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Open Reduction Internal Fixation Versus Primary Arthrodesis for Lisfranc Injuries: A Prospective Randomized Study

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ABSTRACT

Background: **Dislocations and fracture-dislocations involving the tarsometatarsal joint are a relatively common injury. These injuries are associated with long-term disability from subsequent painful osteoarthritis and residual deformity. This study evaluated whether performing a primary arthrodesis (PA) resulted in improved functional outcome and fewer subsequent surgeries as compared to primary open reduction and internal fixation (PORIF).** ***Materials and Methods:*** **Forty patients with acute tarsometatarsal joint fractures or fracture dislocations were prospectively randomized to undergo either PORIF or PA. Clinical and radiographic examination, in addition to Short Form-36 (SF-36) and Short Musculoskeletal Function Assessment (SMFA) questionnaires, were evaluated at intervals of 3, 6, 12, and 24 months following surgery in 32 patients. A patient satisfaction phone survey was also performed.** ***Results:*** **The rate of planned and unplanned secondary surgeries, including hardware removal and salvage arthrodesis, between ORIF and PA groups, 78.6% vs. 16.7% was significantly different. No statistically significant differences were found with physical functioning for the PORIF or PA groups with regard to SF-36 or SMFA scores at any followup time interval. However, time from injury had a significant effect with impaired functioning at three months compared to all future intervals. No difference in satisfaction rates were found between PORIF and PA at an average of 53 months in a phone survey.** ***Conclusion:*** **PA of tarsometatarsal joint injuries resulted in a significant reduction in the rate of followup surgical procedures if hardware removal is routinely performed with no significant difference in SF-36 and SMFA outcome scores when compared to PORIF.**

Level of Evidence: I, Prospective Randomized Study

Key Words: Lisfranc; Arthrodesis; Open Reduction Internal Fixation; Functional Outcomes; Secondary Surgery; Tarsometatarsal Joint

INTRODUCTION

The tarsometatarsal (TMT), or Lisfranc joint complex, is a part of the structural support of the transverse arch of the midfoot. Injuries involving the Lisfranc joint can be associated with long-term disability from subsequent painful posttraumatic osteoarthritis and residual deformity.[1,2,4,6,8,9,11,12,21,22] Various treatment options are recommended. Anatomic reduction of the Lisfranc joints is paramount. Clinical results are related to the accuracy and maintenance of the injury reduction.[2–5,7–9,21,22]

A consensus exists that closed reduction followed by casting is unsuccessful in the majority of cases.[2,6] Casting provides poor restraint to further displacement with disrupted capsular and ligamentous structures.[11] Without removal, interposed soft tissue structures can impede an anatomic reduction.[5,9]

Current preferred management of Lisfranc injuries is primary open reduction and internal fixation (PORIF). Arntz et al. concluded that precise reduction of the TMT joint was achievable using PORIF with AO 3.5/4.5-mm cortical screws.[2] No evidence of redislocation was noted. Stable fixation helped minimize swelling and promote healing.

Granberry et al. recommended primary fusion in any unstable injury requiring open reduction because of the high incidence (11 of 25) of these injuries that went on to arthrodesis.[8] Sangeorzan et al. found a positive correlation between early arthrodesis following failed primary treatment

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with positive results.[25] A primary arthrodesis (PA) potentially prevents a patient from developing a painful, deformed foot and decreases or prevents the need for further surgery and further disability.

The purpose of this prospective randomized study was to compare the outcomes of those who were treated with primary arthrodesis (PA) to those treated with primary open reduction internal fixation (PORIF) for acute Lisfranc injuries. A secondary aim was to determine whether there was a difference in secondary surgeries following each treatment method.

MATERIALS AND METHODS

Over a 5-year period, a prospective, randomized evaluation of patients with TMT or Lisfranc joint injuries was conducted. Patients were randomized to PORIF or PA treatment. The hospital institutional review board approved the study design. All patients who agreed to participate signed an informed consent. The inclusion criteria were: acute Lisfranc injury of less than 3 months duration and closed physes/skeletal maturity. The exclusion criteria was major intra-articular fracture pattern, prior foot trauma, prior foot infection, prior foot surgery, prior foot pathology, chronic injury of greater than three months duration, or associated medical comorbidities such as diabetes mellitus, peripheral vascular disease, peripheral neuropathy, or autoimmune disease. Since closed reduction and percutaneous fixation do not allow for anatomic reduction and rigid stabilization, these treatment methods were not evaluated.

Between March 2000 and August 2005, 185 total TMT injuries were operatively treated. Of the 185 total injuries, 40 patients with 40 injuries (22%) met inclusion criteria and consented to participate in the study protocol. A power analysis estimated a total of 60 injuries would be required to demonstrate statistical significance between the two groups when measuring Short Form 36 (SF-36) and Short Musculoskeletal Functional Analysis (SMFA) scores. A random number generation system assigned numbers to blinded treatments. Patients were assigned PORIF versus PA based on a random number assigned to 60 numbered envelopes. For example, the number five envelope was assigned to the fifth patient entered into the study. After opening the envelope in the pre-operative area, the patient would be assigned either PORIF or PA based upon the designation card within the outer numbered envelope.

