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GENERAL PRINCIPLES OF HALLUX ABDUCTO VALGUS RECONSTRUCTION

According to GV. Yu, M. Schnirring-Judge, C. Gudas, B. Castellano, JT. Sutherland, G. Laporta, WP. Scherer, and DE Marcinko, and others in 2005, the following represent the general indications for HAV surgery.

INDICATIONS FOR HALLUX VALGUS SURGERY

- Pain with or without shoes with increasing deformity.
- Pain with or with out shoes with associated forefoot abnormality, such as hammertoes or callus formation beneath the second metatarsal head.
- Shoe fitting difficulty associated with pain.
- Deep joint pain secondary to degenerative joint disease, osteoarthritis, or rheumatoid arthritis.

Special Considerations:

Bone Density Evaluation

Since most procedures performed on juvenile and adult hallux valgus include an osteotomy of some type, bone stock analysis should be made, especially in the adult female population. Bone stock may be divided into three categories:

Grade I - Bone Stock

Bone stock includes bone that has minimal bone substance or mass present, which may be secondary to collagen or metabolic disease. This includes the bone seen in rheumatoid arthritis, especially those patients who have been prednisone dependent. It is important to note that these procedures must be modified to take into consideration very weak bone stock, especially when one considers implantation of prosthetic devices and various types of fixation.

Grade II - Bone Stock

Bone stock is a post-menopausal female in which there is cortical thinning and decreased trabeculation in which osteosynthesis techniques may have to be supplanted with alternate fixation techniques such as Kirschner wires.

Grade III - Bone Stock

Includes males and females of good general health and activity level with good trabeculation and strong, thick cortices. In this type of patient, most osteotomies and fixation methods can be utilized.

Flexibility Factors

Severe hallux valgus is often seen in extremely flexible patients and those patients who are suffering from neuromuscular disease or congenital ligamentous laxity. These patients often require fusion techniques rather than soft tissue or soft tissue and osteotomy procedures. Flexibility factor is usually graded into three grades:

- Grade I - Extremely inflexible patient with severe buckling of the joint and very little active range of motion.
- Grade II - Normal individual who has moderate flexibility without increased laxity to a great extent. Most types of procedures can be performed on these individuals, with special attention given to the lateral musculature in which an over-release can occur.
- Grade III - Patients who are affected by ligamentous laxity or neuromuscular disease which cause extreme laxity of the ligaments lining the first metatarsal and first metatarsal cuneiform joints. In these patients, fusions may be the procedure of choice, at least at the metatarsocuneiform joint, and when there is spastic overlay, a distal fusion may also be necessary.

Activity Levels

It is important to document the activity level of the patient preoperatively. A ballet dancer would be more affected by bunion surgery than a 65-year old who does a one-mile walk on a routine basis. It is important to assess activity levels in order to perform a procedure which will cause the least amount of functional disability in the extremely active patient.

Patient Expectations

It is important to assess the patient's expectations. Bunion surgery should rarely be performed for purely cosmetic reasons because of the high expectation level of the patient. Patients should be advised that most hallux valgus surgery has an 80-90% correction rate and that complications and functional disruption can occur.

Goals of Soft Tissue (Positional) Correction

The goal of soft tissue correction is to produce a progressive lateral release allowing the sesamoids (flexor plate) to be repositioned beneath the first metatarsal head.

Before initiating a progressive lateral release, joint flexibility should be evaluated in order to avoid over-releasing the lateral segment, which may cause a hallux varus or other complication.

- Release or restore conjoined tendon of adductor hallucis.
- Incremental lateral release of fibular sesamoid ligament from the lateral first metatarsal epicondyle.
- Release of deep transverse inter metatarsal ligament.
- Lateral capsulotomy maintaining long and short flexor tendons.

Goals of Osseous (Structural) Correction

- Decrease inter metatarsal angle (IMA) to 0-5 degrees
- Preserve metatarsal length.
- Reposition medial and lateral sesamoids after adequate soft tissue or bone release.
- Reduce proximal articular set angle (PASA), if needed.
- Reduce distal articular set angle (DASA), if needed.
- Preserve or restore a congruous joint.
- Preserve or increase sagittal plane declination.
- Remove arthritic joint manifestations.

ANATOMIC DISSECTION TECHNIQUES OF THE FIRST METATARSO-PHALANGEAL JOINT

Galen (131-201 AD), the great figure in Roman medicine, emphasized the importance of the site and size of anatomic structures in dealing with wounds. He stated, "If under such circumstances one does not know the position of an important nerve or muscle, or of a large artery or vein, it can happen that one helps the man to death, or sometimes mutilates him, instead of saving him." This thorough understanding of anatomic structures, landmarks, and boundaries, although crude in its initiation, has lead to the principle of accurate surgical anatomic dissection. The techniques of anatomic dissection about the first metatarso-phalangeal joint are basically no different than those applied when addressing the ankle, thorax, or cranium. Separation of the tissues into natural planes ensures for the maintenance of the neurovascular supply to the underlying soft tissues and bony structures. Appropriate dissection of the superficial fascia from the deep fascia will aid in increasing surgical exposure to the abysmal structures that often seem elusive. A decrease in post-operative pain, edema, and fibrosis can also be appreciated when dissection techniques are followed.

The theory of "one-wound-one-scar" can also be appreciated when re-entering a surgical site in which proper dissection technique had been utilized. The principle of accurate anatomic dissection, when applied to hallux abducto valgus correction, allows the surgeon to fully visualize and address the deformities at hand.

Surgical Skin Approaches

Dorsal Medial Approach

The conventional dorsal medial approach to hallux abducto valgus surgery offers the surgeon two distinct advantages. By utilizing proper dissection, the first metatarso-phalangeal joint is easily exposed with little tissue trauma due to aggressive retraction. The first interspace is easily addressed through this incision and adequate visualization and exposure for the lateral release and adductor tendon transfer can be obtained. The full circumferential nature of this approach is also beneficial in that it allows the addressing of other soft tissue structures that may have pathological, deforming forces on the presenting deformity. The incision may be easily extended proximally when base osteotomies are indicated without jeopardizing any major neurovascular structures.

Incision Placement

The dorsal medial incision is made just midline between the extensor hallucis longus tendon and the apex of the presenting deformity. The incision begins approximately 3 cm. proximal to the first metatarsophalangeal joint and is extended distally to the midshaft of the proximal phalanx of the hallux. It may be extended proximally 2-3 cm, if a base osteotomy is performed with a capital procedure. The underlying visible or palpable neurovascular structures may alter the exact placement of the incision as well as dermatological lesions such as macules and papules. Venous structures may be obliterated by exsanguination prior to tourniquet elevation, therefore, tortious venous structures may be marked preoperatively, if necessary.

Another determinate of skin incision placement is a pre-existing surgical cicatrix. Peacock states that "everything we know about the biology of primary and secondary wound healing points to the advantages of going through an old scar rather than removing it and starting all over with a primary wound." Biochemical studies of primary and secondary wounds have shown a decrease in total collagen, both soluble and insoluble, along with a rapid gain in tensile strength of secondary wounds. By placing the new incision directly through the old cicatrix matrix, the rim of remaining scar tissue will act as a circumferential splint to help prevent retraction of wound edges or transmission of external deforming forces to the central area where new collagen synthesis or remodeling will occur.

Once the placement has been determined, the skin incision is performed in two distinct steps in an effort to help control hemostasis and avoid unnecessary tissue trauma. It is important to maintain the blade perpendicular to the skin to avoid skiving and making later closure more difficult.

Although any surgical blade may be employed, the first step is performed traditionally with a #10 surgical blade, taking advantage of the large curvature of the belly of the blade. This is a "controlled depth" incision with the initial stage being made through the epidermis and into the dermis. The skin is tensed with side-to-side pressure to aid in controlling the incision depth. Since the epidermis is essentially an avascular layer, multiple capillary vessels are located in the dermal layer. Although some capillary oozing may be seen, no gross bleeding should be noted since the larger vessels are still protected in the underlying subcutaneous layer. Side-to-side skin tension at this point should not cause separation of the skin edges since the deeper portion of the dermal layer is still intact.

The second portion of the skin incision carries the surgeon through the more fibrous portion of the dermis. A #15 surgical blade is generally employed in a sketching type motion. The incision is continued down to the level of the dermal-subcutaneous tissue interface. Again, only capillary oozing is noted at this point. The skin edges should separate with side-to-side tension and expose the subcutaneous tissue. Superficial vessels may be noted at this time crossing beneath the incision site. These vessels should be intact with no bleeding present. If the incision line was injected preoperatively, injection hematoma may be present but should not be confused with bleeding of the superficial vascular structures.

Subcutaneous Dissection

When addressing the subcutaneous layer, proper dissection technique is of paramount importance. Improper technique can result in a failure of hemostasis control, superficial nerve damage, skin slough and dehiscence, all of which are potential serious postoperative complications. Postoperative edema, hematoma, and pain may be greatly reduced if unnecessary dissection and trauma are avoided.

Dissection Techniques

The terms "sharp" and "blunt" dissection are often used when addressing subcutaneous dissection, and each of these styles may be further divided into specific techniques, each with a different purpose.

The superficial vascular structures of the subcutaneous layer are the first structures to be addressed. Blunt dissection, utilizing either a hemostat or blunt Metzenbaum scissors, is employed to identify the vessels and isolate them from the surrounding soft tissue structures. This technique of separation is necessary when attempting to isolate neurovascular or other fragile structures such as ganglions or bursas from the superficial fascia. Once all the vessels that must be sacrificed have been isolated and properly ligated, either by electrocautery or by vessel ligature, dissection is continued through the subcutaneous tissue.

Sharp dissection is generally employed unless vessels in the deeper plexuses are encountered. The technique of "up and out" retraction will make the identification and separation of tissues much easier.

