Management of Lisfranc Injuries

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Management of Lisfranc Injuries: A Critical Analysis Review

TAKE HOME POINTS

- There is a spectrum of midtarsal injury, ranging from mild midfoot sprains to complex Lisfranc fracture-dislocations.
- Use of appropriate imaging can reduce patient morbidity, by reducing the number of missed diagnoses and, conversely, avoiding overtreatment. Weightbearing radiographs are of great value when investigating the so-called 'subtle' Lisfranc injury.
- Regardless of operative strategy, anatomical reduction and stable fixation is a prerequisite for a satisfactory outcome in the management of displaced injuries.
- Fixation device removal is less frequently reported following primary arthrodesis compared with open reduction and internal fixation based on six published meta-analyses. However, the indications for further surgery are often unclear and the evidence quality of the included studies is typically low. Further high quality prospective randomized trials with robust cost-effectiveness analyses are required in this area.
- We have proposed an investigation and treatment algorithm based on the current literature and clinical experience of our trauma centre.

INTRODUCTION

The Lisfranc injury is named after a French gynaecologist and field surgeon after he defined an amputation through the tarsometatarsal joints (TMTJs),[1] although the injury itself was described by Napoleon's surgeon Larrey. The term implies disruption of this joint with resulting midfoot instability, and encompasses a spectrum of injuries to bone and/or ligamentous structures.[2] Lisfranc injuries are rare making up only 0.2% of all orthopaedic presentations, although recent literature suggests a rising incidence, with unstable injuries now more common in women.[3] **Some injuries are frequently missed; these are commonly subtle injuries sustained through low energy mechanisms or in individuals with distracting injuries, such as the polytraumatised patient.** If not identified and treated promptly these injuries carry high morbidity, typically via accelerated midfoot degeneration and arch collapse.[4-6] This in turn may lead to substantial functional impairment and in some cases, loss of employment.[7] **Open reduction internal fixation (ORIF) of these injuries following delayed diagnosis of up to six weeks is possible,**[8] but outcomes are less satisfactory compared with timely intervention.

This article reviews the surgical anatomy, presentation and diagnosis of Lisfranc injuries, followed by a comprehensive overview of treatment, concentrating on the contemporary literature published over the last decade. A review of subtle Lisfranc injuries in athletes has been published recently,[9] and is not this article's focus.

RELEVANT SURGICAL ANATOMY

The Lisfranc joint and the Lisfranc ligament complex are not to be confused and have traditionally been ill-defined.[10] The Lisfranc joint consists of all the TMTJs reinforced by soft tissue stabilizers; namely the Lisfranc ligament complex, intermetatarsal ligaments (connecting metatarsals II-V, but importantly not I-II), intertarsal ligaments and TMTJ capsular connections. In the coronal plane the Lisfranc joint is formed of contributions from the metatarsal bases and their respective cuneiforms, which are narrower on the plantar side, resulting in a Roman arch (Figure 1). The second metatarsal is recessed between the first and third metatarsals, abutting the middle cuneiform and forming the arch keystone, which if compromised, destabilises the midfoot complex.

Reduced second metatarsal length, relative to foot length, may be a predisposing factor to a ligamentous Lisfranc injury.[11] A number of anatomical variations of the Lisfranc ligament complex have been described,[12-14] but in summary consists of plantar, interosseous and dorsal components, which span between the second metatarsal base and the lateral aspect of the medial cuneiform (Figure 1).[10, 12] **Two key plantar ligaments exist: a shorter longitudinal ligament from the medial cuneiform to the lateral aspect of the second metatarsal base and a long oblique ligament which extends to the third metatarsal base.[14, 15]** The interosseus ligament is the largest and strongest, often referred to as the 'Lisfranc ligament', which if sectioned in isolation in a cadaveric setting has been shown to result in diastasis.[16] Variations in the structure of the interosseous and plantar ligaments, specifically, may play a role in susceptibility to injury.[10]

