Article published online: 2022-10-03

Fractures of the Base of the Fifth Metatarsal Bone: Is my Partially-Threaded Cancellous Screw Useful? 10-Year Experience

Fracturas de la base del quinto metatarsiano: ¿Es útil mi tornillo de esponjosa con rosca parcial? Experiencia de 10 años

Ramiro Vera[1,2] Leonardo Lagos[1,3] Fernando Vargas[1,3] Hugo Henríquez[1,2] Sergio Fernández[1] Christian Bastías[1,2]

[1] Ankle and Foot Team, Orthopedics and Traumatology Department, Clínica Santa María, Santiago, Chile
[2] Ankle and Foot Team, Instituto Traumatológico de Santiago, Santiago, Chile
[3] Ankle and Foot Team, Mutual de Seguridad, Santiago, Chile

Address for correspondence Ramiro Vera Salas, MD, Equipo de Tobillo y Pie, Departamento de Ortopedia y Traumatología, Clínica Santa Maria, Santiago, Chile/Equipo de Tobillo y Pie, Instituto Traumatológico de Santiago, Santiago, Chile (e-mail: ramiroverasalas@gmail.com).

Rev Chil Ortop Traumatol 2022;63(2):e100–e107.

Abstract

Objective To evaluate the surgical result of zone-2 and -3 fractures of the base of the fifth metatarsal bone using partially-threaded cancellous screws with a diameter of 4.0 mm.

Materials and Methods A retrospective evaluation of patients submitted to surgery between 2010 and 2019. We included all of the cases synthesized with this device with a minimum follow-up of three months, and excluded the cases operated on with other devices and follow-up shorter than three months. We evaluated the consolidation and the presence of complications, and determined, screw length, diameter of the endomedullary canal, the distance between the proximal edge of tuberosity and the fracture, and thread pitch over the fracture line on anteroposterior (AP) and oblique radiographs.

Results We evaluated 39 cases, and the sample had an average age of 27 years and male predominance. The most used screw length was 45 mm, and the average diameters of the medullary canal measured on the AP and oblique radiographs were of 4.6 mm and 3.96 mm respectively. The distance from the edge of the tuberosity to the fracture was of 25.8 mm, and the thread pitch over the fracture line was on average 24 mm. The rate of consolidation was of 100%, occurring in an average of 9.4 weeks, and there were 3 cases of consolidation delay, 2 of screw recoil, 1 of intrafocus thread, and 1 of superior cortex fracture. To date, there have been no cases of screw removal.

Keywords
- tarsal joints/injury
- metatarsal bones/injury
- foot injuries/surgery
- fractures

received
May 14, 2021
accepted
January 18, 2022

DOI https://doi.org/10.1055/s-0042-1744462.
ISSN 0716-4548.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Discussion There is no consensus regarding the ideal screw. The international literature recommends intramedullary devices with a diameter of at least 4.5 mm. There are few reports of the use of screws with 4.0 mm in diameter.
Conclusions The partially-threaded cancellous screw with a diameter of 4.0 mm is an effective and safe option, with a low complication rate for the management of these fractures.

Resumen

Objetivo Evaluar el resultado quirúrgico de fracturas de las zonas 2 y 3 de la base del quinto metatarsiano usando tornillos de esponjosa de diámetro de 4,0 mm con rosca parcial.
Materiales y métodos Evaluación retrospectiva de pacientes operados entre 2010 a 2019. Incluimos todos los casos sintetizados con este dispositivo con seguimiento mínimo de tres meses, y excluimos casos operados con otros dispositivos y seguimiento menor a tres meses.
Evaluamos la consolidación y la presencia de complicaciones. Determinamos el largo del tornillo, el diámetro del canal endomedular, la distancia entre el borde proximal de la tuberosidad y la fractura, y la distancia de paso de la rosca sobre el rasgo de la fractura en radiografías anteroposterior (AP) y oblicua del pie.
Resultados Evaluamos 39 casos, y la muestra tenía una edad promedio de 27 años, y predominio del sexo masculino. El largo de tornillo más usado fue el de 45 mm, y los diámetros promedios del canal endomedular medidos en las radiografías AP y oblicua fueron de 4,6 mm y 3,96 mm, respectivamente. La distancia del borde de la tuberosidad hasta la fractura fue de 25,8 mm, y la distancia de paso de la rosca sobre el rasgo de la fractura fue en promedio de 24 mm. Hubo 100% de consolidación, en un promedio de 9,4 semanas, y 3 casos de retardo de consolidación, 2 de retroceso de tornillo, 1 de rosca intrafoco, y 1 de fractura cortical superior. No hubo retiros de tornillos a la fecha.
Discusión No existe consenso respecto al tornillo ideal. La literatura internacional recomienda dispositivos intramedulares de diámetro de al menos 4,5 mm. Existen pocos reportes del uso de tornillos de diámetro de 4,0 mm.
Conclusiones El tornillo de esponjosa de diámetro de 4,0 mm con rosca parcial es una alternativa eficaz, segura y con baja tasa de complicaciones para el manejo de estas fracturas en nuestra población.

