Original Article

A novel flexible fixation technique for Lisfranc injuries: clinical outcomes and radiographic follow-up

Eitan Micah Ingall[1] (ID), Fernando Raduan[2] (ID), John Y. Kwon[3] (ID)

1. Harvard Combined Orthopedic Residency Program, Massachusetts General Hospital, Boston, MA, United States.
2. Division of Foot and Ankle Surgery and Foot and Ankle Sports Medicine Program of Carl J. Shapiro; Department of Orthopaedics Beth Israel Deaconess MedicalCenter Boston, MA, United States.
3. Division of Foot and Ankle Surgery; Department of Orthopedic Surgery, Massachusetts General Hospital, Boston, MA, United States.

Abstract

Objectives: The purpose of this investigation is to present the follow-up results and patient-reported outcome measures (PROMs) of a continuous series of surgically managed Lisfranc injuries whose constructs included a novel technique.

Methods: Our billing database was retrospectively queried by Current Procedural Terminology (CPT) codes to identify all Lisfranc injuries managed operatively between 2018 and 2021. Basic demographic data were collected. Clinical notes and radiographs were reviewed. Patients were contacted prospectively to complete the Foot and Ankle Ability Measurement – Activities of Daily Living (FAAM-ADL), Patient-Reported Outcomes Measurement Information System (PROMIS) Pain Intensity, PROMIS Pain Interference, and PROMIS Depression surveys. Descriptive statistics were calculated.

Results: Sixteen patients were included. While all patients underwent flexible fixation (FF), nine of them underwent concomitant open reduction internal fixation (ORIF) and seven, concomitant primary arthrodesis. Median radiographic and PROMs follow-up time was 7.3 months (IQR 4.4–11.6) and 25.8 (IQR 9.5–32.4), respectively. All fusion patients had evidence of joint fusion, and 8/9 of ORIF patients maintained articular congruity without evidence of arthritis at final follow-up. Median PROMs were 85 (64.75–93.5), 53.1 (49.7–57.75), 45.7 (37.7–51.3), and 46 (43.3–52.28) for the FAAM-ADL, PROMIS Pain Interference, PROMIS Pain Intensity, and PROMIS Depression scores, respectively.

Conclusion: The novel FF technique proposed for residual tarsometatarsal subluxation in Lisfranc injuries appears to be safe and effective, with good PROMs at two-year follow-up and low complication rates, obviating the need for hardware removal.

Level of Evidence IV; Therapeutics Studies; Cases Series.

Keywords: Fracture fixation, internal; Foot injuries; Tarsal joints.

Introduction

Trauma to the midfoot can result in a highly variable constellation of fractures, joint subluxations, and malalignments. Lisfranc injuries specifically result in tarsometatarsal (TMT) diastasis and instability[1]. The second TMT articulation, recessed proximally, acts as the keystone of the arch, and plays a critical role in coronal plane stability. Lisfranc ligament proper is an eponymous term that describes the plantar ligament running from the medial cuneiform to the base of the second metatarsal[2], with isolated injuries causing instability[3]. Given its importance, most of the literature on Lisfranc injuries has focused on this interval, and merits of fusion versus fixation are still debated.

Various implants have been utilized for the treatment of Lisfranc injuries, including plates, transarticular screws, k-wires, sutures, bioabsorbable screws, and staples. As our understanding of surgical fixation continues to evolve, increasing evidence is highlighting foot kinematics alterations caused by rigid constructs[4-6]. Furthermore, metal implants used during open reduction internal fixation (ORIF) are often

considered for secondary removal procedures. Recently, a limited number of studies have introduced the idea of suture or suture-tape based fixation, also known as flexible fixation (FF), across the medial cuneiform–second TMT interval, with promising results[5,7]. To our knowledge, however, the application of such FF methods in other TMT joints has not been studied, nor have outcomes from robust clinical series been reported.

