Is There a Role for Subtalar Arthroereisis in the Management of Adult Acquired Flatfoot?

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**KEYWORDS**
- Adult acquired
- Arthroereisis
- Pes planovalgus
- Subtalar implant
- Subtalar joint

**KEY POINTS**
- Subtalar arthroereisis is 1 treatment option for stage IIA posterior tibial tendon dysfunction, as an alternative to calcaneal medializing osteotomy.
- Subtalar arthroereisis, often combined with Achilles tendon lengthening, is a simple and effective way to treat flexible flatfoot in adults.
- The most common complication is pain in sinus tarsi that usually disappears after removal of implant. Midterm results are good and it does not hinder other treatments in the future.

Adult acquired flatfoot is a common problem for foot and ankle surgeons. The incidence is increasing and it is becoming more widely known among orthopedic surgeons in the last years. The main cause is rupture of posterior tibial tendon (PTT). The morphologic characteristics of this condition are heel valgus and flattening of the medial longitudinal arch. Other characteristics are usually observed, such as supination and abduction of the forefoot and tightening of the Achilles tendon. The deformity is progressive and patients describe “sinking” of their foot. There is no spontaneous correction with time and many patients become symptomatic. Treatment is required when there is progression of deformity and/or pain. Conservative treatment includes supportive footwear and ankle orthosis. The natural evolution of adult flatfoot and failure to treat this condition could lead to persistent pain in the hindfoot, hallux valgus, degenerative arthritis, metatarsalgia, and knee or low back pain.
Surgery is commonly indicated in adult flatfeet. Flexible flatfoot should be treated preferably with extra-articular procedures. There are different surgical options: Tendon transfers, osteotomies, and subtalar joint motion blocking procedures. Shortening of the gastrocnemius or the Achilles tendon is very common in flatfoot. Often, it is necessary to lengthen these structures. The final decision is usually based on the clinical and radiographic assessment of the patient on an individual basis and the surgeon’s preferences. Chambers in 1946 was the first to introduce the idea of restricting subtalar joint motion with an autologous bone block filling the sinus tarsi. In 1952, Grice observed that extra-articular subtalar arthrodesis with cortical graft for flatfoot deformity in children had several problems, such as development of degenerative arthritis in adjacent joints and inability of the hindfoot to adapt to uneven surfaces. Haraldsson and Lelievre pointed out that the most important was to block the sinus tarsi restricting subtalar motion while avoiding arthrodesis. Since then, the term arthroereisis (Latin: artro = joint; -ereisis = support or prop up) is used to describe the limitation of subtalar motion. Viladot and co-workers presented their experience treating PTT dysfunction stage II with arthroereisis.

SUBTALAR ARTHROEREISIS WITH SINUS TARSI IMPLANT

Arthroereisis has been used predominantly to treat flatfeet in the pediatric population. Many arthroereisis procedures have been described to limit subtalar joint motion and to improve position. Lelievre in 1970 introduced the term lateral arthroereisis using a temporary staple across the subtalar joint. In 1977, Subotnick was the first to describe a sinus tarsi implant. He used a block of silicone elastamer. Smith and Millar used a polyethylene screw in sinus tarsi (STA peg, Dow Corning Wright, Midland, MI, USA) and reported a 96% success rate in children. Viladot reported the use of a silicon implant with a cup shape, obtaining 99% good results in 234 children. Presently, Silicon implants are not usually used and have been replaced with troncoconical implants like Kalix (New Deal, Lyon, France) and MBA (Kinitekos Medical, Carlsbad, CA, USA). Zaret and Myerson reported 23 children with flexible flatfoot treated with MBA implants. They reported postoperative sinus tarsi pain in 18% of patients that improved with rest and corticosteroid injection. Two children required implant removal at a mean of 9 months after surgery. Subtalar joint range of motion increased after implant removal. They observed an interesting phenomenon: Removal of the implant was not associated with a reversal of the foot structure.

Vogler classified sinus tarsi implants into 3 types based on their biomechanical properties: Self-locking wedge, axis-altering implant, and impact-blocking device. The majority of sinus tarsi implants are self-locking wedges. All sinus tarsi devices restrict hindfoot valgus and the calcaneus is vertically orientated beneath the ankle joint. The talus is dorsiflexed and externally deviated. Talonavicular subluxation and forefoot abduction are corrected.

