
FIFTH METATARSAL FRACTURES

Biomechanics, Classification, and Treatment

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Fracture of the fifth metatarsal is a commonly encountered podiatric orthopedic clinical event.^{1, 4, 8, 15, 17, 19, 22, 25, 29} The statistical frequency for all types of fifth metatarsal fractures collectively compared against other foot fractures is unknown. Two recent studies from one of the author's Institutions (NW) have identified the proximal junctional diaphyseal-metaphyseal Jones fracture frequency rate as 0.7%–1.9% in a combined total of 10,988 foot fractures.^{12, 13} Classification of the different forms of fifth metatarsal fracture primarily are based on anatomic location and fracture personality. The tuberosity and proximal junctional diaphyseal fractures have received the most attention in the literature owing to the confusion regarding the most effective form of treatment.^{2, 3, 4, 5, 11, 15, 16, 17, 20, 29} The distal capital, cervical, and shaft fractures are less controversial with regard to treatment concepts, but review of the literature also demonstrates considerable variation in treatment methods for these fractures. Surgeon preference, training, and patient-related parameters play a role in the decision for various forms of treatment as well.

This article defines a classification system for fifth metatarsal fractures based on anatomic site, time of encounter, and fracture morphology, and uses this model to direct the surgeon toward an appropriate method of treatment. Additionally, the biomechanics of the fifth metatarsal segment and its interactions are explored to help the clinician understand how fracture occurs within this bone. The biomechanical behavior of this segment and its attachments can be

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used to help the surgeon understand treatment concepts within the classification scheme.

ANATOMY AND BIOMECHANICS

The fifth metatarsal functions with an independent axis of motion.²⁶ The direction and range of motion are determined by orientation of its axis and by its ligamentous and tethering soft tissue attachments. These factors dictate primarily dorsiflexion and plantarflexion with inversion-eversion as the potential movements of this segment.²⁶ Strong plantar ligaments extending from the os calcis span the cuboid to insert at the plantar fifth metatarsal base.²³ A small cuboid fifth metatarsal ligament is present at the undersurface to reinforce the tension surface of this joint, as is a small slip of plantar fascia.²⁴ An interosseous ligament locks the base against the fourth metatarsal.^{15, 28} A dorsal cuboid fifth metatarsal ligament spans the top of the proximal joint to promote dorsal stability.^{24, 28} The peroneus brevis attachment at the tuberosity base provides a powerful dynamic tensile loading capacity with some posterior axial compression as a result of its longitudinal course from the fibular malleolus to the metatarsal base. The contribution to joint stability from peroneus tertius is minimal, as its course emanates proximally and is dorsiflexory. It fires during swing phase and briefly at heel contact phase of gait. Fracture of the fifth metatarsal does not occur during swing or early stance phase; however, a small medial compressive load against the fourth metatarsal is possible with this orientation. The fifth metatarsal is cradled with muscle investitures from the flexor digiti quinti brevis arising from the plantar base region, which sometimes extend more distally to insert laterally on the shaft as well as on the lateral fifth proximal phalanx.⁴ The abductor digiti minimi may have a small insertion on the base of the fifth metatarsal and, occasionally, on the mid-shaft as it progresses toward its final insertion on the base of the proximal phalanx.⁴ As such, it could help cradle this segment laterally and perhaps biomechanically. Intermetatarsal stability is aided by the fourth dorsal interosseous muscle, which originates from both the medial fifth metatarsal shaft and base and from the adjacent area of the lateral fourth metatarsal. The plantar interosseous muscle has no substrate on the fourth metatarsal or the proximal links and thus plays no role in stabilizing the base. The morphology of the bone demonstrates a longitudinal dorsal convexity, like the other metatarsals, to help neutralize bending moments (flexural neutralization) in the loaded closed kinetic chain state. It is the terminal link of the outer part of lateral column of the foot, completing a curved segmented beam linkage formed by the companion components of the os calcis and cuboid. Its design is defined by a distal articular capital segment, a narrowed cervical region that becomes continuous with a dense cortical midregion or shaft with an isthmus. The isthmus has surgical significance for osteosynthesis medullary axial fixation procedures similar to the tibial isthmus; this is discussed subsequently. Progressing proximally, a transition occurs into a metaphyseal expansion, terminating at the most proximal and lateral ends with a narrow tuberosity. There are considerable variations in size and shape.⁴ These anatomic design changes have engineering significance for load acceptance.