Palabras Clave
- articulaciones tarsianas/lesiones
- hueso metatarsiano/lesión
- lesión de pie/cirugía
- fracturas

Introduction

Coming across fractures of the base of the fifth metatarsal bone in the emergency department is quite common, considering their high association with ankle sprains and injuries secondary to sports activities. To recognize and diagnose them, a good physical examination and a high index of suspicion are necessary, and the determination of the conduct to follow requires knowledge of their classification and, thus, their prognosis. In 1902, Sir Robert Jones[1] was the first to describe them; later, Dameron[2] classified them according to their location in 3 zones, which have particular characteristics; and, finally, Torg et al.[3] published a radiological classification for zone-2 and -3 fractures based on radiological findings related to their consolidation potential. Currently, there is consensus regarding the anatomical classification and the different prognosis depending on the time of evolution, the affected area, and the type of patient. This is how, in zone-2 fractures, there is sufficient evidence to support fixation and stabilization, in the acute stage, in young patients who practice sports and high-performance athletes, as well as in the general population when there is delayed consolidation or nonunion.[3–5] In zone-3, fractures the indication in the acute stage is maintained in young patients who practice sports and athletes, while in the rest of the population surgery is recommended when there is clinical and radiological evidence of delayed consolidation or nonunion.[6] After establishing which patients should undergo surgery, the decision must be made as to which device and technique to use for the reduction and fixation of these fractures. For this, numerous surgical techniques have been described, ranging from tension bands, low-profile plates, external fixators, and intramedullary screw fixation, the latter being the most

widely used, with good results, but with known complications that are generally attributed to poor consolidation potential, in cases of delayed consolidation or nonunion, and inadequate screw selection, in which the correct length and, above all, a sufficient screw diameter are very important. This is how in recent years new studies and intramedullary devices have emerged that seek to minimize the presence of complications by increasing the diameter of the device, maximizing compression at the level of the fracture site, offering options of materials other than steel, with screws that are headless, cannulated, multithreaded tapered, among others. To the best of our knowledge, the literature is scarce regarding the clinical outcomes of the use of solid, steel, headed, cancellous, partially-threaded screws with 4.0 mm in diameter. Therefore, the purpose of the present article is to review the clinical and surgical results of zone-2 and -3 fractures treated with these screws from 2010 to 2019, emphasizing the rates of consolidation, associated complications, such as delayed consolidation, nonunion, iatrogenic fractures, and bone or soft tissue impingement. Our hypothesis is that the surgical results with conventional 4.0-mm, small-fragment, cancellous, partially-threaded screws are good on the long term, with a low rate of complications and patient satisfaction.

Materials and methods

A retrospective study of the database of surgeries, clinical records, and radiographs of metatarsal fractures operated on between 2010 and 2019 by 5 subspecialist ankle and foot surgeons was performed.

The inclusion criteria were all fractures of zones 2 and 3 of the base of the fifth metatarsal bone that had radiological records and follow-up longer than 3 months which were resolved surgically with small-fragment, cancellous, partially-threaded screws.

The exclusion criteria were all zone-1 fractures, all zone-2 and -3 fractures in which the reduction and osteosynthesis were performed with a device other than the aforementioned screw, and those zone-2 and -3 fractures that were fixed with said screw but that had a follow-up shorter than 3 months.

We defined fracture of the base of the fifth metatarsal bone as any fracture occurring in the proximal third of that bone, differentiating as a diaphyseal fractures (zone 3) those distal to the joint between the fourth and fifth metatarsal bones, as Jones fractures (zone 3) those that were between the joint between the fourth and fifth metatarsal bones, and as tuberosity fractures (zone I) those proximal to the joint between the fourth and fifth metatarsal bones.

