CHAPTER 12

INTERNAL FIXATION IN PODIATRIC SURGERY

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While various types of internal fixation have been used in foot surgery for many years, it was not until the mid to late 1970s that the science of internal fixation began to be applied to podiatric procedures. While many different ingenious innovations were explored, it was not until the study and adoption of the Swiss techniques for rigid internal fixation that consistency in planning, execution, and management of bone surgery was accomplished.

The application of the Swiss techniques to modern foot surgery incorporates a number of specific principles for a successful solution to the problem of bone surgery. Some of these factors include: osteotomy design and configuration, osteotomy location, techniques of internal fixation, postoperative management, and patient selection. These areas of concern are both technical and philosophical. All factors must be incorporated into the treatment plan for any patient, and failure to adhere to any one of these specific areas can lead to failure of the internal fixation technique.

A fundamental precept for success in internal fixation of bone surgery is mechanical stability. Mechanical stability is afforded through a variety of different concepts including: fixation technique, intrinsic factors, and extrinsic factors.

Intrinsic factors include the fracture configuration, size of fragments, and orientation of the fracture or osteotomy lines. Bone quality is also a factor for success of internal fixation.

Extrinsic forces are those forces which tend to disrupt the osteotomy. These are identified as bending, torsion, and shear. The goal of internal fixation is to resist these forces and protect the osteotomy or fracture site while healing occurs.

FIVE MECHANICAL TECHNIQUES OF INTERNAL FIXATION

Internal fixation can be accomplished through a wide variety of surgical techniques. There are five common applications currently used in foot surgery.

1. K-wire fixation
2. Intraosseous wire loop fixation
3. Lag screw fixation
4. Plate fixation
5. External fixators (The discussion of external fixators will not be presented in this article.)

K-Wire Fixation

K-wires or Steinmann pins have been the most common devices used in past techniques of internal fixation (Fig. 1). The basic premise of their application is splintage. The techniques of splintage can protect an osteotomy or fracture site from bending forces. A modification of the K-wire technique can also protect against torsion or distraction forces however, the use of K-wires alone does not afford the fundamental component of compression to an osteotomy or fracture site.

Crossed K-wire. The use of crossed K-wires is probably the most efficient use of these devices in a successful internal splintage technique (Fig. 2). A single K-wire will allow for distraction of fragments

Figure 1. A transverse base wedge osteotomy of the first metatarsal is fixated with a single K-wire. While this technique affords a minimal degree of splinting, it does little to protect against rotation forces or possible distraction of the osteotomy site by movement along the axis of the pin.

Figure 2. A second K-wire is added to the transverse base wedge osteotomy. This technique protects the site against rotation around the primary pin. The osteotomy has been held in good contact while the second K-wire has been driven in a distal proximal direction which captures the contact of the osteotomy surfaces.

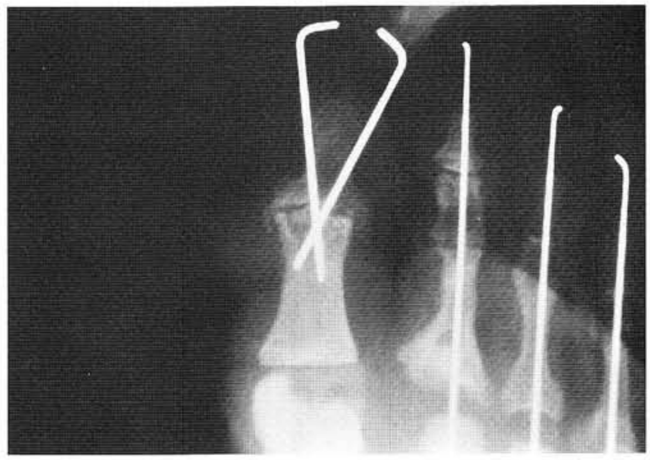

Figure 3. A crossed K-wire technique is used in hallux IPJ fusion where an implant has been placed in the first MPJ. The use of an intramedullary screw is not possible in this situation because of the presence of the stem of the implant.