Dissection is continued through the subcutaneous tissue down to the level of the deep fascia. As dissection is completed, the transverse fibers of the extensor hood apparatus about the first metatarso-phalangeal joint will become apparent. More proximally, the periosteal structures about the first metatarsal shaft and the metatarso-cuneiform joint may be identified.

When progressing through the subcutaneous layer, it is imperative that no deviation is made outside the skin incision line. If dissection deviates into the superficial fascia, one runs the risk of damaging neurovascular structures as well as increasing soft tissue trauma and, therefore, the resultant inflammatory reaction. Unnecessary dissection may therefore lead to disruption of the vascular supply to the skin leading to skin necrosis, wound dehiscence, or distal vascular compromise. Increased dissection will also lead to increase fibrosis postoperatively and increase the chance of nerve entrapment. Superficial nerves that are identified should be noted, handled gently, and protected throughout the remainder of the procedure.

Separation of Superficial Fascia From Deep Fascia

Once the deep fascia is exposed along the entire course of the incision, the next step is to separate the superficial fascia from the underlying deep fascia. For the most part, blunt dissection is adequate for separating the two layers since the superficial fascia is generally only loosely adhered to the deep fascia. In some areas, such as the apex of the deformity, sharp dissection may be necessary.

Beginning distally over the shaft of the proximal phalanx, the back end of the knife handle is inserted between the superficial and deep fascia. This maneuver is generally easily accomplished at this point because of the loose adherence between the two layers. This technique, however, will not suffice more proximally. The back of the knife handle is then advanced plantarly and proximally to expose the medial aspect of the first metatarsophalangeal joint capsule. Along the medial aspect of the deformity, more dense fibrous attachments may be noted and sharp dissection may be indicated. A sweeping stroke with the surgical blade can be used to transect these fibers.

A combination of sharp and blunt dissection with Metzenbaum scissors can also be used, specifically more proximally, where tissue planes are not so freely identifiable. The soft tissues are first spread and separated. If no neurovascular structures can be noted in the separated tissues, the Metzenbaum scissors are inserted into the canal that has been created and the tissues are sharply transected. It is important to note any neurovascular structures, especially the superficial branches of the medial dorsal cutaneous nerve that are often visible after the completion of the dissection.

Next, the superficial fascia must be removed from the dorsal aspect of the first metatarso-phalangeal joint in order to address the first interspace and perform the lateral release. Several methods of blunt dissection can be employed.

The most useful of all surgical instruments, the surgeon's index finger, can be used to lift the superficial fascia from the underlying deep fascia that is the extensor hallucis longus tendon and the extensor hood apparatus. A moistened, sterile sponge can be used to gently brush the two layers apart. Again, the back of the scalpel handle or a pair of Metzenbaum dissecting scissors can be used to separate these layers. Should subcutaneous tissue remain on the deep fascia or should violations exist in the deep fascia with resultant exposure of the extensor hallucis longus tendon, proper technique was not followed and the interface of the layers was missed.

Once the interface has been entered, the index finger can be used in a sweeping motion to help clearly define the superficial fascia from the deep fascial structures within the interspace. The superficial fibers of the deep transverse intermetatarsal ligament represent the roof of the first interspace and can be palpated with the previously mentioned maneuver. The first metatarso-phalangeal joint should be placed through a range of motion prior to the performance of the lateral release so the surgeon can appreciate the effect of each stage of the systematic lateral release. A self-retaining retractor may be used to increase exposure in the interspace. The long end of a Senn retractor is placed in the distal aspect of the incision and plantar and distal retraction is given to help protect the deep venous structures that lie just beneath the deep transverse intermetatarsal ligament. Metzenbaum scissors should be employed to clean any remaining soft tissue structures from the deep fascia. Frequently, small vessels may be noted which will need to be addressed.

Lateral Release with Delivery of Conjoined Adductor Hallucis Tendon

Since hallux valgus is a progressive pathological condition, soft tissue contractures occur along the lateral aspect of the first metatarso-phalangeal joint. A systematic approach is taken when addressing these deforming forces. After each stage is completed, the range of motion of the joint is re-evaluated so the surgeon can appreciate the deforming force of each individual structure.

Much controversy exists over the exact anatomic orientation and relationship of the adductor hallucis conjoined tendon and the deep transverse intermetatarsal ligament. The conjoined tendon has been described as being both dorsal and plantar to the deep transverse intermetatarsal ligament. More consistently, anatomical studies have revealed the deep transverse intermetatarsal ligament as being bifurcate and bearing a common origin from the medial aspect of the second metatarso-phalangeal joint capsule and a split insertion to the lateral aspect of the first metatarso-phalangeal joint capsule and the sesamoid apparatus. Consistently, the conjoined tendon is identified as passing between this bifurcation. Therefore, the superficial fibers of the deep transverse intermetatarsal ligament may represent the roof of the first interspace, and transection of these fibers to expose the adductor hallucis conjoined tendon will leave the deeper fibers intact, representing the floor of the first interspace, to help protect the underlying vasculature.

The superficial fibers of the intermetatarsal ligament are again fully visualized, and its distal most border is identified. A pair of Metzenbaum scissors is inserted distal and plantar to these fibers and opened to bluntly separate this portion of the ligament from the underlying adductor hallucis tendon. Once this maneuver is accomplished, these fibers are then placed between the jaws of the scissors and sharply transected. This maneuver should open the interspace, and repositioning of the self-retaining retractor may be required at this point to increase exposure.

With the superficial fibers of the deep transverse intermetatarsal ligament transected, the conjoined tendon of the adductor hallucis muscle should be clearly visible. Inserting and spreading the scissors below the adductor tendon and fibular sesamoid, will free these structures from any underlying, fibrous soft tissue attachments.

Next, the joint line is identified by distracting the hallux, and noting a "pucker" in the joint capsule. Utilizing a #64 Beaver blade, a horizontal incision is made dorsal to the conjoined tendon into the joint capsule. Synovial fluid should be noted if the incision is properly placed). A curved hemostat is inserted into the incision with the tips pointing medially so as to follow the curvature of the first metatarsal head. The hemostat is rotated so the tip is aimed proximally and spread to isolate the adductor tendon. A curved or straight hemostat is inserted into the canal that has been created to grasp the adductor tendon. Care must be taken not to grasp too deep and therefore disrupt the underlying vascular structures.

The adductor tendon has three distal components of insertion. The medial component inserts into the lateral sesamoid, and the central component inserts into the plantar aspect of the sesamoid. The lateral component inserts into the lateral sesamoid and the plantar lateral aspect of the proximal phalanx with some contributions into the extensor aponeurosis. Rotating the hemostat that is firmly grasping the tendon will draw the tendon away from the base of the proximal phalanx making transection of this insertion easier. Once the distal insertion is transected, the tendon is suspended and dissection is continued proximally in a parallel or co-axial fashion about the tendon. The medial and central components of the adductor tendon are next encountered at the level of the fibular sesamoid. This portion of the adductor tendon is removed from the sesamoid utilizing a "U" shaped stroke with the surgical blade.

Again, rotating the hemostat on the adductor tendon will aid in dissection of the adductor tendon from the fibular sesamoid. The surgical blade is passed lateral to the hemostat. Dissection is continued plantarly, then medially and dorsally, following the contour of the hemostat. Parallel (co-axial) dissection in this fashion will ensure harvesting the tendon without cutting it. Often the surgeon may experience obstruction of the upward stroke because the fibular sesamoid may be encountered.

Due to the insertion of the medial and central bands of the tendon into the plantar aspect of the sesamoid, this hindrance is understandable but can be easily corrected by positioning the knife more lateral.

The "U" type stroke is repeated until the adductor hallucis tendon is completely detached and freely moveable. The tendon is then tagged with 2-0 suture for later transfer or transection.

The first metatarso-phalangeal joint is then placed through a range of motion to evaluate the deforming effects of the adductor tendon. If the sesamoid apparatus is not freely moveable and if the deformity cannot be reduced, attention is redirected back to the lateral capsule. At this point, multiple structures may be hindering the repositioning of the sesamoid apparatus. The first to be addressed are the lateral collateral ligaments and the fibular sesamoid ligament.

A Freer elevator is inserted in the distal aspect of the capsular incision. The blade of the Freer is placed parallel to and against the metatarsal shaft. The Freer is then advanced proximally between the sesamoid and collateral ligaments and the metatarsal and is then rotated 90 degrees to suspend the ligaments which are sharply transected with a surgical blade. Again, all instruments are removed and the deformity is reevaluated. If the sesamoid apparatus is still not freely moveable, to a normal anatomic position beneath the metatarsal head, the deep fibers of the deep transverse intermetatarsal ligament are severed. Care should be taken, as the neurovascular structures run beneath this "floor", in the "cellar" of the first interspace. A more aggressive horizontal capsulotomy of the lateral capsule may be deemed necessary to allow frontal plane rotation of the sesamoid apparatus. Vertical capsulotomies are avoided because they will lead to increased fibrosis at the joint line and disrupt the vascular supply to the distal capsule laterally.

Should the sesamoid apparatus continue to resist repositioning under the metatarsal head, the lateral head of the flexor hallucis brevis tendon, as it inserts into the fibular sesamoid, may be sectioned next. Intracapsular fibrosis between the sesamoid apparatus and the plantar aspect of the metatarsal may also be responsible for a lack of mobility. This can be addressed utilizing a metatarsal elevator to transect these fibrous adhesions.

