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Subtalar Arthroereisis: A New Exploration of an Old Concept

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Subtalar arthroereisis as an adjunct procedure may hold promise for patients who have mild and more severe variants of posterior tibial tendon dysfunction (PTTD). The biomechanics of the implant function have not been fully elucidated, and questions remain about the best clinical indications for the device. The early literature suggests, however, that subtalar arthroereisis seems to aid in the correction of hindfoot deformity and protects the medial soft tissue reconstruction. In mild type II PTTD, the subtalar arthroereisis may obviate a calcaneal osteotomy. In the more severe type II PTTD, subtalar arthroereisis in conjunction with the flexor digitorum longus (FDL) tendon transfer and medial calcaneal osteotomy (MCO) may further normalize parameters that remain under-corrected with the initial procedure. Although the multiple variables involved in clinical use of the implant make definitive studies difficult to perform, there is reason to believe the use of subtalar arthroereisis may lead to better function, less invasive procedures, and possibly shorter rehabilitation times. In the coming years further studies will ultimately define its role in treating the spectrum of the PTTD deformities. This article reviews the limited existing literature and describes the author's personal experience testing subtalar arthroereisis in the laboratory and using the implant clinically for correction of adult flexible flatfoot.

Perspective

Current arthroereisis techniques are the product of more than 50 years of evolution in surgical treatments directed at correcting flexible flatfoot deformity by altering the alignment of the subtalar joint. In a study by Grice on

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correction of pediatric pes planus, patients receiving an extra-articular subtalar arthrodesis consisting of cortical strut grafts placed in the sinus tarsi had late deformity recurrence [1]. Haraldsson [2] inserted allograft cortical bone wedges in the sinus tarsi to restrict subtalar eversion without arthrodesis. In the English literature, the first subtalar arthroereisis with a free floating implant was described in 1977 [3]. Arthroereisis implants are now made of silicone, polyethylene, titanium, stainless steel, or bioresorbable polymers. Implant geometries vary (Fig. 1) [4], and no study has established an advantage of one implant over another.

The few clinical studies available have shown favorable results in pediatric and adult patient populations. Vedantam and colleagues [5] reported satisfactory results in 96% of feet in a study of 78 children who had flexible flatfoot caused by neuromuscular disorders, in whom 140 arthroereisis procedures were performed. Giannini and colleagues [6] reported the 4-year results of subtalar arthroereisis for 21 children who had bilateral flexible flatfoot deformity using a bioresorbable implant. Giannini and colleagues combined their implant insertion with Achilles tendon lengthening and modified Kidner procedures as needed in selected cases. Heel position and