Nine males and five females were in the PORIF group. The average age at time of injury was 37 (range, 20 to 58) years. The mechanisms of injury were falls ($n = 9$), crush ($n = 3$), or motor vehicle accident ($n = 2$). Nine of the 14 (64%) patients were smokers at the time of injury. Four patients (29%) in the PORIF group had a purely ligamentous injury. Ten patients (71%) had metatarsal fractures. Ten injuries (81%) had an associated fleck or avulsion fractures. Five patients (36%) displayed instability of all five metatarsals. Associated foot injuries consisted of cuboid fractures ($n = 1$) and medial cuneiform fractures ($n = 2$) in the PORIF group (Table 1).

Twelve males and six females were in the PA group. The average age at the time of injury was 40 years (range 25–73 years). The mechanisms of injury were falls ($n = 11$), crush ($n = 3$), and motor vehicle accidents ($n = 4$). Six of the 18 (33%) patients were smokers at the time of injury. Two of 18 (12%) patients had a purely ligamentous injury. Twelve patients (67%) had metatarsal fractures. Sixteen of the 18 (88%) had an associated fleck or avulsion fracture. Five patients (28%) displayed instability of all five metatarsals. Instability was defined as subluxation of joint surfaces on static, weightbearing or stress radiographs. Associated foot injuries consisted of medial cuneiform fractures ($n = 5$), a cuboid fracture ($n = 2$), and a navicular fracture ($n = 1$) in the PA group (Table 1).

All operative procedures in the study were performed by three surgeons, who had fellowship training in either trauma or foot and ankle surgery. Once in the operative suite, all injuries were stressed under fluoroscopy to determine and confirm the extent of injury. All patients had general anesthesia.

SURGICAL TECHNIQUE

Primary open reduction internal fixation (PORIF)

PORIF consisted of a 9- to 10-cm, dorsal longitudinal incision over the interval at the base of the first and second TMT joints. This approach allowed visualization and reduction of the first, second, and medial half of the third TMT joints. The first TMT was reduced with a tenaculum clamp and flexion force avoided plantar gapping or malreduction. Crossed 0.062 Kirschner wires secured the reduction. With a tenaculum clamp compressing the joint, a retrograde 0.062 Kirschner wire secured the joint. The medial aspect of the third TMT was visualized through the same incision. When necessary, the lateral 8 cm longitudinal,

Table 1: Demographic and Clinical Data

	PORIF	PA
Men:Women	9:5	12:6
Smokers (%)	9 (64%)	6 (33%)
Fracture Type (%)		
No fractures	4 (29%)	2 (11%)
1-5 TMT instability	5 (36%)	4 (22%)
Cuboid fracture	1 (7%)	1 (6%)
Medial cuneiform fracture	1 (7%)	2 (11%)
Navicular fracture	0 (0%)	2 (11%)
Fleck sign	2 (15%)	5 (28%)

universal incision over the fourth metatarsal allowed access to the lateral aspect of the third and entire visualization of the fourth and fifth TMT joints. After the third TMT was reduced with a tenaculum clamp, a 0.062 Kirschner wire was percutaneously inserted retrograde to stabilize the third TMT joint. If the Kirschner wires were inserted close to the TMT, the wire would not interfere with retrograde drilling and screw insertion. The fourth and fifth TMTs were reduced with dental picks and tenaculum clamps. Retrograde percutaneous 0.062 Kirschner wires were inserted perpendicular to the TMT joint and into the subchondral bone of the cuboid. Temporary reduction was confirmed with anterior-posterior (AP), lateral (Lat), and oblique (Obl) intraoperative fluoroscopic views. Final stabilization was performed in a medial to lateral direction. A step was created on the mid anterior first MT cortical surface with a perpendicular drill through the first cortex only. A 2.5-mm drill with drill sleeve was used to cross the joint about 30 degrees from the anterior cortical surface.[17] Periarticular screws (Zimmer, Warsaw, IN) with a 3.5-mm shaft and a 2.7-mm head size increased joint stability and screw longevity with lessened cortical splitting. Two crossed 3.5-mm cortical screws were inserted at the first TMT joint. The retrograde screw was inserted along the medial half of the first TMT perpendicular to the joint. The antegrade screw was inserted from the lateral half of the medial cuneiform into the base of the first MT. A single retrograde 3.5-mm periarticular screw was inserted perpendicularly across the second TMT joint on the AP view. A percutaneous incision over the mid portion of the third metatarsal was used for insertion of a single retrograde 2.7-mm or 3.5-mm periarticular cortical screw across the third TMT joint. All screws were inserted in a neutral, not lag technique. The final screw position and TMT reductions were confirmed with fluoroscopy. The fourth and fifth TMT Kirschner wires were cut below the skin. A posterior splint in neutral position was applied.

When present, an associated cuboid fracture was reduced and stabilized via the lateral longitudinal incision. A 2.5-mm external fixator (Synthes, Paoli, PA) was inserted across the cuboid from the calcaneus to the fifth MT shaft. The impacted articular surface was carefully elevated with an osteotome or elevator followed by insertion of allograft bone in the void. A mini "T" plate (Synthes, Paoli, PA) stabilized the cuboid fracture and allowed for insertion of "raft" screws into the subchondral bone. Because anatomical fixation of the cuboid articular surface determined TMT reduction and restoration of the lateral column length, the cuboid fracture fixation was performed before fourth and fifth TMT reduction and stabilization with Kirschner wires.

