New Advances in Foot and Ankle Surgery and Rehabilitation

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The following lesson describes some of the more common surgical procedures of the foot and ankle. The subject matter is presented as a collaborative effort between the surgeon and the physical therapist. It is important that the therapist understands the nuances of the surgical procedure and that the surgeon understands the physical therapy needs brought on by their procedure. This professional partnership ultimately results in the very best care to the patient.

ACHILLES TENDON SURGERY

Achilles tendon injuries can be divided into acute and chronic. Ruptures of the Achilles tendon constitute the majority of those acute injuries that require surgical intervention. Surgery is generally recommended for the vast majority of Achilles tendon tears because of the potential for a better functional outcome and lowered risk of rerupture.[1] Ruptures typically occur in the midsection of the tendon (in the area sometimes referred to as the *hypovascular section of the tendon*) because of the diminished blood supply to this region. This diminished blood supply is thought to play a key role in the prevalence of ruptures in this area of the tendon. It also makes repair somewhat problematic because of the degenerative nature of this tissue. Sometimes tissue is imported to supplement the repair.[2]

The technical aspects of an Achilles tendon rupture repair are fairly straightforward. The tendon ends are brought into approximation after devitalized torn tendon ends are débrided. Usually some form of modified Kessler suture is used to lessen ischemia to the tendon repair site and to provide security to the repair.[3] Some surgeons favor a percutaneous repair to be less invasive, which can potentially speed up the recovery process.[4] The negative aspect of percutaneous repair includes the higher potential for sural nerve entrapment because of the blind nature of the procedure. In addition, the surgeon loses the ability to débride devitalized tendon tissue with percutaneous repairs. The last consideration is that estimating appropriate physiologic tension is simpler with open repairs.

The surgeon's confidence of the repair, the status of the tissues that are repaired, and the overall physiologic status of the patient are but a few of the factors that are taken into consideration in determining rehabilitation protocols after Achilles tendon repair. A basic understanding of tendon healing helps in deciding therapy protocols.[5] Right after the repair, tensile strength is good. Around 12 days after the repair, the tendon exhibits a weaker physical state, sometimes referred to as *tendomalacia.* This transient period of weakness can be potentially concerning.

Chronic Achilles tendon surgery can be more problematic. With chronic Achilles tendon pathologic condition, some form of tendon degeneration or tendinopathy typically occurs (Figure 1). The tendon goes through sequential degeneration, which weakens the tendon and eventually leads to rupture. Surgery is contemplated before rupture, particularly if symptoms are painful and functionally limiting. The surgery involves two approaches. The first approach is to débride the tendon (a newer approach is to not only débride the tendon but also to inject growth factors to enhance repair at the site).[6] The second approach is to import tissues because of the unhealthy nature of the involved tissues. The flexor hallucis longus tendon is the usual tissue imported.[7] In either of the two surgical approaches, one must consider the questionable integrity of these tissues in the rehabilitation process.

Figure 1 The sagittal short T_1 inversion recovery (STIR) sequence shows an area of high signal in the midsection of the tendon, indicating early degeneration.

ACHILLES TENDON REHABILITATION

In the rehabilitation of Achilles tendon surgery, one needs to know the mechanism of the injury and whether a component of chronic preoperative tendonosis exists. This information will nuance the rehabilitation strategy and guide the pace and volume decisions in reloading the limb.

Although the patient will be protected with immobilization and nonweight bearing for some weeks after surgery per the surgeon's protocol, early rehabilitation efforts will be oriented at preventing stiffness in the forefoot and midfoot, as well as gentle subtalar mobilization. In addition, activation (as appropriate) of all leg muscle groups in neutral ankle positions can be done.

Once early-phase motion is allowed, rehabilitation is targeted at gaining neuromuscular control of the muscles about the ankle in nonweight-bearing positions. Manual resistive exercise can move from isometric to work through gentle ranges as tolerated. Care should be taken with all range and muscle work not to overstretch the repair because an abnormal length tension relationship will compromise the patient's ability to regain normal plantarflexion strength.[8] This level of therapeutic and manual exercise continues through approximately 6 to 8 weeks postoperative, at which time weight-bearing restrictions are being reduced.

Once axial loading is allowed, closed kinetic chain exercise can be introduced at subbody weight load levels. All neuromuscular reeducation and subsequent strengthening of the calf complex should be performed from ranges of 0 degrees of dorsiflexion into ranges of plantarflexion, thereby avoiding loading the tendon in a stretched position (beyond neutral dorsiflexion) because these muscle loads produce higher levels of stress to the repaired tendon.[9] This phase of protected, nonweight-bearing strengthening is often prolonged to ensure that patients gain complete neuromuscular control and full recruitment of the gastrocnemius-soleus complex and the secondary medial and lateral compartment plantar flexors before progressing to full weight–bearing exercise.

Manual techniques and low-volume partial weight-bearing loads are the primary means of developing this level of muscle function and, in general, avoiding overload to the gastrocnemius-soleus complex before development of significant tendon healing and strength. Because complete development of tendon tensile strength occurs during approximately 1 year, the patient should expect recovery of full strength and functional load tolerance to parallel this time line.

