Chapter 2
Revision Hallux Valgus Surgery

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Foot and ankle surgeons routinely perform surgery of the first ray, such as correction of hallux valgus deformity. The complication rate in hallux valgus surgery ranges between 10% and 55%.[1] Although hallux valgus surgery is common, several common complications can occur that necessitate revision.

There are several causes of hallux valgus surgery failure; often, potential complications can be avoided by performing a thorough and careful preoperative evaluation of the patient. The presence of preexisting, but unexpected, osteoarthritis of the first metatarsal phalangeal joint (MTP) can lead to postoperative stiffness or arthrofibrosis. Recurrence of a previously corrected condition, hallux varus, avascular necrosis, and bone union problems are all some of the causes of revisional hallux valgus surgery. Excluded in this chapter is the discussion of the following conditions that also lead to complications of hallux valgus surgery: infection, hematoma, nerve injury, thrombophlebitis, complex regional pain syndrome, trauma, and disruption of the soft tissue envelope about the first ray.

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2.1 Preoperative Evaluation

Revision surgery can be challenging to the most experienced foot and ankle surgeon. These challenges can often be avoided with an accurate preoperative evaluation. The importance of the initial evaluation is tantamount to the surgical technique in an effort to achieve a successful outcome. If the initial evaluation process is not accurate and detailed, a steep downward slope can ensue for the remainder of the treatment course and may ultimately lead to a need for revision surgery.

The preoperative evaluation begins with a detailed and accurate history and physical examination. There are numerous documented surgical procedures for hallux valgus correction dating back to the nineteenth century.[2] The procedure selected needs to coincide with the patient's age, functional limitations, and lifestyle demands. For example, it would be unwise to choose a complex realignment osteotomy for a sedentary, geriatric patient with limited functional requirements. On the other hand, a minimally invasive procedure may not provide adequate enough correction for a young, active patient.

Patients' goals and expectations should be elucidated. In revision surgery of the first ray, bony and clinical alignment may appear to be "normal" to the surgeon, yet the patient may feel the index procedure was a failure. Going beyond the potential anatomical correction to find out what the patient actually wants is very important in revision surgery. For the first ray, is the patient concerned about the Hallux position: is it too straight, too angled, too stiff or fused in an uncomfortable position? Surgeons need to ask "What is it you hope to achieve from another surgery?," not only to themselves but the patient and possibly even their family members.

Many surgeons are adept at performing an excellent history and physical examination; however, they are uncomfortable performing the necessary procedure to achieve the desired correction. Often times, as a result of lack of training and inexperience, surgeons become habitually familiar with too few available surgical options. This could lead to performing the improper procedure for a given deformity. In short, the surgical procedure should fit the deformity, rather than forcing the deformity to fit the procedure (Fig. 2.1).

The radiographic examination is equally as important as the history and physical examination. Key evaluation parameters include: the first intermetatarsal angle, metatarsal parabola, the presence or absence of metatarsus adductus, and the integrity of the joints of the first ray (hallux interphalangeal, first metatarsal phalangeal, and first metatarsal cuneiform joints).[2] The first intermetatarsal angle is arguably the most important structural parameter that determines osteotomy selection. Undercorrection can lead to recurrence of deformity, while overcorrection can lead to hallux varus.

The metatarsal parabola is frequently underappreciated. Over lengthening the first metatarsal by osteotomy can cause a soft tissue imbalance and retrograde buckling resulting in recurrence, whereas, lesser metatarsalgia is a frequent problem following excessive shortening of the first metatarsal.

Fig. 2.1 An opening base wedge procedure was performed on this patient along with an aggressive medial capsuloraphy. Clearly, the deformity is not adequately reduced. The metatarsal was overly lengthened causing retrograde forces to act at the first metatarsal phalangeal joint; these forces caused the soft tissues to cause the deformity to recur

The metatarsus adductus angle should not be overlooked because the true intermetatarsal angle equals the measured intermetatarsal angle plus the influence of any increase over accepted normal of the metatarsus adductus angle. A large metatarsus adductus angle can give the illusion of a relatively small first intermetatarsal angle, and if not addressed properly, the resultant procedure selection will inadequately correct the deformity.

2.2 Arthrofibrosis

A common postoperative complication of hallux valgus surgery is joint stiffness or arthrofibrosis. The cause can be commonly attributed to unrecognized preoperative osteoarthritis that is identified intraoperatively (Fig. 2.2). Frequently, the sesamoids are degenerated as well. Metabolic disorders, such as diabetes mellitus, advanced

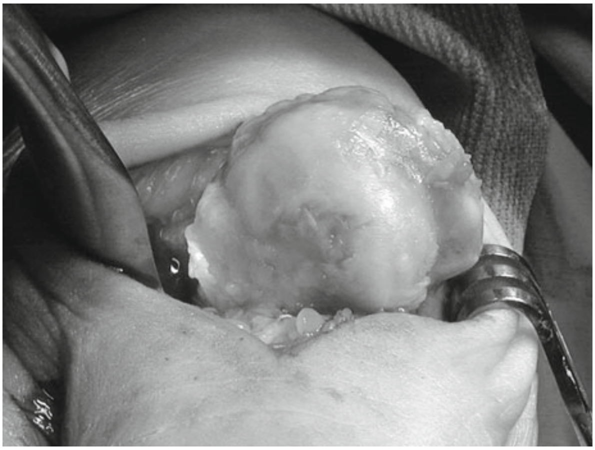

Fig. 2.2 In this clinical picture, degeneration of the first metatarsal head is seen. This is often an unexpected intraoperative finding. Early range of motion is helpful in preventing arthrofibrosis

age, postoperative infection, noncompliance, and the patient's intrinsic propensity to form scar can also lead to arthrofibrosis.