We defined consolidation as the presence of bone callus on radiographs and/or the absence of pain on compression and walking on the fracture site.

Delayed consolidation was defined as the absence of progressive and clear radiological signs of bone callus associated with the persistence of pain in the fracture site detected in the medical controls at 4, 8 and 12 weeks.

We defined nonunion as the absence of radiological signs of consolidation associated with pain at the fracture site on palpation and/or walking after 12 weeks.

Data such as gender, age, laterality, sports practice, fracture mechanism, and fractured area were recorded. In those fractures in which the orthopedic treatment was attempted, we verified how it was performed, for how long, and what was the complication that indicated the step towards surgical resolution.

Regarding surgery, the type of approach, the presence of complications, the type of screw used, and the use of bone graft were verified.

Using the Enterprise Imaging XERO Viewer (Agfa HealthCare NV, Mortsel, Belgium) software, version 8.1.2, preoperative radiographs were evaluated in 3 projections: anteroposterior (AP), lateral (L), and oblique (O) of the foot. In the AP projection, the diameter of the intramedullary canal was determined at the overlapping level of the fourth and fifth metatarsal cortices. In the O projection, the narrowest point of the intramedullary canal of zones 2 to 3 and the distance between the proximal edge of the base of the fifth metatarsal to the fracture line were measured.

In the postoperative radiographs, the length of each screw was verified in the O projection, the thread pitch of the screw over the fracture line was determined.

Regarding the postoperative period, we recorded the consolidation time, if there was any postoperative complication, how long was the return to sports activity, and if there was an alteration of the associated hindfoot axis.

Results

A total of 39 zone-2 and -3 fractures were operated on with a cancellous, partially-threaded screw during the last 10 years in 38 patients (there was 1 bilateral case). The average age was 27 years (range: 14 to 52 years), with a male predominance (77%). In all cases, the diagnosis was established by AP, L, and O radiographs of the foot. The injury was slightly more frequent in the right foot (51%). The most frequent injury was ankle sprain in 74%[29], followed by stress fatigue in 18%[7], and direct trauma in 8%[3]. In 19 cases (48%), the fracture occurred during sports practice, with soccer being the predominant sport. In total, 1 case (2.5%) occurred in an elite national handball athlete, and the rest practiced sports intermittently for at least 30 minutes twice a week, which included other sports and activities such as going for a walk or even running. In 33 cases (85%), the fracture compromised zone 3, and, in 6 cases (15%), it occurred in zone 2. There was 1 patient (2.5%) who, during this period, presented a fracture of the fifth metatarsal bone of both feet, and 10 patients (25%) presented associated cavo varus foot.

A total of 23 cases (59%) received surgical treatment from the beginning, with an average waiting time of 9 days until surgery.

In 16 cases (41%), no initial surgical treatment was performed; of these, in 5 cases (12.8%), the orthopedic treatment was performed with a boot for 12 weeks, confirming nonunion, which required subsequent surgery. In 10 cases (25.6%), the

