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ORIGINAL STUDY

Open Reduction and Internal Fixation Versus Primary Partial Arthrodesis for Lisfranc Injuries Accompanied by Comminution of the Second Metatarsal Base

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The objective of this retrospective study was to compare open reduction and internal fixation (ORIF) with primary partial arthrodesis for the treatment of Lisfranc injuries accompanied by comminution of the second metatarsal base. Thirty-four patients were treated with ORIF or primary partial arthrodesis from 2007 to 2013. The patients were followed for an average of 28.5 months. Evaluation was performed with clinical examination, radiography, Visual Analogue Scale (VAS), the American Orthopedic Foot and Ankle Society (AOFAS) Midfoot Score, and the Short Form 36 (SF-36). Fifteen patients were treated with ORIF, and nineteen patients were treated with primary partial arthrodesis. Anatomical reduction was obtained in all patients. At two years postoperatively, the mean AOFAS Midfoot score was 84.33 points in the ORIF group and 85.05 points in the primary partial arthrodesis group (P>0.05). Also, no significant differences were seen in the VAS for pain (1.20 vs 1.05 points), SF-36 physical component (79.60 vs 79.89 points) or SF-36 mental component (77.07 vs 79.21 points). With longer and conservative postoperative management, ORIF as well as primary partial arthrodesis for Lisfranc injuries accompanied by comminution of the second metatarsal base led to similar medium-term outcome.

Keywords : Lisfranc injury ; open reduction and internal fixation ; arthrodesis ; functional outcomes.

INTRODUCTION

Injuries of tarsometatarsal joints, commonly referred to as Lisfranc injuries, are relatively uncommon. These injuries have an incidence of 1 in per 55,000 annually each year in the United States, accounting for approximately 0.2% of all fractures *(5,17,23,24)*. Lisfranc injuries are often missed or misdiagnosed because of their rarity *(5,13,17,19,23,25)*, yet they can result in substantial consequences, including pain, degenerative arthritis, and chronic instability *(5,13,17,19,23,24)*.

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A variety of treatments that have advocated for Lisfranc injuries exist currently. Nonoperative treatment is reserved for nondisplaced and stable injuries only *(5,23,24)*. However, most injuries are unstable and need for surgical treatment *(5,23,24)*. Over the past few decades, the surgical treatment for Lisfranc injuries have been performed through closed or open reduction and percutaneous pinning *(8,15)*, or open reduction and internal fixation (ORIF) and screw fixation *(1,4,7,9,12-14,17,18,22)* or dorsal plate *(3,20)* or suture-button *(2,16),* or primary arthrodesis *(7,9,13,14,18)*. Currently, ORIF with screws as well as primary partial arthrodesis is recommended treatment for Lisfranc injuries. However, even with anatomic reduction and stable fixation, treatment of these injuries does not have uniformly excellent outcomes *(1,7,13,22)*. The best surgical treatment for Lisfranc injuries is still controversial: ORIF or primary partial arthrodes. *(5,7,9,13,14,18,24)*

Lisfranc injuries frequently combined with tarsal or metatarsal fractures *(5,25)*. To our knowledge, if Lisfranc injuries accompanied by comminution of the second metatarsal base, when ORIF is performed, fixation of Lisfranc screw (a screw going from the base of the medial cuneiform to the base of the second metatarsal) become unavailable. We wondered when the comminuted second metatarsal base was reduced and fixed with dorsal plate while Kirschner wire was used instead of Lisfranc screw in ORIF, if the outcomes was better when compared with the primary partial arthrodesis.

The purpose of the present retrospective study was to evaluate the results in two similar groups of patients who suffered with Lisfranc injuries accompanied by comminution of the second metatarsal base.

MATERIALS AND METHODS

After approval by the institutional review board, we performed a retrospective clinical study.

The inclusion criteria was acute Lisfranc injury of less than 2 weeks duration which needing for surgical treatment. Indications for surgery were fractures and dislocations of the Lisfranc joint, which were displaced more than 2 mm in any plane. The exclusion criteria were: Lisfranc injury associated with ipsilateral limb injury, prior foot trauma, prior foot infection, prior foot surgery, prior foot pathology, chronic injury of greater than three months duration, arthritis of foot, or associated medical comorbidities such as diabetes mellitus, peripheral vascular disease, peripheral neuropathy, or autoimmune disease.

