DIGITAL DEFORMITY ASSOCIATED WITH SUBLUXATION OF THE LESSER METATARSOPHALANGEAL JOINT (MTPJ)

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Introduction

Digital deformity associated with subluxation of the lesser metatarsophalangeal joint (MTPJ) is a relatively common occurrence. The relationship between the digital deformity and the pathological force it creates at the lesser MTPJ is now widely understood and accepted. The evaluation and surgical correction of the digital or metatarsal complaint should not be undertaken without a thorough appreciation and evaluation of this interrelationship. This paper reviews the anatomic and biomechanical relationships of the digit and lesser MTPJ. That information is then utilized as a basis for surgical correction of the digital deformity associated with the subluxated lesser MTPJ.

Normal Anatomy/Biomechanics

Proper appreciation of the digital and lesser MTPJ deformity involves an understanding of the extrinsic and intrinsic musculature as well as their orientation and biomechanical influence in the normal and pathological state. Extrinsic muscles that are of primary concern are the extensor digitorum longus and the flexor digitorum longus. Intrinsic muscles include the extensor and flexor brevis muscles, the dorsal and plantar interossei, the lumbricales, and the quadratus plantae. The static periarticular structures, including the plantar plate, will also be discussed.

The extensor digitorum longus and brevis form a conjoined tendon that trifurcates and inserts into the dorsal aspect of both the middle and distal phalanges. The primary influence of the extensors is through the extensor hood apparatus (Fig. 1) which envelops the proximal phalanx like a "sling." The contraction of the extensors creates a significant dorsiflexion of the proximal phalanx at the MTPJ via the extensor hood apparatus. To a lesser extent the extensors do dorsiflex the proximal and distal interphalangeal joints. The extensor digitorum longus functions during the swing phase of gait to aid in dorsiflexing the MTPJs and ankle.

The flexor digitorum brevis inserts into the plantar aspect of the middle phalanx and the flexor digitorum longus inserts into the plantar aspect of the distal phalanx. Since there is no direct insertion into the proximal phalanx these muscles will apply some plantarflexory force to the MTPJ in the non weightbearing attitude, but a dorsiflexor force to the MTPJ in the weight-bearing attitude (Fig. 2). The

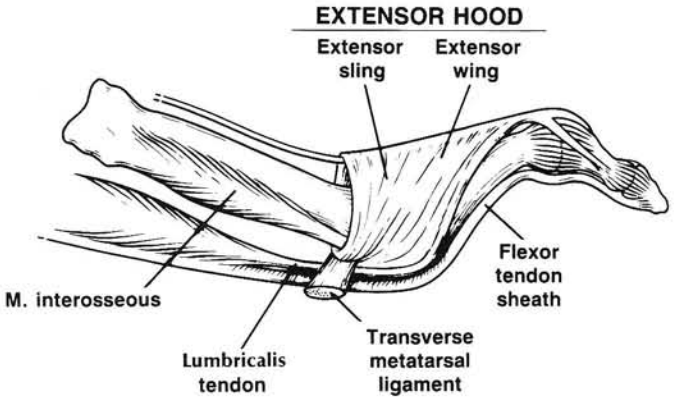

Fig. 1. Extensor hood with extensor "sling."

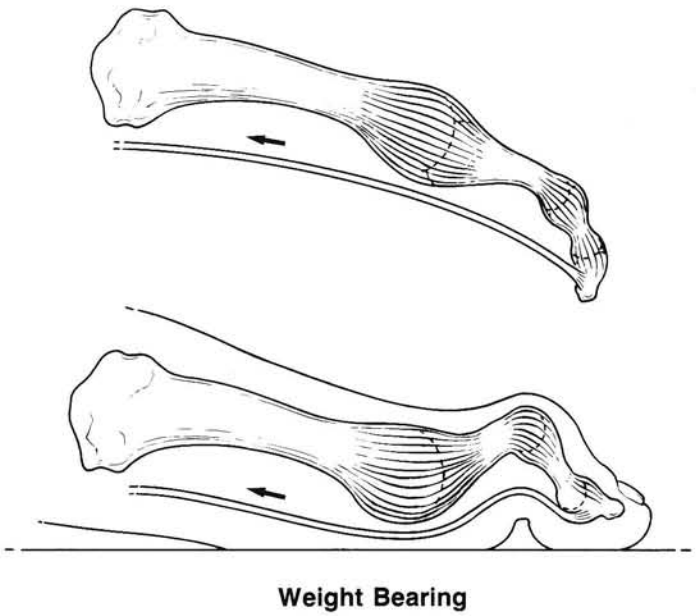

Fig. 2. Function of FDL in non-weightbearing and weightbearing attitude.