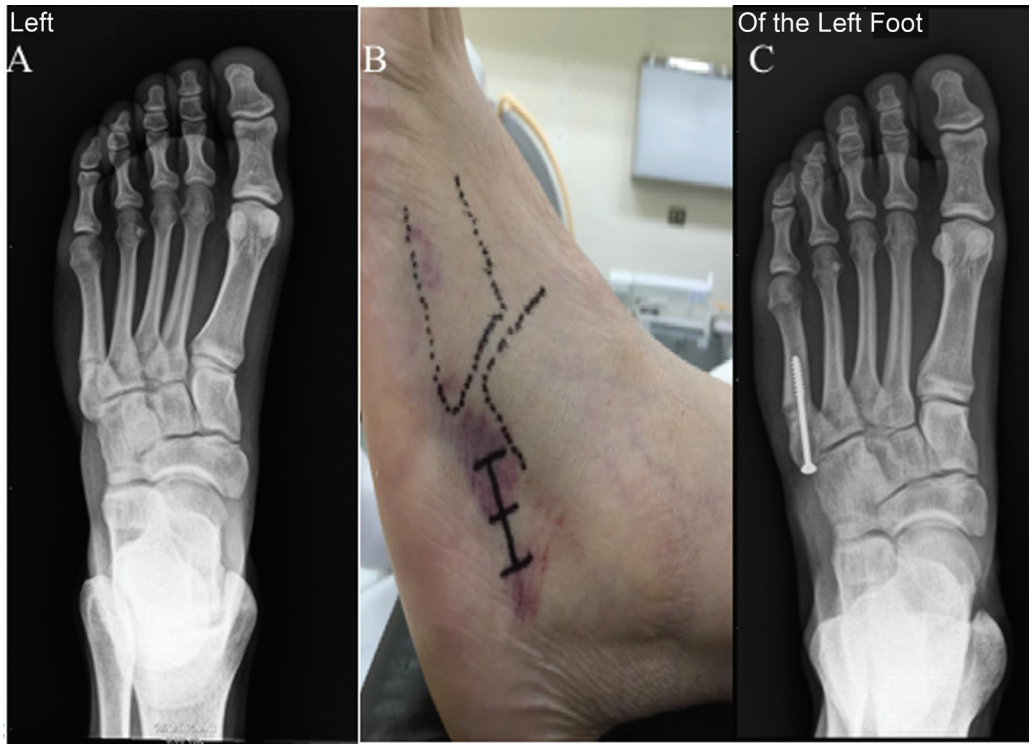

Fig. 1 (**A**) Radiograph showing a fracture at the zone 3 of the base of the fifth metatarsal bone. (**B**) Percutaneous surgical approach. (**C**) The most used screw length was of 45 mm.

orthopedic treatment was started, but then, the surgical treatment was necessary, due to the absence of radiological signs of consolidation associated with persistence of pain on palpation and when walking on the fracture site. The decision was made based on the clinical and imaging findings of the radiographs in the follow-ups, and computed tomography (CT) scans were not deemed necessary. Surgery was performed on average at 6 weeks (range: 4 to 9 weeks). There was 1 case (2.5%) of refracture, which occurred within a month of the consolidation of the fracture, after the patient had undergone adequate orthopedic treatment for 3 months.

In 100% of the surgeries, a classic percutaneous approach was performed. The length of the most used screw was of 45 mm in 22 cases (56%); as for the other cases, the lengths of the screws ranged from 40 mm to 65 mm (►**Figure1**).

In 3 cases (7.5%), a bone graft obtained with a bone biopsy trocar was used: in 2 cases, from the calcaneus, and 1 case, from the medial malleolus.

The mean diameter of the intramedullary canal of the fifth metatarsal bone, measured on AP radiographs at the level of the junction of the fourth and fifth metatarsal cortices, was of 4.6 mm (range: 2.5 mm to 7 mm) (►**Figure 2A**). The average diameter of the narrowest point of the intramedullary canal in O radiographs of zones 2 and 3 was of 3.9 mm (range: 2.4 mm to 7 mm) (►**Figure 2B**). The average distance from the proximal edge of the tuberosity of the fifth metatarsal bone to the fracture line was of 25.8 mm (range: 21 mm to 32.9 mm) (►**Figure 2C**). The average thread pitch over the fracture line was of 24.2 mm (range: 16 mm to 38 mm) (►**Figure 2D**) (►**Table 1**). No intraoperative complications were observed. In the immediate postoperative radiograph, we recorded 1 case (2.5%) of dorsal cortical fracture treated with a 60-mm long screw and 1 case (2.5%) in which the cancellous screw thread remained intrafocus (screw length of 40 mm). In neither of the two cases did the patients present clinical complications or delayed consolidation time. The average follow-up was of 6 months (range: 3 to 12 months). There were 3 cases (7.5%) of delayed consolidation that was finally achieved at 16, 20 and 16 weeks, respectively, 2 cases (5%) of screw recoil, of 4 mm on average (range: 2 mm to 6 mm), that did not show signs of impingement. No cases of nonunion were observed. Successful consolidation was achieved in 100% of the patients in an average of 9.4 weeks (range: 5 to 20 weeks) (►**Table 2**), and to date there has been no need to remove the devices.

Of a total of 19 patients (48.7%) who practiced sports, in 12 cases (63%), the return to sports was recorded, mainly cycling and light jogging, and it occurred after 11.5 weeks on average.

