

# Summary

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the conventional way with formal open reduction and internal fixation, which was done with screw fixation of the medial two or three rays. The indications for Kirschner-wire fixation of the lateral two rays were exactly the same as those in the arthrodesis group. The lateral two rays were not fused in any of the forty-one patients. Standard 3.5 or 4.0-mm cortical screws were utilized depending on the patient's size.

Postoperative follow-up was performed at two weeks, six weeks, three months, and six months, and then annually. We evaluated the outcomes with clinical examination, radiography, a visual analog pain scale (of 0 to 10), the AOFAS

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# TREATMENT OF PRIMARILY LIGAMENTOUS LISFRANC JOINT INJURIES: PRIMARY ARTHRODESIS COMPARED WITH OPEN REDUCTION AND INTERNAL FIXATION

A PROSPECTIVE, RANDOMIZED STUDY

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**Background:** Open reduction and internal fixation is currently the accepted treatment for displaced Lisfranc joint injuries. However, even with anatomic reduction and stable internal fixation, treatment of these injuries does not have uniformly excellent outcomes. The objective of this study was to compare primary arthrodesis with open reduction and internal fixation for the treatment of primarily ligamentous Lisfranc joint injuries.

**Methods:** Forty-one patients with an isolated acute or subacute primarily ligamentous Lisfranc joint injury were enrolled in a prospective, randomized clinical trial comparing primary arthrodesis with traditional open reduction and internal fixation. The patients were followed for an average of 42.5 months. Evaluation was performed with clinical examination, radiography, the American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot Scale, a visual analog pain scale, and a clinical questionnaire.

**Results:** Twenty patients were treated with open reduction and screw fixation, and twenty-one patients were treated with primary arthrodesis of the medial two or three rays. Anatomic initial reduction was obtained in eighteen of the twenty patients in the open-reduction group and twenty of the twenty-one in the arthrodesis group. At two years postoperatively, the mean AOFAS Midfoot score was 68.6 points in the open-reduction group and 88 points in the arthrodesis group ( $p < 0.005$ ). Five patients in the open-reduction group had persistent pain with the development of deformity or osteoarthritis, and they were eventually treated with arthrodesis. The patients who had been treated with a primary arthrodesis estimated that their postoperative level of activities was 92% of their preinjury level, whereas the open-reduction group estimated that their postoperative level was only 65% of their preoperative level ( $p < 0.005$ ).

**Conclusions:** A primary stable arthrodesis of the medial two or three rays appears to have a better short and medium-term outcome than open reduction and internal fixation of ligamentous Lisfranc joint injuries.

**Level of Evidence:** Therapeutic Level I. See Instructions to Authors for a complete description of levels of evidence.

Lisfranc joint injuries (tarsometatarsal dislocations or fracture-dislocations) are uncommon, and they are frequently missed or misdiagnosed<sup>1-4</sup>. However, even with accurate diagnosis and early treatment, these injuries can result in chronic disability<sup>5</sup>. Over the past several decades, Lisfranc complex injuries have been treated with closed reduc-

tion and immobilization, closed reduction and percutaneous pinning<sup>3,6-9</sup>, or open reduction and percutaneous pinning or screw fixation<sup>10-13</sup>. It has become evident that an anatomic reduction is critical for optimal outcomes and that this is best achieved with open reduction<sup>7,11-13</sup>. However, the method of treatment is still controversial. Currently, the recommended and accepted treatment of Lisfranc complex injuries is open reduction and internal fixation<sup>10-13</sup>, but, despite appropriate initial treatment, painful osteoarthritis still develops in some patients<sup>3,8</sup>, necessitating conversion to an arthrodesis of the



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tarsometatarsal joints to achieve pain relief.