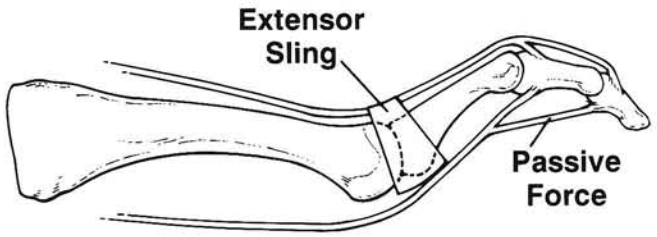

Fig. 3. Passive force of flexor tendons creates IPJ plantarflexion with active extensor tendon function.

flexors in normal gait function to plantarflex and stabilize the digits during the stance phase of gait.

The contractory influence of the extensor tendons is influenced by the flexor tendons. As stated, the extensor will dorsiflex the MTPJ via the hood apparatus. However, the small dorsiflexory force that the extensors exert at the interphalangeal joints is minimal and actually a passive plantarflexion of these joints will occur due to the flexor tendons. In other words, the fixed length of the flexor tendons passively plantarflex the interphalangeal joints (IPJ) when the extensors actively dorsiflex the MTPJ (Fig. 3).

Clearly, there must be some dynamic force to offset the influence of both the extensors and flexors. Certain intrinsic muscles are theorized to have this function. The interossei are thought to counterbalance the flexors and the lumbricales to neutralize the extensors.

The interossei consist of seven muscles and, combined with the abductor digiti quinti, form four pairs. The muscles originate from the metatarsal shafts and insert medially and laterally into each of the lesser digits. These muscles pass above the deep transverse intermetatarsal ligament, but more importantly course below the transverse axis of the MTPJ and insert into the plantarmost aspect of the proximal phalanx of the digit (Fig. 4). Thus, each pair of interossei function to stabilize the corresponding MTPJ in the transverse plane and to plantarflex the MTPJ in the sagittal plane. The interossei function during the stance phase of gait to stabilize the proximal phalanx just prior to the contraction of the flexor tendons. Their plantarflexory force at the MTPJ stabilizes the proximal phalanx on the ground and neutralizes the dorsiflexory buckling force of the flexors in a weightbearing attitude.

The lumbricales are four muscles with an unusual origin from the flexor digitorum longus tendons. They course beneath the deep transverse intermetatarsal ligament and insert medially into the base of the proximal phalanx and into the extensor hood apparatus. The lumbricales create a plantarflexory and adductory force at the MTPJ, dorsiflex the interphalangeal joints, and create slack in the flexor digitorum longus tendon (Fig. 5). Theoretically, this enables the lumbricales to limit the dorsiflexory forces of the extensors at the MTPJ during the swing phase of gait (1).

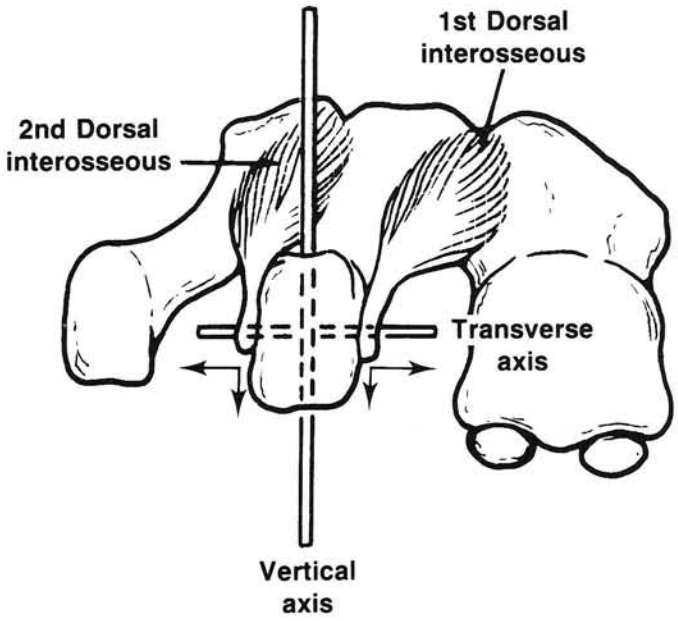

Fig. 4. Interossei function plantar to the transverse MTPJ axis and will plantarflex the joint in the sagittal plane.