CLINICAL PRESENTATION

Up to 70% of Lisfranc injuries occur following a high energy mechanism, with over 40% sustained during road traffic accidents,[17] although some studies have noted a higher proportion of low energy injuries and are likely related to the catchment population.[3] Lower energy injuries usually occur via a sudden downward rotational force and are more commonly sustained during sport.[9, 18-20] Despite a better understanding of the pathoanatomy of these specific injuries,[21] they are frequently missed at the time of initial presentation or diagnosed late, as they are largely isolated ligamentous in nature without an associated fracture.[22] Late presenting patients with persistent pain should be investigated for a missed Lisfranc injury. They may exhibit a bony prominence over the medial aspect of the midfoot, a so-called 'Jut' sign.[23] Compared with low-energy injuries, high energy injuries are more commonly associated with lateral ray involvement and tarsal bone fractures, predominantly the cuboid and navicular. Compartment syndrome of the foot must be considered in high energy injuries.[24, 25] Regardless of mechanism, in the presence of midfoot pain, swelling and/or plantar ecchymosis, a high index of suspicion is required to avoid missed diagnoses.[26]

INVESTIGATIONS

Non-weightbearing radiographs are the primary investigation of choice. Anteroposterior (AP), 30-degree internal oblique and lateral radiographs may demonstrate a diastasis between the medial cuneiform and second metatarsal base, and/or a radiographic 'fleck sign', which are typically pathognomic.[27] However, these may miss subtle injuries and if there is ongoing clinical concern, weightbearing radiographs of both feet to allow side-to-side comparison, when pain allows, are recommended (Figure 2).[3, 28-31] This is routine practice at the authors' institution 10-14 days post-injury and may highlight not only instability between the medial and middle columns, but not infrequently unmask instability at the 1st TMT joint (Figure 5). Side-to-side asymmetry or a distance of >2mm between the second metatarsal base and medial cuneiform is highly specific (96%) in aiding the diagnosis of a ligamentous injury.[32] Deep learning algorithms have reduced misdiagnosis of subtle injuries by a factor of 10.[33]

Dividing the foot into three columns (medial, middle and lateral) helps to visualise the normal alignment of the anatomical zone of interest (Figure 3). The medial and middle columns are inherently rigid, both acting to stabilise the midfoot during gait. Comparatively, the lateral column permits more movement in all planes, allowing an adaptive foot position when navigating uneven surfaces. TMTJ alignment on weightbearing radiographs should be scrutinized; the medial border of the second metatarsal should align with the medial border of the middle cuneiform on the AP radiograph and similarly the medial border of the fourth metatarsal should align with the medial border of the cuboid on the oblique radiograph. Dorsal displacement on the lateral weightbearing radiograph is evaluated by assessment of collinearity between the metatarsal bases and their respective cuneiforms.

At the Lisfranc joint a 'fleck' sign, when present, may indicate an osseous avulsion from either side of the Lisfranc ligament and a diastasis of >2mm raises suspicion of underlying injury. **Loss of radiographic arch height, visualised on the lateral radiograph, may occur following injury.**[31, 32] **Whilst not extensively studied in the literature, it may serve as an adjunct in the diagnosis of subtle injuries and/or confirming accurate reduction intra-operatively.** Injury to the 1st TMTJ, including articular damage, fracture and/or joint incongruity may occur in up to 86% of cases, and has been overlooked previously.[34] **Fractures of the 2nd metatarsal base with no evidence of radiographic instability at the Lisfranc joint are commonly (but incorrectly) interpreted as Lisfranc injuries and are treated conservatively.**

If weightbearing radiographs are not tolerated, or if these are normal despite ongoing suspicion, cross-sectional imaging including computed tomography (CT) or magnetic resonance imaging (MRI) may be helpful. CT is valuable in detecting occult fractures, joint comminution and minor degrees of joint subluxation that may be missed on radiographs,[35] and 3-D reconstructions have shown to improve diagnostic accuracy and reliability compared with 2-D interpretation.[36] **Recognition of articular injury may aid surgical decision making when considering primary arthrodesis. CT is further recommended in high-energy injuries where coexisting fractures, if detected, may impact on surgical management and/or post-operative rehabilitation (Figure 4).** If previous investigations have been normal and there is continuing concern regarding the injury, MRI has been shown to be superior in revealing the so-called 'subtle injury'.[28, 35, 37, 38] Stress testing under anaesthesia has been performed historically, but with advances in imaging is seldom now used for diagnostic purposes, although commonly performed at the time of operative stabilisation. In summary, the diagnosis of a Lisfranc injury can be very challenging. A high index of suspicion based on the clinical presentation, combined with appropriately selected imaging studies, is essential to reduce the number of missed injuries.

