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Current Management of Tarsometatarsal Injuries in the Athlete

By Mark S. Myerson, MD, and Rebecca A. Cerrato, MD

An Instructional Course Lecture, American Academy of Orthopaedic Surgeons

Current management of injuries to the tarsometatarsal complex depends on the type and mechanism of the injury, the forces involved, whether the injury is high or low-energy, and whether it occurred in an athlete. Foot and ankle injuries are some of the more common injuries in athletes, with foot injuries accounting for 16% of all sports-related injuries. Certain athletes are at higher risk. Midfoot sprains occur in 4% of football players per year, with offensive linemen incurring 29.2% of these injuries. Tarsometatarsal injuries in athletes are distinctly different from those due to high-energy trauma. Athletes tend to have subtle clinical and radiographic findings, and a high index of suspicion is necessary to recognize and diagnose these injuries appropriately. A wide spectrum of injuries to the tarsometatarsal and associated interrelated joints is now recognized. Treatment concepts have evolved over the past decade, with use of more rigid forms of fixation and, most importantly for the athlete, intensive rehabilitation.

Anatomy

The tarsometatarsal joint complex includes the three cuneiforms, the cuboid, and the bases of the five metatarsals. From a functional perspective, this complex can be divided into three columns. The medial column includes the first metatarsal-medial cuneiform joint, the middle column includes the second and third tarsometatarsal joints as well as the articulations between the middle and lateral cuneiforms, and the lateral column consists of the articulations between the fourth and fifth metatarsals and the cuboid. The distal articulation of the middle cuneiform (and the corresponding second metatarsal) is recessed 8 mm proximally relative to the medial cuneiform and 4 mm relative to the lateral cuneiform. This “keystone” configuration allows the base of the second metatarsal to articulate with five adjacent bones, creating a tight mortise that provides substantial stability to the entire tarsometatarsal complex. Additionally, the anatomic shape of the transverse arch provides inherent osseous stability. In cross section, the trapezoidal shape of the middle three metatarsal bases and the corresponding shape of the cuneiforms create a Roman arch, which also adds stability to the midfoot. Although the columns of the tarsometatarsal joint complex function interdependently, the motion of each is quite different, which has implications for both diagnosis and treatment. The medial column allows approximately 3.5 mm of dorsal-plantar movement. The middle column permits only approximately 0.6 mm of sagittal plane motion, whereas the lateral column allows an average of 13 mm of movement in this plane. It is therefore interesting to note that the majority of the injuries to the tarsometatarsal joint complex involve the second metatarsocuneiform joint (or the middle column). There is almost no sagittal movement of the second metatarsal and, despite the inherent anatomic rigidity conferred by the recessed position of the base of the metatarsal and despite the strength of the oblique Lisfranc ligament, fracture and/or dislocation (isolated or in combination with additional joint instability) is most common in this articulation.

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Additional stability is conferred on the entire articulation by strong ligamentous attachments, which are classified by topography (dorsal, interosseous, and plantar) and by course (longitudinal, oblique, and transverse)\(^6\). There is a certain symmetry to all of these ligaments with the exception of those at the second metatarsal, where no intermetatarsal ligament is present. The longitudinal and oblique fibers connect the cuneiforms and cuboid to the metatarsals, and the transverse ligaments connect the metatarsal bases. The plantar ligaments are stronger and stiffer than the dorsal ligaments. Between the first and second metatarsals, there is no intermetatarsal ligament; rather, the Lisfranc ligament runs obliquely from the medial cuneiform to the plantar base of the second metatarsal. Biomechanical studies have shown that, of all ligaments in the tarsometatarsal complex, the Lisfranc ligament has the most strength and highest load to failure\(^7\).