In 2019, we presented a novel technique for addressing instability using FF[8]. With second TMT joint stability restored either via ORIF or arthrodesis, adjacent TMT incongruity often remains subtly unstable. To address this issue, our joint-sparing technique consisted of wrapping a non-absorbable suture in a figure-of-eight fashion around two cortical screw posts, one placed in the metatarsal base and the other, in its respective tarsal bone. Potential benefits of our previously described technique include: (1) less rigidity than that of metal implant constructs, (2) joint preservation due to the lack of transarticular fixation, and (3) obviating the need for future hardware removal.

The primary aim of this investigation is to present patient-reported outcome measures (PROMs) at final follow-up of a cohort undergoing FF for Lisfranc injury. Secondary outcomes include complications, secondary surgeries, and radiographic outcomes at final follow-up.

Methods

This study was approved under the Institutional Review Board protocol no. 2021P000129. All data collected were secured in compliance with the Health Insurance Portability and Accountability Act, as per the Institutional Review Boards mandate.

Our billing database was retrospectively queried by Current Procedural Terminology (CPT) codes to identify all Lisfranc injuries managed operatively between 2018 and 2021. Injury radiographs, computed tomography (CT)/magnetic resonance imaging (MRI) scans, operative and clinical notes, and postoperative radiographs were reviewed to identify all patients who received adjunctive TMT FF. Patients were included if they had an operatively managed Lisfranc injury of at least one TMT joint treated with FF. Polytraumatized patients, patients with concomitant injuries to the ankle or hindfoot, and/or conservatively-treated patients were excluded. Sixteen patients met inclusion criteria and formed the study cohort, which represented a consecutive series of patients submitted to this technique.

Basic demographic data were collected, including age, gender, laterality, medical comorbidities, mechanism of injury, social history, and occupation. Operative reports and immediate postoperative radiographs were reviewed. Surgical constructs were categorized based on which joints (i.e., first, second TMT joint) received which construct type (i.e., dorsal plate, staple), as well as on the presence of any adjunctive intercuneiform fixation. Clinical notes and any additional operative records were evaluated to identify complications sustained or secondary procedures performed.

All surgeries were performed by one of two fellowship-trained foot and ankle orthopedic surgeons-senior author (JYK) performed 15/16 of the procedures. The FF technique was described in a previously published manuscript[8]. Briefly, after fixation (using a non-FF construct) or fusion of the second (and/or third) TMT joints(s) was performed, stability of the other TMT joints was assessed by performing a stress test under fluoroscopic guidance. If pathologic joint instability was demonstrated, FF was performed on the necessary joints (Figure 1). The TMT joint was anatomically reduced under direct visualization with fluoroscopic confirmation, being provisionally stabilized via extra-articular k-wire fixation. A 2.7 mm or 3.5 mm screw with washer was then placed in the base of the metatarsal and in the adjacent tarsal bone, respectively. A no. 2 Fiberwire (Arthrex, Naples, Florida) was then looped and tensioned in a figure-of-eight fashion around these screw posts (Figure 2). Suture was tightened and knotted and screws were tied to the bone to secure the construct.

Most recent radiographs were reviewed to evaluate for the presence of joint congruity, arthrosis, or other complication. Joint congruity was evaluated by assessing alignment on anterior-posterior, oblique, and lateral radiographs[1]. Specifically, for the fixation group, presence of TMT joint subluxation on any of these views would indicate malalignment. In patients who were indicated for primary arthrodesis, radiographic evidence of fusion, as evidenced by bridging bone, was evaluated. Radiographic follow-up was defined as time from surgery to the date of most recent radiographs, recorded in months.

