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Percutaneous Internal Fixation of Proximal Fifth Metatarsal Jones Fractures (Zones II and III) With Charlotte Carolina Screw and Bone Marrow Aspirate Concentrate

An Outcome Study in Athletes

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Background: Internal fixation is a popular first-line treatment method for proximal fifth metatarsal Jones fractures in athletes; however, nonunions and screw breakage can occur, in part because of nonspecific fixation hardware and poor blood supply.

Purpose: To report the results from 26 patients who underwent percutaneous internal fixation with a specialized screw system of a proximal fifth metatarsal Jones fracture (zones II and III) and bone marrow aspirate concentrate.

Study Design: Case series; Level of evidence, 4.

Methods: Percutaneous internal fixation for a proximal fifth metatarsal Jones fracture (zones II and III) was performed on 26 athletic patients (mean age, 27.47 years; range, 18-47). All patients were competing at some level of sport and were assessed preoperatively and postoperatively using the Foot and Ankle Outcome Score and SF-12 outcome scores. The mean follow-up time was 20.62 months (range, 12-28). Of the 26 fractures, 17 were traditional zone II Jones fractures, and the remaining 9 were zone III proximal diaphyseal fractures.

Results: The mean Foot and Ankle Outcome Score significantly increased, from 51.15 points preoperatively (range, 14-69) to 90.91 at final follow-up (range, 71-100; $P < .01$). The mean physical component of the SF-12 score significantly improved, from 25.69 points preoperatively (range, 6-39) to 54.62 at final follow-up (range, 32-62; $P < .01$). The mean mental component of the SF-12 score also significantly improved, from 28.20 points preoperatively (range, 14-45) to 58.41 at final follow-up (range, 36-67; $P < .01$). The mean time to fracture healing on standard radiographs was 5 weeks after surgery (range, 4-24). Two patients did not return to their previous levels of sporting activity. One patient experienced a delayed union, and 1 healed but later refractured.

Conclusion: Percutaneous internal fixation of proximal fifth metatarsal Jones fractures, with a Charlotte Carolina screw and bone marrow aspirate concentrate, provides more predictable results while permitting athletes a return to sport at their previous levels of competition, with few complications.

Keywords: Jones fracture; proximal fifth metatarsal; athlete; orthobiologics; bone marrow aspirate concentrate

Fifth metatarsal fractures are among the most common forefoot injuries and are particularly evident among a young athletic population, including elite athletes.[20,24,26] Historically, the proximal fifth metatarsal has been divided into 3 anatomic zones (Figure 1).[7] One fracture occurring in zone II at the metaphyseal-diaphyseal junction has been classically coined as a *Jones fracture* (Figure 2). First described by Sir Robert Jones[11] in 1902, these fractures have since been identified as having the tendency to develop delayed union, nonunion, or refracture after initial healing.[20] Zone III fractures may also develop delayed or nonunion in as many as 25% of cases treated nonoperatively,[5,12] and many ultimately require surgery (Figure 3). The poor blood supply of the fifth metatarsal has been well documented and is significant in that the fracture pattern develops along a watershed area between the intramedullary nutrient and metaphyseal artery distribution.[7,8,22]

The proximal fifth metatarsal fracture presents a difficult clinical problem, particularly in competitive athletes where an early return to sporting activities is of high

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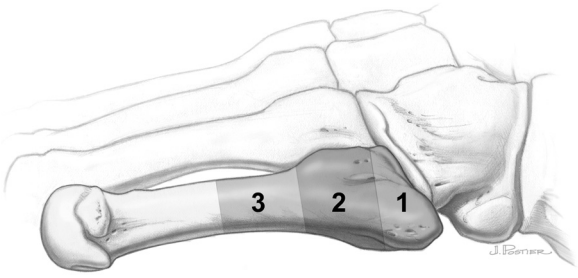

Figure 1. The proximal fifth metatarsal has traditionally been divided into 3 anatomic zones: Zone I is the tuberosity (base); zone II, the metaphyseal-diaphyseal junction (fourth/fifth metatarsal articulation); and zone III, the proximal diaphysis.

Figure 2. A traditional Jones fracture of zone II of the proximal fifth metatarsal.

Figure 3. A zone III fracture in a National Football League running back was treated with inadequate hardware that did not provide proper thread purchase on the outer cortex, thereby failing to compress the fracture. The patient subsequently suffered a refracture and required a revision procedure.

priority. Several studies have demonstrated that nonoperative treatment with nonweightbearing immobilization may not produce optimal long-term outcomes.[2,3,7,12,21,26] The senior surgeon of the present study therefore advocates prompt percutaneous internal fixation in athletes to minimize the potential time lost to a slow or delayed healing process.