Primary arthrodesis (PA)

For PA, the same dorsal access was provided with the two longitudinal incisions. Since the first, second, and third TMT joints are "non-essential" or relatively immobile, the TMT joints were fused. Since the fourth and fifth TMT joints are "essential" or more mobile, the fourth and fifth TMT joints were not fused. The reduction and fixation sequence was similar to PORIF, i.e. medial to lateral. The articular surface was removed with one-quarter inch osteotomes and small curettes. Final subchondral preparation required 2.0 mm drill perforation through the subchondral bone into cancellous bone. The temporary stabilization of the joints was similar to the PORIF group. Screws were inserted via a lag technique to compress the subchondral surfaces with the same screw configuration as PORIF. No additional bone graft or allograft was necessary.

Postoperative management

Postoperative protocol consisted of followup at 2 weeks, 6 weeks, 12 weeks, 6 months, 12 months, and 24 months, with three view radiographs (AP, Lat, Obl) obtained at each interval (Figures 1 to 5). A fusion was confirmed clinically with a stable midfoot exam and maintained midfoot arch. It was confirmed radiographically with resolution of chondral surface, no screw lucencies or breakage, and maintained midfoot arch. Gradual weight bearing began at three months with a controlled ankle motion walker (Donjoy, Vista, CA). External supports (crutches or walker) were weaned until the patient was ambulating independently. No deviation in postoperative protocol concerning weight bearing (WB) or range of motion was made between the two groups. In the PA group, the percutaneous fourth and fifth TMT hardware was removed at three months in the office and WB was started. In the PORIF group, the medial hardware (first, second, third TMT) was generally removed at the third to fourth month within the operative suite under general anesthesia followed by WB.

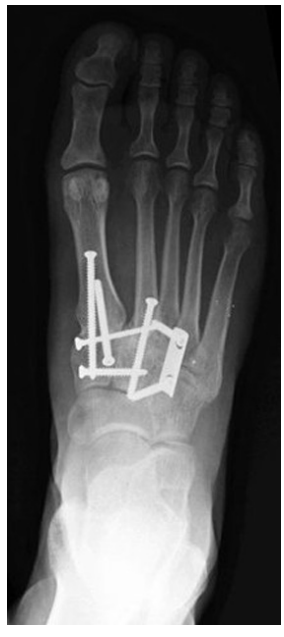

Fig. 1: Final Primary Arthrodesis Results – AP View.

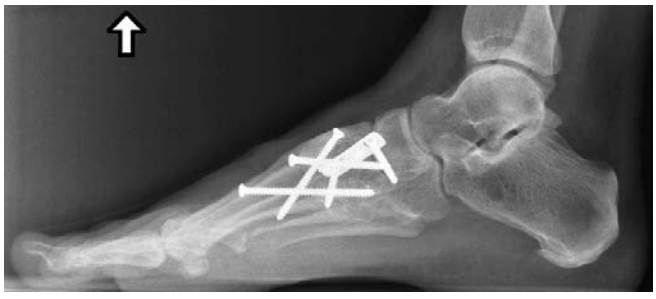

Fig. 2: Final Primary Arthrodesis Results – Lateral View.

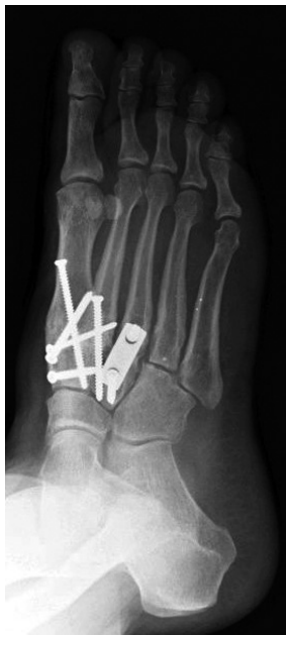

Fig. 3: Final Primary Arthrodesis Results – Oblique View.

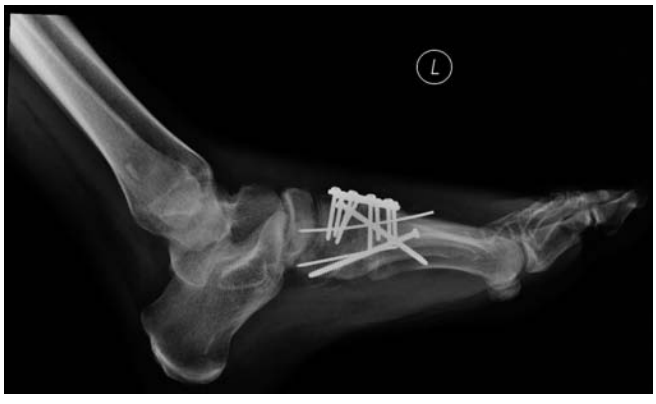

Fig. 4: Final PORIF Results – Lateral View.

Quality of reduction, malreduction, malunion, nonunion, delayed union, fixation failure, hardware failure, incisional healing, infection, pressure sores, amount and duration of pain medications, usage of usual shoes, independent ambulation, time until return to work, and whether patient was able to return to previous position at work were measured at each followup interval.

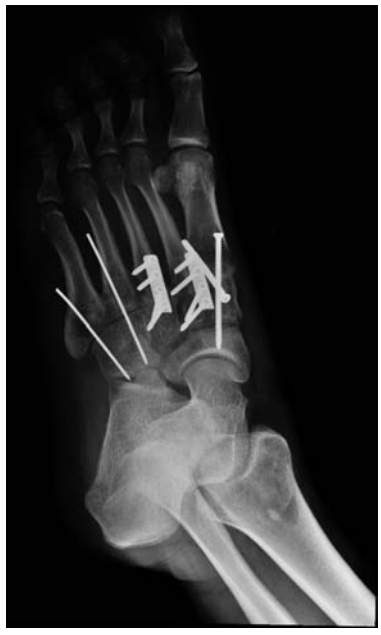

Fig. 5: Final PORIF Results – Oblique View.

