Primary Arthrodesis versus Open Reduction and Internal Fixation for Low-Energy Lisfranc Injuries in a Young Athletic Population

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Abstract

Background: There are 2 Level I studies comparing open reduction and internal fixation (ORIF) and primary arthrodesis (PA) in high-energy Lisfranc injuries. There are no studies comparing ORIF and PA in young athletic patients with low-energy injuries.

Methods: All operatively managed low-energy Lisfranc injuries sustained by active duty military personnel at a single institution were identified from 2010 to 2015. The injury pattern, method of treatment, and complications were reviewed. Implant removal rates, fitness test scores, return to military duty rates, and Foot and Ankle Ability Measure (FAAM) scores were compared. Thirty-two patients were identified with the average age of 28 years. PA was performed in 14 patients with ORIF in 18.

Results: The PA group returned to full duty at an average of 4.5 months whereas the ORIF group returned at an average of 6.7 months ($P = .0066$). The PA group ran their fitness test an average of 9 seconds per mile slower than their preoperative average whereas the ORIF group ran it an average of 39 seconds slower per mile ($P = .032$). There were no differences between the 2 groups in the FAAM scores at an average of 35 months. Implant removal was performed in 15 (83%) in the ORIF group and 2 (14%) in the PA group ($P = .005$).

Conclusions: Low-energy Lisfranc injuries treated with primary arthrodesis had a lower implant removal rate, an earlier return to full military activity, and better fitness test scores after 1 year, but there was no difference in FAAM scores after 3 years.

Level of Evidence: Level III, comparative cohort study.

Keywords: Lisfranc, ORIF, arthrodesis, midfoot

Introduction

Lisfranc injuries affect the tarsometatarsal (TMT), intercuneiform, and the naviculocuneiform joints. They include any combination of bony and ligamentous injury to this complex. Historically they have been associated with high-energy mechanisms such as motor vehicle crash, falls, or crush injuries.¹⁰ The treatment of these high-energy injuries has evolved over time with authors now agreeing that an anatomic reduction through open means is of critical importance.¹ ² ³ ⁸ ¹⁰ ²⁵

Well-designed, prospective studies comparing open reduction and internal fixation (ORIF) with primary arthrodesis (PA) demonstrate comparable outcomes in combined bony and ligamentous injuries and improved outcomes with PA in injuries that are primarily ligamentous.⁹,¹¹

Recently, there has been a greater appreciation of Lisfranc injuries in association with low-energy mechanisms, and there is a growing body of literature in this area.¹ ⁵ ⁶ ⁷ ¹² ¹³ ¹⁶ ¹⁷ Several studies investigated the treatment outcomes for Lisfranc injuries in athletes but they largely consisted of nonoperative management, closed reduction and internal fixation, or ORIF. In many cases, they also describe a more subtle variety of the injury and frequently involve a relatively small number of patients without a comparative group.² ¹³ ¹⁷

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The role of PA is unclear in young, athletic patients who sustain low-energy injuries. The purpose of this study was to compare the outcomes of low-energy Lisfranc injuries treated with PA or ORIF in a young military population.

**Methods**

After local institutional review board approval, operatively managed Lisfranc injuries were identified at a single military tertiary referral center from July 2010 to June 2015. Inclusion criteria included being on active duty in the military, sustaining a low-energy mechanism of injury, and treatment with either ORIF or PA. Exclusion criteria included any hindfoot or ankle injury, high-energy mechanism, initial surgery at another facility, and less than 1 year’s follow-up. Injuries were classified as low-energy if they occurred during athletic activity, ground-level twisting, or a fall from less than 3 feet. Operative database search yielded 80 traumatic Lisfranc injuries. Forty-eight were due to low-energy mechanisms. Ten patients were excluded for not being active duty military, 2 had concomitant hindfoot or ankle injuries, 3 had their initial surgery at an outside hospital, and 1 was lost to follow-up after his 6-month appointment. This left 32 cases (18 ORIF, 14 PA) for inclusion. The patient cohort was composed of 31 males and 1 female with a mean age at surgery of 28 (range, 19-39) years, and a mean follow-up time of 32 (range, 13-70) months. Thirty-four percent reported some tobacco use. Mechanisms of injury included athletic activity (n=23), fall from less than 3 feet (n=6), and ground-level twisting (n=3). There were no significant differences in sex, age, follow-up time, tobacco use, or mechanism of injury between the 2 groups.