Medial Capsulotomy / Capsulorraphy

Joint capsule and other periarticular soft tissue structures are critical components in the reduction of hallux abducto valgus deformity. Effective capsule tendon balance around the metatarso-phalangeal joint will reposition the sesamoidal apparatus, as well as either maintain or accentuate correction of hallux position achieved through osseous procedures. Medial soft tissue dissection consists of a capsulotomy which is used to balance the soft tissue components that influence the joint by incorporating the resection of redundant tissue (capsulorraphy). There are many different medial capsular incisions that may be used. These include linear, semi-elliptical, inverted "L", "T", or "U" shaped incisions. Care must be taken in planning and performing the proposed capsular incision since orientation of the incision, as well as the amount and location of the redundant tissue resected, are critical in determining the end position of the hallux. Resection of tissue and closure of the capsular incision can influence hallux position in all three planes, and care must be taken to avoid overcorrection of the deformity, which may result in a hallux varus deformity.

And, when performing capsular dissection, the axis of the metatarso-phalangeal joint must be taken into consideration. If tissue is taken either too far dorsal or plantar relative to the axis, extension or flexion contracture may result, respectively. Ideally, closure of the medial capsule with the hallux held in either neutral position or in slight adduction, plantarflexion, and inversion (reverse of deformity) should result in even tension dorsal and plantar to the joint axis, with the extensor hallucis longus tendon and hood apparatus in midline.

The delivery of the first metatarsal head is the next step in dissecting hallux abducto valgus deformity. A standard inverted "L" type incision is generally used because it allows the surgeon both ideal exposure and increases the correction capabilities during closure. Placement of the vertical and horizontal arms of the capsular incision is dictated by both structural and anatomical considerations.

The medial aspect of the metatarsal head is relatively free of any soft tissue attachments except in the area of the medial epicondyle. The medial capsule and medial collateral and tibial sesamoid ligaments originate from the medial epicondyle. Knowledge of these anatomic landmarks will not only determine the incision placement but also aid in capsular dissection.

The horizontal arm of the capsular incision begins proximally along the dorsal medial aspect of the metatarsal shaft and extends distally to the level of the metatarso-phalangeal joint passing dorsal to the medial epicondyle. The incision is redirected to course along the dorsal medial aspect of the proximal phalanx. Because the metatarsal head is devoid of soft tissue attachments, a Freer elevator can be inserted at the level of the joint line and passed both dorsal and medial to the head. This maneuver is for demonstration only and serves no functional purpose in capsular dissection.

Next, the hallux is distracted and the joint line is identified. The vertical arm of the capsular incision is then performed proximal to the joint line over the hypertrophic medial eminence just distal to the medial epicondyle. This will help to reduce the risk of cartilaginous damage by the surgical blade. A Freer elevator can again be inserted into this vertical incision and moved proximally along the medial aspect of the metatarsal head. Movement of the Freer dorsally will be obstructed due to capsular and ligamentous insertions into the medial epicondyle. This pocket that has just been identified is referred to as the "resident's" or "student's hole." Recognition of this anatomical landmark will aid in capsular dissection.

The surgical blade is inserted into the anatomical pocket and while maintaining the surgical blade against the medial aspect of the metatarsal head, the scalpel is brought dorsal to the medial epicondyle and the capsular and ligamentous insertions there are transected.

Dissection of this flap is continued proximally until the interface between the capsule and periosteal tissue is identified. Slight adduction of the hallux by the assistant will aid with this maneuver by relaxing the capsular tissues medially.

Plantar dissection of the capsule is necessary only to allow the surgeon to resect the medial eminence and perform the necessary osteotomy. Shereff and colleagues identified arteries in this area for both the capsule and first metatarsal. These vessels originate from the first plantar metatarsal artery during its plantarward course into the first intermetatarsal space. Extensive dissection beneath the metatarsal head will jeopardize the integrity of these vessels therefore interrupting the vascular supply to both the head of the metatarsal as well as the plantar capsular tissues.

Next, attention is directed to the dorsal capsule. Dissection over the dorsal aspect of the metatarsal head is generally dictated by the type of osseous procedure to be performed. A standard Austin type bunionectomy, for example, will require limited dissection dorsally while a Reverdin type procedure or a Cheilectomy of the first metatarsal, will require more extensive dissection for both exposure and visualization. Dissection should be limited dorsally when possible in order to maintain the "dorsal synovial fold". Maintenance of this anatomic structure will aid in increasing post-operative range of motion by decreasing intracapsular fibrosis.

The described inverted "L" type capsular incision can be easily extended and converted to a "T" capsulotomy in order to increase exposure. The capsular tissues are easily removed from the proximal phalanx with sharp dissection. After all capsular tissues are removed, the periosteum is addressed. Utilizing an elevator, the periosteal structures are reflected plantarly and dorsally to expose the first metatarsal shaft. Again, the type of osteotomy to be performed will dictate the amount of dissection. A distal capital procedure will require limited dissection in comparison to a midshaft or base type osteotomy. Generally a periosteal elevator is sufficient for removing the periosteal tissues. However, as the surgeon works closer to the metatarso-cuneiform joint, ligamentous structures about the joint may be encountered and sharp dissection with the surgical blade may be necessary.

Extensive periosteal dissection along the medial aspect of the first metatarsal can be performed without jeopardizing the vascular supply to the first metatarsal, as the nutrient artery enters laterally. With the "T" or inverted "L" incision, a greater amount of reªorientation of the joint is possible with closure and capsulorraphy. When ready to close the joint capsule, evaluation of possible redundant tissue should be made with the forefoot "loaded" to simulate weightbearing and the hallux held in the desired position. Overlap of linear and vertical arms of the capsule incision can then be accurately assessed utilizing two forceps. With the extensor hallucis longus tendon in midline position, redundant tissue can be resected from either the dorsal or plantar flap of the linear arm, according to thickness. The thicker capsule is usually present along the inferior flap. Resection of redundant capsule from this location aids in pulling the sesamoids medially, to a normal anatomic position. The flaps should easily re-appose under physiologic tension.

The vertical arm can be similarly assessed and is actually the more crucial of the two in terms of influence on the final position of the toe. Any resection of tissue from the vertical flap will reduce the deformity in the transverse plane, thereby adducting the hallux.

Usually a small amount of plantarflexion is needed to effectively reduce the deformity, therefore a wider section can be resected at the plantar margin of the vertical arm.

To avoid shortening of the horizontal arm when closing the capsule, a single tag suture may be placed at the dorsal corner of the medial flap. The horizontal incision can then be closed, from proximal to distal, utilizing simple interrupted or running absorbable suture.

When closing the vertical arm, one must again be aware of the midline joint axis, and also hold the hallux in the desired position. A number of simple interrupted "pulley" or "over and over" sutures are used to close the incision and their placement and orientation are crucial. Utilizing non-absorbable or heavy absorbable material, the first suture is thrown at the plantar aspect of the vertical arm, oriented on a bias from proximal dorsal to distal plantar. This orientation will aid in derotating the hallux in the frontal plane, as well as provide slight plantarflexion since it is below the axis level of the joint. Care must be taken to avoid both over tightening this suture and entering the tendon of the abductor hallucis, as this will result in overcorrection of the deformity. The next suture is thrown at the joint level axis as it assists in maintaining transverse plane correction. Additional sutures may now be placed along the incision for the purpose of tissue apposition. If a "T" capsular incision was used, the distal aspect of the incision may now be closed utilizing absorbable suture.

If a linear capsule incision is utilized, redundant tissue can be resected as previously described. If the purpose is simply to reªappose tissue, running absorbable suture may be used. However, if additional correction of the original deformity is needed, over and over non-absorbable suture may be placed just proximal to the joint line and oriented in bias fashion proximal dorsal to distal plantar, making sure to cross the joint line. The hallux should be held in the desired position while the suture knot is tightened. Care must be taken to avoid over tightening, and it should be understood that only limited repositioning of the hallux is possible with a linear capsule incision. Additional suture can now be placed for tissue apposition, thereby completing the closure of the capsule.

Fibular Sesamoidectomy

When addressing the laterally deviated sesamoid systematically, the surgeon is generally able to relocate the sesamoid apparatus beneath the metatarsal head and realign the deforming forces about the first metatarso-phalangeal joint thereby alleviating the need for sesamoidectomy. Once a common adjunctive procedure to hallux abducto valgus surgery, fibular sesamoidectomy is generally reserved for situations addressing hypertrophic or degenerative sesamoids or when addressing a significant structural deformity in individuals in which aggressive osteotomies may not be recommended.

The approach for fibular sesamoidectomy is a continuation of the lateral release. After suspending and sectioning the fibular sesamoid ligament, the small tag of ligament remaining on the sesamoid is grasped to manipulate the sesamoid for excision. The sesamoid is first pulled laterally into the interspace.

While maintaining sesamoid distraction, the distal ligamentous-tendinous attachments between the sesamoid and proximal phalanx are transected. The sesamoid is then drawn distally and the proximal tendinous slips of the flexor hallucis brevis into the fibular sesamoid are transected. The sesamoid is drawn laterally and dorsally and the surgical blade is passed inferior to the sesamoid to shell it from the tendinous attachments of the flexor hallucis brevis plantarly. The knife is then passed up, along the medial aspect of the sesamoid to section the intersesamoidal ligament. Care must be taken with this maneuver to avoid damage to the flexor hallucis longus tendon which lies just beneath this ligament.

Medial Approach

Often a medial approach to hallux abducto valgus may be employed either to increase exposure or for cosmesis. When considering a long, medial type osteotomy such as the Scarf or Mau, the surgeon may prefer a medial type approach to aid in dissection and also visualization of the fixation which is generally placed from dorsal to plantar. Because of the incision placement, it is not readily visible in standard, open shoe gear. Because of the location of the medial neurovascular structures, extra care must be taken during the subcutaneous tissue layer dissection.