Loading of the fifth metatarsal segment under ordinary gait mechanics is generated through a combined mechanism of induced compression from its companion links proximally and from distal gravitational forces at the metatarsal head. Load acceptance depends on intact integrity of the interface segments and soft tissue attachments.^{29, 32} Morbid loading occurs during competitive athletics

with acute or fatigue-related strain distortions.^{4, 5, 12, 13, 14, 33} Excessive acute strain loads are usually flexural; however, torque can occur in inversion injuries.^{23, 31} These forces are usually indirect, mediated by the intrinsic muscle cradling, ligament, and dynamic tendon attachments.^{24, 29} Owing to the locked configuration of the fifth metatarsal base against its companion segments and the significant soft tissue constraints, dislocation is rare.^{11, 14} This configuration creates a long lever arm that focuses maximum bending distal to this heavily locked and stabilized anatomic area with an altered morphologic configuration change.^{14, 16, 31} Direct violence by missile or vertical impact can cause comminution with an open fracture anywhere in the segment; most commonly in the brittle cortical shaft (see Table 1).

CLASSIFICATION BY ANATOMIC SITE

Capitum

Capitum fractures generally occur from direct impact (usually vertical) or missile violence. Infracoracoid compression fracture can also occur, but these are usually stable and in good position (Fig. 1). Comminution or joint distortion may demand removal of the entire head and conversion into an arthroplasty if the site is unreconstructable (Fig. 2).

Cervical

Cervical fractures can be flexural and relatively transverse, spiral (dancer's fracture), or impaction fractures (Fig. 3). Some metaphyseal buckling may be radiographically evident for impactions. These heal well and usually have acceptable alignment^{17, 23} (Fig. 4). Sagittal plane malalignment should be considered for open reduction because of weight transfer factors at this site.^{23, 31} Spiral dancer's fracture displaces medially along the shearing axis of the fracture.³² It



Figure 1. Capitum compression fracture in good position without comminution.

Table 1. ANATOMIC CLASSIFICATION OF METATARSAL FRACTURES WITH TREATMENT OPTIONS

Location	Fracture Personality			DISPLACED
	NONCOMMINUTED	COMMINUTED	NONDISPLACED	
CAPITUM Articular Nonarticular	Closed treatment Closed treatment	Closed or total excision of head Open or closed Option if fixable	Closed treatment Closed treatment	ORIF ORIF
CERVICAL Short transverse	Open or closed Splintage K-wire	Closed if severe Mini-butress plate	Closed treatment	K-wire splintage
Spiral	Closed if nonathlete ORIF if athlete	Circlage if fixable 2.0-mm screws	Closed treatment	K-wire splintage or 2.0-mm screws
SHAFT Transverse	Closed treatment Medullary K-wire if displacement	Miniplate or closed with external fixators	Closed treatment	K-wire splintage
Spiral	Multiple 2.0-mm screws	Butress plate or circlage wire	Closed treatment	2.0-mm screws or circlage wire
JUNCTIONAL Jones fracture	4.5-mm lag screw	4.5-mm lag screw or miniplate	Open for athletes Closed for elderly	ORIF 4.5-mm screw
TUBEROSITY Small fragment Large fragment	Closed simple immob Closed simple immob	Closed treatment Loop wire tension band	Closed Closed treatment	Tension band wire Tension band wire or small lag screw



Figure 2. Comminuted caput fifth metatarsal fracture with companion fourth metatarsal cervical fracture, in satisfactory alignment for closed treatment.



Figure 3. "Dancer's fracture" of the fifth metatarsal cervical neck region. This is usually a spiral fracture that heals well with closed treatment, unless the patient is a competitive athlete or performer.



Figure 4. Healed “dancer’s fracture” with fresh transverse traction fracture at the tuberosity.

suggests an underlying torque force mediated by bending and twisting, most commonly an inversion and plantarflexed foot load.^{8, 9, 17, 31} It often requires open reduction and internal fixation in the competitive dancer or athlete, but otherwise heals well with casting^{8, 9} (Fig. 5).

Shaft

Shaft fracture is often comminuted, occasionally with open wounds, and results from direct violence or impact. Missile wounds can be difficult to manage and produce open fracture with segmental defect that requires special care, including external fixation and subsequent reconstruction¹⁶ (Fig. 6A,B,C,D,E). Closed comminutions can often be managed with casting until consolidation occurs.²³ If consolidation failure occurs, segmental reconstruction with bone graft and possible plating is a good solution.

