CHAPTER **34**

AN ANALYSIS OF DIGITAL ARTHRODESIS

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INTRODUCTION

Foot pain and dysfunction due to digital deformity are extremely common. The digital deformity usually involves some degree of interphalangeal joint (IPJ) plantarflexion contracture, along with an associated dorsiflexion contracture of the metatarsophalangeal joint (MTPJ). By contracture, it is meant that the digit at the interphalangeal joint or joints, or the ray at the MTPJ, is deviated from the straight, or rectus, alignment. The term contracture denotes a permanent or functionally recurrent deviation from the straight, or "healthy," alignment.

When IPJ plantarflexion contracture specifically involves the proximal interphalangeal joint (PIPJ), to the exclusion of the distal interphalangeal joint (DIPJ), the deformity is referred to as a "hammer-toe." When both the proximal and distal interphalangeal joints are plantarflexed, the deformity is specifically referred to as a "clawtoe." The most common mechanical cause of digital and MTPJ contraction deformities is excessive subtalar and midtarsal hyperpronation in stance, affecting compensatory flexor stabilization with resultant overpowering of the intrinsic pedal interosseous musculature by the extrinsic pedal musculature of the posterior compartment of the leg.[1] Other less common mechanical causes of digital and MTPJ contracture include extensor substitution and flexor substitution.[2]

Clinically, digital and MTPJ deformities are designated as flexible, semi-rigid (or semi-flexible), or rigid, based upon the amount of reducibility (straightening) obtained upon manipulation. Standard clinical practice includes application of the push-up test in an effort to determine the degree of reducibility, or straightening, attainable by means of manipulation (Figs. 1A, 1B). The push-up test is performed by applying a dorsally-directed force to the region of the MTPJ flexor plate, with the foot in the open kinetic chain, and observing the reaction of the interphalangeal joints as well as the MTPJ. Similarly, ground reactive force in weight bearing stance functionally mimics

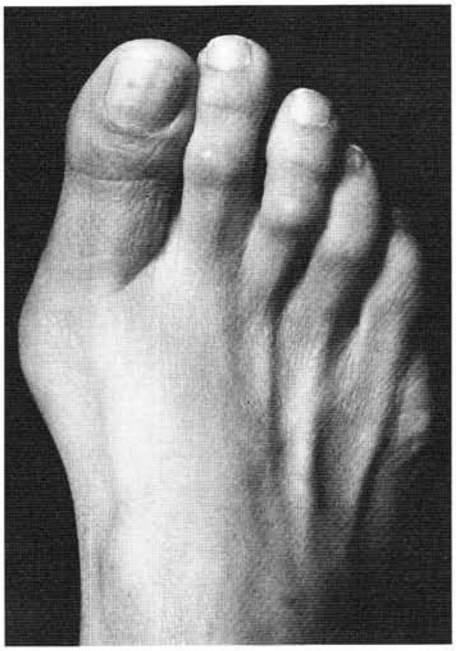

Figure 1A. The push-up test. Open kinetic chain resting attitude reveals bowstrung extensor tendons and interphalangeal and metatarsophalangeal contracture.

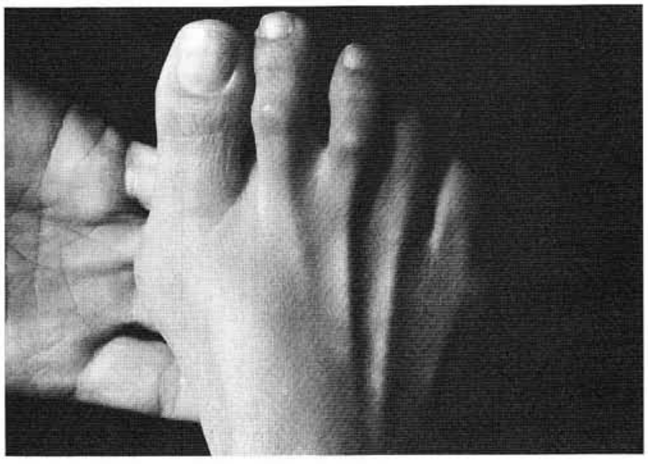

Figure 1B. Dorsally directed plantar force at the level of the metatarsophalangeal joints results in only partial realignment of toes and metatarsophalangeal joints. This is indicative of a "semi-rigid" deformity.

the dorsally directed force of the push-up test. This enables the clinician to determine the degree of digital and MTPJ flexibility. Typically, the push-up test yields some degree of MTPJ relocation, wherein the base of the proximal phalanx realigns on the metatarsal head.