Incision Placement

The medial incision is made starting along the medial aspect of the metatarso-cuneiform joint and continued distally along the medial aspect of the first metatarsal to the level of the hallux interphalangeal joint). The incision can be made more proximal to include the medial cuneiform should the surgeon desire to do a basal procedure. Some have found that the surgical cicatrix over the medial prominence may be irritated by shoe gear and therefore curve the incision below the medial eminence. Others have found that the cicatrix does not hypertrophy, secondary to the pressure presented by the shoe. The decision for exact placement is left up to surgeon while the skin incision and subcutaneous dissection is performed in the same manner as described in the previous dorsal medial approach. The surgeon should expect to encounter a thicker subcutaneous layer proximally and a thinner subcutaneous layer distal to the joint level. With this approach, and with the close approximation of the medial marginal vein, more vessels for ligation may exist. Extra care must be taken to properly identify and retract the dorsal medial cutaneous nerve in this area. Again, dissection through the subcutaneous layer is continued down to the level of the deep fascia, which consists of the first metatarso-phalangeal joint capsule and periosteum of the first metatarsal. The subcutaneous tissues are then separated from the deep fascia along the proposed capsular and periosteal incision line. The previously described techniques of sharp and blunt dissection may be employed here also.

Limited dissection of the subcutaneous layer from the deep fascia is necessary since the lateral release will be performed from an intracapsular, plantar approach rather than from the standard dorsal approach.

It is possible, however, to reach the first interspace from this approach if necessary. Because of the amount of soft tissue dissection and undermining of the subcutaneous layer from the deep fascia, however, this is not a recommended approach due to the increase in post-operative edema, hematoma, and fibrosis.

Capsular Dissection

The medial approach does not limit the surgeon in performing any type of capsular incision. The medial approach does lend itself to a more favorable linear or medial type capsulotomy. The amount of periosteal dissection along the plantar aspect of the metatarsal is generally more extensive to facilitate performing and fixating the midshaft type osteotomies.

Lateral Release with Adductor Hallucis Tenotomy and Lateral Capsulotomy

Visualization of the lateral sesamoid and sesamoid apparatus to address the deforming forces can be easily achieved through the medial capsulotomy. Once the capsular tissue is dissected from the first metatarsal and proximal phalanx and the metatarsal head is delivered, a Ragnell retractor is placed below the first metatarsal and retracted dorsally. A Senn retractor is placed proximal to the sesamoids to avoid damaging the articular cartilage, and the soft tissues are retracted plantarly. This maneuver opens the plantar aspect of the metatarso-phalangeal joint capsule for adequate sesamoid visualization. Next, utilizing the blunt end of a freer elevator, the surgeon presses down on intersesamoidal ligament to increase the access to the fibular sesamoid.

The first maneuver is performed utilizing a #15, #64, #64-B, or #11 surgical blade. A stroke is made along the dorsal aspect of fibular sesamoid. This maneuver is repeated to encompass the lateral one-third of the fibular sesamoid. If performed accurately, lateral attachments into the fibular sesamoid and the fibular sesamoidal ligament are transected. Upon completing the release, the sesamoid apparatus will "drop" plantarly and should be freely moveable beneath the metatarsal head. The metatarso-phalangeal joint is placed through a range of motion to evaluate the deforming forces. If adequate release has not been obtained, attention should be directed to the distal lateral aspect of the fibular sesamoid where soft tissue attachments may still be present and should be released.

While maintaining retraction, the hallux is distracted to perform the lateral capsulotomy. The capsular incision is generally oriented in the vertical manner and will transect the adductor tendon if properly performed. It is a controlled maneuver that does not allow the surgical blade to be haphazardly buried through the capsule into the interspace where numerous venous structures are located.

Additional care must be exercised to avoid damage to the intersesamoidal ligament, flexor hallucis brevis tendon, articular cartilage on the metatarsal head, proximal phalanx and sesamoids.

Should it be necessary to remove the fibular sesamoid, it can be easily excised from the plantar approach. The sesamoid is scooped out of the flexor hallucis brevis tendon with a sharp #15 blade. The conjoined tendon of the adductor hallucis is then clearly visualized and a section may be removed if necessary.

SOFT TISSUE-TENDON CAPSULE BALANCE PROCEDURES

In his treatise of 1923, "The Operative Treatment of Hallux Valgus", Silver described a surgical procedure which became the precursor of many current "soft tissue-tendon balance" procedures. He discussed the deforming forces of hallux valgus and proposed a treatment rationale which included five steps: 1) curvilinear skin incision with downward convexity, 2) Y-shaped capsular incision, 3) resection of medial eminence, 4) U-shaped capsulotomy of lateral metatarso-phalangeal joint and 5) over correctional capsulodesis to maintain position. He advocated the procedure for two reasons.

Primarily, it left articular surfaces unimpaired and would avert a limitation of motion. Secondarily, the technique allowed adjunctive procedures to be performed. Three years later, McBride authored his first in a series on what was to become the classic McBride bunionectomy. Realizing the need to refine the procedure from previous experience, he subsequently published articles in 1935, 1952, 1954, 1963 and 1967. Most importantly, he realized the pathologic force of the conjoined adductor tendon and its need for transplantation into the metatarsal head. He also differentiated between a primary contracture of the adductor tendon and a secondary contracture of the lateral capsule. To clinically distinguish between the two, the patient was examined in a non-weightbearing position with the foot fully relaxed. The hallux was adducted to a corrected position that, if not achieved, indicated a capsular contracture. If a normal position was obtained when the adductor tendon was relaxed, it was tested on weightbearing while contracted. If the hallux still was not brought into alignment, the adductor tendon was deemed the principle deforming force McBride advocated a lateral capsulotomy, conjoined adductor tendon transplantation to the lateral metatarsal head, and fibular sesamoidectomy in the case of a capsular contracture. He also advocated approximation of the first and second metatarsal heads with chromic catgut suture to correct a metatarsus varus deformity, which is not commonly performed today.

"Broken arches and hallux valgus are the result of the same vicious forces working on the feet" was the astute realization of JM Hiss, in his 1928 article, "Cause of Bunions and Simplified Treatment". He proclaimed that a bunion deformity, along with bone and joint changes at the first metatarso-phalangeal joint, was secondary to foot malalignment.

His procedure, known as the "base correction" method, was both manipulative and operative and was composed of one or more portions of the following: a) excision of the fibular sesamoid, b) medial transplantation of the flexor hallucis longus tendon, c) detachment of the adductor hallucis tendon, d) tenotomy of extensor hallucis longus tendon, e) plication of the abductor hallucis tendon and, f) remodeling of the first metatarsal head. Later, in 1931, Hiss advocated a dorsal transfer and readvancement of the abductor hallucis tendon.

In 1947, Rogers and Joplin published an end result study on the Keller bunionectomy and found the results less than satisfactory. This inspired Joplin to look for a new procedure through reduction of a splay-foot deformity at the same time. In 1950, he published the results of a procedure for correction of splay-foot, metatarsus primus varus and hallux valgus. This elaborate procedure consisted of harvesting the fifth extensor digitorum longus tendon at the ankle joint, while maintaining its insertion. The tendon passed under the fourth, third and second metatarsal heads respectively, through to the first. The foot was then compressed in a medial-lateral direction and the extensor tendon sutured into first metatarso-phalangeal joint capsule. The procedure reduced metatarsus primus varus and corrected hallux valgus by adducting the great toe. Joplin performed the procedure on 131 feet and reported satisfactory results, although McBride thought it too severe for use in a patient seeking relief for painful bunions and is not commonly employed today.
Indications

The general indications for soft tissue-tendon balance procedures include:

- Positional hallux abducto valgus deformity.
- Elderly patient with bump pain.
- Adjunctive procedure with various osteotomies.
- Normal proximal and distal articular set angle (DASA).
- Normal articulating joint surfaces without crepitus.
- Normal hallux abductus interphalangeus (HAI).
- Deviated or subluxed first metatarso-phalangeal joint.

The general indications for fibular sesamoidectomy include:

- Inability to anatomically relocate the sesamoids following lateral release.
- Sesamoidal erosion or fracture.
- Inability to transpositionalize the capital fragment after distal osteotomy.

Complications

Hallux Varus Deformity

Hallux varus is a complication of bunion surgery that can be divided into two types, "static" and "dynamic". The "static" type is the result of excessive correction at the time of surgery and may occur when too much medial eminence is resected or "staked".

This will result in a loss of the medial buttress for the base of the proximal phalanx and lead to medial subluxation. On the other hand, the "dynamic" type of hallux varus is more often associated with the McBride procedure. It is the result of severe muscle imbalance around the base of the proximal phalanx, due to the release of both heads of the adductor hallucis tendon as well as the lateral head of flexor hallucis brevis tendon.

Since the modified McBride bunionectomy usually involves some type of lateral release, with or without a fibular sesamoidectomy, the lateral stability at the first metatarsoªphalangeal joint is disturbed. As a result, a dominant medial joint column with unopposed lateral column, is created. The dominant medial musculature consisting of abductor hallucis and flexor hallucis brevis (medial head), gradually deviate medially and once the hallux is passed rectus alignment, the extensor hallucis longus and the flexor hallucis longus exert a dominant force producing a hallux varus or hammered hallux deformity. For example, Miller, after re-doing 5 cases of hallux varus, found the abductor to insert medially in all but one, as opposed to its more plantar insertion in the normal foot. Therefore, the key points in prevention of the varus deformity include securing the flexor hallucis brevis tendon, appropriate fibular sesamoidectomy, maintenance of a positive IMA and PASA, as well as the avoidance of metatarsal head "staking" or medial "peaking" of the tibial sesamoid.

