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Hallux IPJ fusion

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Fusion of the hallucal interphalangeal joint is a familiar procedure to all those who perform surgery of the distal lower extremities. Surgery of the toes has been discussed in the literature for over 100 years [1]. Jones wrote about deformities of the hallux and surgical correction in 1916, though hallucal fusion was the focus of few publications [2] in the next several decades. There was not much attention given to surgery of the hallux until larger surgical textbooks were devoted to the foot. DuVries and Kelikian wrote of hallucal fusions in their textbooks in the 1950s and 1960s [3,4]. Since that time there have been numerous references to the arthrodesis of the interphalangeal joint of the hallux in textbooks and journals with many methods described, some of which are reviewed in this article.

The primary goal of an interphalangeal arthrodesis is to provide a stable lever arm to compensate for the muscular imbalance between the long and short flexor tendons. By establishing a painless bony union, the function of the hallux may be restored. Although the surgical technique has remained fairly universal, the modes of fixation and resulting opinions are multiple.

Indications

Fusion of the hallux is done to overcome painful or otherwise deleterious deformity of the interphalangeal joint of the great toe. This usually results from a flexor/extensor tendon imbalance around the metatarsophalangeal joint complex [5]. Many of these deformities are caused by neuromuscular pathology and will

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manifest most often as a clawed hallux (hallux flexus, hallux malleus). Over the years, poliomyelitis has been the greatest cause of deformity in this group [6–11]. This viral infection is localized to the anterior horn cells and certain areas of the motor nuclei of the brainstem. It may cause progressive muscle weakness and paralysis that can be manifested as many as 30 years from initial virus contraction. Fortunately, in the western hemisphere, the virus has almost been eradicated [9].

Other neuromuscular etiologies of hallux deformity and the many times associated pes cavus foot are cerebral palsy (CP), Charcot-Marie-Tooth (CMT) disease, and Friedrich's ataxia [6]. CP is thought to be associated with cerebral ischemia either pre- or perinatally. The effecting mechanism of action on the victim is still not clear. This is not a progressive disease, and weakness and deformities should be apparent early in life. A peripheral demyelination syndrome, CMT usually becomes apparent in the second to third decade and is progressive. Friedrich's ataxia, a progressive destruction disorder of the axon and myelin, usually affects the victim in late childhood and will most likely start in the lower extremities [12].

Some classify indications for hallucal interphalangeal fusion according to the plane of the deformity. The clawed hallux discussed above would be a sagittal plane member along with an extensus deformity that is often seen in a hallux limitus. Transverse and frontal plane deformities can be present along with hallux abducto valgus or hallux varus [13]. Arthroses can cause deformities in all planes and might cause so much pain, even in a rectus great toe, that IPJ fusion is necessary to alleviate symptoms (Table 1) [6,14–16].

Incisional approach

The incisional approach to this procedure is solely the preference of the surgeon, as there is a wide variety described in the literature. One approach is two semielliptical incisions converging over the interphalangeal joint of hallux. The skin wedge is then excised en toto to reinforce the position of the fusion and to remove redundant soft tissue. Other surgeons prefer a curvilinear approach, such as a serpentine or L-shaped incision. Both provide adequate exposure to the joint and help to eliminate the amount of dorsal epidermal contracture that can occur postoperatively (Fig. 1). The more traditional linear longitudinal incision medial and parallel to the extensor hallucis longus tendon provides another option. Depending on the nature and etiology of the deformity, it may be necessary to

Table 1
Indications that may produce necessity of hallucal IP joint arthrodesis

Neuromuscular disorders	Post-polio syndrome, Cerebral palsy, Charcot-Marie-Tooth Disease, Friedrich's Ataxia, Hemiplegia, Myelodysplasia, Spina Bifida
Arthritic conditions	Traumatic arthritis, Psoriatic arthritis, Rheumatoid arthritis, Osteoarthritis
Iatrogenic	Hallux varus from overaggressive bunionectomy, Any procedure that initiates loss of intrinsic musculature, Sequelae following MTJ implant or fusion procedure
Congenital	Hallux valgus, Hallux varus, Hallucal IP deformity