A trauma fellowship-trained orthopedic surgeon reviewed all plain films and computed tomographic (CT) scans. Radiographic parameters used to assess injury patterns and quality of reduction included any step off or incongruity of the TMT joints; diastasis greater than 2 mm between the medial cuneiform and the base of the second metatarsal; the alignment of the medial border of the second metatarsal with the medial border of the intermediate cuneiform on the anteroposterior radiograph; the alignment of the medial border of the fourth metatarsal with the medial border of the cuboid on the oblique radiograph; and alignment of the talus with the first ray on the lateral radiograph. Weightbearing radiographs were obtained in 27 (84.4%) patients to assess the instability pattern (Figure 1). The remaining patients were unable to bear weight and had diagnostic nonweight-bearing films. The indication for CT scan was to accurately identify all bony injuries for preoperative planning. A primarily ligamentous pattern was identified as having no structural fractures at the unstable joints. Twenty-two patients (69%) had primarily ligamentous patterns. All injuries with isolated instability of the first or second rays were classified as grade II according to the Nunley classification system. According to the Hardcastle (modified by Myerson) classification system, there were 7 type B1 and 25 type B2 injuries. No comminuted intra-articular fractures were seen. There was no lateral column instability that required fixation. There were no statistically significant differences in injury patterns between the 2 groups (Table 1).

The indication for operative management was any demonstrable instability in the Lisfranc joint complex. ORIF was the surgery of choice for most patients who presented in the acute period. PA was selected for any patients who presented greater than 6 weeks after injury. There were 3 patients with primarily ligamentous injuries who underwent PA in the acute period after a shared decision-making process in which the findings of Ly and Coetzee were discussed. Instability patterns were confirmed using intraoperative stress fluoroscopy. Operative techniques mirrored those previously described. All procedures were performed by foot and ankle or trauma fellowship-trained orthopedic surgeons. An open approach to the unstable segments was performed in all cases. The first and second TMT joints as well

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**Figure 1.** Weightbearing radiographs demonstrating a ligamentous Lisfranc injury of the first and second rays.

**Table 1.** Injury Characteristics of the Open Reduction Internal Fixation (ORIF) Group Compared With the Primary Arthrodesis (PA) Group.

<table>
<thead>
<tr>
<th></th>
<th>ORIF, % (n=18)</th>
<th>PA, % (n=14)</th>
<th>P Value</th>
</tr>
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<tbody>
<tr>
<td>Primarily ligamentous</td>
<td>72</td>
<td>64</td>
<td>.71</td>
</tr>
<tr>
<td>Myerson type B1 pattern</td>
<td>22</td>
<td>14</td>
<td>.67</td>
</tr>
<tr>
<td>Displaced articular fracture</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Lateral column instability</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
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as the Lisfranc interval were fixed in each case. The medial intercuneiform joint was typically fixed as well. In the PA group, the joints were prepared and the subchondral bone was perforated. Autograft was used in most cases. The joints were then reduced and provisionally held with clamps or Kirschner wires. Direct visualization and fluoroscopy was used to ensure an anatomic reduction prior to final fixation. Fixation followed with transarticular screws and/or locked compression plates. In the ORIF group, the joints were inspected for debris and then reduced. A mixture of bridge plates and transarticular position screw constructs were used (Figure 2). A medial column plate was used for instability of the naviculocuneiform joints in 3 patients. Following fixation of the unstable medial column, the lateral column was assessed and found to be stable in all cases; thus, no fixation or fusion was performed. Postoperative plain radiographs were reviewed using the parameters described above and an anatomic reduction was achieved in 30 of 32 (94%) patients. No postoperative CT scans were obtained to assess for persistent occult subluxation.

A standardized postoperative course was utilized. A posterior slab splint was used in all patients until 2 weeks. A removable boot or cast was then used in the ORIF and PA groups, respectively. The cast was removed at the 6-week visit and patients in the PA group were made to wear a removable boot. Graduated weightbearing was allowed at 10 weeks in the ORIF group. Weightbearing was restricted in the PA group until there was clinical and radiographic evidence of fusion, which was typically at the 10-week visit. Minor complications included sensory changes in the deep peroneal distribution (n=6), superficial infection (n=2), and symptomatic implants (n=2). The only major complication seen was contracture of the extensor hallucis longus, and this required operative management. Late midfoot collapse or arthritis was seen in 3 patients, and these were categorized as treatment failures. Predictably, implant removal rates were higher in the ORIF group (P < .001).