Patients were then contacted in a prospective manner and requested to complete the Foot and Ankle Ability Measure – Activities of Daily Living (FAAM-ADL), Patient-Reported Outcomes Measurement Information System (PROMIS) Pain Intensity, PROMIS Pain Interference, and PROMIS Depression surveys. The FAAM-ADL survey is a validated tool to measure lower extremity function[9]. It is reported on a 0–100 scale - the higher score, the better function. Minimum clinically important difference for this tool has been previously established as 8 points. The PROMIS Adult Short Form v1.0 – Pain Interference 8a is a validated tool designed to measure the consequences of pain in "relevant aspects of a person's life" using a 7-day recall period[10]. The PROMIS Adult Short Form v1.0 – Pain Intensity 3a is a tool designed to measure pain using a 7-day recall period[11]. The PROMIS scores are reported in t-scores based upon a reference population, where a score of 50 represents the average, with a standard deviation of 10 points[11]. The PROMs follow-up was calculated as the time from surgery to the date of completion of the outcome survey, recorded in months.

Descriptive statistics were calculated and reported using means and standard deviations or medians and interquartile ranges (IQR) for normal and non-normal data, respectively.

Results

A total of 16 patients met inclusion criteria (Table 1). There were nine males and seven females. Mean age at time of
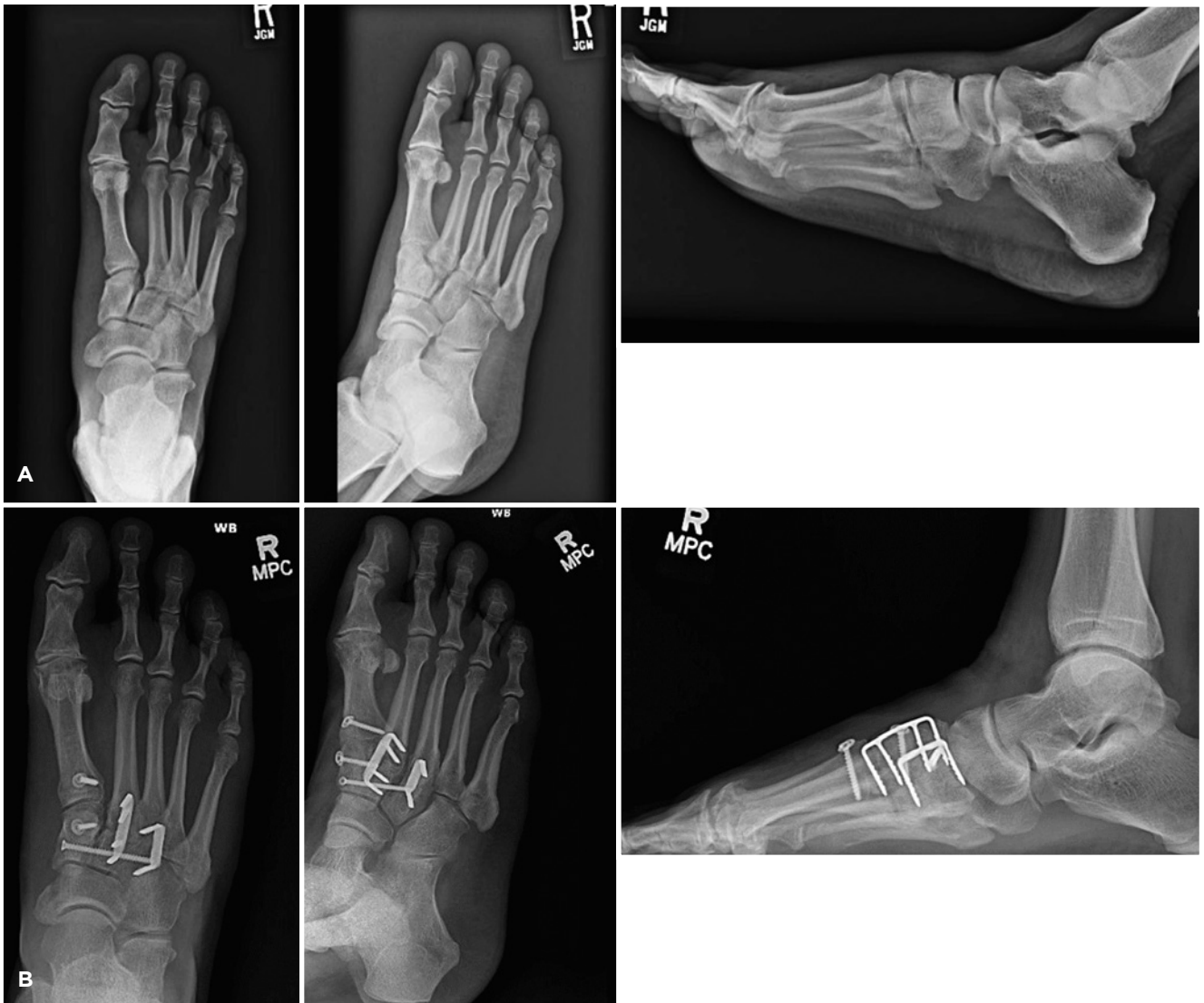
Figure 1. Flexible Fixation. (A) Anterior-posterior, lateral, and oblique injury radiographs of a patient who sustained Lisfranc injury after a mechanical fall. (B) Patient was indicated for primary fusion. After the second and third TMT joints were fused, residual instability was noted at the first TMT and a flexible fixation construct was placed.