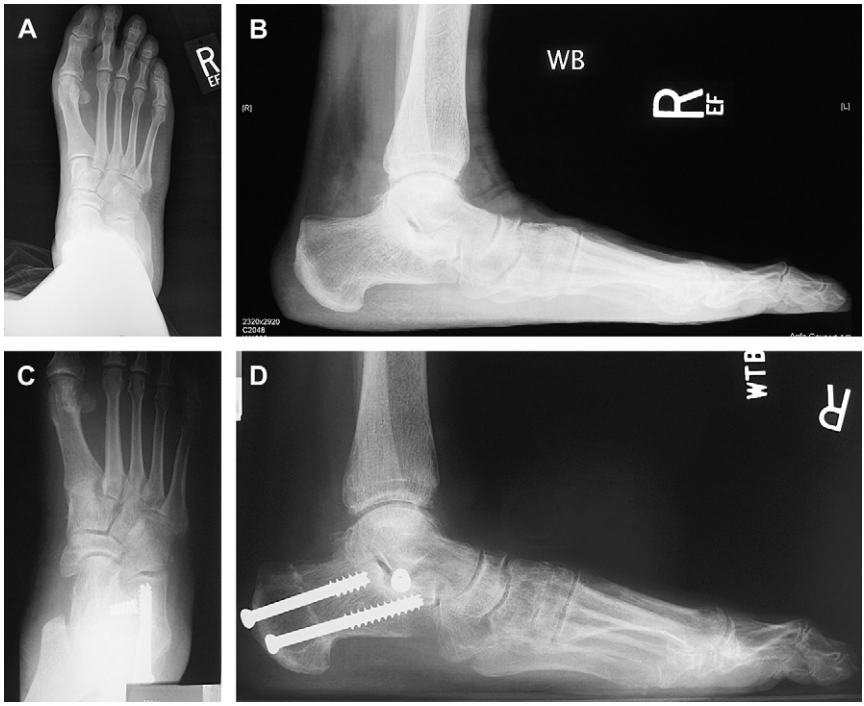

Fig. 1. Radiographs of one patient who had acquired flatfoot and who underwent arthroereisis with medializing calcaneal osteotomy and flexor digitorum longus transfer as described in the text. Preoperative anteroposterior (*A*) and lateral (*B*) views and postoperative anteroposterior (*C*) and lateral (*D*) views are shown.

radiographic parameters were significantly improved from preoperative measurements, and 95% of children were pain-free at follow-up. Viladot and colleagues [7] reported on 21 adults who received subtalar arthroereisis with PTT synovectomy or FDL transfer or percutaneous Achilles tendon lengthening for stage II PTTD; preoperative AOFAS ankle/hindfoot scores had improved at an average of just over 2 years' follow-up. Needleman [8] reported on surgical correction of flexible flatfoot deformity using standard surgical procedures and subtalar arthroereisis with average follow-up of 44 months. Significant improvements were found in radiographic parameters with high patient satisfaction despite the removal of 11 of 28 implants for sinus tarsi pain. Implant removal did not seem to be associated with any complications. The specific effect of the implant could not be isolated in this study.

Recent reviews of subtalar arthroereisis suggest a possible role as an adjunct procedure with MCO and FDL transfer in treatment of type II PTTD without substantially increasing the risk for operative complication or postoperative morbidity [4,9].

Biomechanics

In an effort to elucidate the factors that may generate pain requiring implant removal, the author recently studied the intrusion/extrusion movement in the sinus tarsi of a tapered (conical) versus a cylindric subtalar implant under cyclic axial loading in a simulated flatfoot cadaver model [10]. Specimens were mounted in a load frame and movement was measured with a differential variable reluctance transducer. Specimens were axially loaded from 72 N to 720 N for 500 cycles at a frequency of 0.5 Hertz (Hz). Load and movement into and out of the sinus tarsi were recorded at the initial cycle and at 100 and 500 cycles.

Movement of the implant was nearly the same for both implants at 100 and 500 cycles. Intrusion and extrusion movement was slight at both time points. The maximum force generated on the implant was low (1.3 N). The slight implant movement found suggests that arthroereisis is an inherently stable construct and that generation of pain in subtalar arthroereisis is probably not caused by implant movement into or out of the sinus tarsi.

The author also studied the shape of the sinus tarsi on CT scans and found that the space is more conical than cylindric. The possibility of edge loading of a cylindric implant in a conical space raised concerns about the nonconical implants. A shape that better matches the anatomy perhaps provides a greater distribution of forces, resulting in a lower incidence of pain.

A study by Watanabe and colleagues (unpublished data, 2002) using a cadaver flatfoot model demonstrated limitation of eversion with subtalar arthroereisis. These investigators also found altered kinematics of the foot after insertion of the implant and over-distraction of the subtalar joint. Given

the author's experience with the implant in cadavers and live patients, this over-distraction indicates that too large an implant was selected. At the time of their study, there was little guidance in the literature about correct insertion of the device. In the author's laboratory, Vora and colleagues [11] showed radiographic correction of severe flatfoot in a cadaveric model with MCO and simulated FDL transfer supplemented with arthroereisis. The author's laboratory followed the author's clinical protocol as described for insertion of the implant and did not have over-distraction of the subtalar joint on the radiographs. The implant proved useful in restoring the normal parameters in the severe flatfoot. In a less severe flatfoot, the FDL transfer and MCO were sufficient for correction without the implant, and the author's laboratory showed overcorrection when the arthroereisis was added to the mild model. We did not compare the transfer and MCO versus the tendon transfer and implants for a moderate or mild deformity.