**Mechanism of Injury**

It is important to understand the different mechanisms of injuries to the tarsometatarsal joint complex. Obviously, a high-energy injury associated with a motor-vehicle accident, a fall from a height, or a crushing injury is vastly different from an injury caused by low-velocity indirect forces, which are responsible for the injuries in athletes. Over the past decade, there has been a greater frequency of low-energy twisting injuries in athletes. To a large extent, this is due to the changes in the interface between the athletic shoe and the playing surface, particularly when the athlete is playing on artificial turf. Injuries of the tarsometatarsal joints that take place on regular turf in American football are influenced by the type of shoe and cleat worn and by the forces on the foot when another athlete falls on it while it is in a compromised or fixed position. These athletic injuries to the tarsometatarsal complex can be divided broadly into plantar flexion injuries and abduction injuries, although this is an oversimplification since there are probably varying patterns of each force. Plantar flexion injuries occur when an axial force is applied along the longitudinal axis of a foot that is in slight equinus with the metatarsals firmly planted on the ground distally, resulting in failure under tension dorsally\(^8,9\). As the body moves forward over the forefoot, twisting with rotation and abduction of the forefoot occurs, causing the various patterns of dislocation. The classic example is in an American football lineman who, during a block, has his foot plantar flexed and the metatarsophalangeal joints maximally dorsiflexed. He sustains the injury when a force, such as a tackle, is directed onto the heel or when someone falls onto the firmly planted foot. Abduction injuries occur when the forefoot is forcefully abducted with the hindfoot fixed. As the abduction force increases, the recessed base of the second metatarsal dislocates, and the remaining metatarsals displace laterally. These injuries can also occur in sports in which a stirrup creates a fulcrum effect on the forefoot, such as equestrian sports and windsurfing\(^10\). This is an oversimplification, since many patterns of injury can occur, either as fractures of the metatarsals or as subluxation of the tarsometatarsal and intercuneiform joints.

**Classification**

Several classification schemes have been applied to injuries of the tarsometatarsal joints. Quenu and Küss described different patterns of tarsometatarsal injuries in 1909\(^11\). They organized them into three groups: homolateral, isolated, and divergent. In 1982, Hardcastle et al. discussed their experience with treating 119 tarsometatarsal injuries, noting that the prognosis depended more on articular incongruity than on the mechanism of injury\(^3\). They modified the classification system of Quenu and Küss by dividing the injuries into types A, B, and C. Type A indicates complete displacement of all of the metatarsals or complete incongruity of the tarsometatarsal joint complex, type B reflects partial incongruity, and type C is a divergent pattern. One of us (M.S.M.) and colleagues refined this classification system after reviewing seventy-six fracture-dislocations of the tarsometatarsal joint complex\(^12\). Type-B injuries were divided into medial dislocations (type B1) and lateral dislocations (type B2). Type-C injuries were divided into those with partial incongruity (type C1) and those with total incongruity (type C2). Later, Chiolo and one of us (M.S.M.) described the three-column theory to classify these injuries, emphasizing the separate motion segments of the midfoot\(^1\). That classification system helps with treatment planning since the metatarsals within a column often work as a functional unit. The system also highlights the importance of movement of various parts of the midfoot, which in turn is important with respect to the outcome. Subtle incongruity is less well tolerated in the middle than in the medial or lateral column. Komenda et al. demonstrated that symptomatic posttraumatic arthritis is most common at the base of the second metatarsal\(^14\). The lateral column, which has the greatest sagittal plane motion, is the least likely to be involved in posttraumatic arthritis. This is an interesting concept since movement of these joints must somehow be correlated with the functional outcome of treatment.

