Radiographic Analysis of Transverse Plane Digital Alignment After Surgical Repair of the Second Metatarsophalangeal Joint

Annalisa Y. Co, DPM, AACFAS,[1] John A. Ruch, DPM, FACFAS,[2] and D. Scot Malay, DPM, MSCE, FACFAS[3]

We undertook a retrospective cohort study of 51 feet in 49 patients with surgically managed second metatarsophalangeal joint instability, including repair of the crossover second toe deformity. The fundamental intervention consisted of proximal interphalangeal joint arthrodesis combined with second metatarsophalangeal joint relocation and Kirschner-wire transfixation, and this was performed alone or in combination with one of the following additional surgical maneuvers: flexor tendon transfer or flexor set release, flexor plate repair, placement of a plantar-lateral retention suture, extensor tendon transfer, metatarsophalangeal arthroplasty, metatarsal osteotomy, or second-to-third syndactyly. The outcome of interest was the presence of a transverse plane second metatarsophalangeal joint angle of 0° to 15° measured on the late postoperative follow-up radiograph. Overall, the median angular correction for all second metatarsophalangeal joint interventions was 8°, and second-to-third syndactyly yielded the most long-term correction followed by, in descending order of the amount of angular correction, use of the fundamental intervention in combination with metatarsophalangeal joint arthroplasty, placement of a plantar-lateral anchor suture in the flexor plate, metatarsal osteotomy, flexor tendon transfer, flexor plate repair, extensor tendon transfer, and the fundamental intervention as a solitary procedure. A sensitivity analysis indicated that our results were resistant to the influence that an unmeasured variable would impart on the data. The results of this investigation should aid surgeons treating patients with unstable second metatarsophalangeal joints, and can be used in the development of future clinical trials and observational studies that focus on the management of this common deformity. (The Journal of Foot & Ankle Surgery 45(6):380–399, 2006)

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In an effort to appreciate the multitude of surgical interventions that are available for realignment of the unstable second metatarsophalangeal joint (MTPJ), it is necessary to review the relevant anatomy and function of the joint. The second MTPJ consists of the soft tissue and bony structures that constitute the articulation between the second metatarsal and proximal phalanx of the second toe. The joint capsule dorsally merges with the short and long extensor tendons to form the extensor apparatus, whereas the plantar portion of the joint capsule and the distal slip of the plantar aponeurosis coalesce to form the fibrous plantar plate. The plantar plate is approximately 2 mm to 5 mm thick (1, 2) and firmly adheres to the plantar aspect of the base of the proximal phalanx while being loosely attached to the metatarsal neck (3, 4). There are 2 sets of collateral ligaments in the region of the second MTPJ, the accessory collateral ligaments (ACLs), and the proper or phalangeal collateral ligaments (PCLs) (4, 5). The ACLs, or metatarsoglenoid ligaments, originate from the anterior superior aspect of the metatarsal neck and insert into the plantar plate. The PCLs, or metatarsophalangeal collateral ligaments (4), originate from the anterior superior portion of the metatarsal head and insert into the plantar base of the proximal phalanx. Longitudinally, the deep transverse intermetatarsal ligament (DTIL) connects the first MTPJ capsule and sesamoid apparatus to the second MTPJ plantar plate in a bifurcate fashion (6). The first lumbricale inserts into the medial aspect of the extensor apparatus, and the first and second

Address correspondence to: Dr. Annalisa Y. Co, Northern California Orthopedic Centers, 6403 Coyle Ave Suite 170, Carmichael, CA 95608. E-mail: annalisaco@yahoo.com.

[1]Private Practice, Carmichael, California.

[2]Scientific Chairman, The Podiatry Institute, and Staff Surgeon, Northlake Medical Center, Tucker, Georgia.

[3]Director of Podiatric Research and Co-Director, Foot and Ankle Surgical Residency Program, Penn Presbyterian Medical Center, and the Ankle and Foot Medical Centers of the Delaware Valley, Philadelphia, Pennsylvania.

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dorsal interossei attach on either side of the proximal phalangeal base and partly on the extensor expansion.

