to the classification of Anderson and Shawen.[3] This classification describes grade 1 as a sprain, grade 2 as a partial tear, and grade 3 as a complete tear of the plantar plate. The median time from injury to operative treatment was 20 months, indicating a failed nonoperative approach or late diagnosed tear. This again can indicate that plantar plate injuries can be challenging to diagnose. A plantar plate tear can lead to persistent pain, even though no obvious instability is found at clinical examination. Six of the 10 patients in the present study had a negative Lachman test preoperatively at the outpatient clinic.

All but 2 patients had a hyperextension injury, and an additional component of valgus stress to the great toe was described by 4 patients. The mechanism of injury is in accordance with previous literature.[18,19,24] The patients described pain at loaded pushoff and even at effortless walking. The typical clinical findings were plantomedial local tenderness at the distal attachment of the plantar plate, localized plantar pain at passive hyperextension of the great toe, a subtle malalignment of the hallux, and reduced ROM of the MTPJ-1. Findings and symptoms in the present study are in accordance with previous literature.[16,18,19,29]

It is recommended that the radiological examination consist of standard weightbearing anteroposterior, lateral, and sesamoidal views with contralateral comparison views to rule out avulsion fractures, sesamoid pathologies, and dislocation or migration of 1 or both sesamoids.[25,30] No pathology of the sesamoids was demonstrated for the patients in this study. MRI scans were available for all the patients, but a plantar plate rupture was only described in 5 of 10 MRI reports. There was no consistency regarding MRI protocols or the use of tesla field strength. Only 2 of 10 MRI scans were series with 1-mm slice thickness. These 2 MRI series demonstrated MTPJ-1 plantar plate tear. We prefer MRI scans performed with a 1-mm slice thickness, as these give more nuances and detect ruptures that otherwise can be overlooked on thicker-slice MRI scans.

The MOxFQ in the present study showed excellence results at a median of 29 months after surgery, but no baseline levels are available for comparison. No other studies present MOxFQ scores, but Smith and Waldrop[28] presented a follow-up American Orthopaedic Foot & Ankle Society (AOFAS) hallux score of 91 (of 100) and a visual analog scale pain score of 0.8 after 27 months in 14 patients with primary open repair of plantar plate grade 3 injury. The median NRS pain in the present study was 0, which is comparable with the reported visual analog scale score. The MOxFQ score is a purely patient-reported outcome measure that allows for evaluating the patients' subjective experience. Furthermore, the patients can be contacted via email to complete the scoring. The MOxFQ has demonstrated superior properties compared with the AOFAS scores. The AOFAS scores are combinations of patient-reported outcomes and physical examination parameters and have been criticized for skewed score distribution as scores cluster at high and low ends of the scale. Neither of the scores are validated for sport-related injuries.

All but 1 patient returned to their previous level of activity/sport. This is even better than reported by other authors. Smith and Waldrop[28] described that 11 of 15 players returned to sport, and they reported playing with a custom orthotic inside their cleat upon return. Covell et al[9] reported that 74% of athletes operated on with an open repair of the plantar plate injury returned to a high level of sport activity at least for a period of time.[28] The return to activity/sport and improvement of symptoms after surgery in the present study are promising. However, the minor valgus deformity observed before surgery was only corrected surgically in 2 of 7 patients. A study from 2017 on operative treatment of traumatic hallux valgus in 19 patients did not report hallux position at follow-up.[11]

Limitations

The present study has some inherent weaknesses. This is a small, retrospective case series. We had no final follow-up clinical examination at a median of 29 months after surgery. No baseline patient-reported scores were available to monitor the effect of surgery. The surgical technique underwent some modifications during the inclusion time in terms of technique for joint distraction, suture passing instruments, and size and type of arthroscopic instruments. These variations reflect an early phase on the learning curve and that shorter operating times are expected with increasing experience.

CONCLUSION

The results after arthroscopic repair of MTPJ-1 chronic plantar plate injuries were good with a high rate of return to activity/sport. The procedure time can reflect this arthroscopic approach as an advanced procedure. The arthroscopic approach, however, allows for verification and location of this difficult diagnosed injury and, at the same time, treats the injury with theoretically less soft tissue trauma and a resultant earlier return to preinjury level of activity.

