CHAPTER 19

END-TO-END ARTHRODESIS: Technical Considerations

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Soule, in 1910[1] was the first to describe arthrodesis of the proximal interphalangeal joint (PIPJ) for the correction of a hammertoe deformity. He approached the joint through a plantarlateral incision, retracted the flexor tendons, resected the joint surfaces with a chisel, closed the wounds without deep bone fixation, and splinted the toes in hyperextension with a plaster of Paris bandage. In 1917, Jones[2] popularized PIPJ arthrodesis through a dorsal incisional approach. Since that time, numerous modifications and variations have been described for fixation and arthrodesis design.

The use of Kirschner wires (K-wires) to stabilize the intended fusion site were initially described by Taylor[3] in 1940. In 1941, Selig[4] also advocated the use of K-wires for fixation, but described bending the K-wire at a 90° angle where it exits the distal pulp of the toe to prevent proximal migration. Specially designed screws (i.e., Reese arthrodesis screws)[5], monofilament wire,[6] and absorbable pins[7] have also been described for fixation of the arthrodesis site.

Many different designs for the bony surfaces undergoing arthrodesis have also been described. A simple table-top (i.e. end-to-end arthrodesis), as initially described by Soule[1], has been the most popular. Other fusion site patterns have been espoused to increase the inherent stability at the arthrodesis site. In 1931, Higgs[8] described denuding the contiguous ends of the proximal and middle phalanges and "dovetailing" them by a spike-and-hole method. He shaped the head of the proximal phalanx into a spike, bored a hole into the middle phalangeal base, and then inserted the spike into the hole. In 1938, Young,[9] feeling that the spike was too fragile and susceptible to fracture, advocated that the proximal phalanx be shaped into a truncated cone. In his description, the dorsal cortex was maintained giving additional strength to the proximal phalanx. A hole was then created in the middle phalanx and the truncated cone seated into the middle phalangeal hole.

Subsequent descriptions of arthrodesis site configurations including the peg and dowel,[10] peg in hole[11], and box joint[12] have been embraced by different surgeons, with each preserving the dorsal cortex of the proximal phalanx to provide it with additional strength. In 1993, Pichney et al.[13] described a digital "V" arthrodesis which they attributed to Buckholz. They removed a "V" shaped wedge of bone from the proximal phalangeal head in a dorsal-plantar direction with its apex proximal and its base distal. The middle phalangeal base was then shaped into a matching "V" with the point proximal and the base of the "V" distal. The espoused advantage of each of these designs is improved intrinsic stability at the arthrodesis site. However, Schlefman et al.[11] detailed the concomitant use of a K-wire with the peg in hole arthrodesis, Bernbach and Bernbach[12] utilized a small screw to fixate their osseous box joint, and Pichney et al.[13] utilized a K-wire for fixation of their "V" design. The use of adjunctive fixation by each of these surgeons suggests that the inherent stability of their arthrodesis design is insufficient to maintain proper alignment alone.

Since K-wire fixation is often required regardless of the arthrodesis configuration, the author has frequently reverted to performing the technically easier end-to-end arthrodesis. The purpose of this paper is to review the critical aspects of this surgical technique and to discuss the postoperative care and results.

SURGICAL TECHNIQUE

Simply stated, end-to-end arthrodesis of the proximal interphalangeal joint (PIPJ) consists of resecting the articular cartilage from both surfaces of the joint (i.e., the head of the proximal phalanx and the base of the middle phalanx) and fixating the opposing bones in close apposition with a K-wire (Fig. 1).

The incisional approach can be through a dorsal longitudinal incision, two dorsal longitudinal semi-elliptical incisions, a dorsal transverse incision, or two dorsal transverse semi-elliptical incisions. The plantar approach advocated by

Figure 1. Depiction of amount of bone removed for an end-to-end arthrodesis (left) and a peg in hole arthrodesis (right).

Soule[1] does not offer any advantages to a dorsal approach, and is not routinely performed. A dorsal longitudinal approach is preferred if release of dorsal metatarsophalangeal joint (MTPJ) contracture is required. Either of the dual semi-elliptical approaches offer the advantage of excision of any dorsal heloma which might be present over the joint. A dorsal longitudinal incision is most commonly employed by the author and is usually 2-3 cm in length, and centered over the PIPJ.

