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SUBTALAR ARTHROEREISIS IN THE NEUROLOGICALLY NORMAL CHILD

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The problem of hypermobile flatfoot in children has been well documented in medical literature for many years. Hypermobile or flexible flatfoot refers to a foot that has excessive motion in the form of pronation at the subtalar joint. Pronation of the subtalar joint is a triplane motion consisting of eversion of the calcaneus and adduction and plantarflexion of the talus. Because of this, the clinical presentation of a hypermobile flatfoot can be observed in all three planes. In the sagittal plane, the medial longitudinal arch of the foot is decreased and the talus is plantarflexed. In the frontal plane, the heel is in a valgus position. In the transverse plane, the forefoot may appear abducted and the talus is adducted. During gait, the subtalar joint undergoes maximal pronation during the contact and early stance phase. Normally, during midstance, the subtalar joint begins to resupinate to form a rigid lever during propulsion. In the hypermobile flatfoot, the subtalar joint pronates excessively during contact, resupination does not occur during the late midstance phase, and the foot remains pronated and hypermobile for propulsion.[1]

The surgical treatment options available for this condition include tendon balancing and transfer procedures and osseous procedures including fusions and osteotomies. The idea of treating hypermobile flatfoot by altering the intrinsic motion of this joint was originally described

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by Chambers in 1946. Chambers used a bone graft to raise the posterior facet of the subtalar joint in patients with paralytic dropfoot.[2] Following Chambers' lead, Baker and Hill reported the use of bone graft inserted inferior to the posterior facet of the calcaneus.[3] Selakovich described an opening wedge of the sustentaculum tali in 1973.[4] Many of these procedures were successful in altering subtalar joint motion, but it was found that the insertion of bony wedges interfered with the functionally necessary for subtalar joint motion.[5] In an attempt to block talar motion, Haroldsson reported the results of insertion of bone block into the sinus tarsi.[6] Lelievre reported a similar procedure.[7] This concept of inserting material into the sinus tarsi to block talar motion would become the precursor to today's arthroereisis devices.

Surgeons began inserting various endoprosthetic blocks in place of bone grafts. The purpose of these endoprosthetics was to block talar motion without entering or destroying the subtalar joint itself. This method of arthroereisis has persisted since Subotnick inserted a silicone plug into the sinus tarsi in 1973.[8] Since that time, the procedure has been modified many times to improve the results and simplify the insertion, while preserving subtalar joint motion. Smith designed the first axis altering arthroereisis device.[9] The subtalar arthroereisis (STA) peg is made of ultra high molecular weight polyethylene fashioned into the shape of a peg.[9] This material has a low friction coefficient and has been shown to be well tolerated demonstrating favorable wear qualities and minimal soft-tissue reactivity. The peg is inserted into the dorsal surface of the calcaneus at the anterior aspect of the posterior facet.[9] The goal of this device is to alter the axis of the subtalar joint by preventing excessive anterior shift of the talus as bone grows up and around the peg. Many other devices followed, including a threaded polyethylene screw used as a blocking device by Valenti,[10] and an elastomer umbrella by Viladot.[11] These devices are classified as self-locking wedges, since their purpose is to prevent the contact between the calcaneus and talus.[11] Samuelson described a stainless steel and polypropylene two component blocking device.[12] Lanham used the stem of a Swanson hemi-implant[13] and Addante described a silastic silicone sphere.[14]