Throughout all weight-bearing phases of rehabilitation, be sure to analyze the mechanics of the foot and ankle in standing. Assess the patient's ability to control pronation-supination motions so that a lack of control and coordination can be addressed in the rehabilitation process. Pronation and supination motions can create abnormal loads into the Achilles during function.[10] Thus the medial and lateral muscle groups must be trained in non-, partial, and full weight bearing to gain stability with activities of daily living (ADL) and sport-specific function.

Offer the patient creative ways to cross-train with increasing cardiovascular and strength volumes but, from a strength development perspective, in positions and with loads that are less than full body weight. Beware of traditional exercise equipment that may overload the healing tendon. Being creative and knowing the status of the tendon's healing maturity, as well as the status of the patient's muscular function, can help one design a program using common equipment in nontraditional ways that gradually and safely brings normal strength and function without overstretching or inflammatory setbacks.

If the patient has adequate strength, coordination, and can decelerate well at heel strike, impact and lateral training can sometimes be introduced and progressed as early as 4 months postoperative. Often, however, even in a normal course of Achilles rehabilitation, these loads are not tolerated well until after 6 months postoperative. Therapy should proceed with an awareness of these timelines and expect a somewhat slow but steady return of full muscular recruitment, control, and functional strength.

PERONEAL TENDON SURGERY

Peroneal tendon injuries are relatively common.[11] The peroneal tendon conditions that may require surgery take many forms. These include tendon tear, stenosing tenosynovitis, and subluxating tendons.

Peroneal tendon tears can occur with or without subluxation. These tears most commonly involve the peroneus brevis tendon. They are thought to be the consequence of sprains or attritional wear because of luxation tendencies. In either case the peroneus brevis tendon tears because of its closer proximity to the lateral malleolus, one of the pulley mechanisms for this tendon muscle complex. Sobel et al.[12] has described a classification system for these tendon tears, essentially dividing them into *partial* and *full-thickness tears*. These tears are typically longitudinal in orientation (Figure 2). When symptomatic, these tears are repaired, tubularizing if necessary. As with all tendon repairs, the tendon is protected for ample time in order not to jeopardize the repair site. Chronic subluxation of the peroneal tendons can contribute to abnormal tendon wear and tear. It can also produce symptoms such as pain and/or instability. Repair of these tendons has multiple procedural approaches, including tightening of the peroneal retinaculum, deepening of the retrolateral malleolar groove, and fibular osteotomy.[13] Physical therapy gets even more complex in these scenarios because care must be taken not to jeopardize the reconstructed or tightened pulley system.

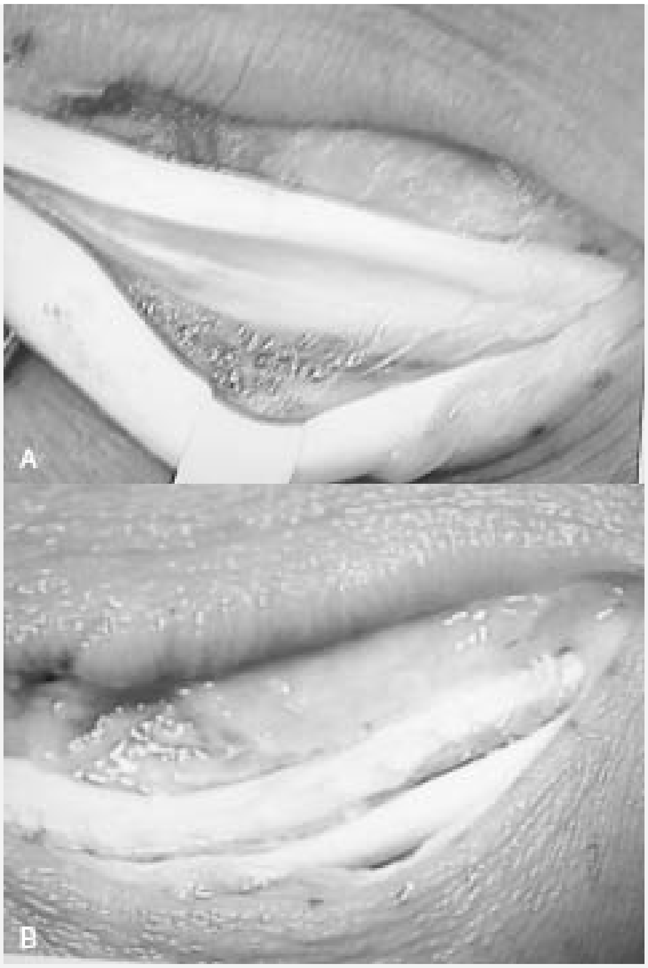

Figure 2 **A,** Longitudinal tear of the peroneus brevis tendon. **B,** The peroneal tendon tear has been repaired by tubularizing it.

Stenosing tenosynovitis is somewhat less complex. In this condition, motion of the tendon within the tendon sheath is prohibited by adhesions that formed from long-term abnormal mechanics or injury.[14] The sheath is opened, and all adhesions are identified and released. If a low-lying muscle belly is present, then this is sometimes débrided proximal to the tunnel. Motion is encouraged early postoperatively to limit the possibility of recurrence.

