

## Original Article

# Stress fracture of the fifth metatarsal in professional soccer players treated with intramedullary fixation: is a return to sports safe?

Carlos Augusto Zazueta-Arnaud<sup>1</sup> , Luis Gómez-Carlín<sup>1</sup> , Luis Felipe Radillo-Ubando<sup>1</sup> ,  
Victor Jonathan Ramírez-Gómez<sup>1</sup> , Elsa Viridiana Sánchez-Hernández<sup>1</sup> 

1. Medyarthros Clinic, Guadalajara, Jalisco, Mexico.

## Abstract

**Objective:** To evaluate the clinical and functional outcomes of professional soccer players with zone 3 fractures of the fifth metatarsal treated with intramedullary fixation; and to determine a safe return time to sports.

**Methods:** This study included professional Mexican soccer players with fractures in zone 3 of the fifth metatarsal treated with intramedullary fixation. The clinical and functional status were evaluated with the VAS and Foot and Ankle Ability Measure (FAAM-Sp) Sport Subscale Score.

**Results:** Twenty-two professional soccer players (average age:  $20.13 \pm 2.85$  years) were included. The average postoperative follow-up time was  $23.54 \pm 15.26$  months. Fracture consolidation was demonstrated at 12-week follow-up in all 22 (100%) subjects. The FAAM-Sp Sport Subscale Score was  $91.45 \pm 8.84$  postoperatively; the safe time to return to sports was  $12.04 \pm 2.21$  weeks, when normal or close to normal function was observed in 21 (95%) players.

**Conclusion:** A safe return to sports at 12 weeks, at the same performance level demonstrated prior to injury, was achieved in 95% of professional soccer players in this sample. To our knowledge, this is the first study to explicitly define a time for safe return to sports activities that is related to the critical time required to allow fracture union.

**Level of Evidence III; Therapeutic Studies; Retrospective Cohort Study.**

**Keywords:** Activities of daily living; Fractures, stress; Soccer.

## Introduction

Fractures of the fifth metatarsal in professional soccer players account for 0.5% of all sport injuries<sup>(1)</sup>. This lesion frequently occurs in zones 1 and 2, whereas a lesion in zone 3, known as a stress fracture, is less frequent and is a result of repetitive loading that occurs during training and competitions. Intrinsic and extrinsic risk factors have been described, such as being a young athlete and participating in intense preseason training<sup>(2,3)</sup>. Recently, an abnormality in the mean malleolar glide angle of the ankle has been shown to be a risk factor for stress fractures in the fifth metatarsal<sup>(4)</sup>.

A conservative treatment approach is not effective for athletes; immobilization to manage stress fractures can be catastrophic and associated with delayed consolidation, pseudoarthrosis, and a prolonged recovery time<sup>(5-8)</sup>. Currently, the consensus is that intramedullary fixation of stress fractures is indicated specifically in subjects with high physical demands, such as professional soccer players<sup>(1,9)</sup>. Surgical management offers the greatest safety for bone union, with advantages that include its technical simplicity and its minimally invasive nature<sup>(10)</sup>, ideal for patients with high levels of physical activity. In 1975, for the first time, Dameron<sup>(6)</sup> suggested that athletes should be operated on early to accelerate bone union.

Study performed at the Medyarthros Clinic, Guadalajara, Jalisco, Mexico.

**Correspondence:** Luis Felipe Radillo-Ubando. Av. Ignacio L. Vallarta 3060, Ladrón de Guevara, 44690. **E-mail:** radillo\_lf09@hotmail.com. **Conflicts of interest:** none. **Source of funding:** none. **Date received:** February 17, 2022. **Date accepted:** February 26, 2022. **Online:** April 30, 2022.

How to cite this article: Zazueta-Arnaud CA, Gómez-Carlín L, Radillo-Ubando LF, Ramírez-Gómez VJ, Sánchez-Hernández EV. Stress fracture of the fifth metatarsal in professional soccer players treated with intramedullary fixation: is a return to sports safe? J Foot Ankle. 2022;16(1):79-84.