Scarlato designed a mushroom shaped silastic cap that accepted the direct impact of the talus during pronation,[11] and Pisani used a stainless steel screw with a silastic crown which was also a direct impact arthroereisis device.[11] Lundeen modified Smith's STA peg by creating an angled face.[11] Shoenhaus described a modified fashioned silastic plug in the sinus tarsi.[15] Maxwell and Brancheau described a cannulated and slotted titanium screw inserted into the sinus tarsi.[1] The Maxwell-Brancheau arthroereisis (MBA) implant was first described in 1995 and was modeled after Valenti's polyethylene threaded screw. The MBA implant is a 15mm long titanium threaded screw with three slots for force absorption and tissue ingrowth. The device comes in four sizes (6mm, 8mm, 10mm, 12mm diameters) and is cannulated for ease of insertion into the sinus tarsi. The recommended positioning of this device is evaluated with an anteroposterior (AP) radiograph. The implant should be no further medial than the bisection of the neck of the talus, and should be less than 1cm from the lateral edge of the calcaneus. Primary indications for this device include the adult collapsing flatfoot, but it is also used in pediatric patients.

Indications for treatment of the hypermobile flatfoot as outlined by Smith include walking intemperance, night cramps, athletic abstinence, sedentary hobby pursuits, arch pain, and postural pain in the foot and leg.[9] Since ligamentous laxity is one of the hallmarks of the hypermobile flatfoot, this condition may be exacerbated in the obese child. First line therapy includes the use of an orthosis, strengthening exercises, and proper shoegear. Those patients who remain symptomatic can be treated surgically, with the understanding that severely pronated feet in children over the age of 6 years do not respond as well to conservative treatment.

Objective signs of the severely pronated foot include a calcaneal stance position greater than 8° valgus, forefoot varus greater than 10° and midtarsal breach. The deformity must be flexible, and there should not be any contributing torsional deformity present.[9]

Radiographic signs of the severely pronated foot include a lateral talocalcaneal angle greater than 40°, dorsoplantar talocalcaneal angle greater than 30°, talonavicular joint less than 50% articulated, anterior break of the cyma line, and talonavicular or navicular cuneiform breach on the lateral view.[9, 16]

The neurological examination is an important part of the work-up of pediatric hypermobile flatfoot. If the foot will not dorsiflex 10° with the knee at a 90° angle, other more complex problems should be suspected (ankle equinus in cerebral palsy, or delayed maturation of the cortical spinal tracts).[17]

Smith recommended surgical treatment of the pronated foot in childhood for patients aged 1 to 3 years with severely pronated feet after 1 to 2 years of treatment with a heel control orthotic.[9] If children presented with a severely pronated foot after 6 years of age, Smith stated that surgical treatment was indicated immediately. It may be more appropriate to modify the surgical indications to include only those children whose symptoms persist despite conservative care using an appropriate orthotic.

The use of arthroereisis to treat hypermobile flatfoot has been shown to effect the foot in all three planes. However, the most significant clinical improvement is usually seen in the frontal plane where a dramatic reduction of calcaneovalgus is usually apparent. Since hypermobile flatfoot affects all three planes, it is imperative that the patient's foot is thoroughly examined for any associated pathology. The most common is a gastro-soleus equinus. If the patient has inadequate dorsiflexion available, limiting subtalar joint motion may exacerbate the patient's pain. An accompanying tendo-Achilles lengthening may be indicated in these cases. It is important to note that if the patient's frontal plane deformity is masking an underlying transverse plane deformity (for example, metatarsus adductus lack of tibial torsion) treatment with arthroereisis may exacerbate the patient's intoeing. For this reason, it is imperative that all other pathologic conditions be addressed at the time of surgery to increase the success of the arthroereisis procedure. In order to compensate for a secondary forefoot varus, Smith has recommended a plantar ephiphyseal arrest of the first metatarsal in patients aged 8 to 11 years and a Cotton opening wedge osteotomy of the medial cuneiform in patients over 11 years old in conjunction with the STA peg procedure.[18] Lundeen stated that a high percentage of children with severe hypermobile flatfoot exhibit naviculocuneiform faults.[19] He related success in alleviating these faults with a combination of the STA peg and appropriate tendo-Achilles lengthening procedures. Lundeen has also advocated the use of a split anterior tibial tendon transfer with or without a Kidner procedure in an attempt to stabilize the naviculocuneiform joint.[19]

In the pediatric population, most patients' feet are flexible and without secondary changes. As the patient matures, secondary changes may become more evident. In the adult flexible flatfoot, associated deformities include gastro-soleus equinus, rigid forefoot varus with metatarsus primus elevatus, midtarsal joint instability, and limitation of motion in the subtalar joint. Tendo-Achilles lengthening, medial column fusions, or lateral column lengthening may address these deformities.