According to the current literature, primary arthrodesis is not recommended for Lisfranc complex injuries<sup>9,11</sup>. Instead, arthrodesis has been reserved as a salvage procedure after failed open reduction and internal fixation, for a delayed or missed diagnosis, and for severely comminuted intra-articular fractures of the tarsometatarsal joints<sup>7,11,14-17</sup>. Kuo et al.<sup>12</sup> suggested that there is a subgroup of patients with a purely ligamentous Lisfranc injury who may be better treated with primary fusion. More recently, Mulier et al.<sup>10</sup> compared the results of primary arthrodesis with those of open reduction and internal fixation for severe Lisfranc injuries in a retrospective, surgeon-randomized study. They advocated open reduction and internal fixation or partial arthrodesis for severe Lisfranc injuries, believing that primary complete arthrodesis should be reserved as a salvage procedure.

The purpose of the present prospective study was to test the hypothesis that treatment of high-energy ligamentous Lisfranc injuries with primary open reduction and internal fixation would have the same or better functional short and medium-term outcomes as treatment with a primary partial arthrodesis.

### Materials and Methods

We performed a prospective study comparing two groups of patients with a Lisfranc joint injury. The study design was to include all injuries that were seen up to one month after the accident, although all forty-one patients had the surgery within three weeks from the date of injury and most had it within the first week. The Lisfranc joint injury had to be primarily ligamentous, with no major fractures present (Fig. 1-A). Lisfranc joint injuries with a fleck sign (an avulsion fracture of the Lisfranc ligament) were considered to be primarily ligamentous and were included in the study. Exclusion criteria were a comminuted intra-articular fracture at the base of the first or second metatarsal; any other substantial foot, ankle, or leg injury; a previous attempt at surgical management of the same injury; insulin-dependent diabetes mellitus; ipsilateral ankle fusion; peripheral vascular disease; peripheral neuropathy; and rheumatoid arthritis.

Between March 1998 and January 2002, forty-one patients who met the inclusion criteria were enrolled in the study; this was a consecutive series as no patient refused to participate in the study. The study was approved by our institutional review board (IRB-0212M37742), and informed consent was obtained from the patients. All patients had been followed for at least two years. A power analysis done before the study showed that we needed thirty-eight patients to demonstrate a significant difference between the two groups with regard to the American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot Scale scores. This number represented a power of 0.8.

Patients were randomized with use of an odd-or-even process, based on the order of presentation, to the arthrodesis group or the open-reduction group as they presented with the Lisfranc joint injury. For example, the first patient was as-

signed to the arthrodesis group, and the next patient was automatically assigned to the open-reduction group. There was no variation from this protocol at any time during the study. Patients in the arthrodesis group were treated with primary arthrodesis of the medial two or three rays, depending on the instability pattern. If the radiographs and computed tomography scan showed an instability pattern that involved the first and second metatarsal-cuneiform joints but no instability of the third, only the medial two rays were fused. However, if the third metatarsal-cuneiform joint was displaced, it was reduced and fused as well. Three patients also had instability between the medial and middle cuneiforms, and that joint was included in the fusion. The first metatarsal-cuneiform joint was fused in all but one patient, in whom only the second and third metatarsal-cuneiform joints were fused. If the radiographs and computed tomography scan showed a subluxation or dislocation of the lateral two rays, they were assessed under fluoroscopy after treatment of the medial rays. If they appeared to be well reduced and stable, no treatment was provided. If there was still a malreduction or if they were unstable with manipulation, the fourth and fifth rays were reduced and were stabilized with temporary Kirschner-wire fixation, but they were not fused. The Kirschner wires were removed at six weeks. Autogenous bone graft or allograft was not utilized in the primary arthrodesis group.

Patients in the open-reduction group were treated in the conventional way with formal open reduction and internal fixation, which was done with screw fixation of the medial two or three rays. The indications for Kirschner-wire fixation of the lateral two rays were exactly the same as those in the arthrodesis group. The lateral two rays were not fused in any of the forty-one patients. Standard 3.5 or 4.0-mm cortical screws were utilized depending on the patient's size.