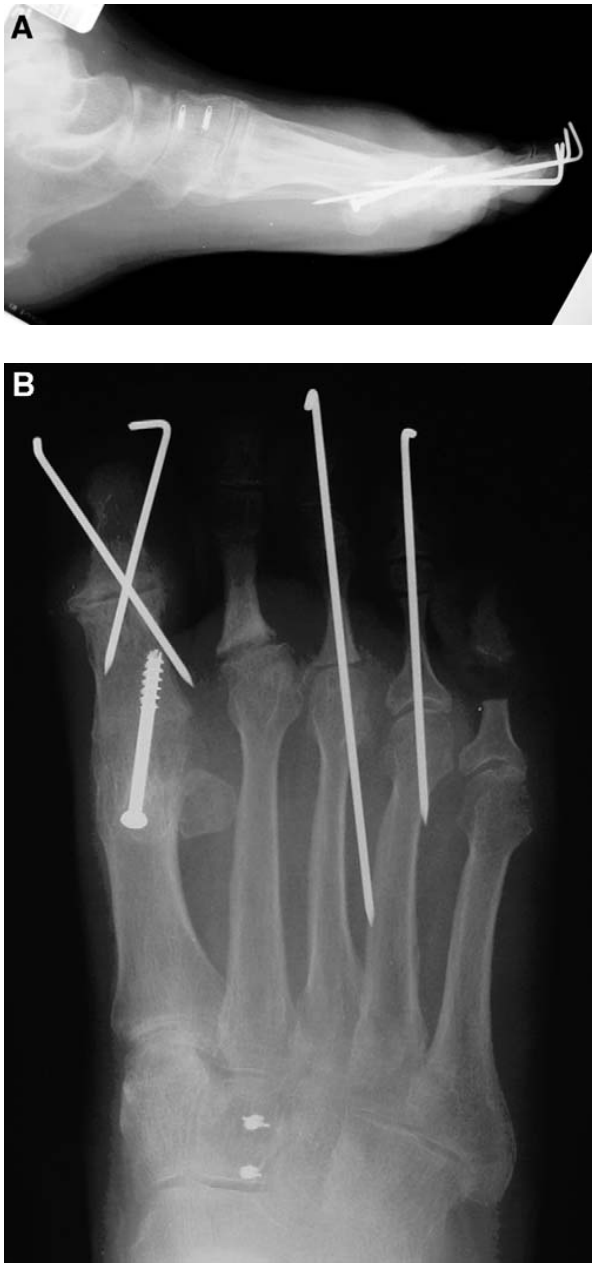


Fig. 1. (*A,B*) Surgical arthrodesis of hallux interphalangeal joint, screw fixation performed with serpentine (S-shaped) incision over the dorsal aspect of hallux IPJ, as to prevent dorsal contracture of distal hallux.

extend the incision proximally to the level of the metatarsophalangeal joint to perform soft tissue work, such as a capsulotomy. When planning the incisional approach, the need for ancillary procedures must also be considered.

Bone cuts

Preoperatively, the deformity must be assessed clinically and radiographically to determine if any osseous correction must be performed before fusion. If no

correction is necessary, an in situ type of arthrodesis may be performed by minimal resection of the articular surfaces, parallel to their existing position in the neutral plane. When accommodative changes are necessary, the osseous deformity must be corrected in two planes. The joint surfaces should either be resected perpendicular to the neutral plane or allow for slight abduction and dorsiflexion [15,17]. Any osseous correction must be obtained in the proximal phalanx, which