Classification of injury

Numerous classifications of Lisfranc injury have been proposed.[30, 39, 40] The most commonly used is the Myerson-modified Hardcastle classification, described in 1986 based on anatomical zone, direction of displacement and TMTJ congruity.[40] Injuries are classified into three main groups (A/B/C), with a fourth group (D) added in 2018.[41] This supplementary group relates to non-displaced injuries, and is further divided into D1 and D2, depending on whether non-operative intervention is appropriate. Although this classification system has shown excellent intra- and inter-observer reliability (intraclass correlation coefficient (ICC) of 0.94 and 0.81 respectively),[42] it is considered less useful in guiding management or predicting prognosis.[43] A classification system for Lisfranc injuries in athletes,[9, 20] produced by Nunley and Vertullo in a study of 15 athletes used a combination of clinical examination, weightbearing radiographs and bone scintigrams.[30] **In summary, no classification system exists that definitively helps guide treatment.**

TREATMENT

Nonoperative

Patient presenting with clinical features suggestive of a midfoot sprain (localised midfoot pain, swelling and/or bruising) but with ≤2mm gap between the medial cuneiform and second metatarsal base on weightbearing radiographs and/or CT/MRI imaging, may be suitable for non-operative treatment in appropriately selected patients.[40, 44] Ponkilainen *et al* followed up 55 patients out of an initial cohort of 110 who were treated initially in a non-weightbearing cast for between four and six weeks, followed by full weightbearing for a further four weeks.[45] At a minimum follow-up of two years, patients reported excellent function according to the Visual Analogue Scale-Foot & Ankle, and only one patient required delayed operative intervention. This study was limited by the large proportion of patients who did not respond to questionnaire (36%) and the lack of clinical examination and radiographic outcomes.

Stødle *et al* prospectively reviewed 26 patients stable injuries who received a non-weightbearing cast for six weeks and were evaluated at a median time of 55 months post-injury.[46] No patient required surgery, and all returned to employment, although two reported limitations with recreation. Chen *et al* investigated the rate of displacement following non-operative treatment of minimally displaced Lisfranc injuries.[47] Fourteen of the 26 patients included (54%) displaced and 12 required surgery. Despite delayed intervention, patient-reported outcome data was comparable to those patients treated successfully without displacement. The authors concluded that non-operative treatment is feasible, but close radiographic follow-up is mandatory to detect early displacement. Whilst discomfort may persist after a midfoot sprain, there is currently limited evidence to indicate that surgery improves outcomes, and consequently high-quality data in this area may help guide the best treatment for this select patient group.

Operative

Percutaneous fixation

To reduce operative morbidity and expedite recovery, percutaneous fixation has been recommended for subtle, low-energy injuries which have no lateral column instability and can be reduced anatomically through percutaneous techniques.[48-53] Insertion of a standard anterograde, or retrograde Lisfranc screw (from base of 2nd metatarsal to medial cuneiform) has been described (Figure 5).[52, 54] Chen *et al* described the technique in 16 consecutive patients that were compared to a control group treated with standard ORIF, matched for age, sex, mechanism of injury and classification.[52] At a mean follow-up of 43 months, patient reported outcomes according to the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot score and the Manchester Oxford Foot Questionnaire (MOXFQ) were significantly better in the percutaneous group, coupled with a lower non-significant rate of radiographic degeneration.

Similar mid-term findings were reported by Vosbikian *et al* in 38 consecutive patients sustaining a low-energy injury.[49] Although no patient experienced a serious complication, 22 patients underwent elective hardware removal, which was offered by the institution. Wagner *et al*, reviewed 22 patients treated with percutaneous fixation and achieved an anatomic or 'near-anatomical' reduction in all.[53] Patients were allowed to weight bear as tolerated three weeks post-operatively and reported excellent rates of return to function.

Only one systematic review on percutaneous fixation has been performed by Stavrakakis *et al*, including just four studies, and concluded that percutaneous fixation was simple, safe and with a low operative morbidity.[55] **However, as with any peri-articular injury, a positive outcome was reliant upon anatomical reduction and some authors consider an open reduction mandatory for all subtle Lisfranc injuries to prevent missing**

concomitant joint injury, that if left untreated may lead to post-traumatic arthritis.[21] There are currently no level one prospective data on this topic.