Indications

According to Johnson and Strom, PTT dysfunction is classified in 3 stages. Stage I PTT has degenerative changes, but no deformity. Stage II is a flexible flatfoot. In the beginning, the hindfoot is in valgus and progresses to abduction and supination in the forefoot. Stage III is a rigid deformity. Myerson described stage IV when the ankle joint is affected. Recently, a refined classification system has been proposed that takes into account forefoot supination, forefoot abduction, and medial column instability. Stage II has been subclassified in A, B, and C substages. There is a valgus deformity in stage A, abduction in stage B, and medial column stability in stage C.
Surgery is indicated for symptomatic flatfoot stage II, which persists despite nonsurgical treatment or when progression of deformity is observed. Tenosynovectomy is not recommended for stage II disease. Surgical options are osteotomies, medial column arthrodesis, tendon transfers, and sinus tarsi implants. Sinus tarsi implants are useful for correcting valgus (substage A). Forefoot abduction (substage B and C) will not be corrected with sinus tarsi implant, even though temporarily some forefoot adduction and supination is observed after arthroereisis (Fig. 1).

Flexor digitorum longus (FDL) transfer has become a mainstay for soft-tissue procedures in patients with stage II PTT dysfunction. Biomechanical analysis shows no change in arch alignment or height with this procedure alone. When performed alone, it fails to restore normal biomechanics of the foot. It has long been recognized that the spring ligament is essential in the foot structure. It should be sutured or replaced when it is torn. An osteotomy should be used to correct deformity in the long term. Medial displacement calcaneal osteotomy (MDCO) and FDL tendon transfer is commonly accepted for treatment in stage IIA (valgus deformity). Sinus tarsi implant and FDL transfer has the same indication as MDCO and FDL transfer. The advantages of arthroereisis compared with MDCO are that is easy and quick to perform, less immobilization is required, there is no risk of nonunion, and it avoids

Fig. 1. (A) Preoperative lateral x-ray. (B) Preoperative anteroposterior x-ray. (C) Postoperative lateral x-ray with Kalix endorthesis. The forefoot is in slight supination. (D) Postoperative anteroposterior x-ray with Kalix in supple adduction.
medial neurovascular structures injuries, troughing, and malunion. It has been demonstrated that the use of a subtalar arthroereisis returns substantially deforming forces and moments of the flatfoot back toward the values experienced in a normal foot.\textsuperscript{20} The disadvantages of arthroereisis are a high percentage of implant intolerance (around 30\% in our experience) and limitation of subtalar motion. There are no controlled trial studies comparing these techniques and the level of scientific evidence is low.

Complications\textsuperscript{8} Complications may be divided into general and implant specific.\textsuperscript{8} General complications include persistent sinus tarsi pain, malposition, overcorrection, undercorrection, wrong implant size, and loss of position (Fig. 2).\textsuperscript{8} The most common complication is intolerance of the implant owing to pain. Saxena and Nguyen\textsuperscript{21} indicated that the implants must be designed and shaped to fit adequately the configuration of the tarsal sinus tarsi. Overcorrection is a cause of pain in sinus tarsi and implant removal has been recommended with good results.\textsuperscript{22} Debris from wear, foreign body reaction, implant degradation, and implant fracture are implant-specific complications.\textsuperscript{8} Arthritis, synovitis, implant fracture, and implant loosening have been reported with the STA-peg implant.\textsuperscript{10} There are case reports of intraosseous cysts within the talus,\textsuperscript{23} osteonecrosis of the talus,\textsuperscript{24} peroneal muscle spasms, and small fracture of the calcaneus.\textsuperscript{25} The authors have observed a case with complex regional pain syndrome type I in a patient with a sinus implant (Fig. 3).
Wound complications can occur with surgical incisions. Predisposing factors for development of these complications include tissue quality, lack of subcutaneous tissue around approaches, and postoperative swelling.26

Operative Technique

The authors usually perform foot surgery under block anesthesia in adults. The patient is placed in a supine position with a pillow under the ipsilateral buttock to avoid excessive external rotation of the foot and facilitate approach to the sinus tarsi. A pneumatic tourniquet is applied at the thigh and the surgical field is prepared leaving the leg exposed.