There are few reports of stress fractures in zone 3 of the fifth metatarsal<sup>(1,3,11)</sup>. Moreover, to our knowledge, no studies have determined the clinical and functional progression of this injury with valid and reproducible scales of surgical results and their relation to the time of return to professional sports at the same performance level reached prior to the injury. Therefore, the objectives of our study were 1) to evaluate clinical and functional outcomes on a visual analog scale (VAS) and the Sport Subscale Score of the Foot and Ankle Ability Measure-Spanish (FAAM-Sp) in professional soccer players with fractures in zone 3 of the fifth metatarsal treated with intramedullary fixation, 2) to determine a safe time for these players to return to play, and 3) to ascertain whether the players reached the same performance level at which they played prior to injury.

## Methods

After a full review, the study was approved by the Ethics Committee of the Jalisco Institute of Clinical Research (No. 14-CEI-005-20170427- No. 1066).

A retrospective cohort study was conducted from July 2013 to February 2018; participants were enrolled consecutively. Players from the Mexican professional soccer league with a primary fracture in zone 3 of the fifth metatarsal that was treated with intramedullary fixation within the first 10 days of injury were eligible and included in the study. Patients who had experienced traumatic events and fractures in zone 1 and/or 2 of the fifth metatarsal were not included. Patients who agreed to participate gave verbal informed consent.

## Study Description

The following variables were included: age, sex, dominant foot, fractured foot, preseason injury, postoperative temporal progression, time until return to the professional sporting level the player had reached prior to injury (weeks), and radiographs at 4-, 8-, and 12-week postoperative follow-up time points to identify whether union, nonunion, or a delay of consolidation and complications occurred. Union required complete bone bridging across the fracture site with or without normal density on radiographs and no tenderness at the zone fracture. The period of inability to participate in sport at the player's preinjury professional level was recorded.

## Evaluation Scales

The clinical and functional status of the fifth metatarsal stress fracture, as well as postoperative outcomes, were evaluated with the VAS and FAAM-Sp Sport Subscale Score<sup>(12,13)</sup>.

## FAAM-Sp Sport Subscale Score

The sports subscale comprises eight elements of high-level activities, such as those required for athletes. The capacity to respond, validity, reliability, and reproducibility of this scale, including the Spanish version<sup>(12)</sup>, were previously verified<sup>(14)</sup>. Tools for assessment, such as self-reporting surveys, use the

patient's response to measure his performance: the survey is useful to evaluate the efficacy of the treatment. The maximum score, 100, corresponds to an ability to perform the sporting activity with the patient's normal technique and participate in the sporting activity for as long as necessary. The minimum score, 20, corresponds to an inability to perform or participate in the sporting activity. Similarly, the current level of function defined by the players was evaluated during sporting activities by a range of scores from 0 to 100 (100 corresponded to their level of function prior to the fracture and 0 corresponded to an inability to perform any of their usual daily activities). In relation to the question, "How do you classify your current function level?" the parameters evaluated were normal, close to normal, abnormal, and severely abnormal.

## Operative Technique

All patients were operated on in the supine position using regional anesthesia and a tourniquet. Patients received prophylactic antibiotics. During the surgical procedure, fluoroscopic monitoring was used. A cannulated drill and a guide wire were used; every surgical procedure was performed via the "high and inside" surgical technique.

## Postoperative Management

Patients received general wound care and minimal handling of the surgical site. They went into non-weight-bearing immobilization in a walker boot for 2 weeks. Subsequently, progressive weight-bearing in regular shoes was indicated as tolerated. In case of any functional limitation, strength-training exercises were prescribed. Between 6 and 10 weeks after surgery, elliptical training and jogging were authorized. The intensity of these activities was decided based on the patient's recovery status. Between 10 and 12 weeks after surgery, patients joined their team for regular training. Our criteria for return to sport were pain relief at the affected zone, adequate physical function, and complete trabecular bridging across the fracture site on radiographs.

## Statistical Analysis

Data were recorded in Excel (Microsoft™, Seattle, WA). Student's *t* test was performed to compare pre-and postoperative VAS scores. A *p*-value of <0.05 was considered statistically significant.

## Results

Twenty-two professional male players with diagnosis of primary fracture in zone 3 of the fifth metatarsal that was treated with intramedullary fixation were included in the study (Figure 1). The age of the patients ranged from 17 to 29 years, with an average age of 20.13 ± 2.85 years (Table 1). The patients were clinically and radiographically evaluated within the first 10 days after the injury. A widening of the fracture line and evidence of intramedullary sclerosis were shown in the

radiographs (Figure 2A-B). Stress fracture occurred during the preseason training phase for 15 (68%) of the 22 players, while it occurred during the competition season for 7 (32%) players.