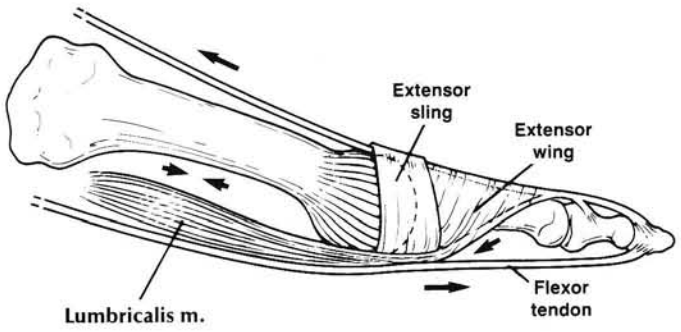

Fig. 5. Multiple actions of lumbricalis muscle.

The quadratus plantae is an intrinsic muscle that should also be discussed. The muscle originates from the calcaneus and inserts into the lateral aspect of the flexor digitorum longus tendon at the level of its division into digital slips. The quadratus plantae functions to straighten the pull of the flexor digitorum longus which would otherwise have a profound medial vector of force due to its anatomical course. When the quadratus plantae is weak or loses its mechanical advantage, the flexor digitorum longus does have a more medial pull and can create significant pathological changes including adduction or adductovarus deformities of the lateral digits.

Finally, the static structures should be discussed. These include the collateral ligaments of the interphalangeal and MTPJs, the transverse metatarsal ligaments, the capsular structures, and the plantar fascia (aponeurosis). Perhaps most important of these structures is the thickening of the plantar capsule of the MTPJ known as the plantar plate.

The plantar plate provides attachments for portions of the tendon sheaths of the flexor tendons, septae from the plantar fascia, the extensor hood apparatus, the deep transverse intermetatarsal ligament, and the respective interossei (2). Any alteration of the position of the plantar plate can drastically effect the function of the MTPJ and corresponding digit.

Digital deformity occurs when the delicate balance of the dynamic and static structures surrounding the MTPJ and digit is disrupted. Once the normal anatomy and biomechanics are understood the pathological anatomy can be discussed.

Pathologic Anatomy/Biomechanics

Digital deformities can be described as static or dynamic in nature. Static deformities are those due to extrinsic forces such as concomitant hallux abductovalgus deformity or confining shoegear. Dynamic deformities are secondary to a muscular imbalance due to neuropathy, hyperactivity, or overactivity. Green (3) has divided the dynamic abnormalities of digital functions into three major categories: flexor stabilization, extensor substitution, and flexor substitution. The relationship of the digital deformity to deformity of the MTPJ and the relationship of both deformities to their function in the gait cycle is of particular importance.

Flexor stabilization is probably the most common cause of digital deformity and likely to be associated with mild subluxation of the MTPJ. The deformity is stated to occur in the hypermobile foot where the flexors gain mechanical advantage over their opposing interossei. In the hypermobile foot type, the flexors fire earlier and longer in an attempt to stabilize the motion of the osseous structures. The flexors are generally unsuccessful at stabilizing the forefoot but they do overpower the interossei and create either a hammertoe or clawtoe contracture. Frequently, the quadratus plantae also loses its mechanical advantage and an adductovarus deformity of the fourth or fifth digits may result. The deformity occurs during the stance phase of gait and clinical evaluation will demonstrate the hypermobile foot (frequently with collapsing pes valgus deformity), with the digits classically attempting to "grip" the ground (Fig. 6).

Fig. 6. Example of flexor stabilization and digits "gripping" the ground.

Extensor substitution occurs during the swing phase of gait and is frequently associated with severe digital deformity and lesser MTPJ contracture and subluxation. Extensor substitution most commonly occurs in the cavus foot where in attempting to create additional dorsiflexion of the ankle, the extensors gain mechanical advantage over the lumbricales causing severe dorsiflexion at the lesser metatarsophalangeal joint. (Fig.7). It may also occur in neuromuscular disease when the lumbricales are decreased in muscle mass due to the disease. Over a period of time, this can lead to a fixed subluxation of the MTPJ and occasionally to dislocation.