Indications and contraindications

The function of the implant during healing remains a matter of conjecture pending further clinical and biomechanical study, but the primary role of the implant is to block nonphysiologic eversion, sometimes referred to as hyperpronation. This function decreases the tendency for the talus to rotate medially and plantarly and may reduce the strain on the medial ligaments and tendons. If these assumptions are correct, the implant allows progressive introduction of weightbearing as the medial tissues heal without jeopardizing medial soft-tissue reconstruction. The author has seen that the implant is typically no longer needed after soft-tissue healing and may be removed without risk to the surgical correction if the implant is symptomatic. Rarely there is inadequate correction with other procedures and the implant is symptomatic because of re-collapse of the foot.

Subtalar arthroereisis is recommended only as an adjunct procedure in correction of pathologic anatomy [8]. In milder cases of type II PTTD, arthroereisis may protect FDL transfer and spring ligament repair, especially in obese patients or those who have diminished healing capacity. Arthroereisis may also reduce the need for an MCO, especially when there is less than 5° of valgus relative to the contralateral side. In more severe cases of type II PTTD, arthroereisis may obviate lateral column lengthening osteotomy or arthrodesis. In these cases the author advises performing the FDL transfer, MCO, and possibly a spring ligament plication with the arthroereisis. Arthroereisis may also be helpful in protecting a reconstruction when the patient is unlikely or unable to comply with postoperative weightbearing restrictions.

The author frequently uses subtalar arthroereisis to supplement surgical reconstructions for type I and type II PTTD in patients who have systemic factors, such as obesity, diabetes, rheumatoid arthritis, and smoking. Heel cord lengthening and opening wedge medial cuneiform osteotomy (Cotton

osteotomy) and MCO are used as needed to correct residual deformity. These criteria for adjunctive arthroereisis have proven clinically useful, but are not yet validated through scientific study.

Risk for foreign body reaction seems to be minimal with the titanium implant [4,8] or the stainless steel models. Currently arthroereisis implants are available in various materials, including polyethylene and bioresorbable poly-L-lactic acid, poly lactic acid, or poly glycolic acid. Reaction to these materials can occur.

Contraindications to arthroereisis include active infection, advanced subtalar arthrosis [8], or previous traumatic or surgical wound overlying the sinus tarsi.

Clinical assessment

Routine preoperative evaluation includes examination of strength, range of motion, and standing foot deformity and weightbearing radiographs of the foot. The patient should be observed during gait, because fatigue of the posterior tibial tendon may not be as apparent during a standing or seated examination.

The author used the following clinical and radiographic guidelines for surgical treatment of type II PTTD. An isolated FDL transfer augmented by subtalar arthroereisis is performed on patients able to invert past the midline with minimal heel valgus ($<5^\circ$ of clinical valgus), minimal abduction deformity (20%–30% talonavicular uncoverage and talo-first metatarsal angle of $<20^\circ$ on anteroposterior [AP] radiographs), and minimal arch collapse (talo-first metatarsal angle of $<10^\circ$ on lateral radiographs). FDL transfer and MCO with subtalar arthroereisis is performed on patients unable to invert past the midline with moderate heel valgus ($<15^\circ$ of clinical valgus), moderate abduction deformity (30%–40% talonavicular uncoverage and talo-first metatarsal angle of 21°–40° on AP radiographs), and moderate arch collapse (talo-first metatarsal angle of 11°–20° on lateral radiographs). Heel cord lengthening or opening wedge medial cuneiform osteotomy is used as needed to correct residual deformity. These criteria have proven clinically useful but are not yet validated.

Technique

Surgery generally consists of three separate procedures: MCO, subtalar arthroereisis, and FDL transfer. The author performs the MCO and arthroereisis first to take advantage of patient positioning and to avoid undue stress on the FDL transfer. The operation is performed under regional, spinal, or general anesthesia to allow for the placement of a thigh tourniquet. This tourniquet placement helps to avoid compressing the FDL muscle

belly, which is transferred in the third stage of the procedure. If ankle block anesthesia is preferred, an elastic ankle tourniquet may be used, provided it is released before tensioning the FDL tendon transfer.