PERONEAL TENDON REHABILITATION

With peroneal tendon rehabilitation, be precise about the exact surgical procedure performed. Identify whether the tendon sheath was released as in stenosing tenosynovitis or whether there was repair of a chronic or acute tendon tear. Know all alteration in bony anatomy that can occur as part of the procedure or repair of a retinaculum or tendon, because these factors will control the pace and reloading of the limb. In addition, identify the probable mechanism of injury and provocative activities that existed preoperatively. In this way, rehabilitation can be planned and designed to address those mechanical issues and muscular deficiencies that may have created the dysfunction and predisposed the patient to the injury. Motions that created stress and irritation preoperatively should be “trained for” in the rehabilitation process to restore full postoperative and lasting function.

Stenosing tendons that have had adhesions released will be moved early and through full ranges postoperatively. Restrengthening and reloading can occur methodically by developing neuromuscular control of the peroneal muscles, along with the gastrocnemius-soleus complex in both open and nonfull weight–bearing closed kinetic chain positions. Chronic instability and weakness of the lateral ankle and/or excessive use of the peroneal muscles as plantar flexors can lead to wear and stress to the peroneals.[15] Rehabilitation should address these tendencies in motion by identifying potentially stressful mechanics and training the appropriate muscles with both open and closed kinetic chain exercise to work as active stabilizers and/or movers of the joint.

In the case of tendon repair or stabilization, early rehabilitation will be much more guarded, allowing bony, tendon, and/or retinacular tissues to heal. Early rehabilitation will involve gentle dorsiflexion and plantarflexion range of motion. Care should be taken to avoid extremes of inversion and eversion motion. These motions, especially when combined with plantarflexion or dorsiflexion, can create stress across the pulley system of the peroneal muscles because they pass posterior to the lateral malleolus. Perform all therapeutic exercise with the ankle in neutral as it relates to the frontal and axial planes of motion. This precaution will allow isometric exercise to the invertors group with the ankle held at neutral and gentle work through the ranges of dorsiflexion and plantarflexion. Exercise for the peroneal muscles directly (when appropriate, several weeks postoperatively) should first be done isometrically, then from positions of mild inversion to positions of neutral motion at the ankle and subtalar joints. Only in the later stages of rehabilitation, once the tendon repair or bony stabilization is well healed, will the peroneal group be worked through a full range of concentric and eccentric motion. Be sure that the gastrocnemius-soleus complex is adequately strong so that the peroneal muscles are not required to overwork as plantar flexors when returning to full function.

Once neuromuscular control and strength is restored through the foot and ankle in open and nonfull weight–bearing positions, rehabilitation work can proceed into full weight bearing. Cue and train the patient to move with normal mechanics at the foot and ankle with all closed kinetic chain therapeutic exercise, ADL, and function. This can be accomplished by having the patient weight shift through the foot, either medially or laterally, to reduce eversion or inversion moments that may create stress to the newly repaired or stabilized tendon. In this way, rehabilitation has the best chance to correct mechanics in the foot and ankle motion that can predispose the tendon to postoperative wear and tear.

POSTERIOR TIBIAL TENDON SURGERY

Surgery of the posterior tibial tendon is indicated for three conditions: (1) stenosing tenosynovitis, (2) accessory navicular problems, and (3) tendinopathy. Each of these conditions is distinctly unique from both a surgical and a physical therapy perspective.

The least complex is stenosing tenosynovitis. As with the peroneal tendon described previously, the condition can originate either from trauma or abnormal mechanics. Distinguishing this condition from tendinopathy is critical in the decision process of surgery. Magnetic resonance imaging (MRI) is useful in determining the presence and extent of tendon degeneration or so-called tendinopathy or tendinosis.[16,17] The presence of tendinopathy may warrant tendon reconstruction. Adhesions within the sheath are not typically appreciated on MRI. To appreciate adhesions, ultrasound may indicate limited tendon movement. Alternatively, tenography is used.[14] Tenography uses an intrasheath injection of lidocaine, contrast dye, and a steroid agent. Diminished flow of contrast dye enables the detection of tendon-to-sheath adhesions. This study is performed in real time using fluoroscopy. On rare occasions, the study may prove therapeutic by virtue of the adhesiolysis effect of the injection itself. The surgical approach, once confirmed, involves opening the tendon sheath and release of adhesions. The amount of immobilization postoperatively is dictated by the extent that the laciniate ligament is released. If it is released completely to gain access to the tendon, then 3 weeks of crutch-assisted nonweight-bearing status is used. Continuous passive motion (CPM) machines may be used during that phase to help lessen the recurrence of the adhesions released at the time of surgery.

The presence of tendinopathy adds significant complexity to the surgery and the therapy. Tendinosis seems to be prevalent in the area behind and below the medial malleolus because of an anatomically consistent hypovascular zone.[18] This zone, coupled with a pronounced pronated foot type, is a formula for tendinosis and tear. When detected in earlier phases, reconstruction is accomplished using the flexor digitorum longus to augment the degenerated posterior tibial tendon.[19] Some form of foot realigning procedure, such as calcaneal osteotomy, may be used to lessen pronatory influence on the repaired tendon in the future. Longer-standing cases of tendon degeneration may be more complex because of eventual arthrosis that develops in the hindfoot joints from long-standing severe pronation. In such cases reconstruction uses arthrodesis of one or more hindfoot joints.