Functionally, sagittal plane stability of the second MTPJ is maintained by a dynamic balance between the tendons of the extensors dorsally and flexors plantarly, as well as the tendons of the lumbricales and interossei. The short and long flexors glide within the central groove of the plantar plate, within their surrounding fibrous flexor sheath, and have small attachments (vinculae) to the plate itself. The plantar plate is generally considered important, along with ground reactive forces and external shoe pressures applied to the second ray during stance and gait, regarding the maintenance of lesser MTPJ sagittal and transverse plane balance and stability. Furthermore, in the transverse plane, second MTPJ stability is thought to be maintained by the PCL, and cadaveric studies have shown that the collateral ligaments and plantar plate act to stabilize the second MTPJ when a straight, vertical force is applied to the joint (7). Others have also identified the intrinsic muscle attachments, consisting of 2 dorsal interossei and the first lumbricale, as dynamic controllers of the transverse plane balance of the second toe (8). In the anatomically balanced second MTPJ, the lateral capsule remains intact and counters the miniscule (owing to the muscle's relatively small size) adduction force of the first lumbricale.

Second MTPJ instability, with or without inflammation of the joint and/or periarticular structures, can lead to multiplanar malalignment. MTPJ instability, as an isolated entity or in conjunction with other neighboring pathology, is referred to in a variety of ways in the published literature, including predislocation syndrome (9, 10), plantar plate dysfunction (11), monoarticular nontraumatic synovitis (12), MTPJ capsulitis and synovitis, metatarsalgia, and crossover toe deformity (13, 14). Yu et al (10) coined the term *predislocation syndrome* and staged the progression of this condition. Fleming and Camasta coined the term *plantar plate dysfunction* and categorized the deformity based on the joints response to a modified Lachman's test (11). They further divided the condition into a predislocation stage, characterized by a negative Lachman's test; a subluxation stage, wherein the phalangeal base subluxates dorsally on the metatarsal head by approximately 50% of the articular surface; and a dislocation stage, wherein nearly 100% dorsal dislocation is observed.

Theoretical etiologies for second MTPJ subluxation and dislocation include the presence of an accessory tendon, observed in a cadaveric investigation, which has been noted in some second-digit crossover deformities (15); a long second metatarsal (16–19); metatarsal head deformation secondary to trauma or Freiberg's infraction; erosion of the proper collateral ligament and lateral joint capsule, as may occur in rheumatoid arthritis and other systemic arthritides (5, 17); plantar plate attenuation or rupture (8, 11, 20–25); lesser metatarsal overload in the presence of first ray pathology (8, 13, 20, 26, 27); and the pathological influence of the DTIL acting on the second MTPJ (28, 29). Despite these speculative etiologies, the exact cause of second MTPJ instability remains unclear, and there may be a combination of factors that influence the development of the condition. Tight stockings and high-heeled shoes have even been hypothesized to maintain the digits in constant hyperextension, leading to subluxation and dislocation of the second MTPJ (13). More recently, others have noted that multiplanar deformity of the second digit is likely due to lateral capsular and collateral ligament disruption with resultant plantar plate displacement and injury (14), and a variety of imaging methods have been used to elucidate the distortion of the involved soft tissues (30–32). This cascade is most likely multifactorial and triggered by a combination of biomechanical and anatomical factors that create a chronic degenerative state that disrupts the periarticular structures, leading to displacement of the flexor tendons.

Nonsurgical treatment of second MTPJ instability includes splinting or taping of the crossover second toe in a corrected or more balanced alignment, although this treatment may inhibit even normal dorsal migration of the phalanx on the metatarsal head. Functional foot orthoses and rocker-bottom shoe modifications have also been advocated to reduce forefoot pressure plantar to the second MTPJ (33); and metatarsal padding, with or without accommodative or functional orthoses, has also be used to off-load the metatarsal head. Of course, nonsteroidal antiinflammatory drugs, as well as the judicious use of injectable or systemic corticosteroids, can also be useful in reducing pain and inflammation related to the pathological joint.

A variety of surgical treatments has also been aimed at the repair and restoration of the alignment and function of the second MTPJ (34), and many of these include first ray intervention due to the common association of first ray dysfunction and deformity with lesser metatarsalgia and deformity. Still further, in patients with second MTPJ instability, the medial column should be evaluated for contributing factors, and appropriate procedures should be implemented accordingly. Popular surgical approaches that have been described in the literature include proximal interphalangeal joint (PIPJ) arthrodesis (8, 35), flexor tendon transfer (FTT) (8, 10, 20, 22, 36–38), plantar-lateral retention suture (21, 39, 40), collateral ligament repair (7, 21, 41, 42), plantar plate repair (11, 20, 43, 44), MTPJ arthroplasty (21, 45, 46), and various metatarsal osteotomies (35, 47–50). Despite the fact that a variety of surgical procedures have been described to address second MTPJ instability, to date there are no long-term studies to document maintenance of the correction after intervention. It is the purpose of this retrospective cohort study to evaluate the maintenance of radiographic correction of the surgically repaired second MTPJ.