LAGGED SYNDESMOTIC FIXATION: Our Clinical Experience

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INTRODUCTION

Ankle fractures are common injuries with a reported incidence of 130 per 100,000 annually (1). The concurrent presence of injury to the deep deltoid and syndesmotic ligaments has been shown to further destabilize the ankle mortise, increasing the incidence and importance of operative reduction (2-4). The incidence of syndesmotic injuries in Weber B and C fractures has been reported as high as 66% and improved functional outcome of the ankle joint following anatomic restoration of the unstable mortise has been elucidated (5). The ankle joint functions in a purposefully well constrained system that tolerates malalignment and instability poorly, which results in accelerated degeneration of the joint (6). Ligamentous instability of the ankle mortise is addressed with anatomic reduction and fixation with positional syndemsotic screw fixation.

Biomechanical studies have noted the physiologic motion present within the syndesmosis and as a result, concern for restriction is pointed to as the prime reason for the utilization of non-lagged fixation across the syndesmosis (2,7). Despite evidence to the contrary that compression of the syndesmosis is not associated with restriction of ankle motion, the literature has continued to advocate against it (8). We found that in certain instances, the reduction achieved with the bone tenaculums could not be maintained with positional fixation intraoperatively in addition to cases of late syndesmotic widening during the postoperative course where the mortise appeared widened despite no obvious hardware failure. We thus began inserting all screws across the syndesmosis with lag technique. In vitro studies have demonstrated that the noncompressed syndesmotic screw is associated with a loss of compression once the bone clamps are removed (1). We found our technique to be associated with maintained radiographic reduction through the postoperative course with no late widening even in our noncomplaint patients. In addition we found no functional loss of subjective complaints with this technique and sought to present our outcomes with this technique. To our knowledge, this is the largest in vivo study ever evaluating this technique.

MATERIALS AND METHODS

Following institutional board review approval, we retrospectively evaluated functional outcomes, subjective complaints related to stiffness, and American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot questionnaire (9). We defined stiffness as motion not comparable to the uninjured contralateral limb. We were concerned of assigning specific numerical targets to the dorsiflexion and plantarflexion endpoints due to potential variables with individual flexibility and the presence or absence of gastrocnemius equinus that in some patients is their norm.

Radiographs were retrospectively analyzed by the study investigators. A thorough chart review of all ankle injuries requiring operative syndesmotic stabilization from January 1, 2009 through December 31, 2011 by the primary author (JJF) was performed. These cases were identified by the Current Procedural Terminology (CPT) code 27829. A total of 275 operations in 273 patients were initially identified with this search criteria. Our inclusion criteria comprised patients who acutely sustained unstable syndesmotic injuries with or without operative fractures, patients who underwent syndesmotic stabilization with only screws that were placed with lag technique, patients 18 years or older, patients who were able to provide consent, closed injuries, and patients available for evaluation via AOFAS hindfoot questionnaire. Unstable syndesmotic injuries were defined by a tibiofibular clear space >6 mm and a medial clear space >5 mm (10-12).

Exclusion criteria included any other concurrent injuries beyond the identified ankle injury with the exception of osteochondral lesions identified intraoperatively, open fractures, syndesmotic screws placed under non-lagged technique, any stabilization performed without screws, patients under the age of 18, patients with documented neuropathy, nonambulatory patients, patients lost to follow-up, patients with previous operatively or non-operatively treated ankle fractures unrelated to the index injury, and patients with previous complaints of ankle pain or instability as reported by the history and physical. All osteochondral lesions were microfractured with a microfracture awl. None were greater than 15 mm in diameter. We excluded 12 patients who sustained severe crushing injuries, 16 pediatric fractures, 7 fractures with concomitant fractures to the ipsilateral limb, 5 patients with previous ankle fractures to the ipsilateral limb, and 10 open fractures (13). Four patients requiring reoperation on the ipsilateral limb for unrelated injuries were excluded by our exclusion criteria. Two patients requiring reoperation as result of acute syndesmotic failure due to noncompliance were included in the study as they met inclusion criteria. An additional 124 patients were lost to follow-up. Ninety-seven operations in 95 patients were available for review and included in this study. No patient developed complex regional pain syndrome.

