Acta Orthop. Belg., 2019, **85**, 150-158

ORIGINAL STUDY

Fractures and dislocations of the lisfranc tarso-metatarsal articulation: outcome related to timing and choice of treatment

Pietro Persiani, Michele Dario Gurzi, Alessandro Formica, Andrea Ruggeri, Ciro Villani

From the Department of Anatomic, Histologic, Forensic and Locomotor Apparatus Sciences; Sapienza University of Rome, Italy

A Lisfranc injury is when one or more of the metatarsals are displaced from the tarsus. The term is more commonly used to describe an injury to the midfoot, centred on the 2nd tarso-metatarsal joint. These fractures are sometimes easily overlooked, especially if they are part of a polytrauma. They are often difficult to diagnose and treat, but if they go undetected and are not properly treated, they can cause long-term or chronic disability. Our team reviewed a group of 71 patients with a Lisfranc fracture dislocation. The lesions were classified according to Meyerson classification. All the patients were re-evaluated 3 years after their surgeries by clinical examination, Ankle-Hindfoot Scale AOFAS questionnaire, X-rays and baropodometric analysis. This review outlines the treatment outcome of this injury, taking into consideration the timing of diagnosis.

Keywords : lisfranc ; outcome ; timing ; surgery ; missed injury ; fracture fixation.

As an author of this article I hereby certify the following: None of the material in the manuscript has been previously published. None of the authors have any conflict of interest, they aren't in any financial and/or personal relationships with other individuals or organisations that could inappropriately influence their work. None of the authors accepted employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding. I accept responsibility for releasing this material on behalf of any and all co-authors.
Pietro Persiani made substantial contributions to the conception and design, or acquisition of data, or analysis and interpretation of data. Each author took part in drafting the article and/or revising it critically for important intellectual content, Pietro Persiani gave the final approval of the version to be published.

INTRODUCTION

The tarso-metatarsal articulation, also called Lisfranc articulation after Jacques Lisfranc (1790-847), a surgeon in Napoleon's army, who described the amputations performed on soldiers who suffered those exact fractures while in battle.

This articulation has two distinctive features: anatomical and functional. From an anatomical point of view, the 2nd metatarsal is the longest of the metatarsal bones. It has a wedged shaped base and it projects backwards, and is held in the recess by three cuneiform bones, which make contact with the base of the 1st metatarsal and 3rd metatarsal. From a functional point of view, the 2nd metatarsal

■ Pietro Persiani[1] MD Ph.D.
■ Michele Dario Gurzi[1] MD.
■ Alessandro Formica[2] MD.
■ Andrea Ruggeri[1] MD.
■ Ciro Villani[1] MD.
[1]*Department of Anatomic, Histologic, Forensic and Locomotor Apparatus Sciences; Sapienza University of Rome, Italy.*
[2]*San Giovanni Hospital Complex, Orthopaedic Department, Rome Italy.*
Correspondence : Pietro Persiani, Mobile: +39.335.497510, Address: Clinica Ortopedica, Piazzale Aldo Moro 5, 00100, Rome, Italy
E-mail : pietro.persiani@uniroma1.it - ppersiani@me.com

base acts as a "keystone" bearing by supporting the longitudinal arch.

Lisfranc fractures and dislocations are not common. They can also be distinguished in dislocations, which occur rarely, and fracture-dislocations, which occur more frequently due to the triangular shape of the plantar apex of the metatarsals and the scarcity of dorsal ligamentous elements, in particular at the height of the 2nd metatarsal base *(9)*.

The traumas, which are almost always high energy, are divided in direct and indirect. In direct traumas, which are typically a result of crushing injuries, the force vector acts vertically to the axis of the foot. In indirect traumas, the force vector acts lengthwise along the axis, with the foot in a plantar hyperflexion position.

The diagnosis is based on standard and oblique X-rays and CT scans.

The general consensus in literature is that Lisfranc injuries are frequently overlooked in emergency (polytraumas). In fact, many authors *(15,23)* have correlated the low incidence reported in literature to continued missed diagnosis.

Myerson's *(16)* classification is, out of all the classifications described in literature *(7),* the most complete.

The proposed treatment methods are: closed reduction and stabilisation in plaster cast; closed reduction and stabilisation with K-wires or screws; open reduction and stabilisation with wires and screws (ORIF).

The goal of our study was to evaluate the correlation between early diagnosis, outcome and type of treatment.