The last form of posterior tibial tendon surgery in this discussion involves cases using an accessory navicular bone, sometimes referred to as an *os tibiale externum.* This accessory bone is not uncommon. It can cause symptoms as the result of prominence. It can also become symptomatic after injuries, typically eversion mechanism of injuries.[20] Patients in this later category can develop a painful diastasis. High signal at the junction of the accessory bone and the navicular on MRI can help support the diagnosis.[21] In recalcitrant cases of either mechanism, removal of the accessory bone is considered.[22] In such cases the surgeon will sometimes insert some form of anchor to supplement the potentially weakened tendon insertion or consider relocating the tendon insertion more plantar to the navicular bone. This portion of the procedure has a profound influence of the physical therapy protocols that follow. In such cases the surgical sire must be respected and protected postoperatively as the surgeon would for any tendon transfer.

POSTERIOR TIBIAL TENDON REHABILITATION

With the rehabilitation of posterior tibialis tendon surgery, therapy should immediately appreciate that preoperative anatomy and mechanics have a major role in injury.[23] Because most posterior tibialis stress and injury is caused by excessive pronation force through the medial foot, ankle, and arch, either chronically or acutely, rehabilitation efforts will focus on creating a medially “stabilized” foot and ankle.[24] By creating a dynamic arch with active muscle tension throughout the rehabilitation process, therapy has its best chances of creating a mechanically sound and functionally prepared foot and ankle.

Therapy must respect the surgical process, identifying degree of bony repair and/or tendon repair or transfer. These procedures require longer immobilization and protection to allow bone and tendon healing. Early rehabilitation targets gentle dorsiflexion, plantarflexion, and inversion range of motion, as well as the strict avoidance of any eversion ranging (because this places significant stress on healing bone or repaired and/or transferred tendon, disrupting or compromising the repair).

As healing progresses and the patient is able to load muscle tissue, neuromuscular reeducation is focused at the muscles of the medial foot, arch, and ankle. Manual techniques should be used to recruit and retrain not only posterior tibialis but also flexor hallucis longus, flexor digitorum longus, and the intrinsic muscles of the arch. When trained, these muscles combine to help stabilize the medial foot and create a “dynamic arch.” This muscle training allows the patient to actively control and reduce pronation forces that were stressful preoperatively and need to be corrected to maximize postoperative success.

This same focus on recruiting and ensuring muscle activity of the medial foot and ankle groups is applied from early manual resistive phases of open-chain training, through non- and full weight–bearing closed kinetic chain training. The patient should be cued to use and maintain a dynamic arch with all functional ADL and sport-specific therapeutic exercises. The therapist can do this by instructing the patient to shift weight toward the lateral aspect of the foot, cupping the arch, with closed kinetic chain exercise and activity.

By exercising and training the patient to use the medial muscle groups, therapy offers the best opportunity for successful return to function because preoperative muscle deficiencies and mechanical tendencies for hyperpronation are thusly addressed.

The use of a medially supportive orthotic device and shoe wear that prevents pronation can be helpful throughout the rehabilitation process. These passive restraints provide relative rest to the tendon and medial foot during weight bearing and help support rehabilitation efforts that address the dynamic aspects of stabilizing the medial foot.[25] Patients, when returning to sport, should be counseled on shoe wear that provides support and control of pronation. Orthotic agents will supplement but should not replace efforts to use muscle activity as medial foot and ankle stabilization.

FASCIA SURGERY

Surgery for plantar fasciitis is less commonly used than in previous years. It is generally accepted that the vast majority of plantar fasciitis patients will respond to conservative care measures if all parties can be patient to undergo what can sometimes be a protracted recovery time for this condition. In those cases requiring surgery, partial plantar fascia release is most commonly used.[26] The procedure has evolved from a total to partial release to mitigate the chances of overlengthening that can lead to lateral column stress and further surgery. Flattening of the arch has also been observed in cases of fascia release.[27] Another benefit of relatively recent advances in this procedure is that it can be effectively carried out by endoscopic means, thereby lessening the convalescence (Figure 3). Whether the procedure is done endoscopically or by open approach, therapy precautions need to be undertaken to avoid stretching out what portions of the fascia remains. Undo stress to the calcaneocuboid joint in such cases may necessitate arthrodesis of this joint to resolve such complaints.

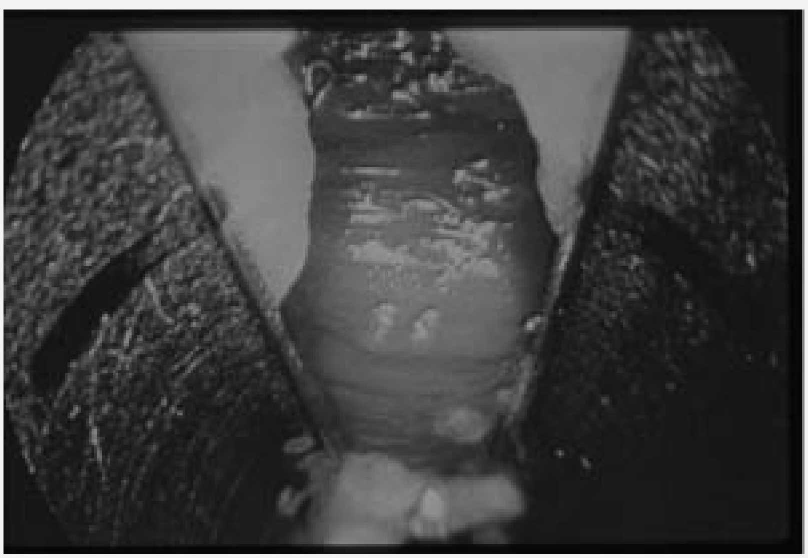

Figure 3 This fascia release is being performed endoscopically. Once released, the underlying muscle belly is visualized.