Once the incision is made, dissection is carried deep through the subcutaneous layer and hemostasis is obtained on any of the small veins or veinlets crossing the incision path. The extensor tendon is then encountered and can be retracted in several ways. First and most commonly, the tendon can be simply sectioned transversely and retracted proximally and distally. Second, the tendon can be divided longitudinally and retracted medially and laterally. Third, the tendon can be sectioned in a Z-plasty fashion to allow lengthening of the tendon at the time of closure.

After the tendon has been addressed and retracted, any MTPJ contracture may be released if desired. A step-wise approach is utilized for this release, and has been previously discussed elsewhere[14]. After adequate release of the MTPJ, the collateral ligaments of the PIPJ are transected, exposing the articular cartilage on the head of the proximal phalanx and the base of the middle phalanx.

The author prefers to resect the cartilaginous surfaces with hand instrumentation to more accurately control the amount and plane of removal. This technique for joint resection also prevents bone necrosis and osseous resorption at the fusion site which can be caused by the heat generated from an oscillating or sagittal saw. The author routinely uses a bone-cutting forceps and rongeur to resect the cartilage from the head of the proximal phalanx and base of the middle phalanx respectively (Figs. 2A-2D). It should be noted that only the cartilage and subchondral bone plate are removed. The entire proximal phalangeal head is not excised as it is with a classic digital arthroplasty, unless shortening of the toe is desired, or it becomes necessary to properly align the fusion site.

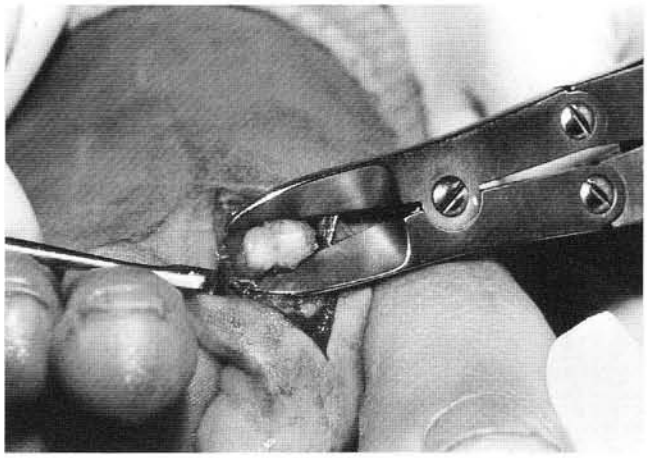

Figure 2A. A bone-cutting forceps is utilized to remove the articular cartilage from the distal end of the proximal phalanx.

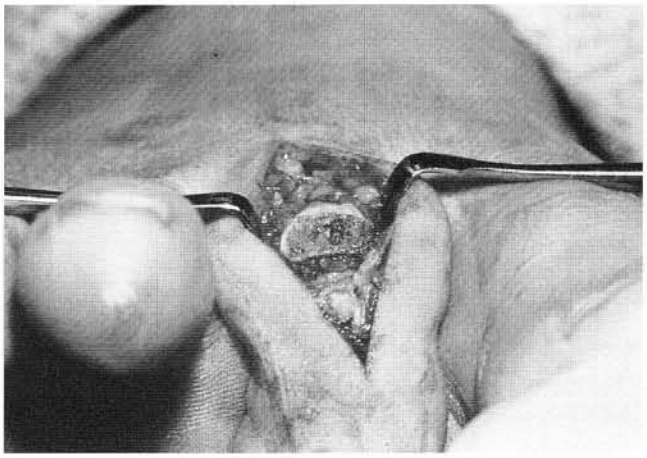

Figure 2B. View demonstrating the end of the resected proximal phalanx.

If multiple hammertoes are being corrected in the same foot, it is recommended that each be similarly addressed to this point. Once resection of all the surfaces to be fused has been completed, a trial

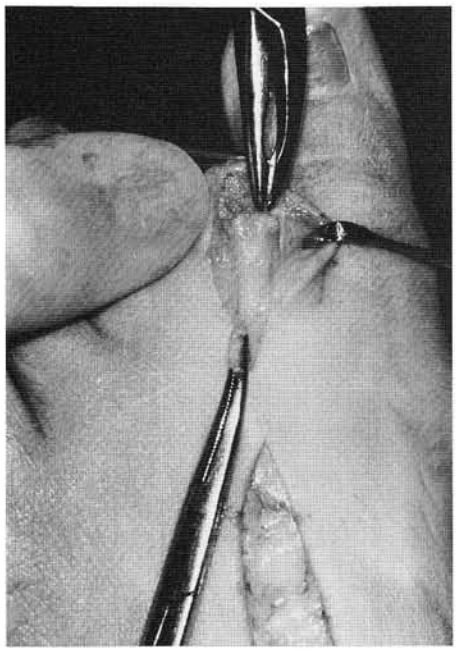

Figure 2C. A bone rongeur is utilized to resect the articular cartilage from the base of the middle phalanx.