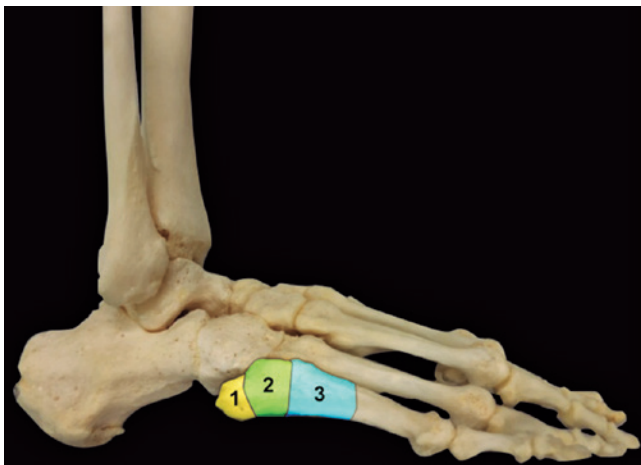
The average duration of follow-up after intramedullary fixation was  $23.54 \pm 15.26$  months (Table 1); 21 (95%) of 22 players were treated with a 4.5 mm cannulated compression screw and only one patient was managed with a 4.0 mm cannulation screw. Consolidation of the fracture, demonstrated with radiographic images in the 12-week follow-up, occurred in

the 22 (100%) players included in the study; good trabeculation across the fracture was shown on radiographs, although some patients still had some visualization of the original fracture line (Figure 2C-D). Delayed consolidation or nonunion was not observed in any player. The average time elapsed between the surgical intervention and return to professional sporting activity was  $12.04 \pm 2.21$  weeks. Only one complication was reported in a patient, a refracture that occurred at 8 weeks postoperatively and was unrelated to sports activities or rehabilitation; the injury occurred when going down a step by the forced inversion mechanism.

There were no more refractures and the patients were able to return to their previous sports activities without reporting pain in the following (24-month) follow-up.

No delay was observed in consolidation of the fractures in any of the patients.

The VAS in the preoperative evaluation revealed an average score of  $8.81 \pm 0.90$ ; at postoperative follow-up after return to sporting activity, the VAS score was  $1.68 \pm 1.52$  ( $p < 0.05$ ) (Table 1).



**Figure 1.** Three types of proximal fifth metatarsal fracture by zone: 1) tuberosity avulsion; 2) metaphyseal-diaphyseal union (Jones fracture); 3) diaphyseal stress fracture.

**Table 1.** Characteristics of professional soccer players with a zone 3 fracture in the fifth metatarsal that was treated with intramedullary fixation (N=22)

Years of age (mean $\pm$ SD)	20.13 $\pm$ 2.85
Sex (male)	22 (100%)
Dominant foot (left/right)	3/19
Fractured foot (left/right)	13/9
Preseason injury (yes/no)	15/7
100% fracture consolidation	22
Postoperative follow-up (months) (mean $\pm$ SD)	23.54 $\pm$ 15.26
Time to return to professional sporting activity (weeks) (mean $\pm$ SD)	12.04 $\pm$ 2.21
Complications	1 <sup>a</sup>
VAS preoperative score <sup>b</sup> (mean $\pm$ SD)	8.81 $\pm$ 0.90
VAS postoperative score after return to sporting activity (mean $\pm$ SD)	1.68 $\pm$ 1.52 <sup>c</sup>

<sup>a</sup> Only 1 patient presented with a refracture, which was unrelated to professional sporting activity and diagnosed at the 8-week postsurgical follow-up; the injury was induced by the forced inversion mechanism when descending a stair.

<sup>b</sup> VAS: visual analog scale.

<sup>c</sup>  $p < 0.05$ .



**Figure 2.** A-B) Anteroposterior and oblique radiographs of the proximal fifth metatarsal demonstrating a wide fracture line. This fracture extends into zone 3 and involves both cortices, with partial obliteration of the medullary canal by sclerosis at the site of fracture. C-D) Anteroposterior and oblique radiographs of the left foot taken at 12 weeks postoperatively. The orientation of a 4.5-mm diameter cannulated screw with washer is seen in both projections, as well as consolidation with evidence of trabeculation through the fracture but without full normal density.