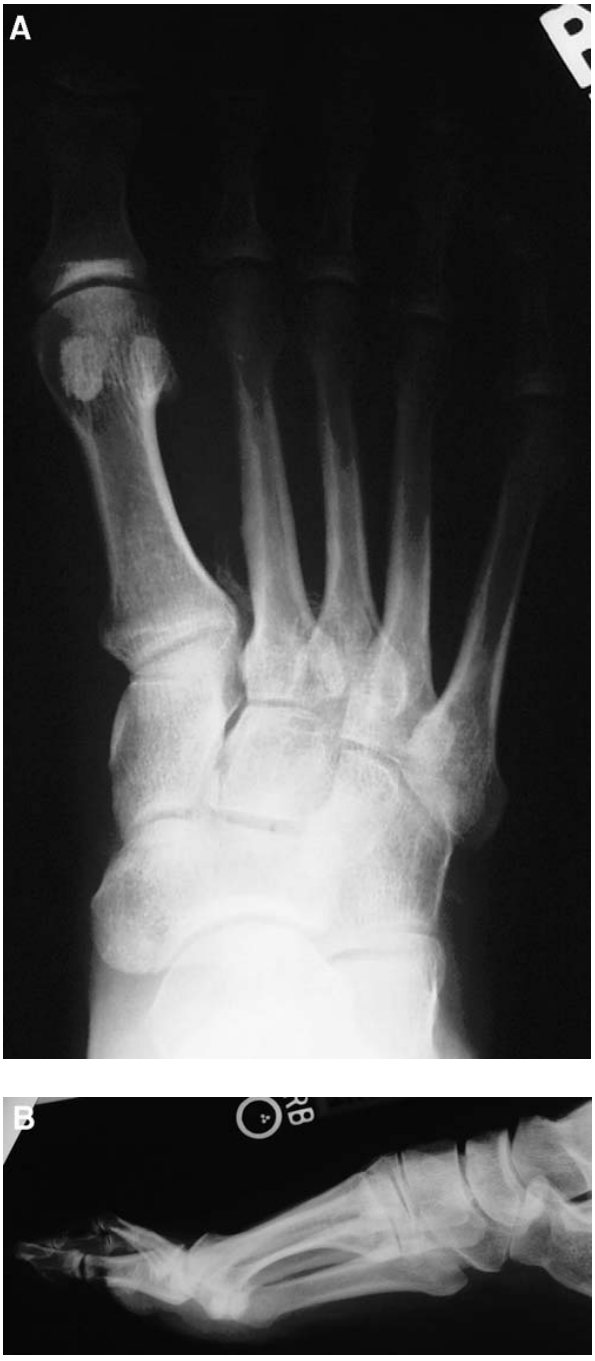


Fig. 2. (*A*–*D*) Surgical arthrodesis, hallux IPJ with frontal plane valgus rotation. Note the prominence of hallux plantar-lateral condyle.

is larger and possesses superior bone stock. Therefore, with resection arthrodesis, the flexion or valgus components are accounted for by removing more bone from the dorsal and medial aspect of the head of the proximal phalanx. In the frontal plane, care must be taken to avoid valgus rotation, as the remaining plantar condyle may become prominent, causing irritation with shoe gear and upon ambulation (Fig. 2).

Oscillating bone saws are the most common method of resecting bone from the proximal phalanx; however, hand instruments, such as osteotomes and bone cutters, are also used. Yu and associates believe that hand instruments yield a more effective fusion [18]. Because they create a rough interface, there is increased friction at the arthrodesis site and greater stability is achieved. Because of the size

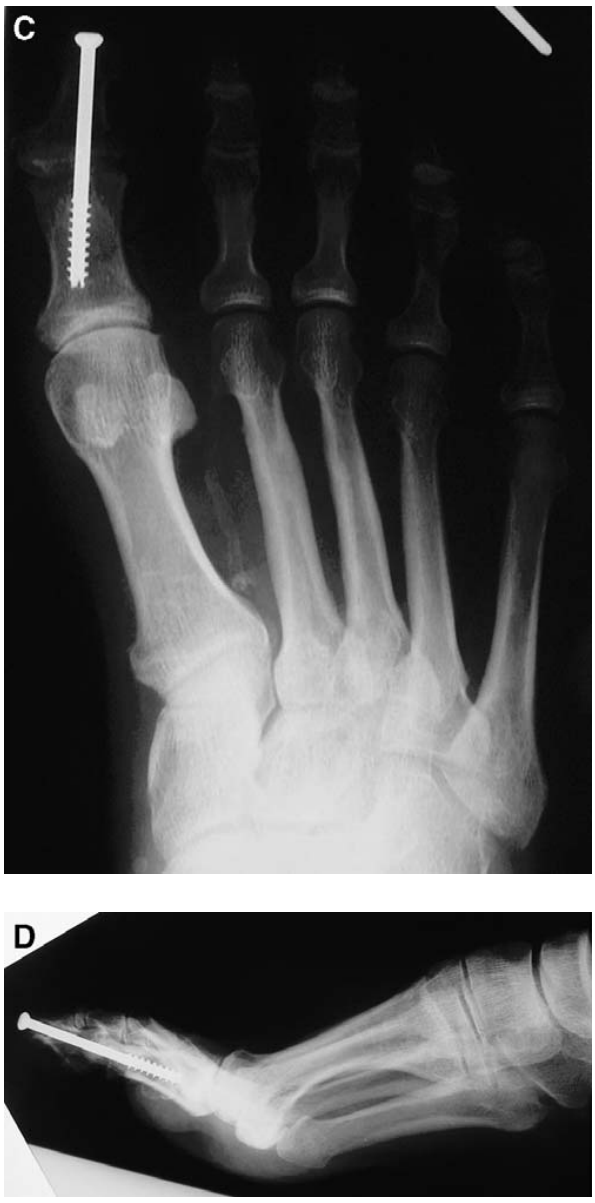


Fig. 2 (*continued*).

and bone stock of the distal phalanx, hand instruments or a power burr should be sufficient to resect the articular surface. Concomitant fenestration of the subchondral bone to enhance revascularization is highly suggested to encourage the fusion process. Overall, the key to a successful fusion is to achieve close apposition of the resected surfaces and, most importantly, the central cancellous bone.