Patients returned to military activity when they were able to perform their primary job duties, and participate in mandatory physical training. Overall return to duty rate was 88% and occurred at a mean of 6.0 (range, 4.3-20.7) months. A timed distance running test is performed bi-annually and annually in the United States Navy and Marine Corps, respectively. Postinjury run times were available in 21 of the 27 (78%) who returned to duty. One patient opted to perform an alternate cardiovascular event, and the other 5 patients returned to full duty but separated from the military for unrelated reasons prior to the next fitness test. The average preinjury run times were calculated and compared to the first postinjury run time. To allow for direct comparison between the Navy and Marine Corps patients, the run times were converted to seconds per mile.

Twenty-seven of 32 (84%) patients completed a phone interview at an average of 35 (range 12-70) months. Each patient was asked about additional surgeries, if they were currently under the care of a surgeon, and if they were still in the military. The Foot and Ankle Ability Measure (FAAM) was also completed over the phone if it had not been done in clinic.

All continuous variables were compared with a 2-tailed Student t test. All categorical variables were compared with Fisher exact test. Significance was set for all analyses at P < .05. Excel (Microsoft, Seattle, WA) was utilized for all statistical analysis.

Results

Open Reduction Internal Fixation Group

Of the 18 patients in the ORIF group, 3 (16%) injuries were initially missed but then diagnosed within the first week. Thirteen (72%) were primarily ligamentous. Mean time to surgery was 18 (range, 11-33) days. Isolated instability of the first and second rays was uniform across this group, and no patients required fixation of the third, fourth, or fifth ray. TMT fixation constructs included screws alone in 10 (56%), screws and plates in 1 (5%), and plate only in 7 (39%). Minor complications included 4 with permanent deep peroneal nerve sensory changes and 2 superficial infections that occurred after implant removal, both were successfully treated with oral antibiotics. The only major complication was contracture of the extensor hallucis longus, and this required operative management. Three treatment failures were seen. One had midfoot collapse and required conversion to arthrodesis at 43 months (Figure 3). The other 2 developed midfoot arthritis, and fusion was recommended.
but the patients declined. Implant removal was performed in 15 (83%). All transarticular screws were removed, whereas some bridge plates were allowed to be left in place. Time to implant removal averaged 120 days.

Sixteen (89%) in the ORIF group were able to return to military duty at an average of 209 (range, 79-343) days. Visual analog scale (VAS) pain score at final clinical follow-up averaged 1.5 (range 0-7), with 7 (39%) being pain free. Average postinjury run time was 39 seconds slower (range 16 seconds faster to 92 seconds slower) per mile than the preinjury average. The first timed run was performed at an average of 369 (range 188-589) days after surgery.

**Primary Arthrodesis Group**

Of the 14 patients in the PA group, 8 (57%) were initially missed, resulting in delayed diagnosis and presentation beyond 6 weeks, thus indicating fusion. Three patients had delayed surgery secondary to inappropriate management from their primary doctor or being lost to follow-up. The final 3 were indicated for primary arthrodesis in the acute period as part of a shared decision-making process. Nine (64%) were primarily ligamentous. Ten underwent arthrodesis of the first and second TMT as well as the medial intercuneiform joint, and the Lisfranc interval. Four required the inclusion of the third TMT and lateral intercuneiform joint. Fixation constructs included screws alone in 8 (57%) and combined screws and plates in 6 (43%). Minor complications included 2 permanent deep peroneal nerve sensory changes and 2 symptomatic medial screws. The 2 symptomatic screws were removed at an average of 13 months. There were no infections in this group. Union occurred uneventfully in all patients at an average of 81 (range, 58-96) days (Figure 4).

Twelve (86%) in the PA group were able to return to military activity at an average of 138 (range, 78-228) days. VAS pain score at final clinical follow-up averaged 1.6 (range, 0-8), with 8 (57%) being pain free. Average postinjury run time was 9 seconds slower (range 31 seconds faster to 61 seconds slower) per mile than the preinjury average.