MATERIALS AND METHODS

Between March 2004 and March 2012, we included in our study 71 patients who were treated for tarso-metatarsal fracture dislocation at the Emergency Department of Orthopaedics and Traumatology of the Policlinico "Umberto I" in Rome and San Giovanni Addolorata Hospital in Rome.

The average age of the patients, 51 men and 20 women, was 48 years old (their ages ranged from 22 to 74). The traumatic mechanism responsible for the injury was 97.8% indirect and 2.2% direct.

Out of the 71 patients in the study, 19 (21.7%) had polytraumas in association with a dislocation or a fracture dislocation of the Lisfranc.

In 78.8% of cases, the diagnosis was made in the emergency room after the execution of X-rays and/or CT scans.

In 21.1% of the cases (93% of the patients with polytrauma), the lesion initially went unrecognised and was diagnosed 14 days later in 9 patients and 20 days later in 5 patients.

The lesions were classified according to Meyerson classification: 18 type A "totally incongruent", 32 Type B "partially incongruent" and 21 Type C "divergent".

Only 3.2% (2 patients) were treated with a closed reduction and subsequent immobilisation in a knee-high plaster cast and no weight bearing for 8 weeks; the remaining 96.8% of Lisfranc fracture dislocations were treated surgically. In 44.3% of the cases (31 patients: 9 type A, 14 type B and 8 type C), the treatment was a closed reduction and synthesis with Kirschner wires, which were removed after 4 weeks (29 patients), or with percutaneous cannulated screws (2 patients). All the patients were immobilised with a plaster cast and were instructed not to bear weight on the foot for 5 weeks. In 52.5% of the cases (37 patients: 9 type A, 18 type B and 10 type C), an open reduction and synthesis was performed with K-wires, which were removed after 4 weeks, and screws, followed by immobilisation in knee-high plaster cast and 5 weeks without bearing weight on the foot. Immediately after surgery, the quality of the reduction was evaluated with AP, lateral and 30° oblique X-rays, by measuring the space between the 1st and 2nd metatarsal base in AP, which is considered normal when less than 4mm6, and the tarso-metatarsal angle in lateral projection, which is considered normal between 0 and 10° *(16)*.

The patients were re-evaluated 3 years after their surgeries, with a clinical examination (pain, walking unsteadiness, need for orthotics or special shoes and current level of work or sport activity compared to that before the injury), the Ankle-Hindfoot Scale AOFAS questionnaire (pain, disability and restrictions on normal daily activities and midfoot alignment, with a score from 0 to 100), X-rays (standing X-rays in AP, lateral and oblique at 30 °), and baropodometric analysis (static and dynamic support of the injured foot compared to the contralateral foot).

RESULTS

At the 3-year post-op follow-up, 8 patients were lost: 4 had amputations, 2 polytraumas were deceased and 2 refused the check-up. Consequently, the check-ups were carried out on a sample of 63 patients. The results were analysed by relating the data obtained through the use of the AOSAF score, those concerning the type of injury, trauma and promptness of diagnosis, and those that emerged from the baropodometric analysis and X-ray evaluations (Table I).

Based on the results of the AOSAF score, we divided the sample into two groups: excellent or good (100-70 points) in 27 patients (42.9%); fair or bad (< 70 points) in 36 patients (57.1%).

Based on the type of lesion: in group 1, 7 type A (25.9%), 9 type B (33.3%), 11 type C (40.7%); in

Table I. — Summarising the results carried out on a sample of 63 patients of the study

		Group 1	Group 2	chi-square p-value	Fisher test p-value
Lesion TYPE	A	7	12	1,189 (0,55)	0,5
	B	9	14		
	C	11	10		
Trauma TYPE	Direct	26	35	0,043 (0,83)	0,6
	Indirect	1	1		
Promptness of diagnosis	Early	26	21	11,736 (>0,001)	> 0,001
	Delayed	1	15		
Treatment	Open reduction K wires and screws	24	9	25,335 (>0.001)	(>0.001)
	Closed reduction K wires and screws	3	27		
	Immobilisation	0	2		
Dislocation mm	< 4 mm	25	17	14,292 (>0,001)	> 0,001
	>4 mm	2	19		
T-MTT Angle	< 10 °	27	15	23,625 (>0,001)	> 0,001
	<10°	0	21		
Reduction loss	Closed reduction wires or screws	0	6	2,536 (0,11)	0,16
	Open reduction wires or screws	2	2		
	Immobilisation	0	1		
Post-trauma arthritis	Yes	25	36	2,754 (0,09)	0,18
	No	2	0		

Fig. 1. — Dorsal-Lateral dislocation with total incongruence (type A). Swelling and hematoma can be seen before surgery. Treated with open reduction and fixation with trans-articular screws from the 1st MT to the 1st and 2nd cuneiform; one screw from the 1st cuneiform to the 2nd MT to recreate the stability of Lisfranc ligament, one additional screw from the 3rd MT to the 2nd cuneiform

group 2, 12 type A (33.3%), 14 type B (38.9%), 10 type C (27.8%). This correlation was not statistically significant ($p = 0.5$).