Junctional

Fracture at the anatomic transition from the cortical shaft with its isthmus to the proximal metaphysis presents the most difficult treatment challenge and questions. This is the classic Jones fracture, described as 1.5 to 3.0 cm distal to the tuberosity^{1, 4, 11, 18, 29} (Fig. 7). This site represents an anatomic and engineering change in configuration, predisposing it to failure under certain loading situations.²⁹ Transition occurs from the shaft cortical structure to a compliant metaphyseal expansion. Thus, there is a geometric contribution with the change in morphology as well as a materials strength consideration.^{29, 32} The combination of biomechanical forces and engineering phenomena unique to this area create the stage for a flexural overload causing either acute fracture or stress fracture. Diagnosis is often made by a combination of clinical examination and radiographic and, occasionally, more complex modern imaging techniques. Treatment depends on the activity level of the patient and whether the fracture is acute,



Figure 5. "Dancer's fracture" internally fixed with double 2.0 mm compression lag screws. This is fairly easy owing to the long spiral surfaces.

fatigue, or chronic nonunion with medullary sclerosis.^{5, 14, 17, 23, 31, 33} This fracture is notorious for prolonged healing and nonunion.^{1, 2, 5, 10-14, 16, 17, 20, 23, 30, 33} As a result, surgery has become the accepted norm and common for the athlete and others who desire more rapid rehabilitation.^{12-14, 16, 20, 30, 33} Medullary screw fixation has emerged as the technique of choice for acute or fatigue-related failure^{5, 14, 16, 18, 20} (Fig. 8A,B). Cannulated screws have taken this concept a step further owing to their greater ease of insertion (Fig. 9).

Tuberosity

The styloid process at the fifth metatarsal base as well as its more distal metaphyseal expansion form the proximal tuberosity flare.⁴ Its rigid attachments of ligaments, tendons, and capsule make it a very stable substrate that is locked firmly against its counterparts—the cuboid and fourth metatarsal base. There is almost total agreement regarding the pathomechanics of fracture through this site.^{4, 17, 19, 22-24, 29} Avulsions represent tensile mediated overloads via traction from the various ligaments and dynamics of the peroneus brevis tendon during inversion and plantar flexion movements.^{22, 24, 31} The avulsions are often irregular but are small and virtually always include portions of the insertion of the peroneus brevis and the plantar ligament or fascia insertions (Fig. 10). These fractures must be assessed carefully in adolescents who have a secondary growth plate^{4, 29} (Fig. 11). The significant features of concern with this fracture relate to whether it enters the cuboid joint and the amount of distraction present^{3, 17, 23, 29} (Fig. 12). It can also be almost transverse, where it enters the intermetatarsal joint (Fig. 13). The forces operational for this pattern are a frictional pivot, with the heel elevated in conjunction with external leg and talar rotation creating adduction at the midfoot and hindfoot, with the forefoot fixed during performance. The tensile overload is directed through the peroneus brevis, the lateral