Preventative treatment for arthrofibrosis is difficult to achieve. Early active range of motion and institution of an aggressive postsurgical physical therapy program are the mainstays of prevention. A novel approach to the treatment of debilitating postsurgical arthrofibrosis is manipulation of the first metatarsal phalangeal joint under anesthesia. The authors follow the guidelines established by Solan et al., whereby, following sedation of the patient and aseptic preparation of the foot, the great toe joint is infiltrated with a combination of 40 mg of Depomedrol and 2 mL of 1% Xylocaine plain.[3] Joint distention is observed under fluoroscopy and the great toe is manually manipulated to achieve a normal range of motion. This is often characterized by a palpable and audible breakup of the scar tissue. The sesamoid apparatus should be freely mobile during range of motion as visualized under fluoroscopy.

2.3 Recurrence

Recurrence of hallux valgus deformity after surgical correction is multifactorial. The incidence has been reported as high as 16%.[4] One of the more common explanations for hallux valgus recurrence is due to incomplete initial correction (Fig. 2.3). Furthermore, anatomical and biomechanical factors can predispose a patient to recurrent deformity. Unfortunately, despite careful analysis, the cause of recurrent deformity may be idiopathic.

Incomplete initial correction is a direct result of failure to properly analyze all pertinent preoperative parameters. Clinical considerations include evaluating the patient's age, Body Mass Index (BMI), functional demands, and unique physiologic and anatomic configurations. For example, a failure to identify a patient with ligamentous laxity may lead to an underappreciation of potential deforming forces

Fig. 2.3 A common cause of recurrence is incomplete initial correction. This picture reveals an uncorrected intermetatarsal angle with recurrent deformity

resulting in an inability to maintain correction. Also, the surgeon must pay careful attention to radiographic structural details such as first intermetatarsal angle, proximal articular set angle, congruence of the first metatarsal phalangeal and hallux interphalangeal joints, the length of the first metatarsal, and sesamoid position.[2]

Following a thorough clinical and radiographic evaluation, the surgeon then must determine what he/she wishes to accomplish with a given procedure or osteotomy. Osteotomies are powerful procedures and are able to correct many parameters of a hallux valgus deformity. The purpose of an osteotomy is to normalize the alignment of the first ray to restore its function in weight-bearing and ambulation.[5] For example, an osteotomy can accomplish transposition of the metatarsal either plantarly, dorsally, medially, or laterally. Furthermore, specific osteotomies can provide angular correction to reduce the intermetatarsal angle and/or proximal articular set angle. Finally, osteotomies can de-rotate the first metatarsal and may also have a linear effect by either lengthening or shortening the metatarsal as necessary.

Adhering to the following general osteotomy principles can mitigate recurrent hallux valgus caused by incomplete initial surgical correction:

- Understand that every osteotomy has a maximal corrective effect.
- Variations in technique or application of an osteotomy generally diminish the primary corrective effect of the osteotomy.
- Determine the desired correction and then select the osteotomy that will allow you to obtain the correction.
- Avoid the temptation of becoming procedure bound.
- The procedure should fit the deformity, rather than the deformity fit the procedure (Jacobs A., 2005, personal correspondence) (Fig. 2.4).

Anatomic factors such as metatarsus adductus or medial column adductus can lead to recurrent hallux valgus deformity. Choosing an osteotomy yet failing to recognize inherent metatarsus adductus or medial column adductus will likely to lead to either an undercorrected deformity or recurrence. The presence of metatarsus adductus gives the radiographic illusion that the hallux valgus deformity is less severe than it is in reality. The effective first intermetatarsal angle equals the measured true intermetatarsal angle plus any degree of metatarsus adductus greater than 15°.[6] For example, a patient with a 10° first intermetatarsal angle and also 26° of metatarsus adductus has an effective first intermetatarsal angle of 21°; the selection of the procedure should be based on this effective first intermetatarsal angle (Fig. 2.5).