In most cases, the first step of the operation is the lengthening of the Achilles tendon. To evaluate whether this tendon is retracted, the authors hold the foot with the hindfoot in neutral position and the knee completely extended. After that, the authors passively dorsiflex the foot. If the authors cannot achieve 10° of dorsiflexion, the authors consider that the Achilles tendon is retracted and it needs to be lengthened. This helps in correcting valgus of the calcaneus and implanting the endorthesis. The authors recommend percutaneous lengthening. Two 5-mm-long incisions are performed on the lateral border of the tendon (at 2 and 6 cm from its insertion in the calcaneus) and one 5-mm-long incision on the medial border (4 cm from the insertion). Through each incision, the tendon is divided transversely approximately half of its width. The foot is dorsiflexed so that the tendon is lengthened until about 15° of dorsiflexion is obtained while the knee is extended.

FDL transfer is made through a medial incision along the entire length of the PTT. The sheath of the PTT is opened and the tendon is inspected. A tenodesis is recommended between the PTT and FDL when the PTT is healthy. FDL transfer is performed if the PTT is in poor condition. The spring ligament should be repaired if there is a disruption. The FDL is passed through the hole in the navicular from plantar to dorsal.14 The tendon is sutured after insertion of sinus tarsi implant. It is important that the implant (final or trial implant) is inserted before completing the tendon transfer. If it is not done this way, the tension of the tendon will probably be wrong and the transfer will fail.

For implantation of the arthroereisis plug, a slightly curved 2-cm skin incision is made on the lateral side of the hindfoot centered over the sinus tarsi, just anterior to

Fig. 3. Complex regional pain syndrome type I after Sinus implant.
the tip of the lateral malleolus. Care must be taken not to damage the peroneal tendons, the sural nerve, and the intermediate dorsal cutaneous nerve (a branch of the superficial peroneal nerve). A direct approach to the sinus tarsi is obtained. The sinus tarsi is debrided removing its contents: fatty tissue with abundant nerve endings. This is important to eliminate the irritating stimuli of the endorthesis in the sinus, which could originate the contracture of the peroneal tendons. The powerful interosseous talocalcaneal ligament must not be damaged, because it is an important hindfoot stabilizer.

The next step consists of restoration of the foot arch and correction of calcaneous valgus deviation. This is achieved using a blunt lever, which is introduced through the sinus tarsi and under the neck of the talus. The correcting procedure is performed: The lever is pushed distally, so that the hindfoot is supinated. At the same time, the assistant pronates the forefoot. The aim of this procedure is to move the head of the talus upward, backward, and outward, so that it is repositioned in its physiologic position and hindfoot pronation is corrected. It is important to bear in mind that, in flatfoot, the talus has slipped forward, downward, and inward.

To conserve the correction obtained, an endorthesis is inserted in the sinus tarsi. First, the trial implants (with increasing diameters) are inserted until the appropriate implant size is determined. The authors choose the smallest implant that corrects the deformity and remains stable in the sinus tarsi while moving the subtalar joint. It is advisable to check the correct position of the trial implant with fluoroscopy. The authors consider that the implant is in the correct position when the lateral edge of the implant is aligned with the lateral border of the talus. Then, the definitive endorthesis is implanted, the same size as the trial implant. The FDL is sutured in a slight inversion permitting plantigrade position simulating weight bearing. Hemostasia is done after taking off Esmarch. Closure of the wound is performed in a routine fashion and a below-the-knee compression cast is applied. The whole procedure does not take more than 40 to 50 minutes. If necessary, additional procedures can be associated, including removal of accessory navicular bone, removal of tarsal coalition, and peroneal tendon lengthening.

**Postoperative management**
A below-the-knee walking cast is applied and sutures are removed 2 to 3 weeks postoperatively. A walker is placed when the skin has healed and weight-bearing is allowed. If there is pain with weight-bearing, the patient should avoid weight-bearing. The walker is removed 6 weeks after surgery if there is no pain with weight-bearing. The patient is advised to wear rigid orthopedic insoles for 6 months to support the correction.