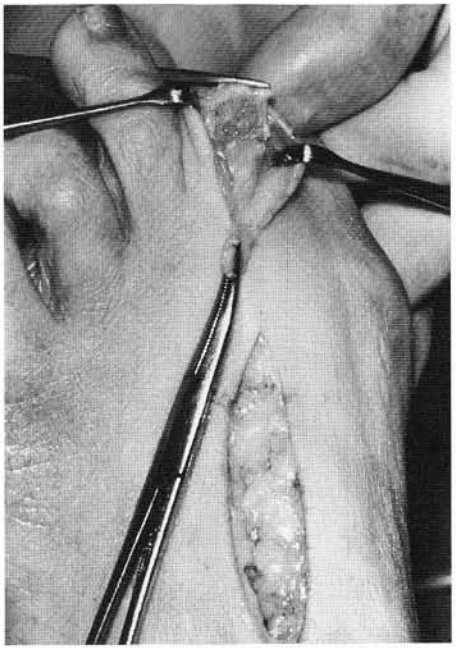

Figure 2D. A view demonstrating the resected base of the middle phalanx.

alignment and assessment of the postoperative digital length parabola can be accomplished. This allows "fine-tuning" (further shortening) of any of the digits to attain the desired digital length pattern. The next step is fixation of the fusion site. This is typically accomplished with a 0.045" (1.1 mm) or 0.062" (1.6 mm) smooth K-wire. The author prefers the larger diameter K-wire in most instances, especially when the MTPJ is also going to be temporarily stabilized. Prior to inserting the K-wire, a guide hole can be created in the proximal phalangeal stump and in the base of the middle phalanx with a K-wire smaller in diameter than the one used for fixation. In other words, a 0.045" (1.1 mm) K-wire will be used to create a guide hole for a 0.062" (1.6 mm) K-wire, and a 0.035" (0.9 mm) K-wire will be used to create a guide hole for a 0.045" (1.1 mm) K-wire. The guide hole in the desired phalanx is created by manually pushing the K-wire down the center of the medullary canal, while carefully stabilizing the phalanx with a thumb forceps (Fig. 3). In smaller toes, it may be difficult to create the guide hole due to the small diameter of the medullary canal. In such instances, a smaller diameter K-wire can be selected to accomplish the guide hole, or a power K-wire driver at very low speed can be used to push the K-wire past the point of impingement. The optimally created guide hole allows precise placement of the larger K-wire down the center of the medullary canal and minimizes premature exiting of the K-wire from the proximal or middle phalanx.

Once the guide holes have been created, the final fixation is achieved. The larger K-wire is

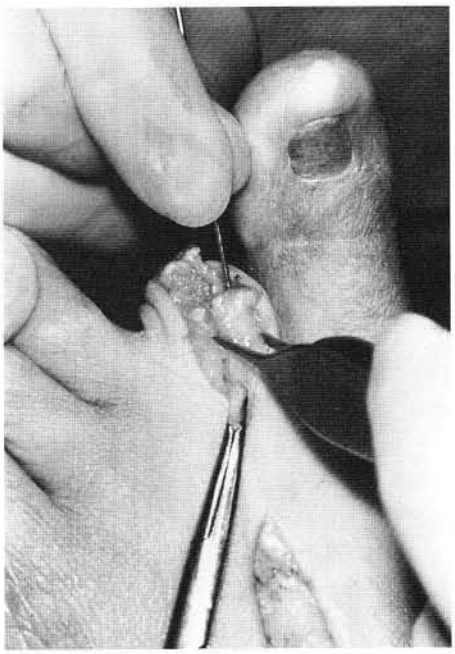

Figure 3. A guide hole is carefully created in the medullary canal of the proximal phalanx.

introduced into the middle phalangeal base and driven out the end of the toe (Fig. 4). During this process, the distal end of the digit is firmly held between the thumb, index, and middle fingers. Dorsiflexory pressure is applied to the distal interphalangeal joint (DIPJ) and the wire is aimed towards the center of the distal, digital pulp. If one is right-handed, this can be accomplished by