Open reduction and internal fixation (ORIF)

In injuries without significant insult to the articular surface, ORIF is considered the gold standard treatment, combining anatomical reduction with rigid internal fixation to restore normal gait and functional outcome[56] maintained at long-term follow-up.[57] Traditionally, exposure has been achieved through multiple dorsal longitudinal incisions, separated by a small skin bridge.[58] A single longitudinal, extensile incision centred over the 2nd metatarsal has a comparable soft-tissue complication profile, yet provides superior exposure of the whole Lisfranc joint via up to three windows.[59] **A transverse incision used for access during arthrodesis procedures in the setting of TMTJ arthrosis has been described,[60] but is used less frequently than longitudinal incisions in the trauma setting.**

Debate continues regarding fixation modalities, chiefly transarticular screw fixation and dorsal bridge plating. Most clinical studies are single-centre, retrospectively designed and include relatively small patient numbers.[61] Transarticular screws are cheaper and may be less irritating to local soft tissues. Opponents of screw fixation report direct chondral injury and retained intra-articular hardware, in the event of screw breakage as primary objections. Bridge plating adds no additional articular insult beyond that imparted by the injury, and may provide superior fixation in comminuted fractures, but typically requires greater surgical exposure and the associated risks. Often, removal of dorsal plates has been recommended, although recent data have suggested that retention is safe with comparable outcomes to removal.[61]. Although hardware is not routinely removed in the our institution, a recent United Kingdom study found that 38% of surgeons routinely remove hardware in the anticipation that this optimises physiological function and reduces the risk of implant breakage,[62] although without evidence to support this contention.

In the laboratory, comparable fixation stability has been demonstrated by transarticular screws and dorsal plates when tested in 13 paired cadaveric limbs through cyclic loading.[63] Lau *et al* studied a group of 62 patients who underwent transarticular screw fixation, dorsal bridge plating or a combination.[64] Reduction quality was more predictive of radiographic outcome than fixation choice. However, combination fixation with both screws and plates resulted in worse radiological outcomes but was often performed in more severe injuries and therefore may be a confounding factor. Kirzer *et al* reported similar findings in their retrospective review of 108 patients treated with transarticular screw fixation (n=38), dorsal bridge plating (n=45) and combination fixation (n=25).[65] Those managed with combination fixation reported a poorer mean AOFAS of 63, compared with 71 in the transarticular and 82 in the dorsal bridge plating groups. Similar patterns were reported in the secondary outcome measures, including patient satisfaction. Dorsal bridge plating was associated with improved anatomical reduction but did not reach statistical significance and there was no difference in complication rates. Again, more severe injuries were managed with combination fixation, commonly including stabilisation of all three columns of the foot, which could explain the inferior outcomes.

Engelmann *et al* conducted a systematic review comparing functional outcome and complication rates of transarticular screw fixation and dorsal bridge plating.[66] One prospective and three retrospective studies were included and found that functional outcome according to the AOFAS was statistically significantly higher in the bridge plating group (mean difference 7 points), although below the minimum clinically important difference (MCID). There was no difference between the two groups for rates of infection, hardware removal, chronic pain or arthrodesis secondary to ongoing pain and/or functional limitation. However, there was a higher incidence of post-traumatic osteoarthritis in the transarticular screw group, potentially linked to the greater degree of chondral injury. Philpott *et al* performed a large systematic review and meta-analysis including all fixation strategies, both rigid and flexible.[67] **Part of the analysis compared transarticular screw fixation with spanning dorsal plate fixation across individual TMTJs** and concluded that plating was non-superior in terms of the AOFAS with a mean difference of five points, which was neither clinically or statistically significant. Although lateral column stabilisation is infrequently reported, these rays are mobile by design and therefore if instability is present after fixation of medial and middle columns, temporary stabilisation with Kirschner wires for no more than six weeks is typically sufficient to maintain reduction, whilst minimising stiffness.[59]

More high-quality data comparing screw and plate fixation are required but given the scarcity of Lisfranc injuries and the broad range of injury patterns, conducting meaningful RCTs on this topic is challenging. Nevertheless, it is clear from the evidence available that anatomical reduction, regardless of fixation strategy, is critical to treatment outcome.