SF-36 and SMFA forms were collected at 3, 6, 12, and 24 months following surgery. The SF-36 is a short questionnaire with 36 items which measure eight multi-item variables: physical functioning (ten items), social functioning (two items), role limitations due to physical problems (four items), role limitations due to emotional limitations (three items), mental health (five items), energy and vitality (four items), pain (two items), and general perception of health (five items).[18,30] Physical health is measured by the physical functioning, role-functioning, and bodily pain scales, and mental health is measured by the social functioning, role-emotional, and mental health scales.[30] For each variable, item scores are on a scale from 0 to 100, with high scores indicating better perceived health and function. The SF-36 reliability ranges from 0.63 to 0.94, with the physical functioning subscale consistently demonstrating the highest reliability.

The Short Musculoskeletal Function Assessment (SMFA) questionnaire consists of 34 items comprising the Dysfunction index, which assesses patient function, and twelve items comprising the Bother index, which assesses how much patients are bothered by functional problems.[26] A low score denotes improved function and less bother. The SMFA is widely used with an excellent reliability, 0.93 for the dysfunction index and 0.88 for the bother index.

For followup, overall satisfaction was assessed. Telephone surveys were conducted by an orthopaedic surgical resident on each patient to determine the level of satisfaction with the surgical results. Satisfaction was measured on a 3-point Likert scale from very satisfied to unsatisfied.

Results were analyzed at yearly intervals. Because of the statistically significant difference in hardware removal rates, other secondary surgery, and no difference in function, the authors decided to discontinue the study to avoid further potential unnecessary surgeries.

Statistical methods

Initially, descriptive statistics were completed. Chi-Square and t-test analyses were performed to confirm a similar sample in each group. The SMFA and SF-36 data were analyzed using the 2-way ANOVA. Satisfaction was analyzed using the two-tailed Fisher's Exact test. Significance was determined at $p < 0.05$ for all statistical analyses.

RESULTS

Forty of a possible 185 patients with operatively treated TMT joint injuries met the inclusion criteria and consented to the study. Of the 40 patients who originally agreed to participate in the study, three patients dropped out early and five patients were lost to followup before the 3-month postoperative visit, leaving 32 patients available for followup. In the PORIF group, 86% returned for their 3-month visit ($n = 12$), 100% at 6 months ($n = 14$), 86% at 12 months ($n = 12$), and 64% at 24 months ($n = 9$). In the PA group, 78% returned for their 3-month visit ($n = 14$), 78% at 6 months ($n = 14$), 72% at 12 months ($n = 13$), and 61% at 24 months ($n = 11$).

Table 2 provides a summary of the Lisfranc injuries, type of surgery, and surgical results. The gender, age, mechanism of injury, and smoking rate was similar between groups ($p > 0.05$).

Primary open reduction internal fixation (PORIF) group

At the time of final followup, 14 of 14 (100%) patients had anatomic reductions, with 11 patients requiring hardware removal surgeries (79%) based on standard protocol. Since no complaints were noted, three patients refused hardware removal despite consenting to the study and advised of the need for hardware removal. One conversion to arthrodesis occurred as a secondary surgery. An asymptomatic broken screw was noted at three months within one patient's first TMT joint. No infection, loss of fixation, neural injury, or malalignment was noted.

At final followup, 13 of the 14 PORIF patients (93%) were employed. Thirteen patients (93%) wore regular fitting shoes comfortably without problems. Two patients (14%) required intermittent pain medication consisting of non-steroidal anti-inflammatory medication. Two patients (14%) required an assistive device for ambulation.

Primary arthrodesis (PA) group

At final followup, 17 of 18 patients (94%) had a solid fusion and anatomic reduction, with three patients requiring additional surgeries (17%). The secondary surgeries consisted of three hardware removals, one for a symptomatic screw, the other two for removal of asymptomatic hardware at the patients' request. In terms of complications, one delayed union associated with a broken first TMT joint screw healed at the 6-month mark, and one non-union of a first TMT joint was treated nonoperatively. At 2 months, one patient had a presumed superficial cellulitis treated successfully with an oral antibiotic alone. No deep infection or neural injury was noted.

At final followup, 16 of 18 PA patients (89%) were employed. Seventeen patients (94%) wore regular fitting shoes comfortably without problems. Two patients (11%) required intermittent pain medication consisting of non-steroidal anti-inflammatory medications. No patients required an assistive device for ambulation.

The difference in all follow up surgeries (hardware removal and other secondary surgeries) between the PORIF and the PA groups was statistically significant (79% versus 17%, $p < 0.05$). The only statistically significant difference between the PORIF and PA groups in either the SF-36 or SMFA scores was in the arm/hand index of the SMFA. However, the PA group had trends of better SMFA index scores as compared to the PORIF. Additionally, time had a statistically significant effect on improved physical functioning, decreased disability related to physical aspects of role, and increased social functioning measured on the SF-36 and improved daily activity, mobility, and physical function measured on the SMFA ($p < 0.05$). Differences were observed at 3 months as compared to the 6-, 12-, and 24-month intervals (Tables 3 and 4).