PLANTAR FASCIA REHABILITATION

When considering plantar fascia injury and surgery from a mechanical point of view, when rehabilitating, one should assume that there was an element of acute or chronic pronation that predisposed the injury. Explore preoperative movement habits and activities to identify mechanical tendencies into the ranges of pronation that may have existed. Postoperatively, the medial foot and arch become additionally vulnerable to losing normal support and medial "posting" based on the injury and release.[28] Be sure to not overstretch the released area in the first several weeks because this can contribute to further collapse medially as weight bearing proceeds through the limb. Additionally, an ineffective arch can lead to lateral column compression, overload to the lateral foot, and subsequent dysfunction.[29] Rehabilitation efforts throughout should be focused at creating dynamic support to the medial foot, arch, and ankle to prevent this potential complication.

Developing the musculature of the medial foot, ankle, and arch requires that the posterior tibialis, flexor hallucis longus, flexor digitorum longus, and the intrinsic muscles of the foot are all activated. This training is done open chained and manually in the early phases of rehabilitation. It can then be advanced to closed kinetic chain exercise. The therapist can be creative in designing partial and full weight–bearing exercise that recruits those muscles of the medial foot, ankle, and arch. Cueing to shift weight to the lateral weight-bearing side of the foot, actively and consciously, during exercise in which the foot is in contact with a platform, surface, or floor, can help recruit the musculature of the medial side and develop this dynamic arch. Muscle reeducation and recruitment starts from the floor up and affects the entire kinetic chain. This effort to maintain focus on the development of medial foot, ankle, and arch control should be maintained through the entire rehabilitation process and is combined with the more obvious elements of restoring full range, flexibility, and mobility of the foot, ankle, and subtalar joints.

In this way rehabilitation efforts are focused on treating the mechanics of injury and/or overuse patterns and have the greatest chances of restoring pain-free and lasting function. As with other medial foot and arch dysfunction, the use of a basic medially supportive orthotic device can be helpful in the return to full weight–bearing activity and function. This passive restraint should be used only as a compliment to excellent neuromuscular control, strength, and endurance of the medially stabilizing musculature of the lower limb.

ARTHROSCOPY OF THE ANKLE AND SUBTALAR JOINT

The range of potential interventions possible by small joint arthroscopic techniques has evolved during the past 15 years.[30] Common techniques for the ankle joint include synovectomies, débridement, removal of loose bodies, reduction of impinging exostoses, revision and microfracture of osteochondral defects, and thermal stabilization techniques. Aftercare is critical to the success of the procedure and differs with each of the described approaches.

Certain general considerations apply to all ankle arthroscopy techniques. Typically two anterior portals are used, one medial the other lateral. Care is taken in portal placement to avoid injury to the overlying nerves.[31] Care is likewise taken in the manipulation of these portals postoperatively to avoid irritation. The development of neuritis by the surgeon or therapist can hinder therapeutic approaches and prolong recovery time. Weight-bearing status can differ significantly with each type of arthroscopic intervention. Removing loose bodies alone usually has the quickest return to weight-bearing status, whereas microfracture the slowest (Figure 4). In the case of microfracture, drilling or use of awls creates limited defects the subchondral bone to promote a fibrocartilage formation (Figure 5).[32] What is initially created is, in essence, a scab on the surface of the bone that converts to its target tissue over time. The initial scab is friable and not sturdy to mechanical irritation. It is generally recommended that 6 weeks of nonweight bearing be observed in such patients. Special considerations also exist with thermal stabilization techniques.[33] Radio frequency surgical wands, holmium lasers, and other heat instrumentation can be used to take advantage of the structure of collagen, which causes it to shrink when subjected to certain temperatures. Weight bearing is again limited and protected for the first 6 weeks, and side-to-side stressful motion is to be avoided for 3 months after the procedure.

Figure 4 The loose body will be removed arthroscopically. Function is returned quickly.

Figure 5 A, Magnetic resonance imaging (MRI) scan of a medial talar dome osteochondral lesion. **B,** Defect is visualized arthroscopically and will be treated with débridement and microfracture. No weight bearing is allowed for 6 weeks.

Subtalar joint arthroscopy is not as universally used because of the anatomic constraints imposed by this joint. The procedure approaches are limited to the larger and more easily accessible posterior facet of the subtalar complex. The most common application of this procedure is in cases of impingement complaints after ankle sprain, more commonly referred to as *sinus tarsi syndrome.*[34] Two lateral portals are used, which allow access to the anterior and lateral margin of the posterior facet. A third posterior lateral portal can allow visualization of the posterior aspect of the joint. Typically, these posttraumatic conditions manifest as overproduction of fibrosynovial tissues at the margins of the joint. In sinus tarsi syndrome, most of this abnormal tissue is seen at the anterior margin of the posterior facet of the subtalar joint. This tissue is readily approached and evacuated by arthroscopic means. Tears of the interosseous ligament have been described.[35] These tears are usually incomplete, and repair is not necessitated (Figure 6). Although the intervention is relatively low-key, nonweight-bearing status is advised for 3 weeks. To prevent recurrent scar tissues, a CPM machine is helpful until the patient initiates conventional physical therapy.