The patient is positioned supine with a beanbag or large bump used to elevate the ipsilateral hip providing access to the lateral aspect of the foot. A longitudinal oblique incision is made starting 2 cm posterior to the fibula at the superior border of the calcaneus and ending just distal to the plantar tubercle of the calcaneus at the margin of glabrous skin in line with the fibula. The incision is approximately 5 cm long and runs just posterior and parallel to the sural nerve. Dissection is carried down through skin and subcutaneous tissue with care taken to avoid the sural nerve and its branches. The incision is carried down to bone, where the periosteum is elevated for 2 to 3 mm posteriorly and 10 mm anteriorly to the planned osteotomy.

A saw is used to create the osteotomy approximately 15 mm posterior to the posterior facet of the subtalar joint. Care is taken to avoid over-penetration of the medial cortex with the saw, which could jeopardize the neurovascular bundle. The osteotomy site is separated using an osteotome or periosteal elevator followed by insertion of one and often two (one smooth and one with teeth) lamina spreaders. Occasionally a periosteal elevator must be used to release soft tissue on the medial side to allow displacement of the osteotomy. Typically a 1-cm spread at the osteotomy site is required to translate the same distance. The calcaneal tubercle is then shifted 7 to 10 mm medially and secured with an axially-placed 6.5-mm or 7.3-mm partially threaded cannulated screw. The guide wire for the screw may be used to secure the osteotomy while position is checked under fluoroscopy. The screw should be placed from the posterior heel to the anterior process of the calcaneus. The author has found a 65-mm long screw with a 32-mm thread length is suitable for most patients.

Once fixation is achieved, positioning of the osteotomy and screw are checked fluoroscopically. The lateral edge of the calcaneus is then contoured with a bone tamp and mallet to reduce the prominence. The wound is irrigated and closed. It is important to line up the skin edges accurately to compensate for the overlap that may occur as a result of the medial translation.

The second step of the surgery, subtalar arthroereisis, is accomplished while the patient is still in a lateral position. Overall foot deformity is assessed with attention to degree of hindfoot valgus and forefoot supination. The goal of arthroereisis is to correct the heel to a neutral position (which may be 4°–12° of hindfoot valgus depending on the severity of initial deformity) without causing supination of the forefoot. In certain feet, the supination of the forefoot can be anticipated and a Cotton osteotomy planned. In these cases the supination of the forefoot occurs before the implant is inserted, so the goal when inserting the implant is not to exacerbate this deformity.

The sinus tarsi is palpated just inferior and distal to the tip of the fibula. A longitudinal 1-cm incision is created dorsal to the peroneal tendons over

this soft-tissue sulcus. Blunt dissection with a hemostat exposes the tarsal canal. A blunt guide wire is then inserted from lateral to medial recognizing that the sinus tarsi is oriented obliquely from anterolateral to posteromedial. Resistance may be felt as the guide wire penetrates the interosseous ligament. The guide wire is advanced until it tents the medial skin just dorsal to the sustentaculum tali. A relaxing puncture wound is then created to allow the wire to pass medially, where it is secured with a hemostat. This medial penetration point of the wire should fall within the planned medial exposure for FDL.

With the guide wire in place, the trial sizers are advanced from lateral to medial into the sinus tarsi beginning with the 7-mm sizer and increasing as necessary by increments of 1 mm. As each sizer is placed, the position and motion of the hindfoot is evaluated. The appropriate sizer limits pathologic eversion without causing hindfoot varus. If the sizer is too small, excessive eversion is present, and if too large, the hindfoot and forefoot are overcorrected into varus. Most adult implants are between 8 and 12 mm. Once the best sizer is identified, the AP radiograph is checked.