Based on the type of trauma: in group 1, 26 cases (96.2%) of direct trauma and 1 (3.7%) of indirect trauma; in group 2, 36 cases (96.2%) of direct trauma and 1 (3.8%) of indirect trauma. This correlation was not statistically significant ($p = 0.6$).

With regard to the swiftness of the diagnosis: in group 1, 26 cases (96.3%) were diagnosed in the ER; in group 2, 21 cases (58.3%) were diagnosed in the ER, while in 15 cases (41.7%) the diagnosis was made at a later time (14-20 days after trauma). The diagnostic swiftness was found to be statistically significant ($p > 0.001$).

With regard to the treatment: in group 1, 24 cases (88.9%) underwent an open reduction and fixation with screws and K wires, 3 cases (11.1%) underwent a closed reduction and fixation with K-wires or screws; in group 2, 9 cases (25%)

Fig. 2. — : Post-operative X-rays at 3 years show full restore of alignment of the metatarsi with the cuneiforms and cuboid, and of the angle between 1st and 2nd MT. A broken screw can be seen in the 2nd cuneiform, clinically irrelevant. Minor swelling can be observed. A computerized foot scan shows a normal distribution of foot loads

underwent an open reduction and fixation with screws and K wires, 25 cases (69.4%) underwent a closed reduction and fixation with K wires or screws, 2 cases (5.6%) underwent a reduction and immobilisation with knee-high plaster cast. The treatment was found to be statistically significant ($p > 0.001$).

The evaluation of the reductions on the post-op X-rays showed that:

In group 1 the space between the 1st and 2nd metatarsal base was an average of 2.9 mm (1.8 mm ± 3.9 mm), while in group 2 the average space was 5.8 mm (4.2 mm ± 7.4 mm).

With regard to the space between 1st metatarsal and 2nd metatarsal, in group 1 it was less than 4 mm in 25 cases (92.6%) and in only 2 cases (7.4%) it was greater than 4 mm; in group 2 it was less than 4 mm in 17 cases (47.2%), while in 19 (52.8%) it was greater than 4 mm. This parameter is statistically significant ($p > 0.001$).

The tarso-metatarsal angle measured an average of 5° (with a range of 0° to 20°) in patients with a good reduction, and 17.5° (with a range of 0° - 40°) in those with a poor reduction. In group 1, an angle of less than 10° was detected in all 27 cases (100%); in group 2, the tarso-metatarsal angle was less than 10° in 15 cases (41.7%) and it was above 10° in 21 cases (58.3%).

A loss of anatomical reduction occurred in 11 patients (26.8%), 2 from group 1 and 9 from group 2. Of these patients, 4 of them were treated with an open reduction and fixation with wires and screws, 6 with a closed reduction and fixation with wires or screws and 1 with a closed reduction and immobilisation in plaster cast.

The loss of anatomical reduction was always accompanied by an alteration of the plantar support surface area, evaluated by electronic baropodometry (with evidence of an increase of the support surface, with “lateralised” loads), and by a painful symptomatology with difficulty walking. This parameter did not require the need for any additional treatment in 4 of the cases (36.4%), while in 6 cases (54.5%) it required the use of orthotics and special shoes. Lastly, in 1 case (9.1%) it resulted in a "rescue" arthrodesis. This finding is not statistically significant (p = 0.11).

The presence of post-traumatic degenerative changes of the arthritic type, evaluated with X-rays at the end of the follow up, was found in 61 patients (90%), regardless of the type of treatment received. This aspect is not statistically significant (p = 0.09).

9 patients who underwent an open reduction and fixation suffered from pain during standing activities and ended up changing jobs, the remaining 18 were able to go back to their work life within 6 months. 16 patients who underwent a closed reduction and fixation suffered from pain from prolonged standing activities during work and, therefore, had to change jobs. Both the patients treated with a closed reduction and cast immobilisation suffered chronic pain with prolonged standing and had to change to sedentary jobs. A return to sports activities was possible only for 3 patients who underwent an open reduction and fixation and 2 who underwent a closed reduction and fixation.