Flexor substitution is the least common of the digital abnormalities and occurs during stance phase when the triceps surae is weak. When the triceps surae is weak, the flexor digitorum longus along with the deep posterior and lateral muscles will substitute for the weak triceps surae and try to create additional plantarflexory power at the ankle. When this occurs flexors, as in flexor stabilization, will overpower the interossei and create digital deformity.

Thus, digital deformity associated with subluxation of the MTPJ occurs most commonly with extensor substitution but can occur with any of the other dynamic digital deforming forces or with static deforming forces.

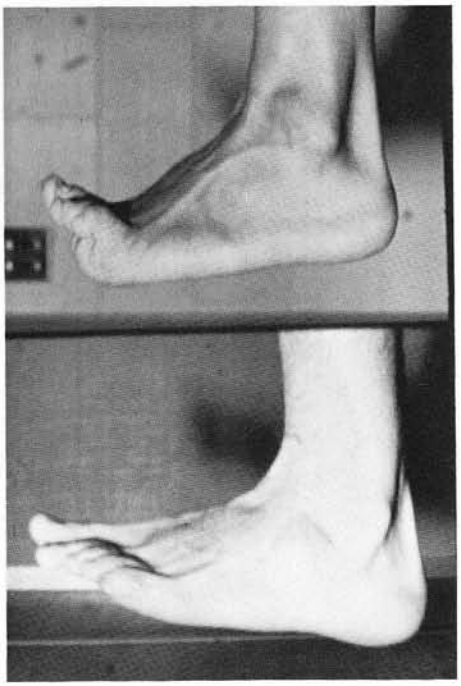

Fig. 7. Example of active MTPJ dorsiflexion in extensor substitution (TOP) and normal gait (BOTTOM).

Clinical Presentation

The digital deformity with associated subluxation of the lesser MTPJ presents with varying symptoms. The patient may complain of dorsal heloma durum of the digit or of submetatarsal keratosis. (frequently intractable plantar keratosis). With more severe deformity, chronic inflammation occurs in the involved lesser MTPJ. The deformity in most instances worsens with time as a vicious cycle occurs with:

1. digital deformity with dorsiflexion at the metatarsophalangeal joint,
2. retrograde buckling of the metatarsophalangeal joint with plantarflexion of the metatarsal,
3. increased digital deformity due to passive pull of the extensors,
4. more retrograde buckling.

Clinical evaluation of the deformity should include both stance and gait evaluation. Identification of static and/or dynamic deforming forces should be identified. Loading of the lesser metatarsal head plantarly (i.e., Kelikian push-up test) should be performed and the amount of MTPJ reduction visualized.

Further, if possible the position of the plantar plate should be determined. Most frequently, it will be displaced medially and the push-up test can identify adduction of the digit in the transverse plane at the MTPJ. Its position can also be determined by asking the patient to actively plantarflex the digits at the MTPJ and observe the direction of movement of the digits. Likewise, if the patient has a flexory superficial plantar response, it may be uti-