Following discharge, we additionally sought to evaluate patients from a longer term functional perspective to inquire of any impairments that could be attributed to this technique. Of these 95 patients, 31 were available for evaluation with the AOFAS hindfoot clinical rating system and questionnaire.

Postoperative management consisted of immobilization in a well-padded posterior splint with the ankle in neutral alignment. Range of motion exercises were begun when the wounds were "sealed" and sutures/staples were removed. Serial radiographs were obtained at weeks 2, 6, 10, 16, and 20 postoperatively unless the patient was discharged before this time, then bimonthly if the patient required further follow-up. Progressive protected weightbearing was initiated when radiographic and clinical union were present. Mean follow-up for the 95 patients was 18 months, range 10-46 months. There were 55 males with a mean age of 49.58 years, range 19-84 years, and 40 females with a mean age of 46.1 years, range 19-81 years.

Of the 31 patients available for AOFAS hindfoot questionnaire evaluation, there were 18 males and 13 females. There were 16 right-sided and 15-left sided injures. Additional demographics on this group are provided in Table 1.

We classified our fractures with the Orthopaedic Trauma Association classification of long bones. There were twenty-three 44-C fractures, sixty-eight 44-B fractures, one 44-A, and three isolated syndesmotic ruptures without fibular fracture. There were 39 bimalleolar equivalent fractures defined by the presence of an isolated fibular fracture with a medial clear space >5 mm. There were 19 trimalleolar equivalent fractures defined by the presence of isolated fibular and posterior malleolar fractures with a medial clear space >5 mm without fracture of the medial malleolus. There were 26 trimalleolar fractures, 5 bimalleolar fractures, and 3 maisonnueve fractures, one of which also presented with an operative posterior plafond fracture and a deltoid injury resembling trimalleolar equivalent. Seven patients underwent open reduction and internal fixation of their posterior malleolar fracture as it involved 25% of the plafond evaluated on the sagittal reconstruction computed tomography (CT) scan. All fractures with posterior malleolar component underwent CT evaluation. There were no bilateral injuries. There were 46 right-sided injuries, and 49 left-sided injuries.

RESULTS

Two of the 5 patients with the bimalleolar fractures were available for the AOFAS questionnaire and presented with respective scores 90 and 100 (Figure 1). The former complained of episodic weather related uneasiness but functioned without restrictions. All 5 were a result of low energy mechanical fall. On discharge for the remaining 3, 2 offered no complaints. The third however presented with subjective and objective stiffness, and presented for intraarticular cortisone ankle injections at months 8, 10, and 17 that resulted in symptomatic relief.

Figure 1. Top row demonstrating the sequential placement of a fully threaded lagged syndesmotic screw on the anterior-posterior fluoroscopic projection where both cortices of the fibula are overdrilled. The lateral and medial tibial cortices are subsequently underdrilled. Only the lateral cortex in this instance was underdrilled because of the blocking effect of the medial malleolar screws. The syndesmotic screw is inserted to two-finger tightness.