surgery was 40 years of age (16–70). Nine patients had ORIF as their index surgery, while seven patients were indicated for acute primary arthrodesis of at least one TMT joint. Fifteen out of the 16 patients surveyed (93.3%) had FF inclusive of their first tarsometatarsal joint; one patient had isolated FF of their fourth TMT. One patient had FF of the second TMT and another patient, of the third TMT, in addition to the first TMT joint.

In the selective arthrodesis group, all patients had evidence of radiographic and clinical joint fusion and maintained midfoot alignment at time of final follow-up. As for the ORIF group, 8/9 of patients (88.8%) had maintained articular congruity, assessed as described above, without evidence of

arthritis at final radiographic follow-up. Median radiographic follow-up time was 7.3 months (IQR 4.4–11.6).

Two patients who underwent initial ORIF required secondary arthrodesis. First patient was a police officer, body mass index (BMI) > 45, who was injured in a work-related motor vehicle accident. This patient was submitted to FF of the first and second TMT joints which was converted to fusion at 7.2 months after index surgery due to recurrent diastasis. Second patient was converted from ORIF to fusion at 10.8 months after index surgery due to persistent pain. Both patients underwent uncomplicated arthrodesis and successful fusion was noted at final radiographic follow-up.

Figure 2. Flexible Fixation of the first TMT *in situ*. Two screws are placed in the metatarsal and in the respective cuneiform. A non-absorbable suture is wrapped in a figure-of-eight fashion and tied.

Elective, unplanned removal of hardware (ROH) was performed in 4/16 (25%) of the overall cohort, and only in 3/9 (33.3%) of patients who underwent ORIF. On average, ROH was performed 7.9 months after index procedure. Irritation from the FF hardware or suture knot, specifically, was not an indication for hardware removal in any case, with predominant complaint being "stiffness".

The PROMs were collected at a median follow-up time of 25.8 (9.5–32.4) months. Median IQR for FAAM-ADL, PROMIS Pain Interference, PROMIS Pain Intensity, and PROMIS Depression scores can be found in Table 2.

Discussion

The FF use to treat Lisfranc injuries has garnered increasing interest due to prior investigations demonstrating need for removal of hardware, altered gait mechanics, increased plantar foot pressures, and stiffness after surgical treatment of Lisfranc injuries using more rigid constructs[6,12]. While these previous investigations have mostly focused on the Lisfranc interval itself, the present investigation is the first to report outcomes of a novel FF method for Lisfranc injuries to treat residual TMT instability, mostly of the first TMT joint. Radiographic evidence at final follow-up consistently demonstrated maintenance of joint alignment. Median FAAM-

ADL was 85%, with a median patient PROMIS score (Pain Interference, Intensity, and Depression) near or better than that of the reference population.