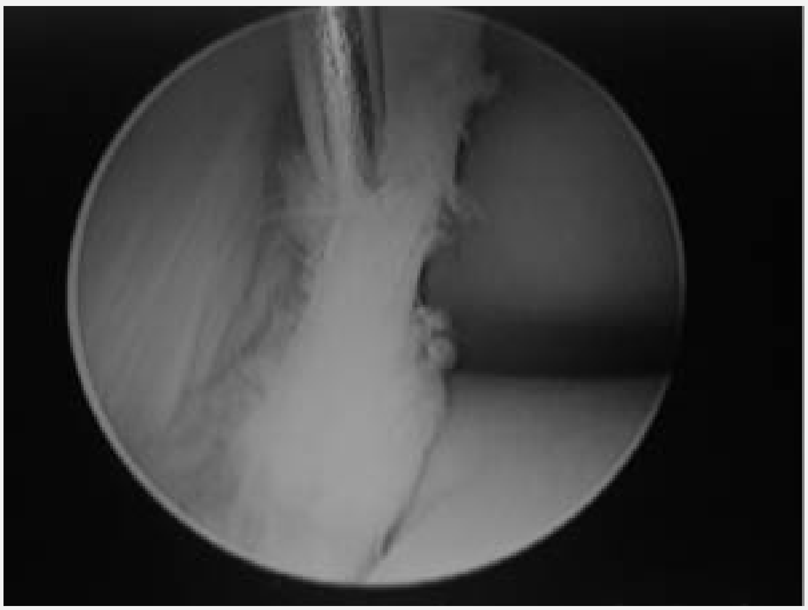

Figure 6 This is an arthroscopy of the subtalar joint. Partial tear of the interosseous ligament should be noted.

REHABILITATION OF ANKLE ARTHROSCOPIC PROCEDURES

Ankle arthroscopy allows a rapid onset and progression of rehabilitation with the procedures that remove scar, fibrous tissue, or loose bodies. Because its purpose is to remove binding or irritating tissue, the ankle, subtalar, and foot joints are moved soon after surgery. Once the surgeon allows motion and the portals are adequately healed, continuous and frequent motion in as full a range as tolerated, with minimal amounts of immobilization, helps to prevent the reformation of scar and fibrous tissue growth that may again restrict motion and cause pain.

Arthroscopic techniques performed to repair cartilage defects or stabilize the ankle by shrinking collagen tissues require a more mechanically nuanced approach in rehabilitation. Weight-bearing loads will be strictly avoided for 6 to 8 weeks. In the case of cartilage repair in which subchondral bone has been intentionally disturbed to create fibrocartilage scar, early continuous range of motion allows the most "organized" remodeling of the fibrocartilage scar, whereas compressive forces may disrupt that same healing.[36] Similarly, the collagen tissues shortened under the influence of heat need adequate time to "set" at their new length and should not be exposed to range or loading techniques for a similar amount of time. Muscle activation techniques, done manually and with the surrounding muscles held isometrically, can help reduce the degree of inhibition that can develop in the postoperative immobilization and protection phase.

Once loading is allowed, the rehabilitation specialist should be acutely aware of precise areas of the joint surface that have been repaired. In this way, partial and full weight–bearing training can be designed to control joint compressive forces through that area of the joint surface. Consider the patients weight-bearing mechanics, their preoperative provocative activities or exercises, along with precise knowledge about the area of the joint surface manipulated to position the foot, ankle, and limb when doing closed kinetic chain exercise. Correcting tendencies to pronate or supinate "into" the lesion will help relocate and reduce the joint reaction forces away from the surgical site. In addition, the clinician should be aware of motion in the sagittal plane that may increase or decrease compressive loading through the surgical site and select exercise positions accordingly to work the limb without simultaneously overloading the lesion. In this way the patient is neuromuscularly trained, from the foot up through the entire kinetic chain, to use muscle function that supports favorable limb alignment.

Similarly, with thermal stabilization procedures, the patient should be cued to maintain a foot and ankle position that holds the lateral, repaired collagen tissues in a neutral to shortened range for all closed kinetic chain activities. Range-of-motion activities to encourage normal flexibility are not avoided in total; however, they are reserved for the later phases of rehabilitation and are measured—creating adequate but not excessive mobility of the tissues repaired.

With both of the more complicated arthroscopic procedures, functional, impact, and lateral loads are not added until approximately 4 months after surgery. All mechanical nuance applied in the early and midphases that focused on neuromuscular control, muscular strength, and muscular endurance continue to be applied through the progression into full function. The muscles of the lower leg, foot, and ankle must be well trained as "shock absorbers" and highly effective at decelerating load through the joint to appreciate a lasting functional result.