One should not assume that an injury to the tarsometatarsal joints includes only the base of the metatarsals and the corresponding cuneiform and cuboid. Frequently, there is involvement of the intercuneiform space or the naviculocuneiform joints. This was reported in 1986\(^15\), and since that time this pattern of injury has been observed far more frequently in athletes and, in the United States, particularly in American football players. The instability, and therefore the potential for posttraumatic arthritis, is greater with this pattern of tarsometatarsal as well as intertarsal injury, and treatment of these injuries differs from that of the more common isolated middle-column subluxation. We should therefore avoid using the eponym “Lisfranc injuries” as well as the term “tarsometatarsal joint” and use the broader term “tarsometatarsal joint complex” to refer to all types of injuries in the midfoot.
Classification systems are useful for comparison of one study with another, and they can help to guide treatment and describe the radiographic appearance of traumatic high-energy injuries. They are less helpful in the diagnosis and management of the more isolated and subtle injuries in athletes. Having said this, we still believe that they provide a good framework for the concept of three functional columns. Ligamentous injuries in athletes are routinely classified with use of the American Medical Association’s Standardized Nomenclature of Athletic Injuries. First and second-degree sprains are defined as partial tears, and a third-degree sprain is a complete rupture of the ligamentous support. Nunley and Vertullo reported on the management of midfoot sprains in fifteen athletes and created a new classification system to address subtle tarsometatarsal injuries with minimal or no displacement seen on weight-bearing radiographs. They classified the injury on the basis of clinical findings, radiographs, and bone scintigrams. With stage-I injuries, patients were able to bear weight but could not return to playing sports; <2 mm of diastasis between the first and second metatarsals was seen on the weight-bearing anteroposterior radiographs. The physical findings associated with stage-II injuries were similar to those seen in stage I, but there was 2 to 5 mm of diastasis between the first and second metatarsals. Despite the instability of the first-second tarsometatarsal joint seen on anteroposterior radiographs, lateral radiographs showed no collapse of arch height (Figs. 1-A and 1-B). Stage III included injuries to both the first and the second intermetatarsal space, with diastasis, but there was loss of arch height, defined by a decreased distance between the fifth metatarsal and the medial cuneiform as seen on lateral weight-bearing radiographs. When using this classification system, one has to be certain that the patient is able to fully bear weight since weight-bearing and/or stress radiographs are an important tool in the diagnosis and planning of treatment.

Diagnosis
A midfoot sprain is often subtle, and, when examining an athlete, one should have a high index of suspicion for a tarsometatarsal injury since it is not as easy to diagnose as a high-velocity injury. Often, the athlete describes a "pop" in the foot occurring at the time of injury and has pain that is aggravated by weight-bearing. One should look for asymmetry between the first and second toes, subtle swelling, and point tenderness over the midfoot. Planter ecchymosis confined to the midfoot is a clinical finding that is highly suggestive of a midfoot injury in an athlete. Gentle manipulation of the midfoot by passively pronating and abducting the forefoot can be used to assess the stability of the tarsometatarsal complex (Fig. 2). Passive dorsiflexion and abduction of the forefoot places a strain...
across the medial column, and pain will serve as an "apprehension sign."\(^{17,19}\)

Shapiro et al. described two provocative maneuvers that they found to produce pain in some athletes with a tarsometatarsal injury: (1) compression of the midfoot and (2) dorsal and plantar deviation of the first metatarsal head while the examiner stabilizes the second metatarsal head. One must not assume that simple manipulation of the first metatarsal in the sagittal plane is diagnostic since the medial column is frequently not involved in the injury and the first metatarsocuneiform joint may be asymptomatic. Another clinical stress test consists of squeezing the first-second interspace in the coronal plane to stress the base of the middle and the medial column in an attempt to elicit pain or a palpable click (Fig. 3). We have found this test to be more specific for the diagnosis of injury. There can be a diastasis between the first and second metatarsals or a diastasis between the medial and middle cuneiforms combined with a diastasis between the first and second metatarsals. In the latter situation, compression of the interspace under fluoroscopy will confirm the extent of the instability.