Biomechanical influences can predispose a patient to recurrent hallux valgus. Excessive pronation can destabilize the first ray and cause medial migration of the first metatarsal with concomitant lateralization of the great toe.[7] Therefore, control of pathologic pronatory deforming forces will minimize the chance for recurrence. Ankle equinus contracture is known to lead to hyperpronation. Therefore, ankle equinus is important to recognize and treat in conjunction with the hallux valgus procedure.[8] Surgical management of ankle equinus is based upon the Silverskold maneuver and can include either tendo-Achilles lengthening or gastrocnemius recession. Finally, patients with excessive pronation who demonstrate heel valgus, longitudinal arch collapse, and

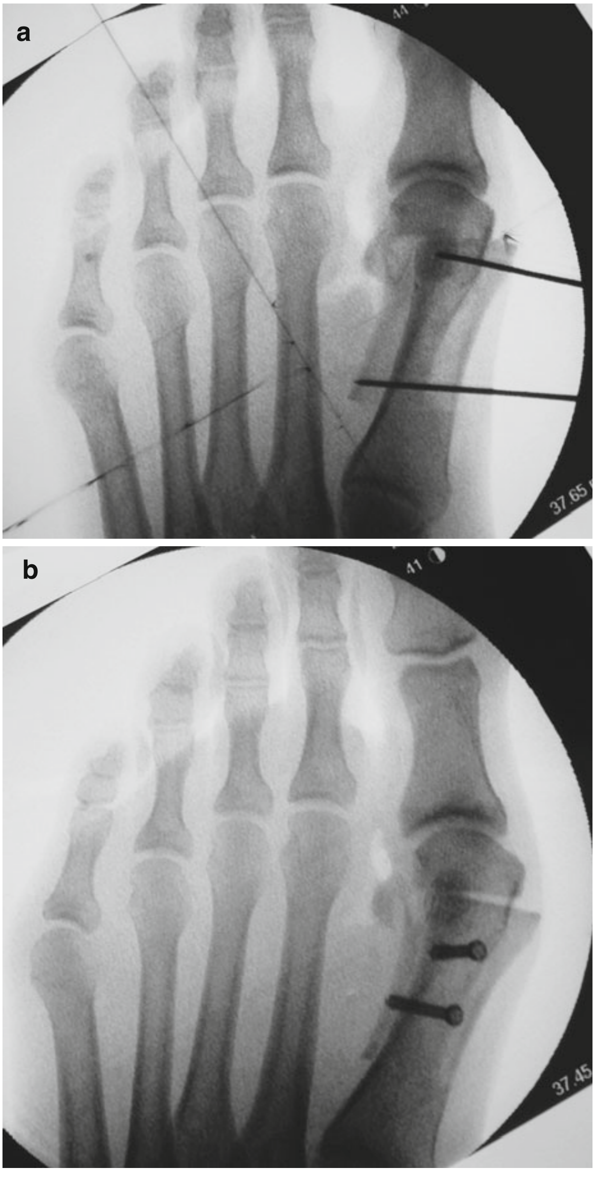

Fig. 2.4 (**a**) The Z-type osteotomy has been strictly translated. The surgeon was not satisfied with correction. (**b**) The osteotomy has been subsequently translated with rotation of the capital fragment. The rotation of the capital fragment allows for a more complete correction of the deformity but compromises the amount of translation that can be achieved

Fig. 2.5 It is imperative to take metatarsus adductus into account when assessing the hallux valgus deformity. The metatarsus adductus can mask the severity of the bunion deformity

midfoot abductus may also benefit from custom foot controlling orthoses postoperatively as a measure of protection to guard against hallux valgus recurrence.

2.4 Hallux Varus

Hallux varus most commonly occurs after a proximal metatarsal osteotomy (Fig. 2.6). The incidence rate of hallux varus has been reported to be as high as 10–12%.[4] Paradoxically, many patients with hallux varus are asymptomatic and do not require treatment, particularly if the hallux varus measures less than 10°.[9] However, when symptoms occur, they usually result from an associated hallux

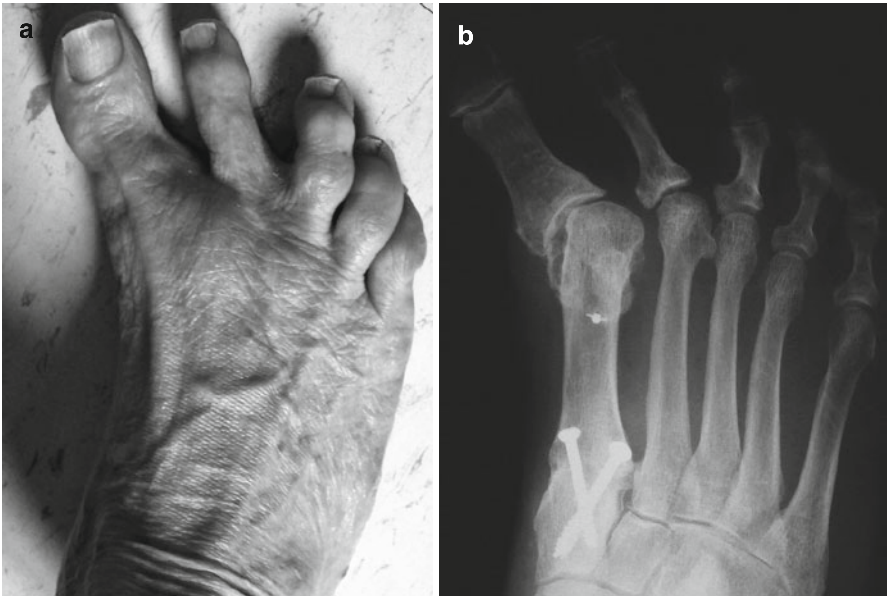

Fig. 2.6 (**a**) In this photograph, the hallux varus deformity is clear. This deformity can make wearing shoe gear quite uncomfortable for the patient. (**b**) A Lapidus procedure was performed with an overaggressive resection of the medial eminence. The staking of the first metatarsal head resulted in hallux varus

malleus, a rigid deformity that limits footwear, and arthrosis of the first metatarsal phalangeal joint.