HALLUX VALGUS SURGERY

Numerous procedures address the different components that constitute hallux valgus deformity. The trend has been to concentrate the correction on some form of distal metatarsal osteotomy, proximal metatarsal osteotomy, and/or first metatarsal-cuneiform arthrodesis to restore alignment to these deformities.[37] The determination as to which procedure is most appropriate is arrived at by a combination of factors including radiographic angles, flexibility of the deformity, nature and stability of the foot type, and procedural preference of the operating surgeon.

The type of procedure materially affects the nature of the recovery time and follow-up care used. The postoperative restrictions are most severe for arthrodesis procedures of the first metatarsal-cuneiform joint, referred to as the *Lapidus procedure* (Figure 7). This procedure has enjoyed increasing popularity in recent years because of its stability over time, but the convalescence is extreme.[38] Eight to 12 weeks of cast immobilization is used. Half of that time is spent in a nonweight-bearing cast. Accelerated programs will potentially carry a higher risk for nonunion of the arthrodesis site that not only prolongs recovery but also can potentially necessitate revision surgery (Figure 8). Because of the long convalescence protocols to regain functional use of the extremity, encouraging range of motion of the first metatarsophalangeal (MTP) joint is beneficial.

Figure 7 A, Lapidus procedures work well for patients with high intermetatarsal angles. **B,** In this same patient, a Lapidus procedure was performed. A Lapidus procedure involves arthrodesis of the first metatarsal-cuneiform joint. Immobilization is important with this form of hallux valgus correction.

Figure 8 Early mobilization or premature aggressive therapy and breakdown of a Lapidus arthrodesis site.

Base wedge osteotomies have similar indications and postoperative management issues as a Lapidus procedure.[38] They are most commonly used for the more severe hallux valgus deformity in which a marked divergence of the first and second metatarsals occurs. The angle between the first and second metatarsals is sometimes referred to as the *intermetatarsal angle.* Six to 8 weeks of protected weight-bearing status by cast and/or cast boot is used.

The most common bunion operations performed are distal osteotomy procedures.[39] The most common of these are sometimes referred to as a *chevron* or *Austin type of bunionectomy* (Figure 9). This procedure involves not only reduction of the enlarged medial first metatarsal head but also includes making a V-shaped cut in the distal metaphysis of the first metatarsal. The first metatarsal is then transposed an appropriate number of millimeters to reduce the deformity and the divergence of the first and second metatarsal. Fixation is usually used, making the osteotomy stable for weight bearing and early motion exercises. A stiff-soled postoperative shoe is used for 4 to 6 weeks, then one transitions to reasonable shoe gear thereafter.

Figure 9 With an Austin or chevron type of bunionectomy, the osteotomy is made distally. The osteotomy is stable for weight bearing. Rigid fixation further enhances the stability of the procedure.

With all the bunion procedures described, ancillary portions of the procedure are additional considerations for how aggressive the care can be postoperatively. For example, various medial capsular tightening procedures are used, so one needs to be cautious to keep the toe in a centralized position when any range-of-motion exercises are initiated postoperatively. Excessive abduction stress on the first MTP joint can lead to recurrence of deformity. The type of fixation used can influence postoperative care. Kirschner wire (also known as *K wire*) fixation is not as stable as screw fixation. Loosening of hardware and destabilization can result from premature excessive activity on an osteotomy or fusion site that has lesser forms of fixation. In addition, many long-standing hallux valgus deformities have varying degrees of arthrosis. Degenerative joints may not tolerate the same degree of rehabilitation protocol measures postoperatively (Figure 10).

Figure 10 Many long-standing bunion deformities have wear of the articular cartilage. Sometimes microfracture type of procedures are performed at the same time. This would limit the type of therapy that is used postoperatively.

HALLUX VALGUS REHABILITATION

Anatomically and mechanically, hallux valgus is the result of stress to the foot in ranges of plantarflexion, hyperpronation, and hyperabduction.[40] All procedures that correct this deformity involve bony manipulation and repair and may also involve ligamentous repair. Depending on the procedure, early weight bearing will be allowed or protected and rehabilitation will proceed accordingly. Early range efforts will target gentle flexion and extension at the first MTP joint and dorsiflexion and plantarflexion at the ankle joint. Some element of inversion range of motion can be performed. Ranges that stress the medial aspect of the great toe and/or arch should be strictly avoided throughout the rehabilitation process. Do not range or load the foot, particularly the midfoot and forefoot, into any degree of eversion and/or abduction.

As with the rehabilitation of the plantar fascia and posterior tibialis injury and surgery, significant focus is placed on establishing a medially stabilized foot and arch dynamically. Use manual techniques to recruit all medial foot, ankle, and arch stabilizers—posterior tibialis, flexor digitorum longus, flexor hallucis longus, and intrinsic muscles of the foot. Because the vulnerable joint is distal in the kinetic chain, care should be taken not to create large levers across the MTP joint or the first metatarsal when working those muscle groups. Patients should be worked from a neutral position at the foot and ankle into inverted, adducted, and supinated ranges.

When proceeding to partial and full weight–bearing therapeutic exercise, be sure to set the patient up in foot and ankle positions that hold against hyperpronation, abduction, and eversion. This cueing allows the patient to recruit and use the muscles of the medial foot, arch, and ankle to stabilize stressful pronation forces while working in weight bearing. This training helps reduce stress to the repaired and/or reconstructed metatarsal or MTP joint, thus addressing predisposing stressful mechanics and muscle deficiencies.