Figure 4. Complications with an Austin technique have required the use of multiple K-wires in a crossed K-wire configuration. This technique will stabilize the capital fragment, preventing rotation, distraction, or additional movement of the osteotomy site.

along the axis of the K-wire, as well as rotation around the axis of the primary wire fixation. The addition of a second K-wire in a different plane or angle will block rotation around the primary fixation pin, and also prevent distraction or movement along the primary axis of the first fixation pin. Care should be taken when using crossed K-wire technique, to maintain contact of bone surfaces while the second K-wire is driven to avoid distraction of the osteotomy or fracture site, which will be captured once the second pin is seated.

There are a wide variety of applications of the crossed K-wire technique. These include areas where the bone quality or substance is too soft to accept the more traditional forms of screw fixation, or areas where the introduction of a screw or plate would impinge upon some other structure, such as an implant in the great toe joint (Fig. 3). The crossed K-wire technique is a valuable adjunct technique to be used if a primary form of internal fixation fails (Fig. 4).

Intraosseous Wire Loop Fixation

The use of wire loop fixation was originally popularized in the 1960s for base wedge osteotomies of the first metatarsal (Fig. 5). A single wire loop was used to capture the dorsal cortex of the first metatarsal osteotomy. This technique afforded apposition of the dorsal surface of the osteotomy, but afforded little protection of the osteotomy site itself. Common complications of this technique included dorsiflexion, as the internal fixation device did little to protect movement of the first metatarsal.

A technique of intraosseous wire loop fixation was described by Gingrass et al.[1] The technique described included the application of a horizontal or vertical wire loop through four cortices of the bone (Figs. 6A-6D). The plane of the wire loop is perpendicular to the surface of the osteotomy or fracture line, and is placed midway between the dorsal and plantar, or medial and lateral surfaces of the bone. This technique creates compression of the osteotomy surface, and acts as a tension band device as movement in dorsiflexion or plantar flexion is blocked by the placement of the wire loop. Plantar flexion will initiate gapping of the dorsal cortex but is restricted by the placement of the wire loop and converts the force into compression of the plantar cortex. Similarly, dorsiflexion of the segment converts plantar distraction into compression of the dorsal cortex. This technique is most efficiently employed in transverse osteotomies of long bones such as the first and fifth metatarsal.

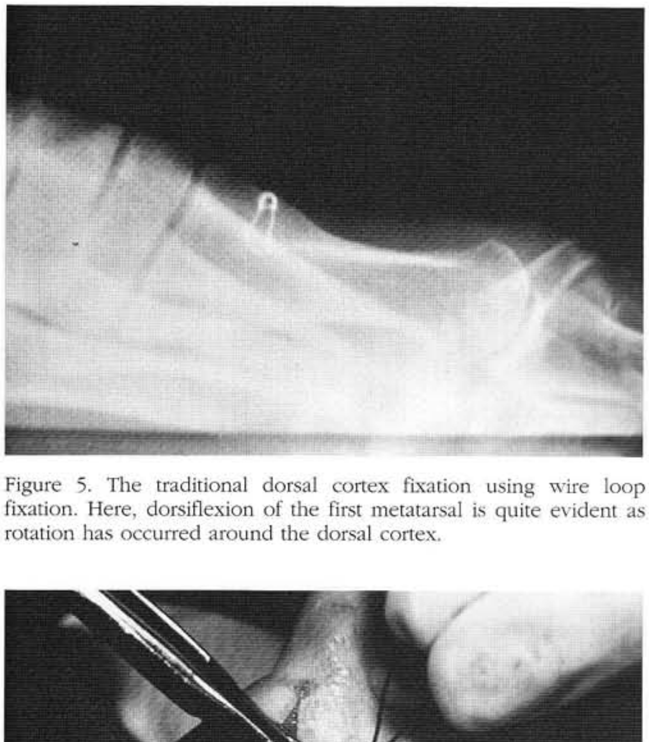

Figure 5. The traditional dorsal cortex fixation using wire loop fixation. Here, dorsiflexion of the first metatarsal is quite evident as rotation has occurred around the dorsal cortex.