Discussion

Proper management of this type of fracture is essential; its possible poor evolution when receiving orthopedic management is related to high rates of nonunion, of delayed consolidation, and of refracture,[7] which are explained by a combination of biological and biomechanical factors. A fracture in an area with terminal irrigation[8] does nothing more than increase the vascular supply deficit, and generates a mobile point at that level, which enables the distal fragment to rotate on its axis, causing great mobility,[9] which becomes a vicious circle that predisposes to nonunion. Additionally,

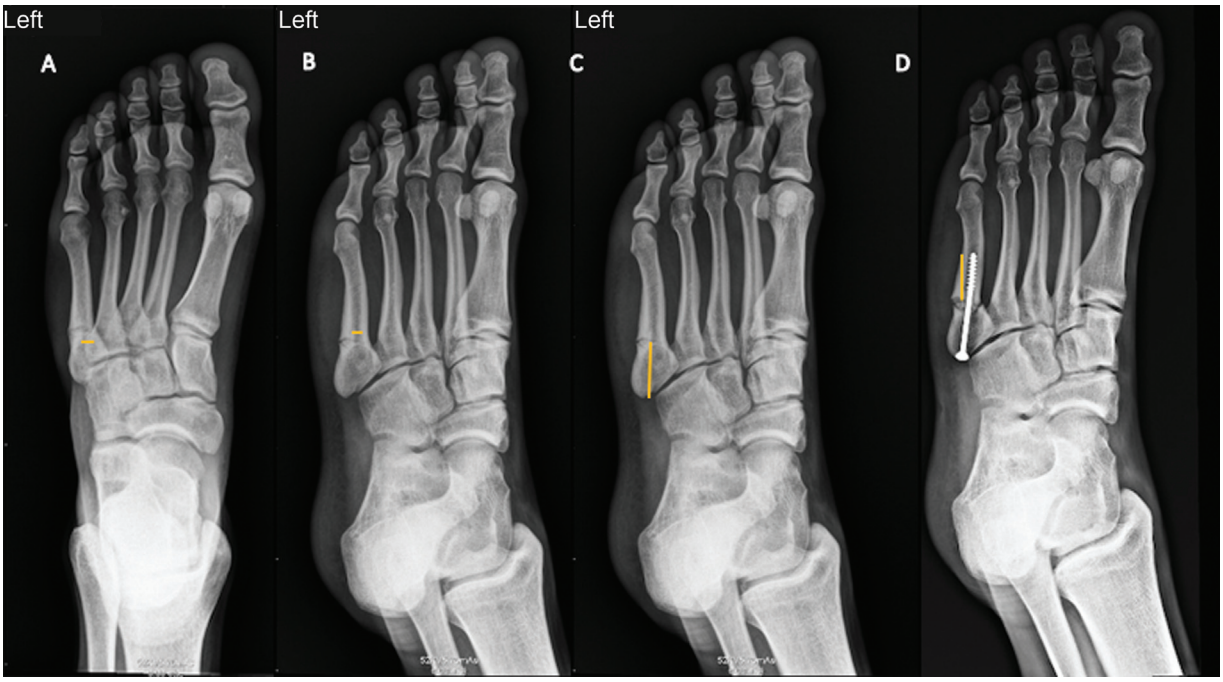

Fig. 2 Anteroposterior (AP) and oblique (O) radiographs. (**A**) Measurement of the diameter of the intramedullary canal on AP projection at the level of the overlap of the fourth and fifth metatarsal bones. (**B**) Measurement of narrowest point of zones 2 and 3 on O projection. (**C**) Distance from the proximal edge to the fracture line on O projection. (**D**) Distance of the screw thread pitche over fracture line on O projection.

Table 1 Average radiological diameters and distances

Screw	Length most used	Diameter of the diaphysis on anteroposterior and oblique X-rays respectively	Distance from the tuberosity to the fracture	Thread pitch
Cancellous, partially threaded, 4.0 mm in diameter	45 mm	4.6 mm and 3.9 mm	25.8 mm	24.2 mm

these fractures receive torsion and traction forces, which is transmitted by the peroneus brevis tendon and the insertion of the plantar fascia.[10,11] That is why primary surgical fixation is currently the first choice for many ankle and foot surgeons.

Many surgical techniques have been described for the management of this type of fracture; currently, intramedullary screw fixation is the surgical method of choice, and on which the greatest number of studies have been performed, which have concluded that the primary factor in most failures is the poor selection of the screw mainly with respect to its diameter and length.[12–14] This adequate selection seeks to avoid the occurrence of iatrogenic fractures and provide the greatest possible stability to the fracture so that it achieves consolidation. Along these lines, much has been published about the requirements in relation to diameter, length, compression, design, and material that the screw to be used must have, and we thought it important to analyze them in the cancellous, partially-threaded screw, which is the device that we use the most.

