REPAIR OF IATROGENIC HALLUX LIMITUS

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Hallux limitus/rigidus represents a continuum of a condition where there is an inadequate range of motion of the first metatarsophalangeal joint. Hallux limitus indicates that the 65 to 75 degrees of dorsiflexion necessary for normal ambulation is not totally available. Hallux rigidus indicates an absence of motion of the first metatarsophalangeal joint. Hallux limitus/rigidus may be caused by a number of conditions including: a long first ray, metatarsus primus elevatus, hypermobility of the medial column, degenerative joint disease, post-traumatic arthrosis, and immobility of the first ray. In each of these situations hallux limitus or rigidus ensues because of a disruption in the normal cycle of the lst metatarsophalangeal joint motion. It is important to realize that hallux dorsiflexion occurs relative to the lst metatarsal. The hallux actually plantarflexes only approximately 25 degrees on the first metatarsal. The remaining plantarflexory motion is attributable to other joints of the first ray. The concept of reciprocal motion of the first metatarsal and hallux is critical to understanding the etiology of hallux limitus.

The second factor that is important to recognize in these conditions is the location of the axis of the first metatarsophalangeal joint. This axis runs in a horizontal direction, but changes with joint dynamics. This dynamic axis has not been replicated by any type of endoprosthesis currently in use.

A third component that one needs to appreciate when discussing hallux limitus/rigidus is the role of the sesamoids in first metatarsophalangeal joint motion. During gait, the hallux and the sesamoids become planted firmly on the ground, and the metatarsal plantarflexes on the hallux. During this time, the first metatarsal must slide over the sesamoids. Mobility of the sesamoids is clearly critical to allowing the function of relative dorsiflexion of the hallux on the first metatarsal. The previously listed conditions tend to inhibit dorsiflexion and result in jamming of the hallux against the first metatarsal. Later, fibrillation of articular cartilage, erosion, cystic degeneration, and/or joint margin proliferation may become evident.

JOINT ANATOMY

Several aspects of normal joint anatomy are important to understand in determining the etiology of iatrogenic hallux limitus.

Cartilage

Cartilage comes in three basic forms: (1) Fibrocartilage, which contains a high proportion of collagen, and is located at the insertion of ligaments into bone. (2) Elastic cartilage in which there are a high number of elastin fibers in the matrix. This type of cartilage is found in the external ear and the epiglottis. (3) Articular cartilage.

Articular cartilage is the focus of this paper. This particular kind of cartilage is made of collagen fibrils and a hydrated glycoprotein gel. The collagen fibrils are not oriented randomly, but rather in a structural pattern that reflects the stresses applied to that particular joint. It is the unique properties created by the combination of the proteoglycan gel and the collagen fibril network that allows articular cartilage to function so efficiently. These two substances are responsible for providing adequate slipperiness and resilience, yet maintaining durability despite severe loading.

Articular cartilage appears smooth macroscopically. However, under the scanning electron microscope, there are small undulations present on the surface of cartilage which help to entrap synovial fluid, thus facilitating the lubrication of a joint. An important histologic landmark in articular cartilage is the tidemark. This depicts a line marking the junction between the calcified and the non-calcified cartilage. When mechanical failure of cartilage occurs, it is usually at this junction, as opposed to the bone and cartilage interface.

SURGICAL ERRORS PRECIPITATING HALLUX LIMITUS

There are a variety of errors of surgical technique that can result in hallux limitus. However, many of these iatrogenic deformities may also be attributed to poor preoperative

planning. Specifically, it is important to recognize those patients in whom a structural or functional elevatus already exists, and who are predisposed to the development of a hallux limitus. When a hallux valgus surgery is performed, there is generally a reduction in range of motion at the joint in most patients. If a first metatarsal elevatus is present, then a patient may be set up for the development of a hallux limitus deformity.

Soft tissue alignment is particularly important for normal joint function. There must be a good capsular repair in order to ensure that synovial fluid can maintain the nutrition of the articular cartilage. In addition, the capsule must have sufficient mobility to allow for the necessary motion. Excessive reefing of the capsule will restrict movement. Both the integument and the surrounding tendons must be able to be sufficiently mobilized postoperatively to prevent any adhesions that might limit first metatarsophalangeal joint motion. For example, although the actual percutaneous approach in minimal incision surgery demonstrates a very small visible scar, the superficial fascia ends up being fibrosed to bone in all areas where the burr is utilized. If the skin adheres to the bone, it further limits the ability of the first metatarsal to plantarflex and/or the hallux to dorsiflex.