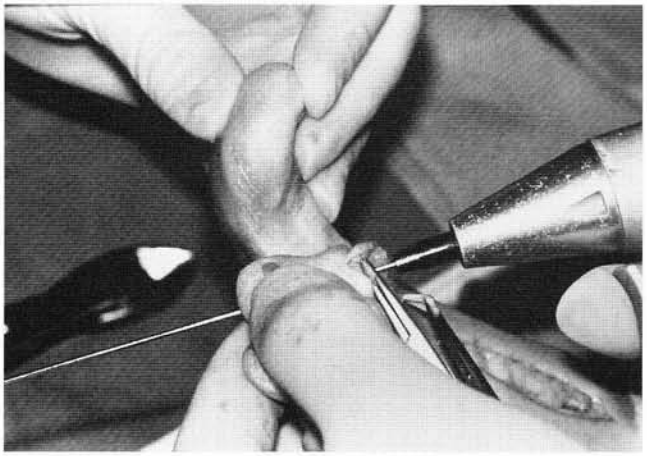

Figure 4. The K-wire is initially driven from proximal to distal through the middle and distal phalanges and out the end of the toe. Proper hand position allows one to stabilize the toe, ensuring dorsiflexion of the DIPJ and proper K-wire position.

placing the middle finger of the left hand plantar to the middle phalanx, the index finger of the left hand plantar to the distal phalanx, and the thumb of the left hand over the dorsum of the DIPJ. Downwards or plantar pressure applied to the thumb will then allow dorsiflexion of the DIPJ. The right hand is then used to control the K-wire driver. If one is left-handed, the hands are simply reversed. Ideally, the K-wire should exit the center of the distal, digital pulp away from the nail and nailbed.

The K-wire driver is then attached to the end of the K-wire protruding distally from the digit. The middle and proximal phalanges are aligned and the K-wire is carefully routed into the guide hole created in the proximal phalangeal stump (Figs. 5A-5B). This is most easily accomplished by driving a majority of the K-wire out the end of the toe so that only the tip of the K-wire is left protruding from the middle phalangeal base. The proximal phalanx is then stabilized in the left hand or by an assistant with a thumb forceps and the protruding tip of the K-wire is visually seated into the guide hole in the proximal phalanx. Once across the PIPJ, the K-wire is slowly advanced until it abuts the subchondral bone plate at the base of the proximal phalanx.

Figure 5A. The K-wire driver is then brought to the distal end of the toe, and the K-wire is driven across the base of the middle phalanx.

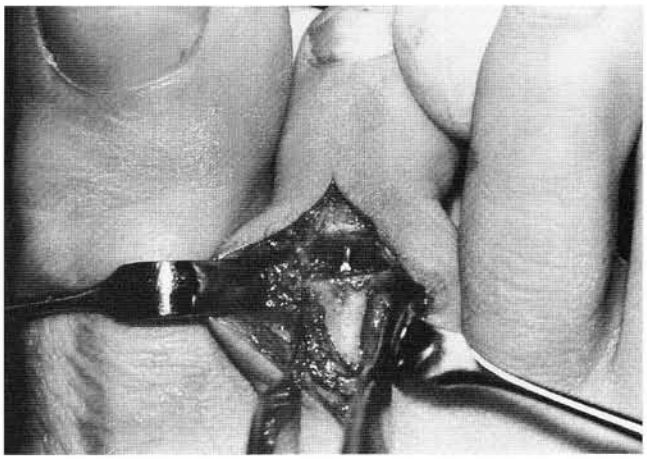

Figure 5B. Note that the tip of the K-wire exiting the middle phalangeal base is carefully seated in the previously made guide hole in the proximal phalanx, before driving it into the subchondral bone.

With practice and experience, the resistance of the subchondral bone plate will be felt. If desired, the MTPJ may be placed into the desired position, and the K-wire advanced across this joint as well. Positioning of the MTPJ is best accomplished with the same three fingers. If one is right-handed, the middle finger of the left hand is placed dorsally over the distal shaft of the lesser metatarsal, the index finger of the left hand is place dorsally over the proximal phalanx, and the thumb of the left hand is placed plantarly under the metatarsal head. In this fashion, the MTPJ can be manipulated into the desired position and the K-wire advanced using the K-wire driver in the right hand. Again, the hands are reversed if one is left-handed. If the MTPJ is not going to be temporarily stabilized, the end of the wire is left seated in the subchondral bone of the proximal phalanx. It should be noted that seating the K-wire in the subchondral bone

plate is preferred to leaving the end of the wire in the medullary canal of the phalanx. The subchondral bone provides better anchoring of the K-wire, decreasing the likelihood of inadvertent or accidental dislodgement of the K-wire during the postoperative course.