According to some biomechanical studies,[15,16] the importance of the diameter of the screw lies in the fact that a narrow diameter would be associated with delayed consolidation, nonunion and refracture due to lower resistance to extraction and therefore instability; on the other hand, very wide diameters are associated with iatrogenic fractures and burst. In this sense, in 2015, Scott et al.[15] conducted a cadaveric study in which they manually measured the diameters of the intramedullary canal on the dorsal and medial lateral plantar planes of the distal third of the fifth metatarsal, and they determined that the 4.5 mm is the narrowest effective screw diameter for the management of these fractures. Islen et al.[16] used CT to measure the diameter of the distal third of the fifth metatarsal bone in 27 patients with fractures in zones 2 and 3, and they concluded that 93% had a diameter greater than 4 mm, and 7%, narrower than 4 mm, recommending that a diameter of 5.5 mm would be the most reliable to stabilize this fracture.

Regarding the length of the screw, the first investigations[4] concluded that the longest possible screw should be used for the stabilization of this fracture; however, current studies[17] have suggested and shown that using a very long screw causes a straightening of the bone diaphysis, which loses its usual curvature, which separates the edges of the fracture in

Table 2 Results of the study sample

Treatment	Age (years)/ Gender	Mechanism	Sports	Fracture zone	Screw diameterxlength (mm)	Union (weeks)	Complication
Surgical	27/M	Stress	Soccer	3	4.0 × 65	6	No
	18/M	Sprain	N/R	3	4.0 × 50	10	No
	22/M	Sprain	N/R	3	4.0 × 45	12	No
	28/M	Stress	N/R	3	4.0 × 65	6	No
	18/M	Stress	N/R	3	4.0 × 40	8	No
	17/M	Sprain	Soccer	3	4.0 × 45	5	No
	17/M	Sprain	Soccer	3	4.0 × 45	8	No
	17/F	Sprain	Handball	3	4.0 × 50	8	No
	20/M	Sprain	Soccer	3	4.0 × 55	6	No
	31/M	Sprain	N/R	2	4.0 × 45	7	No
	18/M	Sprain	Running	3	4.0 × 45	10	No
	36/M	Sprain	Rugby	3	4.0 × 45	12	No
	33/M	Trauma	Capoeira	3	4.0 × 45	12	No
	16/M	Trauma	Soccer	3	4.0 × 45	6	No
	17/M	Sprain	Soccer	3	4.0 × 45	6	No
	52/F	Sprain	No	3	4.0 × 45	16	CD
	22/M	Sprain	No	3	4.0 × 45	10	No
	19/M	Sprain	No	3	4.0 × 50	20	CD
	21/M	Sprain	N/R	3	4.0 × 50	8	No
	45/F	Sprain	N/R	3	4.0 × 45	8	No
	32/M	Sprain	N/R	2	4.0 × 45	8	No
	17/M	Sprain	Gym workout	3	4.0 × 50	16	CD
	16/M	Sprain	Soccer	2	4.0 × 50	6	No
	29/F	Sprain	No	2	4.0 × 50	6	No
	14/M	Sprain	Soccer	3	4.0 × 50	8	No
	17/M	Sprain	Soccer	3	4.0 × 45	8	No
	47/M	Sprain	No	2	4.0 × 45	10	No
	30/F	Stress	No	2	4.0 × 45	8	No
	26/M	Sprain	Soccer	3	4.0 × 40	8	SR and IS
	39/M	Trauma	N/R	3	4.0 × 50	12	No
	23/M	Sprain	Soccer	3	4.0 × 55	10	No
	41/M	Stress	Soccer	3	4.0 × 50	8	No
	26/M	Sprain	N/R	3	4.0 × 45	10	No
	37/F	Sprain	Soccer	3	4.0 × 45	11	No
	24/M	Sprain	Soccer	3	4.0 × 45	6	No
	34/F	Stress	N/R	3	4.0 × 45	12	SR
	50/F	Sprain	N/R	3	4.0 × 45	8	DF
	30/F	Stress	No	3	4.0 × 45	8	No
	26/M	Sprain	No	3	4.0 × 50	12	No
Summary	Edad X: 27; M: 77%; F: 23%	Sprain :74%; stress:18%; DT: 8%	Practiced sports: 19; sedentary lifestyle: 9; N/R: 12	Zone 2: 15%; zone 3: 85%	45 mm (56.4%); 50 mm (28.2%); 55 mm (5.1%); 65 mm (5.1%); 40 mm (5.1%)	X: 9.4; 100% of union	3 CD; 2 SR; 1 DF 1 IS