Table 1

Sex	Age	Mechanism	AO Fx	Fx Details	Follow Up	AOFAS Score	Comments
M	43	Rotational	44C	Right maisonneuve fracture, trimalleolar equivalent.	41 MO	83	6 month postop ankle arthrofibrosis. 17 month postop HWR.
M	65	Rotational	44B	Right bimalleolar equivalent fracture	28 MO	90	None. 28 month postop episodic edema
M	31	Rotational	44B	Left trimalleolar fracture	38 MO	96	Crepitus and stiffness 7 mo postop. Osteochondral injury. 38 month postop occasional stiffness
F	57	Thrown from horse	44B	Left trimalleolar equivalent fracture	38 MO	85	None. 38 months postop, occasional pain and stiffness on uneven terrain
M	37	Rotational	44B	Left trimalleolar equivalent fracture	52 MO	64	None. 52 months postop, severe pain, pain in toes, abnormal gait
M	29	Rotational	44C	Left trimalleolar fracture	32 MO	60	None. 32 months postop, constant but moderate pain, moderate restriction
F	40	Rotational	44B	Right trimalleolar fracture	38 MO	96	None. 38 months postop, occasional pain
M	27	Fall > 6 feet	44C	Left bimalleolar equivalent fracture	43 MO	81	None. 43 months postop, pain with prolonged activity. Can't run at same pace.
M	34	Rotational	44B	Left trimalleolar equivalent fracture	42 MO	100	8 months postop, stiffness in ankle dorsiflexion. Resolved at latest followup.
F	37	Rotational	44B	Right bimalleolar equivalent fracture	39 MO	90	None
M	64	MVA	44B	Right bimalleolar equivalent fracture	32 MO	90	1yr postop, ankle arthritis & joint effusions resolved with injection. 32 months postop, episodic pain
M	42	Rotational	44B	Left bimalleolar equivalent fracture	28 MO	81	Noncompliance. 4 months postop, good ROM. 13 months postop, ossification of syndesmosis. 28 months postop, pain, edema and stiffness with running
F	46	Fall > 6 feet	44B	Left bimalleolar equivalent fracture	38 MO	87	4 month postop stiffness in ankle dorsiflexion. 7 month postop insertional plantar fasciitis. 9 month postop lateral ankle bursitis resolved by injection. 11 month postop neuritis 13 month postop synovitis left ankle. 19 month postop retained painful HW. 38 months postop ambulates with brace, reports edema and episodic fatigue
M	32	Rotational	44B	Right trimalleolar equivalent fracture	41 MO	90	None
M	62	Rotational	44C	Right bimalleolar equivalent fracture	22 MO	100	Partial HWR 1.5mo postop. 22 months postop complains of issue related to knee, not ankle
F	33	Rotational	High Ankle Sprain	Left isolated syndesmotic injury	24 MO	90	None
F	49	Rotational	44B	Left bimalleolar equivalent fracture	46MO	100	None
M	64	Rotational	44B	Right trimalleolar fracture	34 MO	88	None
M	46	Rotational	44B	Left trimalleolar equivalent fracture	35 MO	100	None
M	62	Rotational	44B	Right trimalleolar equivalent fracture	31 MO	100	Excellent ROM
F	63	Fall > 6 feet	44B	Left bimalleolar equivalent fracture	35 MO	81	2 weeks postop stiffness in ankle dorsiflexion. 2 month resolved to excellent ROM
F	56	Rotational	44B	Right trimalleolar fracture	37 MO	90	None
M	84	Rotational	44B	Left trimalleolar fracture	18 MO	94	None
F	53	Rotational	44B	Right bimalleolar fracture	26 MO	100	5 month postop nondisplaced calcaneus fracture s/p fall nonoperative
M	52	Assault	44C	Right maisonneuve fracture	23 MO	80	None
M	56	MVA	44B	Right trimalleolar equivalent fracture	32 MO	89	7 month postop HWR and arthroscopy
F	49	Rotational	44B	Left bimalleolar equivalent fracture	48 MO	93	8 month postop screw loosening
F	47	Unknown	44B	Right bimalleolar equivalent fracture	43 MO	42	None
F	35	Rotational	44C	Left trimalleolar fracture	36 MO	100	None
F	55	Rotational	44A	Right bimalleolar equivalent fracture	32 MO	100	2.5 month postop delayed union with screw loosening
M	51	Rotational	44B	Right trimalleolar fracture	29 MO	100	None

Legend

HW	Hardware Removal
DC	Discharged from care with direction to follow up as needed.
MVA	Motor vehicle accident
HWR	Hardware
MO	Month

There were a total of 39 bimalleolar equivalent fractures, 11 of which were available for the AOFAS questionnaire. Their demographics can be found in Table 1. One was a result of an unknown mechanism. This same patient recorded an AOFAS score of 42 at a 43-month follow-up. She was subsequently diagnosed with multiple sclerosis that progressed during her postoperative course. Four were a result of high-energy injuries, and the remaining 5 were low energy rotational injuries.

Only 1 of the high-energy injuries reported AOFAS scores ≥90, and conversely only 1 of the low-energy rotational injuries reported a score of ≤90. Of the remaining 28 patients not available for the AOFAS questionnaire, 5 sustained high-energy injuries involving falls ≥6 feet. The remaining 23 sustained low energy rotational injuries. The 5 patients who sustained these high-energy injuries yet not available for the AOFAS questionnaire were discharged at a mean of 6.4 months, range 2.5-8 months, with clincal findings motion comparable to the uninjured contralateral limb and no subjective complaints whatsoever.