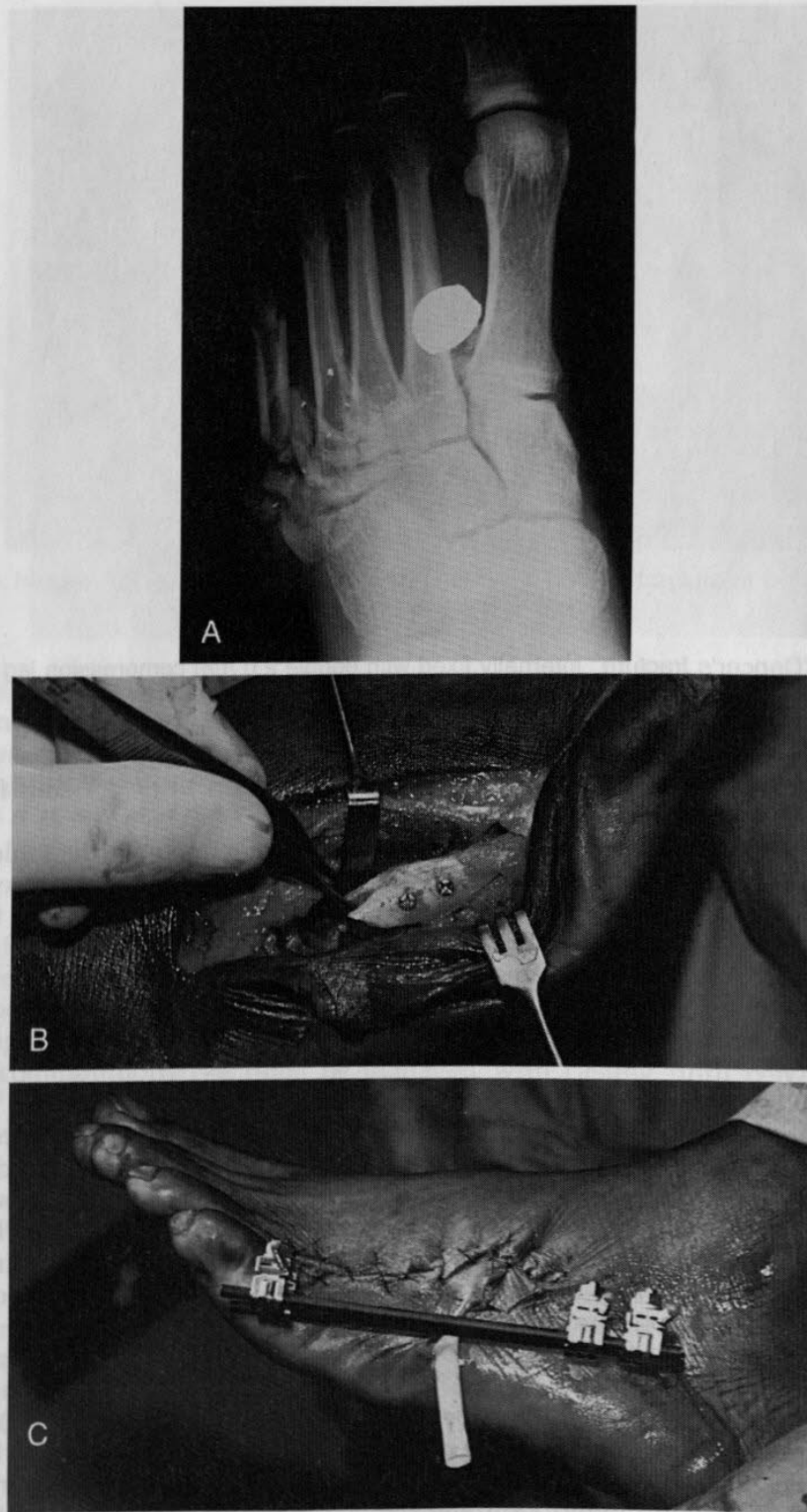


Figure 6. A, Comminuted fifth metatarsal fracture from low velocity missile impact. Segmental distortion is present near the "junctional" region and base. B, Intraoperative situation, repairing the larger comminutions with 2.0 mm screws to prepare for external fixation buttress stabilization. C, Final stabilization with mini AO external fixator and carbon rod.

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Figure 6 (Continued). *D*, Imaged view of previous clinical situation, showing combination of internal and external fixation stabilization. *E*, Final "late" reconstruction with interposition bone graft and buttress plate and splintage pin.

slip of the long plantar ligament, and the plantar fascia insertion at the styloid.²⁴ The fracture does not displace significantly and heals uneventfully, like most nondisplaced tuberosity fractures, with simple immobilization in about 4 to 6 weeks.^{2-4, 6, 16, 17, 21, 23, 29, 31} Surgery should be considered for avulsions with distraction, intra-articular orientation with displacement, painful nonunions, or comminuted unrepairable fragments.^{2, 3, 7, 16, 17, 19, 22, 25, 29, 31} Tension banding, with or without splintage pins, is effective for small fragments; small lag screws are easier to use for larger fragments.^{21, 22, 31}



Figure 7. Classic "junctional" fresh Jones fracture with comminuted butterfly fragment.