When an injury to the tarsometatarsal joint complex is suspected, standard radiographs of the foot (preferably made while the patient is bearing weight), including anteroposterior, \(30^\circ\) internal oblique, and lateral views, should be made. The goal of diagnosis is to determine if there is displacement or instability of the joints, since this indicates whether operative treatment is needed. Normally, the medial border of the second metatarsal lines up with the medial border of the middle cuneiform on the anteroposterior radiograph, and the medial border of the fourth metatarsal lines up with the medial border of the cuboid on the oblique radiograph. Displacement of >2 mm between the first and second metatarsal bases should raise the suspicion of a tarsometatarsal injury and must be compared with the first-second intermetatarsal space in the contralateral foot. One of us (M.S.M.) and colleagues\(^{13}\) described the fleck sign, which is a small avulsion fragment arising from either the lateral edge of the medial cuneiform or the medial aspect of the second metatarsal base. These fragments are the points of attachment of the tarsometatarsal (Lisfranc) ligament. A lateral radiograph should show the normal continuity from the dorsal cortex of the first metatarsal to the medial cuneiform. Faciszewski et al. emphasized that the lateral weight-bearing radiograph helps to differentiate a simple sprain from a complex ligamentous disruption\(^{20}\). They calculated the distance from the plantar base of the fifth metatarsal to the base of the medial cuneiform and compared it with the distance in the uninjured foot. Patients with a negative value (the medial cuneiform was plantar to the base of the fifth metatarsal) had collapse of the longitudinal arch and poor outcomes.
If a patient presents with pain in the midfoot following an injury and radiographs demonstrate normal findings, the next step should be to evaluate the stability of the midfoot. A tarsometatarsal injury and its stability are documented with bilateral radiographs made with the patient bearing as much weight as tolerated on the injured foot (Figs. 4-A and 4-B). Because of pain, weight-bearing on the injured foot may not be easy for the patient, but weight-bearing will often demonstrate subtle shifts of the midfoot that are otherwise not apparent. It has been estimated that 20% of tarsometatarsal joint injuries are missed on the initial radiographs. Stress radiographs, computed tomography, and magnetic resonance imaging are indicated if initial radiographs show normal or equivocal findings when a tarsometatarsal injury is suspected.

Stress radiographs are very important if a diagnosis of midfoot injury is suspected because of tenderness over the tarsometatarsal joint complex but the radiographic findings are either normal or equivocal. Stress radiographs should be performed with the patient under appropriate anesthesia and with fluoroscopy. Curtis et al. recommended manipulation of the midfoot with passive pronation and simultaneous abduction. They believed that the pronation-abduction stress test was sensitive and assisted in determining patterns of instability, and they found it to be particularly useful for distinguishing unstable third-degree sprains from stable first and second-degree sprains in athletes. There can be variation between the instability in the medial column and that in the middle column, and the instability can extend between the cuneiforms. This pattern of injury is not easy to demonstrate with a standard passive pronation-abduction test; therefore, another stress test, consisting of squeezing between the medial and middle columns and looking for radiographic evidence of instability, can be used. Nunley and Vertullo disputed the utility of stress radiographs because the investigator can exert only limited force on the tarsometatarsal complex manually, as compared with weight-bearing, and there is lack of standardized criteria for defining the result. This has not been our experience, and since the stress radiographs are always performed with the patient under anesthesia we believe that they are a reliable indicator of the pattern of instability that is present.

When a patient has a suspected midfoot injury and the weight-bearing radiographs do not demonstrate instability, we routinely perform stress radiographs with the patient under anesthesia to guide our treatment. The most frequent unexpected pattern of displacement or instability that we see on stress radiographs is displacement at the first
metatarsocuneiform joint or the intercuneiform joints.

Computed tomography can detect subtle injuries of the tarsometatarsal joint complex. In a cadaver study, Lu et al. compared the sensitivity of computed tomography scans and plain radiographs in detecting subtle injuries at the tarsometatarsal region. Displacements of <2 mm were seen on the computed tomography scans of all twelve specimens but were appreciated on the plain radiographs of only two. However, computed tomography can be too sensitive, often demonstrating fractures that do not require treatment if the foot is stable. Furthermore, computed tomography imaging is a static test that cannot be used to assess stability. The most appropriate indication for performing a computed tomography scan for a patient with a tarsometatarsal injury is a complex midfoot injury with comminution, as the choice of surgical management may be affected by the findings.

Magnetic resonance imaging is another very sensitive study that can be used to diagnose subtle and purely ligamentous midfoot injuries in the absence of subluxation or dislocation (Fig. 5). A magnetic resonance imaging scan is not necessary in the presence of obvious diastasis. Rather, it should be employed to confirm the diagnosis and guide the treatment of a stable tarsometatarsal sprain as determined by stress radiographs.

Bone scintigraphy is another imaging tool that can be used to help to diagnose subtle midfoot injuries or those for which the diagnosis was delayed. Nunley and Vertullo reported that fifteen athletes with a midfoot sprain all had positive bone scans. They argued that bone scans are widely available, easy to interpret, and inexpensive and can remain positive for over a year after a midfoot injury.

