A pictorial review of reconstructive foot and ankle surgery: elective lesser forefoot procedures

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ABSTRACT

This pictorial review focuses on basic procedures performed within the field of podiatric surgery, specifically for elective procedures of the lesser forefoot including the correction of hammertoes and lesser metatarsal deformities. Our goal is to demonstrate objective radiographic parameters that surgeons utilize to initially define the deformity, lead to procedure selection and judge post-operative outcomes. We hope that radiologists will employ this information to improve their assessment of post-operative radiographs following reconstructive foot surgeries. First, relevant radiographic measurements are defined and their role in procedure selection explained. Second, the specific surgical procedures of the digital arthroplasty, digital arthrodesis, lesser metatarsal osteotomy, and correction of metatarsus adductus are described in detail. Finally, specific plain film radiographic findings that judge post-operative outcomes for each procedure are detailed.

REVIEW ARTICLE

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PICTORIAL REVIEW

The intention of this review is to present radiologists with a basic overview of common procedures performed within the field of podiatric foot and ankle reconstructive surgery. This article specifically focuses on elective procedures of the lesser forefoot including hammertoes and metatarsal osteotomies. Our goal is to emphasize radiographic findings that surgeons utilize to judge post-operative outcomes, but we will also review the pre-operative radiographic parameters that initially define the deformities and lead to procedure selection. It is our hope that radiologists will employ this information to improve their ability to assess post-operative radiographs following reconstructive foot surgeries.

Digital Deformity Radiographic Presentation

The term “hammertoe” is a simplified descriptive term for deformity of one or more of the lesser digits [1]. The lesser forefoot is an anatomic descriptor that refers to the second, third, fourth and fifth digits with their corresponding metatarsals (essentially excluding the first metatarsal and hallux). The diagnosis of hammertoes is primarily made clinically, and involves the physical examination and palpation of the several bones and multiple joints of the digit. Pre-operative radiographs are universally utilized however, and may play an important role in pre-operative surgical planning. Because nearly all foot and ankle deformities have a dynamic biomechanical component, it is important to always evaluate these deformities with weight-bearing radiographs taken in the angle and base of gait [2]. With that said, it is also important to appreciate that most post-operative radiographs will be ordered as non-weight bearing views in order to protect the surgical site.

With the presentation of hammertoes, the metatarsal-phalangeal joint is generally in a relatively dorsiflexed or extended position, and this can be appreciated radiographically in the transverse plane with an anterior-posterior (AP) or dorsal-plantar (DP) foot projection as decreased joint space or even the complete loss of joint space with overlap of the base of the proximal phalanx on the head of the metatarsal (Figure 1) [1]. All the lesser metatarsal-phalangeal joints, but particularly the 2nd, may present with a chronic subluxation or dislocation of the joint with the proximal phalangeal base located dorsal to the head of the metatarsal (Figure 2). This particular finding may be associated with partial tear or complete rupture of the plantar plate of the metatarsal-phalangeal joint [1]. Although clinically this is primarily a sagittal plane deformity with flexion/extension, it is also important to radiographically assess the transverse plane positioning of these joints as well.

With significant biomechanically-induced deformity, the metatarsal-phalangeal joints may be noted to be in a relatively adducted position (Figure 1 and Figure 2 left image). In other deformities, such as with advanced rheumatoid arthritis, there may be a relatively abducted transverse plane positioning of all lesser digits (Figure 3) [2]. Although an objective angular measurement is described between the long axis of the metatarsal and corresponding digital proximal phalanx, this is not typically utilized in clinical practice or for pre-operative procedure planning.

More distally in the digit, the proximal interphalangeal joint (PIPJ) and distal interphalangeal joint (DIPJ) are generally in a relatively plantarflexed position and this can also be appreciated radiographically as bony overlap on the AP projection [1]. A “gun barrel” sign may be seen on this view (Figure 4) [3]. This is a consequence of the sagittal plane deformity of the phalanges and radiographic projection where one seems to be “looking down the barrel” of the shaft of the proximal phalanx.

A final important finding within the digit is to note whether a synostosis is present at the PIPJ or DIPJ level. This is most common at the DIPJ of the 5th digit, occurring in up to 40% of the population, and may alter procedural planning (Figure 5) [4].

The assessment of hammertoes is one area of podiatric surgery where pre-operative radiographs actually have relatively little impact on procedural selection. Although the degree of deformity may be subjectively evaluated with radiographs, the decision to proceed with a specific surgical procedure is more likely through physical examination techniques and clinical assessment.

Digital Deformity Surgical Correction: Arthroplasty procedure

Arthroplasty of the PIPJ is the most common procedure utilized for correction of the hammertoe deformity and has remained primarily unchanged since its original description by Post in 1882 [5]. The procedure involves planal resection of the head of the proximal phalanx, on an angle perpendicular to the long axis of the remainder of the proximal phalanx (Figure 6) [1]. In other words, an even amount of bone is resected dorsally, plantarly, medially and laterally to prevent secondary distal deformity.

This procedure may be performed without fixation (as with digits 4 and 5 in Figure 6), or a percutaneous intramedullary Kirschner wire (K-wire) may be used to maintain the position during the post-operative period (as in digits 2 and 3 in Figure 6) [1]. If a K-wire is utilized, then several parameters are evaluated on the post-operative radiograph. First, there should be some diastasis between the resected margin of the proximal phalanx and the base of the middle phalanx (Figure 7). This area will eventually fill in with scar tissue, maintain the length of the digit, and help the long-term positioning of the joint. Second, the position of the K-wire within the bones of the digit is evaluated. This form of fixation is aimed to be intramedullary, and should be well within the canal of the distal, middle and proximal phalanges, as well as the corresponding metatarsal if applicable. The third radiographic parameter is to appreciate the final proximal position of the K-wire. Most commonly, it is the aim of the surgeon to have the tip of the wire within the base of the proximal phalanx (as in Figure 7) or within the corresponding metatarsal (as in Figure 6). The surgeon may choose to cross the metatarsal-phalangeal joint with the wire to achieve a more stable construct post-operatively and more definitively hold the sagittal position of the correction. If the metatarsal-phalangeal joint is crossed, then it is important to assess the transverse plane positioning of the joint, particularly compared to pre-operative views.