Although the sesamoids are not characterized as soft tissue structures, interference with their function impairs gliding motion, similar to the above problems. This most commonly occurs when a fixation device has been driven into the sesamoid, and/or the sesamoids have been violated by a saw or other instrument during the course of the surgery. The mobility of the first metatarsophalangeal joint should be evaluated carefully prior to leaving the surgical area. The sesamoids should be carefully inspected, as well as the plantar articular surface of the first metatarsal head. If the joint is immobilized in a cast or dressing for several weeks following surgery, then intraoperative compromise of soft tissues will result in significant fibrosis and limitation of motion.

Osseous causes of iatrogenic hallux limitus include displacement of capital osteotomies or base osteotomies in such a fashion as to create a structural or functional metatarsus primus elevatus. Failure to accurately apply the concepts of the hinge axis principle, or failure of fixation with actual physical displacement at the osteotomy site are two specific problems which may limit motion postoperatively. In addition to the possibility of sagittal plane displacement, displacement of an osteotomy in the frontal or transverse planes may cause uneven wear of the joint. Displacement of an osteotomy that results in angulation of articular cartilage may cause jamming in the joint, an ineffective range of motion, or abnormal wear patterns. Again, this may occur as the result of an improperly applied osteotomy, failed fixation, or inappropriate attention to postoperative management.

Problems with cartilage which may precipitate iatrogenic hallux limitus generally occur as a result of abnormal wear patterns created by malalignment, compromise of the joint intraoperatively, and penetration of cartilage through subchondral bone on both sides of the joint (thus facilitating fusion).

There are a variety of other causes for hallux limitus or rigidus. Essentially, the prerequisites for normal motion are that there must be healthy cartilage, the mechanical ability for reciprocal motion of the hallux upon the first ray, and good sesamoid mobility. Postoperative management can contribute to hallux limitus either by excessive immobilization of a joint, inappropriate bandage position, and/or early weight bearing resulting in displacement of osteotomies.

TECHNIQUES FOR REPAIR OF HALLUX LIMITUS

The goal of reconstructing a deteriorated joint requires some mechanism to rehabilitate deformed cartilage. This can be done most effectively by abrasion chondroplasty, which is useful in treating compromised areas of the articular surface. Numerous experiments have demonstrated that full thickness cartilage defects down to the level of subchondral bone will fill with granulation tissue and eventually heal with fibrocartilage. Occasional, small islands of hyaline cartilage may also be noted in these areas. In addition, abrasion chondroplasty has been used for many years in the treatment of osteochondral defects of the talus. The technique in the first metatarsalphalangeal joint is very similar. It involves the creation of full thickness defects down to the subchondral bone by means of power drills. In joints where there are large sections of chondromalacia, multiple small drill holes should be placed. In those situations where it is impractical to remove all of the deformed cartilage or where there are small isolated defects, these should be removed and drilled down to subchondral bone. A more difficult problem arises when there are defects on both sides of the joint. The author performs significant drilling on only one side of the joint, that usually being the metatarsal head. Chondroplasty is not a primary procedure in hallux limitus repair, but it is a very valuable adjunctive technique in order to allow reconstruction rather than the performance of a joint destructive procedure.

Capital Osteotomies

The successful surgical treatment of hallux limitus requires that the first ray be positioned to allow successful plantar flexion of the first metatarsal with concomitant dorsiflexion

of the hallux during gait. Many times, metatarsal base osteotomies are necessary in order to achieve successful reconstruction of a significant hallux limitus and/or rigidus. In addition, it is imperative to follow many of these patients with functional orthoses to prevent recurrence of deformity. Nonetheless, metatarsal head osteotomies have had a long and valued place in the treatment of hallux limitus. There are three essential purposes for the use of head osteotomies in this repair: 1) angulation of useable or functional cartilage to a more advantageous position, 2) plantar flexion of the capital fragment, and 3) shortening/decompression of the first ray.