Fixation

In the early 1900s the most common methods of achieving stability were by doubled 28-gauge monofilament wire and suturing the stub of the extensor hallucis longus tendon to the periosteum of the dorsal aspect of the proximal phalanx. In 1943, fixation of the interphalangeal joint by a longitudinal K-wire was introduced. Eventually, crossed K-wires and screw fixation became more prevalent secondary to the high incidence of nonunion achieved by the earlier methods.

Today multiple methods of fixation have been described to achieve a successful hallux interphalangeal arthrodesis. No single method appears most appropriate, but it is important to be aware of the indications, which may require one technique over another.

The most popular form of fixation to date is the use of K-wires. O'Donoghue and Stauffer [2] first introduced the use of a longitudinal K-wire in the mid 1940s as an improved technique over stainless steel wire. They described passing the pin distally out the distal phalanx, positioning the toe, and then driving the wire across the fusion site into the proximal phalanx, careful to avoid the metatarsophalangeal joint. The wire was ideally placed perpendicular to the vector of compression [7,8,15]. Postoperative results of 20 patients demonstrated fibrous union in 75%. In a study performed at the Mayo Clinic, Shives and Johnson found that 44% of their 166 patients who underwent a hallux interphalangeal arthrodesis with a single longitudinal intramedullary K-wire developed a pseudarthrosis [5,7,17,18]. The high failure rate with this type of fixation is primarily from the lack of stability in more than one plane. As a result, the bones are able to separate and piston around the single wire, distracting the fusion site. With such motion available at the fusion interface, it is extremely difficult to obtain a successful outcome (Fig. 3).

The technique of crossing K-wires developed in an effort to decrease the failure rates of this type of surgery. Although no axial compression is achieved, crossing the wires yields stability in more that one plane, providing resistance to separation and rotation. When inserting the wires, both should be retrograded out through the distal tuft, so one exits medially and the other laterally. This is most easily accomplished by beginning both wires centrally in the base of the distal phalanx with one located dorsally and the other more plantarly [13,18]. Once the toe is positioned correctly, the pins are driven across the fusion site into the medial and lateral diaphyseal bone of the proximal phalanx. Cortical bone should be penetrated proximally for stability, so the wires are not left floating and unstable in the cancellous bone of the medullary canal. By increasing the angle between the wires, there is diminished chance of external migration as the probability

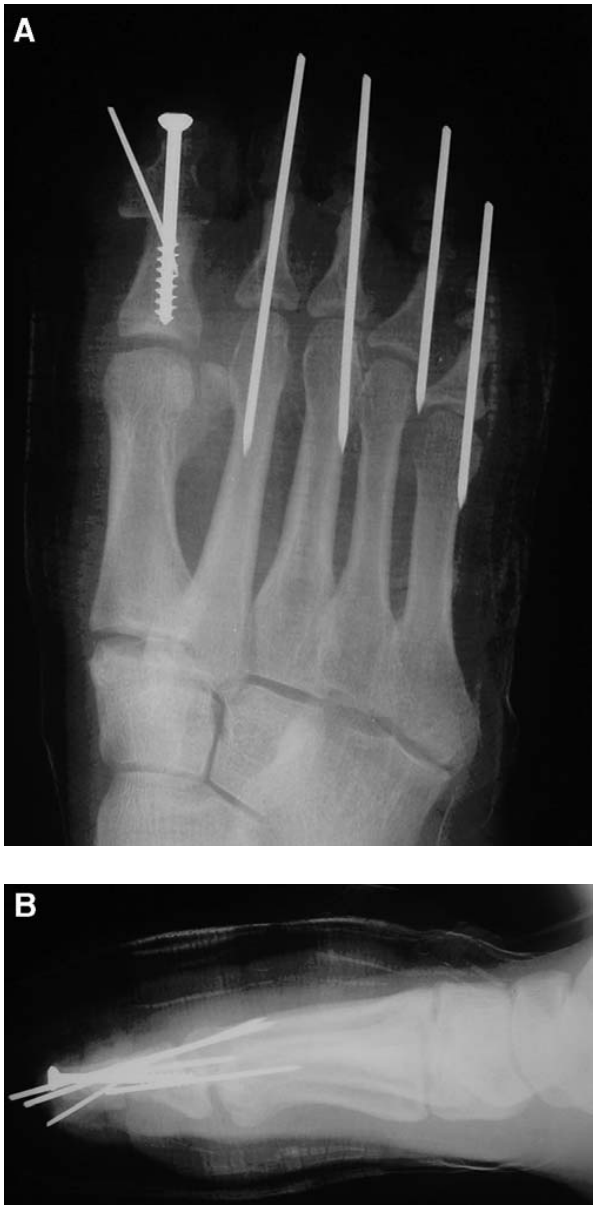


Fig. 3. (*A,B*) K-wire fixation as one-point fixation can allow for pistoning of bone, distally. Pistoning motion across arthrodesis site will decrease chance of complete fusion.