Hallux Hammertoe Deformity

A hallux hammertoe can occur after surgery either alone or in combination with hallux varus, as demonstrated by Hansen. This is usually the result of injury to the lateral and/or medial head of flexor hallucis brevis due to fibular sesamoidectomy. Once the plantar stability of flexor hallucis brevis is lost, the extensor hallucis longus and extensor digitorum brevis become the dominating force with an intact flexor digitorum longus. This will lead to an extension deformity at the metatarso-phalangeal joint and flexion deformity at the interphalangeal joint, creating a hammered hallux. Severance the flexor hallucis longus tendon creates a greater tendency toward a hallux extensus. Therefore, it is imperative to maintain the medial or lateral head of the flexor hallucis brevis or the flexor hallucis longus tendon.

Intractable Plantar Keratoma

An intractable plantar keratoma (IPK) beneath the tibial sesamoid may occur following fibular sesamoidectomy. This is due to increased weightbearing force which was previously dissipated by both sesamoids.

Recurrent Hallux Valgus Deformity

Among the causes of recurrent hallux valgus are, a) inadequate lateral metatarso-phalangeal joint release, b) inadequate medial capsulorraphy, c) abductor hallucis transection, and d) poor procedural choice.

Results of Surgery

In his study of 300 cases, Hawkins found that an adductor tendon release or transplantation alone would not cause a hallux varus deformity. He cited three cases of hallux varus whose cause was either secondary to sesamoid excision or injury to the lateral head of the flexor hallucis brevis tendon. Therefore, it is wise to detach only the superior portion of the conjoined tendon of the adductor, leaving the lateral head of flexor hallucis brevis intact.

In another study of 139 feet with follow-up of 5-8 years, Hansen found hallux varus to occur in 18 feet. He felt that the flexor hallucis longus and extensor hallucis longus tendon maintained the deformity once the great toe was carried medially to the joint axis with the additive effect of adductor tendon release. He recommended omitting a sesamoidectomy because of lost flexor hallucis brevis and intersesamoidal ligament function. In conjunction with a hallux varus, some patients also experienced a hallux flexus and metatarso-phalangeal joint extension deformity. Interestingly, in the thirteen feet where a fibular sesamoidectomy was not performed, such deformities did not develop.

McBride in his original analysis of 35 patients, reported two cases of hallux varus deformity, both patients were under 25 years of age and underwent fibular sesamoidectomy with complete release of the lateral head of the flexor hallucis brevis. In a study reviewing 200 cases of the Duvries modification, a 4% incidence of severe hallux varus was noted. This was decreased to 2% by modifying the Duvries modification of leaving the fibular sesamoid intact and only releasing the transverse metatarsal ligament, permitting the sesamoids to be reduced beneath the metatarsal head.

Finally, Martin reviewed the effects fibular sesamoidectomy had on intermetatarsal angle, hallux abductus angle, and tibial sesamoid position. It appears from this study that a fibular sesamoidectomy has a much greater effect on reducing the hallux abductus angle, with limited effect on reducing the intermetatarsal angle. Performing a fibular sesamoidectomy also allowed for a greater reduction in the tibial sesamoid position.

FIXATION METHODS IN HALLUX ABDUCTO VALGUS SURGERY

Introduction

Over the past twenty years, many different surgical osteotomies have been popularized for the treatment of hallux valgus deformity. Similarly, much time has been spent on the development of internal fixation devices and the decision regarding which device to use is based upon many factors such as anatomic location, inherent osteotomy stability, bone integrity, choice of immobilization and surgeon preference. Additionally, there is often more than one fixation technique available for a particular osteotomy and when the primary means of fixation fails, the knowledge and ability to perform a satisfactory alternative technique is required.

The use of rigid internal compression fixation, as championed by the Swiss Association for the Study of Internal Fixation, (ASIF/AO), has been widely used in modern podiatric surgery. Rigid internal fixation has the advantage of allowing early joint motion while resisting inter-fragmental movement. This allows for primary bone healing and elimination of external (irritation) bone callus formation. While ideal for certain first ray osteotomies, its application may prove difficult or unnecessary in others. Interestingly, an excessive amount of inter-fragmental compression may not be advantageous. For example, more than thirty pounds per square inch of pressure will cause necrosis of cortical bone. Because of this potential hazard, it must be kept in mind that it is not desirable to tighten compressive devices any more than needed to resist motion.

Therefore, the purpose of this review section is to present a overview of fixation devices and techniques which are commonly used in hallux abducto valgus surgery.

CORTICAL AND CANCELLOUS BONE SCREWS

Classic Cortical Lag Screw Technique

- The osteotomy is reduced and stabilized with K-wires or reduction clamps.
- A glide hole is drilled through the near cortex with the appropriate drill bit and wide end of the double-sided drill guide.
- The narrow end of the drill guide is used as an insert sleeve, by placing it into the glide hole, until engaged into the far cortex. The appropriate drill is inserted into the drill guide and a thread hole is drilled through the far cortex.
- The glide hole is countersunk.
- Screw length is determined with a depth gauge.
- The thread hole is tapped and the wide end of the drill guide used to protect soft tissue structures.
- The screw is inserted and tightened with two-finger pressure.

Small Fragment Technique

- The osteotomy is reduced.
- The thread hole is drilled through both the near and far cortices.
- The glide hole is drilled through the near cortex.
- The glide hole is countersunk and screw length determined
- The thread hole is tapped and the screw inserted and tightened.

Cancellous Screw (4.0 mm)

- The osteotomy is reduced and a thread hole is drilled through both the near and far cortex with a 2.5 mm drill bit and guide.
- The near cortex is countersunk and screw length determined.
- The thread hole is tapped with a 3.5 mm cancellous tap and 3.5 mm drill guide.
- The screw is inserted and tightened.

Special Considerations

- The size of the screw should be matched to the size of the bone being fixed.
- Smaller screws place more threads across the cortex of small bones with thin cortices.
- It is recommended that at least three threads cross and engage the far cortex when a lag screw technique is performed.
- Small screws may be mechanically superior to larger screws when placed in thin cortical bone. When smaller screws are used, less bone stock is removed by

drilling and counter-sinking. Finally, small screws produce smaller "stress risers", minimizing the risk of bone fracture.

- Two screws should be used, when possible, since one may act as an axis of rotation upon which the bone fragments can rotate. Crossed screws should be inserted in different planes to give multidirectional stability. Stress risers are also separated from one another in this manner.
- If a single screw is used to fix a hinged osteotomy, it should be inserted by bisecting the angle formed by a line drawn perpendicular to the long axis of the bone and a line perpendicular to the reduced osteotomy. A screw inserted in this orientation will cause the near fragment to shift distally. The cortical hinge is placed under tension that is converted to additional compression, at the osteotomy surface.

NOTE: A 2.5 mm drill bit may replace the old 2.0 mm bit when forming thread holes for 3.5 mm or 4.0 mm screws. This larger drill does not weaken the fixation, allows for easier placement, is stronger and has a reduced risk of breakage.

SELF-TAPPING BONE SCREWS

A self-tapping screw utilizes a shallow channel machined into its tip that functions as a cutting flute. When the screw is inserted, the sharp edge of the cutting flute allows the screw to cut threads into the thread hole. Because the screw itself forms the bone threads, there is no need to tap the bone prior to insertion. The use of a cutting flute provides for intimate contact between the screw and the bone since the threads cut in the bone correspond exactly to the diameter size of the screw itself. On the other hand, the fluted area of the tip contains no threads and is therefore unable to engage the bone. Because of these opposing characteristics, controversy exists over the purchasing power of self-tapping screws. However, several studies have shown that self-tapping screws behave similarly to non-self-tapping screws, when subjected to pull out tests.

The use of a 2.0 mm self-tapping bone screw, for the fixation of an Austin osteotomy, has recently been reported in the literature, and may used as an example, in the following manner.

- The self-tapping screw is inserted from the medial aspect of the dorsal osteotomy wing, in a plantar-proximal direction, terminating through the plantar cortex.
- A 1.5 mm drill bit is used to make a thread hole through both the near and far cortices and a 2.0 mm drill bit is used to make a glide hole in the near cortex.
- The glide hole in the near cortex is countersunk.
- A depth gauge determines proper screw length.

CANNULATED SCREWS

Cannulated screw systems offer the advantage of temporarily fixating osteotomies over guide wires supplied with the system. Unfortunately, when K-wires are used to temporarily hold osteotomies, they often interfere with placement of traditional cortical or cancellous screws. The problem is exaggerated in the first ray since the ideal area of screw placement if often quite small. Current systems have been designed to provide lag screw compression by engaging the cancellous bone of the far fragment. They are not designed to pass through the far cortex as in a traditional cortical lag screw technique. This limits application in the first ray, because of the small quantity and quality of cancellous bone, but is useful in hallucal fusions, oblique base wedge osteotomies and metatarsal base fusions.

Surgeons are cautioned not to use excessive force when drilling holes with cannulated drill bits. The long drill bits cannot withstand the same amount of torsional force as solid drill bits of similar diameter and are therefore more susceptible to breakage. The described application technique is specific to the Small Cannulated Screw System produced by Synthes (USA). This system allows the insertion of both fully threaded and smooth shank 3.5 mm screws. Although the specific application steps for cannulated screw systems produced by different manufacturers may vary, the basic concepts remain the same.