Flexible fixation devices

Recreation of the Lisfranc ligament with a flexible fixation device has been investigated in numerous recent biomechanical and clinical studies. Several commercial constructs are available, aiming to permit residual movement at the Lisfranc joint, reduce the incidence of hardware removal and minimise implant breakage. **Given the flexible nature, any observed advantage will benefit ligamentous injuries only and stabilization of the 1st TMTJ is not feasible with current devices.**

Data from biomechanical studies, whereby flexible devices have been tested to failure through cyclical loading have found these devices to be non-inferior to rigid fixation.[68-70] Cho *et al* compared 31 patients treated with a suture button device with 32 patients treated with a rigid Lisfranc screw.[71] All procedures were performed percutaneously, and hardware was removed within six months post-operatively in the rigid screw group only. The suture button was superior according to the AOFAS midfoot score and VAS prior to screw removal, but no difference was found at one year and beyond, following hardware removal. Two patients in the suture button group experienced recurrent diastasis with the button failing at the medial cuneiform, compared with one diastasis in the screw group.

Cottom *et al* evaluated radiographic reduction and functional outcomes after suture button stabilisation of the Lisfranc joint supplemented with an intercuneiform screw (medial to middle) in 104 patients with ligamentous injuries.[72] There were 84 patients with a minimum follow-up of three years. Mean return to full weightbearing in a supportive orthosis was 11 days and no suture buttons failed, required removal, or resulted in significant radiographic degeneration. Patient reported outcome according to the AOFAS improved from 31 at injury to 90 post-operatively. Supportive data from small retrospective series including both acute,[73, 74] and chronic injuries,[75] have been reported. Concerns regarding fixation purchase in poor quality bone limit the indication of these implants to younger patients with purely ligamentous injuries and there are currently no level 1 data to support use. Research including robust cost effectiveness analyses to justify the increased implant cost, balanced against the potential reduction in hardware removal rates is needed. A protocol for a meta-analysis of comparative studies has been published.[76]

Internal fixation (IF) vs. primary arthrodesis (PA)

Historically, arthrodesis was reserved as a salvage option for either late presenting patients or following failed initial treatment.[77] **However, there is some evidence that PA may provide superior results to IF in select patient groups, including injuries that are purely ligamentous, high-energy and/or in the presence of severe articular damage at the time of injury.** There are currently six published meta-analyses on this topic (Table 1)[78-83]. However, the diverse techniques described, and the heterogeneous nature of the injuries included in make it challenging to draw firm conclusions.

Stødle *et al* randomized 48 patients with unstable Lisfranc injuries to IF (n=24) or PA (n=24) and completed follow up to two years.[84] In the PA group, the medial three TMTJs were fused primarily, whereas in the IF group a temporary bridge plate was placed over the first TMTJ, with the second and third TMTJs fused as per the PA group. The mean AOFAS and median VAS pain scores were comparable between the two groups at both the one- and two-year assessment points. In those patients treated with IF, 46% (n=11) developed post-traumatic degenerative changes in the first TMTJ, but only one patient required secondary arthrodesis. So *et al* performed a retrospective study comparing complications and reoperation rates in 130 patients treated with IF and 66 patients treated with PA.[85] The reoperation rate was significantly higher in the fixation group (78% vs. 20%), but when hardware removal cases were excluded the reoperation rates were comparable, as were the overall complication rates. Van Den Boom *et al* performed a recent comprehensive systematic review on the topic.[79] Twenty studies (12 suitable for meta-analysis) were included, with 392 patients treated with IF and 249 patients with PA. The RCT performed by Stødle et al,[84] was part of this review and according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) criteria was the only study to yield high-level evidence, in relation to the primary outcome (AOFAS Midfoot Score). Overall, PA performed statistically significantly better than IF (AOFAS mean difference of 6.3 points), but this value was not felt to be clinically significant and fell below the MCID of 8.4.[86] Furthermore, in addition to the overall quality of evidence being low, it was not possible to differentiate between injury types, energy at the time of injury and specific fixation strategies. The authors stated explicitly that further large prospective multicentre RCTs, including cost-effectiveness analyses are required.