From March 2007 to June 2013, 36 trauma patients with Lisfranc injuries accompanied by comminution of the second metatarsal base were conducted. They were treated by ORIF or primary partial arthrodesis. Thirty-five patients met the inclusion criteria, and 34 were available for follow-up. There were 20 males and 14 females, with a mean age of 39.5 years (22-58 years). 9 males and 6 females who treated by ORIF met the inclusion criteria, with the average age of 38.9 years (range, 22-54 years). While in the primary partial arthrodesis group, 11 males and 8 females met the inclusion criteria, with the average age of 39.6 years (range, 26-58 years).

The injury mechanism in the enrolled patients treated by ORIF involved 6 motor vehicle accidents, 7 crush injuries, and 2 falls from a height and of the patients treated by primary partial arthrodesis, 7 motor vehicle accidents, 8 crush injuries, and 4 falls from a height.

Preoperative radiographs and computed tomography scans were examined. Lisfranc injuries were classified according to a system described by Myerson et al. *(15)*. In the ORIF group, 1 patient had type A injuries, 10 were type B2, 3 were type C1, and 1 type C2. While in the primary partial arthrodesis group, 1 patient had type A injuries, 12 were type B2, 4 were type C1, and 2 type C2. (Table I)

Thirty-four patients were closed injuries, and were not suffered compartment syndrome of the foot. All patients were not managed with closed reduction and fixation preoperative, because of comminuted intra-articular fractures which failed or were not manageable with closed reduction and fixation. All patients used ice therapy and fixation of splint after injury. To minimize wound problems, operations were performed after soft-tissue swelling has subsided. The mean operation time of the patients was 10.9 days after injury (range, 8-14 days).

Table I. — Demographic and Clinical Data

	ORIF	Primary partial arthrodesis
Age (y)		
Mean	38.9	39.6
Range	22 to 54	26 to 58
Gender (n)		
Male	9	11
Female	6	8
Mechanism of injury (n)		
Motor vehicle accidents	6	7
Crush injuries	7	8
Falls from a height	2	4
Myerson classification (n)		
Type A	1	1
Type B1	0	0
Tybe B2	10	12
Type C1	3	4
Type C2	1	2

ORIF open reduction and internal fixation

Surgical technique

Surgeries were performed by six attendings. Fixation choice was dictated by surgeon preference for fixation of each individual fracture.

ORIF

Two dorsal longitudinal incisions-one between the first and second metatarsals and the second centered between the fourth and fifth metatarsals-were made. Before reduction, care is taken to irrigate the joints adequately. Any small, free pieces of cartilage and hematoma should be removed. At this point, a reduction is attempted. Comminution of the second metatarsal base were reduced and fixed using a dorsal plate. Screw fixation of the first metatarsal-cuneiform joint was performed. The Lisfranc screw was not available because of comminution of the second metatarsal base and fixation of the dorsal plate. Then, a Kirschner wire instead of Lisfranc screw fixation of the Lisfranc ligament was performed. The third metatarsal-cuneiform joint was reduced and fixed with a Kirschner wire or a screw. Kirschner wires were placed in each of the lateral two rays. The medial cuneiform should be secured with a screw to the middle cuneiform if unstable. If necessary, make another dorsal incision to reduction and fixation of the metatarsal shaft fractures using dorsal plates. (Fig. 1-3)

Primary partial arthrodesis

Standard incisions were made as described for the ORIF group. The steps for reduction and fixation in primary partial arthrodesis were generally the same as in ORIF. The difference was primary arthrodesis of the second metatarsal-cuneiform joint. Open reduction was performed, cartilage and fibrous tissue of the second metatarsal-cuneiform joint were resected, and the joint were decorticated. A dorsal plate was placed from the second cuneiform to the metatarsal for fixation. The Lisfranc screw was placed to strengthen the effect of fixation. Then, autologous bone graft was performed in the second metatarsal-cuneiform joint. (Fig. 4-6)

Postoperative Management

Postoperatively, the treatments in two groups were generally the same. Follow-up was performed at 4 weeks, 8 weeks, 12 weeks, 6 months, 9 months, and the annually.