General Application Technique

- The osteotomy is reduced and temporarily fixated with a 1.25mm. guide wire which possesses a threaded trochar tip. The wire is driven in the same direction and depth of the intended screw.
- The 1.25 mm drill sleeve can be used while driving the guide wire to prevent soft tissue damage.
- Radiographs or an image intensifier is used to confirm proper orientation of the guide wire. A second guide wire is placed parallel to the first to prevent rotation of the bone fragments.
- A direct measuring device is placed over the guide wire and slid until it engages the near cortex. To determine the proper thread hole and screw length, 5 mm is subtracted from the measuring device length. This prevents both loosening of the guide wire and penetration of the far cortex during drilling.
- A 2.7 mm cannulated drill bit is placed into the drill guide, with an adjustable drill bit stop, and is set to the previously determined length by the measuring device. The entire drill assembly is slid over the guide wire and drilled into the bone fragments until the quick coupling end of the drill bit contacts the drill guide with stop.
- If a fully threaded screw is used, a 3.5 mm sleeve is inserted into the drill guide with stop, and a glide hole is formed in the near cortex with the 3.5 mm cannulated drill bit. Again, the entire drill assembly is slid over the guide wire and the near cortex is drilled.
- The cannulated countersink is slid over the guide wire and a recess is formed in the near cortex for the screw head.
- The near cortex is tapped with the cannulated 3.5 mm tap and guide by sliding the tap over the guide wire until it engages the near cortex. When the screw is inserted into dense metaphyseal bone, the entire non-threaded length of the guide wire is tapped.

- Select a cannulated screw of the same length as the depth of the thread hole. The screw is inserted over the guide wire with the cannulated screw driver and the guide wire is removed and discarded.

Herbert (R) Bone Screw

The Herbert Bone Screw System R, produced by Zimmer USA, is a screw made of a titanium alloy and is buried under both the near and far cortex, avoiding soft tissue irritation and allowing its use on articular surfaces. Compression is accomplished by using a screw which has threads with different pitches on each end. Since the threads at the leading end of the screw have a greater pitch than the threads at the trailing end, the screw draws the fragments together producing inter-fragmental compression. Although the system provides a jig which automates screw placement, the freehand technique is preferred when fixating capital fragment osteotomies.

Jig Application

- A jig supplied with the system is used like a bone clamp to provide reduction while remaining instrumentation is inserted in a cannula running through the jig. Once the jig is in place, and the osteotomy reduced, the length of screw can be determined from calibrations on the jig.
- A 2.4 mm drill bit is inserted into the jig and the near cortex thread hole is drilled.
- A 1.9 mm drill bit is inserted into the jig and the far fragment thread hole drilled.
- The thread hole of the far fragment is tapped with the instrument provided with the system.
- The screw is inserted through the jig and tightened with the provided screw driver.

Freehand Insertion

- A .9 mm drill bit is used to make a hole through the near cortex, across the osteotomy, and into the far fragment. The free hand drill guide can be used to protect soft tissue structures and provide a direct measure of screw length from its calibrations.
- A 2.4 mm drill bit is used to drill the near cortex. It has a stop allowing it to be inserted only as deep as is necessary for the trailing threads to engage the near cortex.
- A K-wire or traditional depth gauge can be used to determine proper length.
- The hole is tapped the full length to accommodate the distal threads.
- A screw of proper length is chosen and inserted until it is buried under the near cortex.

The titanium alloy, used in the fabrication of Herbert bone screws, is inert and generally accepted without foreign body reaction. This allows the screws to be left in place indefinitely in most patients. A specialized bone trephine is provided with the system in case a reaction, infection or traumatic event necessitates removal. If cortical bone growth has covered the insertion point, locating the screw for removal may prove problematic.

NOTE: Zimmer recommends that the near cortex be drilled with a 3.5 mm drill bit, rather than the standard 2.4 mm drill bit, when the Herbert screw is used in thick cortical bone. This is to prevent fracture of the near cortex when the self-tapping threads of the trailing end of the screw purchase the bone.

Reese (R) Arthrodesis Screw

The Reese screw is a headless 316 L stainless steel screw which possesses right handed threads at its leading end and left handed threads at its trailing end. The two threaded ends of the screw are joined by a short smooth core. With this unique design, the screw can be drive into two opposing surfaces at the same time, drawing them together and causing inter-fragmental compression. The right handed side of the screw, which engages the proximal phalanx, comes in 2.4, 2.7, 3.0, 3.3 and 4.0 mm diameters. The trailing end of all screws is 3.0 mm in diameter, with the exception of the 4.0 mm screw which also has a 4.0 mm trailing end diameter. It is the 4.0 mm screw that is used for hallux fusions.

Re-sorbable poly-L lactic acid mini staples, pins, wire and screws, as described by Barca, may also be considered and used.

KIRSCHNER WIRES

Traditional K-wires provide rigid splintage of osseous segments and although they do not produce primary compression, threaded wires can be used to maintain the compression that is generated from bone clamps. K-wires are not the ideal type of fixation for inherently unstable osteotomies. However, when more sophisticated devices fail, or the patient's bony integrity does not allow their use, K-wires are a viable means of fixation. They are produced in both smooth and threaded varieties and can be used in either a buried or percutaneous fashion. They are available in 0.028, 0.035, 0.045 and 0.062inch diameters, with the larger diameter wire most frequently used in first ray procedures. It is important to remember that the trochar tip of most K-wires possess a cutting edge designed to cut through cortical bone. The cutting edge will not engage the bone unless the wire driver is set in the forward position and is true of both threaded as
well as smooth K-wires.

When threaded wires are used, a smooth wire of the next smaller diameter can be used to "pre-drill" the fragments and prevent distraction of the far fragment during insertion. If a wire is to be used in a percutaneous fashion, it is driven through skin adjacent to the surgical incision. Threaded wires that are to be buried beneath the skin are cut with one or two threads exposed above the proximal cortex. They can not be bent. Smooth wires can be bent into small hooks and twisted to lay flat against the cortical surface. Neighboring joints should always be visualized to assure they are not being violated by the wires.

ORTHOSORB (R) ABSORBABLE PINS

One drawback to all metallic internal fixation devices is that subsequent removal mandates the performance of a second surgical procedure. This problem has lead to research and development of absorbable fixation plates, cortical screws, cancellous screws and malleolar screws. For example, several researchers developed absorbable screw manufactured from a polyester of polylactic and glycolic acid homo- or co-polymers. Davis and Geck has developed the Bioflex R self reinforced polyglycolic acid polymer rod fixation system. The 2.0-diameter rods are more flexible than a 0.062 K-wire but less flexible than a 0.045 wire. FDA approval for this system was obtained in 1989 and it represents another form of internal fixation for the foot surgeon.

Another absorbable device which has been approved for use in the United States is the Orthosorb Absorbable Pin. The pin is produced by Johnson & Johnson Orthopedics Inc., Raynham, Mass. It is manufactured from poly (p-dioxanon) and D&C violet, which has previously been used in the manufacture of absorbable suture material. The pins are 40 mm in length and 1.3 mm in diameter. They are packaged in two types of sterile kits, containing either one pin or three pins with associated applicators. Both kits contain two 1.3 mm K-wires, one depth gauge device and one plunger device which works in conjunction with the application tube. A new tapered pin is available. It is attached to a K-wire wider at its proximal end.

These pins do not possess great amounts of torsional or bending strength, but they do resist considerable amounts of shear force. They are not designed to produce inter-fragmental compression, but instead act as a form of internal splintage. They have been used successfully to fix capital fragment osteotomies of the first metatarsal. Since the pins produce neither true rigid splintage or inter-fragmental compression, they are best suited for inherently stable procedure, and are described below for use in a traditional Austin osteotomy.

The reduced osteotomy is temporarily fixated with one of the 1.3 metallic wires provided with the kit. The wire is driven from the dorso-lateral cortex of the first metatarsal, proximal to the osteotomy cut, into the lateral aspect of the metatarsal head. Preferably, the cartilage of the metatarsal head is not violated. The second 1.3 mm metallic wire is driven from the dorso-medial cortex of the first metatarsal, across the osteotomy, into the medial aspect of the head.

The wire is withdrawn and a Orthosorb pin is inserted into the hole with an application tube and plunger. No depth gauge is needed, as the pin is driven until it stops at the end of the hole that was formed with the metallic wire. The lateral metallic pin is withdrawn and replaced with an Orthosorb pin again utilizing the application tube and plunger. The pins are driven slightly divergent to one another to afford increased stability. The excess pin material is removed by cutting it flush with cortical bone.

MONOFILAMENT WIRE & SUTURE MATERIAL

For many years either monofilament wire or suture material was used to fix a wide variety of first ray osteotomies. These materials have the advantage of being inexpensive and readily available, and do not require the use of special instrumentation. Because of simplicity and inherent strength, monofilament fixation rarely breaks. However, as with K-wires, monofilament wire does not provide compression but can be used as a tension band if a cortical hinge is maintained.

Procedures which do not place a great deal ground reactive forces through the osteotomy, such as the Akin procedure, can be fixated with consistently good results with monofilament wire.

The use of monofilament wire may also be utilized, if other forms of rigid internal compression fixation fail, or if a fracture develops in addition to the osteotomy when other forms of fixation are being implanted. For this reason the technique of box wiring base wedge osteotomies is be reviewed.

Hinged Osteotomies

- A hinged osteotomy is performed.
- A K-wire (wire pass drill bit) is used to make holes in the cortex of the involved bone on both sides of the osteotomy, opposite the cortical hinge. The holes pass through the cortex and end within the osteotomy site.
- Either a single or doubled strand of monofilament wire is passed through the holes facilitated by a wire pass loop or hook.
- The two ends of the monofilament wire, which protrude out of the holes at both sides of the osteotomy, are twisted while the osteotomy is held closed.
- Excess wire is cut leaving a "tail" of twisted wire approximately one centimeter long.
- A separate hole is then drilled into the cortex and the tail is imbedded into it.

<u>NOTE</u>: When this technique is used on an osteotomy with plantar hinge, a tension band is formed with the hinge absorbing tensile forces. This converts the force of weight bearing into a compressive force at the top of the osteotomy.

