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# Primary fusion versus open reduction internal fixation for purely ligamentous lisfranc injuries: A Prospective comparative study and analysis of factors affecting the outcomes

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ABSTRACT

*Background:* The studies evaluating the outcomes of treatment of purely ligamentous unstable Lisfranc injuries are scarce. This study aimed at comparing outcomes of primary tarso-metatarsal joints fusion versus open reduction and internal fixation in treatment of such condition and determining the possible factors that may alter the outcomes.
*Methods:* This study comprised 30 patients; 16 in fusion group and 14 in ORIF group. One column was operated on in 2 patients, two columns in 21, and three columns in 7. The mean follow-up period was 36 months.
*Results:* There was no statistically significant difference between both groups regarding patients or injury characteristics. The mean AOFAS and FFI-Rs scores were 88.9 and 22.7 in the fusion group, compared to 61.7 and 34.5 in the ORIF group (P = .03,.04 respectively). At final follow-up all patients in the primary arthrodesis group were maintaining an anatomical reduction versus 71.5% in the ORIF group. Sixteen patients (53%) reported prominent hardware troubles that required removal. Five patients in ORIF group developed osteoarthritis, and four of them underwent secondary fusion. There was significantly higher incidence of posttraumatic osteoarthritis in patients with non-anatomical reduction and complete injuries. Better mean AOFAS and FFI-Rs scores occurred with non-smokers and with anatomical reduction.
*Conclusion:* Based on this limited case series, purely ligamentous Lisfranc injuries were found to have better outcomes when managed with a primary fusion as co [illegible]

Achieving and maintaining anatomical reduction was the most important factor that is significantly attributed to improved outcomes. Possible arthritic changes and additional surgeries apart from implant removal could be avoided by primary fusion.
*Level of evidence:* level I- prospective comparative case study.



## 1. Introduction

Purely ligamentous Lisfranc injuries are uncommon, accounting for approximately 30% of all Lisfranc injuries [1–7]. Purely ligamentous Lisfranc injuries are difficult to diagnose as they mostly occur during recreational sports as a result of low-energy trauma and are often misdiagnosed as a midfoot sprain [5,8–10]. Unstable injuries may lead to midfoot osteoarthritis, deformities and chronic disability if not properly managed [10,11]. That is why it is important to stress the concept that knowing the relevant anatomy and the mechanism of injury is the best way to make a correct diagnosis [8]. Lisfranc injuries were classified according to direction and degree of displacement into five categories as described by Myerson et al.,[12]: type A, total incongruity of the tarso-metatarsal joints (TMTJ) in any plane or direction (homolateral complete); type B1, partial-medial incongruity in which the displacement affects the first metatarsal in relative isolation (homolateral incomplete medially); type B2, partial-lateral incongruity in which the displacement affects one or more of the lateral four metatarsals in any plane (homolateral incomplete laterally); type C1, a divergent pattern, with the first metatarsal displaced medially and the lateral four in any other concomitant pattern of displacement with partial incongruity (diver-

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gent partially) and type C2, a divergent pattern with total incongruity (divergent completely). Treatment of purely ligamentous injuries is challenging [10]. The aim of surgical management of a ligamentous Lisfranc injury is to reduce and stabilize the TMTJ either by internal fixation or fusion. There has been an ongoing debate regarding the optimal surgical procedure for purely ligamentous Lisfranc injuries [13]. It was reported in the literature that these injuries should be first treated with open reduction and internal fixation (ORIF) while fusion was reserved for cases that developed symptomatic arthritic changes [14]. Other studies reported that primary fusion is the optimal treatment due to poor healing of osseo-ligamentous interface and high incidence of arthritic changes in patients treated with ORIF [10,15]. To the authors' knowledge, the literature comparing the functional outcomes of both techniques is very scarce. Moreover, there was no detailed analysis of the factors affecting the outcomes. So, the primary aim of this prospective study was to compare the clinical, functional and radiological outcomes of primary fusion versus ORIF of TMTJ in treatment of purely ligamentous unstable Lisfranc injuries, along with, the secondary aim of determining the possible factors which can potentially affect these outcomes.

## 2. Patients and methods

This prospective study was carried out between the period from May 2013 to December 2018 and enrolled 30 adult patients with purely ligamentous unstable Lisfranc injuries. In all cases, plain x-rays and CT scans of the affected foot were done and reviewed. Lisfranc injuries with avulsion fracture of the Lisfranc ligament (fleck sign) were considered to be purely ligamentous. Lisfranc injury is considered unstable if > 2 mm of displacement exists at the TMTJ on conventional radiographs and computed tomography scans. If < 2 mm displacement at the TMTJ, stability was assessed by weight-bearing radiographs or stress views performed under anaesthesia. Children with open physes, patients with Lisfranc fracture-dislocations, stable TMTJ, Charcot foot, previous foot or ankle surgery and injuries with delayed presentation (> 4 weeks) were excluded from the study. The study protocol was approved by the ethics committee of our University. The procedures used in this study adhered to the tenets of the Declaration of Helsinki.