When K-wires are utilized, it is not desirable to have the proximal portion of the pin within any joint or within the surrounding soft tissues. Although there are certainly times when these wires may end up within the soft tissue of the interspaces and still be considered acceptable, it is more appropriate to have it in an intramedullary position (Figures 8-11).

Finally, an adjunctive arthroplasty procedure may also performed on the head of the middle phalanx for deformity at the DIPJ level (Figure 12), with or without fixation.

Digital Deformity Surgical Correction: Arthrodesis procedure

Severe digital deformities, especially those that are rigidly contracted, are treated with arthrodesis of the PIPJ and/or DIPJ [1]. On initial radiographic evaluation, the arthrodesis and arthroplasty procedures may look very similar post-operatively, but an arthrodesis involves bone resection from the base of the middle phalanx in addition to the head of the proximal phalanx [1]. On the post-operative radiographs, one should be able to appreciate the osseous resection from both the base of middle phalanx and the head of the proximal phalanx, and this joint will now be directly and tightly apposed instead of having a diastasis present (Figure 13).

Arthrodesis procedures nearly always involve K-wire fixation as described in the previous section, but may also utilize a variety of specialized and commercially available implantable devices including screws, prosthetic implants and absorbable pins (Figure 14) [3]. K-wires are generally inserted percutaneously with planned removal between 4-6 weeks [3]. These other buried devices may remain in situ indefinitely, as long as they remain asymptomatic to the patient.

Uncommonly, different shapes are utilized for resection of the bone from the joint (Figure 15). The common bone resection is a transverse "table top" cut from both sides of the joint as has been previously described (Figure 15A), but a "V" shaped resection (Figure 15B) and "peg-in-hole" (Figure 15C) resection are also occasionally performed [1]. These have little effect on post-operative positioning, assessment, and the goals of the procedure, and more often represents the preference of the surgeon.

Multiple soft tissue procedures may also be performed for the correction of hammertoe deformities in addition to the osseous procedures described here. These may include extensor tendon lengthening, flexor tendon tenotomy or transfer, and joint capsule release [1]. These will certainly have an effect on final positioning and outcome, but are not visible radiographically.

Metatarsal Deformity Radiographic Presentation

Pain and subjective symptoms of the lesser metatarsals are generally known by the term "metatarsalgia," but can refer to one of a number of different pathologies or structural deformities. Generally speaking and most commonly, excessive plantar pressure is generated under one or more of the lesser metatarsal heads with the clinical presentation of pain and callus formation (Figure 16) [1]. One way this excessive pressure may be generated is with an associated hammertoe deformity, as the dorsal displacement of the digit at metatarsalphalangeal joint (MTPJ) level places a retrograde force on the metatarsal head and drives it in a relatively plantar direction. The dorsally displaced digit literally pushes the metatarsal head into the ground. It may also result from a structural deformity when a given metatarsal is elongated, plantarly displaced and/or possesses enlarged anatomy (head and/or plantar condyles) relative to the adjacent metatarsals [1]. The key to the preceding sentence was the term "relative". Surgeons tend to think of the lesser metatarsals acting as a unit during weight-bearing and gait, and assume that a "normal" metatarsal parabola will result in the effective transfer of pressure medially and distally during propulsion (Figure 17) [1]. An elongated, plantarly displaced, or enlarged metatarsal ineffectively increases the pressure on that metatarsal, just as a shortened or dorsally displaced metatarsal decreases the pressure on that metatarsal and subsequently increases the pressure on the adjacent metatarsals.

The term parabola refers to the generalized structure of the forefoot, specifically with respect to the distal extension of the metatarsals on a DP projection in the angle and base of gait [6]. Traditionally, a gradual taper of length is expected to progress across the forefoot from the second metatarsal to the fifth metatarsal, with the first metatarsal being somewhat shorter than the second (2 > 1 = 3 > 4 > 5). However, it is also deemed acceptable if the first and second metatarsals are found to be of equal length (1 = 2 > 3 > 4 > 5). The first and second metatarsal lengths are considered normal if they are within 2mm of each other [7].

The length pattern of the metatarsals is most easily visualized by drawing a straight line across the most distal aspect of the lesser metatarsal heads (Figure 18). Any deviation off of this straight line indicates a metatarsal that is considered either too "long" or "short" [6]. The right image of Figure 18 demonstrates the pre-operative radiograph of a patient with second and third metatarsals that are too "long" and causing clinical symptoms.

An obvious problem with this type of radiographic assessment is that surgeons are attempting to assess a dynamic sagittal plane deformity (relative plantarflexion of the metatarsal head) with a static transverse plane measurement (AP radiographic projection). As surgeons, we assume that as the metatarsal extends further distally, then it also extends further plantarly given the normal anatomic declination of the metatarsal. Some surgeons however prefer to assess this sagittal plane deformity with a sesamoid axial radiographic projection which takes into account a more direct visualization of the sagittal plane position, as well as more closely resembling the structure of the plantar forefoot during gait (Figure 19) [6].