Postoperative follow-up was performed at two weeks, six weeks, three months, and six months, and then annually. We evaluated the outcomes with clinical examination, radiography, a visual analog pain scale (of 0 to 10), the AOFAS Midfoot Scale<sup>18</sup>, and a clinical questionnaire. Alignment was assessed on weight-bearing anteroposterior, lateral, and oblique radiographs, which were made at each follow-up visit except for the one at two weeks. Alignment was assessed on the basis of whether the medial border of the second metatarsal lined up with the medial border of the middle cuneiform on the anteroposterior radiograph, whether the medial border of the fourth metatarsal lined up with the medial border of the cuboid on the oblique radiograph, and whether there was any dorsal displacement of the metatarsals relative to the tarsal bones on the lateral radiograph. The clinical questionnaire included questions regarding patient satisfaction (dissatisfied, somewhat dissatisfied, neutral, somewhat satisfied, or very satisfied) with the treatment and questions regarding their return to their previous level of physical or sports activities. In addition, the patients were asked to estimate their level of activities as a percentage of the level before the injury. Finally, the patients were asked to rate the pain on a visual analog pain scale that ranged from 0 (no pain) to 10 (severe pain).



Fig. 1-A  
Anteroposterior radiograph of a primarily ligamentous Lisfranc joint injury, showing the instability pattern of the tarsometatarsal joints.

#### *Open-Reduction Group*

There were twenty patients, thirteen men and seven women, in the open-reduction group. Twelve patients were injured in a motor-vehicle, snowmobile, or all-terrain-vehicle accident. Five patients fell from a height of >4 ft (>1.2 m). One patient was playing basketball when another player fell on his foot. Another patient was injured in a pile-up in an ice hockey game, and one patient stepped into a 2-ft (0.6-m) deep hole in the ground. The average age at the time of injury in this group was 32.4 years (range, nineteen to fifty-two years), and the average duration of follow-up was forty-two months (range, twenty-five to sixty months).

#### *Arthrodesis Group*

There were twenty-one patients, fourteen men and seven women, in the arthrodesis group. Ten patients were injured in a motor-vehicle, snowmobile, or dirt-bike accident. Seven pa-

tients fell from a height of >4 ft (>1.2 m). Two patients fell off a horse while the foot was stuck in the stirrup, and two patients stepped into a deep hole. The average age at the time of injury was thirty-two years (range, nineteen to forty-two years), and the average duration of follow-up was 43.4 months (range, twenty-five to sixty months).

#### *Surgical Technique*

##### *Open Reduction and Internal Fixation*

Two dorsal longitudinal incisions—one between the first and second metatarsals and the second centered between the fourth and fifth metatarsals—were made. Open reduction and screw fixation of the first, second, and third metatarsal-cuneiform joints was performed (Fig. 1-B). Then, if necessary, Kirschner wires were placed in each of the lateral two rays, but the rays were not fused. Seven patients in the open-reduction group required Kirschner-wire fixation of the lateral rays. The Kirschner wires were removed between six and eight weeks postoperatively. The screws were not routinely removed unless they caused symptoms, and they were never removed before three months.



Fig. 1-B  
Intraoperative view of the open reduction and screw fixation of the Lisfranc joints.



Fig. 1-C

The screws were removed at seven months. These radiographs, made at eighteen months, show degenerative changes of the first and second tarsometatarsal joints.

### Arthrodesis

Standard incisions were made as described for the open-reduction group. Open reduction was performed, cartilage and fibrous tissue were resected, and the joints were decorticated. Reduction and screw fixation was then performed. If the third metatarsal-cuneiform joint was seen to be displaced on the computed tomography scan or was clearly unstable on direct examination, it was fused in the same fashion. The rationale for treatment of the lateral two rays was exactly the same as the rationale in the open-reduction group. Nine patients in the arthrodesis group underwent temporary Kirschner-wire fixation of the lateral two rays.