The medial column (first and second TMTJ) was operated on (either primary fusion or ORIF) in all cases. Primary fusion or ORIF of the middle column (third TMTJ) ± ORIF of the lateral column (fourth and fifth TMTJ) were done for cases where there was joint instability. Patients included in the study were divided into two groups; fusion and ORIF groups. All patients were fully instructed that there were two operative methods and they were informed that there was controversy over which method was better. They were informed that fusion is believed to be more radical in eliminating short term complaints but can cause surroundingjoints to become arthritic in future and while ORIF is believed to conserve the affected joints but still has higher rate of short term dissatisfaction in which case they might have to get fusion (the first choice) done eventually. The questionnaire was usually perceived by patients as “Do you want to give your joints a less than 50–50 chance to return as before or you want a more guaranteed earlier return to normal life that can affect you later?”. Primary fusion or ORIF was done depending on patient choice after explanation of the surgical techniques and their possible outcome and complications. As a result, this study comprised 16 patients in fusion group and 14 patients in ORIF group. A written informed consent was obtained from all patients regarding study participation.

Table 1 demonstrated the patient characteristics, Myerson classification [12], the number of columns requiring surgical interventions, timing between the surgery and date of the injury, and the follow up period. There were 19 male and 11 female with a mean age of 39.8 years (range; 23–50). Seven patients (23%) were diabetic and 17 (56%) were smokers. The injury was in the right foot in 17 patients and the left in 13. The mechanisms of injury included sports activities in 12 cases, motor car accidents in eight patients, fall from height in five cases and simple fall in five cases. The injuries were complete (A and C2) in 16 patients, and incomplete (B1 and B2) in 14 patients according to Myerson classification [12]. The mean timing between the surgery and date of the injury was 11 days (range; 8–14). One column was operated on in 2 patients, two columns in 21, and three columns in 7. The mean follow-up period was 36 months (range; 23–60).

**Table 1**
Patients' characteristics, injury classification, operated columns, timing of surgery, and follow up periods for both groups.

| Variable | ORIF (n = 14) | Fusion (n = 16) | Total (n = 30) | P-Value* |
|---|---|---|---|---|
| **Age** (Y) | | | | |
| Mean ± SD (R) | 35 ± 3.45 (23–44) | 44 ± 4.56 (35–50) | 39.8 ± 4.11 (23–50) | .34 |
| **Gender,** n (%) | | | | |
| M/ F | 8 (57)/6 (43) | 11 (69)/5 (31) | 19 (63)/11 (37) | .7 |
| **DM,** n (%) | 4 (29) | 3 (19) | 7 (23) | .67 |
| **Smokers,** n (%) | 7 (50) | 10 (62) | 17 (56) | .71 |
| **Side,** n (%) | | | | |
| RT/LT | 7 (50)/7 (50) | 10 (62)/6 (38) | 17 (57)/13 (43) | .71 |
| **Myerson,** n (%) | | | | |
| A | 5 (36) | 4 (25) | 9 (30) | |
| B1 | 1 (7) | 1 (6) | 2 (7) | .92 |
| B2 | 5(36) | 7 (44) | 12 (40) | |
| C2 | 3 (21) | 4 (25) | 7 (23) | |
| **No of operated columns,** n (%) | | | | |
| One column | 1 (7) | 1 (6) | 2 (7) | |
| Two columns | 9 (64) | 12 (75) | 21 (70) | .8 |
| Three columns | 4 (29) | 3 (19) | 7 (23) | |
| **Timing of surgery** (D), | | | | |
| Mean ± SD (R) | 11.2 ± 2.3 (10–14) | 10.8 ± 3.4 (8–12) | 11 ± 3.5 (8–14) | .77 |
| **Follow up** (M) | | | | |
| Median (R) | 38.6 (23–60) | 33.7 (26–50) | 36 (23–60) | .82 |

(n; number, Y; year, SD; standard deviation, R; Range, M; male, F; female, DM; diabetes mellitus, RT; right, LT; left, D; day, M; month) (*p value between fusion and ORIF groups)

### 2.1. Surgical technique



The surgical [illegible] primary fusion and ORIF. Stress examination under anesthesia was done to determine which joints were involved in the instability pattern. Stress maneuvers were performed under fluoroscopy which included; rotational stress (by pronation/supination of the forefoot), coronal stress (by abduction/ adduction of the forefoot and midfoot), sagittal stress (by dorsiflexion/ plantarflexion of the 3 columns of the foot) and squeezing of the forefoot and midfoot. Using thigh tourniquet and patient in supine position, the leg was hold with knee flexed to allow the foot to be lying comfortably on the table to provide easy access to the dorsum of the foot.

*Incisions:* Two dorsal longitudinal incisions were used with at least 4 centimeters between them to preserve vascularity of the intervening skin bridge. The medial incision was done in all cases, about 5–7 cm, and placed between the first and second rays starting proximally at the level of cuneiforms. The lateral incision was done in cases where the two or three columns were operated on, and was placed dorsally in line with the fourth metatarsal.