After the K-wire has been inserted, the position of the toe and desired fusion site are evaluated. Further, if multiple toes are being done on one foot, they should each be fixated and inspected prior to final wound closure. Any necessary adjustments can be easily accomplished at this point. If uncertainty exists regarding the position of a K-wire or fusion site, intraoperative radiographs or fluoroscopy can be utilized to assess the surgical site. Each K-wire is then bent 90° where it protrudes from the toe, leaving approximately 3-5 mm between the tip of the toe and the bend in the wire. The bent portion of the wire is then cut, leaving about 6 mm of wire to which a small K-wire cap or piece of cork can be attached. Bending the K-wire in this fashion prevents accidental migration of the K-wire into the digit.

Closure of the wound is then accomplished. The extensor tendon is reapproximated with 3-0 absorbable suture. Subcutaneous structures are reapproximated with 4-0 absorbable suture, and skin is closed with 5-0 absorbable or 4-0 nonabsorbable sutures. The suture sizes may vary depending upon the patient's tissue quality, age, health, and anticipated activity level.

POSTOPERATIVE CARE

Postoperatively, the patient is maintained in a sterile dressing until the K-wires are removed. The first postoperative dressing change is performed after 3-5 days, and approximately every 2-3 weeks thereafter. The K-wires are removed after 4-8 weeks. The author prefers to maintain the K-wires intact for 6 weeks, as premature removal of the K-wires will increase the potential for nonunion or malunion at the arthrodesis site. If the K-wire crosses the MTPJ, some surgeons prefer to retrograde the wire back across the MTPJ, so it is only in the toe, after 3 weeks. In this manner, the PIPJ is stabilized for 4-6 weeks, but the MTPJ is allowed to begin active and passive motion after only 3 weeks. However, early pulling of the K-wire across the MTPJ may cause some discomfort for the patient, and care must be taken to avoid inadvertent complete removal of the wire. In most instances, the author has found no advantage in retrograding the K-wire early, and therefore maintains the K-wire across the MTPJ for the entire 6 week period.

During the initial postoperative period, while the K-wires are in place, the patient should be allowed to ambulate only in a padded surgical shoe or below-knee cast. If the former is to be used, the surgical shoe is padded with 1/4" to 1/2" Korex, piano felt, or other similar material from the heel to the digital sulcus. In this fashion, as the patient walks in the shoe, they will "roll off" the end of the padding and not stress the K-wires. This padding is especially important if the K-wires are across the MTPJs.

During the postoperative period, serial radiographs are taken to assess the intended arthrodesis site (Fig. 6). Preferably, radiographs should be taken during the first 3-5 days to evaluate the alignment of the fusion sites and the position of the K-wires. Additional radiographs are not usually necessary until K-wire removal is planned. Although complete osseous union need not be seen prior to K-wire removal, radiographic changes suggestive of healing are ideal.

After 4-8 weeks, the K-wires are removed. This is best accomplished in the office with the patient recumbent. The wire is firmly grasped with pliers in the dominant hand, while the toe is stabilized in the other hand. The K-wire is gently rotated from side-to-side as it is removed. A light dressing or band-aid is applied to the pin exit site. The patient is instructed to remove the light dressing after 24 hours and begin bathing. No further dressings are needed unless wound problems are noted. Following K-wire removal, digital retainers or splints may be used to help maintain any correction obtained at the MTPJ. Physical therapy may also be used to aid in returning full MTPJ motion. Long-term, orthoses and appropriate shoes should be considered in most patients.

RESULTS

End-to-end arthrodesis generally provides excellent results. Potential complications include those inherent to any digital surgery, as well as those inherent to the arthrodesis technique and fixation. Complications associated with digital surgery in general include prolonged edema (sausage toe), wound complications, infection, dysvascular episodes (which ultimately can result in loss of the

Figure 6. Postoperative radiograph demonstrating end-to-end arthrodesis of the PIPJ of toes 2,3, and 4. A post-arthroplasty was performed on the PIPJ of the fifth toe. Note the excellent digital length pattern, and that each K-wire is seated in the subchondral bone at the base of the proximal phalanx.

toe), floating toe (where the toe fails to purchase the ground during stance), and loss of digital function. Additionally, any PIPJ arthrodesis procedure can result in malunion, delayed union, or nonunion at the arthrodesis site. With the end-to-end arthrodesis, premature K-wire removal will often result in a failed arthrodesis, arthrodesis in a flexed position, or recurrent deformity (Fig. 7). Occasionally, after digital arthrodesis, a patient will complain of excessive