The remaining 23 patients who sustained low-energy injuries yet not available for the AOFAS questionnaire were discharged at a mean of 7.69 months, range 2-35. Among these patients, 1 required reoperation at week 3 following the index procedure that involved reinsertion of the syndesmotic screw that was retrograding as a result of early weightbearing. This patient proceeded with an uneventful convalescence otherwise. Another required hardware removal at 19 months due to prominence and irritation of the lateral plate. A third patient received an intraarticular cortisone ankle injection that resulted in symptomatic relief. One patient however complained of stiffness upon discharge with objectively less motion than was available in the uninjured contralateral limb. Thus 23 in this cohort underwent benign and good outcomes defined by our criteria.

Of the 20 trimalleolar equivalent fractures (19 true trimalleolar equivalents by our definition and the third maissonnueve with a mortise that presented as a trimalleolar equivalent), 8 were available for the AOFAS questionnaire. Mean follow-up on these 8 averaged 39 months, range 31- 52. Mean AOFAS scores for these patients were 88.87, range 64-100. There were 3 high-energy mechanisms among these 8, where the remaining 5 sustained low-energy rotational injuries. Despite their scores, subjective reports early in the postoperative course were less optimistic. Of the low energy group, 1 patient who underwent operative repair of a concurrent posterior malleolar fracture developed stiffness and pain 6 months postoperatively that was unresponsive to an intraarticular cortisone injection but developed some symptomatic relief following hardware removal at month 17. Another who concurrently sustained an operative posterior malleolar fracture complained of stiffness at 8 months but was resolved at their latest follow-up at 42 months. The remaining 3 patients who sustained low energy injuries and were available for the AOFAS questionnaire underwent benign and good outcomes defined by our criteria.

In the high-energy group 2 of the 3 were available for our AOFAS questionnaire. One recorded a score of 85 and complained of episodic weather related stiffness that resolved with increased activity. The other recorded a score of 89 at the latest followup of 32 months after undergoing removal of hardware and ankle arthroscopy at seven months (Figure 2).

Of the remaining 12 trimalleolar equivalent injuries not in the AOFAS group, 5 sustained high-energy injuries where the remaining 7 sustained low-energy rotational injuries. In this high-energy group 2 patients presented with residual complaints at their latest followups at 26 and 32 months respectively. The former sustained a concurrent operative posterior malleolar fracture after he was thrown off a motorcycle and was grossly noncompliant during the postoperative course, and presented at month 5 for the first postoperative followup. This patient went on to develop radiographic changes of post-traumatic arthritis 14 months postoperatively. The second patient continued to complain of residual stiffness at 10 months postoperatively. In the low-energy group 1 patient with a concurrent operative posterior malleolar fracture presented with clinical findings of stiffness at 18 months postoperatively. Another was diagnosed with ankle synovitis and received intra-articular cortisone injections that offered symptomatic relief at 8 and 30 months postoperatively. Two additional patients relayed weather-related changes that resolved with activity but on examination had mindfoot and ankle motion comparable to the uninjured contralateral limb. Thus in the AOFAS group, there were 2 operative posterior malleolar fractures, both of which were associated with low-energy injury mechanisms. In the non-AOFAS group, there were 2 operative posterior malleolar fractures 1 of each in the high-energy and low-energy group.

There were 26 trimalleolar fractures 8 of which were available for the AOFAS questionnaire. Of these 8 the mean score was 90.5, range 60-100. Six were ≥90. These were all low-energy rotational injuries, none of which had operative posterior malleolar fractures. One however sustained a concurrent osteochondral lesion that was visualized intraoperatively and complained of stiffness at 7 months postoperatively yet at the 38-month followup, complained of mild and episodic pain with no restriction otherwise. The demographics of the remaining patients can be reviewed in Table 1.

Fifteen of the remaining 18 patients in the non-AOFAS

Figure 2A. Right ankle fracture following a motor vehicle accident with an asymmetric mortise.

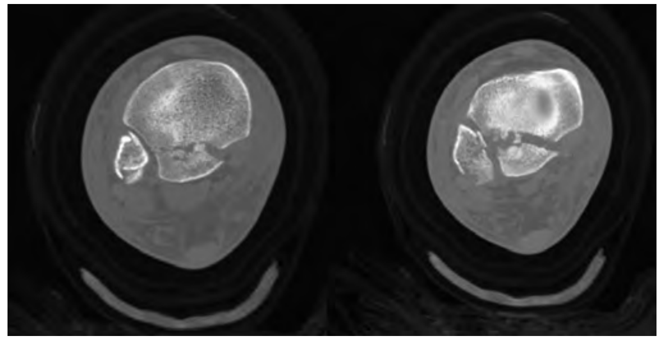

Figure 2B. Axial computed topography image demonstrates a large posterior malleolar fracture with small intraarticular fracture fragments.