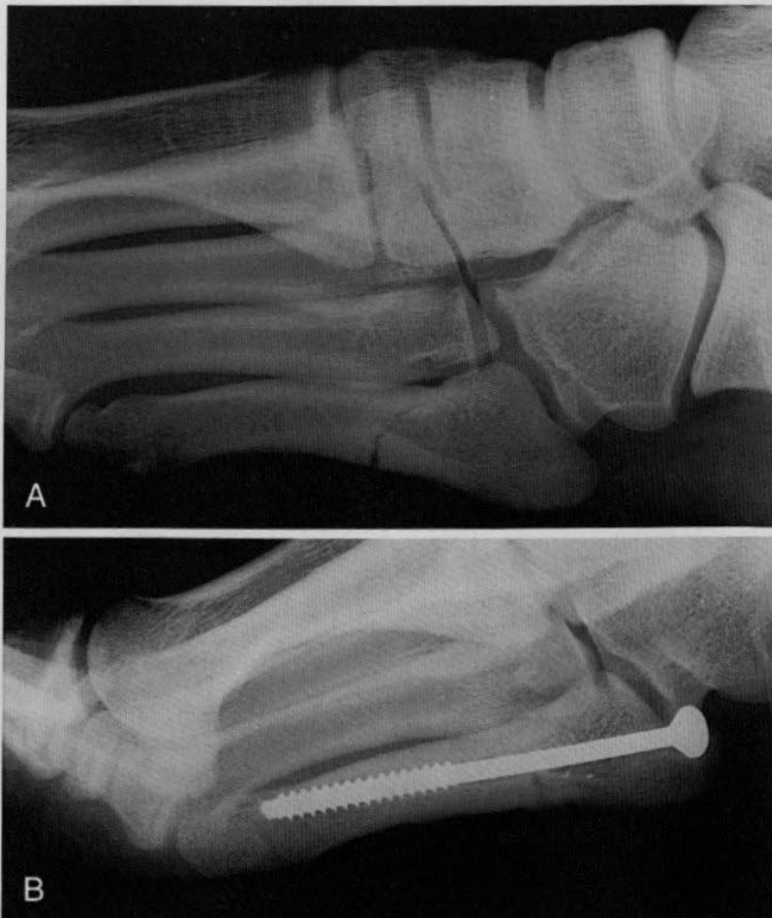


Figure 8. A, Stress Jones fracture in a young soccer athlete. B, Repaired with 4.5 mm AO axial medullary malleolar screw.



Figure 9. ACE (ACE Medical Company, El Segundo, California) 4.5 titanium lag screw, cannulated delivery on skeletal model.



Figure 10. Small tuberosity avulsion fractures resulting from dynamic traction from the peroneus brevis and long plantar ligament slip. This heals well with minimal immobilization treatment.



Figure 11. Intra-articular tuberosity fracture, nondisplaced, with a small secondary growth center at its classic location.



Figure 12. Displaced intra-articular tuberosity fracture. This needs open reduction and internal fixation. Tension banding is best.

TREATMENT

The most important question for many fifth metatarsal fractures is whether to use surgical versus nonsurgical treatment. Working from the anatomic classification, this discussion progresses from distal to proximal.

Fractures of the capitum can be infracoracoid compression injuries, which are usually stable and well positioned (*see* Fig. 1). If they are intra-articular with significant fragmentation, closed reduction can be attempted, or minimal open reduction may be considered, if possible. This is often not possible, and excision



Figure 13. Transverse traction tuberosity fracture in the intermetatarsal joint. This requires simple immobilization.



Figure 14. Comminuted "dancer's" cervical fracture fixed with three interfragmentary 2.0 mm lag screws.

of the fragments with conversion to an arthroplasty is usually the best option. Small plates have poor bone purchase in this subcutaneous area and are not recommended.

Cervical fractures or infractions can be managed using closed reduction with distraction techniques under local anesthesia^{8, 9, 17} (see Fig. 2). If there is significant angulation or sagittal plane malalignment, then open reduction is required. This can be accomplished in perferential manner as all these fractures heal well. Techniques available include simple insertion of interfragmentary 2.0-mm lag screws for spiral orientations (Fig. 14), use of medullary splintage pins entering the distal lateral metatarsal head sliding down the medial cortical metatarsal wall (Fig. 15A,B,C,D), and placement of monofilament wire loops.^{16, 17, 21-23, 31} Plates are the least desirable option in this location unless there is segmental loss that requires interposition bone grafting.

Shaft fractures can be managed using the same concepts as cervical fractures. Medullary splintage is simple and effective with K-wires^{3, 16, 31} (Fig. 16). Plates can be used in this area because there is adequate bone mass for purchase, but they are usually reserved for comminutions or segmental loss.³¹ Occasionally, external fixation is needed as a temporary construct until more suitable circumstances permit conventional osteosynthesis link-up (see Fig. 6C-D).

Junctional fracture, or Jones fracture, is the most celebrated injury of the fifth metatarsal (Fig. 17).^{1, 2, 3, 5, 6, 10-16, 18-20, 29, 30, 33} It has been recognized as a problem since the time of its original description by Jones in 1902.¹¹ The optimal form of treatment for this fracture and its natural history over time are unclear. Torg has drawn attention to the healing difficulties of this fracture and proposed in-laid bone grafting for the sclerotic delayed and nonunion situations.^{18, 30, 33} The best choice for primary treatment has remained somewhat confusing. Kavanaugh et al and Delee et al have popularized medullary 4.5-mm A-O malleolar screw fixation as the primary treatment of choice for competitive athletes and other active individuals^{5, 14} (Fig. 18). Two recent Swedish studies by Josefsson et



Figure 15. A, "De-gloving" injury with open fracture of the fourth and fifth metatarsals with comminution. The fifth metatarsal is a cervical fracture and the fourth a comminuted shaft fracture. This is a motorcycle injury. B, The radiographic appearance demonstrating cervical fifth metatarsal fracture and comminution of the fourth metatarsal shaft.