Prior investigations have reported on other FF strategies, including suture-button fixation, as well as the use of non-absorbable suture-tape fixation across the Lisfranc interval. In a recent study by Cho et al.[5], authors reported no difference in radiographic outcomes or American Orthopaedic Foot & Ankle Society (AOFAS) scores at one year follow-up between a group treated with traditional screw fixation and those treated with a suture-button placed across the Lisfranc interval. Interestingly, their study also confirmed the presence of altered plantar foot pressures in the screw fixation group prior to screw removal. Importantly, their study was limited to ligamentous injuries and to the placement of suture-button fixation across the Lisfranc interval only, while our study included more heterogenous Lisfranc phenotypes and applied FF beyond the Lisfranc interval. The use of FF for residual first, third, and lesser TMT joint instability may further optimize midfoot function by preventing unnecessarily rigid fixation.

Delman et al.[7] introduced the use of non-absorbable suture tape (InternalBrace, Arthrex, Naples, Fl) for the treatment of ligamentous Lisfranc injuries. Their technique paper described the application of InternalBrace to the medial cuneiform–second TMT interval as a joint-preserving technique. They suggested that, if used for other TMT joint instability, supplementation with dorsal plating should be considered (which can subsequently be removed while retaining the InternalBrace). Although comparison with the current investigation is difficult, given their lack of reported outcomes, the results of our study suggest that suture fixation can be used independent of dorsal plating, obviating the need for future removal of hardware.

Our interest in developing this technique resulted from frequently encountered subtle instability after a second TMT stabilization, particularly of the first TMT joint. We should emphasize that it is unclear whether FF is adequate for primary stabilization of the Lisfranc interval itself. Furthermore, it would seem intuitive that FF would be of inadequate rigidity if arthrodesis is to be performed. Rather, FF is meant to be a low-profile construct for joint-sparing stabilization specifically to address residual subluxation without committing to future hardware removal (i.e., if a dorsal plate is placed) and/or more rigid or expensive constructs (Figure 3). We feel that this technique addresses a specific need in fixation of Lisfranc injuries that have otherwise not been addressed.

Removal of hardware in our cohort was required in 3/9 of patients in the ORIF group and 1/7 of patients in the fusion group (we should stress that patient was submitted to previous ORIF and required ROH due to conversion to arthrodesis). Prior studies have evaluated ROH rates in Lisfranc injuries and have found planned ROH after ORIF to be as high as 70%–80%[13]. While unplanned ROH has been demonstrated to necessitate removal far less frequently, the

Table 1. Cohort details.