On AP fluoroscopy, the trial implant or (for the ProStop system) the sizer (in this system, the sizer and trial implant are the same) typically crosses half of the mediolateral diameter of the talar neck and should not protrude beyond the lateral border of the talar neck. In general, the leading edge of the implant should not cross the midline of the talar neck. The fluoroscopy image should be checked at this stage to avoid deceptive correction caused by overly shallow or deep insertion of the trial, resulting in incorrect size of the definitive implant. For instance a small implant may give correct foot position, but to achieve the correct position it would need to be inserted too deeply. Motion and position of the hindfoot are then assessed to ensure proper correction. If this proves satisfactory, the depth of the implant is noted by looking at the laser markings on the trial implant post relative to the skin. Typically this distance is 20 to 30 mm. For the ProStop system, the trial implant is attached to the insertion post and is therefore easy to remove. Extracting the trial implant with other manufacturers' devices may be easy, but sometimes the implant disconnects from the screwdriver or insertion post. In these cases gently everting the foot to create a counterforce for purchase of the implant threads helps. If trial removal proves problematic, a cannulated probe can be inserted medially to assist in extraction.

The subtalar implant is then inserted over the guide wire to the depth noted by the laser markings on the post, which should correlate with it being flush with the lateral border of the talar neck. AP fluoroscopy should be checked. Once the implant is properly positioned, the guide wire is removed and the wound closed.

Finally, the FDL transfer with or without medial capsular or ligamentous plication are performed medially. Two additional adjunctive procedures may be used for type II PTTD reconstruction: gastrocnemius soleus recession (GSR) (Strayer procedure) and dorsal opening wedge medial cuneiform

osteotomy (Cotton). The author routinely checks heel cord tightness after performing MCO and arthroereisis and lengthens the Achilles tendon when necessary. A plantarflexion opening wedge medial cuneiform osteotomy may be used in conjunction with MCO, arthroereisis, and FDL transfer to correct residual forefoot varus. The author uses this procedure in reconstruction if there are 5° or more of forefoot varus remaining after MCO and subtalar arthroereisis have corrected the heel to a biomechanically neutral position. In contrast to the Lapidus procedure, the opening wedge osteotomy spares the first metatarsal cuneiform joint, therefore maintaining accommodative motion. Preoperative and postoperative radiographs for one patient are shown in Fig. 1.

Postoperative management

Postoperatively the wound is sterilely dressed and a bulky cotton dressing with splint is applied. Surgery may be performed on an outpatient basis or with an overnight stay. Patients return to the office in 10 to 14 days for a wound check and suture removal. Patients are nonweightbearing on the operative extremity for the first 6 weeks postoperatively and gradually begin protected weightbearing in a walking boot from 6 weeks to 3 months. At 3 months patients are transitioned to a lace-up or stirrup ankle brace and allowed full weightbearing. Full recovery may take up to 1 year, but in general the author finds patients reach 75% improvement at 3 months and 90% improvement at 6 months. Arthroereisis implants may be symptomatic and require removal in up to one third of patients. This may be accomplished electively as an outpatient procedure. The author delays implant removal until at least 6 months to allow time for the patient to stress the foot in a controlled fashion without overstressing the medial soft tissue reconstruction.

Complications

Postoperative infection after arthroereisis may occur, but the author has not found elevated risk greater than that associated with elective foot and ankle surgery. Incidental nerve injury and scar pain can usually be avoided with meticulous technique. Persistent sinus tarsi pain may be present in a small percentage of patients and typically is relieved with implant removal. Implant migration and subtalar arthrosis are theoretic concerns that have not been observed in the author's patients to date. It is important to adhere to proper insertion protocol to avoid overstuffing the sinus. Too large an implant could result in pain and might also cause supination of the forefoot or varus of the hindfoot. Loss of correction with implant removal may also occur, though this has not been evident radiographically in 45 of the author's cases retrospectively reviewed at short-term follow-up of up to 1 year postoperatively (Schon, unpublished data, 2007). A prospective institutional

review board (IRB-approved) study currently underway at the author's institution may identify these or other potential complications.

The limited literature available demonstrates only minor complications associated with subtalar arthroereisis. Sinus tarsi pain was reported in 6 of 19 adult patients who underwent subtalar arthroereisis for acquired flatfoot, with two patients eventually requiring implant removal [7]. Transient sinus tarsi pain was also reported in 2 of 21 patients in a recent study of subtalar arthroereisis performed with a bioresorbable implant in pediatric flexible flatfoot patients. This pain resolved, however, without implant removal as the material resorbed [6].