In the weight bearing, sagittal plane, radiographic view of the human foot, the average metatarsal declination angle (the angle formed between the substrate and the long axis of the metatarsal) is understood to be approximately 20 degrees. Therefore, a balanced MTPJ alignment involves a relative angle of 20 degrees of dorsiflexion of the phalanx, relative to the long axis of the metatarsal. When performing the push-up test, attention is directed to the relationship between the base of the proximal phalanx and the metatarsal head, as well as to the interphalangeal joints. If there is no straightening in the alignment at either the IPJs or the MTPJ, the deformity is said to be rigid, or non-reducible. If partial straightening is noted, the deformity is said to be semi-rigid, or semi-flexible. If complete realignment to a straightened position is observed, then the deformity is said to be flexible.

It is understood that rigid or minimally reducible (semi-rigid) deformities, as well as digital and MTPJ contractures involving multiple rays, respond more favorably to sequential release of each element of the deformity. Complete sequential release involves adequate open Z-tenotomy of the long extensor tendon, MTPJ extensor hood recession, capsulotomy of the PIPJ and MTPJ, resection of the PIPJ, release of the MTPJ flexor plate, and, finally, PIPJ arthrodesis with pin stabilization of the IPJs and the MTPJ.

It has been previously noted that lesser metatarsalgia, or weight-bearing pain in the ball of the foot, localized to the intermediate pedal rays (second, third, and fourth), is mechanically linked to an associated contracted digit and MTPJ.[3] The influence of digital and MTPJ deformities has been shown to effect increased weight-bearing force through the area of the MTPJ flexor plate, by means of retrograde plantar buckling of the MTPJ (Fig. 2).

Increased plantar pressure, which may or may not be associated with plantar hyperkeratosis, has been shown to decrease following straightening of the deformed digit and relocation of the MTPJ. An added benefit of surgical, as well as non-surgical measures to realign the IPJs and MTPJs, is alleviation of lesser metatarsalgia and alteration of plantar hyperkeratotic lesions.

MATERIALS AND METHODS

Thirty-one patients who underwent surgical correction of contracted digits, (hammertoes and clawtoes), were retrospectively evaluated relative to the results of surgical intervention. All of the patients were treated and evaluated by the author between August of 1992 and January of 1996. The analysis involved review of preoperative and postoperative subjective and objective findings. Patients exhibiting strictly non-mechanical causes of digital and MTPJ deformity, or metatarsalgia, were excluded from the study. Patients with mechanically induced digital deformity with or without metatarsalgia, who were satisfactorily alleviated with non-surgical measures, or who were deemed inadequate surgical candidates, were also excluded from the study.

The review was not limited to patients who had undergone digital fusion as an isolated procedure. All of the patients involved in the study had failed to satisfactorily respond to non-surgical treatment prior to the decision to undergo surgical treatment. All of the patients were asked to subjectively grade their preoperative and postoperative pain, using an analog pain scale of 0 to 4:

0 = none
1 = mild
2 = moderate
3 = severe
4 = excruciating

Twenty-eight of the thirty-one patients were treated on an outpatient basis. All three of the patients receiving inpatient care underwent extensive forefoot reconstruction, including panmetatarsal or lesser (second through fifth) metatarsal head resections, with or without

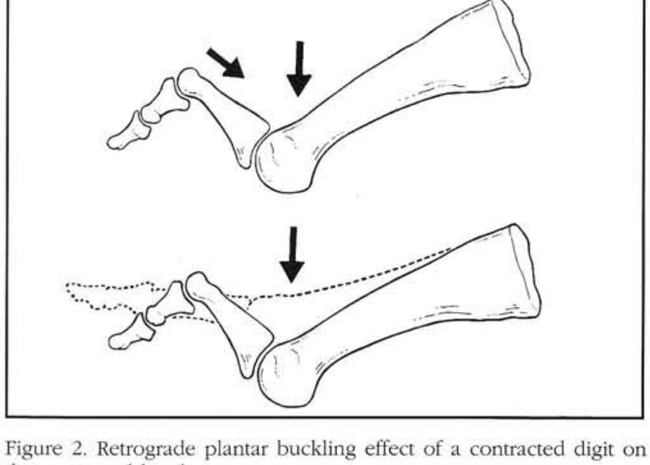

Figure 2. Retrograde plantar buckling effect of a contracted digit on the metatarsal head.