Figure 2C. Sagittal reconstruction of the aforementioned posterior malleolar fracture. Note the impaction just anterior to primary fracture line on second image.

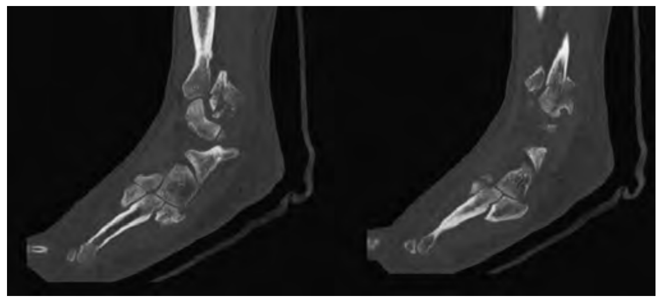

Figure 2D. Concomittant comminuted fibular fracture.

Figure 2E. Postoperative anterior-posterior, mortise, and lateral radiographs of the reconstructed ankle with double plating and lagged syndesmotic fixation.

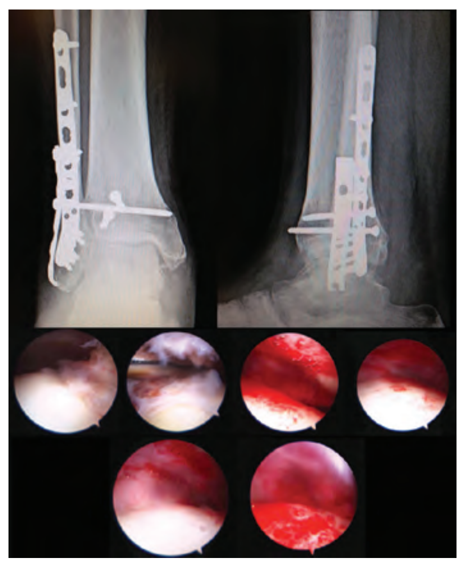

Figure 2F. Eight month postoperative anterior-posterior and lateral radiographs with second look arthroscopy with evidence of significant arthrofibrosis and residual chondral injury.

trimalleolar group all sustained low energy injuries. One sustained injury due to an unknown mechanism. This patient complained of pain and stiffness on discharge at 6 months. The remaining 2 sustained vehicular modulated injuries. There were 3 operative posterior malleolar fractures, none of which were among the high-energy injury group. Of these 3 who sustained operative posterior malleolar fractures, 1 presented with residual stiffness and restriction of motion on discharge. Another in this low-energy group sustained an osteochondral lesion. This patient continued to complain of pain 1 year postoperatively and objective restriction. The mean follow-up for the trimalleolar non-AOFAS group was 11.13 months, range 2.5-34. The only deep venous thrombus in the entire study occurred in this group.

There were 3 maissonnueve injuries, one of which was already described in the trimalleolar equivalent group as the patient also presented with an operative posterior malleolar fracture. Of the remaining 2, one was available for evaluation with the AOFAS questionnaire. He recorded a score of 80 at 23 months and clinically demonstrated moderate restriction compared to the uninjured limb. At the latest followup of 20 months, the final patient presented with no subjective complaints but documented restriction in range of motion.

Of the 3 isolated syndesmosic injuries, only 1 was available for the AOFAS questionnaire. This patient sustained a rotational injury and at the latest follow-up, complained of incisional pain. His hardware was removed by another physician 13 months following the index procedure. Of the remaining 2, one presented with a completely normal examination at 11 months post-operatively but sustained a fall and began complaining of pain thereafter. He underwent removal of all his hardware at 22 months postoperatively and at his latest followup at 24 months provided no complaints. The final patient underwent stabilization and at the last followup at 11 months, presented with no symptoms and a normal physical examination with motion comparable to the uninjured contralateral limb.