The procedure for insertion of the STA peg and postoperative course are as follows: A classic Ollier incision is made approximately 1 cm distal to the fibula following the curve of the sulcus of the subtalar joint (Figs. 1, 2). Deep dissection is carried out to expose the muscle belly of the extensor hallucis brevis muscle (Fig. 3). A U-shaped flap is then formed, with the concavity of the *U* proximal and the convexity of the *U* distal. This allows the muscle belly to be reflected proximally and allows visualization of the subtalar joint and the posterior aspect of the sulcus. The floor of the sulcus is also readily identified (Fig. 4). If the anterior edge of the posterior facet is enlarged, it is resected at this time with an osteotome and mallet. The resection is curved slightly so that it will balance with the obliquity of the posterior facet of the subtalar joint. Following this, the floor of the sulcus is leveled as necessary. A 5.1 mm trephine is then used to core through the floor of the sulcus (Fig. 5). This is done approximately 1.5 cm medial to the lateral border of the calcaneus. After the plug of bone is removed, a sizer is inserted to determine the appropriate size STA-peg (Fig. 6). The floor of the sulcus may be

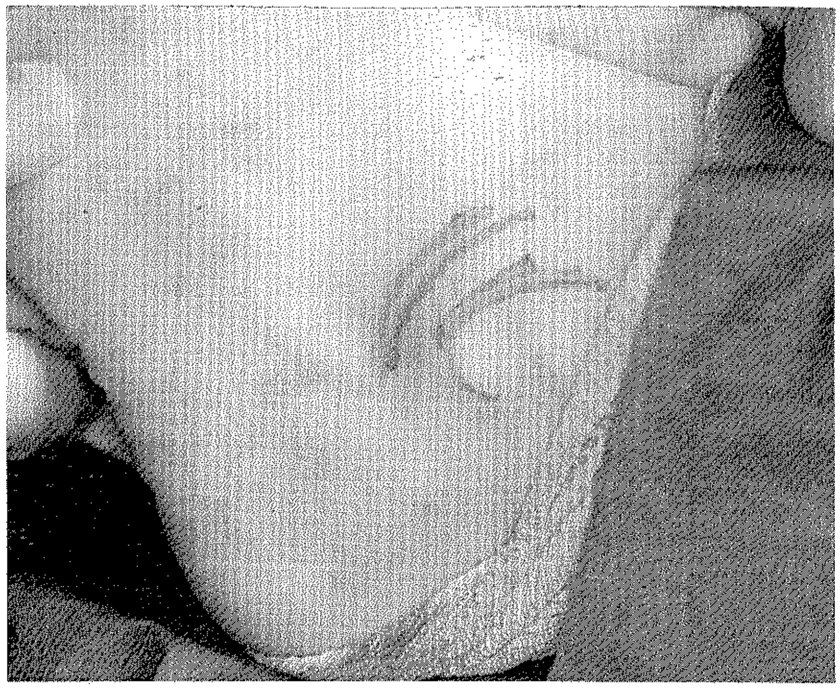

Figure 1. Incision is planned following the curve of the sulcus of the subtalar joint.