No deep infection was observed. In 3 of the cases, a superficial infection of the K-wires insertion site was detected. These patients were treated with antibiotics and weekly ambulatory medications until fully healed. There were no cases of nerve palsy or CRPS. A breakage of 3 K-wires was observed. A screw breakage was encountered in 4 cases during the follow-up. Trans-articular screws were removed in 13 patients post-operatively after 1 year.

The data were analysed with the chi-square test and the Fisher test because of discrete or nominal data. The calculation was performed using the SPSS 20.0 statistical test.

DISCUSSION

The treatment and outcomes of Lisfranc fracture dislocations in literature is controversial, because of both the diagnostic and therapeutic problems regarding this type of lesion. Moreover, almost 20% of cases are diagnosed late, or missed entirely *(19,25)*.

A result that emerged from our study was the correlation between the promptness in delivering a normal joint congruity and the quality of the outcome achieved. In fact, none of the patients that had a delayed diagnosis reported excellent or good results during their follow up. Based on the results obtained, the element closely related to the delayed identification of this lesion is polytrauma.

Given the frequency of lesions of this particular articulation, the literature recommends the execution of complete radiological examinations (AP, lateral and oblique at 30°) and in forefoot stress during the treatment of a polytrauma, in order to recognise the tarso-metatarsal dislocations *(21)*.

Lisfranc injuries are to be associated with both high-energy trauma, responsible for 50-67% of the injuries *(5,10)*, and low-energy trauma. These injuries tend to be overlooked precisely because of the minor extent of the trauma. Many authors conclude that, following a seemingly trivial trauma such as tripping or falling, complete lesions of the tarso-metatarsal ligaments can occur and a simple X-ray obtained in standard projection is not sufficient for a proper diagnosis *(5,19,17,24)*.

This emerged from a clinical trial, in which the correlation between the different types of trauma and the lesions that resulted were evaluated to better interpret the pathogenesis of these fracture-dislocations, and to diagnose them faster *(11)*.

Another important element that affects the promptness of the diagnosis is the isolation of the injury, by part of the radiologist and orthopedist, on the X-rays.

It literature, it has been reported that even orthopedic experts have a hard time identifying Lisfranc fracture-dislocations in a series of patients, with a 19% of false negatives *(25)*.

We believe that a careful clinical examination and X-rays in AP, 30° oblique and LL should be always performed in the ER on patients who were involved in high-energy traumas of the lower limbs. The 30° oblique X-ray should be precise, in order to show the Lisfranc articulation. When dealing with a polytrauma, a delayed assessment should be done within three weeks, or a CT scan should be performed if adequate X-rays are not available. A careful investigation of the injury mechanism is mandatory in both high and low energy traumas involving forefoot and midfoot, with particular

Fig. 3. — Fracture-dislocation with partial inconcruence (type B). Fleck sign can be seen at the base of the 2nd MT. High swelling can be seen in the middlefoot after trauma. Open reduction was performed. Intra-operative X-Ray shows osteosynthesis with trans-articular screws from the 1st MT to the 1st cuneiform; one screw from the 1st cuneiform to the 2nd MT to recreate the stability of Lisfranc ligament, one screw from the 2nd MT to the 2nd cuneiform and one additional screw from the 3rd MT to the 3rd cuneiform. X-Rays at 3 years show good alignment of the 1st and 2nd MT, though initial arthritis can be seen at the base of the 2nd and 3rd MT. Pedobarography shows altered load distribution on the right foot

attention on traumas in axial compression, which typically stress the Lisfranc articulation. We also suggest caution when dealing with tarsal or metatarsal fractures, even if they are apparently isolated, since, from an analysis of our database, Lisfranc injuries are associated with foot fractures in 79.3% of all cases, and with a single middle-foot or forefoot fracture in 58% of cases.

Another aim of our study was to search for a possible therapeutic algorithm for this type of injury. This objective was pursued by comparing the results obtained in relation to the type of treatment.

The simple reduction of the dislocation followed by a plaster cast immobilisation, with or without a stabilisation with percutaneous K-wires, was not sufficient in order to obtain a good reconstruction of the articular anatomy from the beginning, or for the frequent loss of reduction initially obtained, as evidenced with the follow up X-rays.