Orthotic support for the arch may be helpful to passively support the foot while dynamic support is being developed. Assist the patient in selecting shoe wear that can do the same and may also reduce flexion moments across the first MTP joint.

Be sure to restore as much flexion and extension range at the MTP joint (and through the midfoot) as possible, because elements of degenerative joint disease may also exist at the joint. This flexibility and range can decompress joint reaction forces with movement required for pain-free ambulation and other functional activity.

ANKLE STABILIZATION SURGERY

Surgical stabilization of the ankle is considered in the active individual who has chronic instability of the ankle (as a result of one or more previous injuries) that created attenuation or insufficiency of the lateral ligaments. Although ankle bracing and strengthening of the ankle-supporting musculature can provide adequate functionality in many patients with chronic instability, such measures fall short in many more active patients. A case can be made for more aggressive approaches in such patients because chronic instability and repetitive injuries do create theoretical concerns of developing premature arthritis.[41]

Dozens of procedural approaches exist for the chronic unstable ankle patient. The best way to approach the procedural types is by dividing them into categories: tenodesis, delayed primary repair, ligament reconstruction, and thermal stabilization. The tenodesis operations generally use a portion of the peroneal tendons, which is rerouted into the fibular (thereby providing a restraint to inversion of the ankle). Most of these procedures do not selectively restrict motion of the ankle joint alone, but also restrict motion of the subtalar joint.[42] These methods have the longest track record and are generally successful. One theoretical shortcoming is that they also block subtalar joint motion. In those patients exhibiting subtalar instability, this may prove beneficial. In most, this additional limitation of motion on a neighboring joint is superfluous. The delayed primary repair, sometimes referred to as the *Brostrom procedure,* plicates the lateral collateral ligaments that have been attenuated or stretched out from prior trauma. It is more selective than the tenodesing operation in terms of its restriction of motion.[43] A shortcoming is that it is dependent on the quality of the tissues that are tightened. Ligament reconstruction generally imports other tissues, such as allograft, and replicates the course of the previously damaged lateral ligaments. Again it is more selective in limiting motion of the ankle alone. Healing can be longer, depending on the nature of the tissues that are imported. The thermal stabilization procedure is the newest of the procedures. First done on shoulders, thermal stabilizations offer an arthroscopic alternative to the stabilization group of procedures. It has been demonstrated that heat, applied by a radio frequency probe or laser, can cause the collagen to shrink because of its helical configuration. Arthroscopic procedures are preferred because of the lower morbidity and shorter healing times generally associated with these procedures when compared with their open-technique counterparts. However, these arthroscopic alternatives are relatively new, and the long-term outcomes still require scrutiny.

The majority of the lateral ligament tightening and reconstructive techniques require fairly long convalescences and cast immobilization postprocedure. Obvious concerns exist regarding causing premature or excessive inversion motion postoperatively in these patients because it may compromise the operative results. As a result, therapy is often initiated at the end of the postoperative repair process versus at the beginning.

ANKLE STABILIZATION REHABILITATION

As with the other rehabilitation procedures discussed in this chapter, preoperative mechanics and muscle deficiencies in the ability to add support and stabilize the ankle joint have a major influence on the postoperative rehabilitation programs for ankle stabilization procedures. After identifying the precise procedures chosen by the surgeon for repair and appropriately protecting the joint in terms of range and joint loading according to those tissues manipulated, therapy will address preoperative mechanical and muscular deficiencies.

Most ankle stabilization procedures will require approximately 6 to 8 weeks of protection, whether tendon was relocated or ligament was repaired and reinforced.[44] This allows adequate time for tissue healing to occur. Any therapeutic procedures allowed during that period would strictly avoid all ranging into inversion and would primarily target generating muscular recruitment in the dorsiflexor, plantar flexor, and invertor groups isometrically. Tension of the evertor (peroneal) muscle groups should be avoided, especially with procedures in which peroneal tendon was used as the stabilizer.

Once allowed, neuromuscular recruitment techniques should address all planes of the ankle, but especially address the retraining of the lateral ankle musculature. This work would proceed through ranges of neutral ankle motion into ranges of eversion. Eccentric or loaded motion into ranges of inversion should be reserved for the later phases of rehabilitation.

As with arthroscopic stabilization procedures, the patient should be cued and positioned with all non- and full weight–bearing closed kinetic chain exercise to hold the ankle in a position that avoids inversion and/or supination moments. The patient is thusly trained to actively recruit peroneal muscle concurrent with all pressing, calf-raising, and squatting movements, as well as other functional exercises. This type of cueing and training not only addresses muscle deficiencies preoperatively that will help support the procedure performed but also has elements of proprioceptive training that become important in the total rehabilitation of the ankle and limb.

Impact and lateral motion should not be introduced in the rehabilitation process until approximately 4 months postoperative. The patient should demonstrate adequate muscle function and range before proceeding to these final phases of functional rehabilitation. Early return to activity may be supported with some type of external restraint in the form of ankle bracing or a laterally elevated shoe wedge as additional protection to inversion/supination loads.

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