**Primary Arthrodesis vs. ORIF Outcome Comparison**

There was no difference in return to duty rates, VAS pain score at final follow-up, and days to fitness testing between the 2 groups. The average time to return to full military activity was 2 months sooner in the PA group ($P = .0066$). Other than undergoing ORIF, there were no other risk factors for a delay in return to military activity. The average pre- to postinjury run time was 29 seconds faster per mile in the PA group ($P = .032$) (Table 2). The FAAM Activities of Daily Living (ADL) score was 84.7 and 83.3 for the ORIF and PA groups, respectively. The FAAM ADL Single Assessment Numerical Evaluation (SANE) was 77.5 and 82.1 for the ORIF and PA groups, respectively. The FAAM Sports Subscale was 70.4 and 69.2 for the ORIF and PA groups, respectively. The FAAM Sports Subscale SANE score was 67.9 and 70.7 for the ORIF and PA groups, respectively. There were no differences in any of the FAAM subscale scores at an average of 35 months’ follow-up (Table 3).

**Discussion**

The management of acute Lisfranc injuries has evolved over time. Nonoperative management was replaced by closed reduction and Kirschner wire fixation, and now open reduction with rigid fixation is recommended for all displaced
Primary arthrodesis was initially used as a salvage procedure for midfoot arthritis or collapse after failed ORIF. Following a study showing high failure rates of ORIF in primarily ligamentous injuries and a surgeon-stratified cohort study showing comparable outcomes between ORIF and PA, a randomized trial was performed. The landmark study by Ly and Coetzee found better short- and medium-term outcomes with PA in high-energy ligamentous injuries. An additional Level I study in mixed bony and ligamentous high-energy injuries found comparable results between ORIF and PA, with high rates of secondary procedures for HWR in the ORIF group. It is important to note that none of these comparative studies involved any significant number of low-energy injuries or athletes.

The subsequent indications for acute primary arthrodesis suggested by Coetzee and Ly are as follows: major ligamentous disruptions and multidirectional instability of the Lisfranc joints; a comminuted intra-articular fracture at the base of the first or second metatarsal; and crush injuries of the midfoot with an intra-articular fracture dislocation. Another suggested indication for primary arthrodesis is a significant delay to surgery, although the cut-off time for definitive fixation is not agreed upon. We used 6 weeks as the upper limit for fixation as this is the most conservative time frame in line with expert opinion.

The indications for primary arthrodesis in low-energy athletic injuries are not established. Myerson has recommended against primary arthrodesis in athletes, regardless of the potential for a rapid return to activity, believing that primary arthrodesis may prevent the restoration of normal foot function. However, there are no clinical data regarding the long-term consequences of midfoot fusion in the athletic or general population.

The literature describing ORIF after sports-related injuries consists of multiple case series without any comparative groups. Curtis et al reported a case series of 19 patients in which 14 were managed nonoperatively and 5 underwent ORIF. They recognized the severity of even subtle injuries and recommended fixation of all unstable joints. Nunley et al reported a case series of 15 patients in which 7 were managed nonoperatively, 6 were treated with closed reduction and internal fixation, and 2 received ORIF. Fourteen were reported to have excellent outcomes. More recently, Deol et al examined the return to training and competition of 17 elite soccer and rugby players after mostly ORIF. Sixteen were able to return to training and then full competition at an average of 20 and 25 weeks, respectively. Return to full military activity averaged 6 months in the current study. This is at the high end of the 14 to 25 weeks required to return to competitive sport seen within the literature. Returning to full duty requires the patient to do their daily work, any assigned athletic activity, and possibly be assigned to remote locations. It is therefore not surprising that this cohort was on the longer end of the reported range. Despite the relatively good return to sport data, there is a growing body of literature showing the short- and medium-term failure rates of ORIF. It is important to remember that these failure rates are in high-energy injuries and there are no clinical data regarding the long-term failure rates of ORIF in low-energy injuries.