A telephone survey was performed at an average followup of 53 months. Ten of 14 (71%) PORIF patients and 13 of 18 (72%) PA patients were located. In the PORIF group, six patients reported to be very satisfied, three reported satisfied, and one reported to be unsatisfied with the outcome of their treatment. In the PA group, eight reported to be very satisfied, four reported satisfied, and one reported unsatisfied with the outcome of their treatment. No difference in satisfaction rates were noted when comparing PORIF (9/10, 90%) versus PA (12/13, 92%).

DISCUSSION

To compare the clinical outcome of Lisfranc joint injuries, a prospectively randomized evaluation of PA versus PORIF treatment was undertaken. This study's sample was representative of and comparable to historical Lisfranc research with regard to mechanism of injury, injury pattern, and associated injuries.[1–2,4,6,8,9,11,12,21,22] The rate of followup surgery was significantly reduced ($p < 0.05$) in PA patients when compared to PORIF patients. Similar clinical results, as measured by functional outcomes, clinical assessment, and patient satisfaction, were obtained with PORIF or PA for Lisfranc joint injuries.

Table 2: Summary of Lisfranc Injuries and Results

Case	Surgery	Age at Surgery	Cuneiform Fx	Navicular Fx	Cuboid Fx	MT Base Fx	TMT Jts Injured	Reduction	Implant Removal	Implant Failure	Salvage Procedure	Arthrosis Med	Arthrosis Lat	Alignment Maintained
1	PA	73	no	no	no	0	1,2,3,4,5	anatomic	yes	no	none	no	no	yes
2	PA	47	no	no	no	0	1,2	anatomic	no	no	none	no	no	yes
3	PA	50	no	no	no	0	1,2,3	anatomic	no	no	none	no	yes	yes
4	PA	29	no	no	no	3,4	1,2	anatomic	no	no	none	no	no	yes
5	PA	51	no	no	no	3	1,2,3	anatomic	no	no	none	no	no	yes
6	PA	34	no	no	no	2,3	1	anatomic	no	no	none	no	no	yes
7	PA	29	med	yes	no	2	1,2,3	anatomic	no	no	none	no	no	yes
8	PA	57	med,mid,lat	no	yes	1,2,3,4,5	1,2,3,4,5	anatomic	no	no	none	no	no	yes
9	PA	41	med,mid	no	no	0	1,2	anatomic	no	no	none	no	yes	yes
10	PA	32	no	no	no	2	1	anatomic	no	no	none	no	no	yes
11	PA	25	no	no	no	2,4	1,2,3	anatomic	no	no	none	no	yes	yes
12	PA	48	med	no	no	2,3	1,2	anatomic	no	no	none	no	yes	yes
13	PA	29	no	no	yes	0	1,2	anatomic	yes	no	none	no	no	yes
14	PA	27	no	no	no	2,3,4	1	anatomic	no	no	none	no	no	yes
15	PA	32	med,mid	no	no	4	1,2,3,4,5	anatomic	no	no	none	no	yes	yes
16	PA	42	no	no	no	3,4	1,2,3,4,5	anatomic	yes	no	none	no	no	yes
17	PA	26	no	no	no	2	1,2,3,4,5	anatomic	no	no	none	no	no	yes
18	PA	51	no	no	no	0	1,2	anatomic	no	broken screw	none	no	no	yes, with asymptomatic nonunion
19	PORIF	24	no	no	no	2	1,2,3	anatomic	yes	no	none	no	no	yes
20	PORIF	33	no	no	no	1,2,3,4	1,2,3,4,5	anatomic	yes	no	none	yes	yes	yes
21	PORIF	47	no	no	no	2,3,4	1,2,3,4	anatomic	yes	no	none	no	yes	yes
22	PORIF	29	no	no	no	1	1,2	anatomic	yes	no	none	no	no	yes
23	PORIF	47	med	no	no	2,3,4	1,2	anatomic	yes	no	none	yes	yes	yes
24	PORIF	58	no	no	no	2,3,4	1,2,3	anatomic	yes	broken screw	none	yes	no	yes
25	PORIF	24	no	no	no	2,3,5	1,5	anatomic	yes	no	salvage fusion	yes	no	yes
26	PORIF	42	no	no	yes	2,3,4,5	1,2,3,4,5	anatomic	no	no	none	no	no	yes
27	PORIF	20	no	no	no	1	1,2	anatomic	yes	no	none	no	no	yes
28	PORIF	26	no	no	no	0	1,2,3,4,5	anatomic	no	no	none	no	no	yes
29	PORIF	28	med,mid	no	no	0	1	anatomic	no	no	none	yes	yes	yes
30	PORIF	38	no	no	no	2,4	1,2,3,4,5	anatomic	yes	no	none	yes	no	yes
31	PORIF	46	no	no	no	0	1,2,3,4,5	anatomic	yes	no	none	no	yes	yes
32	PORIF	57	no	no	no	0	1,2,3	anatomic	yes	no	none	no	yes	yes