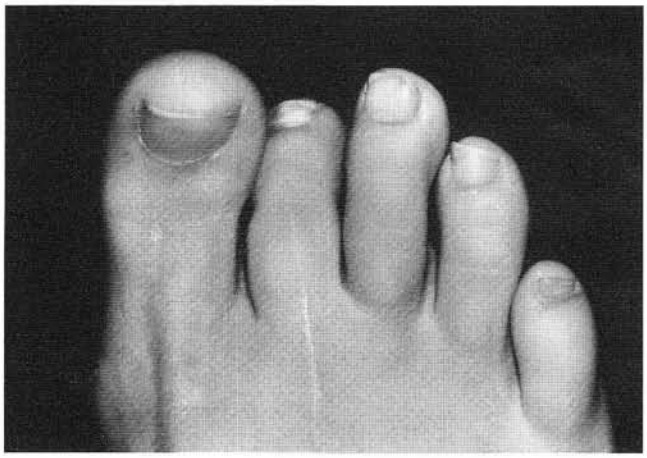

Figure 7. 6-month postoperative appearance of a second toe that had a PIPJ end-to-end arthrodesis performed. The K-wire was prematurely removed after only 3.5 weeks, and the toe ultimately fused in a flexed position.

stiffness, shortening of the toe, mallet toe formation, or poor cosmetic appearance (e.g., complaining that it is too straight). These concerns can often be avoided by discussing the anticipated postoperative function and appearance of the toe(s) prior to surgery. Finally, problems related to K-wire fixation can occur. These include pin tract infections, pin migration, and pin breakage. Proper insertion and good postoperative management will avoid most problems associated with the K-wires.

Few authors have provided long-term results of the end-to-end arthrodesis with K-wire fixation. Most of the reports are in regards to other arthrodesis configurations. Pichney et al.[13] stated that they had performed over 100 digital "V" arthrodeses with only one fusion demonstrating mild distraction and delayed radiographic evidence of healing. Schlefman et al.[11] retrospectively reviewed 43 randomly selected patients averaging 7.5 months postoperative. Sixty feet involving 125 peg in hole digital arthrodeses were evaluated. In all cases, solid union of the arthrodesis was found. However, problems including postoperative metatarsalgia, postoperative scar contracture, mallet toe formation, and reflex sympathetic dystrophy were present in 7 patients (16%). Alvine and Garvin[10] reviewed their results after utilizing the peg and dowel fusion of 73 toes. They found all but 2 toes (3%) to be united at the arthrodesis site and 87% of their patients related that the surgery was beneficial, providing relief of pain and allowing the return to normal shoes. However, there were no infections or wound complications. Finally, Bernbach[15] reported good results in 22 of 35 cases and excellent results in 13 of the same 35 cases, with no nonunions or recurrent deformities using the box joint arthrodesis. Newman and Fitton[16] reviewed 28 cases of end-to-end arthrodesis without fixation, 15 cases of end-to-end arthrodesis with K-wire fixation, and 15 cases of Higgs' spike and hole arthrodesis. Medial or lateral deviation of the toe was found in 6 cases (10%) of PIPJ arthrodesis, and was equally distributed between the three types of arthrodesis evaluated. Overall, they found fair or excellent results as subjectively judged by the patients' assessment of symptom relief in 76% of the cases. Finally, Ohm et al.[6] retrospectively evaluated 25 patients in whom 62 end-to-end arthrodeses with monofilament wire fixation had been performed. Objectively, their series had a 21% incidence of some residual digital

anesthesia: 19.5% incidence of limited range of motion at the MTPJ with a floating toe; 14.6% incidence of residual edema; 4.8% incidence of residual pain; 2.4% incidence of transverse plane deformity at the MTPJ; and a 2.4% incidence of mallet toe deformity. However, all toes demonstrated solid fusion with no cases of malunion or nonunion. Subjectively, all patients interviewed considered their surgery successful in eliminating their chief complaint.

The author has found end-to-end arthrodesis to be a reliable procedure for the semi-rigid or rigid hammertoe deformity; especially when caused by dynamic muscular imbalance. The end-to-end arthrodesis offers the advantage of being technically easy to perform, and is relatively free from complications and digital shortening. A K-wire or other fixation device is mandatory for stability of the arthrodesis site during the immediate postoperative period.

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