Each of the published six meta-analyses found that hardware removal rates were lower following PA but there were conflicting results regarding return to function and functional outcomes. It has since been noted that the studies contained within the meta-analyses used different variations of the AOFAS questionnaire, making direct comparisons invalid.[87] It must also be noted that the published MCID for the AOFAS is based on patients undergoing hallux valgus surgery and an updated value specifically for Lisfranc injuries would be of assistance when drawing future conclusions.

Treatment outcomes

Early failure may be attributed to multiple factors, including under-appreciation of injury severity, non-anatomical reduction, incorrect implant selection and non-union. Surgical arthrodesis in these situations provides the most reliable salvage option.[77, 88] Following successful initial treatment, there are limited studies reporting the longer-term outcome of Lisfranc injuries, with the few available reporting outcomes from small cohorts.[57, 89, 90] Dubois-Ferrière *et al* followed up 61 patients at 11 years and reported satisfactory patient reported outcome (AOFAS mean score 79) but with evidence of radiographic degeneration in 72% of patients.[90] Half of the cohort had symptomatic degeneration, which was associated with poorer outcomes, but only four patients required reintervention. Others have also found no association between radiographic osteoarthritis and poor clinical scores, although this cohort were treated with Kirschner wire stabilisation,[89] which may not provide as predictable fixation as screws or plates. However, these studies highlight the fact that the development of radiographic osteoarthritis does not in itself necessitate secondary arthrodesis and patients should be assessed for symptom correlation and not through radiographs alone. Given the young age of many patients in this cohort, return to activity, including sport following treatment has been addressed in recent literature.[9, 20, 91-95] **Rates of return to sport of 94%, with nearly three**

quarters returning to preinjury levels, have been reported in a recent meta-analysis.[92] In contrast, change of employment or indeed unemployment following injury may occur in up to 30% of patients,[7] particularly following delayed diagnosis or in the presence of a workers' compensation claim.

Management algorithm for Lisfranc injuries

Based on the current literature and the experience of the authors' institution, we have proposed an investigation and treatment algorithm for managing Lisfranc injuries (Figure 6).

CONCLUSIONS

Lisfranc injuries are varied and often complex, presenting numerous management challenges (Table 2). Weightbearing imaging should improve diagnostic accuracy and reduce the number of missed or late diagnoses. Non-operative treatment is successful in undisplaced injuries but requires careful radiographic surveillance to detect late displacement. In the presence of an anatomical closed reduction, percutaneous stabilisation is safe with low complication rates. As reduction quality is a marker of treatment outcome, a low threshold for performing an open reduction should be always employed. Once reduced, the choice of implant for stabilisation may be left to surgeon discretion. Whilst some studies claim to support primary arthrodesis over internal fixation, most have been unable to detect a clinically meaningful difference in functional outcomes and concerns persist regarding primary TMTJ fusion in young active patients. Flexible fixation devices may reduce hardware removal rates but are limited in their application to purely ligamentous injuries only. Further high-quality studies comparing these treatment options, including cost effectiveness analyses are required.

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FIGURE LEGENDS

Figure 1: The 'Roman Arch' of the midfoot showing the Lisfranc ligament complex.

Figure 2: Non-weightbearing AP radiograph of the left foot initially reported as normal. Subsequent bilateral weightbearing feet radiographs clearly demonstrate a ligamentous Lisfranc injury on the left side.

Figure 3: Anteroposterior (a) and oblique (b) schematic of the tarsometatarsal region of the foot, demonstrating the three columns of the foot.

Figure 4: Computed tomography imaging with 3-D reconstruction in patient presenting with a high-energy Lisfranc injury, demonstrating associated cuboid and base of 5th metatarsal fractures.

Figure 5: Subtle right Lisfranc injury seen on AP non-weightbearing radiograph (A), which demonstrated additional instability on stress weightbearing radiographic assessment between the medial and middle columns, and the 1st TMT joint (B). One-year radiographic follow-up following percutaneous reduction and fixation (C).

Figure 6: Algorithm for diagnosis and management of Lisfranc injuries based on the current literature and clinical experience of our trauma centre. NWB: non-weightbearing, WB: weightbearing, FWB: full-weightbearing, AP: anteroposterior, CT: computed tomography, MRI: magnetic resonance imaging, ORIF: open reduction internal fixation.

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