A short leg splint was applied for 2 weeks followed by a short leg cast for 4 to 6 weeks. Kirschner wires of the fourth and fifth joints were removed at 8 weeks postoperatively. Kirschner wire (going from the base of the medial cuneiform to the base of the second metatarsal) was removed at 12 weeks. In the ORIF group, the internal fixation was maintained until radiographs showed evidence of osseous union. In this series, screws and dorsal plates were routinely removed at 9.9 months postoperatively (range, 8-12 months). (Fig. 7) While in the primary partial arthrodesis group, hardware was not routinely removed. (Fig. 8) All patients were permitted fully bear weight on the limb at 12 weeks.

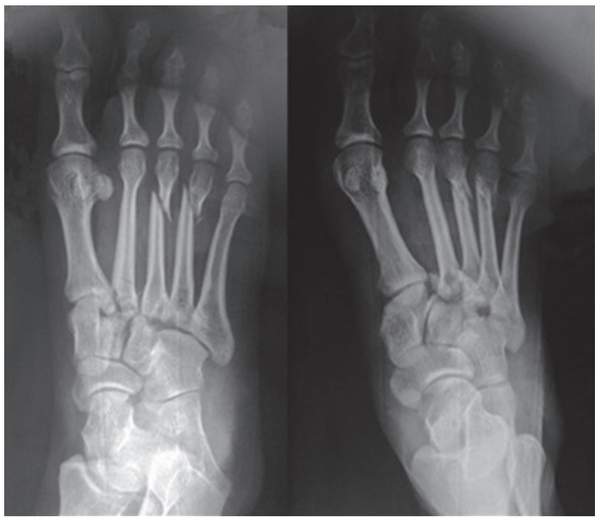

Fig. 1. — Anteroposterior and oblique radiograghs of the right foot of 24-year-old women who sustained a Lisfranc injuries accompanied by comminution of the second metatarsal base after a motor vehicle accident.

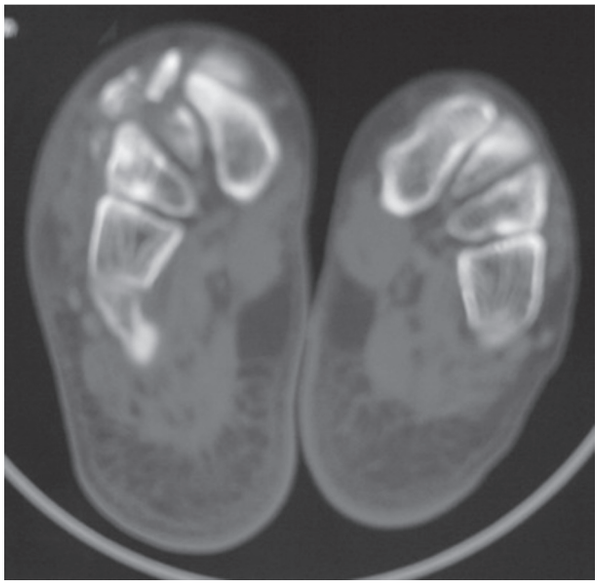

Fig. 2. — Computed tomography scans of the right foot of 24-year-old women who sustained a Lisfranc injuries accompanied by comminution of the second metatarsal base after a motor vehicle accident.

We evaluated the outcomes with clinical examination, radiography, Visual Analogue Scale (VAS) for pain (of 0 to 10), the American Orthopedic Foot and Ankle Society (AOFAS) Midfoot Score *(11)*, and the Short Form 36 (SF-36) *(21)*.

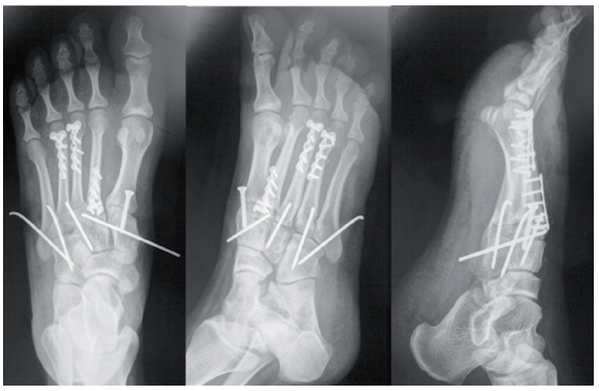

Fig. 3. — Anteroposterior, oblique and lateral radiograghs showed anatomical reduction of the Lisfranc injury postoperatively, a Kirschner wire was used for the fixation of the Lisfranc ligament.