of purchasing stable cortical bone is increased and vice versa. The wires should ideally cross at or as close to the arthrodesis site as possible to ensure increased stability.

To prevent migration, rotation, or loosening, a new technique of bending the distal aspects of the K-wires so they are parallel to the distal tuft of the hallux has been described. The wires are then secured together with tape, steri-strips or some other means to increase the stability of the fusion site during the early stages of bone healing [13,18].

Although K-wires do not provide the technical advantage of compression, they do not limit or prevent healing as long as the device is strong enough to resist

bending forces. Some literature recommends 0.062-in wires or larger [15], though many physicians have achieved success with smaller wires. The use of wires is advocated in cases where poor bone stock is concerned, such as rheumatoid arthritis, postpoliomyelitis, the elderly, and other conditions with severe osteoporosis. In these instances, rigid internal fixation is almost impossible as there is no adequate bone for the screw threads to purchase. If the bone is severely osteoporotic, the use of threaded pins should be strongly considered to help provide friction and stability and prevent distal migration.

The use of cross K-wires has greatly diminished the previously high rate of pseudarthrosis associated with the single longitudinal K-wire [10]. Bony union can be achieved by leaving the wires in place for 12 weeks or until radiographic signs of fusion were apparent on plain films. They related no incidence of nonunion and suggest a positive correlation between pseudoarthrosis and premature removal of the wires at 6 weeks. Faraj advocated the use of K-wires over screw fixation even in patients with adequate bone stock. Besides having 100% success and an absence of nonunions, the wires were easily removable once consolidation had occurred [10].

Besides lack of compression, there are other disadvantages associated with using K-wires. Premature removal may lead to a nonunion. Their use also requires a longer period of immobilization postoperatively secondary to the lack of compression and decreased stability of the fusion site. Therefore, a compliant patient is helpful in achieving a successful outcome. Finally, because the wires are exposed, there is always the risk of developing a pin tract infection.

The use of cortical and cancellous bone screws inserted by traditional AO technique has gained in popularity. Although the AO technique may be technically more challenging than other modes of fixation, it is able to yield a compressive force perpendicular to the arthrodesis site. Because of the compression provided, the arthrodesis site is able to undergo primary bone healing, allowing for a quicker recovery period with the absence of callus formation. A firm, stable, and compressive type of fixation, such as screws, is able to cut down on the number of nonunions seen with K-wire fixation. The degree of pain and swelling is also lessened secondary to the maintenance of a stable position of the proximal and distal phalanges during bone healing. Because rigid screw fixation enhances consolidation, patients may experience a shorter immobilization time, enabling an earlier return to work and regular activity. In 1975, Shives and Johnson [7] first described the use of a longitudinally placed minicancellous screw. They found a definite improvement in postoperative results when compared with a single longitudinal K-wire, as it provided compression across the arthrodesis site [15,17].

The technique of inserting a 4.0 cancellous screw to achieve interphalangeal arthrodesis of the hallux is as follows: a 2.0-mm bit is drilled longitudinally from proximal to distal, exiting the end of the toe. The deformity is reduced and the resected surfaces are aligned in the corrected position. The 2.0-mm drill bit is then retrograded distal to proximal across the arthrodesis site and into the base of the proximal phalanx. The distal tuft is countersunk according to the surgeon's preference, as will be discussed later. A depth gauge determines the proper screw

length. Before insertion of the screw, a 3.5-mm tap is used to precut the thread pattern. This step is also optional. The 4.0 cancellous screw is then inserted from distal to proximal across the arthrodesis site. In one study, successful results were reported in the absence of either a tap or countersink [8].

The primary disadvantage of using a 4.0 screw is the large size of the screw. If the screw is too large for the distal phalanx, compression will be compromised and there will be no benefit over pin fixation.