*For Fusion:* Preparation of all articular surfaces to be fused before proceeding to fusions was done. Proper exposure of joint surfaces mandated removal of the torn ligaments and joint capsules with great care not to massively devascularize the bones by extensive releases. Removal of the articular cartilage with subsequent exposure of the subchondral bone was done by small surgical blade or a sharp curved 3 mm osteotome to peel off the articular cartilage. Subchondral bone is decorticated in a shallow manner using the fish-scale technique. Fusion of the first TMTJ was to be taken out first by one or if necessary two ante- or retrograde screws (cortical 3.5 mm or partially threaded cancellous 4 mm). The proper reduction of the joint was confirmed by fluoroscopy and maintained by a temporary K-wire. Compression through a fused joint was achieved by a reduction clamp prior to screw insertion or the use of a lag screw if the bone density was well enough to hold a compressing screw. After fixation of the first TMTJ, a rigid construct was created to hold second ray against by the "home-run" screw from medial cuneiform to the base of second metatarsal after placing a reduction clamp between the two bones. If there was instability between the cuneiforms, inter-cuneiform fusion with an inter-cuneiform screw was done. The third metatarsal was then fused to the lateral cuneiform, and inter-cuneiform fusions, using a similar technique of fixation. After stabilization of the first three TMTJs, the stability of the fourth and fifth TMTJs was tested. If they were unstable, they were immobilized with K-wires.

*For ORIF:* The procedure was essentially the same as fusion, but the steps of removal of articular cartilage, supporting ligaments or capsules were not done. This was followed by closure of skin and application of a below knee slab. We did not use screws in compressive pattern as enough compression was pre-applied through using fracture clamp across the joints.

### 2.2. Postoperative care and follow up

The wound was checked 5 days after discharge from hospital. After stitches removal (2–3 weeks postoperative), a fracture boot was applied and ankle range of motion exercises were initiated. X-ray radiographs were done at 6th week postoperative. Partial weight-bearing began 6–8 weeks postoperative (or signs of union appear on radiographs for fusion group). The K-wires in the lateral column were removed 8 weeks after surgery. Then cases were followed up every 3 weeks by till sound fusions were obtained. Full weight-bearing was then permitted. Weight-bearing radiographs were done at the final follow up.

All cases were assessed 1, 3, 6, and 12 months postoperative, then every 6 months till the last follow-up.

### 2.3. Outcome assessment

The quality of reduction was assessed according to Myerson's criteria [12,16] (<2 mm diastasis in anterior posterior plane between the base of the first and second metatarsal, or medial and middle cuneiform, and <15° talometatarsal sag in the dorsoplantar plane). Sound fusion (in fusion group) was assessed clinically (absence of pain, tenderness and motion when stressing the fused joints) and radiographically (appearance of bridging bony trabeculae). CT scan was done between 8 and 12 weeks postoperatively in all cases of the fusion group to assess union. Functional outcomes were assessed by the American Orthopedic Foot and Ankle Society (AOFAS) Midfoot Scale and Foot Function Index–Revised short form (FFI-Rs). AOFAS Midfoot Scale assesses three items; pain, function, and alignment. Total score is 100 with the higher score correlates with better foot function. FFI-Rs has 34 items with 4 subscales; pain, disability, activity limitation, and psychosocial activities and quality of life related to foot health. FFI-Rs score is between 0% and 100% with lower score correlates with better foot function [17,18]. Finally, the patients were queried about their satisfaction and classified into completely satisfied, some reservations, important reservations, and dissatisfied.

### 2.4. Statistical analysis

The patients' characteristics were analysed with frequencies and percentages for categorical variables and with mean and standard deviation (SD) for continuous variables. Comparisons between the groups were assessed with a *t*-test for continuous explanatory variables and a Fisher's exact test for categorical variables. Significant correlation was considered when two-sided P value < .05. Statistical analysis was performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp, Armonk, NY, USA).

## 3. Results

There was no statistically significant difference between both groups regarding patients' characteristics, side and severity of injury, number of the operated columns, timing between injury and surgery, and follow up periods (Table 1). However, the primary arthrodesis group had more men (69% versus 57%), higher mean age (44 years versus 35 years), more smokers (62% versus 50%), and less diabetic (19% versus 29%), along with shorter mean follow-up (33.7 months versus 38.6).

Regarding the functional outcome, there was a statistically significant improvement among the fusion group, compared to the ORIF group (Table 2). The mean AOFAS score was 88.9 (range: 60–100) in the fusion group, compared to 61.7 (range: 30–90) in the ORIF group (P = .03). The mean FFI-Rs score was 22.7 (range: 18–50) in the fusion group, compared to 34.5 (range: 24–90) in the ORIF group (P = .04).

Anatomic reduction was achieved initially in all cases in both groups (Figs. 1 and 2). However, there was loss of reduction in the ORIF group over time. So, at final follow-up all patients in the primary fusion group were maintaining an anatomic reduction compared with 71.5% in the ORIF group (P = .03). In the fusion group, sound bony union across the fused joint in an anatomical position was achieved in all patients in a mean period of 12.91 weeks (range: 11.5–15) except one patient who took 24 weeks to achieve sound fusion. This patient was male, 50 years old, diabetic and smoker.