In a recent study [12] the author assessed short-term radiographic outcomes using standard reconstruction with adjuvant arthroereisis using a cylindric implant (as opposed to a conical implant, which the author currently prefers) to determine whether arthroereisis introduced any undesirable effect. Twenty-seven patients who had adult acquired flatfoot were treated by means of a subtalar implant coupled with other corrective procedures, including FDL tendon transfer, calcaneal osteotomy, and heel cord lengthening by one surgeon. Preoperative and postoperative weightbearing radiographs at 6 months and 1 year were compared for angular measurements, subtalar arthritis, and peri-implant lucency. Significant improvements in talonavicular uncoverage angle were found in the study period. Just less than half of the implants were removed, most for sinus tarsi pain. Evidence of mild subtalar arthritis was found in two patients after implant removal. In less than half of the patients who retained the implant at 1 year, mild radiographic lucency was found. These complications represent areas of concern, but the clinical impact has yet to be examined.

In the author's experience, implant removal can occasionally prove challenging. In these situations, the author inserts the guide wire with fluoroscopic guidance as needed to aid screwdriver alignment. Gentle eversion of the foot is used to gain added purchase in reversing the implant. The percutaneous addition of a cannulated probe medially over the guide wire may also facilitate extraction. The probe is used to push the implant out of the sinus tarsi. Another technique is to use a hemostat to grasp the implant with one arm placed centrally and the other on the perimeter. The design of the Arthrex ProStop arthroereisis implant incorporates a concavity on the lateral end of the implant to facilitate cannulation or grasping.

The author has performed more than 70 cases with 1- to 5-year follow-up in pediatric and adult cases using three different implants: the MBA (a cylindric metal implant) by KMI, the Futura (a conical metal implant) by Nexa, and the ProStop (a conical implant) by Arthrex (the author is one of three inventors). A less radical procedure than what most foot and ankle surgeons may choose was possible in approximately 50% of the cases. In 20% of the higher risk cases (patients who had diabetes, overweight patients, smokers, and neuropathic or rheumatologic cases), the author was able to achieve and maintain correction without resorting to a fusion. Overall the author has removed 30% to 40% of

the implants. One patient had persistent pain after removal of the implant. This patient responded incompletely to a cortisone injection (temporarily excellent relief but then only partially improved) and is scheduled for a resection of the shoulder of the talus.

Future of the technique

Use of subtalar arthroereisis in surgical correction of type II PTTD seems beneficial with a low risk profile. The high implant removal rate is a concern, but as in procedures using other hardware, removal typically results in resolution of the pain without loss of correction. The surgical technique is simple and reproducible with little additional morbidity when added to MCO and FDL transfer. The procedure does not limit future surgical options. Biomechanical studies and early clinical research have been promising, and the author looks forward to seeing more definitive biomechanical and long-term clinical reports in the coming years. As mentioned previously, the large number of variables involved in the treatment scenario for adult flexible flatfoot and the difficulty of performing large randomized prospective studies may limit the ability to obtain a truly definitive report on this adjunct procedure. An IRB-approved prospective clinical study underway at the author's institution should help to further illuminate technique, complication concerns, and benefit of arthroereisis in combination with proven corrective measures for treatment of flexible flatfoot.

In the meantime, the author continues to use the subtalar arthroereisis as an adjunct procedure in correction of flexible flatfoot deformity at our institution with good results.

Summary

Subtalar arthroereisis can be considered as an adjunct procedure for patients who have posterior tibial tendon deficiency. The implant mechanics have not been completely elucidated, but studies are underway. In a substantial percentage of patients the implant removal for pain results in alleviation of the associated symptoms without additional consequences. In the near future, better studies will help define the best results and outcomes. Currently the biomechanical and clinical experience at the author's institution suggests that subtalar arthroereisis seems to aid in the correction of hindfoot deformity and to protect soft-tissue reconstruction without risk to the patient or the reconstruction.

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