McKeever arthrodesis. Two of these were rheumatoid patients chronically medicated with prednisone, and one who was exhibiting post-traumatic metatarsalgia secondary to an injury involving multiple metatarsal fractures. The majority of cases involved the use of local anesthesia with concomitant intravenous sedation, with the patient in the supine position. In all but four of the cases, hemostasis was achieved using anatomical dissection along with dilute epinephrine (1:200,000 or 1:400,000 dilution) in the local anesthetic mixture, without the use of a tourniquet. The ankle tourniquet was used in the remaining four cases.

Following standard orthopedic skin preparation, surgical dissection for each digital fusion proceeded, with the use of a dorsal-linear incision extending from the level of the most dorsally prominent aspect of the base of the proximal phalanx, to the level of the proximal metaphysis of the middle phalanx. The incision was deepened through superficial fascia and subcutaneous tissue, and hemostasis was acquired as necessary.

The digit was then gently distracted distally away from the metatarsal head, and medial and lateral fibers of the MTPJ extensor hood were transected longitudinally, resulting in recession of the fibers of the extensor hood (Figs. 3A, 3B). This allowed the tendon to bowstring dorsally, eliminating the influence of the long extensor on the proximal phalanx and MTPJ. The long extensor tendon was then incised in an open-Z fashion, and the proximal and distal segments retracted to expose the dorsal aspect of the MTPJ.

Attention was then directed to the PIPJ, where the joint was plantarflexed, followed by sectioning the medial and lateral collateral ligaments. The head of the proximal phalanx was thereby exposed and evaluation of the components of the PIPJ completed. The proximal phalanx was then distracted and slightly plantarflexed, allowing isolation of the MTPJ capsular tissues, which were sectioned transversely about the dorsal, medial, and lateral aspects of the joint. Care was taken to assure that MTPJ capsular tissue was adequately sectioned near the plantar aspect of the joint, approaching the flexor plate, in an effort to prevent residual dorsal contracture.

After each sequential step in the dissection, the push-up test was performed to assess the need to continue with the next step in sequence, thereby effecting complete soft tissue release at both the interphalangeal and metatarsophalangeal levels. If the push-up test revealed persistent transverse or sagittal plane deviation at the MTPJ, the McGlamry metatarsal elevator was used to gently deglove the fibrous adhesion of the flexor plate at the plantar aspect of the metatarsal head, where the cartilaginous joint surface becomes contiguous with periosteum and joint capsule. If further testing revealed a tendency toward residual deformation, then a nonabsorbable 3-0 anchor suture was used to secure the flexor plate in a balanced alignment, plantar to the metatarsal head. The anchor suture purchased the fibrous flexor sheath and approximated it to the deep transverse inter-metatarsal ligament and the superficial fibers of the MTPJ capsule on the side of the joint, opposite to the direction of re-deformation. Three of the patients, two rheumatoid and one with traumatic disruption of the metatarsus, required actual resection of the metatarsal heads.

Following sequential release, PIPJ arthrodesis

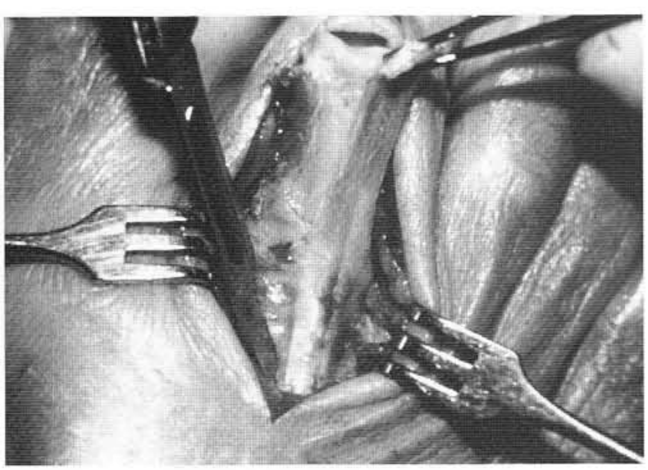

Figure 3A. Extensor hood recession. Transect fibers of extensor hood parallel to long extensor tendon.