**Table 2.** Average FAAM-Sp Sport Subscale Score<sup>a</sup> in the postoperative period of professional soccer players with a zone 3 fracture that was treated by intramedullary fixation (N=22)

	Mean $\pm$ SD	Minimum	Maximum
Sport Subscale Score	91.45 $\pm$ 8.84	72	100

<sup>a</sup> FAAM-Sp<sup>(12,15)</sup>.

The average score of the FAAM-Sp Sport Subscale Score was  $91.45 \pm 8.84$  (ranging from 72 to 100) (Table 2) in the postoperative period. In Figure 3, the average score obtained by the athletes is shown in relation to the following specific maneuvers: running, jumping, landing, starting and stopping quickly, cutting and lateral movements, and low impact activities. Among the 22 professional soccer players included in the study, 14 (64%) players had a score between 90 and 100.

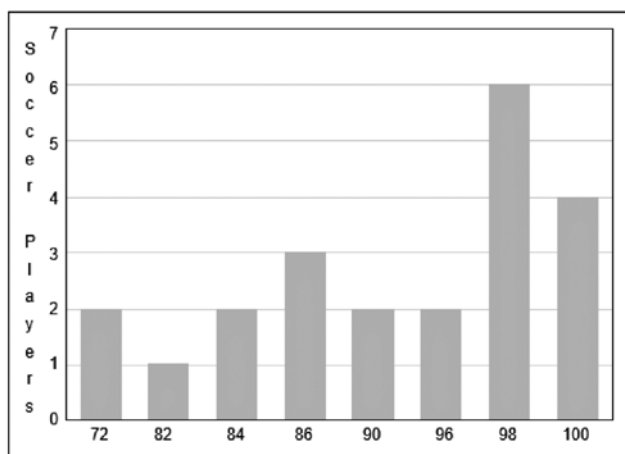
During postoperative follow-up, the level of functional activity related to the sport was determined by the FAAM-Sp Sport Subscale Score upon the player's return to sporting activity. The average score was  $91.13 \pm 10.11$  (Table 3); in 17 (77%) of the 22 players, a score between 90 and 100 was reported. The players' functional level upon return to the sporting activity was evaluated with the question "How do you classify your current function level?"; among the 22 players, 21 (95%) classified themselves as having a normal or close to normal functional level, and only one player reported an abnormal functional level.

## Discussion

In our study, a safe return to sports for professional soccer players was demonstrated to be possible 12 weeks after the intramedullary fixation of a stress fracture in the fifth metatarsal; at that time, performance was normal or close to normal in 95% of the athletes (FAAM-Sp Sports Subscale Score). To our knowledge, this is the first study in the literature to

define the timing for safe return to sporting activities in terms of the critical time required to allow fracture consolidation.

For professional soccer players, a stress fracture in the fifth metatarsal could mean the end of their participation in the sport<sup>(1)</sup>. The decreased time to return to sports and the reliability of healing are the main reasons for pursuing operative fixation<sup>(15)</sup>. The functional prognosis of a player's return to the sport following the intramedullary fixation of a stress fracture in the fifth metatarsal had not been defined. In a recent study of professional soccer players with stress fractures who were treated with intramedullary fixation, Miller et al.<sup>(9)</sup> found that an early return (8 weeks) to professional sporting activity was associated with a radiological delay of fracture union in 9 (24%) of the 37 cases, suggesting that, in the absence of symptoms, this radiological finding did not limit the players' time of return to sports activity. In contrast, another study reported that return to full activity before complete radiological union was predictive of failure<sup>(16)</sup>; surgeons must be cognizant of the risk of refracture, particularly in dealing with high-demand populations, and avoid the temptation to return patients to high-impact activities before radiographic union<sup>(17)</sup>.



Foot and Ankle Ability Measure-Spanish Sport Subscale (FAAM-Sp). Average score of the 8 categories: Running, Jumping, Landing, Starting and stopping quickly, Cutting/ lateral movements, Low impact activities, Ability to perform activity with your normal technique, Ability to participate in your desired sport as long as you would like.