### Postoperative Management

Postoperatively, all patients wore a short leg splint for two weeks followed by a short leg cast for four to six weeks, and all remained non-weight-bearing during this time. The patients then slowly advanced to full weight-bearing over the next four weeks while wearing a prefabricated fracture boot. Physical therapy was started at six to ten weeks and included gait-training, swelling control, and range-of-motion exercises. Over-the-counter or custom-made orthotics were prescribed on an as-needed basis, depending on residual symptoms.

### Statistical Analysis

GraphPad InStat software (GraphPad Software, San Diego, California) was used to perform the statistical analysis for the study. The Mann-Whitney test was used to derive an unpaired two-tailed p value. A p value of  $<0.05$  indicated significance.

### Results

#### Open-Reduction Group

##### Complications and Additional Surgery

Of the twenty patients in the open-reduction group, sixteen underwent secondary surgery to remove prominent or painful hardware. The screws were removed at an average of 6.75 months (range, three to sixteen months). Follow-up radiographs showed evidence of loss of correction, increasing deformity, and degenerative joint disease in fifteen patients (Fig. 1-C). Five of these patients required conversion to tarsometatarsal arthrodesis at an average of thirty-five months (range, fourteen to sixty months) after the injury. Two more patients were scheduled for conversion to an arthrodesis at the time of manuscript preparation.

#### Functional Questionnaire

We present the functional results that were determined at the most recent follow-up evaluation. The results for the patients

**TABLE I Patient Satisfaction at the Time of the Last Follow-up**

	No. of Patients	
	Arthrodesis	Open Reduction and Internal Fixation
Very satisfied	16	8
Somewhat satisfied	5	3
Neutral		3
Dissatisfied		6

who underwent a secondary fusion were determined at the last follow-up visit prior to the fusion.

Eight patients reported that they were very satisfied with the result, three were somewhat satisfied, three were neutral, and six were dissatisfied (Table I). Five of the six patients who were dissatisfied with the outcome went on to have a tarsometatarsal fusion. All five later reported that they were very satisfied with the result at the time of the last follow-up. Six of the twenty patients reported that they were able to return to their preinjury level of physical or sports activities, and fourteen stated that they were not able to do so. On the average, the patients estimated their return to physical or sports activity, as a percentage of the preinjury level, to be 44% at the six-month postoperative visit, 61% at the one-year visit, and 65% at the two-year visit (Table II).

#### Arthrodesis Group

The arthrodesis group as a whole did very well. Anatomic reduction was obtained in twenty of the twenty-one patients. The average time to fusion was 10.6 weeks. Nineteen patients had an uncomplicated fusion, one needed treatment with a bone stimulator, and one required bone-grafting and revision fusion. Twelve patients had three rays fused, and nine had two rays fused; there was no difference in outcome between these two subgroups.

#### Complications and Additional Surgery

Of the twenty-one patients in the arthrodesis group, four (19%) required a second surgical procedure, primarily for removal of painful hardware. The screws were removed at an average of 6.5 months (range, five to ten months). One patient had a delayed union at seventeen weeks; a bone stimulator was used, and a solid fusion was achieved over the next eight weeks. One patient with a nonunion at twenty weeks underwent a revision arthrodesis with bone graft from the calcaneus. The fusion healed uneventfully at eight weeks after the revision surgery. Another patient had a posttraumatic intrinsic compartment syndrome that resulted in clawtoes. This patient underwent percutaneous flexor tendon release of the lesser toes and was pleased with the result.

#### Functional Questionnaire

Sixteen patients reported that they were very satisfied with the result, and five were somewhat satisfied (Table I). Fifteen patients reported that they were able to return to their previous

level of physical or sports activities, and six stated that they were unable to do so. The patients' estimation of their return to physical and sports activity, as a percentage of the preinjury level, averaged 62% at six months postoperatively, 86% at one year, and 92% at two years (Table II).