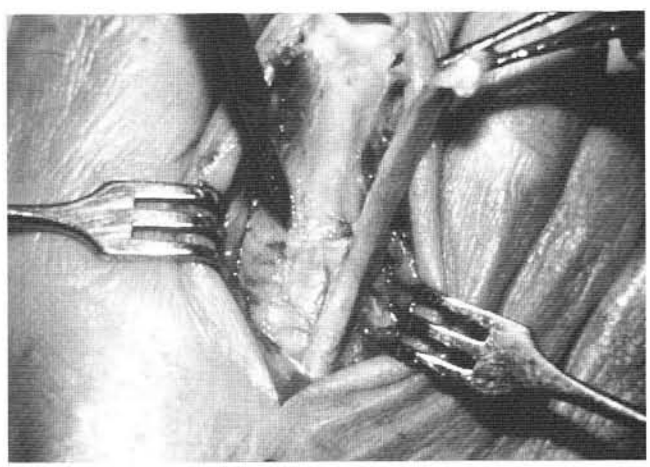

Figure 3B. Exposure of underlying MTPJ and elimination of long extensor tendon influence on the digit.

was then accomplished by addressing the head of the proximal phalanx. This was either fashioned into the shape of a peg, preserving the dorsal cortex, or transversely sectioned at the level of the metaphyseal flare. When performing the peg-in-hole arthrodesis, the base of the middle phalanx was carefully reamed with a narrow football-shaped bur, preserving the surrounding cortices. When the end-to-end arthrodesis was performed, the base of the middle phalanx was resected using a combination of straight edge bone cutting forceps and rongeur, with some application of a burr to effect a smooth cortical surface. The decision to perform either end-to-end or peg-in-hole arthrodesis was based primarily on whether or not shortening of the digit would lead to a functional or cosmetic problem. In an effort to avoid excessive shortening, the end-to-end technique was selected.

Stabilization of the digit and the MTPJ was performed while maintaining the DIPJ in a slightly dorsiflexed position in the sagittal plane, with a neutral transverse and frontal plane alignment. A 0.045 inch Kirschner wire (K-wire) was then used to maintain the corrected alignment of the digit and MTPJ. The K-wire was first driven from proximal to distal through the middle phalanx and across the DIPJ, then out through the tip of the toe, taking care to avoid the nail bed. The K-wire was then retrograded across the seated arthrodesis interface and, while holding the MTPJ in corrected position, driven proximally across the repositioned MTPJ and at least 3 to 4 centimeters into the head and neck of the metatarsal. Care was taken to recreate a balanced position of the phalanx on the metatarsal head without excessive plantarflexion.

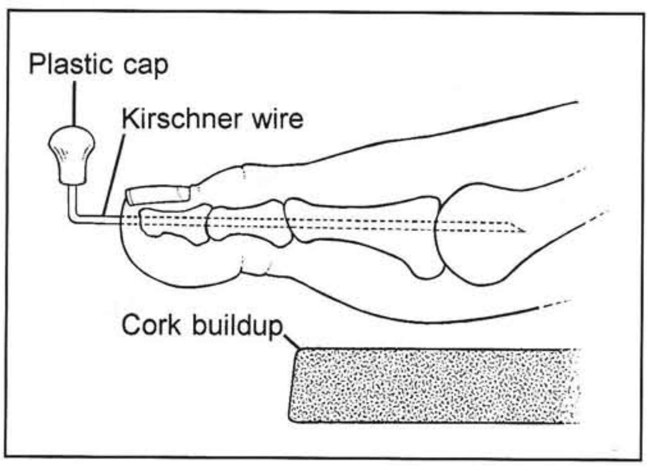

Figure 4. Built-up surgical shoe.

The K-wire was then bent to a right angle, distal to the tip of the toe, cut and capped.

The wound was lavaged, and then closed in anatomic layers. A dry, sterile, gently compressive bandage was then applied, and the patient fitted with a built-up surgical shoe, modified with one-inch felt extending from the heel to the level of the metatarsal heads (Fig. 4). This modification was done to prevent the stabilized toes from purchasing the ground while allowing the patient to bear weight on the operated foot.

The patients were evaluated at appropriate postoperative intervals. At approximately three weeks postoperative, the K-wire was pulled distally out of the metatarsal and across the MTPJ to be retained across the PIPJ arthrodesis for an additional period of time. The supportive bandage and built-up shoe were maintained until approximately 5 to 6 weeks postoperative, when clinical and radiographic evidence of a satisfactory fusion mass were identified at the arthrodesis site. The patient was then allowed to wear a sneaker or comfortably fitted shoe, with the use of a soft digital retainer, for an additional 3-4 weeks.