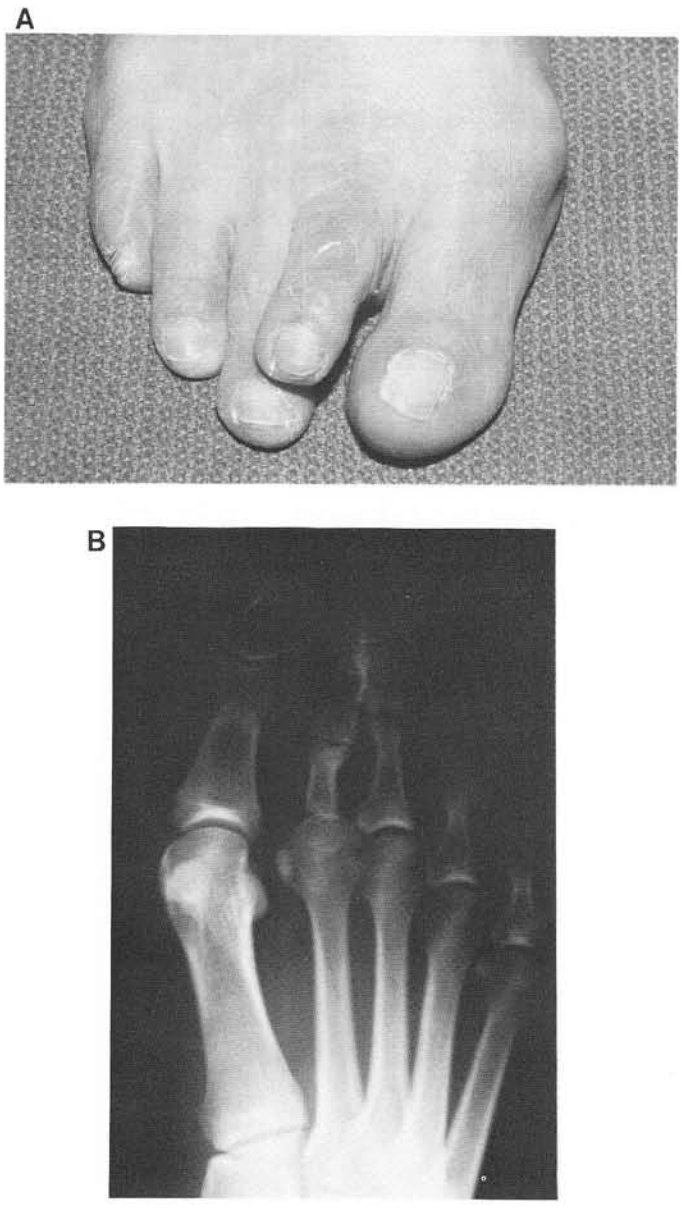

Fig. 8. A. & B. Clinical and radiographic appearance of unstable "floating" second toe 18 months after proximal phalangeal base resection.

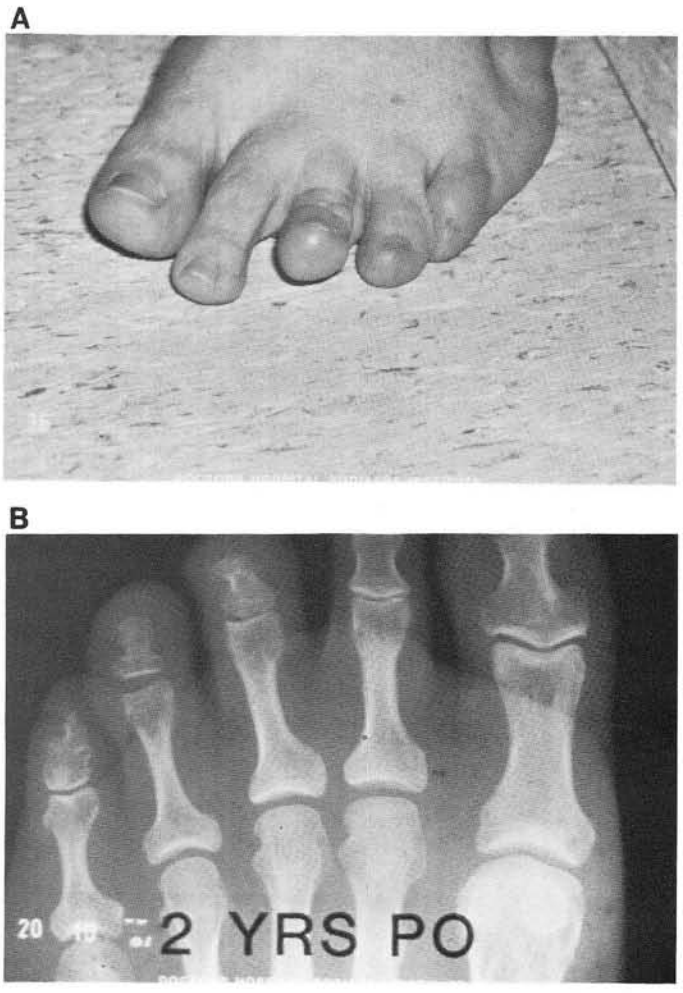

Fig. 9. A. & B. Clinical and radiographic appearance of "floating" third and fourth toe two years after middle phalangectomies.

lized to assess the direction of plantarflexory contraction at the MTPJ. If the digit contracts in an adducted direction at the MTPJ, it can be assumed that the plantar plate is displaced medially. If the digit contracts in an abducted direction at the MTPJ, it can be assumed that the plantar plate is displaced laterally. If the digit contracts at the MTPJ without movement in the transverse plane it can be assumed that the plantar plate remains directly plantar to the MTPJ. Finally, injection of radio-opaque dye into the flexor sheath can permit visualization of the displaced position of the plantar plate (4).