**Nonoperative Treatment**

Nonoperative treatment is rarely indicated for unstable injuries of the tarsometatarsal joint complex. The extent of displacement correlates with the outcome. Residual displacement of as little as 2 mm decreases the articular contact area, and surgery is probably indicated for even minimally displaced fracture-dislocations of the tarsometatarsal joints. Left untreated, the majority of displaced midfoot sprains lead to arthritis. Operative treatment is certainly recommended for all obviously displaced injuries. However, the role of nonoperative treatment for stable and minimally displaced injuries, particularly in an athlete, has been less clearly delineated in the literature. Curtis et al. performed a retrospective study of nineteen athletes with a tarsometatarsal joint injury. Seven of their nine patients with no diastasis had a good-to-excellent result of nonoperative treatment. Two of three patients with a third-degree sprain were treated with open reduction and internal fixation and had a good or excellent result, whereas the third, treated with cast immobilization, was unable to return to sports. Curtis et al. concluded that poor functional results were commonly correlated with a delay in diagnosis and inadequate treatment of unstable injuries with nonoperative immobilization. Faciszewski et al. reviewed the cases of fifteen patients with a subtle tarsometatarsal injury, defined as a diastasis between the first and second metatarsal bases of between 2 and 5 mm. They recognized that some patients with residual displacement had a good result and sought to identify factors that might be associated with good or poor functional outcomes. They found no correlation between the extent of the diastasis and the patient’s functional outcome. They proposed that maintenance of the longitudinal arch is the critical factor necessary to achieve a good outcome. Shapiro et al. reported on nine athletes with an isolated rupture of the tarsometatarsal ligament. Eight were treated with a removable splint for four to six weeks followed by progressive weight-bearing. One patient, with the widest diastasis (5 mm), opted for surgical treatment. All patients were able to return to playing sports; however, the average time until they returned was 14.5 weeks. On the basis of a review of the results in fifteen athletes with a tarsometatarsal injury, Nunley and Vertullo recommended that stage-I (nondisplaced) injuries be treated conservatively with a non-weight-bearing cast for six weeks, followed by the use of a custom orthosis, and that stage-II injuries (those with diastasis) and stage-III injuries (those
with diastasis combined with loss of arch height) should be treated with anatomic reduction and internal fixation.

We believe that, if the midfoot is injured but no instability is noted on weight-bearing or stress radiographs, the injury is a stable sprain and can be treated with immobilization in a boot. As long as the foot remains stable on repeat weight-bearing radiographs made two weeks later, weight-bearing is permitted as tolerated. We typically add a firm off-the-shelf padded orthotic arch support inside the boot, which is used until there is no midfoot pain on firm palpation and on stress examination with forced (but gentle) passive pronation and abduction of the midfoot. At six to eight weeks, the midfoot is examined for tenderness. Weight-bearing out of the boot may commence once there is no pain on stress, but the return to activities must be closely monitored. The athlete is permitted to resume training and exercise but may not engage in any activity that involves pronation, torque, or twisting of the midfoot. It is recommended that a stiff-soled shoe with a rigid orthotic support inside it be worn for six months. These modifications are for both daily shoe wear as well as athletic shoes. An alternative to the stiff orthotic is a steel shank added to the sole of the shoe to inhibit midfoot motion and minimize midfoot torque. The athlete is allowed to return to exercises but initially performs them in a swimming pool and on stationary machines, including running on a treadmill. Running on an uneven surface and twisting or cutting activities are not permitted for four months. Many athletes return to activities including running, football, and other ball sports by three months after a non-displaced sprain, but it is not realistic to expect a full recovery before this time.

The timing of the return to full athletic activities by these patients depends on the severity of the sprain and the type of treatment. The protocol for rehabilitation is the same as that after operative treatment, but the return to full athletic activity can be as long as eight to nine months after these severe sprains.

**Operative Management**

Surgery is indicated for displaced fractures and dislocations as well as unstable ligamentous injuries. Once it is decided to proceed with surgery, several questions should be asked. When should the surgery be performed? If there has been a delay in diagnosis, is it too late for surgery? Should the procedure be performed percutaneously or open? Which type of fixation is better: Kirschner wires, screws, or a ligament reconstruction? When should a primary arthrodesis be performed? How should the patient be managed postoperatively? When should the hardware be removed? When can the athlete expect to return to functional and sports activities?