Metatarsal Deformity Surgical Correction: The Weil Osteotomy

Lesser metatarsal surgery primarily aims to restore the metatarsal parabola to one of the accepted length patterns (2 > 1 = 3 > 4 > 5, or 1 = 2 > 3 > 4 > 5). This is best achieved by one or multiple shortening osteotomies performed at the level of the metatarsal neck. The most common of these is the Weil osteotomy which produces a cut through the metatarsal neck and parallel to the ground [8,9]. Following completion of the cut, the head of the metatarsal can then be shifted proximally and "shortened" to fall back in line with the remainder of the parabola (Figure 20 and Figure 21). This osteotomy is typically fixated with a single screw [8,9].

Bunionette Deformity Radiographic Presentation

The fifth metatarsal requires special mention because of the unique "bunionette" deformity that may be present. This is similar in nature and presentation to the hallux abductovalgus (HAV) deformity as described in a separate portion of this pictorial review [10], but involves the 5th metatarsal-phalangeal joint instead of the 1st. In this case, the lateral aspect of the 5th metatarsal head is prominent and may be symptomatic.

Two unique angles are described for the pre-operative evaluation of this deformity, and are also used for post-operative assessment of deformity correction:

-The 4-5 intermetatarsal angle is the resultant angle between the longitudinal bisection of the 4th metatarsal and a line drawn tangential to the proximal medial aspect of the 5th metatarsal shaft. (Figure 22). The normal value of this measurement is approximately 6 degrees, with any value over 9 degrees considered abnormal [1, 11].

-The lateral deviation angle is the resultant angle between the longitudinal axis of the 5th metatarsal head/neck and a line tangential to the proximal medial aspect of the 5th metatarsal (Figure 23). This measures any intrinsic deformity or lateral "bowing" within the metatarsal itself. The normal value of this measurement is approximately 3 degrees, with any value over 8 degrees considered abnormal [1, 11].

Bunionette Deformity Surgical Correction

Surgical correction of the bunionette deformity is also similar to correction of the HAV deformity, but involves medial translation of the distal aspect of the fifth metatarsal relative to the remainder of the shaft. So-called "head", "shaft" and "base" procedures are described and fixated comparable to the HAV deformity, only applied in "reverse" or medial direction [1]. In fact, the names of the procedures often highlight, for example the "reverse Austin" which is performed within the head of the fifth metatarsal (Figure 24). The reader is encouraged to read the previously published first part of this foot and ankle pictorial review series for detailed descriptions of these procedures [10]. Procedure selection and surgeon preference often dictate use of fixation for these osteotomies, ranging from no fixation, to K-wires, or finally screw placement. However, some studies show that use of fixation produces a more stable construct with fewer complications [12].

Metatarsus Adductus Radiographic Presentation

A final deformity affecting the forefoot is a global medial transverse plane displacement, or adduction, of the forefoot relative to the midfoot and rearfoot. This is typically the result of deformity within the metatarsals themselves, or a deformity at the tarsal-metatarsal articulation [13]. The metatarsus adductus angle may be utilized to describe this deformity, but can be difficult and complex to perform in clinical practice. For this reason, a more simplified angle is often used known as Engel's angle (Figure 25). This is the resultant angle between the longitudinal bisection of the 2nd metatarsal and the intermediate cuneiform. An abnormal measurement is greater than 24 degrees [13, 14].

Metatarsus Adductus Surgical Correction

As the metatarsus adductus deformity involves all of the metatarsals, surgical correction usually involves osteotomy and fixation of all the metatarsals. Most commonly, wedge-type or rotational osteotomies are performed within the proximal aspect of the metatarsal shaft or within the metatarsal bases, and fixated accordingly (Figure 26) [13]. Surgeons typically judge appropriate correction based on a return to normal values for Engel's angle and the first intermetatarsal angle.

TEACHING POINT

The preceding was a basic review of common procedures utilized by foot and ankle surgeons for correction of hammertoe and lesser metatarsal deformities. We attempted to emphasize which specific radiographic findings and measurements lead to procedure selection, as well as provide as a basic visual understanding of the most commonly performed procedures. It is our hope that radiologists will employ this information to improve their ability to assess post-operative radiographs following foot and ankle reconstructive surgeries.

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FIGURES

Figure 1 (right): This weight-bearing AP projection of a left forefoot of a 56 y/o female demonstrates mild hammertoe deformities, with emphasis on the transverse plane assessment. There is subtle irregular joint space narrowing of the 2nd metatarsal-phalangeal joint (MTPJ) compared to the other lesser digits which indicates dorsal contracture of the second digit at the MTPJ. This joint is also somewhat adducted in the transverse plane relative to the long axis of the 2nd metatarsal. Incidental not is made of hallux abductovalgus deformity of the 1st MTPJ, as well as contracture of the interphalangeal joints of digits 3, 4 and 5.