The mean time lag between surgery and return to work was 19 weeks in fusion group and 17 weeks in ORIF group (p = .87). It was noticed that patients with no medical insurance (n = 15) returned to work earlier than those with medical insurance (n = 15) (mean time

**Table 2**
Outcomes and complications for both groups.

| Variable | ORIF (n = 14) | Fusion (n = 16) | Total (n = 30) | p-value* |
|---|---|---|---|---|
| **Time to work return** (W), Mean ± SD (R) | 17 ± 2.6 (13–28) | 19 ± 3.5 (13–29) | 18 ± 2.8 (13–29) | .87 |
| **Functional scores** Mean ± SD (R) | | | | |
| **AOFAS** | 61.7 ± 7.8 (30–90) | 88.9 ± 10.5 (60–100) | 76.2 ± 9.6 (30–100) | .03 |
| **FFI-Rs** | 34.5 ± 4.5 (24–90) | 22.7 ± 3.6 (18–50) | 28.2 ± 4.1 (18–90) | .04 |
| **Quality of reduction**, n (%) | | | | |
| **Anatomical** | 10 (71.5) | 16 (100) | 26 (86.7) | .03 |
| **Non Anatomical** | 4 (28.5) | 0 (0) | 4 (13.3) | |
| **Complications**, n (%) | | | | |
| Sympathetic dystrophy | 4 (29) | 5 (31) | 9 (30) | 1 |
| Wound complications | 5 (35) | 5 (31) | 10 (33) | 1 |
| Prominent hardware | 7 (50) | 9 (56) | 16 (53) | 1 |
| OA | 5 (36) | 0 (0) | 5 (17) | .01 |
| **Additional surgery**, n (%) | | | | |
| Secondary fusion | 4 (28) | 0 (0) | 4 (13) | .03 |
| Screws removal | 7 (50) | 9 (56) | 16 (53) | 1 |
| **Satisfaction**, n (%) | | | | |
| Completely | 6 (43) | 9 (56) | 15 (50) | |
| Some Res. | 1 (7) | 3 (19) | 4 (13) | .1 |
| Important Res. | 1 (7) | 2 (12.5) | 3 (10) | |
| Dissatisfied | 6 (43) | 2 (12.5) | 8 (27) | |

(n; number, W; week, SD; standard deviation, R; Range, AOFAS; American Orthopedic Foot and Ankle Society Midfoot Scale, FFI-Rs; Foot Function Index–Revised short form,OA; osteoarthritis, Res.; Reservations) (*p value between fusion and ORIF groups)

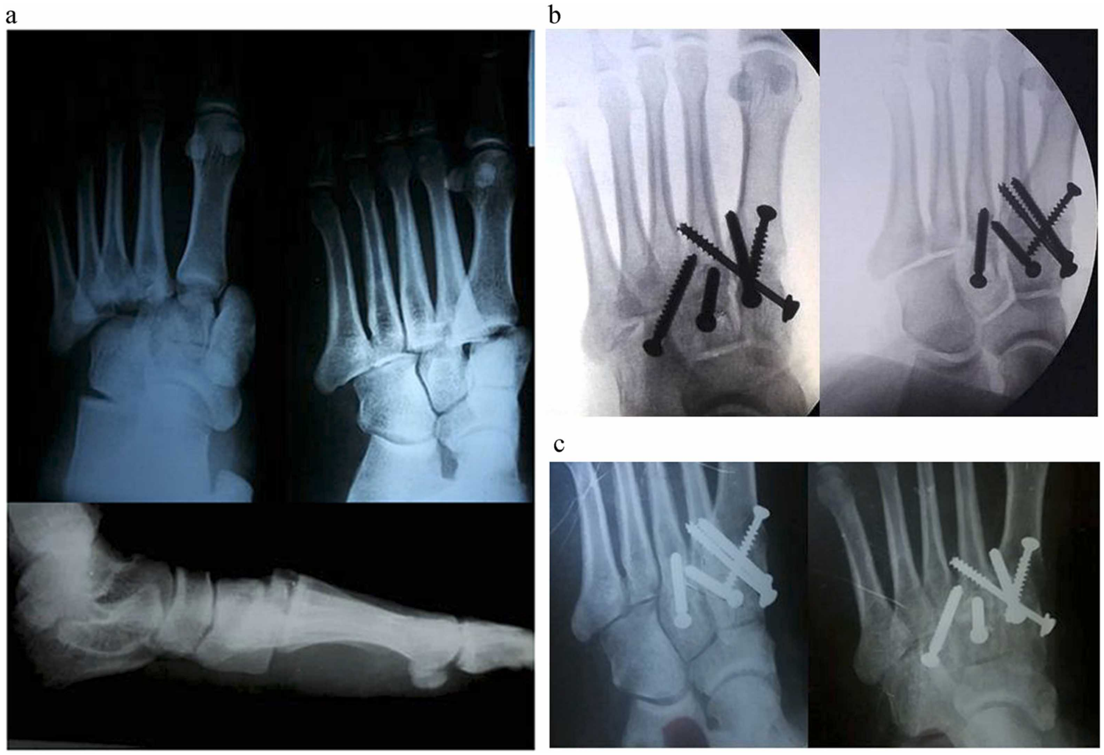


**Fig. 1.** Purely ligamentous Lisfranc injury that was treated by primary fusion of two columns (medial and middle) of the foot. Preoperative (A), immediate postoperative (B) and final follow up (C) radiographs.