**Timing of Surgery**

As a general rule, the sooner that surgery can be performed, the quicker the rehabilitation. It is ideal, however, to perform the surgery when the swelling has decreased, unless a percutaneous approach to fixation is to be used. The most important factor influencing the decision regarding the timing of surgery is the associated injury to the soft tissues, particularly when there has been a direct crushing type of injury to the foot. In the absence of a compartment syndrome, the use of an intermittent-compression foot-pump device can facilitate reduction of the soft-tissue edema. If the diagnosis is missed, delayed surgery without arthrodesis may still be performed successfully, but preferably the operation should be done within six weeks after the injury. Displaced fractures and dislocations are difficult to reduce after two months, and a satisfactory outcome is less likely if deformity persists. However, we have performed successful open reductions of tarsometatarsal joint subluxations, associated with neither a fracture nor arthritis, up to a year after the injury. The success of such a late reduction depends on the extent of articular incongruity, and it cannot be accomplished in the presence of a malunited fracture. Generally, in these cases of late reduction, it is preferable to do an open reduction and perhaps even a delayed primary arthrodesis rather than use the percutaneous method of treatment, since the thick scar in the first web space must be resected in order to reduce the joints.

**Percutaneous Compared with Open Fixation**

An anatomic reduction is the most important goal of the treatment of injuries of the tarsometatarsal joint complex, and the quality of the reduction has been shown to correlate with the outcome. Dislocations are easy to reduce closed, and closed reduction should be attempted for all patients regardless of the type of fixation that is to be used. Under fluoroscopic visualization, first gentle axial traction is applied by pulling on the hallux and lesser toes while the hindfoot is pulled posteriorly. Then, slight pressure is applied at the midfoot, and the forefoot is pulled medially. Once the articulation is noted to be in reasonable alignment, the reduction is maintained with a large bone-reduction clamp, applied between the base of the second metatarsal and the medial cuneiform. When the clamp is carefully squeezed, the base of the second metatarsal is gradually reduced into its anatomic position.

Once the dislocation has been reduced, the type of internal fixation can be chosen. We generally use cannulated screws placed over a guide pin. The sequence of fixation is important. Although the middle column is the point around which the rest of the midfoot gains stability, the medial column is fixed first. Assessment of instability of the first tarsometatarsal joint is very important, and this is where stress evaluation of the joint helps. Although subluxation of the second tarsometatarsal joint is usually obvious, manipulation of the foot with passive pronation and abduction will identify subluxation of the first tarsometatarsal joint. The fixation of the first tarsometatarsal joint is performed by pulling the hallux into varus and simultaneously pushing laterally on the base of the first metatarsal with the thumb, which forces the first metatarsal into alignment with the medial cuneiform (Figs. 6-A and 6-B). Once the first metatarsal is fixed with a guide pin, the
middle column is reduced with the bone-reduction clamp, and a partially threaded screw is inserted obliquely from the medial cuneiform into the second metatarsal, compressing the base of the second metatarsal into the mortise, which locks it into place (Fig. 7).

If closed reduction does not succeed, the failure is usually due to a bone fragment or soft tissue interposed at the base of the second metatarsal. Soft-tissue interposition (for example, a torn tarsometatarsal ligament) does not typically block reduction, since the ligament falls to the plantar surface of the foot. If, however, it is not possible to reduce the injury by closed means, open reduction and internal fixation is indicated. We prefer one longitudinal incision placed over the dorsum of the involved tarsometatarsal joints. If more than one incision is used, then it is important to maintain as wide a skin bridge as possible.