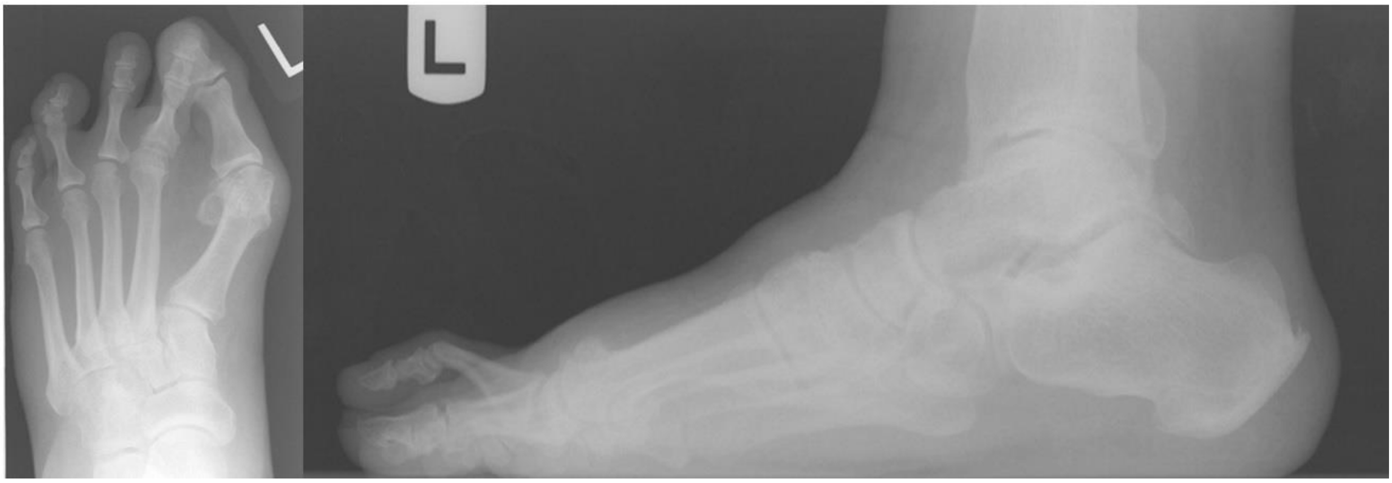

Figure 2: AP (left) and lateral (right) projections of a left foot of a 45 y/o female demonstrating a severe hammertoe deformity with emphasis on both the transverse and sagittal planes. On the AP projection there is complete obliteration of the 2nd MTPJ joint space which correlates with the 2nd proximal phalanx base subluxed to a position on top of the 2nd metatarsal head. There is also transverse plane adduction of the joint. On the lateral projection, the degree of sagittal plane deformity is appreciated with the second digit clearly visible in a dorsiflexed position. Clinical assessment of the integrity of the plantar plate of the joint would be performed in this case.

Figure 3: AP projection of a 44 y/o female with advanced rheumatoid arthritis demonstrating laterally subluxed (abducted) lesser MTPJs. Biomechanically-induced hammertoe deformity typically presents with a relative medial dislocation (adduction) of the digit(s) at the MTPJ, while inflammatory arthritides may present with lateral dislocation (abduction). Although an objective angle is described between the long axis of the metatarsal and corresponding digital proximal phalanx, usually a more descriptive and subjective assessment is performed.

Figure 4: Coned AP view of the left forefoot of a 36 y/o male demonstrates derangement with overlap of the lesser PIPJs/DIPJs, as well as a "gun barrel" sign (arrows). Note the circular pattern observed within the proximal phalanges of digits 2, 3, and 4. This "gun barrel" sign is the result of a relatively dorsiflexed position of the proximal phalanx that makes it appear as though you are "looking down the barrel" of the proximal phalanx.

Figure 5: Coned AP view of a right forefoot demonstrates synostoses of the DIPJs of both 4th and 5th digits. This is a common finding, particularly of the 5th digit DIPJ, and may alter procedure selection for correction of a hammertoe deformity.

Figure 6: In this coned post-operative AP projection of a 35 y/o male, there are arthroplasty procedures of the 2nd, 3rd, 4th and 5th proximal interphalangeal joints, with Kirschner wire (K-wire) fixation of the 2nd and 3rd digits. Note how equal bone has been removed in a medial and lateral orientation from the heads of the 2nd, 3rd and 5th proximal phalanges. This resection should be made perpendicular to the long axis of the

proximal phalanx. On the 4th digit, however, it appears as though more bone was removed medially than laterally, which could subsequently push the distal toe into a relatively adducted or medially displaced orientation. Also note how the bases of the middle phalanges are intact, indicating that this was an arthroplasty and not an arthrodesis procedure.

Figure 7: Coned AP post-operative view of a right forefoot of a 32 y/o female demonstrates an appropriate and acceptable 2nd digit following PIPJ arthroplasty. Note the transverse osteotomy of the proximal phalanx head (removing equal portions of bone medially and laterally), the diastasis achieved at PIPJ level with the K-wire, the position of the K-wire within the center of the medullary canal of the distal, middle and proximal phalanges of the 2nd digit, and the proximal placement of the K-wire within the base of the 2nd proximal phalanx. Compare this to the K-wire placement in the 3rd digit which is offset laterally, relatively short and not well-fixated within the proximal phalanx.

Figure 8: Post-operative AP view of a right forefoot of a 27 y/o female demonstrates poor positioning of the K-wire within the second digit. Note the proximal positioning of the K-wire residing within the MTPJ space which can result in cartilage damage. This pin should be pulled back in the post-operative recovery room, so that the tip resides within the base of the proximal phalanx and not within the joint.

Figure 9 (right): Post-operative AP view of a right forefoot of a 42 y/o female demonstrates relatively poor positioning of the digital K-wires with the fixation of the 2nd digit completely missing the proximal phalanx and ending well within soft tissue structures, fixation of the 3rd digit close to residing within the 3rd MTPJ, and fixation of the 4th digit being too short and not well fixated within the 4th digit proximal phalanx shaft or base.

Figure 10 (left): Post-operative oblique view of a 37 y/o female demonstrates relatively poor K-wire fixation with the proximal portion of the K-wires not residing within the second and third metatarsal shafts, but instead well within adjacent soft tissue structures. One buried and one percutaneous K-wire are also noted in the first metatarsal for correction of the hallux abductovalgus deformity with a distal first metatarsal osteotomy.