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al agree. They also defined the natural history of this injury with surgical and nonsurgical courses of treatment with their outcomes.^{12, 13} The Swedish studies represent the largest series and most extensive analysis of Jones fractures in the world literature. From this study, it is clear that in most cases the Jones fracture will ultimately heal with nonsurgical means if given enough time. Twenty percent of these fractures can be expected to undergo delayed union or refracture with nonsurgical treatment. Kavanaugh et al reported 66% delayed union and



Figure 15 (Continued). *C*, Internal fixation demonstrating sliding splintage in the cervical fifth metatarsal fracture and splintage with interfragmentary screws in the fourth metatarsal. *D*, The final healed anatomic situation.

41% stress fractures.¹⁴ There are no known statistics for the rate of permanent nonunion.^{12, 13} The Swedish studies indicate that about 59% of the Jones fractures can be anticipated to be stress fractures. This fracture most often affects younger patients.^{12, 13, 14, 30}

Cannulated screws offer the additional advantage of ease of insertion and indirect reduction for fixation of this fracture. Newer cannulated ACE titanium 4.5-mm lag screws with a lower profile head represent a simple method of delivery with the necessary screw design and the superior metallurgic strength of titanium (Fig. 19). The 4.0-mm A-O lag screw appears inviting, but it has a small "root diameter" at the run out, predisposing the screw to fracture as it passes the isthmus of the metatarsal shaft, exposing it to considerable bending moments.⁵ This is avoided with the newer 4.5-mm cannulated titanium lag screws. The anatomic shaft isthmus creates an interference fit with the screw. Screws longer than 46 mm should be avoided as they may penetrate the medial distal cortex. Consolidation is rapid and dependable with medullary screw delivery; clinical union can take place as soon as 7 weeks, compared to 15 weeks for casting.^{12, 14, 18, 20} The screw should be left in place for competitive athletes until the end of their careers because of the high rate of refracture following retrieval.¹² Occasionally, screw head prominence can be troublesome and may require early removal following union. It is not clear whether sclerotic non-unions require decortication with bone grafting rather than medullary axial compression screw repair. Torg et al^{18, 30, 33} believe that inlaid bone grafting was



Figure 16. Classic medullary splintage for shaft fracture.



Figure 17. Acute Jones fracture in classic location.



Figure 18. Healed Jones fracture with 4.5 mm AO axial medullary compression screw.

required, whereas Delee et al⁵ believe axial compression screw alone is effective. Clearly, axial compression screw fixation is easier and may represent a better method of treatment, even for chronic nonunions.

Thus, current recommendation for treatment of the acute or stress-related Jones fracture is insertion of medullary lag screws (4.5-mm cannulated titanium screws) for the active patient. If the medullary canal and isthmus are small, a 4.0-mm lag screw with washer can be used. If the site is very sclerotic, consideration should be given to an inlaid Torg bone graft; alternatively, a local bone graft with an axial compression 4.5-mm cannulated titanium screw can be used. Non-weight-bearing casting can be considered for high-risk patients and those with no particular urgency for recovery.^{3, 14, 30} In the event of delayed union

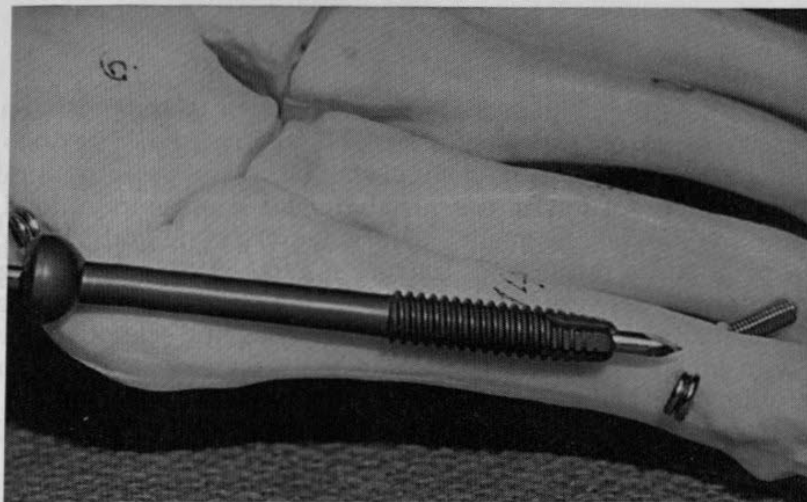


Figure 19. Anatomic model demonstrating ACE (ACE Medical Company, El Segundo, California) 4.5 mm titanium cannulated lag screw axial delivery.