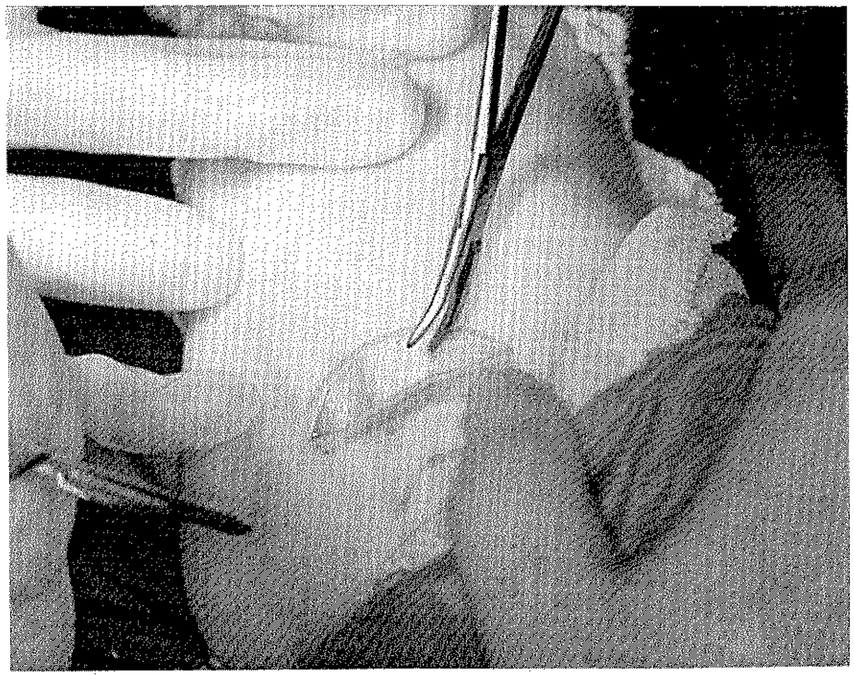

Figure 2. An Ollier incision is made 1 cm distal to the fibula.

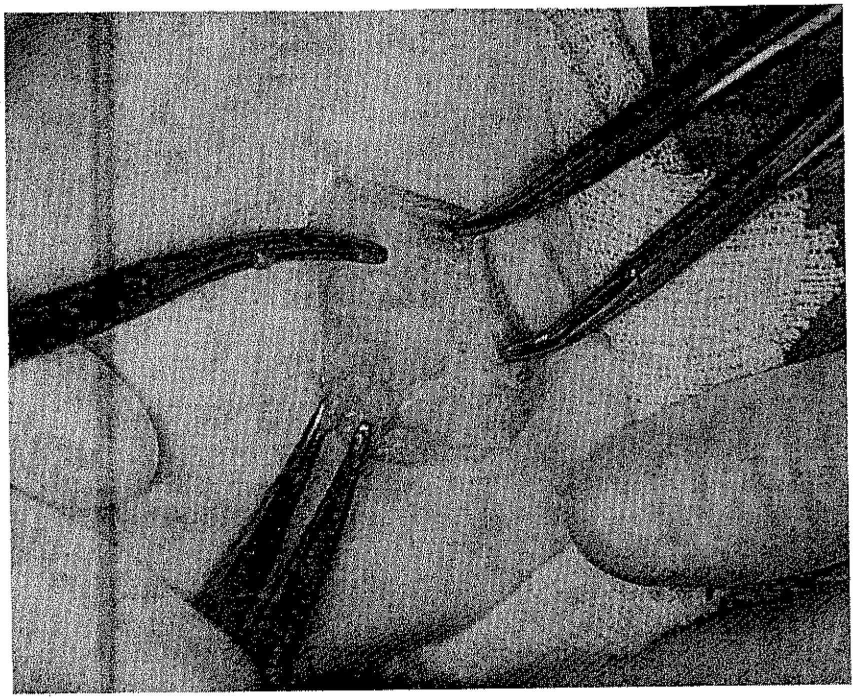

Figure 3. Dissection is continued to expose the extensor digitorum muscle belly.