Figure 11 (bottom): Post-operative AP (left) and lateral (right) projections of a 35 y/o female demonstrate relatively poor fixation with the K-wire likely completely missing the 2nd metatarsal head dorsally and laterally, and not able to effectively hold the position of the joint in the desired position.

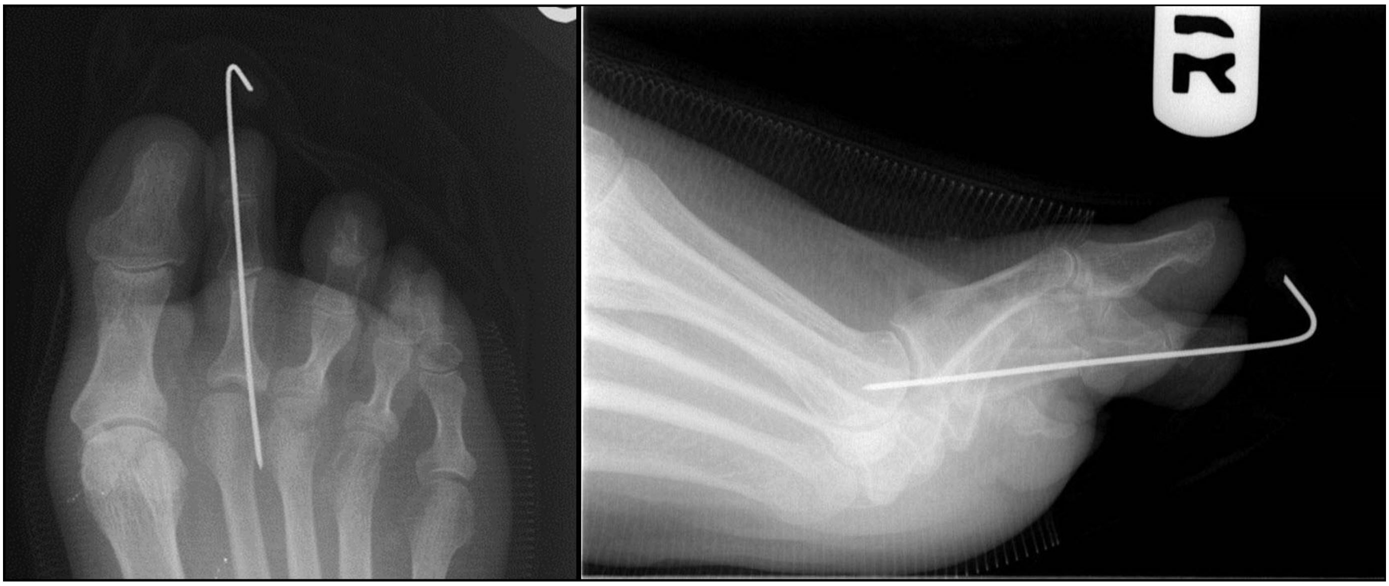

Figure 12: Post-operative AP projections demonstrate arthroplasty procedures performed at distal interphalangeal joint (DIPJ) level. The left image demonstrates a second digit DIPJ arthroplasty fixated with a single K-wire in the setting of a previous PIPJ arthrodesis of a 19 y/o female. Note the head of the middle phalanx has been resected in a transverse orientation. The right image demonstrates DIPJ arthroplasties of digits 2, 3, and 4, as well as a PIPJ arthroplasty of the 5th digit of a 51 y/o female, all without K-wire fixation.

Figure 13 (left): Post-operative oblique view of a right forefoot of a 43 y/o male depicts both an arthrodesis of the 2nd PIPJ and arthroplasty of the 5th PIPJ. Compared to the arthroplasty procedure, one can appreciate in the arthrodesis that planal resection from the base of the second middle phalanx was performed in addition to the head of the proximal phalanx, and a relatively tight approximation of the resected surfaces is achieved with the K-wire instead of a diastasis as seen in the fifth digit.

Figure 14: Post-operative AP views of left feet demonstrate different forms of arthrodesis for correction of hammertoe deformity. The left image of a 41 y/o male demonstrates use of a buried implantable implant designed for the lesser digits. These digital implants come in a variety of shapes and designs, but will always span the joint and reside within both the proximal and middle phalanges. The right image of a 37 y/o male demonstrates a 2nd digit arthrodesis fixated with a screw. Note that the screw crosses and will hold position of both the PIPJ and the DIPJ. A distal first metatarsal osteotomy has also been performed, as well as a previous arthrodesis of the 3rd digit which has healed in a suboptimal abducted position.