Adams described the use of a 3.5 cortical bone screw for interphalangeal arthrodesis of the hallux in 1976 [7]. It was advocated as a salvage fixation procedure when stripping of the 4.0 screw was encountered. In this situation, the distal phalanx is overdrilled with a 3.5-mm drill bit. The cortical threads are then able to purchase denser intramedullary bone in the head and midshaft of the proximal phalanx. Eventually, the 3.5 screw was used as a primary fixation technique. An advantage over the 4.0 cancellous screw is the easier removal secondary to the smaller pitch and therefore decreased bony ingrowth about the smooth shaft.

Literature also describes multiple and less commonly used techniques for screw fixation. One study describes 2.0-mm cortical screws oriented diagonally across the arthrodesis site [17]. Besides obtaining interfragmentary compression, this screw positioning preserves the medullary canal. This is important in cases where an adjunctive salvage procedure, such as a total joint interpositional arthroplasty at the metatarsophalangeal joint, is indicated. Another study advocates the use of a single 2.7-mm cortical screw oriented from dorsal to plantar across the fusion. To obtain adequate fixation with this technique, increased bone resection is required in the sagittal plane. The author indicated this as a procedure for patients with poor bone stock.

As illustrated, screw insertion is a technically complex and somewhat time-consuming technique. Successful results are dependent on multiple factors, mainly the quality of bone stock. Although the quality of metaphyseal and diaphyseal bone of the proximal phalanx varies between subjects, there are two primary sites for a single longitudinally placed bone screw to purchase—the outer cortex of the distal tuft of the hallux and the subchondral cancellous bone at the base of the proximal phalanx [17]. By purchasing these areas with the screw, there is increased chance of achieving interfragmentary compression and decreased chance of stripping the screws. A useful technique to ensure the proper screw length and positioning of the screw is to insert a smooth wire along an original drill hole and subsequently withdraw enough to allow motion at the metatarsophalangeal joint [17]. Visualization of the osseous structure of the hallucal phalangeal bones is also critical in obtaining good results. The entire shaft of the proximal phalanx is anatomically aligned with the dorsal aspect of the phalangeal head. Staying as close to the dorsal cortex as possible with the drill is vital to remain within the bone. This allows the most dorsal threads to partially purchase the cortex and enhance the screw's effectiveness [8].

The use of screws also raises the issue of whether to countersink. In some patients, the osseous structure of the distal tuft may be insufficient to withstand

countersinking. Other times the surgeon may overcountersink the distal phalanx. In either case, intraosseous migration of the screw into the soft metaphyseal and diaphyseal bone may result, causing a lack of compression secondary to iatrogenic loss of the distal cortical surface. The drawback of not countersinking is a potentially prominent screw head, which has the tendency to become sympto-

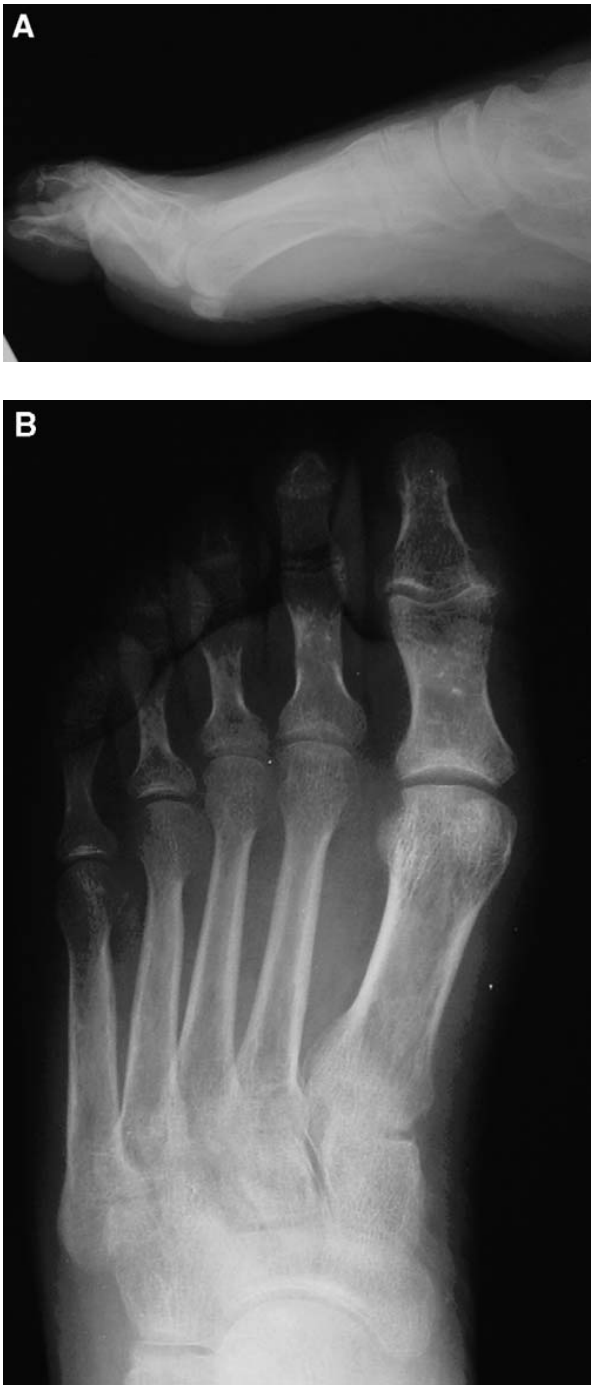
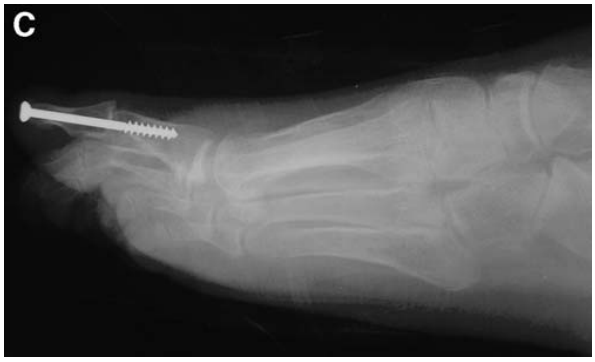