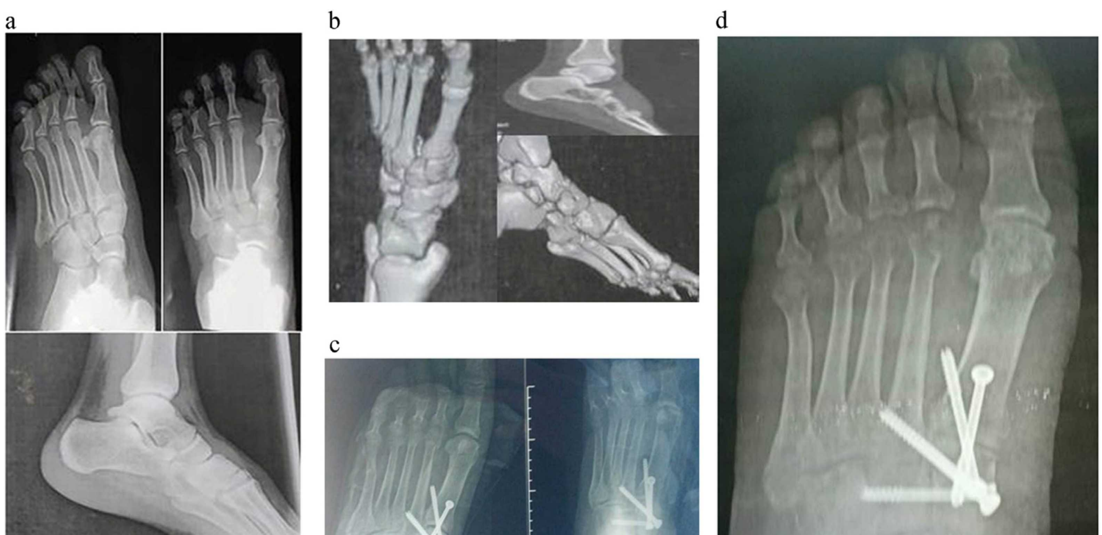


**Fig. 2.** Purely ligamentous Lisfranc injury that was treated by open reduction and internal fixation of one column (medial) of the foot. Preoperative radiographs (A), preoperative CT (B), immediate postoperative (C) and final follow up (D) radiographs.

was 14 weeks and 22 weeks respectively, $p = .04$). Postoperative level of activities was 89% of the pre-injury level in fusion group versus 66% in ORIF group ($p < 0.005$).

Nine patients (out of 30) had a mild degree of sympathetic dystrophy (5 in fusion group and 4 in ORIF group) in the form of mild periarticular osteopenia associated with mild to moderate swelling and pain that readily responded to medical treatment. Wound complications occurred in 10 patients, all of which were smokers, in the form of 6 cases superficial necrosis (4 cases in fusion group, and 2 in ORIF group) and 4 cases of superficial infection (one case in fusion group, and 3 in ORIF group). Superficial wound necrosis was of 1–2 centimeters long and 3–4 millimeters wide portions of the wounds margins. However no specific management was required for them other than the daily dressing. Improvement occurred within 3–4 weeks. Superficial wound infection was treated by oral antibiotics and repeated dressings. None of them need surgical debridement. Sixteen patients (53%) reported prominent hardware troubles (9 in fusion group and 7 in ORIF group) in the form of interfering with certain types of foot wear despite not limiting their activities. All of these sixteen patients had the offending screws removed. At the final follow up, there was no hardware breakage detected by radiographs in the other patients in both groups.

There were five patients in ORIF group who developed posttraumatic osteoarthritis four of which elected to undergo secondary fusion due to persistent foot pain. The average time from the first operation (ORIF) to secondary fusion was 17 months (range: 10–30). There were no neurovascular injuries or deep infection encountered while conducting this study.

In terms of patient's satisfaction; 12 patients (75%) were satisfied (completely or with some reservations) in fusion group versus 7 (50%) in ORIF group ($p = .1$). The causes of dissatisfaction included the need for reoperation, DJD and one patient had the feeling that she had to choose between two bad options.