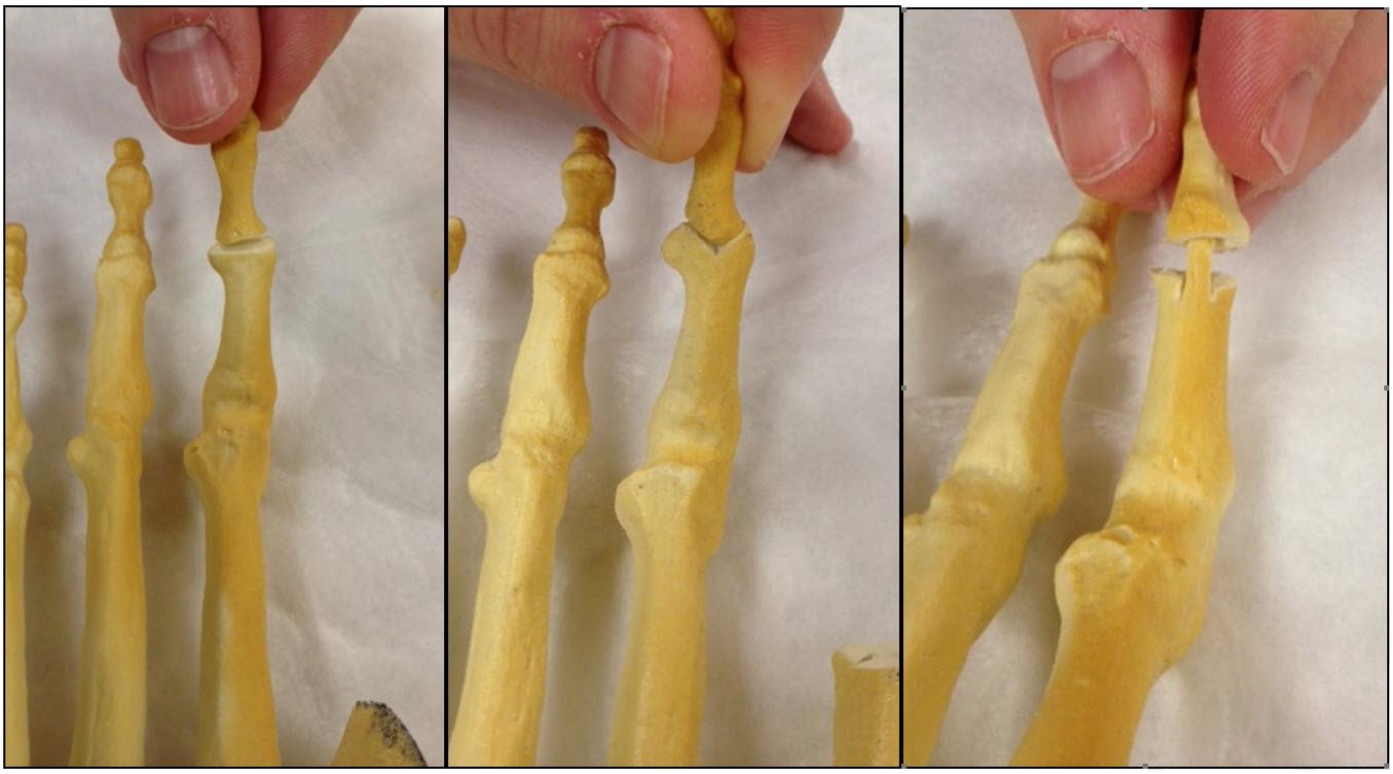

Figure 15: The arthrodesis procedure for correction of the hammertoe deformity always involves resection of the cartilage from the head of the phalanx and corresponding phalangeal base. The most commonly arthrodesis is in a transverse "table top" fashion (left), but may also be performed in the shape of a "V" (center) or "peg-in-hole" (right).

Figure 16: This clinical picture of the plantar aspect of the right foot of a 66 y/o male demonstrates localized callus formation directly underneath the 2nd metatarsal head. One would expect increased pressure under this metatarsal, which could be the result of a variety of structural or biomechanical etiologies.

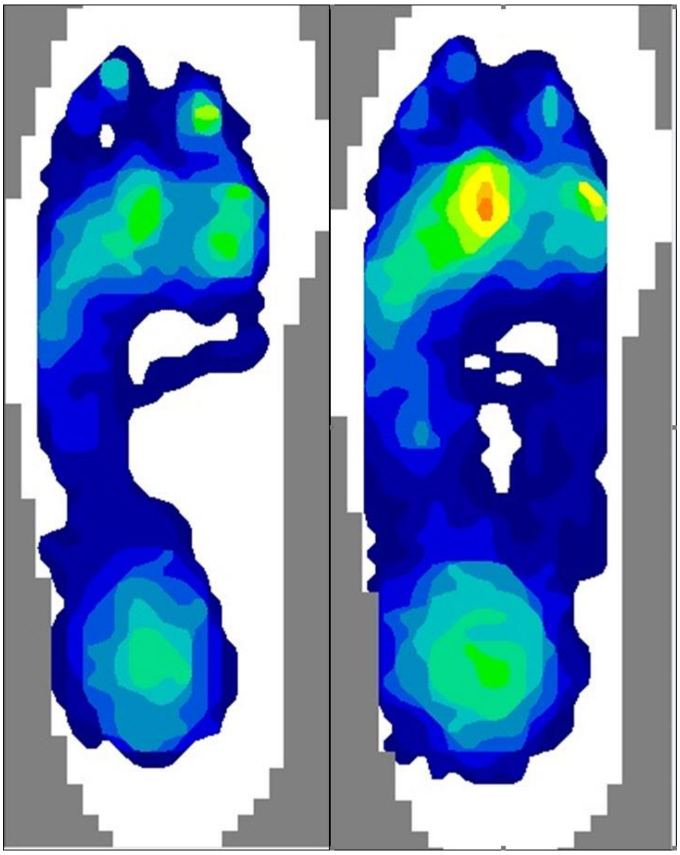

Figure 17: These pedobarograph images provide a dynamic description of forces generated on the plantar foot while walking. The left image shows a relatively uniform distribution of pressure across the metatarsal heads as evidenced by the uniform blue and green colors, while the image on the right shows a relative "hot spot," or area of increased pressure as evidence by the yellow and red colors localized underneath the second metatarsal head. This represents a likely location for the development of metatarsalgia.