One exception to the order of reduction is in the presence of a Lisfranc injury with a fracture and a shortened cuboid. The length of the cuboid and the lateral column of the foot must be restored to normal to avoid a permanent abduction deformity of the forefoot. Although fractures of the cuboid are infrequently associated with low-energy athletic injuries, if the cuboid is fractured the first step should be a lateral reduction. This restores the length of the cuboid, which in turn helps to align and reduce the middle and medial columns. If the cuboid cannot be reduced manually, an indirect reduction technique with temporary external fixation to lengthen the lateral column of the foot can be used. Pins are placed into the fifth metatarsal and the calcaneus, and a distractor is applied between the pins. The articular surfaces of the cuboid are inspected. Comminuted fragments should be elevated if that is necessary to restore the surface congruity. Fixation of the cuboid is frequently difficult. An H-plate can be used to maintain its length (Fig. 8). Spanning the cuboid with the H-plate either to the bases of the fourth and fifth metatarsals or to the calcaneus may be necessary. The plate is removed once the cuboid fracture has healed.

**Fixation**

Early reports described pin fixation alone, and supporters of Kirschner-wire fixation can be found in the literature\(^1\,\!^2\,\!^3\). Kirschner wires have a limited role in the treatment of midfoot injuries, but they should rarely be used as the sole form of fixation. Kirschner wires are easy to insert and easy to pull out. Thus, if they are used, the reduction may be lost if they become loose or back out. This leads to failure because the joints must be reduced and held reduced for at least four months. Kirschner wires can be used to stabilize the lateral column of the foot, where rigid fixation can result in functional loss of motion. They are inserted obliquely from the bases of the fourth and fifth metatarsals into the cuboid or more medially into the cuneiforms. Kirschner wires should be buried subcutaneously to decrease the risk of infection.
Current recommendations generally are for more rigid fixation than can be obtained with Kirschner wires. Lee et al. found that screw fixation provided more stability to the medial and middle columns than did Kirschner-wire fixation in a cadaver model of the tarsometatarsal joint complex (Figs. 9-A and 9-B). Thordarson and Hurvitz studied fourteen patients treated with polylactide screws to fix tarsometatarsal injuries. At twenty months, there was no local soft-tissue reaction, osteolysis, or loss of reduction. Because screw fixation placed across articular surfaces clearly can damage the joint, application of a dorsal plate to the first and/or second tarsometatarsal articulation to avoid the use of crossing intra-articular screws has been studied. Alberta et al. compared fixation with transarticular 3.5-mm screws with fixation with a dorsal one-third tubular plate in a tarsometatarsal cadaver model and found no difference in the resistance to tarsometatarsal joint displacement with a weight-bearing load. These plates can be removed at the same time that screws traditionally have been removed: once the articulation is stable, at between fourteen and sixteen weeks.

**Primary Arthrodesis**

Primary arthrodesis has recently been advocated for some tarsometatarsal injuries. This may be an alternative treatment for severely comminuted intra-articular fractures, but such fractures are not typical of the low-energy injuries that we encounter in athletes. There is minimal motion in the middle-column joints, and an arthrodesis may have the same outcome as reduction and internal fixation. However, when a primary arthrodesis is performed, more dissection is required, more bone is removed, small articular fragments are removed, larger defects may require bone-grafting, and it is more difficult to achieve fixation. We rarely perform a primary arthrodesis in an athlete.

In a randomized prospective study, Ly and Coetzee compared open reduction and internal fixation with primary arthrodesis in forty-one patients who had an isolated ligamentous tarsometatarsal injury. They found that the group treated with the primary arthrodesis had more rapid recovery, a higher final foot function score, and a superior return to function. Furthermore, five patients in the open reduction and internal fixation group were ultimately treated with an arthrodesis. However, these five patients all had a high-energy injury, and none were high-performance athletes. Mulier et al. studied a group of patients randomized to treatment by two surgeons, one who performed an arthrodesis and one who performed an open reduction and internal fixation, and found far more complications and complaints of stiffness in the group treated with the arthrodesis. While arthrodesis decreased the symptoms of posttraumatic arthritis, the majority of these patients had a preoperative deformity that required correction and few underwent an isolated single-column arthrodesis. In summary, although primary arthrodesis has been advocated by a few authors, it is a difficult operation and the resulting stiffness may not be desirable when compared with the outcome in a patient who recovers well from open reduction and internal fixation or closed reduction and internal fixation. Primary arthrodesis is not recommended for athletes, regardless of the potential for a rapid return to activity. We believe that maintenance of motion in the medial column as well as the limited motion in the middle column is necessary to restore full function in these patients.