**Endorthesis**
Since 1998, the authors have been using the Kalix endorthesis (Newdeal SA, Vienne, France) for child and adult flatfoot surgical treatment (Fig. 4). This implant consists of a metal cone trunk, which is introduced into another polyethylene cone trunk that expands. It is manufactured with biocompatible materials: Titanium and high-density polyethylene. Its conical shape fits well into the sinus tarsi and the lateral fins prevent the implant from moving out of the sinus tarsi. In 2009, the authors started using the Sinus implant (Fig. 5). It is a troncoconical device that can be screwed into the sinus tarsi. Both implants can be visualized radiographically owing to their metallic component.
RESULTS

Subtalar arthroereisis has proved to yield good mid to long-term results in children.⁹-¹¹,²⁷ However, there is little scientific evidence that proves its usefulness in adults with acquired flatfoot deformity.⁷ Lelievre⁵ treated flatfeet in children and adults inserting a bone graft into the sinus tarsi reporting a 90% success rate. Maxwell and associates²⁸ described the use of the Maxwell-Brancheau arthroereisis for the correction of PTT dysfunction having successful outcomes. Zaret and Myerson⁷ reported on 12 adults treated with the MBA prosthesis. Good clinical and radiographic results were obtained, although 2 patients required removal of the prosthesis owing to persistent sinus tarsi pain; no recurrence of the deformity was observed in these patients after prosthesis removal. Viladot and colleagues⁶ studied 19 patients with stage II PTT dysfunction treated with Kalix implant and tendon repair. They excluded overweight patients, those who had previous surgery, and neuropathic and osteoarthritic foot. American Orthopedic Foot and Ankle Society (AOFAS) score improved from 47.2 to 81.6 at follow-up. Only 2 patients were dissatisfied. Two patients required implant removal. Needleman²⁹ reported his results on 28 feet with flatfoot deformities in adult patients (≥18 years old) using an MBA implant. He

Fig. 4. Kalix endorthesis.

Fig. 5. Sinus implant.
included neurologic flatfoot. The exclusion criteria included infection, rigid flatfoot, evidence of osteoarthritis, and previous hindfoot surgery. Excessive weight did not affect inclusion in this study. AOFAS score improved from 52 to 87 points, and 78% of patients were satisfied with the result. Four patients (5 feet; 18%) said that they would not have the surgery again. The MBA implant was removed from 11 of 28 feet (39%) because of postoperative sinus tarsi pain.

More recently, Adelman and co-workers reported their results on 10 patients with symptomatic stage IIB PTT dysfunction treated by endoscopic gastrocnemius recession, subtalar arthroereisis with the MBA implant and FDL tendon transfer to tarsal navicular. All patients showed significant improvement of radiologic measurements. Four patients (40%) referred pain at sinus tarsi but only 1 patient required implant removal. The authors conclude that this surgical combination provides satisfactory correction of stage II PTT dysfunction.

Arthroereisis has been used for treatment in children with talocalcaneal coalition owing to bad results after interposition. The results were encouraging. The use in adults needs to be determined with more studies.

**DISCUSSION**

Acquired flexible flatfoot in adults is a common condition that requires surgery in most cases. If they fulfill the inclusion criteria mentioned, surgical treatment is indicated. Numerous treatment options have been proposed and, probably, there is not a single treatment that is appropriate for every patient. The operative procedure most frequently used to treat adult flatfoot secondary to stage II PTT dysfunction consists of MDCO and FDL transfer. This technique has proven to be effective for this condition, although calcaneal osteotomies are not free from complications. Myerson and colleagues published good results in 129 patients, but with these complications directly or indirectly related to the calcaneal osteotomy: One progressive hindfoot valgus deformity, 2 varus malunion of the osteotomy, 3 sural neuritis, and 5 numbness in the distribution of the medial plantar nerve. Greene and associates studied the relationship between the MDCO and the medial neurovascular structures in 22 cadaver specimens. They found that the osteotomy site was crossed by an average of 4 neurovascular structures, most of them branches of the lateral plantar nerve and the posterior tibial artery.