Statistical analysis comparing the incidence of OA with the patient's characteristics (gender, smoking, and diabetics), degree of injury, the number of the operated columns and the quality of reduction is presented in Table 3. The patients with non-anatomical reduction had a significantly higher incidence of posttraumatic osteoarthritis than did those with anatomical reduction (100% compared with 3.8%, $p < .001$). Also, a significantly higher incidence of OA occurred in patients with complete injuries (31% compared with 0% with incomplete injuries, $p = .04$), and in the patients in ORIF group (36% compared with 0% in fusion group, $p = .01$). Although there was a higher incidence of OA in diabetics (29% compared with 13% in non- diabetics), this difference was found to be non-significant ($p = .56$). With the numbers available, the development of posttraumatic arthritis was not found to be associated with other variables (gender, smoking, and the number of the operated columns).

Statistical analysis comparing the functional outcome scores (AOFAS and FFI-Rs) in relation to the variables mentioned above showed that smoking and adequacy of reduction can have statistically significant effect on functional outcomes. Better functional outcomes, mean AOFAS and FFI-Rs scores, were significantly attributed to non-smokers and injuries where anatomical reduction could be initially attained and maintained during the follow up period.

## 4. Discussion

Although the Lisfranc joint is stabilised by numerous ligamentous structures, it has very little inherent stability [19–21]. As a result, the outcome of the injury depends somewhat on the quality of the scar tissue [19]. So, the outcome of treatment of Lisfranc fracture-dislocations is better than that of purely ligamentous injuries because bone healing is much stronger than the scarred fibrous tissue which is supposed to render stability through midfoot in purely ligamentous injuries.

It has become clear that anatomical reduction and stable fixation of the Lisfranc joint is imperative for improved outcome [15,22–27]. There has been an ongoing debate regarding when primary fusion or ORIF are most indicated and in whom they result in better outcomes [28]. The aim of this study was to compare outcomes of primary TMTJ fusion versus ORIF in treatment of purely ligamentous unstable Lisfranc injuries and also determine the possible factors affecting these outcomes.

In our study, primary fusion was superior to ORIF in patients with purely ligamentous Lisfranc injuries as regard functional and radiological outcomes, patients' satisfaction, and rate of complications especially secondary OA. Patients' satisfaction was related to several factors as early return to work, compliance with complications, and need for additional surgeries. Hardware irritation was the most frequent complication and also the most common cause for second surgery (hardware removal). This factor is actually an implant-related complication rather than surgery-related. This may explain the non-significant correlation between fusion and ORIF regarding patients' satisfaction. We did not routinely remove the hardware. VanPelt et al. [29], reported that routine hardware removal following ORIF of lisfranc injuries might not be necessary as retained hardware appears to be well tolerated.

There were several studies that had evaluated the treatment of acute Lisfranc injuries (Table 4). However, most of these studies addressed the purely ligamentous and osseo-ligamentous Lisfranc injuries, as similar entities, and compared the outcomes of fusion versus ORIF not taking in consideration the discrepant natures of these two different patterns of injuries which should be reflected on their methods of treatment [10,14,30,31]. Other studies did only ORIF for these combined injuries [23,32]. Relating these studies to our work seems irrational as we implied two different techniques on purely ligamentous injuries and compared their outcomes.

According to the authors' knowledge, there were few studies that evaluated the treatment of purely ligamentous Lisfranc injuries [33–35]. Porter et al. [34], did only ORIF to treat these injuries without primary fusion. Albright et al. [35], focused on the cost effectiveness for comparison between fusion and ORIF. In a study that was closely similar to our work, Ly and Coetzee compared the outcomes of primary fusion ($n = 21$) with ORIF ($n = 20$) in treatment of purely ligamentous Lisfranc injuries [33]. They concluded that primary fusion of TMT had have a better short and medium-term outcome than ORIF of ligamentous Lisfranc injuries. Despite the resemblance of between our and their studies design, we proceeded with ours as the total number of studies with similar design and patients enrolled in them cannot provide solid statistical evidence of the superiority of one technique over the other especially that scarifying midfoot joints,eventually, will lead to arthritis in nearby joints as a part of the cascade that is very common for foot and ankle surgeons to be confronted with which can only be avoided if the first fusion set could be avoided. Moreover, Ly and Coetzee had no aim at analyzing the factors affecting the outcomes of those procedures while performing their work.

To the authors' knowledge, our study is the first one comparing the outcomes of primary fusion with those of ORIF in purely ligamentous Lisfranc injuries along with analysis of the possible factors affecting them and posttraumatic arthritis incidence following these procedures. Smoking, adequacy of reduction, and type of treatment were the factors that significantly affecting the functional outcome. Other factors as other patients' characteristics, number of operated columns, and degree of injury didn't significantly affect the functional outcome. Kirzner et al. [31], had anlalysed the factors affecting the functional outcome scores and found a significant association between the quality of reduc-