Upon stance, the contracture at the MTPJ will many times be visualized, especially in more severe cases. The digit in these instances will not purchase the ground and when hallux abductovalgus is present, a crossover second toe deformity may be seen.

Surgical Considerations

Many different procedures have been described for the digital deformity. The procedures in most instances have been attempted for the digital deformity with the subluxated lesser MTPJ. However, many such procedures are doomed to failure from an anatomical and biomechanical standpoint.

Two classical examples of such procedures are proximal phalangeal base resection and phalangectomy (proximal or middle). The proximal phalangeal base resection obviously destroys significant structures inserting into the phalangeal base, including the insertion of the interossei. The procedure will aggravate any existing contracture at the MTPJ and when performed alone virtually assures the need for additional surgery and probably syndactylization (Fig. 8). The middle phalangectomy similarly destroys vital insertions of the extensors and the flexor digitorum brevis. Again, the digit will be less stable and any contracture at the MTPJ will be exaggerated (Fig. 9).

The classic Post arthroplasty also is poorly suited for surgical correction of the digital deformity associated with the severely contracted lesser MTPJ. The arthroplasty will create "slack" at the level of the PIPJ but this is distal to the extensorhood apparatus and other deforming forces at the MTPJ. Thus, it will be inadequate to allow anatomic return of the proximal phalangeal stump.

The flexor tendon transfer can also be utilized for the correction of the deformity. However, if severe displacement of the plantar plate has occurred the deformity may be aggravated by a flexor tendon transfer. Also, the resultant biomechanical function of a digit following a flexor tendon transfer is many times unpredictable in these deformities.

Correction of the digital deformity associated with subluxation at the MTPJ requires a multifaceted surgical approach which stabilizes the digit and relocates the displaced plantar plate. A logical or progressive approach may be utilized for correcting the deformity including:

1. Lengthening of the extensor tendon
2. Extensor hood recession
3. MTPJ capsulotomy
4. Plantar capsule/plate release
5. Plantar plate relocation
6. PIPJ arthrodesis
7. PIPJ/MTPJ positional maintenance

In release of the structures surrounding the MTPJ, steps 2-5, the Kelikian push-up test may be performed after each step and MTPJ relocation assessed. If the MTPJ position is found to be satisfactory the later steps of the soft tissue release may be avoided and one may proceed to steps 6 and 7.

Arthrodesis at the PIPJ and the extensor hood recession allow the extensors to be effectively limited in their ability to dorsiflex the MTPJ. Any dorsiflexory pull following arthrodesis will be limited by the length of the flexors and the passive force the flexor digitorum brevis applies to the now united proximal and middle phalanges. The buckling effect created by the flexors at the PIPJ is also effectively eliminated by the arthrodesis. Release and relocation of the plantar plate will allow any adhesions of the flexors to be released recovering the full length of the tendons, and will allow for more normal function of the periarticular structures.

If severe degenerative changes exist at the MTPJ, an implant may be utilized with digital stabilization. Digital stabilization remains the critical adjunct to prevent undue stress on the implant. Implant arthroplasty of the MTPJ will destroy a significant portion of the periarticular anatomy and should be used only when the joint cannot be salvaged.

Surgical Technique (Currently recommended)

The procedure begins with a dorsal longitudinal incision extending from the MTPJ distally to the mid-portion of the middle phalanx. The incision may be extended proximally over the MTPJ if necessary but should be slightly curved over the MTPJ (Fig. 10A). If redundant skin is present over the PIPJ it may be excised by using two transverse semi-elliptical incisions over the PIPJ. This skin ellipse can be excised and joined to the proximal linear or curvilinear incision. The ellipse of skin should be excised in "controlled depth" fashion with care taken to avoid compromising the underlying vascular structures. The linear incision is then carried deep through the superficial fascia with care taken to obtain hemostasis. Once the deep fascial plane is identified the tissues may easily be reflected medially and laterally.