DISCUSSION

In one of the earliest studies investigating this concept, Tornetta et al sought to determine if overtightening the syndesmosis was possible (8). The study involved the comparison of ankle range of motion in open chain before and following placement of a 4.5 mm lag screw across the syndesmosis. The investigation was based on the historical premise that because of the unique anatomy of the talar trochlear, which is wider anteriorly than posteriorly, syndesmotic screws should be placed with the ankle in dorsiflexion to prevent restrictive ankle kinematics. The concern however lies with potential risk of malreduction since the fibula externally rotates when the talus dorsiflexed (2). Despite their findings that ankle dorsiflexion was not restricted with syndesmotic compression, the authors still discouraged the use of lagged fixation across the syndesmosis.

The presence of posterior malleolar fractures has been associated with poorer outcomes. Stufkens et al demonstrated that only 58% of ankle fractures with posterior malleolar fractures had good to excellent outcomes 4 years post injury (14,15). Furthermore the retromalleolar apporach involving dissection and retraction of the flexor hallucis longus can result is an indeterminable ammount of scar tissue formation during convalescence that can result in ankle stiffness.

The ankle capsule is injured with tearing during the rotational mechanism of the injury and at times with inatrogenic insult. The healing of this capsule occurs under a reparative pathway that involves replacement with scar tissue, which histologically lacks the elasticity of the native tissue. The generation and abundance of this is under gene expression and individualized. Indeed, it is rational to believe that this variability can confere undesired stiffness.

The ankle fracture and syndesmotic injuries rarely occur in open chain. Under these circumstances, the fully loaded plafond internally rotates and torques on the fully loaded trochlear of the talus. The incidence of cartilagenous injury even if macroscopically invisible is likely higher than reported (Figure 3). Hepple et al reported on the utilization of arthroscopy and reported incidences of 60-75% of intraarticular injury (5). Yoshimura et al reported chondral injury in all 4 of their cases. One of these presented with partial thickness fissuring of the cartilage <50% of its thickness and 3 presented with full chondral injury down to

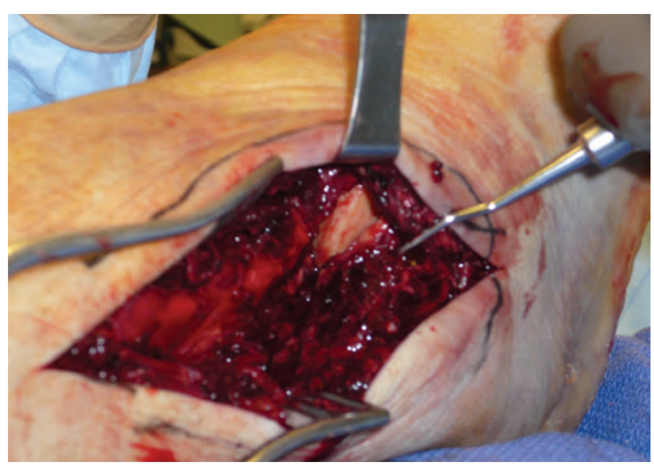

Figure 3. Weber B fracture with hemarthrosis and significant chondral delamination along the entire lateral shoulder of the talus.

subchondral bone (16). Loren et al similarly reported 63% of traumatic articular injuries in their cohort, 19 of which were located on the talus and 11 on the tibia (17). Indeed the relative unpredictability of chondral healing of the talus has been illucidated (18). However Loren et al's report of chondral tibial lesions points to another interesting confounder in outcomes, as tibial lesions are notoriously associated with poor outcomes (19). Even beyond the chondral injury itself, arthrofibrosis native to the reparative process can similarly worsen ankle stiffness (20).

Syndesmotic malreduction is another variable that can influence the outcome of these ankle injuries. In their 68 cases, Sagi et al reported that of the 13 who underwent direct open visualization and the 55 who underwent closed and indirect repair of their syndesmotic injury, 2 and 24, respectively presented with malreductions on CT visualization (21). They also found that patients with malreductions presented with poor functional outcomes and further recommended that CT evaluation of the contralateral limb and the postoperative reduction would help improve outcomes. Gardner et al reported a malreduction rate of 52% when subsequently evaluated on CT (22). Indeed, despite our best efforts, the two-dimensional evaluation of the syndesmosis has little bearing on the true anatomic reduction as subtle sagittal malreductions and most difficult to evaluate the coronal plane rotation of the reduction can occur (21,23-29). Certainly in instances where the transmalleolar axis is not appreciated the syndesmosis can be malreduced (30).