#### AOFAS Midfoot Scores

#### and Visual Analog Pain Scores

At the time of the two-year follow-up, the AOFAS score averaged 88.0 points (range, 63 to 100 points) in the arthrodesis group and 68.6 points (range, 16 to 100 points) in the open-reduction group ( $p = 0.005$ ). At the time of final follow-up (at an average of forty-two months in the open-reduction group and forty-three months in the arthrodesis group), the AOFAS Midfoot score averaged 57.1 points (range, 16 to 100 points) in the open-reduction group (including the five patients who had undergone conversion to a tarsometatarsal arthrodesis) and 86.9 points (range, 63 to 100 points) in the arthrodesis group ( $p < 0.0001$ ). When the five patients in the open-reduction group who had had a conversion to midfoot arthrodesis were excluded, the average final AOFAS Midfoot score for the remaining fifteen patients was 65.2 points (range, 27 to 100 points), and the arthrodesis group still had a better average score than the open-reduction group ( $p < 0.0024$ ).

As stated, five of the patients who were originally treated with open reduction and internal fixation had a conversion to a fusion. Three of the four who had the arthrodesis more than two years before our review were available for evaluation. Their mean AOFAS score at two years was 79.0 points, which was better than the mean for the open-reduction group but lower than that for the primary arthrodesis group. These four patients' mean estimate of their functional ability after the fusion was 80% of their preinjury level. The number of patients in this subgroup is too small for us to draw any conclusions, but the findings show a trend toward improvement after secondary fusion but results that are not as good as those following a primary fusion.

At the time of final follow-up, the average score on the visual analog pain scale was 4.1 points in the open-reduction group and 1.2 points in the arthrodesis group ( $p = 0.0002$ ).

#### Discussion

Treating intra-articular fractures and dislocations poses unique challenges. It is important to look at every joint's

**TABLE II Patient's Estimation of Level of Functional Participation Compared with Preinjury Status**

	Percentage of Preinjury Level		
	6 Mo	12 Mo	24 Mo*
Arthrodesis	62	86	92
Open reduction and internal fixation	44	61	65

\*The difference between the treatment groups was significant ( $p < 0.005$ ).

function specifically when deciding which treatment options are realistic. For example, a fusion of the knee is very seldom used, even as a salvage procedure, for the treatment of a distal femoral fracture. In contrast, feet with a Lisfranc joint fracture are often salvaged with a fusion, without a devastating effect on function. However, we are not aware of any prospective studies in the literature focusing on the issue of primary fusion or comparing fusion with open reduction and internal fixation for Lisfranc joint injuries, although it is evident from the literature that the results of open reduction<sup>7,11-13</sup> are better than those of closed reduction and that screw fixation is better than percutaneous pinning<sup>3,6,7,9-13</sup>, at least for the medial three rays. Recently, most authors have recommended open reduction and internal fixation instead of primary arthrodesis for Lisfranc joint injuries<sup>9-13</sup>. However, because persistent pain and posttraumatic degenerative changes occur despite anatomic reduction<sup>3,8</sup>, we speculated that there may be a subset of Lisfranc injuries that are better treated with primary arthrodesis of the involved tarsometatarsal joints.

Kuo et al.<sup>12</sup> pointed out that purely ligamentous Lisfranc injuries do not always heal following open reduction and internal fixation and that there was a tendency for this type of injury to result in osteoarthritis (a finding in six of their fifteen patients). In our study, fifteen of the twenty patients in the open-reduction group lost correction and had at least some deformity and degenerative arthritic changes, which ranged from a minor loss of correction to substantial collapse and degenerative changes. Five of our patients had persistent pain and underwent a salvage arthrodesis, and two more patients were awaiting an arthrodesis at the time of writing. The mean AOFAS Midfoot score in our open-reduction group (57.1 points) was lower than the mean score for the patients in the study by Kuo et al. (78.8 points). However, our arthrodesis group had a better outcome, with a mean AOFAS Midfoot score of 86.9 points. This information suggests that patients with a primarily ligamentous Lisfranc injury should be treated with primary arthrodesis.