Figure 20. Displaced transverse tuberosity fracture. This requires open reduction and internal fixation with tension banding.

with nonsurgical means, 100% union can be anticipated with late lag screw fixation.^{12, 14}

Tuberosity fracture management is usually nonsurgical and almost always successful.^{3, 4, 13, 16, 17, 29, 30, 31} Surgical reduction is necessary only when the joint is involved with displacement or when distraction of the fragment is apparent (Fig. 20). Tension banding is an excellent option in these cases and can be used for many situations, from the smallest avulsions (Fig. 21A-B) to larger tuberosity portions²¹⁻²³ (Fig. 22A-B). If the tuberosity portion is large enough, 3.5-mm or 4.0-mm lag screws can be delivered easily and effectively (Fig. 23A,B,C,D). Small nonunion fragments can be considered for excision with local tendon repair.^{7, 27, 29} If the tuberosity is too comminuted, the same concept can apply. Simple immobilization is effective in most cases of tuberosity fracture and forms the basis of treatment at this anatomic site.

SUMMARY

Fractures of the fifth metatarsal are treated conceptually based on anatomic location and character of the fracture site. Intra-articular disruptions require reconstruction, if possible. Malalignment of acute fractures requires either closed reduction or open reduction if the malalignment represents a load-bearing dysfunction to the forefoot. Segmental defects require bone grafting and stabilization with plate and screws. Jones fracture is most effectively managed with medullary lag screw delivery in the active or athletic patient. Casting can be considered for high-risk patients. Late bone grafting for sclerotic nonunion is necessary with inlaid grafts harvested from the calcaneus or tibia. Tuberosity fractures require open reduction only when articular involvement is a problem or when distraction is apparent. Otherwise, they can be expected to heal rapidly without long-term problems.

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Figure 21. A, Very small tuberosity avulsion fracture representing a traction fracture from the peroneus brevis tendon. B, Small fragments containing the peroneus brevis insertion can be captured by a "loop wire" without K-wire splintage pins.



Figure 22. A, Oblique avulsion fragment, partially displaced, nonarticular. B, Tension banding of prior avulsion fragment, with splintage pins.