Numerous surgical techniques have been described as a means of treatment for Jones fractures.[7] These techniques include minifragment screws, tension band wiring, and Kirschner wire pinning. Intramedullary screw fixation is currently the predominant method of choice for most surgeons in treating these difficult injuries.[2,6,8,12,13,17] While each surgical method has potential advantages and disadvantages, the myriad fixation issues currently employed to treat proximal fifth metatarsal fractures may not always lead to predictable outcomes in a poor biological environment. Furthermore, none of the previous hardware

employed for intramedullary fixation was designed specifically for the Jones fracture; consequently, there is discontinuity among the range of contemporary screws available.

In an effort to address these concerns, the current study examined a standard noncannulated, semithreaded Charlotte Carolina screw (Charlotte Carolina Jones Fracture System, Wright Medical Technology, Arlington, Tennessee), designed with a uniform thread pitch to address the mechanical aspect of the fracture by minimizing implant failure and maximizing compression across the fracture site while maintaining resistance to bending fatigue failure. The varying lengths (4.5, 5.5, and 6.5 mm) and diameters (40-70 mm) of the screw allow the surgery to be individualized to the anatomy of the patient.

The poor biological potential of this fracture is due to its poor blood supply. The current study attempted to address not just the mechanical concern of reducing the fracture but also the biological concern by using a bone marrow aspirate concentrate (BMAC). The use of autologous bone marrow aspirate has been reported in the treatment of poor-healing fractures.[10] Bone marrow contains hematopoietic and mesenchymal stem cells.[23] The latter can differentiate in osteogenic precursor cells, whereas the former differentiate into platelets. These osteogenic cells are capable of forming osteogenic tissue when combined with stimulatory factors, such as those released from the α-granules of platelets.[4] The use of BMAC may therefore be beneficial in treating an injury with an area of poor blood supply and historically poor healing potential.

We report the results of 26 consecutive athletic patients undergoing percutaneous internal fixation of a proximal fifth metatarsal Jones fracture with Charlotte Carolina screw and autologous BMAC.

MATERIALS AND METHODS

Between January 2007 and August 2009, 26 consecutive athletic patients (18 men and 8 women) underwent percutaneous internal fixation of a proximal fifth metatarsal Jones fracture under the care of the senior surgeon (J.G.K.).

Study patients were identified through a search in the senior surgeon's practice database of the surgical CPT codes relevant to fifth metatarsal fracture fixation. Inclusion criteria consisted of any patient having undergone percutaneous internal fixation of an acute fifth metatarsal Jones-type fracture with Charlotte Carolina screw and BMAC. For the current study, we defined *acute* as having surgery within 14 days of the injury episode. Based on the recommendation from Chuckpaiwong et al,[2] fifth metatarsal diaphyseal fractures (zone III) were included with the traditional Jones fractures (zone II) and therefore defined the study group; zone II and zone III were collectively referred to as *Jones fractures*. The exclusion criteria consisted of nonathletes or athletes who had not completed at least 1 full season of athletic play after surgery, delayed unions or nonunions, concomitant pathologic treatment, a revision procedure, and any means of fixation (alone or in combination) other than the Charlotte Carolina screw. A nonathlete was defined as any patient not taking part in an organized athletic sport at the time of injury.

Indications for surgery included any athletic patient having suffered a fifth metatarsal Jones fracture (as defined above). In the senior surgeon's practice, surgical fixation is recommended to athletic patients as the first line of treatment owing to the known risks of delayed union, nonunion, and refractures after returning to competition. Contraindications to surgery were any patient identified as a smoker, as having diabetes, being over the age of 60 years, or skeletally immature.

No patient eligible for the present study was lost to follow-up. The patient records were reviewed for each study participant. Patient age and follow-up time, in addition to the sport and level of competition per patient (recreational, high school, collegiate, professional), was documented. Also recorded was whether the athlete returned to the previous level of competition after surgery as well as returned to play in athletic competition. Return to play was considered the amount of time elapsed from the day of surgery to the day when the athlete returned to competition.

All patients completed preoperative Foot and Ankle Outcome Score and SF-12 outcome questionnaires. Furthermore, each patient was contacted by the telephone and sent a final questionnaire-based follow-up assessment to complete via e-mail.

Each study participant had standard anteroposterior, lateral, and oblique foot radiographs preoperatively (at the last patient office visit before surgery) and postoperatively (at 14 days), an average of 5 weeks (range, 4-6) and 3 months. Radiographic union was defined as the presence of continuous trabeculation across the fracture site on each of the 3 radiograph views. Three-dimensional CT scan was performed on select patients when standard radiographs showed complete union at early time points before 6 weeks postoperatively. This was used to confirm healing before allowing the player to begin sport-specific training.