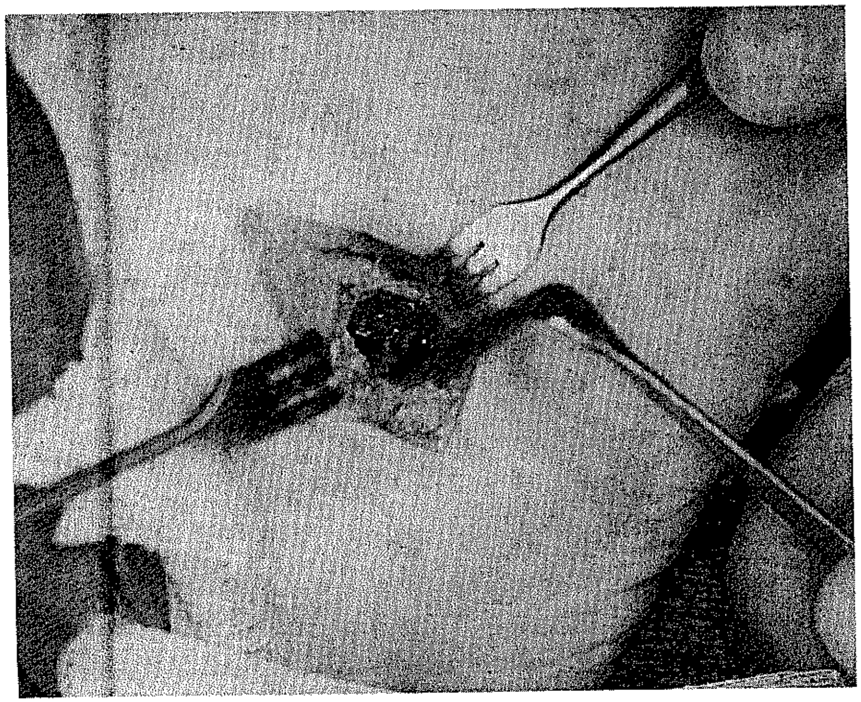

Figure 4. The floor of the sulcus of the subtalar joint is identified.

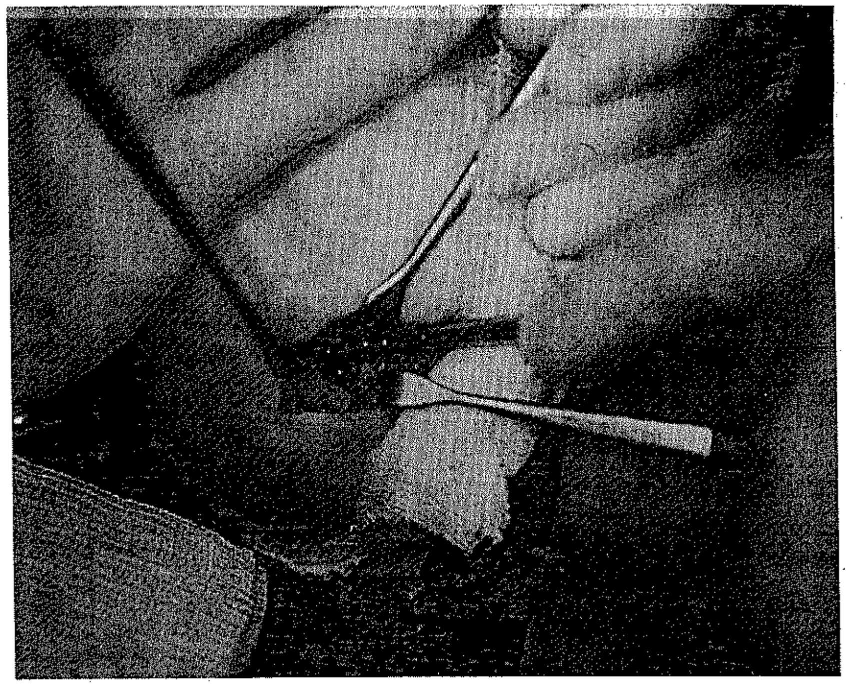

Figure 5. A 5.1 mm trephine is used to core through the floor of the sulcus.