Secondary dislocations, in fact, are quite frequent because the external restraint is often insufficient, due to its indirect action on the bone structures *(6,7,17,20)*.

The unsuccessful outcomes of closed and minimally invasive treatments were evidenced from our research and have been confirmed by current literature *(7)*. After a good initial result, immediately after surgery, the timing of the K-wire removal (about 6 weeks) recorded a loss of initial anatomic reduction in 63.6% of the cases treated this way.

In agreement with the other authors *(6)*, we consider a closed reduction and fixation with K wires a therapeutic solution that needs to be used only in special cases (cutaneous or vascular problems related to trauma or pre-existing conditions). Open reductions and synthesis should always be favoured when possible, and not only for cases with of interposition of soft tissue and of multi-fragmented and/or comminuted fractures.

The ORIF allows, with a single or double dorsal access, a more accurate and precise reconstruction of the articular anatomy and a steadier biomechanical stabilisation for faster healing.

One very important aspect, related to the best results obtained in our series (10 cases treated with ORIF, all with excellent results), was the sequence of the synthesis with screws and/or wires. A first compression screw must be placed through the medial cuneiform to the base of the 2nd metatarsal, and a second screw must be positioned between the base of the 1st metatarsal and the medial cuneiform. One can then apply a third oblique screw between the base of the 3rd metatarsal and the second cuneiform. The stabilisation of the most lateral portion of the Lisfranc can, instead, be obtained with simple K wires or with screws. The screws used must be of the cortical kind and at least 3.5 mm in diameter. Moreover, it is always advisable to use at least 2 screws to reduce the risk of them rupturing and to ensure a greater rotational stability *(2)*.

The risk of an arthritic degeneration of the tarso-metatarsal joints, regardless of the treatment chosen, usually presents itself after many years and is not always disabling *(22)*.

Although our study does not involve any cases of primary arthrodesis, we agree with other authors that, even though this method is valid, it should be reserved for the acute treatment of Lisfranc "crush injuries", while is to be used only as a delayed salvage procedure in less serious injuries *(5,10,14,26)*.

Lastly, as already stated by other authors, our study also shows that the classifications currently in use to describe the lesion in the acute phase, regardless of the type of treatment carried out, have poor prognostic value *(18,20,13)* and, therefore, do not provide a useful indication for the choice of treatment.

In conclusion, tarso-metatarsal fracture dislocation are potentially highly disabling injuries that are difficult to diagnose and treat. A rapid diagnosis is imperative and the treatment with an anatomical reduction and a stable synthesis is necessary for good results. A complete series of X-rays (anterior-posterior, lateral and oblique at 30°) in the ER, both on mild forefoot isolated traumas and multiple traumas, is a fundamental step. As for the treatment, in order to obtain satisfactory outcomes, it is of great importance to reduce the dislocation *(3,22,23,25,26)* and, in particular, the base of the 2nd metatarsal. Not setting this structure causes a persistent instability of the dorsal arch of the metatarsals and the failure to reconstruct both the anatomical and functional complex. A closed reduction, followed by the stabilisation with percutaneous wires or screws, should be performed only in selected cases (cutaneous or vascular problems related to trauma or pre-existing conditions) and only in the absolute certainty that the anatomy of the Lisfranc joint has been restored.

Acknowledgement: The Authors would like to thank Miss Tracy Caputo in quality of translator for her assistance and contribution in translating and improving linguistically the text of the article.

REFERENCES

1. **Aitken AP, Poulson D.** Dislocations of the tarsometatarsal joint. *J Bone Joint Surg* 1963 ; 45A : 246-260.
2. **Alberta FG, Aronow MS, Barrero M** *et al.* Ligamentous Lisfranc joint injuries: A biomechanical comparison of dorsal plate and transarticular Screw Fixation. *Foot Ankle Int* 2005 ; 26 : 462-473.
3. **Basset F.** Dislocation of the tarsometatarsal joints. *S Med J* 1964 ; 57 : 1294-1302.
4. **Bolognini N, Goldmann F.** Management of major forefoot trauma. *J Foot Surg* 1985 ; 24-2 : 88-89.
5. **Calder JD, Whitehouse SL, Saxby TS.** Results of isolated Lisfranc injuries and the effect of compensation claims. *J Bone Joint Surg Br* 2004 ; 86 : 527-30.
6. **De Marchi F.** Fratture-lussazioni del complesso tarso-metatarsale trattate con riduzione aperta e sintesi percutanea