Fig. 4. (*A–D*) Surgical arthrodesis IPJ hallux contracture in flexion deformity. Fixated with 4.0 partially threaded cancellous screw later removed secondary to distal hallux irritation.

matic, especially in shoe gear. The other reason to gently countersink the distal tuft is to prevent stress risers and splitting of the fragile bone.

Other possible complications with screw fixation include superficial skin necrosis secondary to poor traumatic tissue handling, technical errors, short threads with subsequent distraction of the arthrodesis, and loss of compression.



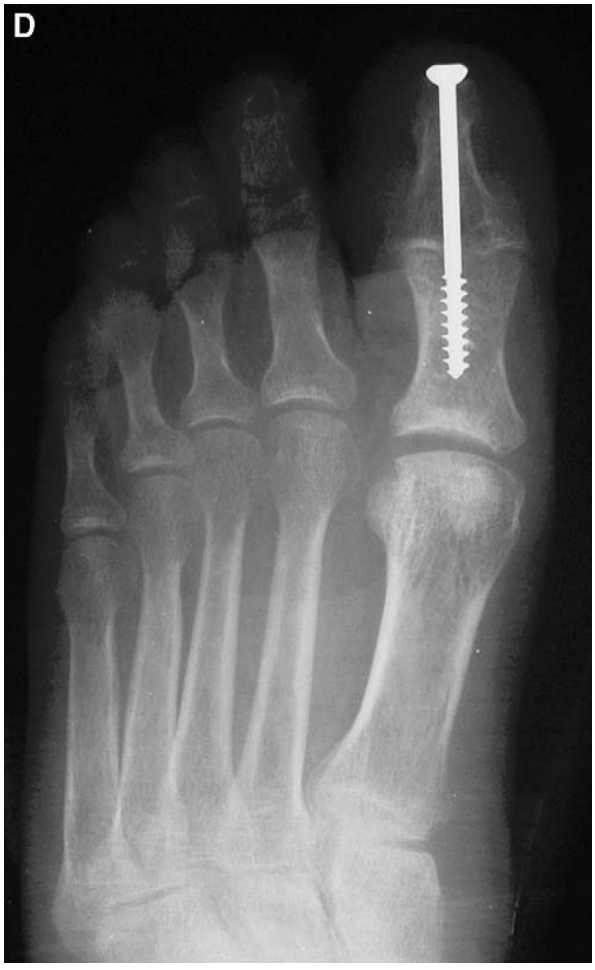


Fig. 4 (*continued*).

Case report

A 67-year-old man presents with history of painful and deformed hallux interphalangeal joint for a period of 2 years. Pain is present in shoe gear and with ambulation and has gotten markedly more painful within the past 3 months. Patient denies any trauma to the area, but relates a history of aching and throbbing at the hallux IP joint. Pain is worse after increased activity and gets increasingly more painful throughout the day. This patient has tried change in shoe gear, as well as NSAID medications, with no relief. Patient sought surgical correction of the deformity (Fig. 4).