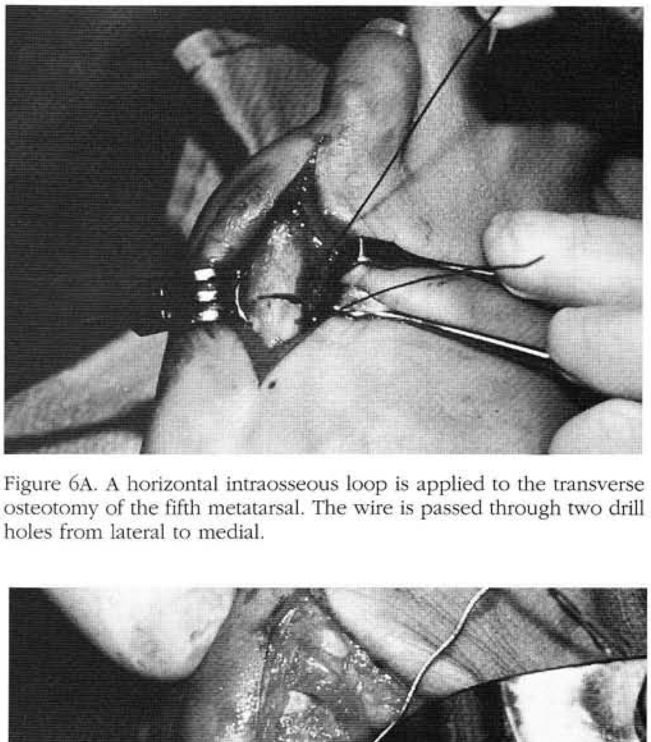

Figure 6A. A horizontal intraosseous loop is applied to the transverse osteotomy of the fifth metatarsal. The wire is passed through two drill holes from lateral to medial.

Figure 6B. The wire loop is tightened along the base of the osteotomy to compress the osteotomy.

Figure 6C. The wire loop is tightened and secured, affording primary compression of the osteotomy surface.

Figure 6D. Primary bone healing occurring in a transverse osteotomy of the fifth metatarsal with intraosseous wire loop fixation.

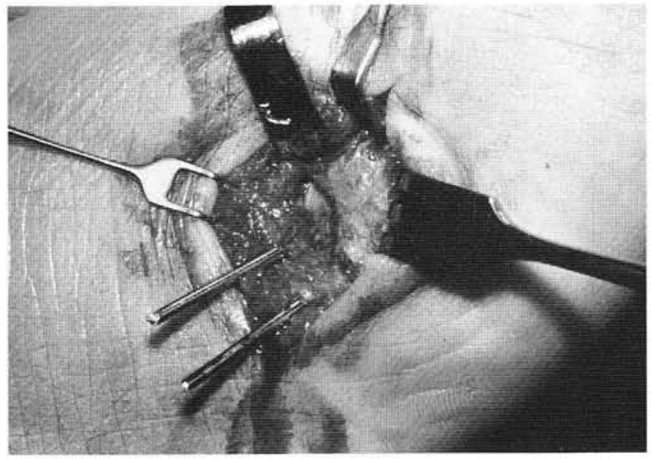

Figure 7A. An avulsion fracture of the base of the fifth metatarsal is initially fixated with two parallel K-wires.

Figure 7B. Intra-operative radiograph showing anatomic reduction of the fracture fragment and primary fixation.