The causes of hallux varus have been attributed to scar contracture, fibular sesamoidectomy with excessive plication of the medial capsule, aggressive resection of the medial eminence (staked first metatarsal head), and the overcorrection of the first intermetatarsal angle.[10] Avoiding these surgical pitfalls can prevent the development of hallux varus.

Nonsurgical management of hallux varus includes early recognition, physical therapy, and soft tissue mobilization. For example, passive abduction exercises of the great toe performed in conjunction with dynamic buddy splinting may arrest a developing deformity.

When surgical correction is indicated for a flexible hallux varus, a methodical stepwise approach is followed. A thorough sequential release of the deformity is performed from superficial to deep anatomic structures. Beginning with the skin, a Z-plasty or other similar plastic-type skin incision should be considered. Next, extensor and/or abductor hallucis tendon lengthening is performed followed by first metatarsal phalageal joint capsule release. This may be all that is required for a mild deformity.

An intraoperative decision is then made to follow either a soft tissue or osseous pathway.

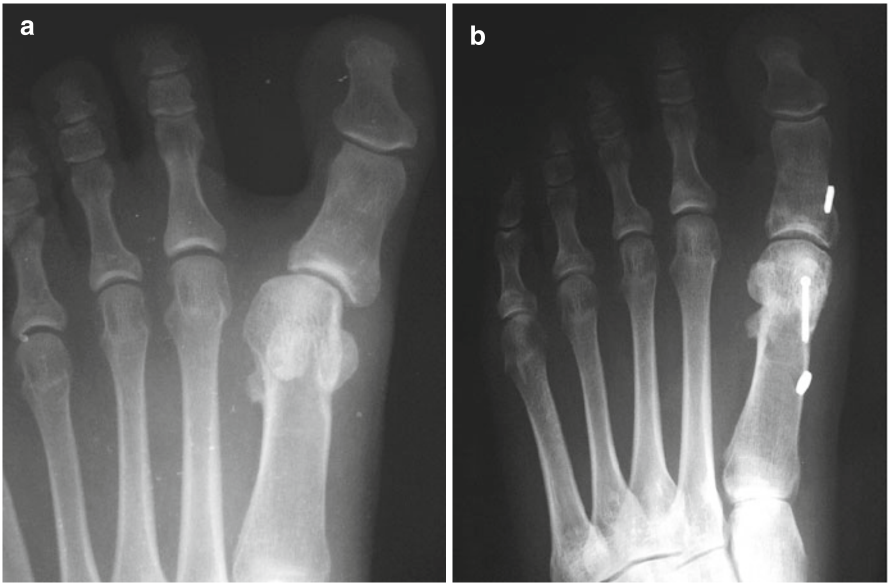

Fig. 2.7 (**a**) Note the hallux varus deformity with peaking of the tibial sesamoid. (**b**) In this surgical correction of the hallux varus deformity, an Arthrex Mini-Tightrope was used. The joint has been realigned and the sesamoid apparatus has been relocated

The authors' preferred soft tissue approach is to follow the technique described by Juliano, Meyerson, and Cunningham whereby the extensor hallucis brevis (EHB) tendon is divided proximally and routed deep to the transverse metatarsal ligament and through a drill hole in the first metatarsal.[11] The procedure may be modified by using a Mini-Tightrope (Arthrex) in place of the EHB for tendon augmentation (Fig. 2.7).

The osseous pathway makes use of a distal first metatarsal osteotomy. A reverse chevron with internal fixation is often sufficient to realign the first metatarsal phalangeal joint (Fig. 2.8).

In cases where the hallux varus is long-standing, rigid, and/or demonstrates arthrosis of the first metatarsal phalangeal joint, a first metatarsal phalangeal joint arthrodesis is the procedure of choice. However, a Keller arthroplasty can also be considered for geriatric patients.

2.5 Avascular Necrosis

Although uncommon, avascular necrosis (AVN) of the first metatarsal head following hallux valgus surgery can lead to loss of function of the first metatarsophalangeal joint. AVN most commonly follows distal first metatarsal osteotomies and is caused by a disruption of the blood supply to the metatarsal head.[12] The resultant cascade of avascularization with subsequent revascularization of the head can lead to articular collapse and degeneration of the joint.