Postoperatively radiographs were accessed to determine if anatomical reduction was achieved. The reduction was considered anatomical if this relationship was intact, nearly anatomical if it was within 2mm, and nonanatomical if it was off by greater than 2mm *(4,12)*.

During the process of fracture healing, bone morphology was accessed by radiographic. Moreover, fractured bone function and complications were also investigated clinically. Nonunion was defined as no healing of the fracture after three months. Posttraumatic osteoarthritis was accessed clinically and on weight-bearing radiographs and was deemed to be present if there was any radiographic evidence of osteophytes, joint-space narrowing, or subchondral cysts or sclerosis in conjunction with tarsometatarsal joint pain and tenderness and pain with joint motion. The degree of posttraumatic osteoarthritis was classified "none," "mild," "moderate," or "severe" according to the Kellgren-Lawrence scale *(10)*.

Statistical Analysis

For statistic calculations, SPSS statistics (SPSS Inc, Chicago, IL) version 17.0 was used. For evaluation of differences of average age, follow-up time, and score values, Two-Independent-Samples t test was applied. The level of significance was set at $P>0.05$.

Fig. 4. — Anteroposterior and oblique radiograghs of the left foot of 51-year-old man who sustained a Lisfranc injuries accompanied by comminution of the second metatarsal base after a crush injury.

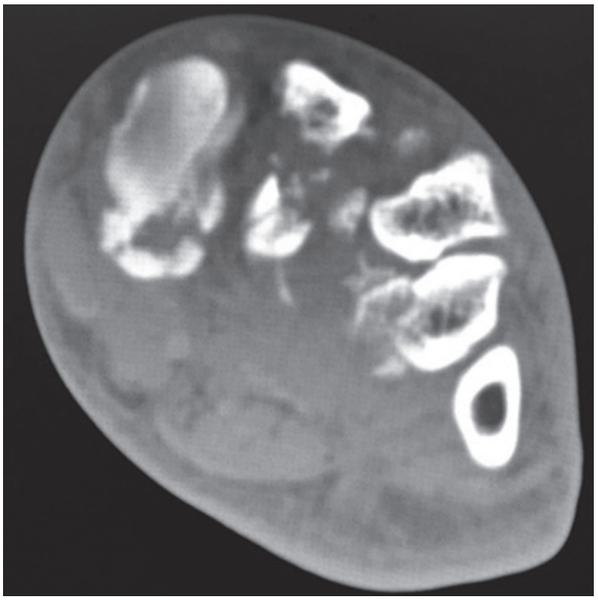

Fig. 5. — Computed tomography scans of the left foot of 51-year-old man who sustained a Lisfranc injuries accompanied by comminution of the second metatarsal base after a crush injury.

RESULTS

Thirty-four patients were followed-up for 28.5 months (range, 24-37 months).

The progression of incision healing was delayed in three patients (1 in the ORIF group, and 2 in the primary partial arthrodesis group) because of marginal necrosis. There was no evidence of infection, but simply wounds that healed secondarily following dressing changes. Two cases were cured at 3 weeks postoperation and 1 case was cured at 4 weeks postoperation.

Anatomical reduction was obtained in all patients. The average time to fusion was 10.5 weeks (range, 8-12 weeks). None of the patient suffered hard tissue broken. Radiographs routinely demonstrated mild degree of early posttraumatic osteoarthritis, consisting of joint space narrowing at the tarsometatarsal joint line with small osteophyte formation (Fig. 7).

At the time of the two-year follow-up, the AOFAS Midfoot Score averaged 84.33 points (range, 59-97 points) in the ORIF group and 85.05 points (range, 62-95 points) in the primary partial arthrodesis group (P>0.05). The average score on

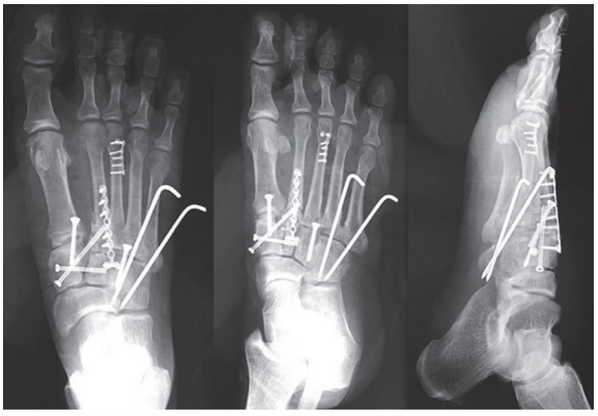

Fig. 6. — Anteroposterior, oblique and lateral radiograghs showed anatomical reduction of the Lisfranc injury and primary arthrodesis of the second metatarsal-cuneiform joint was performed, a dorsal plate was placed from the second cuneiform to the metatarsal for fixation and the Lisfranc screw was placed to strengthen the effect of fixation.