All of the patients initiated at-home range of motion exercises for MTPJ sagittal plane passive and active motion, at approximately one week, following removal of the K-wire from across the MTPJ. This was accomplished through written and oral instructions, and in-office demonstration of the technique. Specific objective and subjective post-operative findings were determined and recorded.

RESULTS

The results of the analysis of digital arthrodesis are as follows. Sixty toe fusions were performed on thirty one patients. The mean average age of the patients was 52.90 ± 16.20 years, with a range of 23 to 86 years of age. Twenty-four of the patients were female, and seven were male. Twenty-five of the patients displayed flexor stabilization induced digital and MTPJ contracture, while one displayed dropfoot and hemiplegia with extensor substitution induced clawtoes. Five of the patients were diagnosed with rheumatoid arthritis with resultant clawtoes and metatarsalgia.

Overall, twenty-one patients exhibited intermediate lesser metatarsalgia preoperatively, and seventeen of these displayed an intractable plantar keratoma (IPK). Twelve of the patients had an essentially sedentary lifestyle (weight bearing less than one continuous hour per day), eleven patients were partially weight bearing (between 1 to 4 hours constant weight bearing), and eight were constantly weight bearing (greater than four hours continuous weight bearing).

All of the patients related symptoms that developed insidiously over an extended period of time. The average duration of symptoms, prior to seeking professional treatment, was 20.94 ± 15.14 months. Sixteen of the patients displayed an antalgic gait prior to surgery, and the average period of non-surgical therapy was 8.90 ± 5.04 months.

The average postoperative follow up period was 14.23 ± 8.54 months, with a range of 5 to 32 months. On average, the K-wires were pulled at 5.42 ± 0.6 weeks into the postoperative phase. Using the subjective analog pain scale of 0 to 4, the mean average preoperative level of pain was 3.48 ± 0.51, and the average postoperative level of pain was 0.39 ± 0.76. Tables 1 and 2 depict the distinct clinical patterns of forefoot deformities encountered in the study.

Of the sixty arthrodeses performed, 49 were via peg-in-hole and 11 were performed using the end-to-end technique. The complications encountered are noted in Tables 3, 4, and 5.

Table 1

DISTINCT CLINICAL PATTERNS of CONTRACTED DIGITS

(n = 60 FUSIONS in 31 PATIENTS*)

1.	(7, 22.58%)	-	4, 5, (TB, MC exost.
2.	(6, 19.36%)	-	2, HAV
3.	(4, 12.90%)	-	2-4, 5
4.	(4, 12.90%)	-	2-4, 5, PAN &/OR McKEEVER
5.	(2, 6.45%)	-	2-4, 5, HAV
6.	(2, 6,45%)	-	2/3, HAV
7.	(2, 6.45%)	-	2-4
8.	(2, 6.45%)	-	4
9.	(1, 3.23%)	-	2, 5, HAV
10.	(1, 3.23%)	-	4, 5, HAV
11.	(1, 3.23%)	-	2

*32 Scenarios in 31 Patients, 1 Bilateral Case

DISCUSSION

Digital arthrodesis can be used with a high degree of success in patients exhibiting symptoms due to recalcitrant digital deformities with or without associated metatarsalgia. The results of this study indicate a satisfactory improvement relative to digital and MTPJ deformity and pain following sequential soft tissue release, and PIPJ arthrodesis for the treatment of recalcitrant hammertoes and clawtoes. It is shown that mechanically induced metatarsalgia does diminish in response to digital stabilization and realignment. Although this study included patients with a variety of etiological factors, and multiple forefoot deformities, the result of each PIPJ fusion was emphasized.

The longer the deforming influences act unchecked upon the MTPJ and digit, the greater the degree of subluxation at the level of the PIPJ and MTPJ. Advanced deformities require surgical intervention at each level (PIPJ and MTPJ), and use of the metatarsal elevator becomes a necessary component of the dissection. Furthermore, placement of a nonabsorbable anchor suture in the flexor plate, can provide a great deal of control of the soft tissues and maintenance of MTPJ transverse and sagittal plane alignment. Theoretically, it is possible to effect MTPJ limitus using this technique, however, no cases of symptomatic lesser MTPJ limitus were encountered in this study.