Box Wire Technique

- Once the osteotomy is made, a thread hole is made on both sides, passing through both the dorsal and plantar cortices at a right angle to the long shaft of the bone.
- A single or double strand of monofilament wire is passed through these holes, with the loose ends exiting their dorsal aspect.
- The wire ends are grasped and tightened until the osteotomy is closed. Excess wire is cut and the tail buried. Alternatively, it may be buried on the dorsal bone surface to allow for removal at a later date.

The technique is performed at both the medial and lateral cortices if a complete osteotomy is performed. In osteotomies that which incorporate a cortical hinge, one box wire opposite to this cortical hinge may be sufficient.

Cerclage Wire

Cerclage wire fixation is often used to supplement other forms of fixation. It simply involves surrounding a bone which contains an osteotomy with a section of monofilament wire to pull the two osseous segments into tight apposition. An example is an osteotomy fixated with one screw in which a cortical hinge has broken during screw fixation. This form of fixation must be used on an osteotomy that preserves a cortical hinge or in combination with another form of fixation. If used alone with a complete osteotomy, cerclage wire will often cause sliding of the bony segments along the plane of the osteotomy when the wire is tightened.

Modified Tension Band Technique

The modified tension band technique is actually a form of static compressive, in which the monofilament wire is used in conjunction with a K-wire (screw), to produce compression across an osteotomy site. It is used in an osteotomy without an eccentric load, because it does not need to convert ground reactive force into compressive force.

- A hinged osteotomy is obliquely held with a K-wire (screw)
- The protruding end of wire is cut with a small exposed section bent into a hook on the side of the bone that is opposite the cortical hinge.
- A drill hole is made opposite the protruding K-wire on the other side of the osteotomy and a strand of monofilament wire is passed through the drill hole and across the osteotomy, wrapping it around the K-wire in a "figure of eight" fashion.
- A needle driver is used to twist the ends of the wire around one another until it compresses the osteotomy site. The tail is buried in a separate drill hole.

Absorbable Suture Fixation

Absorbable sutures are used to hold an osteotomy through holes formed opposite the cortical hinge on both sides of the osteotomy. Large gauge absorbable suture is then passed through both of these drill holes with a large tapered semicircular needle. The suture is tied while the osteotomy is reduced.

The obvious advantage of this technique is that the suture will absorb and therefore there is no fixation device to be removed at a later date. The disadvantage is that minimal compression can be generated with this technique and it does not rigidly splint the osseous fragments.

STAPLE FIXATION

The use of staples have generally been reserved for the larger bones of the rearfoot. The development of smaller more refined pneumatic staple drivers however have made their use in first ray surgery more practical. One advantage of staple fixation is its reduction of operating time but they do not provide inter-fragmental compression. When using a staple, it must be large enough to purchase sufficient bone on both sides of the osteotomy. Staples should be as long as possible but should not be allowed to violate uninvolved bones. Staples which are unnecessarily large may also cause fracture of the involved bone and their placement in areas of minimal soft tissue coverage should be avoided as irritation may occur.

Manual Staples

A staple loaded into its holder that controls entry into the bone. The staple is positioned perpendicular to the osteotomy, grasping equal amounts of bone on each side. The holder is gently struck with a mallet causing the staple to firmly seat into the bone. It is removed and the staple is driven with a adequate counter resistance to avoid damage at the osteotomy site. Seating a staple into hard cortical bone can be facilitated by drilling "pilot" holes prevent staple slippage. Some manual staple sets come with bone clamps designed to provide compression across the osteotomy site while the staple is being driven. The staple maintains the compression provided by the clamp even after the clamp is removed. Others systems provide drill jigs which allow for accurate placement of pilot holes to ease initial staple placement.

Re-sorbable poly-L lactic acid mini staples can be considered.

Pneumatic Staples

Pneumatic staple gun fixation allows insertion with speed and simplicity. One such system is the 3M Staplizer (R) Power Metaphyseal Stapler. The staples used are rectangular with conical points. They are relatively thin which reduces the chance of fracture during placement. The staples are packaged in sterile single-use plastic cartridges that contain five staples of the same size.

The staples are produced in several sizes ranging from 7 mm x 7 mm to 16 mm x 25 mm., and several widths (7mm, 10 mm, 13 mm, 16 mm).

The staple cartridge is connected to the driver attachment and two triggers are located on the staple gun. The top trigger is used to load the gun while the bottom trigger is used to drive the staple. The gun is held firmly in place with the driver and the bottom trigger pulled to seat the staple into the bone. Without changing position the bottom trigger is pulled another four to five times to drive the staple. A manual counter sink and a staple pry are provided with the set.

FIXATION PLATES

Plates are seldom used as the primary form of fixation in first ray surgery. Due to the lack of adequate soft tissue coverage, plates often cause post-operative irritation which necessitate their subsequent removal.

Plates also require the insertion of multiple screws causing the loss of substantial bone stock. These problems have been minimized by the introduction of small and mini plates used with 2.7 mm, 2.0 mm and 1.5 mm cortical screws. The plates come in many shapes and include dynamic compression plates used with 2.7 mm and 2.0 mm cortical screws.

Buttress plates can be used to maintain the length of the first metatarsal when an opening wedge osteotomy is performed with the insertion of a bone graft. The plate acts to rigidly fix the metatarsal as the graft is resorbed and replaced with new bone. They are also useful to repair non-unions while neutralization plates can be used to protect lag screws in unstable osteotomies, such as the oblique base wedge. Dynamic compression plates are rarely used in first ray surgery, but could theoretically provide compression across transverse osteotomies, such as a base wedge or Lapidus procedure. Finally, plates applied to take advantage of the tension band effect are impractical, as the tension side of the first metatarsal is on its plantar aspect and is very difficult to access.

General Plate Application

The osteotomy is reduced and temporarily fixed. If a neutralization plate is used, the osteotomy can first be fixed with a lag screw. A plate is selected and bent to conform to the bone surface allowing for the greatest amount of contact and structural integrity. The plate is held in place and a drill bit for the screw(s) selected and thread holes formed through the plate crossing over both the near and far cortices. The thread holes are measured to determine screw length and the thread holes are tapped. Screws are inserted through the plate on both sides of the osteotomy and the remaining screws inserted in a random order.

Poly Glycolic Acid (PGA), Poly L-Lactic Acid (PLLA) and Poly Para Dioxanone (PDS)

Polymers of Poly Glycolic Acid, Poly Para Dioxanone (PDS) and Poly L-Lactic Acid (PLLA) have many applications in internal fixation: pins, plates and screws. They were originally designed at the University of Helsinki, and the Tampere University Technology Center in Finland. Screws are available as 1,5 mm, 2.0 mm, 2.7mm, 3.5mm, 4.0 mm and 4.5 mm, cortical sizes.

Standard staple configurations include: circular, square, curvilinear, equilateral triangle and curvi-linear triangle.

Standard intra-medullary nail cross-section configurations include: Diamond, Schneider, Sampson, Kuntscher and AO/ASIF.

Bone Anchoring Devices

Bone Anchoring and bone-tendon anchoring devices include systems from: Arthrotek, Arthrex, Biomet, Bionex, Bonutti Research, Curv-Tech, Howmedica, Innovasive, Instrument Maker, Li Medical, Linvatec, Mitek, Ogden, Orthopedic Biosystems, Smith & Nephew, Statak, and Wright Medical devices.

COMPLICATIONS OF INTERNAL FIXATION AND IMPLANT REMOVAL

Device Fatigue And Fracture

Depending on its size, shape and composition, a fixation device will withstand a characteristic number of cyclic stresses before it develops a fatigue fracture. When an osteotomy is first made, the device used for fixation must absorb a large portion of force transmitted through the operative site. As bony union ensues, the bone itself is able to absorb a larger portion of force and reduces the stress placed on the device. It is therefore important that inherently unstable osteotomies be given sufficient time to heal before the patient is allowed to weight bear. This requires good judgment on the part of the surgeon and compliance from the patient. Post-operative shoes, splints and casts can also be utilized to protect the osteotomy site until bony union is achieved.

When metallic implants are exposed to internal tissue structures and bodily fluids, corrosion can result. When the body interacts with a metallic fixation device a passive layer is initially formed which helps to resist continued corrosion.

If two devices come in contact with one another and movement is permitted, the passive layer will breakdown and allow corrosion to continue. If the two implants are of dissimilar metals, an electric field may be created which will cause galvanic corrosion.

When a fixation device deforms, fractures or becomes displaced, it will no longer cause rigid splintage or inter-fragmental compression. It may also resist proper reduction of the osteotomy site, maintain distraction and enhance the chances for the formation of a delayed union, non-union, or malunion. In this instance, the device must be removed and the osteotomy adequately re-fixed to allow bone healing to commence.

Bone Failure

Fracture of healthy bone can occur if the size of the fixation device does not match the size of the bone being fixed. Screws, staples or other fixation devices that are larger than needed, produce stress risers and potentiate bone fracture.

Bone which is osteoporotic or which has been weakened by local or systemic disease, may be difficult to fix. This is especially true of devices such as screws that are designed to produce rigid internal compression fixation. In this situation, it is often prudent to settle for rigid splintage with staples or Kªwires which due not necessitate the formation of bony threads that can strip and do not place excessive compressive forces upon the bone, leading to fracture.

Soft Tissue Irritation

Irritation to soft tissue structures overlying fixation devices may be sufficient to warrant the removal of the devices. When joints, ligaments and tendons are irritated by fixation devices, adhesions can develop which will cause pain and decrease range of motion. Neuritis and neuroma formation will cause continued pain and disability. Finally, prominent implants can cause repetitive trauma to overlying skin during ambulation. This can cause pain, hyperkeratosis and possible ulceration formation.