the VAS was 1.20 points in the ORIF group and 1.05 points in the primary partial arthrodesis group (P>0.05). The mean value of SF-36 physical was 79.60 (range, 53-96 points) in the ORIF group and 79.89 points (range, 56-94 points) in the primary

Fig. 7. — At 2-years follow-up, anteroposterior and oblique radiograghs showed hardware had already routinely removed, and joint space narrowing at the tarsometatarsal joint line with small osteophyte formation which demonstrated mild degree of posttraumatic osteoarthritis.

partial arthrodesis group (P>0.05). The SF-36 mental averaged 77.07 points (range, 47-94 points) in the ORIF group and 79.21 points (range, 58-92 points) in the primary partial arthrodesis group (P>0.05). (Table II)

Table II. — Outcomes in pain, function and satisfation in lisfranc injuries

Score	ORIF	Primary partial arthrodesis	P value
VAS	1.20 (0-3)	1.05 (0-3)	0.698
AOFAS Midfoot	84.33 (59-97)	85.05 (62-95)	0.794
SF-36 physical	79.60 (53-96)	79.89 (56-94)	0.922
SF-36 mental	77.07 (47-94)	79.21 (58-92)	0.479

ORIF open reduction and internal fixation, VAS Visual Analogue Scale, AOFAS Midfoot American Orthopedic Foot and Ankle Society Midfoot Score, SF-36 Short Form 36

DISCUSSION

The classification of Lisfranc injuries was originally described by Quenu and Kuss in 1909, and was modified by Hardcastle et al. *(8)* in 1982 into A, B, and C categories. In 1986, Myerson et al. *(15)* subdivided previous type B and type C injuries into B1, B2, C1 and C2. Although Myerson classification system has become universally accepted, outcome and treatment do not reliably correlate with any injury type *(4,12)*. Myerson et al. *(15)* and Rajapakse et al. *(17)* reported the most common injury type was B2 (36% and 38%). Our study reconfirmed the finding of the prior studies with result of 22 (64.7%) type B2 injuries. Highly morbidity of type B2 injury may due to the mechanism of Lisfranc injuries accompanied by comminution of the second metatarsal base.

Early acute diagnosis, anatomical reduction and stable fixation is the recommended treatment of Lisfranc injuries *(1,12,17,19)*. General agreement exists in the literature that stable anatomical reduction of the Lisfranc joint is important for optimal outcome *(1,4,8,12,14,15,17-19,22,23)*. Comparison with anatomical reduction, patients with nonanatomical reduction had a significantly higher prevalence of persistent pain, posttraumatic osteoarthritis, joint separation and midfoot collapse *(4,12,14,22)*. In our study, all of the 34 patients obtained anatomical reduction. As has already been reported in other studies *(12,15)*, we also found that a good anatomical reduction was generally the major determinant for the best outcome. At the time of the two-year follow-up, the AOFAS Midfoot Score averaged 84.74 points (range, 59-97 points).

The treatment regimens of Lisfranc injuries have changed with the time. Currently, ORIF as well as primary partial arthrodesis are well accepted for Lisfranc injuries *(1)*. However, most manuscripts have demonstrated that it was rather uncommon for patients who had sustained a Lisfranc injury to achieved a full recovery *(1,7,13,22)*. The best surgical treatment for Lisfranc injuries remains controversial *(5,7,9,13,14,18,24)*. The controversies on treatments of Lisfranc injuries include the method of fixation and the need for primary arthrodesis in severe injuries *(5,7,9,13,14,18,24)*.