Abbreviations: F, female; DF, dorsal fracture; M, male; N/R, not recorded; CD, consolidation delay; SR, screw recoil; DT, direct trauma; IS, intrafocal screw; X, average.

the lateral cortical bone, tilting the fracture focus, which generates delayed consolidation and nonunion, in addition to increasing the risk of iatrogenesis due to perforation of the medial cortical bone distal to the fracture.[17] Ochenjele et al.[18] performed a detailed anatomical analysis of the fifth metatarsal bone of 119 patients, based on three-dimensional CT reconstructions and plain radiographs, in which, among other measurements, they determined the total average length of the metatarsal bones and the average distance between the tuberosity of the fifth metatarsal bone and posteroplantar curvature. The authors[18] recommended that, to avoid iatrogenesis due to excessive screw length, screws no longer than 68% of the total length of the metatarsal bone should be used, and they suggested 40 mm as a safe length.

In relation to the cannulated design of some screws, certain authors have reported device breakage as a complication, especially in high-demand athletes.[19] Glasgow et al.[20] reported a high rate of breakage using 4.5-mm cannulated screws.

Regarding the material of the intramedullary device, Devries et al[21] compared cases operated with cannulated stainless-steel screws with cases fixed with cannulated titanium screws, obtaining similar results, without statistical significance for consolidation time and complications, leaving the decision to use one or the other material at the surgeon's discretion. On the other hand, Reese et al.,[13] in a biomechanical study, subjected cadaveric pieces to repetitive cyclic loading and compared the resistance of cannulated titanium screws versus cannulated stainless-steel screws, determining that stainless steel is more resistant than titanium.

Concerning soft-tissue irritation caused by the screw head, Nagao et al.[22] reported up to 30% of discomfort, especially among young patients who practice sports, suggesting the use of headless screws in those patients who are athletes. In the present series, mainly among the population of young patients who practice sports only occasionally, no cases of soft-tissue impingement at the insertion site were observed.

Regarding the type of thread of the different screws available, Orr et al.[23] biomechanically compared the use of threaded conical compression screws and cancellous partially-threaded screws, and they determined that the latter provided greater compression and less tilting of the fracture site, with no statistically significant differences in relation to the stiffness they provided.

At present, we agree that the intramedullary device is the most recommended for the proper management of this type of fracture; we believe that the success of the surgical result is mainly due to the stability of the fracture site rather than its compression, and that the selection of adequate diameter and length of the device is the key. In this sense, the diameter of 4.0 mm presented good clinical results, and we have concluded that, with this diameter, we were able to stabilize this type fracture in our patients, and it enabled a correct consolidation, which correlates with the finding that the average of the narrowest point of the intramedullary canal in the O foot radiograph of our studied population was of less than 4.0 mm. Regarding the length of the screw to be used, we always recommend measuring the distance between the fracture line and the entry site of the screw in the tuberosity of the fifth metatarsal bone, paying special attention when using screws shorter than 40 mm and longer than 65 mm due to the possibility of causing alterations in the consolidation due to intrafocus threads or to the risk of iatrogenic fractures respectively.

In our experience, there were no cases of screw breakage, so we believe that the solid steel screw is a reliable and safe option. Finally, we did not observe cases of impingement of soft tissues or between the cuboid bone and the screw head, including the two cases of screw recoil; however, we believe that it is an important factor to consider, especially in young patients, professional athletes, or high-demand patients.

The present work has certain limitations; it is retrospective and descriptive, but we have managed to correlate the 4.0-mm diameter cancellous, partially-threaded screw with the size of the intramedullary canal of our operated patients, which could explain the good clinical results obtained using this device. Moreover, the study is also a review of the results of the management of this type of fracture with this type of screw for a period of 10 years without severe complications, which makes this implant a reliable alternative to be considered by ankle and foot surgeons when selecting an intramedullary device for our population.

Conclusions

The surgical treatment with a screw with 4.0 mm in diameter, partially-threaded, solid, made of stainless steel, and with a head, is a safe, effective alternative, with a low rate of complications, to fix fractures of the base of the fifth metatarsal bone in zones 2 and 3 in our population.

Conflict of Interests

The authors have no conflict of interests to declare.