**Figure 3.** FAAM-Sp Sport Subscale in the postoperative period. The average score obtained by the athletes is shown in relation to the following specific maneuvers: running, jumping, landing, starting and stopping quickly, cutting and lateral movements, and low-impact activities.

**Table 3.** Function level scores<sup>a</sup> during sport-related activities in soccer players with the diagnosis of a zone 3 fracture that was treated with intramedullary fixation (N=22)

Case no.	Current level of function during sport-related activities <sup>b</sup>	In general, how do you classify your current level of function? <sup>c</sup>
1	100	Normal
2	100	Normal
3	95	Normal
4	95	Close to normal
5	85	Close to normal
6	100	Close to normal
7	90	Close to normal
8	90	Close to normal
9	90	Close to normal
10	95	Normal
11	100	Normal
12	100	Normal
13	95	Normal
14	90	Close to normal
15	100	Normal
16	90	Close to normal
17	100	Normal
18	75	Close to normal
19	95	Normal
20	80	Close to normal
21	60	Abnormal
22	80	Close to normal

<sup>a</sup> FAAM-Sp Sport Subscale Score<sup>(12,13)</sup>.  
<sup>b</sup> The score of 100 corresponds to the level of function prior to the injury, and the score of 0 corresponds to the inability to perform any of the usual daily activities.  
<sup>c</sup> Normal, close to normal, abnormal, or severely abnormal

Bucknam et al.<sup>(17)</sup> reported 32 patients with fifth metatarsal fractures of zone 2 or 3.

They included both zones under eponymous Jones fractures because current data suggest a similar vascular watershed and a subsequent impaired healing response within zone 3; the mean follow-up was 24.2 (SD, 21.2) months. All patients (100%) achieved osseous union at a mean of 10.8 weeks, with return to restriction-free activities at an average 13.0 weeks (to include high-impact activities). There were no refractures or nonunions, and overall patient-reported satisfaction was 100% at a mean follow-up of just over 2 years. In our study, the average time of return to sporting activity was 12 weeks after surgery, which was related to consolidation of the fracture, and the level of function was normal or close to normal in 21 (95%) of the 22 professional soccer players with primary stress fracture. Our results are comparable to those reported by Ekstrand and Torstveit<sup>(3)</sup>, which included an average time of 12 weeks for professional soccer players with a stress fracture in the fifth metatarsal to return to normal sport activities. We believe a return to sport after 12 weeks is safe and that consolidation of the fracture in the fifth metatarsal in professional soccer players is currently predictable.

Stress fractures, unlike traumatic injuries, have an insidious course that is related to overuse. In a biomechanical analysis of stress fractures, Orendurff et al.<sup>(18)</sup> showed that the highest flexion moments during acceleration are applied to the fifth metatarsal; this moment is characterized by the forward inclination of the torso, forefoot contact, and a relatively large propulsive force from the lower extremities. The metatarsal pressure incurred during acceleration is twice as large as the pressure incurred during cutting maneuvers, lateral movements, and jumping, landing, and running actions at a constant speed in a straight line. Therefore, acceleration exerts the largest load on the fifth metatarsal compared with other maneuvers performed on courts and sports fields. The highest frequency of fractures in zone 3 of the fifth metatarsal was related to the preseason period due to the repetitive stresses incurred during intense physical training; in our study of Mexican soccer players, 15 (68%) of the 22 players incurred a stress fracture during the preseason period. The repetition of stress on the lateral-plantar region of the fifth metatarsal is a risk factor for fracture in zone 3<sup>(4,19)</sup>; in contrast, fractures in zones 1 and 2 are related to acute traumatic injuries, mainly during the competition period. It is important to understand this concept and apply it in a preventative manner in training strategies to reduce the frequency of stress fractures in the fifth metatarsal during the preseason period<sup>(1)</sup>.