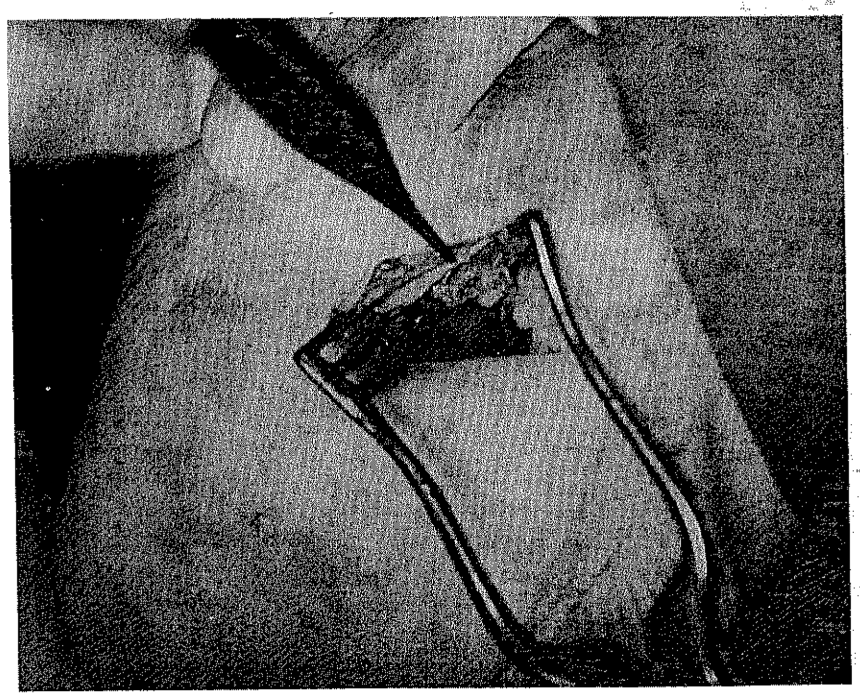

Figure 6. A sizer is inserted to determine the desired amount of correction.

further remodeled after evaluating the position of the calcaneus with the sizer in place. Polymethylmethacrylate is then applied to the chosen implant, and it is inserted abutting against the edge of the talus (Fig. 7). The fit should be tight to minimize loosening or instability of the implant. The foot is held in maximum eversion to exert pressure on the STA peg as the polymethylmetacrylate sets. Excess polymethylmetacrylate is carefully removed from the wound. The authors recommend continuing to hold the foot in valgus until the polymethylmetacrylate has hardened completely. After this has been accomplished, closure is performed.

Postoperatively, the foot is placed into a flexible cast for 2 weeks followed by gradual return to activities. Range of motion and gradual strengthening exercises are begun at home. Barring complications, activity is increased over the next 2 to 4 weeks. Physical therapy is prescribed if there are limitations or progress is slow. This includes passive range of motion, active and resistance exercises and proprioception board exercises. By week 6 to 7 the patient should be ambulatory and returning to normal activity. Noncontact sports such as swimming or biking are encouraged for approximately 6 months postoperatively. High velocity sports, such as hockey, football, and basketball are not allowed.