References

1 Jones R. I. Fracture of the base of the fifth metatarsal bone by indirect violence. Ann Surg 1902;35(06):697–700.2
2 Dameron TB Jr. Fractures and anatomical variations of the proximal portion of the fifth metatarsal. J Bone Joint Surg Am 1975;57 (06):788–792
3 Torg JS, Balduini FC, Zelko RR, Pavlov H, Peff TC, Das M. Fractures of the base of the fifth metatarsal distal to the tuberosity. Classification and guidelines for non-surgical and surgical management. J Bone Joint Surg Am 1984;66(02):209–214
4 DeLee JC, Evans JP, Julian J. Stress fracture of the fifth metatarsal. Am J Sports Med 1983;11(05):349–353
5 Quill GE Jr. Fractures of the proximal fifth metatarsal. Orthop Clin North Am 1995;26(02):353–361
6 Rosenberg GA, Sferra JJ. Treatment strategies for acute fractures and nonunions of the proximal fifth metatarsal. J Am Acad Orthop Surg 2000;8(05):332–338
7 Kavanaugh JH, Brower TD, Mann RV. The Jones fracture revisited. J Bone Joint Surg Am 1978;60(06):776–782

8 Smith JW, Arnoczky SP, Hersh A. The intraosseous blood supply of the fifth metatarsal: implications for proximal fracture healing. Foot Ankle 1992;13(03):143–152
9 Lawrence SJ, Botte MJ. Jones' fractures and related fractures of the proximal fifth metatarsal. Foot Ankle 1993;14(06):358–365
10 Morris PM, Francois AG, Marcus RE, Farrow LD. The effect of peroneus brevis tendon anatomy on the stability of fractures at the fifth metatarsal base. Foot Ankle Int 2015;36(05):579–584
11 Vertullo CJ, Glisson RR, Nunley JA. Torsional strains in the proximal fifth metatarsal: implications for Jones and stress fracture management. Foot Ankle Int 2004;25(09):650–656
12 Mindrebo N, Shelbourne KD, Van Meter CD, Rettig AC. Outpatient percutaneous screw fixation of the acute Jones fracture. Am J Sports Med 1993;21(05):720–723
13 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(07):1736–1742
14 Kelly IP, Glisson RR, Fink C, Easley ME, Nunley JA. Intramedullary screw fixation of Jones fractures. Foot Ankle Int 2001;22(07): 585–589
15 Scott RT, Hyer CF, DeMill SL. Screw fixation diameter for fifth metatarsal jones fracture: a cadaveric study. J Foot Ankle Surg 2015;54(02):227–229
16 Iselin LD, Ramawat S, Hanratty B, Klammer G, Stavrou P. When Planning Screw Fracture Fixation Why the 5.5 mm Screw is the Goldilocks Screw. An Observational Computer Tomographic Study of Fifth Metatarsal Bone Anatomy in a Sample of Patients. Medicine (Baltimore) 2015;94(18):e756
17 Horst F, Gilbert BJ, Glisson RR, Nunley JA. Torque resistance after fixation of Jones fractures with intramedullary screws. Foot Ankle Int 2004;25(12):914–919
18 Ochenjele G, Ho B, Switaj PJ, Fuchs D, Goyal N, Kadakia AR. Radiographic study of the fifth metatarsal for optimal intramedullary screw fixation of Jones fracture. Foot Ankle Int 2015; 36(03):293–301
19 Granata JD, Berlet GC, Philbin TM, Jones G, Kaeding CC, Peterson KS. Failed Surgical Management of Acute Proximal Fifth Metatarsal (Jones) Fractures: A Retrospective Case Series and Literature Review. Foot Ankle Spec 2015;8(06):454–459
20 Glasgow MT, Naranja RJ Jr, Glasgow SG, Torg JS. Analysis of failed surgical management of fractures of the base of the fifth metatarsal distal to the tuberosity: the Jones fracture. Foot Ankle Int 1996;17(08):449–457
21 DeVries JG, Cuttica DJ, Hyer CF. Cannulated screw fixation of Jones fifth metatarsal fractures: a comparison of titanium and stainless steel screw fixation. J Foot Ankle Surg 2011;50(02):207–212
22 Nagao M, Saita Y, Kameda S, et al. Headless compression screw fixation of jones fractures: an outcomes study in Japanese athletes. Am J Sports Med 2012;40(11):2578–2582
23 Orr JD, Glisson RR, Nunley JA. Jones fracture fixation: a biomechanical comparison of partially threaded screws versus tapered variable pitch screws. Am J Sports Med 2012;40(03):691–698