Subtalar arthroereisis is an alternative to calcaneal osteotomy in the treatment of stage II PTT dysfunction, particularly in stage IIA, where valgus hindfoot is the main deformity. These are the advantages of subtalar arthroereisis compared with MDCO: It is easy and quick to perform; it is a less invasive procedure; there is no risk of nonunion or malunion; there is no risk of damaging medial neurovascular structures and the sural nerve; and it requires less immobilization time and less non-weight-bearing time after surgery (shorter recovery time). Subtalar arthroereisis has a greater potential of hindfoot valgus correction than calcaneal osteotomy: The limit for calcaneal displacement is one third of its width approximately, whereas greater valgus correction can be achieved with arthroereisis using increasing implant sizes. Finally, subtalar arthroereisis provides a 3-dimensional correction of the flatfoot deformity by repositioning the talus in its physiologic position, preventing it from slipping forward, inward, and downward. It is not so clear that MDCO provides this type of correction.

There are also disadvantages of subtalar arthroereisis: It limits subtalar motion, although it is not completely blocked. The rate of pain at sinus tarsi is high (10%–40% of patients); this pain may be temporary and may require implant removal. Another
disadvantage of arthroereisis is that most implants in the market are more expensive than the 1 or 2 screws needed for calcaneal osteotomy. Calcaneal osteotomy and subtalar arthroereisis can be performed combined on the same patient. Schon\textsuperscript{34} performs the MDCO first and, if he cannot achieve proper heel position with the osteotomy, he performs a subtalar arthroereisis through a different approach to gain more heel valgus correction.\textsuperscript{34} Finally, he repairs the PTT. The authors prefer to start with the arthroereisis because, if more correction is needed, the authors use a bigger size implant and, in most cases, the calcaneal osteotomy is not needed. In any case, the fact is that both techniques can be associated if needed. Bruyn and colleagues\textsuperscript{35} had good results using a combination of Evans calcaneal osteotomy and STA-arthroereisis. They reported 25 symptomatic severe flexible pes valgo planus treated with a combined operative technique and patients were 100\% satisfied or very satisfied. The authors do not recommend combining subtalar arthroereisis with a calcaneal lengthening osteotomy. In this situation, the osteotomy is performed very close to the implant site and implant stability may be at risk.

Only minor complications have been reported with subtalar arthroereisis in adults. Sinus tarsi pain is the most frequent complication.\textsuperscript{6-8,30,33} Different causes could explain sinus tarsi pain: Impingement of the implant against the posterior subtalar facet and irritation of the nerve ends at the sinus tarsi caused by the prosthesis or implantation of an oversized prosthesis. When this complication develops, it can be

Fig. 6. (A) Preoperative lateral x-ray. (B) Postoperative lateral x-ray with Sinus subtalar arthroereisis. (C) Lateral x-ray after Sinus implant removal. The correction continues after removal.

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managed in different ways: Immobilization in a brace for several weeks, physiotherapy, or corticosteroid injections into the sinus tarsi. These treatments solve the problem in most, but not all, patients. When pain persists, removal of the implant is indicated. The question is: Can implant removal cause a relapse of the deformity? Almost all the literature available on subtalar arthroereisis in children and adults agrees that the possibility of recurrence is very low after implant removal. It is also our experience that implant removal usually eliminates sinus tarsi pain without clinical or radiologic recurrence of the flatfoot (Fig. 6). The authors think that this phenomenon can be explained because arthroereisis acts as an internal orthotic device that keeps the foot in the correct position while the medial soft tissues are healing. The authors think also that some degree of arthrofibrosis generates at the subtalar joint that prevents it from subluxating after implant removal. In our experience, the incidence of implant intolerance with sinus tarsi pain is very frequent. When the authors recommend a subtalar arthroereisis sinus tarsi implant to treat a stage IIA PTT dysfunction, the patient is informed about the possibility of postoperative sinus tarsi pain that may require a second surgery for implant removal.

SUMMARY

Subtalar arthroereisis, often combined with Achilles tendon lengthening, is a simple and effective way to treat flexible flatfoot in adults. The most common complication is pain in sinus tarsi, which usually disappears after removal of the implant. Midterm results are good and it does not hinder other treatments in the future.

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