REFERENCES

1. Anderson RB. Turf toes injuries of the hallux metatarsophalangeal joint. *Tech Foot Ankle Surg*. 2002;1(2):102-111.
2. Anderson RB, Hunt KJ, McCormick JJ. Management of common sports-related injuries about the foot and ankle. *J Am Acad Orthop Surg*. 2010;18(9):546-556.
3. Anderson RB, Shawen SB. Great-toe disorders. In: Porter DA SL, ed. *Baxter's The Foot and Ankle in Sport*. 2nd ed. Elsevier; 2008:421-429.
4. Brophy RH, Gamradt SC, Ellis SJ, et al. Effect of turf toe on foot contact pressures in professional American football players. *Foot Ankle Int*. 2009;30(5):405-409.
5. Clanton TO, Butler JE, Eggert A. Injuries to the metatarsophalangeal joints in athletes. *Foot Ankle*. 1986;7(3):162-176.
6. Clanton TO, Ford JJ. Turf toe injury. *Clin Sports Med*. 1994;13(4): 731-741.
7. Coker TP, Arnold JA, Weber DL. Traumatic lesions of the metatarsophalangeal joint of the great toe in athletes. *Am J Sports Med*. 1978; 6(6):326-334.
8. Coughlin MJ, Kemp TJ, Hirose CB. Turf toe: soft tissue and osteocartilaginous injury to the first metatarsophalangeal joint. *Phys Sportsmed*. 2010;38(1):91-100.
9. Covell DJ, Lareau CR, Anderson RB. Operative treatment of traumatic hallux valgus in elite athletes. *Foot Ankle Int*. 2017;38(6):590-595.
10. Dawson J, Boller I, Doll H, et al. Responsiveness of the Manchester-Oxford Foot Questionnaire (MOXFQ) compared with AOFAS, SF-36 and EQ-5D assessments following foot or ankle surgery. *J Bone Joint Surg Br*. 2012;94(2):215-221.
11. Doty JF, Coughlin MJ. Turf toe repair: a technical note. *Foot Ankle Spec*. 2013;6(6):452-456.
12. Drakos MC, Fiore R, Murphy C, DiGiovanni CW. Plantar-plate disruptions: "the severe turf-toe injury." Three cases in contact athletes. *J Athl Train*. 2015;50(5):553-560.
13. George E, Harris AH, Dragoo JL, Hunt KJ. Incidence and risk factors for turf toe injuries in intercollegiate football: data from the National Collegiate Athletic Association injury surveillance system. *Foot Ankle Int*. 2014;35(2):108-115.
14. Hawker GA, Mian S, Kendzerska T, French M.Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis Care Res (Hoboken)*. 2011;63(suppl 11):S240-S252.
15. Jones J, Palumbo R, Roebke A, Martin K. Great toe metatarsophalangeal joint arthroscopy: simple technique for painful nonunion. *Arthrosc Tech*. 2021;10(4):e1067-e1071.
16. Lui TH. First metatarsophalangeal arthroscopy in patients with post-traumatic hallux valgus. *Foot (Edinb)*. 2015;25(4):270-276.
17. Lundeen RO. Arthroscopic approaches to the joints of the foot. *J Am Podiatr Med Assoc*. 1987;77(8):451-455.
18. McCormick JJ, Anderson RB. The great toe: failed turf toe, chronic turf toe, and complicated sesamoid injuries. *Foot Ankle Clin*. 2009; 14(2):135-150.
19. McCormick JJ, Anderson RB. Turf toe: anatomy, diagnosis, and treatment. *Sports Health*. 2010;2(6):487-494.
20. Morley D, Jenkinson C, Doll H, et al. The Manchester-Oxford Foot Questionnaire (MOXFQ): development and validation of a summary index score. *Bone Joint Res*. 2013;2(4):66-69.
21. Najefi AA, Jeyaseelan L, Welck M. Turf toe: a clinical update. *EFORT Open Rev*. 2018;3(9):501-506.
22. Nakajima K. Arthroscopy of the first metatarsophalangeal joint. *J Foot Ankle Surg*. 2018;57(2):357-363.
23. Nery C, Baumfeld D, Umans H, Yamada AF. MR imaging of the plantar plate: normal anatomy, turf toe, and other injuries. *Magn Reson Imaging Clin N Am*. 2017;25(1):127-144.
24. Nery C, Fonseca LF, Goncalves JP, et al. First MTP joint instability—expanding the concept of "turf-toe" injuries. *Foot Ankle Surg*. 2020; 26(1):47-53.
25. Prieskorn D, Graves SC, Smith RA. Morphometric analysis of the plantar plate apparatus of the first metatarsophalangeal joint. *Foot Ankle*. 1993;14(4):204-207.
26. Rodeo SA, O'Brien S, Warren RF, Barnes R, Wickiewicz TL, Dillingham MF. Turf-toe: an analysis of metatarsophalangeal joint sprains in professional football players. *Am J Sports Med*. 1990;18(3):280-285.
27. Seow D, Tengku Yusof TNB, Yasui Y, Shimozono Y, Kennedy JG. Treatment options for turf toe: a systematic review. *J Foot Ankle Surg*. 2020;59(1):112-116.
28. Smith K, Waldrop N. Operative outcomes of grade 3 turf toe injuries in competitive football players. *Foot Ankle Int*. 2018;39(9):1076-1081.
29. Waldrop NE III. Assessment and treatment of sports injuries to the first metatarsophalangeal Joint. *Foot Ankle Clin*. 2021;26(1):1-12.
30. Waldrop NE III, Zirker CA, Wijdicks CA, LaPrade RF, Clanton TO. Radiographic evaluation of plantar plate injury: an in vitro biomechanical study. *Foot Ankle Int*. 2013;34(3):403-408.
31. Watson TS, Anderson RB, Davis WH. Periarticular injuries to the hallux metatarsophalangeal joint in athletes. *Foot Ankle Clin*. 2000;5(3): 687-713.