**Table 3**
Analysis of functional outcomes and osteoarthritis prevalence.

| Variable | AOFAS (mean) | p-value | FFI-Rs (mean) | p-value | OA (n, %) | p-value |
|---|---|---|---|---|---|---|
| **Gender** | | | | | | |
| M (n = 19) | 79 | .94 | 27 | .87 | 3 (16) | 1 |
| F (n = 11) | 71 | | 30 | | 2 (18) | |
| **Smoking** | | | | | | |
| Yes (n = 17) | 69 | .04 | 35 | .03 | 3 (18) | 1 |
| No (n = 13) | 85 | | 19 | | 2 (15) | |
| **Diabetic** | | | | | | |
| Yes (n = 7) | 70 | .48 | 32 | .14 | 2 (29) | .56 |
| No (n = 23) | 78 | | 27 | | 3 (13) | |
| **Injury severity** | | | | | | |
| Complete (n = 16) | 75 | .56 | 26 | .35 | 5 (31) | .04 |
| Incomplete (n = 14) | 77 | | 30 | | 0 (0) | |
| **Type of Treatment** | | | | | | |
| ORIF (n = 14) | 61 | .03 | 34 | .04 | 5 (36) | .01 |
| Fusion (n = 16) | 89 | | 23 | | 0 (0) | |
| **No of operated columns** | | | | | | |
| One column (n = 2) | 70 | | 30 | | 0 (0) | |
| Two columns (n = 21) | 78 | .71 | 26 | .62 | 4 (19) | .77 |
| Three columns (n = 7) | 72 | | 34 | | 1 (14) | |
| **Quality of reduction** | | | | | | |
| Anatomical (n = 26) | 78.9 | .001 | 22.15 | < .001 | 1 (3.8) | < .001 |
| Non Anatomical (n = 4) | 58.6 | | 67.5 | | 4 (100) | |

(AOFAS; American Orthopedic Foot and Ankle Society Midfoot Scale, FFI-Rs; Foot Function Index–Revised short form, OA; osteoarthritis, n; number, M; male, F; female)

**Table 4**
Comparison between studies on Lisfranc injuries.

| | Study, publication Year | Number | Type of Injury | Smokers (%) | Diabetic (%) | Scores | Good Reduction (%) | Implant Removal (%) | Osteoarthritis (%) | Follow Up (M) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Kuo et al.[23], 2000 | 48 ORIF | Combined | – | – | AOFAS MFA | 79 | 25 | 25 (50% need Fusion) | 52 |
| 2 | Mulier et al.[14], 2002 | 12 fusion 16 ORIF | Combined | – | – | PFS' | 66 fusion 75 ORIF | 100 ORIF | ORIF: 96 | 30.1 |
| 3 | Ly and Coetzee[34], 2006 | 21 fusion 20 ORIF | Ligamentous | – | – | AOFAS VAS | 95 fusion 25 ORIF | 19 fusion 30 ORIF | ORIF: 75 (1/3 need fusion) | 43.4 fusion 42 ORIF |
| 4 | Rajapakse et al.[33], 2006 | 16 ORIF | Combined | – | – | AOFAS | 100 | – | 6 (100% need fusion) | 42.6 |
| 5 | Henning et al.[31], 2009 | 18 fusion 14 ORIF | Combined | 33 fusion 64 ORIF | – | SMFA SF-36 | 94 fusion 100 ORIF | 17 fusion 79 ORIF | – | 53 |
| 6 | Qiao et al.[10], 2017 | 8 fusion 17 ORIF | Combined | – | – | AOFAS SF-36 VAS | – | 75 fusion 88 ORIF | – | 15 fusion 7.5 ORIF |
| 7 | Porter et al.[35], 2019 | 82 ORIF | Ligamentous | – | – | AAOS | – | – | – | – |
| 8 | Kirzner et al.[32], 2020 | 18 fusion 21 ORIF | Combined | 16 fusion 33 ORIF | 11 fusion 4.8 ORIF | AOFAS MOXFQ | 78 fusion 29 ORIF | 50 fusion 71 ORIF | – | 52 fusion 38 ORIF |
| 9 | Our study | 16 fusion 14 ORIF | Ligamentous | 62 fusion 50 ORIF | 19 fusion 29 ORIF | AOFAS FFI-Rs | 100 fusion 71 ORIF | 56 Fusion 50 ORIF | ORIF: 36 (80% need fusion) | 33 fusion 38 ORIF |

(ORIF; open reduction internal fixation, AOFAS; American Orthopedic Foot and Ankle Society Midfoot Scale, MFA; Musculoskeletal Function Assessment, PFS; Baltimore Painful foot Score, VAS; visual analog pain scale, SMFA; Short Musculoskeletal Function Assessment, SF-36; Short Form-36, AAOS; American Academy of Orthopedic Surgeons, MOXFQ; Manchester Oxford Foot Questionnaire score, FFI-Rs; Foot Function Index–Revised short form, M; months)

tion and functional scores. Significantly better mean scores were associated with anatomic reduction. There were no significant associations between Myerson types A and C2 and the number of columns fixed with the functional outcome. But, their study was on combined ligamentous and osseo-ligamentous injuries.

Posttraumatic osteoarthritis remains one of the most common complications after Lisfranc injuries [36,37]. The incidence of OA is variable in the literatures [14,23,32,33]**.** In our study, we tried to highlight the factors associated with high OA incidence. There were five patients in ORIF group that developed OA. The incidence of OA was significantly related to the severity of injury, adequacy of the reduction, and type of the treatment. There was 3.8% of patients with anatomical reduction developed OA, compared with 100% of those with non-anatomical reduction. Also, 31% of patients with complete injuries (Myerson A and C2) and 36% of patients treated by ORIF developed OA. None of the patients with incomplete injuries or that treated by primary fusion developed OA till the final follow up.