The current study was the first to compare PA and ORIF in low-energy injuries. In addition, it assessed return to athletic activity in a young population. This study found that those treated with primary arthrodesis were able to return to full military activity an average of 2 months earlier. A possible confounding factor is that the ORIF group underwent planned implant removal in 83% of cases and this second surgery may have slowed down the rehab process. The current study also found that those who underwent primary arthrodesis scored closer to their preinjury time in a 1.5- or 3-mile timed run. This is likely secondary to bony healing being faster and more durable than soft tissue healing. Once a solid fusion is seen, pain should be minimal and all activity limitations are removed from the patient, allowing for a rapid return to training. At an average of 35 months’ follow-up, the FAAM scores were equal between the 2 groups. Unfortunately, the current study does not contain multiple data points for run times and FAAM scores, so it is not possible to follow functional recovery over time as tested by these modalities. The functional differences seen at different time points in this study can be explained in one of 2 ways. It may be that the PA group recovered more quickly.

### Table 2. Military Specific Outcomes of the Open Reduction Internal Fixation (ORIF) Group Compared With the Primary Arthrodesis (PA) Group.

<table>
<thead>
<tr>
<th></th>
<th>ORIF (n = 18)</th>
<th>PA (n = 14)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTD Rate</td>
<td>89%</td>
<td>86%</td>
<td>.1</td>
</tr>
<tr>
<td>Days to RTD</td>
<td>209</td>
<td>138</td>
<td>.0066</td>
</tr>
<tr>
<td>Days to first run test</td>
<td>369</td>
<td>320</td>
<td>.4</td>
</tr>
<tr>
<td>First run time minus</td>
<td>39 s slower/</td>
<td>9 s slower/</td>
<td>.032</td>
</tr>
<tr>
<td>preinjury average time</td>
<td>mile</td>
<td>mile</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: RTD, return to duty.

### Table 3. Foot and Ankle Ability Measure (FAAM) scores of the open reduction internal fixation (ORIF) group compared with the primary arthrodesis (PA) group.

<table>
<thead>
<tr>
<th></th>
<th>ORIF</th>
<th>PA</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAAM ADL Score</td>
<td>84.7</td>
<td>83.3</td>
<td>.84</td>
</tr>
<tr>
<td>FAAM ADL SANE</td>
<td>77.5</td>
<td>82.1</td>
<td>.54</td>
</tr>
<tr>
<td>FAAM Sports Score</td>
<td>70.4</td>
<td>69.2</td>
<td>.91</td>
</tr>
<tr>
<td>FAAM Sports SANE</td>
<td>67.9</td>
<td>70.7</td>
<td>.79</td>
</tr>
</tbody>
</table>

Abbreviations: ADL, activities of daily living; SANE, single-assessment numerical evaluation.
than the ORIF group and had better function after 1 year as tested by the timed run, but this functional advantage evened out after 3 years as tested by FAAM scores. Another explanation is that a timed run test is a more sensitive test of function than FAAM scores, and if a timed run was performed at 3 years, the advantage seen in the PA group may persist. The high attrition rate of military members over time makes this long-term evaluation challenging.

The limitations of this study primarily stem from the inherent bias present in retrospective studies. This bias was mitigated by the lack of significant differences in the group demographics and injury characteristics. The fact that the study was made up of mostly young, military males, may make it less generalizable. All patients had isolated instability of the first and second rays, and although the fixation constructs were variable, all had formal approaches with rigid screw or plate fixation. The primary arthrodesis group had a delayed presentation in many cases and underwent surgery on a delayed basis, which may have affected the results. Another potential limitation is the lack of postoperative CT scans in the ORIF group. Based on accepted radiographic parameters, 89% of the ORIF group in the current study had anatomic reductions. If occult subluxation was present in some of the presumed anatomic reductions, it could potentially contribute to worse outcomes. That being said, the highest-quality clinical studies examining midfoot injuries do not include the use of postoperative CT scans to assess the quality of reduction. Finally, although the clinical follow-up was very consistent, the time period in this study is too short to discuss long-term outcomes, but it is sufficient to discuss return to work, return to sport, and short-term functional outcomes.

In conclusion, this retrospective study demonstrated both ORIF and PA to be safe interventions with similar rates of return to a demanding profession in a young cohort. PA may decrease the time required for return to work and improve the ability to run in the short term, although functional scores were no different at 35 months. The long-term consequences of arthrodesis in young, athletic patients remain unknown, and because of this, primary arthrodesis cannot be recommended universally in this population at this time. Long-term, prospective studies of low-energy injuries in athletes would be beneficial to establish and evaluate indications for primary arthrodesis in this population.

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