The blood supply to the first metatarsal includes the nutrient artery, metaphyseal vessels, and periosteal network. The vessels are branches of the first dorsal metatarsal artery that originate from the dorsalis pedis artery, the first plantar metatarsal artery, and the medial plantar artery.[13] The dorsal vessels supply the superior two thirds of the first metatarsal head and the plantar vessels supply the inferior one third of the head. The lateral and dorsal aspects of the first metatarsal head have a better blood supply compared to the remainder of the head.[14] The nutrient artery divides into a proximal and distal branch with the later anastomosing with the capital vessels.[12]

Much has been written about soft tissue lateral release as a cause of AVN. Meier and Kenzora reported a 20% AVN rate with osteotomy alone and 40% when combined with lateral release.[15] More recently, several studies indicate that a lateral release may be performed without compromising blood supply.[16]

All metatarsal osteotomies have the potential to cause AVN secondary to a disruption of blood flow to the metatarsal head. Distal osteotomies can compromise the flow from the nutrient artery. In these circumstances, the remaining blood flow to the head stems from the capsular vessels. If the capsular network is breached, the overall blood supply to the head is altered and AVN can occur. Furthermore, lateral transposition of the capital fragment of an osteotomy can stretch the vasculature and potentially compromise perfusion to the head. Finally, thermal necrosis from the modern saw blade can not only result in osseous damage but also jeopardize the metatarsal blood supply.

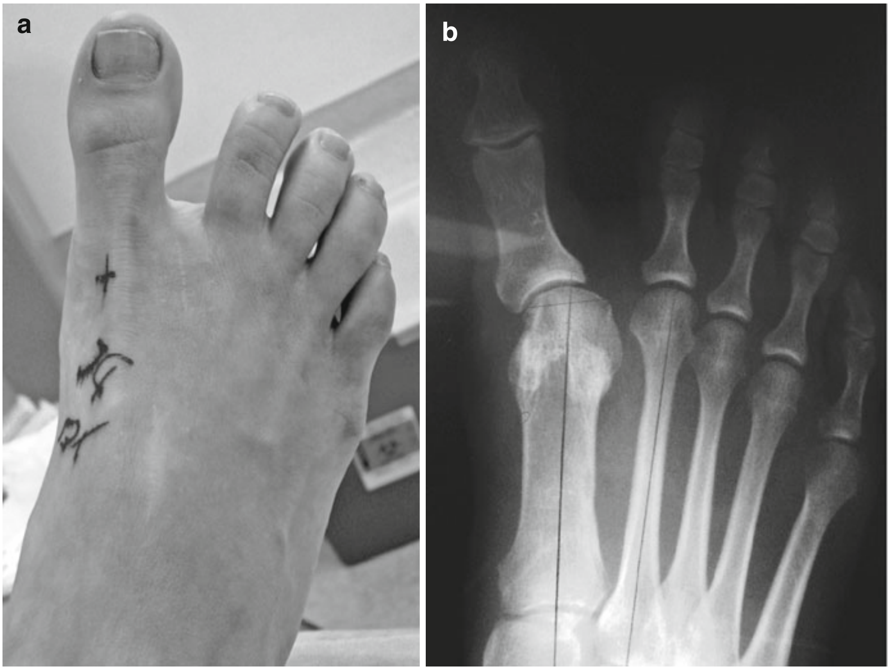

Fig. 2.8 Preoperative clinical photograph (**a**) and radiograph (**b**) following a hallux valgus surgery. Again, staking of the first metatarsal head has occurred. (**c**, **d**) Postoperatively, the iatrogenic hallux varus has been corrected. As this was a more moderate deformity, an osseous procedure was selected. A reverse chevron was performed and fixated with two screws

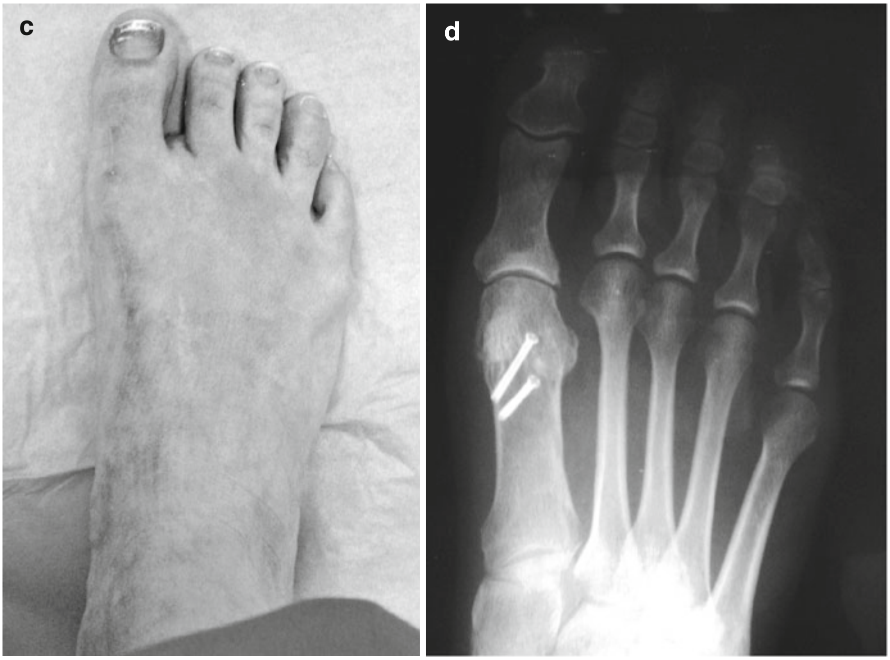

Fig. 2.8 (continued)

Preservation of the capsular network is critical for the prevention of AVN. Meticulous soft tissue technique and maintenance of the dorsal synovial fold that contains the capsular vessels is advocated. It is recommended to avoid multiple saw blade passes and use of worn saw blades when performing an osteotomy.[17]

The predominant early clinical findings of AVN are pain and joint swelling but can occur at variable times after surgery. For example, one should expect AVN if such findings are noted at follow-up at a time when the osteotomy is expected to be healed. Later, there may be stiffness and transfer metatarsalgia.