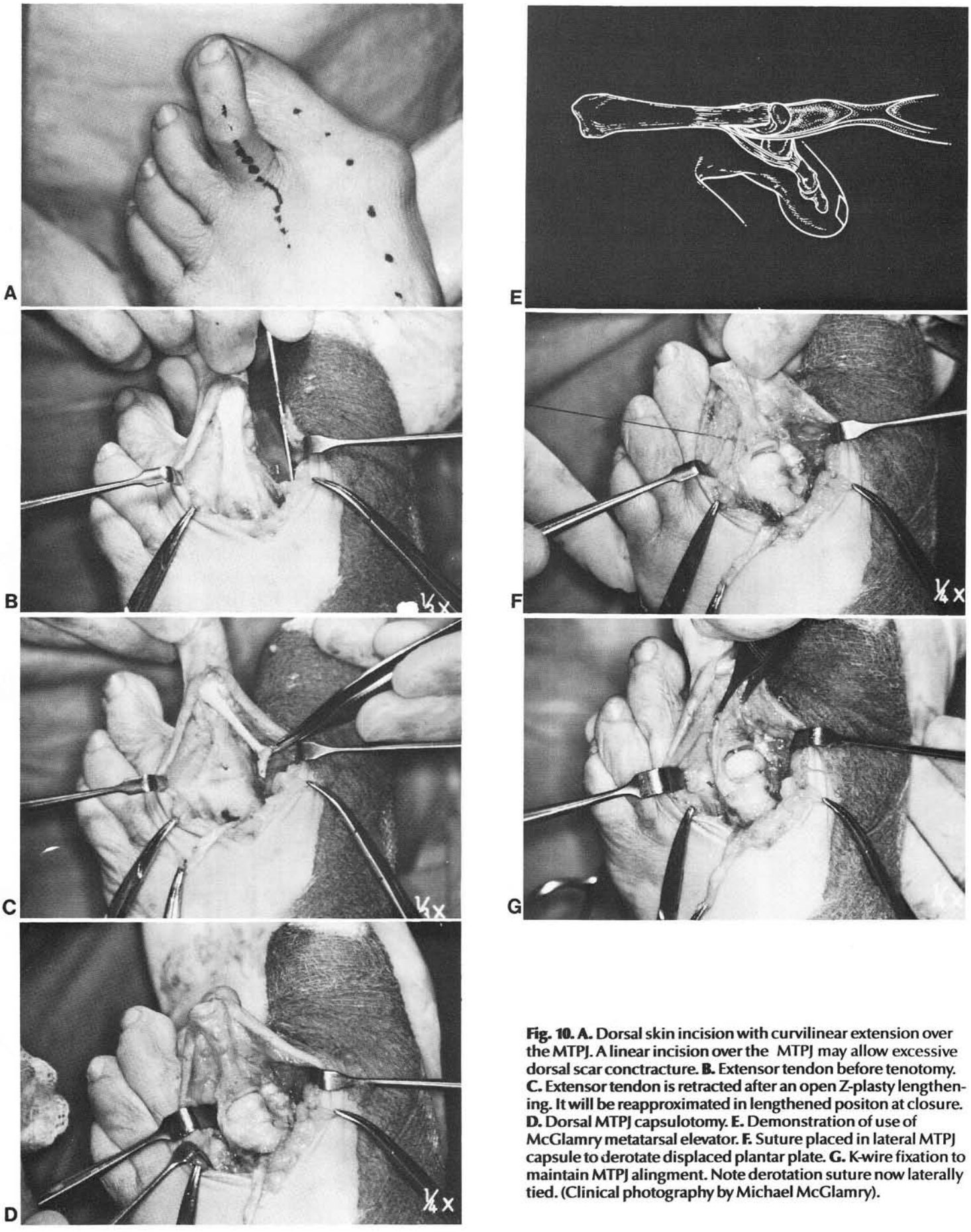

Fig. 10. A. Dorsal skin incision with curvilinear extension over the MTPJ. A linear incision over the MTPJ may allow excessive dorsal scar conctracture. **B.** Extensor tendon before tenotomy. **C.** Extensor tendon is retracted after an open Z-plasty lengthening. It will be reapproximated in lengthened positon at closure. **D.** Dorsal MTPJ capsulotomy. **E.** Demonstration of use of McGlamry metatarsal elevator. **F.** Suture placed in lateral MTPJ capsule to derotate displaced plantar plate. **G.** K-wire fixation to maintain MTPJ alingment. Note derotation suture now laterally tied. (Clinical photography by Michael McGlamry).