Advances in technology have made cannulated screws available, which may ease the difficulty of insertion into the fifth metatarsal; the recommendation is to use the largest screw possible and be cautious with the use of screws less than 4 mm in diameter<sup>(20)</sup>. On the other hand, in one study, the biomechanical stiffness of a 4.5-mm solid malleolar screw and a 4.5-mm cannulated screw was examined in a cadaveric fifth metatarsal model<sup>(21)</sup>; the force to displacement was not different between the two screws. The authors noted that the

choice of screws from a biomechanical standpoint was at the surgeon's discretion. In our study, all cannulated screw diameters were 4.5 mm except in one patient, with a diameter of 4.0 mm. We considered the intramedullary fixation of a stress fracture in the fifth metatarsal with a 4.5-mm cannulated screw to be reliable for achieving effective healing in fifth metatarsal stress fractures, both clinically and radiographically<sup>(22)</sup>.

It is currently argued that solid screws have a higher resistance to bending fatigue, as published by Nunley et al.<sup>(23)</sup>; however, potential bias should be considered since this research was funded by the company that develops the screws under study. In most published series, there are no statistically significant differences observed between the use of solid or cannulated screws; however, there also seems to be a consensus about using screws of the largest possible diameter and the necessary length for the distal threads of the intramedullary screw to generate axial compression to the fracture line<sup>(24)</sup>.

In 2005, Porter et al.<sup>(22)</sup> reported on 23 athletes treated with intramedullary fixation with 4.5-mm cannulated screws. The authors concluded that 100% of the patients returned to their sporting activities after an average of 7 weeks.

A strength of this study is the clinical and functional evaluation with the FAAM-Sp Sports Subscale Score, which has been validated to determine the results of the surgical procedure; the reliability and reproducibility of the Spanish version have also been verified<sup>(14)</sup>. Another strength of the study is the homogeneity of the patients, a group of professional soccer players who had stress fractures in the fifth metatarsal and underwent the same surgical procedure of intramedullary fixation at a specialized Foot and Ankle Clinic that sees patients from throughout the country. On the other hand, limitations include the retrospective design and the fact that biomechanical evaluations were not performed.


## Conclusion

In conclusion, our study demonstrated safe return of professional soccer players to sporting activity with normal or close to normal performance in 95% of the athletes (FAAM-Sp Sports Subscale Score) at 12 weeks after intramedullary fixation of a stress fracture in the fifth metatarsal; this procedure achieved fracture consolidation in all cases with excellent clinical and functional outcomes. Based on the results of our study, it is possible to predict the safe return of professional soccer players to sporting activity 12 weeks after surgery. Future prospective studies to validate this recommendation are warranted.

## Acknowledgment

The authors thank Dr. Ana María Contreras-Navarro of the Unidad de Investigación y Desarrollo Tecnológico (UNIDET) Mediarthros for her advice when drafting this article.



**Authors' contributions:** The authors contributed individually and significantly to the development of this article: CAZA \*(<https://orcid.org/0000-0002-4135-3748>) Conceived and planned the activities that led to the study, interpreted the results of the study, wrote the article; LCA \*(<https://orcid.org/0000-0002-0812-2497>) Conceived and planned the activities that led to the study, interpreted the results of the study, wrote the article; LFRU \*(<https://orcid.org/0000-0002-5000-1592>) Wrote the article and tables; VJRG \*(<https://orcid.org/0000-0002-7384-7080>) Wrote the article, approved the final version; EVSH \*(<https://orcid.org/0000-0001-8238-2353>) Wrote the article, approved the final version; The authors read and approved the final manuscript. ORCID (Open Researcher and Contributor ID) .