Table 3: Comparison of PORIF and PA SF-36 Scale Scores Over Time

		Initial		3 months		6 months		12 months		24 months	
		PORIF	PA	PORIF	PA	PORIF	PA	PORIF	PA	PORIF	PA
Physical	Physical Functioning*	32.4	34.5	31.1	34.1	41.3	39.4	43.8	47.1	44.0	46.7
	Role-Physical*	44.9	39.3	36.2	36.7	44.8	42.7	47.9	48.6	47.2	45.3
	Bodily Pain	45.1	43.8	42.4	41.9	47.9	44.5	48.9	48.7	44.0	48.5
	General Health	54.2	53.6	49.7	52.8	51.2	52.5	53.2	54.2	51.1	50.0
	Vitality	52.8	51.9	50.8	47.2	50.9	48.4	52.1	52.3	49.5	52.1
Mental	Social Functioning*	43.0	40.9	41.3	42.1	49.2	46.3	51.2	52.6	47.8	48.3
	Role-Emotional	43.8	48.0	43.0	40.3	48.0	43.8	49.6	47.2	53.8	46.7
	Mental Health	46.8	50.2	49.9	45.7	51.3	45.5	52.9	51.5	51.4	48.6

*, Time had a significant effect with decreased functioning at 3 months compared to 6, 12, and 24 months. No statistically significant differences between PORIF and PA at any time interval ($p < 0.05$).

Table 4: Comparison of PORIF and PA SMFA Index Scores Over Time

	3 months		6 months		12 months		24 months	
	PORIF	PA	PORIF	PA	PORIF	PA	PORIF	PA
Daily Activity*	28.8	32.1	16.4	17.5	10.9	10.5	17.0	8.6
Emotional	30.4	33.5	25.0	30.6	20.6	21.7	23.0	17.2
Arm/Hand§	0.8	3.1	0.4	1.0	0.5	1.7	1.0	2.3
Mobility*	38.1	33.5	24.0	22.3	19.9	13.2	21.9	13.1
Dysfunction*	25.0	27.4	16.4	17.6	13.4	12.7	18.0	10.1
Bother	25.3	30.9	13.3	21.4	14.1	17.0	22.9	13.3

§, The PORIF group had significantly greater arm/hand dysfunction than the PA group. *, Time had a significant effect with decreased functioning at 3 months than at 6, 12, and 24 months ($p < 0.05$).

The treatment regimens of Lisfranc injuries have changed with time. Current judgement favors rigid internal fixation with screws for the medial three TMT joints.[14] The lateral two TMT joints have been favorably treated with temporary ORIF. Controversy exists as to the timing and necessity of hardware removal.[2–4,10,14,15,20,21,23,24,28,29,31] Post-traumatic degenerative changes resulting in radiographic changes, pain, and midfoot collapse are common with TMT

injuries.[3] Arthrodesis of symptomatic TMT joints is a well accepted salvage procedure.[25,27]

Arntz et al. reported on 34 patients with TMT fracture dislocations treated with open reduction and screws.[3] At an average of 3.4 years followup, 27 of 29 patients (93%) who initially presented with closed injuries reported an excellent or good outcome. All patients in this study had standard AO technique for internal fixation. Cortical screw size varied from 2.7 mm to 3.5 mm based upon the location and size of the osseous segment. Stable fixation for the medial three TMT and intercuneiform joints was achieved in all patients. If involved, the lateral two TMT joints had temporary fixation with 0.062 Kirschner wires. Greater than 90% of the patients had an excellent or satisfactory outcome with the techniques (Table 2).

Kuo et al. evaluated the outcome of ORIF of Lisfranc injuries. Forty-eight patients were followed for an average of 4 years.[14] The average American Orthopaedic Foot and Ankle (AOFAS) midfoot score was 77. Fifteen of the 48 patients (31%) had purely ligamentous injuries. Compared to the combined midfoot arthrosis rate of 25% (12 of 48), the purely ligamentous group demonstrated a 40% (six of 15) arthrosis rate. The purely ligamentous subgroup had worse outcomes despite initial anatomical reductions and rigid internal fixation. Since ligamentous injuries are potentially more difficult to maintain stability and have worse outcomes than other injury patterns, this randomized study was designed to evaluate two different treatment methodologies. The PA group compared favorably to the PORIF group when treating these unstable ligamentous injury patterns. When compared to the Kuo results of 40% arthrosis, this study had four patients (29%) with medial and six patients (43%) with lateral based arthrosis (Table 1). As in this study, the patient population and surgeon training were similar. These results support anatomic stable fixation.

In patients who fail to resolve symptoms following initial treatment and rehabilitation, arthrodesis is recommended.[8,12,25] A retrospective review by Johnson et al. examined dowel arthrodesis of old Lisfranc injuries.[12] At 37 months, 11 out of 13 (85%) patients demonstrated satisfactory pain relief with three cases of non-union. Sangeorzan et al. evaluated 16 patients who were treated with arthrodesis after failed prior treatment.[25] Excellent results in 11 of 16 patients (69%), and fair or poor results in five of 16 patients (31%) was demonstrated. Mann et al. reported satisfactory results for patients undergoing arthrodesis of the TMT, intercuneiform, or naviculocuneiform joints.[16] At an average of 35 months, Komenda et al. analyzed 32 patients with intractable post-traumatic midfoot pain.[13] From a score of 44 preoperatively, AOFAS midfoot scores improved to 78 at 4 years. Arthrodesis is an accepted salvage procedure to lessen pain and improve function.

A scarcity of published literature comparing PORIF to PA exists. Mulier et al. retrospectively compared PORIF ($n = 16$), to partial ($n = 6$), and complete arthrodesis ($n = 6$).[19] No significant difference was found in outcome scoring between the PORIF and partial arthrodesis group. Complete arthrodesis yielded poor results. The 30-month followup analysis discovered a 94% rate of degenerative changes in the PORIF group, and pseudarthrosis in 33% of the arthrodesis group.