Radiographs at the time of clinical presentation, more often than not, demonstrate articular collapse with varying degrees of arthrosis. It is difficult to recognize the pre-collapse stages; these stages are more easily recognizable in retrospect.

Because many AVN cases are asymptomatic, nonoperative treatment may be employed. Mildly symptomatic patients may improve with joint debridement and synovectomy.[17] When surgical intervention is required, a Keller arthroplasty or a first metatarsophalangeal joint arthrodesis with or without bone graft may be performed.[17]

2.6 Nonunion

Osteotomies are commonly utilized to correct hallux valgus. Reports of nonunion following first metatarsal osteotomy are rare, and vary depending on the procedure. As most procedures are performed through the metaphyseal region of the bone, healing is predictable.[4] Modern improvements in fixation have also reduced nonunion rates.

Fig. 2.9 Hypertrophic nonunions are characterized by exuberant bone callous. This callous is evident in the radiograft

There are two basic causes of nonunions: biomechanical and biological. Because of the orientation of the first metatarsal, osteotomies are subjected to loads perpendicular to the long axis of the metatarsal; this results in unique forces acting across the osteotomy sites.[18] Proximal osteotomies are more likely to lead to nonunion than distal osteotomies as there is an increased moment arm through which loads are applied. Any osteotomy is intrinsically unstable if it has a single plane that is directed from dorsal proximal to plantar distal (i.e., Ludloff); also, any osteotomy that is made perpendicular to the shaft of the first metatarsal is unstable (i.e., closing abductory base wedge).[18]

Appropriate fixation should also be utilized to reduce the potential for nonunion; the more inherently unstable the osteotomy, the more essential fixation is. In the event that stability is compromised and motion occurs at the osteotomy site, a nonunion can develop. Factors such as hardware failure, poor construct design, and patient noncompliance (premature weight-bearing) are common causes of mechanically induced nonunions.

Nonunions of mechanical etiology are most likely to be hypertrophic in nature with demonstrating exuberant bone callus (Fig. 2.9). This is indicative of a robust blood supply with poor stability at the osteotomy site. One can think of these nonunions as

Fig. 2.10 At the site of the osteotomy, there is a large gap with no bone callous present. This is indicative of an atrophic nonunion

"crying out for stability." If the osteotomy position has not been compromised, often hypertrophic nonunions may be cast immobilized in order to provide stability. Revision surgery is considered only in the event that the osteotomy is malpositioned.

Biological causes of nonunions are most often the result of altered blood supply to the osteotomy site. These types of nonunions are atrophic and minimal or no bone callus is visualized (Fig. 2.10). There are many factors that may contribute to the cause of atrophic nonunions. For example, patients with advanced age have a thinner periosteum resulting in a relatively poorer periosteal blood supply.[19] Patients with hormonal imbalances, such as diabetes mellitus and hypothyroidism, are more susceptible to develop an atrophic nonunion.[19] Exogenous steroids can retard bone repair as can certain medications, such as heparin. Hypoxia caused by anemia and cigarette smoking can lead to aberrant bone healing at an osteotomy site.

The majority of nonunions are symptomatic secondary to motion at the osteotomy site. Most atrophic nonunions require surgical intervention. However, regardless of the cause, mechanical or biologic, the surgical protocol remains the same. The tenets of nonunion operative management are as follows:

1. Debridement of the nonunion
2. Bone graft osseous defect

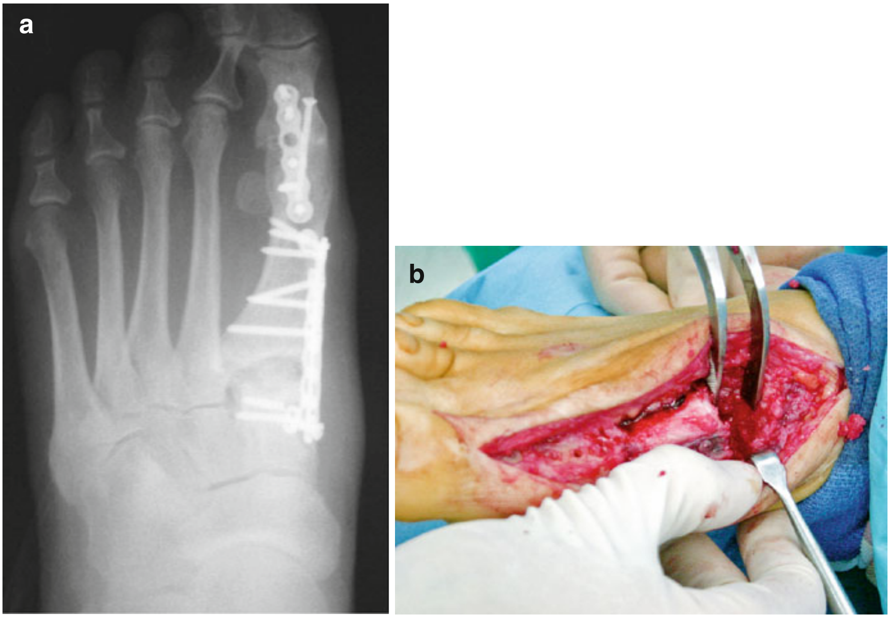

Fig. 2.11 (**a**) A nonunion is evident at the first metatarsal cuneiform joint after a failed Lapidus. Note the broken hardware in the medial cuneiform. (**b**) Aggressive debridement of the nonunion at the first metatarsal cuneiform joint is performed

3. Re-alignment of the osteotomy
4. Stable fixation
5. Consideration of adjunct bone healing enhancements (bone growth stimulator, bone morphogenic proteins, mesenchymal stem cells, etc.)

Debridement of the nonunion is the initial critical step of the revision process. Hypertrophic bone and/or fibrous tissue need to be resected from the nonunion site to obtain adequate exposure, demonstrate healthy bleeding bone margins, and allow for manipulation of the osteotomy segments (Fig. 2.11).

Following debridement, an assessment of bone graft size is required. Next, appropriate structural allogenic or autogenous bone graft is selected, measured, cut, and placed into the defect (Fig. 2.12). There are many differences between allogenic and autogenous bone grafts. Allogenic bone graft offers an advantage of ease of accessibility without volume restrictions. Autogenous bone grafts require a second surgical site and may be limited in supply but will not demonstrate histocompatibility problems. Furthermore, patients often relate prolonged donor site pain. Autogenous bone grafts were once considered to be the "gold standard" of bone grafting and thought to have a superior fusion potential. However, recent literature suggests that allogenic grafts have equivocal fusion rates when compared to autogenous bone grafts.[20]

With the graft in place, the osteotomy is realigned to restore the original intent of the initial hallux valgus procedure. Careful attention is paid to the three-dimensional

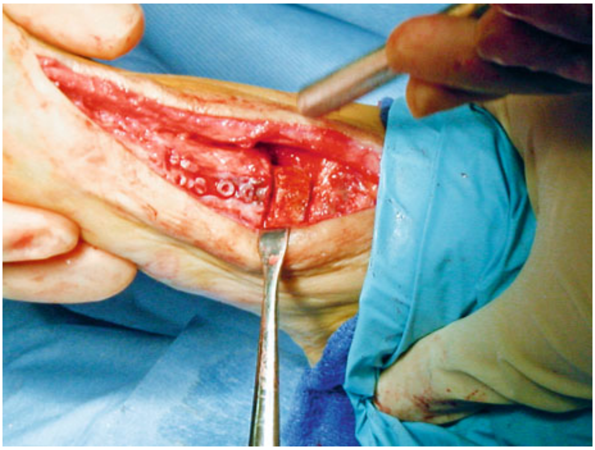

Fig. 2.12 Autogeous tricortical iliac crest bone graft is placed into the nonunion defect

orientation of the capital segment in the three cardinal planes. Anatomic length of the first metatarsal is restored at this step.

The revision is then fixated. A combination of internal and external fixation may be considered with the ultimate goal being rigid stabilization. Internal fixation will likely require a plate and screw construct (Fig. 2.13). In recent years, anatomic plate designs specific toward foot and ankle surgery have been developed. Furthermore, locking plates have gained popularity because of their greater stability and ease of use when compared to traditional plates. The strength of a locked plate construct equals the sum of the screws and plate at the bone interface.[21] A locking plate acts as the near cortex of the bone and each screw locks into the plate at either a fixed or variable angle. Thus, the strength of the construct is distributed through all of the screws. This is inherently more stable than a traditional plate and screw construct where the strength is dependent upon only a single screw and the frictional force that occurs between the plate and the bone.[22] With a locked plate construct, all of the screws must fail for the entire construct to fail; a single screw's failure can lead to a construct's failure with traditional plate and screw fixation. Finally, if after internal fixation is applied and the stability of the construct is questioned, external fixation should be considered as adjunct fixation.

There are modalities to help promote healing after revision hallux valgus surgery.