Patient Demographics

The mean patient age at the time of surgery was 27.47 years (range, 18-47). Each patient was followed for a minimum of 1 year after surgery before inclusion in the present study. The mean follow-up time was 20.62 months (range, 12-28). Patient sports and levels of competition are shown in Tables 1 and 2. Of the 26 total fractures, 17 were traditional zone II Jones fractures, and the remaining 9 were zone III proximal diaphyseal fractures. All fractures were of traumatic origin.

Bone Marrow Aspirate

The bone marrow aspirate was extracted from the ipsilateral iliac crest. With the patient in a supine position on the operating table, a sharp trocar with hollow aspiration sleeve was used to aspirate the anterior ilium, just posterior to the anterosuperior spine. The trocar was advanced between the cortices and into the cancellous bone. Approximately 60 mL of bone marrow was extracted with

TABLE 1
Athletic Population as Characterized by Sport, n

Sport	Men	Women
Soccer	7	3
Football	6	0
Basketball	3	2
Gymnastics	1	1
Track	0	2
Baseball	1	0

TABLE 2
Athletic Population as Characterized by Level of Athletic Play, n

Level of Play	Total
Recreational	4
High school	8
Collegiate	11
Professional	3

a standard syringe. The aspirate was then prepared and centrifuged using a standard bone marrow concentration system (Harvest SmartPReP 2 BMAC system, Harvest Technologies Corporation, Plymouth, Massachusetts), thereby yielding a concentrate (BMAC).

Surgical Procedure

The surgical procedure has been described.[15] By using a "high and inside" starting point (ie, dorsal and medial on an anteroposterior radiograph), a guide wire was placed under fluoroscopic guidance through the medullary canal of the proximal fracture and across the fracture site to the distal medulla. A small skin incision of approximately 1 cm in length was made to accommodate the drill and screw. Care was taken to avoid any aberrant branches of the sural nerve. The drill guide was then placed over the wire and, under fluoroscopic guidance, the drill was advanced to the distal diaphysis. Once this was achieved, intramedullary taps were advanced, beginning at 4.5 mm. Once cortical engagement and an interference fit were achieved, the screw size was selected from the corresponding tap size. The tap sizes go up in increments of 1 mm to a maximum diameter of 6.5 mm. This ensures maximal compression by allowing the threads to grip the inner table of the cortex, thereby using a lag principle to compress across the fracture site (Figure 4). The BMAC was then injected into the medullary canal by inserting the needle of the syringe, which was then followed by advancement of the screw until compression was felt and seen fluoroscopically. To ensure an adequate blood supply about the fracture site, a Kirschner wire (.045 in. [0.1143 cm]) was drilled percutaneously under fluoroscopic visualization, circumferentially about the fracture site. Creating multiple microdrill holes to serve as neovascular healing channels may potentiate a callous response that is analogous to the spot welding technique.[9] The remaining amount of BMAC was then injected under fluoroscopic guidance to the fracture site following screw placement. The method of BMAC injection was uniform in all cases performed.

Figure 4. A Charlotte Carolina screw transfixes a healing fracture of the proximal fifth metatarsal.

Postoperative Protocol

The patient wore a postoperative splint for 2 weeks after surgery and a walking boot for 4 weeks thereafter. Motion, including ankle pumps but excluding side-to-side movement, was included at 2 weeks after surgery, but the patient was nonweightbearing for 4 full weeks. From 4 to 6 weeks postoperatively, the patient was allowed to progressively increase weightbearing to full weightbearing at 6 weeks. Typically, the patient jogs on a treadmill for short distances and at low intensity at the 6-week point. Sport-specific therapies were started thereafter, based on the patient's symptoms. Return to athletic competition

was considered at 8 weeks after surgery, based on clinical and radiographic evidence of union.

Statistical Analysis

The *t* test was used in statistical comparison of the preoperative and postoperative outcome scores and therefore assigned a *P* value. The significance level was set at $\alpha = .05$.

RESULTS

The mean Foot and Ankle Outcome Scores significantly increased, from 51.15 points preoperatively (range, 14-69) to 90.91 at final follow-up (range, 71-100; $P < .01$). The mean physical component of the SF-12 significantly improved, from 25.69 points preoperatively (range, 6-39) to 54.62 at final follow-up (range, 32-62 points; $P < .01$). The mean mental component of the SF-12 also improved significantly, from 28.20 points preoperatively (range, 14-45) to 58.41 at final follow-up (range, 36-67 points; $P < .01$).