## References

1. Ekstrand J, van Dijk CN. Fifth metatarsal fractures among male professional footballers: a potential career-ending disease. *Br J Sports Med.* 2013;47(12):754-8.
2. Brockwell J, Yeung Y, Griffith JF. Stress fractures of the foot and ankle. *Sports Med Arthrosc Rev.* 2009;17(3):149-59.
3. Ekstrand J, Torstveit MK. Stress fractures in elite male football players. *Scand J Med Sci Sports.* 2012;22(3):341-6.
4. Kizaki K, Yamashita F, Mori D, Funakoshi N. Ankle structures of professional soccer (football) players with proximal diaphyseal stress fractures of the fifth metatarsal. *J Foot Ankle Surg.* 2019;58(3):489-91.
5. Dameron TB Jr. Fractures of the proximal fifth metatarsal: selecting the best treatment option. *J Am Acad Orthop Surg.* 1995;3(2):110-4.
6. Dameron TB Jr. Fractures and anatomical variations of the proximal portion of the fifth metatarsal. *J Bone Joint Surg Am.* 1975;57(6):788-92.
7. Gómez-Carlín LA, Ortiz-Garza JI, Gutiérrez-Parada CA. Stress fractures in the athlete: epidemiology and management. *Orthotips.* 2016;12(1):12-22.
8. Lee KT, Park YU, Young KW, Kim JS, Kim JB. Surgical results of 5th metatarsal stress fracture using modified tension band wiring. *Knee Surg Sports Traumatol Arthrosc.* 2011;19(5):853-7.
9. Miller D, Marsland D, Jones M, Calder J. Early return to playing professional football following fixation of 5th metatarsal stress fractures may lead to delayed union but does not increase the risk of long-term non-union. *Knee Surg Sports Traumatol Arthrosc.* 2019;27(9):2796-801.
10. Sauer S. Intramedullary screw fixation of a proximal fifth metatarsal stress fracture in an elite athlete: a case report. *Surg J (N Y).* 2017;3(1):e6-e8.
11. Larsson D, Ekstrand J, Karlsson MK. Fracture epidemiology in male elite football players from 2001 to 2013: 'How long will this fracture keep me out?'. *Br J Sports Med.* 2016;50(12):759-63.
12. Cervera-Garvi P, Ortega-Avila AB, Morales-Asencio JM, Cervera-Marin JA, Martin RR, Gijon-Nogueron G. Cross-cultural adaptation and validation of Spanish version of The Foot and Ankle Ability Measures (FAAM-Sp). *J Foot Ankle Res.* 2017;10:39.
13. Martin RL, Irrgang JJ, Burdett RG, Conti SF, Van Swearingen JM. Evidence of validity for the Foot and Ankle Ability Measure (FAAM). *Foot Ankle Int.* 2005;26(11):968-83.
14. Shazadeh Safavi P, Janney C, Jupiter D, Kunzler D, Bui R, Panchbhavi VK. A systematic review of the outcome evaluation tools for the foot and ankle. *Foot Ankle Spec.* 2019;12(5):461-70.
15. Chuckpaiwong B, Queen RM, Easley ME, Nunley JA. Distinguishing Jones and proximal diaphyseal fractures of the fifth metatarsal. *Clin Orthop Relat Res.* 2008;466(8):1966-70.
16. Larson CM, Almekinders LC, Taft TN, Garrett WE. Intramedullary screw fixation of Jones fractures. Analysis of failure. *Am J Sports Med.* 2002;30(1):55-60.
17. Bucknam RB, Scanaliato JP, Kusnezov NA, Heida KA Jr, Dunn JC, Orr JD. Return to weightbearing and high-impact activities following Jones fracture intramedullary screw fixation. *Foot Ankle Int.* 2020;41(4):379-86.
18. Orendurff MS, Rohr ES, Segal AD, Medley JW, Green JR 3rd, Kadel NJ. Biomechanical analysis of stresses to the fifth metatarsal bone during sports maneuvers: implications for fifth metatarsal fractures. *Phys Sportsmed.* 2009;37(2):87-92.
19. Thevendran G, Deol RS, Calder JD. Fifth metatarsal fractures in the athlete: evidence for management. *Foot Ankle Clin.* 2013;18(2):237-54.
20. Reese K, Litsky A, Kaeding C, Pedroza A, Shah N. Cannulated screw fixation of Jones fractures: a clinical and biomechanical study. *Am J Sports Med.* 2004;32(7):1736-42.
21. Pietropaoli MP, Wnorowski DC, Werner FW, Fortino MD. Intramedullary screw fixation of Jones fractures: a biomechanical study. *Foot Ankle Int.* 1999;20(9):560-3.
22. Porter DA, Duncan M, Meyer SJ. Fifth metatarsal Jones fracture fixation with a 4.5-mm cannulated stainless steel screw in the competitive and recreational athlete: a clinical and radiographic evaluation. *Am J Sports Med.* 2005;33(5):726-33.
23. Nunley JA, Glisson RR. A new option for intramedullary fixation of Jones fractures: the Charlotte Carolina Jones Fracture System. *Foot Ankle Int.* 2008;29(12):1216-21.
24. Ruta DJ, Parker D. Jones fracture management in athletes. *Orthop Clin North Am.* 2020;51(4):541-53.