Darwish et al applied a relatively novel approach to the effects of compression across the syndesmosis. The study investigators transected the syndesmotic ligaments and inserted a pressure sensor within the incisura. When the bone tenaculums were then placed along the transmalleolar axis and clamped to simulate reduction, the pressure monitor registered 61 N. Following placement of a positional 3.5 mm cortical screw and release of the bone tenaculum, the pressure sensor reading dropped to 23 N. Conversely, the 3.5 mm and 4.5 mm cortical lag screws placed maintained the compressive effect initially achieved. Indeed the physiologic implications of this approach are theoretical, however, the crux of their investigation demonstrated that the positional screw was unable to maintain even a third of the compression achieved by the bone tenaculum (1).

The weaknessnes of our study are those inherent in any level IV study. We performed no null hypothesis and furthermore we presented no control group in order to compare the effects of positional transfixation. We did no investigation into effects of stainless versus titanium. However, the literature supports no statistically significat diference in this regard (12).

There were no recent followup radiographs in our patient population who completed our AOFAS questionnaire to acertain the fate of the ankle joint. And furthermore, the reliability of the objective components of the AOFAS scoring system itself is not validated or standardized. However, because it has been used for many of the previous studies, we sought to employ it as well in order to allow some relative comparison. Nonetheless, the rationale behind this thought is and approach is flawed. And though we referenced instances of clinically good motion, we included no actual measurernents in this study. We were unable ton objectivley standardize the amount of force needd to reproduce a rneasureable and quantifiable amount of dorsiflexion, thus we focused on clinical, macroscopic, and patient subjective accounts regarding their perceived restrictions and motion. Under this assumption we also sought to prioritize patient subjective reports because the objective absence of 10 degrees of dorsiflexion may be normal for one patient and not the other. Despite our best attempts, comparison of motion in the contraleral uninjured limb is based on the educated assumption that the involved limb, prior to injury had the exact same kinemantics, indeed and educated guess at best but a guess nonetheless.

Finally and most importantly a significant portion of our population was lost to followup. There are a host of reasons that can cause stiffness and confound outcomes in these i njuries. But the deleterious effects of syndesmotic compression have been theorized but has never truly been substantiated. In our cohort, we sought to demonstrate that since all these patients underwent lag syndesmotic compression, based on the historical premise, none should have good range of motion. These were certainly not our findings (Figure 4).

Though we saw no specific association with injury

Figure 4. Weightbearing dorsiflexion view of a patient who underwent ORIF of a Weber B bimalleolar equivalent with lag syndesmotic screw fixation.

mechanism and outcome, we similarly noticed no specific detrimental outcome associated with the lagged syndesmotic screw as we saw a mixture of patients with good and poor outcomes despite the utilization of the lagged syndesmotic screw. The results of this observational investigation could help guide the development of additional randomized controlted trials and prospective studies on appropriate recommendations on tibiofibular syndesmotic stabilizations when indicated.