The mean time to fracture healing on standard radiographs was seen at 5 weeks (range, 4-24). All but 1 patient had complete bony consolidation at 8 weeks postoperatively (96%). This patient developed a delayed union and received a platelet-rich plasma injection, followed by ultrasound bone stimulation for 8 weeks, until the fracture line consolidated at 24 weeks after surgery. In the 12 patients who had 3-dimensional CT scans, all but 1 (92%) showed 360° osseous union at that time. This was the same patient who developed a delayed union, which was defined as no evidence of interval healing on standard radiograph for a period of 4 weeks and confirmed with a 3-dimensional CT scan.

The mean return to sporting activities was seen at 7.6 weeks (range, 5-8). Return to play was seen at a mean of 10.1 weeks (range, 8-14). These time points do not include the 2 patients who did not return to their sports (see below).

Two patients did not return to preinjury sporting levels: 1 athlete retired for non-injury-related causes; the other was a college football offensive lineman who was treated for a zone III fracture that occurred during off-season workouts. A 3-dimensional CT scan before returning to play confirmed that the fracture was healed circumferentially. Nevertheless, the patient refractured during the first preseason game after surgery and required a subsequent revision procedure.

A single case of transient sural nerve neurapraxia was the only surgical complication reported, which resolved 6 weeks postoperatively without delaying the return to sport. Two patients developed pain near the screw head, 1 of whom was a competitive snowboarder and developed pain 6 months after surgery and 4 months after return to sport. A plain film series demonstrated lucency about the screw head, indicating loosening of the screw. An MRI indicated insertional tendinosis of the peroneus brevis, presumably precipitating from irritation of the screw head on the tendon. The screw was removed, and the patient has since done well. The second patient was a runner and soccer player. A plain radiograph showed impingement of the screw on the tarsal cuboid joint. An ultrasound-guided diagnostic injection into this area with lidocaine and bupivacaine hydrochloride (Marcaine) resolved all symptoms: the screw was removed and the patient has done well and returned to unrestricted activities.

DISCUSSION

Proximal fifth metatarsal fractures are common athletic injuries and have historically been classified by 3 anatomic zones.[7,20,24,26] In particular, fractures in zones II and III (the metaphyseal-diaphyseal junction and proximal diaphysis, respectively) have traditionally been separated and reported as 2 distinct entities. Contrary to this, Chuckpaiwong et al[2] reported that the general treatment outcomes of these 2 fracture locations do not differ significantly; as such, they proposed that differentiation is not necessary and that zones II and III fractures be collectively referred to as Jones fractures. We used this recommendation in designing the current study, which examined the retrospective functional and radiographic outcomes after percutaneous internal fixation of proximal fifth metatarsal Jones fractures (zones II and III) by employing a standard Charlotte Carolina screw designed for the fifth metatarsal with varying lengths and diameter, as well as autologous BMAC.

In 1902, Sir Robert Jones initially described the Jones fracture after having suffered the injury himself 6 years earlier while dancing around a tent pole at a military party.[11] Since then, numerous reports have further characterized these fractures, including the tendency of the poor healing associated with the proximal fifth metatarsal. In 1927, Carp[1] highlighted the concern of delayed union and vascular insufficiency when he reported 20 adult fractures of the fifth metatarsal, of which 25% of the cohort suffered from a delayed union. Smith et al[22] subsequently used a cadaver model to describe the intraosseous blood supply of the fifth metatarsal. An avascular, or "watershed," region develops as a consequence to the fracture pattern between the nutrient artery (which enters at the middle third of the diaphysis) and metaphyseal artery distribution (which arises from the surrounding soft tissue). Because of this poor blood supply, a significant portion of the historical outcomes reporting nonoperative treatment for these injuries has been largely unpredictable or poor.[2,3,7,12,21,26]

The treatment paradigms for acute nondisplaced Jones fractures typically consist of a period of nonweightbearing immobilization for 6 to 8 weeks.[7,21] Kavanaugh et al[12] reported a series of Jones fractures in 22 patients, where 12 of the 18 nonoperatively managed cases (66.7%) demonstrated a delayed union and 50% of the cohort (n, 11) refractured after the initial injury. The authors also reported the results of intramedullary screw fixation in 13 patients, with a 100% union rate and no cases of

refracture. This prompted Kavanaugh et al to advocate immediate intramedullary screw fixation in athletes, highlighting the fact that long periods of disability are detrimental to the career of any athlete and may indeed be minimized with surgery.