Patient	Sex	Age	Side	Mechanism of injury	Occupation	Major medical comorbidities	Fusion or ORIF?	Flexible fixation location	Remainder of construct	Radiographic follow-up (Months)	If fusion, radiographic evidence of fusion?	Secondary surgery (Time from index procedure)	PROMs Follow-up (Months)
1	F	39	Right	Acrobatics	Property management	None	Fusion	1st TMT	Lisfranc interval staple, 2nd TMT Fusion (with staple)	12.6	Yes		32.4
2	M	30	Right	Sports	Unemployed	None	ORIF	1st TMT	Lisfranc screw, intercuneiform screw, dorsal bridge plate of 2nd TMT	9.4	N/A		17.6
3	F	34	Right	Syncope fall	Nurse	None	ORIF	1st TMT	Bridge plating of 2nd and 3rd TMT, intercuneiform screw	13.6	Yes	Fusion (10.8 months)	27.6
4	F	29	Left	Dancing	Customer service	None	Fusion	1st TMT	Lisfranc screw, 2nd TMT, 3rd TMT staple, intercuneiform screw, lateral column plate dorsal spanning plate	4.0	Yes		4.7
5	F	16	Left	Sports	Student	None	ORIF	1st TMT	Lisfranc screw, intercuneiform screw, dorsal bridge plate of 2nd TMT	11.8	N/A	ROH (10 months)	23.9
6	M	70	Right	Trip and fall	Retired	None	Fusion	4th TMT	Fusion of 1st-3rd TMT with staples, bridge plate over 1st TMT, ORIF 2nd TMT shaft with plate bridging into the medial cuneiform, inter cuneiform screw	10.8	Yes		32.6
7	M	66	Right	Trip and fall	Boxing coach	None	Fusion	1st TMT	Fusion of 2nd and 3rd TMT with staples, intercuneiform screw	4.8	Yes		5.5
8	M	37	Left	Fall from 15 ft	Real estate broker	None	ORIF	1st TMT	Dorsal plates of 2nd, 3rd, 4th TMT, intercuneiform screw	3.8	N/A		18.1
9	F	27	Right	MVC	Software designer	None	ORIF	1st TMT	Lisfranc screw, intercuneiform screw, dorsal bridge plate of 2nd TMT	7.3	N/A	ROH (8.5 months)	34.9
10	M	19	Right	Sports	Student	None	ORIF	1st TMT	Lisfranc screw, intercuneiform screw	4.1	N/A	ROH (5.4 months)	30.8
11	F	40	Left	Fall from standing	Billing manager	None	ORIF	1st TMT	Lisfranc screw, intercuneiform screw, dorsal bridge plate of 2nd TMT	7.5	N/A		29.4
12	M	42	Right	MVC	Police officer	Smoking	ORIF	1st TMT	Lisfranc screw, intercuneiform screw, dorsal bridge plate of 2nd TMT	4.4	N/A		7.0
13	M	30	Right	MVC	Police officer	Obesity	Fusion	1st and 2nd TMT	Lisfranc staple, intercuneiform screw	24.7	Yes	Fusion (7.2 months); ROH (16.3 months)	32.8
14	F	50	Left	Trip and fall	Personal care assistant	None	ORIF	1st TMT	Lisfranc screw, dorsal bridge plate of 2nd TMT	5.7	N/A		10.4
15	M	49	Right	Trip and fall	Radiologist	None	Fusion	1st TMT	Lisfranc staple, 2nd TMT staple	2.3	Too early		3.0
16	M	56	Left	Trip and fall	Teacher	None	Fusion	1st and 3rd TMT	Lisfranc staple, 2nd TMT dorsal bridge plate	10.8	Yes		34.5

MVC: Motor vehicle collision; ORIF: Open reduction internal fixation; TMT: Tarsometatarsal; N/A: Not applicable; ROH: Removal of hardware; PROMs: Patient-reported outcome measures.

Table 2. Patient-reported outcomes collected prospectively approximately two years postoperatively.

Outcome scores	Median (IQR)
FAAM-ADL	85 (64.75–93.5)
PROMIS Interference	53.1* (49.7–57.75)
PROMIS Intensity	45.7* (37.7–51.3)
PROMIS Depression	46* (43.3–52.28)

IQR: Interquartile range; FAAM-ADL: Foot and Ankle Ability Measurement – Activities of Daily Living; PROMIS: Patient-Reported Outcomes Measurement Information System.
*T-score metric - 50 is the mean of a relevant reference population, and 10 is the standard deviation (SD) of that population.

Figure 3. Stress testing after Lisfranc fixation/fusion. (A) After second TMT fusion (in this case), residual subtle instability was noted clinically. (B) Decision was made to stabilize the joint using the flexible fixation technique described.

previously accepted practice of removing hardware placed during ORIF may be changing, and the senior author does not routinely remove hardware after Lisfranc fixation. In any event, our series demonstrates low ROH rates and, importantly, no removals were specifically indicated due to irritation from the FF construct. Given concerns over wound-healing issues or nerve injuries after hardware removal[14], avoiding this secondary surgery is a possible benefit of this technique.