Oftentimes, it is not possible to determine which of these elements will be most important for the repair of any given deformity until the joint has been inspected. Re-angulation of useable cartilage has been one of the most common techniques for repair of hallux limitus. The Watermann osteotomy is a dorsiflexory osteotomy of the capital fragment of the first metatarsal. In most instances in hallux limitus, there is very good range of motion in a plantar direction. The Watermann osteotomy converts this good plantar cartilage into functional dorsal cartilage in order to allow a better dorsal excursion of the first metatarsophalangeal joint. This procedure was originally described as the removal of a trapezoidal wedge of bone with the wider side being dorsal. The capital fragment can clearly be unstable unless adequate fixation is used. The more common technique utilized for performing a Watermann osteotomy involves resection of a triangular wedge of bone maintaining the plantar cortex intact. Either technique also has the additional benefit of joint decompression by reducing the internal osseous content of the joint.

The Watermann osteotomy is often combined with a more proximal plantarflexory osteotomy of the metatarsal base. When the metatarsal base is plantarflexed by osteotomy, it exaggerates the plantar location of the functional cartilage. It may become even more important then to realign the articular cartilage through a Watermann type of osteotomy. In those situations where there is an insufficient amount of functional articular cartilage, an implant arthroplasty can be performed or an abrasion chondroplasty of the joint with subchondral drilling. The Watermann osteotomy has been found to be most useful as an isolated procedure in middle age and older patients with hallux limitus. The osteotomy can be fixated with absorbable or nonabsorbable suture, or pin fixation.

Another beneficial component of capital osteotomies is that one may plantarflex the head of the first metatarsal. In order to have a functional first metatarsalphalangeal joint, the first metatarsal must be in a position to allow reciprocal motion of the hallux in a dorsal direction over a plantar flexing first metatarsal. There are a variety of ways of achieving this capital plantarflexion with head osteotomies. A very useful technique is modifying the axis of the traditional Austin bunionectomy. By raising the axis to go from dorsal medial to plantar lateral, the capital fragment will displace in a plantar direction as it goes laterally. This type of osteotomy is very useful in a patient with hallux valgus and some degree of limitus. A very significant degree of plantar flexion can be achieved through this technique.

Another very useful procedure is the Youngswick modification of the Austin osteotomy. This modification involves an additional bone cut parallel to the dorsal component of the traditional osteotomy. This serves to shorten and plantarflex the first ray. Consequently, this Youngswick modification has a dual effect in hallux limitus repair. Youngswick's modification, similar to the modified axis technique, does not address the angulation of functional articular cartilage. In many younger patients, the cartilage may not need to be addressed by the Watermann type of osteotomy. In these cases, the Youngswick modification or modified axis technique can be useful in creating a stable first ray to allow hallux dorsiflexion.

Two other types of osteotomies for hallux valgus repair, also have a component of plantarflexion. These are the Mitchell and Hohmann procedures. Both of these osteotomies are distal transverse osteotomies that allow the metatarsal head to be shifted both plantarly as well as laterally. Each one also results in significant shortening of the first metatarsal. Although decompression of the first ray is often an important element in repair of hallux limitus, excessive shortening can lead to lesser metatarsalgia. Metatarsalgia has been a common complication following these types of osteotomies, and more than likely is attributable to dorsal shift of the capital fragment. This circumstance is most often due to inadequate fixation. Warrick and Edelman, 1984, described the use of interfragmentary compression for fixation of the Hohmann osteotomy. This would seem to make a substantial contribution to the overall stability of the procedure. Nonetheless, the excessive shortening with these procedures make them uncommon procedures in the hands of the author.

As previously mentioned, head osteotomies also allow for shortening and decompression of the first ray. Frequently, in a hallux limitus or rigidus, there is a long first metatarsal with a resultant jamming of the first metatarsophalangeal joint. As part of the correction of this deformity, it is frequently important to create shortening adjacent to the joint. This can be achieved via the Watermann osteotomy. When a greater degree of overall shortening is required, it can usually be best achieved by the modified axis technique of the Austin osteotomy. For shortening, the axis would be directed from medial distal to lateral proximal. The axis can also be directed in a plantar direction at the same time in order to

create concomitant plantarflexion of the metatarsal head.

It is important to look at the indications for these procedures in terms of the patient's age, and the overall degree of deformity in the joint. In young active patients with first metatarsal elevatus, the author most commonly performs a plantarflexory base osteotomy. A Watermann osteotomy may or may not need to be performed, as well as an abrasion chondroplasty of the joint.

In patients with a mild to moderate degree of elevatus in conjunction with a hallux valgus, the author will frequently perform a plantarflexory Austin procedure in order to create a more stable first ray. In older patients with a mild to moderate degree of elevatus, a capital osteotomy can be performed as a solitary procedure in order to create a more functional joint. As with hallux valgus repair, hallux limitus surgery generally requires that the surgeon be more aggressive with a functional repair in the younger individuals.