Table 2

CLINICAL PATTERNS of CONTRACTED DIGITS

(n = 60 FUSIONS in 31 PATIENTS)

1. 19 PTS (61.29%) with 5th TOE ARTHROPLASTY
2. 12 PTS (38.71%) with HAV
3. 12 PTS (38.71%) HT 2-4 ONLY
4. 7 PTS (22.58%) HT 4 & 5 ONLY
5. 3 PTS (9.68%) LESSER PANMET.
6. 3 PTS (9.68%) ISOLATED INTERMED. TOE

(5% OF 60 DIGITAL FUSIONS)

Table 3

GENERAL COMPLICATIONS OF DIGITAL ARTHRODESIS

(n = 60 FUSIONS in 31 PATIENTS)

1. 3 (5%) PSEUDOARTHROSIS
2. 3 (5%) FLOATING TOE
3. 3 (5%) RECURRENT METATARSALGIA
4. 0 (0%) RECURRENT IPK
5. 1 (1.67%) INFECTION
6. 1 (1.67%) EDEMA
7. 1 (1.67%) RECURRENT TOE PAIN

Table 4

SPECIFIC COMPLICATIONS OF DIGITAL ARTHRODESIS

(n = 60 FUSIONS in 31 PATIENTS)

PSEUDOARTHROSIS (3/60, 5%)
2 End-To-End
1 Unpinned Peg-in-Hole

FLOATING TOE (3/60, 5%)
3 Peg-in-Hole, All Crossover 2ND
With HAV,1 Painful

RECURRENT IPK (0%)
100% Resolution of IPK, 76.47% (13/17)
Resolution of metatarsalgia due to IPK

INFECTION (1/60, 1.67%)
1 Peg-in-Hole, Pulled 3rd Toe Pin
of Fusion 2-4,
Cleansing Debride POD#3,
No Pseudoarthrosis

EDEMA (1/60, 1.67%)
1 End-to-end 4th Toe

RECURRENT TOE PAIN (1/60, 1.67%)
1 Peg-in-Hole 2nd, Floating, No HD

Table 5

RECURRENT METATARSALGIA FOLLOWING DIGITAL ARTHRODESIS

(n = 60 FUSIONS in 31 PATIENTS)

RECURRENT METATARSALGIA (3 PTS, 6 PEG-IN-HOLE)

Patient 1	HAV, CROSSOVER 2nd, IPK McB-REV, 2nd PEG-IN-HOLE ANALOG PAIN 4 -> 2, FLOAT, TYLOMA FLOATING 2nd WAS PAINFUL
Patient 2	RA, HAV & HR, CROSSOVER 2nd, IPK OSTEOCHONDRAL FRACTURE 3rd MET. KELLER, 2nd & 3rd PEG-IN-HOLE ANALOG PAIN 4 -> 2, FLOAT, TYLOMA
Patient 3	RA, HAV, IPK ANALOG PAIN 4 -> 3, RECURRENT SUBLUX. 2-4 PEG-IN-HOLE, ARTHROPLASTY 5 RETURNED FOR PANMET. HEAD & McKEEVER

CONCLUSION

Proximal interphalangeal arthrodesis, performed in conjunction with sequential digital and MTPJ release and K-wire stabilization, is a reliable surgical method for the treatment of recalcitrant digital and MTPJ contracture with or without associated lesser metatarsalgia. Particular attention should be paid to the extensor hood, which should be thoroughly recessed in order to eliminate the long extensor's deforming influence on the MTPJ. Moreover, careful attention should be directed at intra-operative realignment of the MTPJ flexor plate, and the use of a nonabsorbable anchor suture can be helpful in this regard. Overall, it is difficult to avoid development of a floating second digit when treating the crossover second toe deformity that accompanies an advanced hallux abductovalgus deformity with associated sub-second metatarsalgia.

When comparing the results of digital fusion using the peg-in-hole technique versus the end-to-end technique, it can be said that the peg-in-hole appears to be more reliable relative to ultimate radiographic evidence of fusion mass consolidation. All of the peg-in-hole fusions went on to solid arthrodesis, with the exception of the one that was not stabilized with a K-wire. An asymptomatic, functional pseudoarthrosis was developed in 18.18% of the end-to-end fusions. There was no subjective difference in the rate of patient satisfaction between individuals undergoing end-to-end arthrodesis in comparison to those undergoing peg-in-hole arthrodesis.

Digital stabilization and MTPJ relocation reliably alleviate associated metatarsalgia by virtue of elimination of the mechanical influence of the dorsally displaced toe on the metatarsal. Potentially complicating factors relative to recurrent metatarsalgia include rheumatoid arthritis, osteochondral lesion of the metatarsal head, and the crossover second toe deformity.

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