con fili: risultati a lungo termine ed evoluzione clinico. *Italian J Orthop Traum* 2007 ; 33 : 153-159.
7. **Fino A, Torasso G, Valente A, Sabatini I, Trecci A, Uslenghi M.** Le fratture lussazioni della Lisfranc: aggiornamento sulla classificazione, diagnosi e trattamento. *Minerva ortopedica e traumatologica* 2008 ; 59 : 179-191.
8. **Goosens M, De Stoop N.** Lisfranc's fracture dislocation: etiology, radiology, and results of treatment. *Clin Orthop* 1983 ; 176 : 154-162.
9. **Jarde O, Trinquier-Lautard JL, Filloux JF, de Lestang M, Vives P.** Fractures-luxations de l'interligne de Lisfranc. *Rev Chir Ortoph* 1995 ; 81 : 724-30.
10. **Jeffreys TE.** Lisfranc's fracture dislocation: a clinical and experimental study of tarsometatarsal dislocations and fracture-dislocations. J Bone Joint Surg 1963 ; 45B : 564-7.
11. **Juha – Pekka V, Hannu TA.** Lisfranc joint injuries: Trauma mechanism and associated injuries. *J Trauma* 1993 ; 35 : 40-45.
12. **Kenzora JE, Edwards CC.** Acute management of major trauma involving the foot and ankle with Hoffman external fixation. *Foot & Ankle* 1981 ; 1 : 348-361.
13. **Kuo RS, Tejvani NC, Di Giovanni CW, Holt SK, Benirshcke. SK, Hansen JR** *et al.* Outcome after open reduction and internal fixation of lisfranc joint injuries. *J Bone Joint Surg* 2000 ; 82A : 1609-18.
14. **Ly TV, Coetzee JC.** Treatment of primarily ligamentous Lisfranc joint injuries: primary arthrodesis compared with open reduction and internal fixation. A prospective, randomized study . *J Bone Joint Surg Am* 2006 ; 88 : 514-20.
15. **Mantas JP, Burks RT.** Lisfranc injuries in the athlete. *Clin Sports Med* 1994 ; 13 : 719-30.
16. **Meyerson MS, Fisher RT, Burgess AR, Kenzora JE.** Fracture Dislocation of the tarsometatarsal joints: end results correlated with pathology and treatment. *Foot & Ankle* 1986 ; 6 : 225-242.
17. **Meyerson MS.** Diagnosis and treatment of injuries to the Lisfranc joint complex. *Orthop Clin N Am* 1989 ; 20 : 655-64.
18. **Modrego FJ, Garcia-Alvarez F, Bueno AL, Palanca D, Seral F.** Results of the surgical treatment of Lisfranc fracture-dislocations. *Musc Skelet Surgery* 2002 ; 87 : 189-94.
19. **Mulier T, de Haan J, Vriesendorp P., Reynders P.** The Treatment of Lisfranc Injuries: Review of Current Literature. *Eur J Trauma Emerg Surg* 2010 ; 3 : 207-21.
20. **Mulier T, Reynders P, Dereymaeker G, Broos P.** Severe Lisfrancs injuries: primary arthrodesis or ORIF? *Foot Ankle Int* 2002 ; 23 : 902-5.
21. **Rabin S.** Lisfranc dislocation and associated metatarsophalangeal joint dislocations. *Am J Orthop* 1995 ; 4 : 305-309.
22. **Rammelt S, Schneiders W, Schikore H.** Primary open reduction and fixation compared with delayed corrective arthrodesis in the treatment of tarsometatarsal (Lisfranc) fracture dislocation *J Bone Joint Surg Br* 2008 ; 90 : 1499-506.
23. **Saab M.** Lisfranc fracture-dislocation: an easily over-looked injury in the emergency department. *Europ J Emergency Med* 2005 ; 12 : 143-6.
24. **Salathe EP, Arangio GA.** A biomechanical model of the foot: the role of muscles, tendons, and ligaments. *J Biomech Eng.* 2002 ; 124 : 281-7.
25. **Sherief TI, Mucci B, Greiss M.** Lisfranc injury: how frequently does it get missed? And how can we improve?. *Injury* 2007 ; 7 : 856-60.
26. **Teng AL, Pinzur MS, Lomasney L, Mahoney L, Havey R.** Functional outcome following anatomic restoration of tarsometatarsalfracture dislocation. *Foot Ankle Int* 2002 ; 23 : 922-6.