Ly et al. compared PORIF to PA of primarily ligamentous Lisfranc joint injuries in a prospectively randomized study.[15] There are differences between Ly's study and this study. Ly's study randomized patients based on an odd-or-even presentation to the clinic, while this study randomized patients using a random number generating system. The screw insertion technique differed. Two crossed 3.5-mm screws at the first TMT joint were inserted instead of one 3.5-mm screw used by Ly et al. Patients had a predictable hardware removal time of 4 months compared to a variable removal time of 3 to 16 months in the study by Ly et al. At 2 years, Ly reported significantly higher AOFAS midfoot scores in the PA compared to the PORIF group. Despite lacking statistical significance in this study, SMFA scores demonstrated a trended improvement in PA as compared to the PORIF group at 2 years. Both groups improved in physical functioning over time.

Followup surgeries were more common in patients treated with PORIF than PA in this study. All but one of the followup surgeries in the PORIF group was hardware removal. Controversy exists as to the timing, necessity, and role of hardware removal in PORIF for TMT joint injuries. Rationale for removing all hardware is potentially returning normal foot TMT joint motion. Hardware retention reduces TMT motion, increases hardware breakage, and increases reconstruction complexity. In simplified terms, hardware retention is equivalent to arthrodesis without actually achieving osseous union. A comparison study evaluating outcomes and complications of patients treated with hardware retention versus removal may shed light on this matter. If hardware removal surgery were not necessary, the rate of followup surgery plummets.

The successful fusion rate of 94% in the PA group is comparable to standard fusion rates of TMT joints in both traumatic and nontraumatic settings. Thompson et al. demonstrated a 96% fusion rate in 201 feet with first TMT fusion for flatfoot reconstruction.[27] Mann et al. reported a 98% union rate in 179 midtarsal and tarsometatarsal joints in patients with traumatic osteoarthrosis, degenerative osteoarthrosis, and inflammatory arthritis.[16]

The strengths of the study are many. A truly prospective analysis was performed. A randomized system, not surgeon or patient generated, assigned patient groupings and treatment. Treatment techniques were similar despite three different surgeons performing the procedures. Hardware was removed at similar intervals based upon protocol and did not vary. Patients were followed until reaching maximum medical improvement and beyond. For 2 years,

functional outcome measures were obtained at scheduled intervals. Outcomes are an objective method of analyzing and comparing treatments.[26]

This study has limitations. A small number (40 of a possible 185 patients, 22%) of the authors' total operatively treated TMT joint injuries met the inclusion criteria and consented to the study protocol. When patients were told that the study was randomized and they could not choose the treatment, most patients elected out of the study. Furthermore, followup rates were not as high as desired. Three patients dropped out postoperatively and five patients were lost to followup early in the study. At the time of the final phone survey, an additional nine patients were unable to be contacted after an exhaustive search. Of those patients contacted, a significant number declined to come in for clinical followup. In addition, only a 2-year clinical followup was measured. A longer followup period would allow for evaluation of potential further degenerative changes, possible collapse, and secondary compensatory changes in the foot following PORIF and PA. The surgeon directed examinations and grading of radiographs could also have generated bias. Blinded examinations and radiographs could have potentially reduced these biases. Because patients undergoing PA were doing clinically as well as the PORIF patients with significantly fewer followup surgical procedures and without adverse outcomes, the study was discontinued prematurely at forty patients. Since the goal of 60 patients was not achieved, a beta error may have occurred resulting in the study not demonstrating statistical significance comparing SMFA and SF-36 scores between groups.

CONCLUSION

PA resulted in a statistically significant decrease in the number of followup surgeries performed compared to PORIF if hardware removal is routinely performed. Patients treated with PA for primarily ligamentous TMT joint injuries function as well as those patients treated with PORIF. If performed properly, patients are satisfied with either technique. Only the medial three TMT joints, or nonessential joints, should be fused. The lateral two TMT joints, or essential joints, should be only temporarily stabilized.

EDITOR'S NOTE

The authors are to be commended for performing an excellent Level I study on this challenging problem. They clearly are skilled surgeons as they achieved anatomic reductions in all of their patients and only had one nonunion in the fusion group. Personally, I was surprised that their arthrodesis functional outcomes were not better since they had such a high fusion rate. I would anticipate that their fusion outcomes will remain stable but their PORIF results will likely deteriorate over time as posttraumatic arthrosis develops in some patients. It was not surprising that the PORIF group had a higher secondary surgery rate as routine screw removal was built into the study.