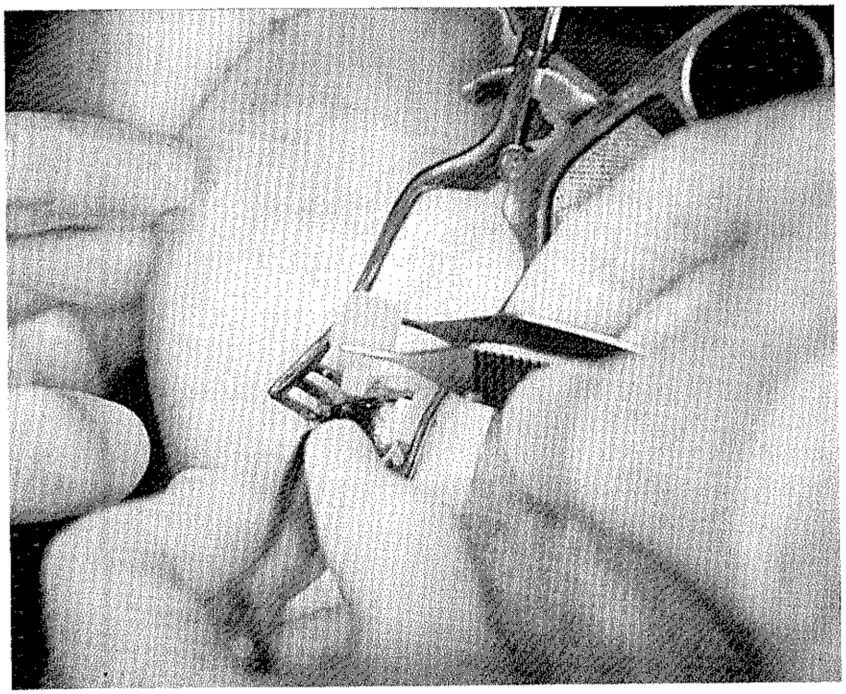

Figure 7. The STA-peg is inserted butting against the edge of the talus.

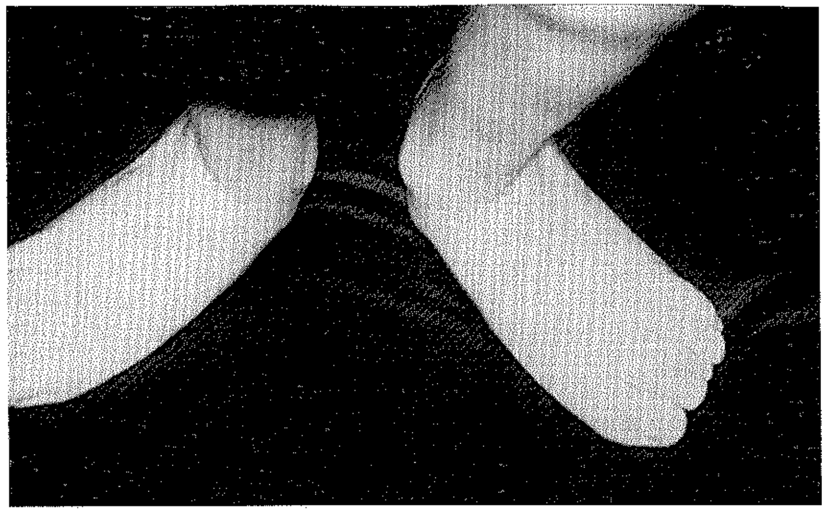

Figure 8. Preoperative view. Note forefoot abduction, decreased medial longitudinal arch, and calcaneal valgus.

The patient is allowed to participate in high impact sports after 8 months.

The clinical results of the STA peg procedure include limitation of pronation and reduction of heel valgus (Figs. 8, 9). Radiographic results

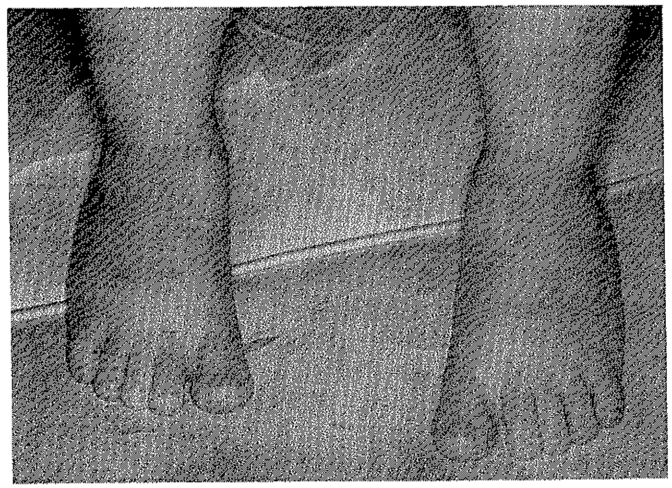

Figure 9. Postoperative view showing increased arch height, decreased forefoot abduction, and decreased calcaneal valgus.