Allergy

Over the years, a great deal of research has been done to produce inert biomaterials for fixation devices. These materials include alloys of both stainless steel and titanium. While the cases of true allergic responses is rare, they have been reported. Sensitivity to nickel used in surgical grade stainless steel is the most commonly reported allergic reaction. A small number of patients will also develop allergic responses to the materials used to produce absorbable sutures and other absorbable fixation devices.

Infections

The presence of internal fixation devices at the site of a post-operative infection can complicate treatment. Ideally, the device remains in place if stable. On the other hand, removal of the device, before osseous healing has occurred, will result in instability and may expose portals of entry for the infection to invade the bone. Empirical broad spectrum antibiotic therapy should be initiated immediately and changed to treat specific organisms, as soon as identified. If necessary, an incision and drainage should be performed to remove localized purulence and necrotic tissue.

If the operative site is to be reopened after healing has occurred, the fixation device should be removed. The device should also be removed if it becomes loose. If healing has not occurred, and the fixation device is seen to provide continued stability, it may be left in place while the infection is treated. If an infection does not respond to treatment at a site where a fixation device has been left in place, it must be removed.

Concluding Remarks

We believe the material outlined in this review will prove helpful to those studying for board certification examinations.

References:

- Alvarez R, Haddad R, Gould N, and Trevino S: The simple bunion: anatomy at the metatarsophalangeal joint of the great toe. Foot and Ankle, 4: 229-240, 1984.
- Anderson JE: Grant's atlas of anatomy, 8th edition, Williams and Wilkins, Baltimore, 1983.
- Austin DW, Leventen EO: A new osteotomy for hallux valgus. Clinical Orthopedics, 157: 25-30, 1981.
- Barca, F and Busa, R: Re-sorbable poly-L lactic acid mini staples for Akin fixation. JFS, 36: 106-111, 1997.

- Beck El: An evaluation of the DuVries modification of the McBride hallux abducto valgus correction. JAPA, 61: 455-456, 1971.
- Borges AF: Relaxed skin tension lines (RSTL) versus other skin lines. Plast. Reconstr. Surg, 73: 144, 1984.
- Borges AF, Alexander JE: Relaxed skin tension lines, Z- plasties on scars, and fusiform excision of lesions. Br. J Plast., 15: 242, 1962.
- Bulacio Nunez AW: A new theory regarding the lines of skin tension. Plast. Reconstr. Surg, 53: 663, 1974.
- Castellano, BD and Southerland, JT: Traditional Procedures for the repair of HAV McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, William and Wilkins, Baltimore, 2002.
- Clemente CD: Gray's Anatomy, 30th edition, Lea and Febiger, Philadelphia, 1985.
- Cortiss EH, Longacre JJ, deStephano GA, Brizio L, and Holmstrand K: The placement of elective skin incisions. Plast. Reconstr. Surg., 31: 31,1963.
- Clutton JJ: The treatment of hallux valgus. St. Thomas Rep., 22: 1-12, 1894.
- Craiggmile DA: Incidence, origin, and prevention of certain foot defects. Br Med J., 2: 749, 1953.
- Davis L: Christopher's textbook of surgery, 6th edition, WB Saunders Company, Philadelphia, 1956.
- Downey, MS: First MPTJ arthrodesis for salvage of failed HAV surgery. Podiatry Institute Update, 1998.
- Draves DJ: Anatomy of the lower extremity, Williams and Wilkins, Baltimore, 1986.
- Gerbert J, Sokiloff TH (eds): Textbook of Bunion Surgery. Mt. Kisco, NY, Futura Publishing Co., 1981.
- Freund, MD: Capsular closure after HAV surgery. Foot Ankle Institute: 20: 137, 1999.
- Haber, JA and O'Mara, B.: Preparing for hallux abducto valgus surgery. Clinics in Podiatric Medicine and Surgery, 1: 17, 1989.
- Hansen C.E.: Hallux valgus treated by the McBride operation. A follow up. Acta Orthop Scand., 45: 778-792, 1974.
- Hawkins F.B.: Acquired hallux varus: cause, prevention and correction. Clinical Orthopedics and Related Research, 76: 169-176, 1971.
- Hiss MJ: Hallux valgus: its cause and simplified treatment Am J Surg., 11: 51-57, 1931.
- Inmann VT: Hallux valgus: a review of etiologic factors. Orthop Clin North Am., 5: 5-66, 1974.
- Joplin RJ: Sling procedure for correction of splay-foot, metatarsus primus varus, and hallux valgus. JBJS, 32A, 779-785, 1950.
- Joseph B., Chacko V., Abraham T., and Jacob M: Pathomechanics of congenital and acquired hallux varus: A clinical and anatomical study. Foot and Ankle, 8: 137-143, 1987.
- Kelikian H: Hallux valgus, allied deformity of the forefoot and metatarsalgia. Saunders, Philadelphia, 1965.
- Keller WL: Further observations on the surgical treatment of hallux valgus and bunions. NY Med J, 95: 696, 1912.

- Keller WL: The surgical treatment of bunions and hallux valgus. NY Med J., 80: 71-742, 1904.
- Kempe, S.A. and Singer, R.H.: The modified McBride bunionectomy utilizing the adductor tendon transfer. JFS, 24: 24-29, 1985.
- Kenzora, J.E.: Complications in bunion surgery. Complications in Orthopedics., 5: 79-89, 1990.
- Kimizuka, M and Miyanaga H.: The treatment of acquired hallux varus after the McBride procedure. JFS, 19: 135-138, 1980.
- Kitaoka, HB: Salvage treatment of Failed HAV operations. Foot and Ankle: 19: 127, 1998.
- Lapidus PW: The elusive bunion: etiology, mechanics, treatment. Orthop Rev 3: 35-45, 1974.
- Marcinko, DE: Use of the Shaw scalpel in podiatric surgery. JFS, 24: 162, 1985.
- Marcinko, David Edward (Editor): Comprehensive Textbook of Hallux Abducto Valgus Reconstruction. Mosby-Yearbook, 1993.
- Martin, W.J., Mandracchia, V.J., and Aiken, S.K.: A preliminary analysis of fibular sesamoidectomy in the McBride bunionectomy. JAPA., 73: 577-580, 1983.
- Mayo CH: Eine meue modifikation der hallux valgus operatin. Zbl. Chir, 53: 3215-3268, 1926.
- McBride E: Hallux valgus, bunion deformity: its treatment in mild, moderate and severe stage. J Int Coll Surg 21: 99, 154.
- McBride ED: A conservative operation for bunions. JBJS 10: 735-739, 1928.
- McBride ED: The McBride bunion hallux valgus operation. J Bone Joint Surg 4A: 1675-1683, 1967.
- McGlamry, ED.: Comprehensive Textbook of Foot Surgery, Williams and Wilkins, Baltimore, 1987.
- McGlamry, E.D. and Feldman, M.H.: A treatise on the McBride procedure, JAPA., 61: 161-173, 1971.
- Meyer, J.M., Hoffmeyer, P., Borst, F: Treatment of hallux valgus in runners utilizing the modified McBride procedure. International Orthopedics 11: 197-200, 1987.
- Miller J.W.: Acquired hallux varus: a preventable and correctable disorder, JBJS., 57A: 183-187, 1975.
- O'Rahilly: Basic human anatomy, WB Saunders Company, Philadelphia, 1983.
- Patton, GW, Tursi, F., and Zelichowski, J.: The dorsal synovial fold. JFS, 26: 210, 1987.
- Peacock EE, Van Winkle W: Wound repair, 3rd edition, WB Saunders Company, Philadelphia, 1984.
- Peabody CW: The surgical cure of hallux valgus. JBJS, 13: 273-282, 1931.
- Ruch JA, Banks AS: Anatomical dissection of the first metatarsophalangeal joint. In, Comprehensive Textbook of Foot Surgery, Vol. 1, ED McGlamry (Ed), Williams and Wilkens, Baltimore, 1987.
- Sarrafian SK: Anatomy of the foot and ankle, JB Lippincott Company, Philadelphia, 1983.
- Sellman J: Surgical approaches to the great toe. Clinical Orthopedics and Related Research, 157: 21-24, 1981.

* Shereff M, Quing Y, and Kummer F: Extraosseous and intraosseous arterial supply to the first metatarsal and metatarsophalangeal joint. Foot and Ankle, 8: 81-93, 1987.
* Silver D: The operative treatment of hallux valgus. JBJS, 5: 225-231, 1923.
* Talbot, KD. How good is that AP radiograph? Foot Ankle Institute: 19: 547, 1998.
* Valvo P, Hochman D, Reilly C: Anatomic and clinical significance of the first and most medial deep transverse metatarsal Ligament. JFS 26: 194-203, 1987.
* Woodle, AS: Preoperative planning for hallux valgus bunion surgery: photonics versus templates. Clinics in Podiatric Medicine and Surgery, 1: 29, 1989.
* Yen, RG, Giacopelli, JA, Granoff, DP and Steinbroner, RJ: The Biofelx absorbable rod - a preliminary report. JAPMA, 81: 62, 1991.
* Yu, GV, and Schnirring-Judge. Complications of HAV Surgery. McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, William and Wilkins, Baltimore, 2002.
* Bauer, G: Principals of External Fixation. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Chang. T: Bone Anchors. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Cicchinelli, L: In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Malay, S.: Instrumentation. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Phillips, A: Power Instrument Skills. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Ray, R: Methods of Osseous Fixation: Principals of Internal Fixation. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.
* Yu, GV: Suture Materials and Needles. In: McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Lippincott, Williams and Wilkins, Baltimore, 2002.

Acknowledgements:
This material was originally prepared for FARC, Inc. by: Charles J. Gudas, DPM, Paul M. Greenberg, DPM, W. Kevin Pearson, DPM, Christoph C. Zenker, DPM, Thomas J. Azzolini, DPM. Updates and research has been continual by FARC medical professionals.