**Ligament Reconstruction**

Ligament reconstruction is an option for the treatment of an acute midfoot subluxation. The procedure is particularly applicable to an isolated subluxation that is associated with diastasis...
between the middle and medial columns. In the ideal case, the tarsometatarsal ligament would be restored directly or indirectly, but it is not possible to directly repair this ligament. It passes from the base of the second metatarsal obliquely into the distal-lateral edge of the medial cuneiform. It is extremely strong and is situated on the plantar surface of the joint, making direct repair impossible. However, indirect reconstruction of the ligament was described by Nery, who used different tendon-graft substitutes, passed through drill holes placed to recreate the isometry and anatomy of the Lisfranc ligament. Nery followed eighteen patients for an average of six years after treatment of a tarsometatarsal injury with a “neoligament plasty.” Fifteen of the eighteen patients had a good-to-excellent result according to their foot function score. However, we are not aware of any other studies evaluating this technique, and at this point ligamentous repair or reconstruction should be considered investigational.

Postoperative Management
In the postoperative period, several issues must be addressed, including the duration of immobilization and limited weight-bearing, when activity and exercise can be resumed, and most importantly when to remove the internal fixation. Most athletes do not return to full athletic function until at least eight months after an open reduction, and it may take up to one year before high-performance athletes are asymptomatic. Nunley and Vertullo reported a 93% rate of excellent outcomes in athletes with a stage-I or II injury who had been treated with open reduction, with the athletes returning to playing sports at an average of 14.4 weeks. This rapid return to sports activity has not been the case in our experience. Rather, it has been rare that an athlete has been able to return to unrestricted sports activity, particularly those involving twisting and cutting movements, before six months.

Early active motion of the adjacent joints combined with protected weight-bearing is ideal for patients treated with rigid screw fixation. No weight-bearing is allowed for two weeks, but partial protected weight-bearing in a walking boot is permitted once the incisions have healed. Athletes can begin activity in a swimming pool three weeks postoperatively, followed by exercise on a stationary bicycle with high repetitions and little resistance by four weeks. Progressive weight-bearing in a boot is begun at six weeks, and use of the boot is discontinued between eight and ten weeks, as dictated by the symptoms. When the athlete begins walking without the boot, he or she wears a shoe that has been stiffened as much as possible with the addition of a very rigid orthotic arch support. Alternatively, a carbon-fiber or graphite orthotic plate can be placed inside the shoe. This rigid support is particularly important when the patient returns to athletic activity, since most athletic shoes are quite flexible. As the athlete increases sports activity, he or she is monitored for aching, soreness, and swelling of the midfoot. When the athlete begins running in a swimming pool, we allow more activity on a bicycle and an elliptical trainer, and ultimately we permit running on a treadmill. Running on grass or the beach with cutting activities is not permitted for about six months because of the torsion that these activities place on the midfoot.

Removal of Hardware
Internal fixation is maintained for a minimum of four months to allow ligamentous healing. Compared with fractures of the forefoot, these dislocations take far longer to heal and far more time is needed to achieve joint stability. There are even times when the hardware is left in permanently if the patient is asymptomatic. Motion does occur between the medial and middle columns of the foot, and this will ultimately lead to
fatigue failure of the fixation in some patients. In some cases, aching and pain start to develop in the midfoot at about three months following surgery. If there is any concern about the stability of the midfoot and healing of the ligaments, then the patient should start wearing the boot again and the rehabilitation intensity should be decreased until the symptoms fully resolve. Another alternative that has recently been discussed, but not yet described in the published literature, is to remove the screws and substitute a fixation suture (the so-called tightrope system) to stabilize the midfoot. This permits motion at the first-second articulation, is less rigid than screw fixation, and may facilitate rehabilitation with less risk of recurrent subluxation. If there is any uncertainty regarding the stability of the foot, it is prudent to maintain fixation for as long as possible.

Mark S. Myerson, MD
Rebecca A. Cerrato, MD

The Institute for Foot and Ankle Reconstruction at Mercy,
301 St. Paul Place, Baltimore, MD 21202.
E-mail address for R.A. Cerrato: boohincck2@yahoo.com

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