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REFERENCES

1. **Aitken, A; Poulson, D:** Dislocations of the tarsometatarsal joint. J Bone Joint Surg Am. **45A**:246–260, 1963.
2. **Arntz, C; Hansen, S:** Dislocations and fracture dislocations of the tarsometatarsal joints. Orthop Clin North Am. **18**:105–114, 1987.
3. **Arntz, C; Veith, R; Hansen, S:** Fractures and fracture-dislocations of the tarsometatarsal joint. J Bone Joint Surg Am. **70**:173–181, 1988.
4. **Buzzard, B; Briggs, P:** Surgical management of acute tarsometatarsal fracture dislocation in the adult. Clin Orthop Relat Res. **353**: 25–133, 1998. http://dx.doi.org/10.1097/00003086-199808000-00014
5. **Cassebaum, W:** Lisfranc fracture-dislocations. Clin Orthop Relat Res. **30**:116–129, 1963. http://dx.doi.org/10.1097/00003086-196300300-00014
6. **Faciszewski, T; Burks, R; Manaster, B:** Subtle injuries of the Lisfranc joint. J Bone Joint Surg Am. **72**:1519–1522, 1990.
7. **Goossens, M; DeStoop, N:** Lisfranc's fracture-dislocations: Etiology, radiology, and results of treatment. A review of 20 cases. Clin Orthop Relat Res. **176**:154–162.
8. **Granberry, W; Lipscomb, P:** Dislocation of the tarsometatarsal joints. Surg Gynecol Obstet. **114**:467–469, 1962.
9. **Hardcastle, P; Reschauer, R; Kutscha-Lissber, E; Schoffmann, W:** Injuries to the tarsometatarsal joint: Incidence, classification and treatment. J bone Joint Surg Br. **64**:349–356,1982.
10. **Hunt, S; Ropiak, C; Tejwani, N:** Lisfranc joint injuries: Diagnosis and treatment. Am J Orthop. **35**:376–385, 2006.
11. **Jeffreys, T:** Lisfranc's fracture-dislocation: A clinical and experimental study of tarso-metatarsal dislocations and fracture-dislocations. J Bone Joint Surg Br. **45**:546–551, 1963.
12. **Johnson, J; Johnson, K:** Dowel arthrodesis for degenerative arthritis of the tarsometatarsal (Lisfranc) joints. Foot Ankle Int. **6**:243–253, 1986.
13. **Komenda, G; Myerson, M; Biddinger, K:** Results of arthrodesis of the tarsometatarsal joints after traumatic injury. J Bone Joint Surg Am. **78A**:1665–1676, 1996.
14. **Kuo, R; Tejwani, NC; Digiovanni, CW; et al.:** Outcome after open reduction and internal fixation of Lisfranc joint injuries. J Bone Joint Surg Am. **82A**:1609–1618, 2000.
15. **Ly, T; Coetzee, J:** Treatment of primarily ligamentous Lisfranc joint injuries: Primary arthrodesis compared with open reduction and internal fixation. A prospective, randomized study. J Bone Joint Surg Am. **88**:514–520, 2006. http://dx.doi.org/10.2106/JBJS.E.00228
16. **Mann, RA; Prieskorn, D; Sobel, M:** Mid-tarsal and tarsometatarsal arthrodesis for primary degenerative osteoarthrosis or osteoarthrosis after trauma. J Bone Joint Surg Am. **78**:1376–1385, 1996.
17. **Manoli, A; Hansen, ST:** Screw hole preparation in foot surgery. Foot Ankle Int. **11**: 105–106, 1990.
18. **Martin, D; Engelberg, R; Agel, J; Swiontkowski, M:** Comparison of the Musculoskeletal Function Assessment questionnaire with the Short Form-36, the Western Ontario and McMaster Universities Osteoarthritis Index, and Sickness Impact Profile health status measures. J Bone Joint Surg Am. **79A**:1323–1335, 1997.
19. **Mulier, T; Reynders, P; Dereymaeker, G; Broos, P:** Severe Lisfranc injuries: Primary arthrodesis or ORIF? Foot Ankle Int. **23**:902–905, 2002.

20. **Mulier, T; Reynders, P; Sioen, W; et al.:** The treatment of Lisfranc injuries. Acta Orthopaedica Belgica. **63**:82–90, 1997.
21. **Myerson, M:** The diagnosis and treatment of injuries to the Lisfranc joint complex. Orthop Clin North Am. **20**:655–664, 1989.
22. **Myerson, M; Fisher, R; Burgess, A; Kenzora, J:** Fracture dislocations of the tarsometatarsal joints: End results correlated with pathology and treatment. Foot Ankle Int. **6**:225–242, 1986.
23. **Rajapakse, B; Edwards, A; Hong, T:** A single surgeon's experience of treatment of Lisfranc joint injuries. Injury. **37**:914–921, 2006. http://dx.doi.org/10.1016/j.injury.2005.12.003
24. **Sands, A; Grose, A:** Lisfranc injuries. Injury. **35**:S-B71–S-B76.
25. **Sangeorzan, B; Veith, R; Hansen, S:** Salvage of Lisfranc's tarsometatarsal joint by arthrodesis. Foot Ankle Int. **10**:193–200, 1990.
26. **Swiontkowski, M; Engelberg, R; Martin, D; Agel, J:** Short Musculoskeletal Function Assessment questionnaire: Validity, reliability, and responsiveness. J Bone Joint Surg Am. **81A**:1245–1260, 1999.
27. **Thompson, IM; Bohay, DR; Anderson, JG:** Fusion rate of first tarsometatarsal arthrodesis in the modified Lapidus procedure and flatfoot reconstruction. Foot Ankle Int. **26**:698–703, 2005.
28. **Thompson, M; Mormino, M:** Injury to the tarsometatarsal joint complex. J Am Acad Orthop Surg. **11**:260–267, 2003.
29. **Trevino, S; Kodros, S:** Controversies in tarsometatarsal injuries. Orthopedic Clinics of North America. **26**:229–238, 1995.
30. **Ware, J; Kosinski, M; Gandek, B:** SF-36 Health Survey: Manual & Interpretation Guide. Lincoln, RI, QualityMetric, 2000.
31. **Yuen, J; Yung, S; Wong, M:** Open reduction and temporary rigid internal fixation of Lisfranc fracture-dislocations. Singapore Med J. **42**:255–258, 2001.