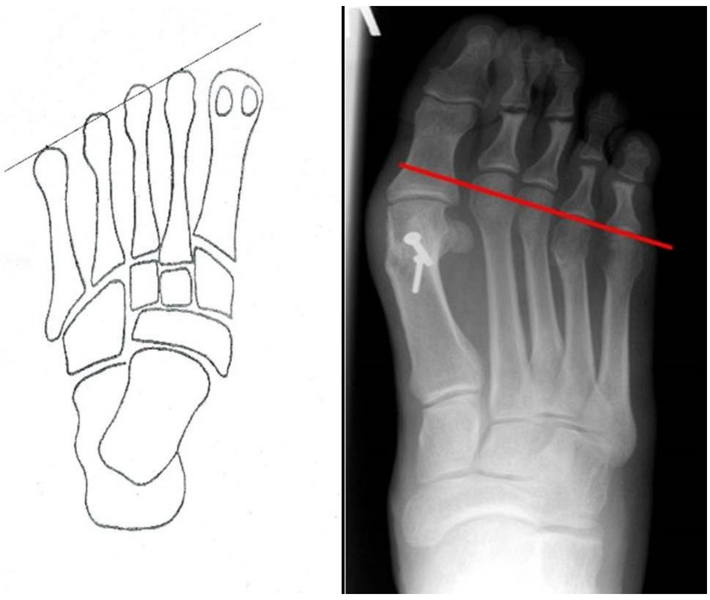

Figure 18 (left): Note the difference between the left image where all of the lesser metatarsals extend along a straight line versus the right image where the second and third metatarsals appear to extend beyond the straight line. In this case, the second and third metatarsals are considered too "long" and clinically caused symptoms with excessive plantar pressure.

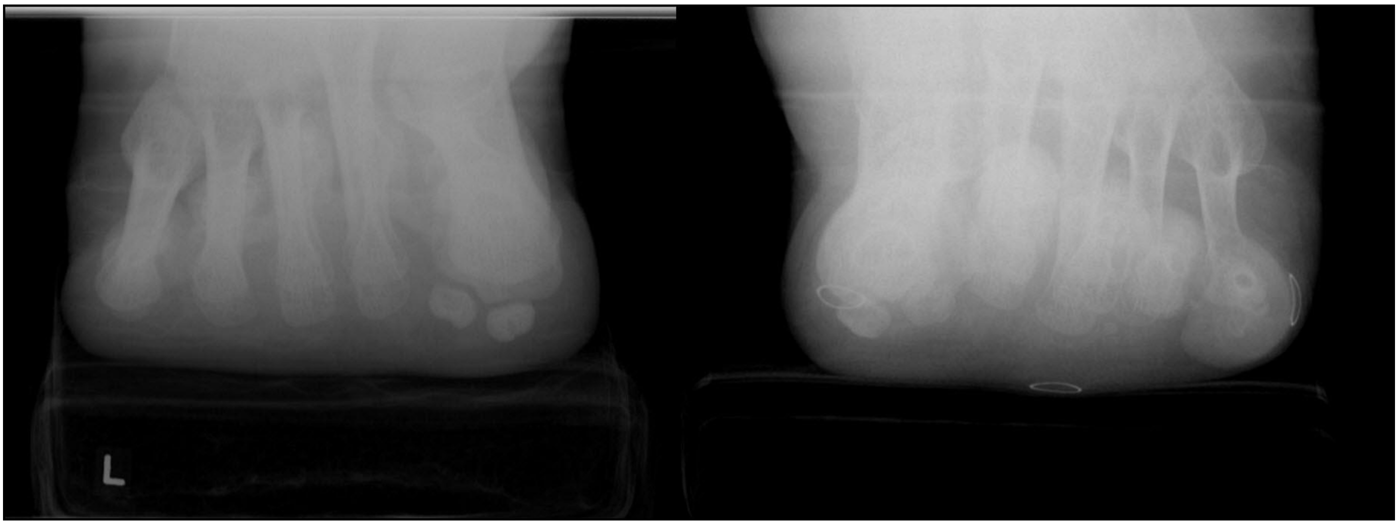

Figure 19: These are two sesamoid axial radiographic projections are used to more specifically assess the plantarflexion of the metatarsal heads during gait. The left image demonstrates metatarsals which all fall on a relatively straight line in this view. The right image demonstrates a third metatarsal head which is extending further plantarly than the adjacent second and fourth metatarsal heads. A marker also corresponds to this area, where there was localized pain and tenderness.