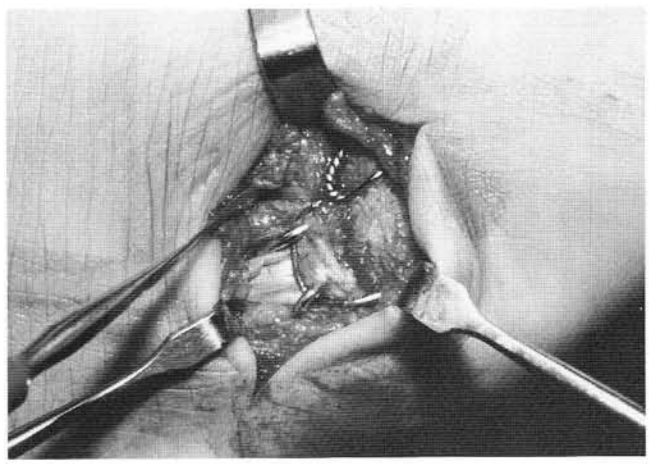

Figure 7C. An intraosseous wire loop is applied to the external surface of the fracture, incorporating the proximal fixation pins. The wire is tightened, creating compression across the osteotomy surface.

Figure 7D. Anatomic reduction of the fracture and a combination splintage and cerclage wire technique.

A combination of K-wire splintage and intraosseous wire loop fixation is commonly employed in avulsion fractures such as the fifth metatarsal base or medial malleolus (Figs. 7A-7D). This technique utilizes two parallel K-wires for internal splintage and then a intraosseous wire loop is applied to the external cortex in a classic tension band technique. This technique affords effective protection against bending forces as well as compression through the osteotomy site. The technique is useful in small fragments or softer bones where the use of screws may not provide adequate purchase of the bone fragments.

Lag Screw Fixation

The cornerstone of modern reconstructive foot surgery has incorporated the use of single screws as lag screws for compression of osteotomy and fracture sites. The technique is accomplished through the use of specifically-inserted cortical screws, as well as the traditional lag screw or partially threaded cancellous screw. This technique has enjoyed the widest variety of applications in foot and ankle surgery.

There are two basic fundamentals for the use of screws for lag compression.

1. The use of cortical screws requires over-drilling of the near cortex or creation of a gliding hole to create compression between the bone fragments.
2. If a cancellous or partially threaded screw is used, all threads on the distal portion of the screw must cross the fracture line and engage secure bone on the opposite site of the fracture to create effective compression.

Single screws may be effective for most small fragment configurations however, a single screw is dependent upon compression alone to protect the site from rotation. This factor must be taken into consideration in a wide variety of techniques. However, single screw fixation is a common and widely-used technique.

The most effective use of single screws is when two or more screws are combined for fixation of the particular fracture or osteotomy site. In most instances where an avulsion type fragment is fixated, the screws are placed parallel to each other.

The unique fracture configuration or osteotomy design of the oblique or long oblique fracture draws upon a different mechanical basis for stability of the osteosynthesis site. In long oblique fractures (Fig. 8), the initial fixation screw is placed perpendicular to the long axis of the bone. This screw is defined as the anchor screw, and prevents shortening or telescoping of the fracture itself. The additional screws are then placed in an orientation perpendicular to the plane of the fracture, and are the true compression screws for the fracture or osteotomy surface. This technique has become the primary standard for the classic oblique base wedge osteotomy of the first metatarsal (Fig. 9).

Figure 8. A long oblique fracture of the fibula fixated with single lag screws. The central screw is the anchor screw and is perpendicular to the long axis of the bone. The other screws are perpendicular to the plane of the fracture and are the compression screws.

Figure 9. The traditional oblique base wedge osteotomy of the first metatarsal. The proximal screw is perpendicular to the long axis of the bone and is the anchor screw. The oblique screw or distal screw is perpendicular to the plane of the fracture. This combination has proven to be the standard for base wedge osteotomies.

Plate Fixation

Although plate fixation in foot surgery is not common, it still has its specific areas for application. Plate fixation includes the use of two different types of plates including the thinner tension band plates and thicker dynamic compression plates (DCP). Both devices are employed with the same basic mechanical principles.

The simplest form of plate application is that when a plate is used as splint or as a neutralization plate (Fig. 10). This technique is used to protect a fragile osteosynthesis such as a short oblique fracture in a long bone. The short oblique fracture can be primarily fixated with a single compression screw, but it is not strong enough alone to protect the site from bending or other forces. A plate is applied neutrally to the external surface of the bone to protect the site from these disrupting forces. The plate is contoured to match the surface of the bone and all screws are drilled centrally to avoid any shift or movement of the fragment as the plate is secured to the bone.