Clapper et al[3] reported a case series of 25 Jones fractures treated with 8 weeks of nonweightbearing cast immobilization. Of the patients, 72% achieved union at a mean time of 21.2 weeks. The remaining 28% showed evidence of nonunion 25 weeks after the initial injury and consequently underwent intramedullary screw fixation. The authors reported union in all 7 cases of intramedullary screw fixation at a mean time of 12.1 weeks after surgery.

A 1995 literature review by Quill[19] reported that one-third of proximal fifth metatarsal fractures treated nonoperatively eventually refractured, thus posing a strong case for early surgical intervention. Over time, surgeons have more often begun to choose surgical treatment, the results of which are promising and have become accepted as a more predicable means of treating these difficult fractures.

Porter et al[17] reported 100% clinical healing and 98.9% radiographic healing and no refractures in 23 athletes treated with 4.5-mm cannulated screw fixation. DeLee et al[6] treated 10 athletes with intramedullary screw fixation and reported 100% union but with pain noted over the screw head in 70% of patients. Mindrebo et al[14] reported a series of athletes with full clinical and radiographic union, whereas Portland et al[18] evaluated the surgical management of Jones fractures and found that a more predicable union rate was achieved compared with other treatment strategies. Nevertheless, while good outcomes are reported in these cases of intramedullary fixation, the myriad fixation methods currently used have caused this procedure to be associated with failure in terms of refracture and screw breakage.

Wright et al[25] published a detailed study outlining 6 cases of refracture after full healing following intramedullary screw fixation in athletes, with 4 types of cannulated screws, ranging from 4.0 to 5.0 mm in diameter. These cases of refracture occurred the day after a full return to activity in 3 cases and within 4.5 months of a full return to activity in all 6 patients. The authors recommended a larger diameter screw in active patients as well as functional bracing or shoe modification in the first season after return to play, suggesting that these guidelines would minimize the rate of refracture. Larson et al[13] published a study with a significant failure rate of 40% in 15 patients with cannulated screw fixation. The authors concluded that an early return to activity has the potential to increase the risk of procedural failure (ie, refracture, hardware failure) and that complications remain a problem following intramedullary screw fixation.

The current study addressed the concerns of previous studies by minimizing implant failure with a standard noncannulated Charlotte Carolina screw and individualizing the varying lengths and diameters of the hardware to the anatomy of the patient, as well as by addressing the biological healing potential of the fracture site with autologous BMAC. Nunley and Glisson[16] biomechanically evaluated the Charlotte Carolina screw and compared it with 3 commonly used contemporary screws currently used for Jones fracture fixation. The authors demonstrated that the Charlotte Carolina screw outperformed the contemporary screws by a significant margin in terms of fatigue resistance via cyclic loading testing.

The current study reported a 96% union rate at the 8-week postoperative time point and a mean fracture healing time of 5 weeks postoperatively on standard radiographs. The 3-dimensional CT scans obtained at 6 weeks postoperatively on 14 patients showed 360° osseous union in 93% of patients. The single case of refracture in the current study was in a college football offensive lineman, which occurred in the first preseason game after return from injury. The complication rate of the present cohort is otherwise low. The 2 cases of screw head–related pain after surgery were addressed in the present study, but they do raise some concern about the size of the screw head and whether it can be reduced to prevent this occurrence in the future.

To the best of our knowledge, the current study is the first to evaluate the use of an intraoperative biologic in surgically treated proximal fifth metatarsal Jones fractures. The use of BMAC in treating difficult fractures has been reported.[10] When treating an area with a historically poor blood supply, the use of BMAC can improve the local biological environment to promote bone healing. We acknowledge that, to date, the mechanism by which BMAC promotes neovascularization and osteointegration is not yet known. Furthermore, we acknowledge that a randomized controlled trial is needed to discern the efficacy of BMAC and that without a control group, this is not clearly demonstrable. The current study does however provide a basis for re-examination of the traditional surgical treatment strategies for proximal fifth metatarsal Jones fractures.

CONCLUSION

Jones fractures of the proximal fifth metatarsal (zones II and III) have proven themselves to be challenging injuries to manage. The fracture requires mechanical stability and biological activity to achieve full bony consolidation in a reasonable period with predictable results. In an athlete, the most predictable outcome can be achieved with surgical intervention and screw fixation. The screw should be individualized in length and diameter to achieve the greatest possible mechanical compression across the fracture site, and biological consideration is important to achieve the optimal potential of mechanical fixation. A randomized controlled clinical trial is warranted to compare the Charlotte Carolina screw with and without BMAC. Basic science studies will investigate variables such as the optimal dose and composition of BMAC, which are not yet known. In addition, refinement of the Charlotte Carolina screw head may help obviate potential irritation while maintaining mechanical compression of the fracture site.

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