REFERENCES

1. Darwish HH, Glisson RR, DeOrio JK. Compression screw fixation of the syndesmosis. Foot Ankle Int 2012;33:893-9.
2. Peña F, Coetzee JC. Ankle syndesmosis injuries. Foot Ankle Clin 2006;11:35-50.
3. Tornetta P III. Competency of the deltoid ligament in bimalleolar ankle fractures after medial malleolar fixation. J Bone Joint Surg Am 2000;82:843-8.
4. Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. Arthroscopy 1994;10:558-60.
5. Hepple S, Guha A. The role of ankle arthroscopy in acute ankle injuries of the athlete. Foot Ankle Clin 2013;18:185-94.
6. Summers HD, Sinclar MK, Stover MD. A reliable method for intraoperative evaluation of syndesmotic reduction. J Orthop Trauma 2013;27:196-200.
7. Den Daas A, van Zuuren WJ, Pelet S, van Noort A, van den Bekerom MPJ. Flexible stabilization of the distal tibiofibular syndesmosis: clinical and biomechanical considerations: a review of the literature. Strategies Trauma Limb Reconstr 2012;7:123-9.
8. Tornetta III P, Spoo JE, Reynolds FA, Lee C. Overtightening of the ankle syndesmosis: is it really possible? J Bone Joint Surg Am 2001;83:489-92.
9. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating system for the ankle-hindfoot, midfoot, hallux, and lessers toes. Foot Ankle Int 1994;15:349-53.
10. Lin CF, Gross MT, Weinhold P. Ankle syndesmosis injuries: anatomy, biomechanics, mechanism of injury, and clinical guidelines for diagnosis and intervention. J Orthop Sports Phys Ther 2006;36:372-84.
11. Metzler AV, Johnson DL. Dynamically unstable syndesmosis injuries. Orthopedics 2013;36:201-11.
12. Zalavras C, Thordarson D. Ankle syndesmotic injury. J Am Acad Orthop Surg 2007;15:330-9.
13. Kwaadu KK, Fleming JJ, Lin D. Management of complex fibular fracture: double plating of fibular fractures. J Foot Ankle Surg Epub Ahead of Print.
14. Irwin TA, Lien J, Kadakia AR. Posterior malleolus fracture. J Am Acad Orthop Surg 2013;21:32-40.
15. Stufkens SAS, van de Bekerom MPJ, Kerkhoffs GMMJ, Hintermann B, van Dijk CN. Long-term outcome after 1822 operatively treated ankle fractures: a systematic review of the literature. Injury 2011;42:119-27.
16. Yoshimura I, Naito M, Kanazawa K, Takeyama A, Ida T. Arthroscopic findings in Maissonnueve fractures. J Orthop Sci 2008;13:3-6.
17. Loren GJ, Ferkel RD. Arthroscopic assessment of occult intra-articular injury in acute ankle fractures. Arthroscopy 2002;18:412-21.
18. Deol PPS, Cuttica DJ, Smith WB, Berlet GC. Osteochondral lesions of the talus: size, age, and predictors of outcomes. Foot Ankle Clin 2013;18:13-34.
19. Mologne TS, Ferkel RD. Arthroscopic treatment of osteochondral lesions of the distal tibia. Foot Ankle Int 2007;28:865-72.
20. Utsugi K, Sasaki H, Hiraoka H, Yashiki M, Mogi H. Intra-articular fibrous tissue formation following ankle fracture: the significance of arthroscopic debridement of fibrous tissue. Arthroscopy 2007;23:89-93.
21. Sagi HC, Shah AR, Sanders RW. The Functional consequence of syndesmotic joint malreduction at a minimum 2-year follow-up. J Orthop Trauma 2012;26:439-43.
22. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreductions of the tibiofibular syndesmosis in ankle fractures. Foot Ankle Int 2006;27:788-92.
23. Marmor M, Kandemir U, Matityahu A, Jergesen H, McClellan T, Morshed S. A Method for detection of lateral malleolar malrotation using conventional fluoroscopy. J Orthop Trauma. Epub Ahead of Print.
24. Marmor M, Hansen E, Han HK, Buckley J, Matityahu A. Limitations of standard fluoroscopy in detecting rotational malreduction of the syndesmosis in an ankle. Foot Ankle Int 2011;32:616-22.
25. Franke J, von Recum J, Suda AJ, Grutzner A, Wendl K. Intraoperative three-dimensional imaging in the treatment of acute unstable syndesmotic injuries. J Bone Joint Surg Am 2012;94:1386-90.
26. Nault ML, Hérbert-Davies J, Laflamme GY, Leduc S. CT Scan assessment of the syndesmosis: a new reproducible method. J Orthop Trauma. Epub Ahead of Print.
27. Grenier S, Benoit B, Rouleau DM, Leduc S, Laflamme GY, Liew A. APTF: anteroposterior tibiofibular ratio, a new reliable measure to assess syndesmotic reduction. J Orthop Trauma 2013;27:207-11.
28. Ebraheim NA, Lu J, Yang H, Mekhail AO, Yeasting RA. Radiographic and CT evaluation of tibiofibular syndesmotic diastasis: a cadaver study. Foot Ankle Int 1997;18: 693-8.
29. Miller AN, Carroll EA, Parker RJ, Boraiah S, Helfet DL, Lorich DG. Direct visualization for syndesmotic stabilization of ankle fractures. Foot Ankle Int 2009;30: 419-26.
30. Nimick CJ, Collman DR, Lagaay P. Fixation orientation in ankle fractures with syndesmosis injury. J Foot Ankle Surg 2002;52:315-8.