Lau et al. [38], reported that a good anatomical reduction had an 18 times decreased risk of severe OA compared with a fair or poor reduction. Similarly, Adib et al. [39], reported 35% of patients with an anatomical reduction developed OA, compared with 80% of those with a non-anatomical reduction. Kuo et al.[23], reported that the incidence of OA was 25% and was related to quality of reduction and type of injury. They suggested that the injury itself, rather than the type of the treatment, has more influence on the outcome as patients with purely ligamentous injury had a trend toward a higher rate of degenerative sequelae compared with patients with osseo-ligamentous injuries even when they had been anatomically reduced. They found no correlation of OA incidence with the number of TMTJ involved, associated cuneiform or cuboid fracture, or delayed in diagnosis. Kirzner et al. [31], showed that OA was related to the severity of the initial injury independent of the type of treatment. However, they didn't mention any specific incidence of OA to either ligamentous or osseo-ligamentous injuries.

Achieving anatomical reduction has a great effect on improving the functional outcome and decreasing OA incidence. But, maintaining this reduction is very crucial for better outcomes as loss of anatomical reduction could occur despite being initially achieved. We believe that achieving and subsequently maintaining anatomical reduction is the most important factor affecting the outcomes. In our study; there was no loss of reduction in fusion group versus 4 cases (28.5%) in ORIF group. Ly and Coetzee reported 75% of cases in ORIF group had lost correction [33]. In the study of Kirzner et al. [31], there was 53% loss of reduction quality in the ORIF group. Loss of reduction occurred with ORIF because healing of the ligaments did not provide sufficient strength to maintain the initial reduction due to the poor healing potential of the ligament-osseous interface [33]. Qiao et al. [10], reported that the ligaments do not heal after ORIF.

Plate fixation for purely ligamentous Lisfranc injuries seems to have the advantages over trans-articular screws through minimizing articular damage of relatively small joint surfaces and the potential for being a stiffer fixation that can minimize secondary displacement [40]. However, the biomechanical studies comparing the fixation stability of Lisfranc injury using a plate versus trans-articular screws found that there were no statistically significant differences between the two fixation methods in 3D motions across all 5 TMTJs during both abduction and axial loading and the plate fixation may not provide adequate stability in the transverse plane or along the Lisfranc ligament [41,42]. Notably, these biomechanical studies did not involve multiple columns as seen with high energy Lisfranc injuries. In addition, Lau et al., in two different studies found no significant difference when comparing plate versus screw fixation outcomes and concluded that the functional outcomes related to quality of anatomical reduction not the implant of fixation [38,43]. Kirzner et al. [44], reported that there was better functional outcome and quality of reduction in patients managed with plate fixation than transarticular screw fixation or a combination of the two techniques. In a recent systematic review, Philpott et al. [45], found that superior functional outcomes with use of bridge plate fixation was reported by only a small number of studies. They reported that further evidence is needed to ascertain which injuries are best managed with each fixation method or whether one fixation construct is universally superior. We believe that the main issue about purely ligamentous Lisfranc injury that probably guide the outcome may be the ability to regain stability through only ligamentous healing in the face of the body weight stresses. This issue is directly attributed to the nature of the injury which will stay the same regardless the method of fixation used.

Our study had several limitations. Firstly, the number of patients was relatively small as this study comprised only the purely ligamentous injuries that are considered relatively uncommon injuries. Secondly, there were more females in ORIF group and a slightly greater mean age in the primary fusion group, which could be a source of bias due to lower expectations. Thirdly, power analysis was not done to assess the sample size prior to study performance. So, we do not have statistical power to draw statistically significant conclusions. Fourthly, the cost was not compared between both groups. Fifthly, ORIF by plate was not included in our study. Finally, the follow up was short to medium term. Longer term follow up studies with larger number of patients and addressing both methods of ORIF may reveal more different outcomes and conclusions.

## 5. Conclusion

Based on this limited case series, purely ligamentous Lisfranc injuries were found to have better outcomes when managed with a primary fusion as compared to open reduction and internal fixation. Achieving and maintaining anatomical reduction was the most important factor that is significantly attributed to improved outcomes. Possible arthritic changes and additional surgeries apart from implant removal could be avoided by primary fusion.

## Ethics approval and consent to participate

The study protocol was approved by the ethics committee of Benha University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki. The methods were carried out in accordance with relevant guidelines and regulations.


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## Conflict of interest/ competing

On behalf of all authors, the corresponding author states that there is no conflict of interest. The authors declare they have no financial interests. The authors have no relevant financial or non- financial interests to disclose.

## Consent to participate

Written informed consent was obtained from all patients regarding study participation.

## Consent for publication

patients signed informed consent regarding publishing their data and photographs.

## Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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