Sixteen of the twenty patients in our open-reduction group had removal of hardware, and we believe that that was a confounding factor for the poor results seen in that group. However, we also believe that the injury itself, being primarily ligamentous, plays a major part in the healing and outcome of these injuries. A review of the radiographs made prior to hardware removal indicated that some early degenerative changes and collapse of the midfoot had developed in the majority of patients. Radiographs made at a later follow-up visit showed that most of the patients went on to have progressive degenerative changes after the screws were removed. We postulate that, because these injuries were primarily ligamentous, healing of the ligaments and capsules provided insufficient strength to maintain the initial reduction. This is evidenced by the fact that, despite initial anatomic reduction in eighteen of the twenty patients, some loss of correction, further collapse, and degenerative changes of the Lisfranc joint developed after screw removal in fifteen patients.

Recent studies<sup>10,14,16</sup> have compared complete and partial arthrodeses for the treatment of Lisfranc joint injuries, and we

found one study comparing open reduction and internal fixation with primary arthrodesis. In that surgeon-randomized study of twenty-eight patients, which had some similarities to our study, Mulier et al.<sup>10</sup> compared open reduction and internal fixation (sixteen patients) with complete arthrodesis (six patients) and partial arthrodesis (six patients). They concluded that a complete fusion (of all five tarsometatarsal joints) yields poor results and that open reduction and internal fixation provides a better functional outcome. We agree with that conclusion. Mulier et al. reported that, at the time of final follow-up (at thirty months), 94% of their open-reduction group already had radiographic signs of degenerative changes of the tarsometatarsal joints. At that juncture, the open-reduction group had the same functional score as the group treated with partial fusion, but it can be assumed that the score in the open-reduction group would decrease with time because of the high rate of identified degenerative changes.

The authors of two previous studies recommended that only the medial two or three rays be fused. We concur with Komenda et al.<sup>14</sup> and Sangeorzan et al.<sup>16</sup> that it is beneficial for a patient to have motion in the lateral two rays and that it is not necessary to perform a complete fusion to obtain optimum results. Komenda et al. reported the results of arthrodeses that were performed to treat intractable pain at a mean of thirty-five months after traumatic tarsometatarsal joint injury. The mean AOFAS Midfoot score was 78 points at a mean of fifty months postoperatively. In our study, the mean AOFAS Midfoot score in the arthrodesis group was 86.9 points at a mean of 43.4 months postoperatively. This finding suggests that performing immediate primary fusion helps patients to avoid several years of persistent pain and disability.

Our study had several limitations. First, the allocation of treatment with an open-randomization, odd-or-even format could have introduced selection bias. Using a random-numbers table or computerized randomization would have been a better way to allocate our patients. Second, the attending surgeon performed the follow-up clinical examination and gathered the questionnaires, which raises a concern about bias. However, the patients were given the questionnaires when they arrived at the clinic and had completed them on their own by the time that they were seen in the clinic. The attending surgeon just gathered the forms and made sure that they were entered into the database. Third, we did not obtain information or determine the outcomes for the patients with Lisfranc joint injuries who were not included in the study because they met our exclusion criteria. Outcome information on the patients with osseous involvement would have provided a group with which to compare our patients, who had the less common, ligamentous Lisfranc injuries. Fourth, hardware removal could have contributed to the poor results that were seen in the open-reduction group.

In summary, because of the poor healing potential of the ligament-osseous interface and the trend toward a higher rate of correction loss, increasing deformity, and degenerative arthritic changes, we believe that primarily ligamentous injuries are a subset of Lisfranc joint injuries that are not as ame-

nable to internal fixation. We believe that stable arthrodesis is a better primary treatment for these injuries, with superior short and medium-term outcomes than those following open reduction and internal fixation. ■

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