The extensor tendon is then lengthened as the first step of the surgical correction. The tendon is lengthened in open Z-plasty fashion and retracted (Figs. 10 B & C). Generally the proximal interphalangeal joint is opened at this point to allow more ease in the remainder of the correction.

The second step of the correction is the extensor hood recession. Lengthening of the tendon without release of the extensor hood would only allow "slack" distal to the MTPJ. However, once the extensor hood is released the tendon lengthening will create "slack" throughout the length of the tendon and across the MTPJ. In very mild deformities, the push-up test will reveal satisfactory reduction of the MTPJ and one may proceed to steps 6 and 7.

Next, the shaft of the proximal phalanx is grasped with a forceps and placed under distal traction. The MTPJ capsule is then opened with a "U-shaped" incision. The arms of the "U" extend proximally along the medial and lateral sides of the MTPJ (Fig. 10D). Again, if the push-up test reveals satisfactory reduction of the MTPJ then steps 4 and 5 can be eliminated.

Step 4 of the process involves release of the plantar capsule and plantar plate. Through the capsulotomy with the digit maximally plantarflexed, a McGlamry metatarsal elevator or other similar instrument may be inserted and passed plantarly through the MTPJ (Fig. 10E). By passing the elevator carefully proximal-plantarward the metatarsal head is effectively degloved of any adherent structures. If there is any fixed contracture of the flexors between the metatarsal head and their insertion this is released.

Next, if possible, any displacement of the plantar plate is corrected. If desired, the interosseus muscle or lumbricale on the side of the transverse plane deformity may be lengthened or released. Many times the plantar plate will be seen to be displaced medially and relocation of the plate plantarly via capsular correction and capsulorraphy needs to be performed. This is technically the most difficult step of the procedure. The capsular sutures (usually 3-0 absorbable) will be placed obliquely in an attempt to derotate the digit. The sutures may be placed but not tied until after the arthrodesis and wire insertion to the level of the MTPJ.

The sixth stage is the critical step in the correction of the deformity and the prevention of recurrence. An arthrodesis of the PIPJ is effected by either an end-to-end or peg-in-hole approach. After appropriate bone resection, a 0.045" Kirschner wire is driven out the end of the toe and retrograded across the resected PIPJ. The capsular sutures are then tied at the MTPJ.

Finally, the digit is held in the corrected (or perhaps slightly overcorrected) position and the Kirschner wire is driven across the MTPJ (Figs 10 F & G). Dorsal capsular structures are generally allowed to remain open. If very mild deformity has been corrected requiring only the early steps of correction, then a dressing alone may be used to maintain the corrected position at the MTPJ. In virtually all cases of MTPJ subluxation, the Kirschner wire (K-wire) will need to be driven across the MTPJ to maintain the corrected position. Care must be taken when positioning the digit to avoid excessive tension and possible neurovascular compromise.

The extensor tendon is then reapproximated in a lengthened position under physiologic tension with a 3-0 or 4-0 absorbable suture. The subcutaneous structures are closed with 4-0 absorbable suture and the skin with the suture of the surgeon's preference. Steri-strips, a saline moistened sponge, and a dry sterile dressing are then applied.

Postoperative Care

Followup care consists of maintaining the corrected position. A cast or surgical shoe is utilized. If a surgical shoe is chosen it should be modified by adding at least one-half inch of felt or cork from the heel to the sulcus under the toes. This will prevent bending forces on the wire at the MTPJ and possible wire breakage.

The wire is generally maintained for six weeks postoperatively. However, in milder deformities, the wire may be retracted across the MTPJ and left only across the PIPJ after 3-4 weeks. Active and passive motion is begun at the MTPJ as soon as the wire is retracted across it, whether at 3, 4 or 6 weeks.

Summary

The logical approach to the surgical correction of the digital deformity associated with MTPJ subluxation can provide satisfactory results in a majority of cases. It is the preferable method of reorienting pathologic anatomical changes and obtaining a dynamic and lasting correction.

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