Arthrodesis was performed at our institution, using two semielliptical incisions and re sectional bone cuts. Fixation was achieved with a 4.0 partially threaded cancellous screw from the distal aspect of the hallux through a minimal incision. Postoperative course included partial weight bearing with a walker in a surgical shoe. Patient began having pain and discomfort at the distal aspect of the hallux 4 weeks postoperatively. Radiographic examination revealed a bone arthrodesis at 5 weeks postoperatively, with migration of the fixation distally. The cancellous screw was removed under local anesthesia 9 weeks postoperatively, with resolution of the pain following screw removal

Discussion

Arthrodesis of the hallux interphalangeal joint can be performed as a primary procedure or with other procedures to achieve a combined result. Some of these procedures include tendon transfers, tenodesis procedures, and other first-ray arthroplasties or arthrodeses. Johnson [19] stated that a necessary adjunctive procedure of hallux varus is arthrodesis of the hallux IPJ. Many indications have been included for arthrodesis of the hallux IPJ to achieve a less painful or better functioning first ray. Neuromuscular indications were discussed, such as cerebral palsy, Charcot-Marie-Tooth disease, and Friedrich's ataxia. These neuromuscular disorders typically result in a hallux flexus or hallux malleus. Langford and Fenton [5] discussed hallux hammertoe, which develops from intrinsic muscle wasting or following procedures at the first MPJ and may result in neuropathic ulcerations in the diabetic patients. Claw toe deformities are often more common and more severe in patients with contralateral amputations [7]. Other indications for surgical arthrodesis of the hallux interphalangeal joint included hallux valgus, hallux varus, traumatic arthritis, osteoarthritis, rheumatoid or osteoarthritis, and iatrogenic sequelae from previous surgery.

Surgical arthrodesis of the hallux interphalangeal joint is used to provide a stable lever arm for the muscle imbalance between the short and long flexor tendons. The surgical approach to this procedure begins with the planning of the skin incision to the fixation technique. When determining the angle and size of bone cuts, it is important to recognize any osseus deformity about the hallux IPJ. If the arthrodesis is to achieve a pain-free joint, without deformity present, then resection of the bone in a neutral plane, or simple curettage, are adequate and

preferred techniques. If contraction is present, ascertain whether the deformity is secondary to a length problem, in which case more bone could be resected from the proximal phalanx. Sagittal and transverse plane correction can be achieved with the bone cuts, and care must be taken to avoid too much valgus rotation about the hallux. These may appear to be small issues intraoperatively, but can lead to larger issues when returning patients to normal shoe gear. Once again, close apposition of the bone ends secondary to proper bone cuts and adequate resection is vital to a successful arthrodesis.

The next key element to surgical planning and a successful arthrodesis is internal fixation and compression. Several techniques exist for hallux IPJ arthrodesis, with no one described as superior to the others. These are the same techniques that are described for most arthrodesis, including K-wire fixation, cross K-wires, cortical or cancellous screws, and staples. The failure rate of a single K-wire is primarily from the lack of stability in one plane [19]. Crossing K-wires for arthrodesis allowed more stability, but no axial compression [5]. Cross K-wires are especially indicated for patients with poor bone stock, in which cases rigid internal fixation could not be achieved.

Finally, rigid internal fixation using proper AO technique is used for achieving hallux interphalangeal arthrodesis. This method of fixation provides compressive and axial forces about the arthrodesis site. Screw fixation is believed to decrease the number of fibrous nonunions of this joint [12]. Several techniques have been described and reviewed in this article, with no one technique proven as superior in achieving arthrodesis. Types and sizes of screws are facility dependent and most often based on surgeon's preference. Failures of screw fixation may include improper technique or size of screw, lack of compression, inadequate bone resection, postoperative infections, and poor bone stock.

Summary

Surgical arthrodesis of the hallux interphalangeal joint can be used as an isolated procedure to address painful or deformed joints or in conjunction with other procedures to create a better functioning first ray. This type of arthrodesis may be necessary in neuropathic patients to prevent ulcerations or amputations. Several etiologies exist that result in a deformity about the hallux IPJ, some can be pain-free, others may be extremely debilitating to a patient. Many different surgical approaches have been described and used when performing a hallux IPJ arthrodesis. Developing your own technique enables you to understand what works for you and your patients and allows you to determine the most effective way to achieve arthrodesis. The goal is to prevent painful nonunions and address the underlying deformity. It is also important to understand that a successful arthrodesis in a patient who has a neurological disorder is the only way to prevent recurring deformities secondary to the underlying disease process. The ability to properly work-up and surgically address deformities of the hallux interphalangeal joint is necessary for those who perform lower extremity surgery.

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