We also report PROMs that are consistent with prior literature. It is well-known that studying clinical outcomes after Lisfranc injuries is difficult because they are both uncommon and heterogenous. Despite this heterogeneity, multiple prior investigations[15–18] have used the FAAM-ADL survey with scores generally falling between 80% and 90%. Our findings, of 85% (IQR 64–93), corroborate these results. In terms of PROMIS scores, patients scored within half of one standard deviation of the t-scores of a reference population for the PROMIS Pain Interference, Pain Intensity, and Depression surveys. These outcomes, at a median of over two years of follow-up, are indeed promising, suggesting that this method of addressing residual TMT stability is both safe and effective.

Finally, two patients required secondary surgery (other than ROH) in our cohort. One was a patient who underwent primary ORIF and was later converted to arthrodesis at approximately 10 months after index surgery due to continued pain. Although there was no malalignment visualized on radiographs and only minimal evidence of arthrosis on CT, patient opted for arthrodesis rather than a trial of hardware removal due to confirmed joint pain based on diagnostic injections. Prior literature reports a variable rate of post-traumatic arthritis, approximately 25%, with a subset of patients requiring conversion to fusion[19,20]. For one patient (in a cohort of 16 patients) to undergo a secondary arthrodesis procedure at a median of two years of follow-up would not be unexpected and likely not attributable to the use of FF. Our second complication was a failure of the FF construct in a police officer patient with BMI > 45 who sustained a high energy Lisfranc injury after a motor vehicle accident. While initial injury was primarily ligamentous and ultimately converted to arthrodesis successfully, this was admittedly a failure in judgement. Given his body habitus and significant occupational demands, patient was likely best served with primary arthrodesis as index procedure. While our technique appears adequate for the majority of patients, judicious use should be considered in obese patients or in those with a high risk for postoperative non-compliance.

There are several limitations to our study. First, our study is limited by the heterogeneity of Lisfranc injuries and the resultant need for a similarly heterogenous choice of procedures and fixation strategies. In spite of this, our results demonstrate that this technique is promising at treating residual instability across a variety of injury presentations, including those of higher energy. Secondly, this study is limited by its case series nature and lack of a comparative

control group, which is often inherent to a single-surgeon series. However, as surgeons develop new techniques to address clinical problems, these early reports in literature are critical to demonstrate efficacy and safety and to promote the conduction of more rigorously designed studies.

Certain host and injury factors should be carefully considered prior to applying this technique. Patients with uncontrolled diabetes mellitus, neuropathy, and those with significantly elevated BMI may require a more rigid fixation than that afforded with this technique. Similarly, if there is a concern for non-compliance with weightbearing restrictions, this technique should be considered carefully, as the extra stiffness of a dorsal plate/screw construct may be advantageous if joints are being consistently loaded prior to ligamentous healing. Furthermore, specific injury characteristics should be evaluated prior to the application of this technique. In significant metatarsal base fractures, if comminution and/or dislocation is present, more rigid constructs may be preferred given the significant disruption of secondary osseo-ligamentous stabilizers of the TMT joints. Similarly, this method of stabilization may not be adequate for sole stabilization of the second TMT joint or the Lisfranc interval. We recommend this technique for stabilization of surrounding TMT joints (most notably, the first TMT joint) only after this key articulation has been stabilized using traditional techniques. In this vein, FF is not a ligament repair or reconstruction technique per se, but rather a form of internal stabilization secondarily addressing ligament disruption.

Conclusion

The novel FF technique proposed for residual TMT subluxation in Lisfranc injuries appears to be safe and effective, with good PROMs at two-year follow-up and low complication rates. This joint-sparing technique may be a reasonable alternative to adjunctive rigid fixation with dorsal plating, transarticular screws, or staples in selected patients, and may obviate the need for hardware removal.

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