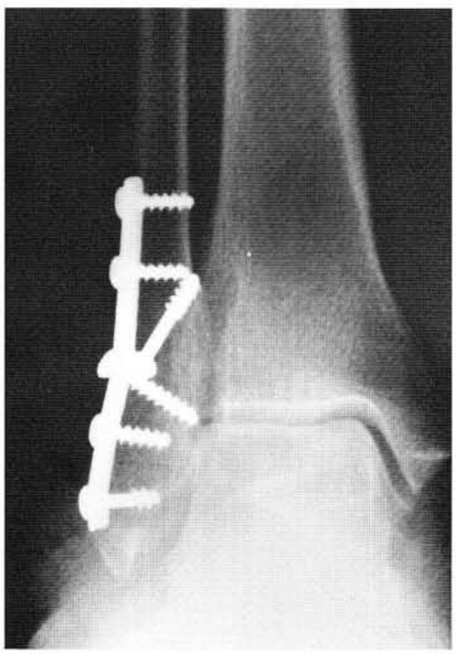

Figure 10. Combination fixation of the short oblique fracture of the fibular includes an interfragmental compression screw across the primary fracture line. The plate is then applied to the external cortex as a neutralization plate. It is contoured to the surface of the bone and all screws are drilled centrally within the plate to neutralize any disturbing forces across the osteosynthesis site.

A second use of plates is for creation of compression across the fracture or osteotomy site. This technique requires the contact surface of the bone is perpendicular to the long axis of the bone. This configuration will prevent telescoping or instability as the shift of fragments is created by the movement of the screws within the plate.

The technique of axial compression with a plate is accomplished with the load screw principle. The initial screw on either side of the fracture or osteotomy surface is offset drilled away from the fracture site. As the head of the screws seat themselves in the contours of the plate, the screw moves toward the fracture site, carrying the bone fragment with it, creating compression against the opposite surface. This technique tends to produce gapping on the opposite cortex and must be countered by pre-bending the plate to prevent distraction of the opposite cortex with tightening of the load screws.

A third use of plates incorporates both interfragmental compression with a single lag screw as well as compression with the plate itself (Fig. 11). This is a common application in foot surgery, especially in arthrodesis sites such as the first metatarsocuneiform joint for Lapidus fusion.

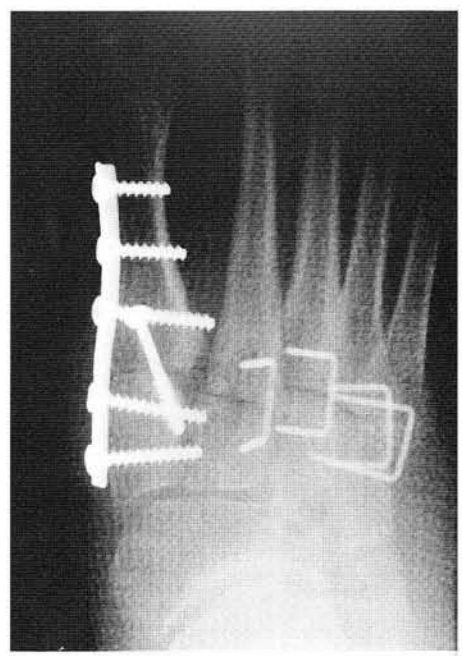

Figure 11. Additional combination technique using an interfragmental compression screw of the first metatarsocuneiform joint and then a medially applied tension band plate using the standard load screw technique to afford additional compression across the osteotomy surface.

The techniques of internal fixation have significantly changed the practice of podiatric surgery. It is through a combination of improved technique and a better understanding of the requirements of successful bone healing that physicians are better able to control the results of reconstructive surgery.

REFERENCE

1. Gingrass et al: Intraosseous wiring of Complex Hand Fractures. *Plast Reconst Surg* 66(3):383-394, 1980.