ORIF is the most common treatment for displaced Lisfranc injuries *(18)*. Current judgement favors rigid

internal fixation with screws for the medial and middle columns, and the lateral column fixed with Kirschner wires *(6,24)*. In our study, Lisfranc injuries were accompanied by comminution of the second metatarsal base, and fixation of Lisfranc screw became unavailable when ORIF was performed. We used a Kirschner wire instead of Lisfranc screw for fixation of the Lisfranc ligament. It had been reported with high rate of failure when Kirschner wires were used, because of infection, migration, unstable fixation and loss of position *(4,12,14,20)*. In our ORIF group, there was no evidence of Kirschner wire failure. The following reasons may lead to good outcomes in our study. First, anatomical reduction and the second tarsometatarsal joint considered to be the "keystone" owing to the recessed position of the base of the metatarsal *(1)*, then a Kirschner wire across a reduced joint to maintain the corrected joint position was enough. Secondly, sample size is not large enough and more cases should be recruited. ORIF has been proved appropriate with good outcomes. However, despite appropriate initial treatment, some patients developed painful arthritis, necessitating conversion to an arthrodesis of the tarsometatarsal joints to achieve pain relief *(5,8,13,17,18,20,24)*. In the ORIF group, all of the patients demonstrated some degree (14 mild and 1 moderate) of posttraumatic osteoarthritis changes at follow-up (Fig. 1 G-H), but this did not appear to compromise their function. Our study reconfirmed prior studies *(1,4,8,12,14,15,17-20,22,23)* and found that the degree of posttraumatic arthritis is directly proportional to the degree of gross damage to the articular surface and to the adequacy of stable anatomical reduction.

Fig. 8. — At 2-years follow-up, anteroposterior and oblique radiograghs showed hardware was not routinely removed, and no loss of initial reduction.

Primary arthrodesis for Lisfranc injuries has demonstrated with satisfactory results, and significantly decreased rate of additional surgeries, as well as a tendency toward improved long-term clinical outcome scores when compared with ORIF *(9,13,18,23,24)*. However, loss of motion, stiffness in the forefoot, persistent pain, nonunion and pseudarthrosis, adjacent joint arthritis were often occurred after arthrodesis, especially in the complete arthrodesis group *(1,14,22)*. In order to avoid further complications, combined primary partial arthrodesis and ORIF for the treatment of Lisfranc injuries had been advocated *(6)*. In our primary partial arthrodesis group, we only performed arthrodesis of the second metatarsal-cuneiform joint. All patients healed well, with the AOFAS Midfoot Score averaged 85.05 points (range, 62-95 points) at the time of the two-year follow-up. High fusion rate after primary partial arthrodesis may due to the hyperemia that follows the severe injury *(18)*, as well as stable anatomical reduction.

Lisfranc joints have very little inherent stability, and the result of the injury depends somewhat on the quality of the scar tissue that is formed *(7)*. Stable fixation after surgical treatment help minimize swelling and promote healing *(9)*. To preserve the anatomic reduction and promote solid and reliable scar formation of the Lisfranc ligament, we also suggest with longer and conservation postoperative management, including fixation with cast and delay the time of weight-bearing *(1)*. In our study, all patients were fixed with a short leg splint or cast for 6 to 8 weeks, and weight-bearing were not permitted until 12 weeks. All patients were preserved anatomic reduction, and had good fusion with the average fusion time 10.5 weeks.

Extra operation would be performed to remove the hardware after ORIF, although controversy exists as to the timing and necessity of hardware removal *(1,4,9,12,13,24)*. Hardware retention reduces tarsometatarsal joint motion, increases hardware breakage, and increases reconstruction complexity *(1,9)*. In simplified terms, hardware retention is equivalent to arthrodesis without actually achieving osseous union *(9)*. We believe rationale hardware removal after ORIF is potentially returning normal foot tarsometatarsal joint motion. In the ORIF group, screws and dorsal plates were routinely removed at 9.9 months postoperatively (range, 8-12 months). While in the primary partial arthrodesis group, hardware was not routinely removed. No one suffered hardware broken.

Our study had several limitations. First, sample size is not large enough to reveal a significant difference between the outcomes of two groups. Second, only a 2-year clinical follow-up was performed. A longer follow-up period would be more valuable for evaluation of potential further complications. We anticipate that the primary partial arthrodesis outcomes will remain stable but the ORIF results will likely deteriorate over time as posttraumatic arthrosis develops in some patients. Third, independent surgeons would choose treatment according to their experiences and bias based on our retrospective study. A randomized controlled trial is needed for better illustration.

In summary, with longer and conservative postoperative management, ORIF as well as primary partial arthrodesis for Lisfranc injuries accompanied by comminution of the second metatarsal base led to similar medium-term outcome. Precise and stable anatomical reduction is critical for optimum results.

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