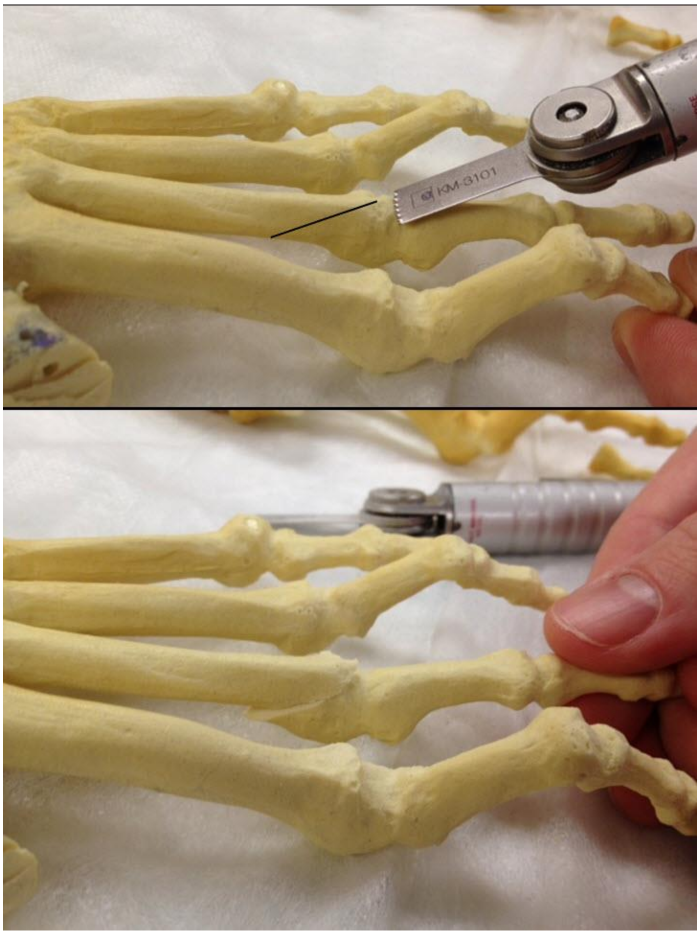

Figure 20: These Sawbones models depict the Weil shortening lesser metatarsal osteotomy. The sagittal saw is used to make an osteotomy parallel to the weight-bearing surface within the metatarsal neck. The head of the metatarsal can then be repositioned proximally which will relatively shorten and dorsiflex the head relative to the adjacent metatarsals.

Figure 21: This figure demonstrates pre- and post-operative AP views of a 39 y/o male following Weil osteotomies of the second and third metatarsals. In the pre-operative figure on the left, the second and third metatarsals are relatively "long" compared to the remainder of the metatarsal parabola and the second metatarsal specifically "long" compared to the first metatarsal. Following a shortening osteotomy (and fixation with a single screw), all lesser metatarsals fall on a straight line and the second metatarsal is now within 2 millimeters of the first metatarsal in terms of length. An Akin osteotomy of the proximal phalanx of the hallux has also been performed.

Figure 22: AP radiograph of a right foot of a 39 y/o female demonstrates measurement of the 4-5 intermetatarsal angle used in the pre-operative evaluation of a bunionette deformity. This is the resultant angle between the longitudinal bisection of the 4th metatarsal and a line drawn tangential to the proximal medial aspect of the 5th metatarsal shaft. The normal value of this measurement is approximately 6 degrees, with any value over 9 degrees considered abnormal.

Figure 23: AP radiograph of a right foot of a 39 y/o female demonstrates measurement of the lateral deviation angle used in the pre-operative evaluation of a bunionette deformity. This is the resultant angle between the longitudinal axis of the 5th metatarsal head/neck and a line tangential to the proximal medial aspect of the 5th metatarsal. This measures any intrinsic deformity or lateral "bowing" within the metatarsal itself. The normal value of this measurement is approximately 3 degree, with any value over 8 degrees considered abnormal.

Figure 24: Examples of bunionette surgical correction. The left image of a 32 y/o female demonstrates an Austin-type "V" osteotomy with fixation by a percutaneous K-wire. The right image of a 38 y/o female demonstrates more of a Weil-type osteotomy fixated with two screws. The right image also demonstrates Weil osteotomies of metatarsals 2, 3 and 4, in addition to a distal first metatarsal osteotomy for correction of a hallux abductovalgus deformity.

Figure 25: Pre-operative AP projection of a right foot of a 28 y/o male demonstrates a metatarsus adductus deformity. Although one can subjectively appreciate the transverse plane adduction of all metatarsals at the tarsal-metatarsal joint level, a radiographic measurement helps to objective the deformity. Most simply, an angle can be created between the longitudinal bisection of the second metatarsal and the longitudinal bisection of the intermediate cuneiform (known as Engel's angle). An abnormal measurement of this relationship is greater than 24 degrees.

Figure 26: Post-operative AP projection of the same foot in Figure 25 demonstrates the correction achieved by a metatarsus adductus surgery. Osteotomies were performed within the bases of metatarsals two, three, four and five with lateral rotation of the respective metatarsal shafts. These were all fixated with a single screw. A Lapidus first metatarsal-medial cuneiform arthrodesis, Reverdin procedure and Akin osteotomy were also performed for hallux valgus deformity. Note appropriate correction of Engel's angle and the first intermetatarsal angle to within their normal range.

Clinical Diagnosis	Pathoanatomy	Radiographic Findings	Surgical Treatment Options
Hammertoes	Deformity of the lower extremity digits defined as extension of the metatarsophalangeal joint and flexion of the proximal interphalangeal joint.	Decreased joint space and "gun barrel" sign on the AP plain film radiography view.	Arthroplasty or arthrodesis of the involved joint, often involving fixation with K-wires or implants.
Lesser Metatarsal Deformity	Excessively long or short lesser metatarsals causing areas of increased plantar foot pressure and clinical pain.	An abnormal metatarsal parabola or metatarsal break pattern.	Shortening osteotomy of the head of the metatarsal, often involving fixation with internal screws.
Bunionette	Prominence of the lateral head of the fifth metatarsal causing clinical pain.	Abnormally increased 4-5 intermetatarsal angle or lateral deviation angle.	Displacement osteotomy of the fifth metatarsal moving the head into a more medial orientation, often involving fixation with screws, wires or plates.
Metatarsus Adductus	A medial displacement of all lesser metatarsals towards the midline of the body.	An abnormally increased Engel's angle.	Osteotomy of the lesser metatarsals often performed within the metatarsal base resulting in lateral translation of the metatarsal shafts.

Table 1: Summary table for metatarsal deformities.

ABBREVIATIONS

AP = Anterior-posterior
DP = Dorsal-plantar
DIPJ = Distal interphalangeal joint
HAV = Hallux abductovalgus
K-wire = Kirsner wire
MTPJ = Metatarsophalangeal joint
PIPJ = Proximal interphalangeal joint

KEYWORDS

Podiatric surgery; Hammertoe; Metatarsalgia; Bunionette; Metatarsus adductus

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