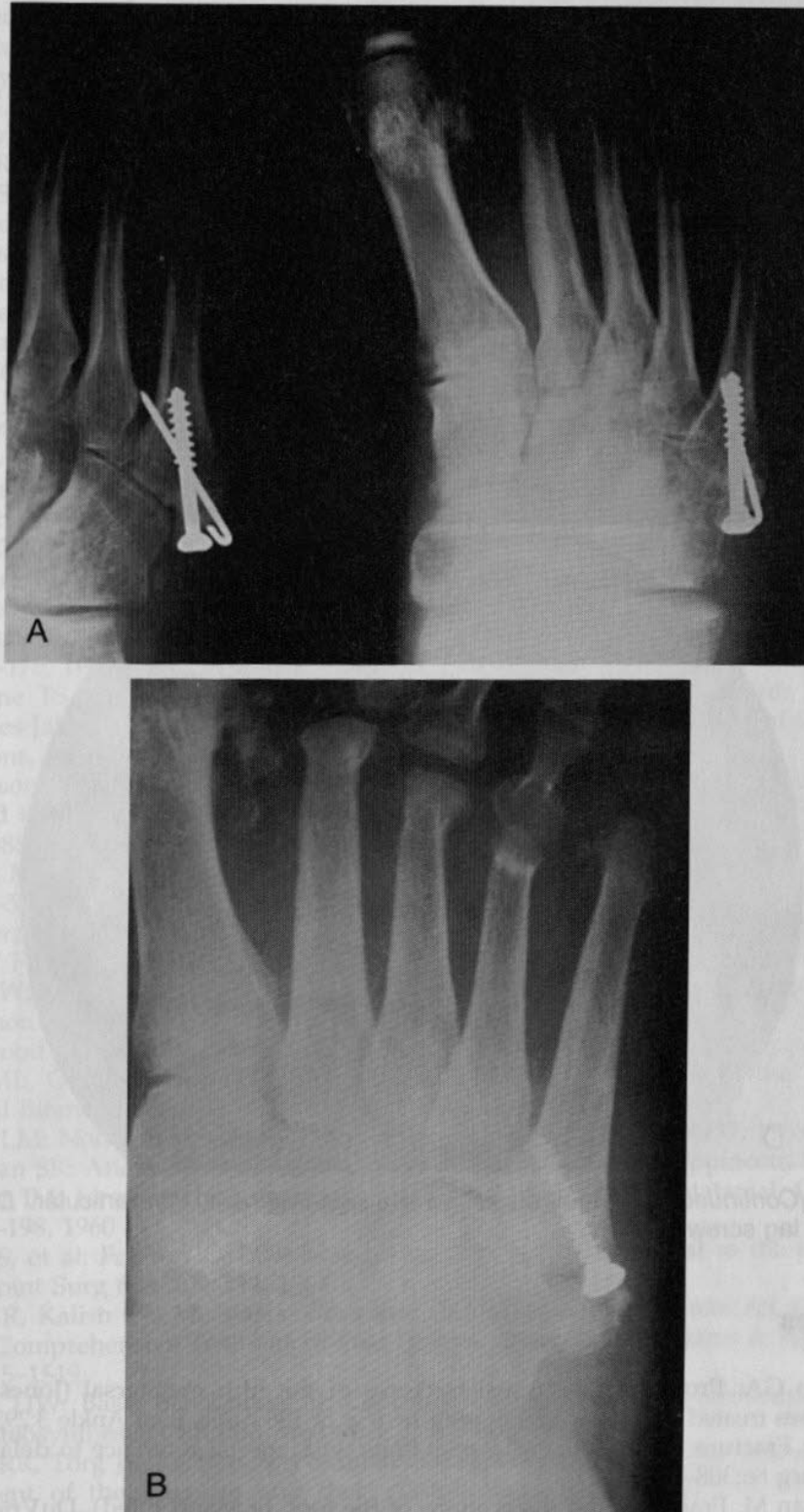


Figure 23. A, Lag screw fixation of small avulsion fragment with a secondary antirotation splintage pin. B, Accidental "telescoping" of 3.5 mm screw with inaccurate delivery.

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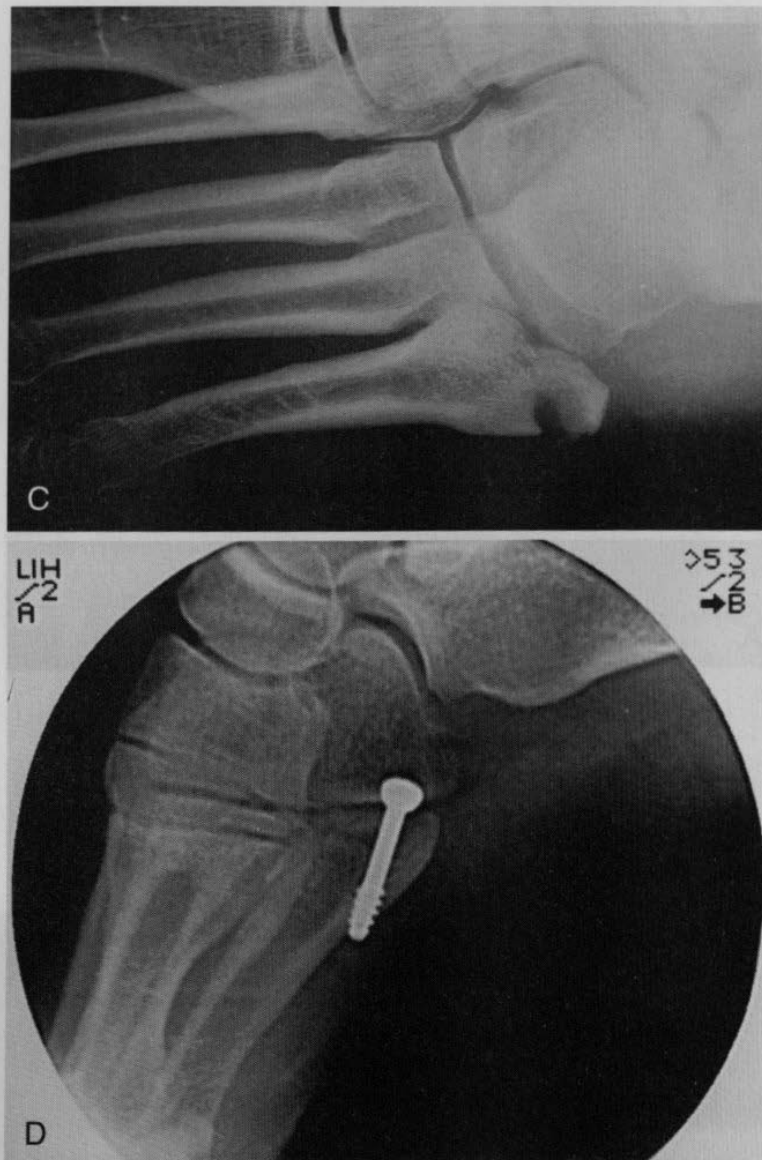


Figure 23 (Continued). *C*, Small displaced avulsion fragment, intra-articular. *D*, Repaired with proper lag screw delivery.

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