Bone graft substitutes have been found to aid healing of bone fusions. Studies have demonstrated that ceramic-based bone graft substitutes (i.e., Vitoss) are equivalent to iliac crest graft.[23] Vitoss is a calcium phosphate bone graft substitute that, when combined with bone marrow aspirate, has osteoinductive, osteoconductive, and osteogenic properties. Cell-based bone graft substitutes (Trinity Evolution) employ mesenchymal stem cells to facilitate bone healing; Trinity Evolution also provides osteoconduction, osteoinduction, and ostegenesis to a fusion site.[24] In one study, a 91.3% rate of union was found in revision foot and ankle surgery.[25]

Bone morphogenic proteins (BMPs) are a group of growth factors and cytokines that promote formation of bone and cartilage; specifically, BMP-2,7 have been found

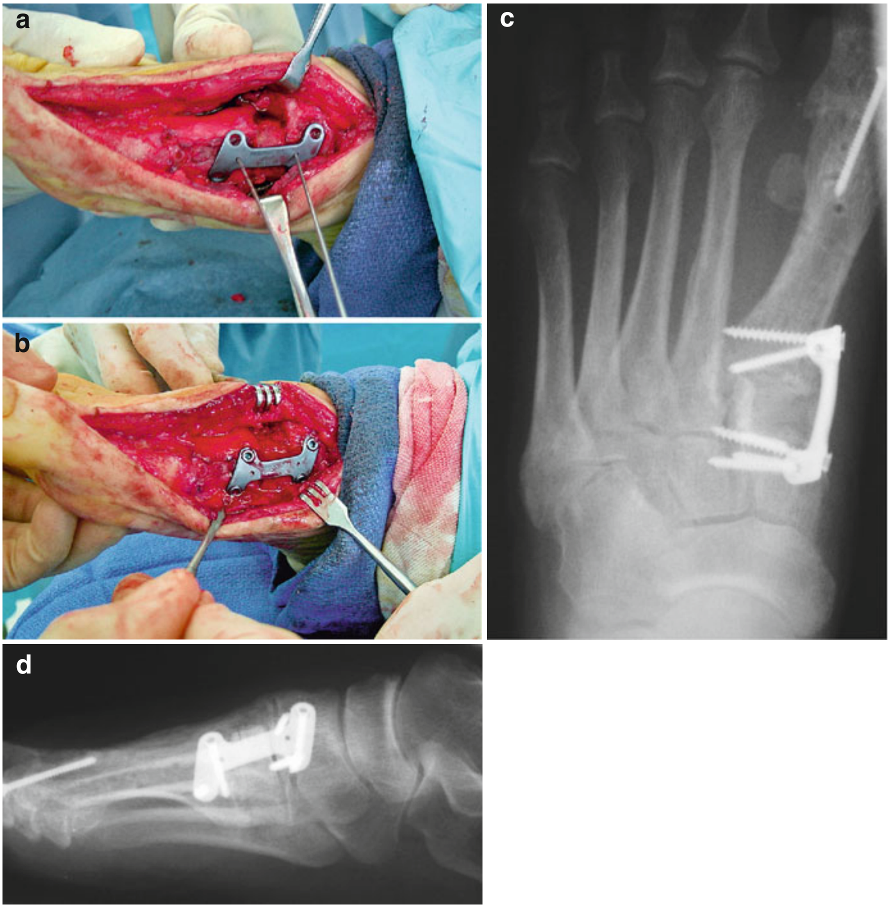

Fig. 2.13 (**a**, **b**) An atomically designed four-hole locking plate is applied spanning the autogenous bone graft. AP (**c**) and lateral (**d**) radiographs at 3 months postoperatively demonstrate consolidation at the graft site

to have a pivotal role in osteoblast differentiation.[25,26] There are two of these products on the market today, BPM-2 (Infuse™) and OP-1 BMP-7 (Stryker™); both have Food and Drug Administration (FDA) indications for delayed unions and nonunions.

Finally, there are many types of bone stimulation devices. There are internal and external bone stimulators; internal bone stimulators have a reported success rate in nonunions of as high as 89% but require a second surgery to remove the device[27] (Fig. 2.14). There has been a trend toward using non-implantable devices. These devices are user friendly and can be used in the patient's home. There are four types of external bone stimulators: inductive coupling, combined magnetic field, capacitative coupling, and ultrasound.[28] For example, the Exogen Ultrasound bone stimulator reports a 86% healing rate for nonunions.[29] Bone stimulators are an important adjunct to nonunion surgery.

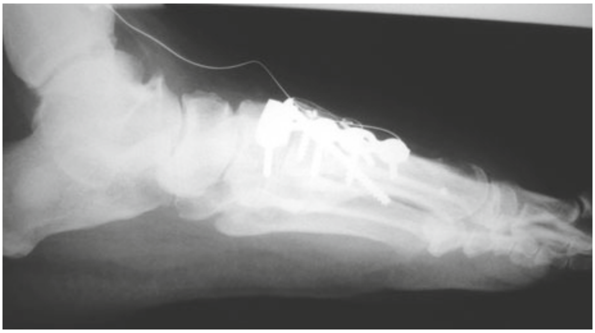

Fig. 2.14 Lateral radiograph reveals an implantable bone growth stimulator

2.7 Conclusion

Hallux valgus is one of the most common elective foot and ankle procedures performed in the USA. There are potential complications that can occur that lead to revision surgery. The most common complications leading to revision hallux valgus surgery are arthrofibrosis, recurrence, hallux varus, avascular necrosis, and nonunion. Careful preoperative planning along with meticulous intraoperative dissection, osteotomy execution, and appropriate fixation are all factors to help reduce the need for revision surgery.

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