Regardless of the osteotomy that is performed, it is imperative to begin mobilization of the joint as soon as is practical. The more superior the fixation of any osteotomy, the earlier that mobilization can be performed with confidence.

Base Osteotomies

Plantar flexion of the first metatarsal and reconstruction for hallux limitus is generally designed to increase the available range of motion by creating a stable first ray capable of undergoing plantarflexion. In order for this procedure to be successful, the hallux limitus deformity must be at least partially related to a first metatarsal elevatus deformity.

Plantar flexion of the first ray can be achieved at least three different ways: 1. A closing wedge osteotomy with the hinge of the osteotomy dorsal distal to plantar proximal. This procedure is performed through a medial approach, and the osteotomy goes from medial to lateral. Visualization of this osteotomy is excellent. The major difficulty with this osteotomy is that it places the apex of correction distally on the metatarsal, thus losing one of the prime advantages of doing a plantarflexory base osteotomy. 2. My own preference is to perform the osteotomy with the hinge proximal dorsal and the osteomy running distal plantar. With the hinge being located proximal dorsal, the fixation is then orientated from distal dorsal to plantar proximal. Both numbers 1 and 2 are essentially diaphyseal osteotomies. They can be secured quite readily with one 4.0 cancellous screw or a 3.5mm cancellous screw. More commonly, the author utilizes two screws either one 4.0 and one 2.7mm or two 2.7mm screws can be utilized.

A third alternative for plantar flexion of the first metatarsal involves utilizing the standard closing base wedge oblique osteotomy, and making a through and through cut in the hinge. The K-wire is driven across the osteotomy at the location of the hinge, and the osteotomy is then fixated with two 2.7mm screws. This osteotomy must be done in a long oblique fashion in order to be able to get two screw purchase.

The primary advantage in performing these base osteotomies should be to move the apex of correction more proximal, and to achieve the greatest degree of plantarflexion. The combination of base plantarflexory osteotomies and cheilectomy with abrasion chondroplasty is generally performed in young patients for whom the likelihood of joint restoration is greatest. It is important to recognize that the security of the fixation on this osteotomy is even more critical than usual. In order to make a restorative procedure effective, range of motion must be re-established to the first metatarsophalangeal joint immediately. The base osteotomy must be secure to allow for immediate range of motion without disruption of the osteotomy. Failure to achieve joint mobility following surgery will negate the major effects of the abrasion chondroplasty. Without immediate return to motion, the joint will become fibrosed and may eventually ankylose.

Rehabilitation

In order to adequately rehabilitate a joint, there must be minimal swelling. In order for there to be minimal swelling, there must be true rigidity of the fixation. In addition, the patient's edema will be significantly reduced if there are no percutaneous pins present. Percutaneous pins, not only cause more edema, but also limit skin movement, thereby decreasing the ability to affect range of motion exercises. The author's regime is to begin range of motion exercises, three to four days postoperatively. These range of motion exercises are done by the patient, and on a very gentle and gradual basis. Approximately one week following surgery these exercises are increased to a regimented structure three times per day with full joint excursion. Two weeks postoperatively, when the skin incision is relatively well healed, bathing of the foot is allowed (as long as there are no percutaneous fixation devices or other open areas of wound), and the patient begins more aggressive mobilization of the joint. Patients are instructed to use warm soaks prior to motion exercises, and to ice down afterwards. Non-steroidal anti-inflammatory drugs are utilized in order to assist in the control of swelling and edema, to enhance the comfort level while performing the exercises. The emphasis on these exercises is placed upon full excursion of range of motion, rather than multiple repetitions of small amounts of motion.

SUMMARY

After many years of experience with implant arthroplasties, the limitations of joint prosthesis in the first metatarsophalangeal joint have become apparent. To date, there is no prosthesis which accurately reproduces the true axis of motion of the first metatarsal phalangeal joint. In addition, there are limitations with the types of materials currently available. Given the above, there is no wonder that there has been increasing interest in functional repair of the patient with hallux limitus. It is now clear that joint destructive procedures such as arthroplasty or implant arthroplasty must be left to those situations where functional repair is not possible. Capital osteotomies in conjunction with abrasion chondroplasty and other techniques can often give the patient a functional first metatarsal phalangeal joint and significantly improve the patient's gait.

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