of STA peg arthroereisis include decreased talar declination, increased calcaneal inclination, and increased articulation of the talo-navicular joint (Figs. 10 and 11). In the long term, these improvements in position create the potential for preventing secondary changes that may occur with excessive pronation. These include painful degenerative joint disease and deformities such as metatarsus primus elevatus, hallux limitus, hallux valgus, hammer digit syndrome, and metatarsalgia.

There are several advantages of the STA peg procedure compared to other flatfoot procedures. Unlike many other surgical procedures designed to treat flexible flatfoot, the STA peg can be used early. Postoperative immobilization is unnecessary after the STA peg, and the results can be expected to improve with continued growth of the patient. This procedure is technically easier to perform than many other flatfoot procedures.[9]

A number of complications have been observed. These including detritic synovitis,[9] dislocation of the implant, failure to correct,[20] subtalar joint arthritis,[20] sinus tarsi syndrome, peroneal spastic flatfoot,[9] and intraosseous cyst formation.[21] The complication rate varies from surgeon to surgeon.

Smith discussed his results from 27 patients and 53 feet in which he used the STA peg subtalar arthroereisis between 1974 to 1979. He reported that the mean calcaneal stance position decreased from 10.31° to 3.19° everted. Subtalar joint eversion was decreased from a preopera-

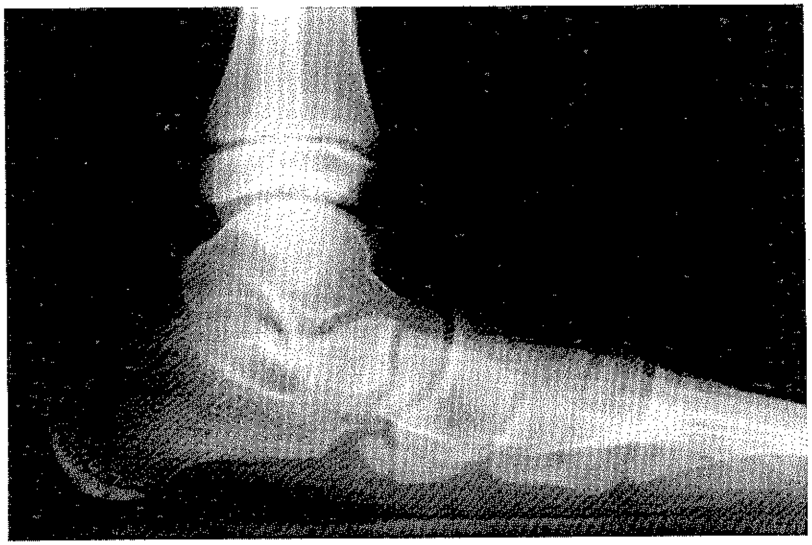

Figure 10. Preoperative radiograph showing increased talar declination, decreased calcaneal inclination angle, and talonavicular fault.

Figure 11. Postoperative radiograph showing improved talar declination angle, increased calcaneal inclination, and decreased talonavicular fault. The position of the STA-peg is also visible.

tive mean of 12.17° to a postoperative mean of 5.83°. Forefoot varus decreased from a mean of 8.40° to a mean of 2.40°. Radiographically, talar declination decreased from 64.25° to 26.10°. At 3 years postoperative, 51 patients were asymptomatic (96.2%) and 2 patients remained symptomatic (3.8%). Complications included pain and swelling in the sinus tarsi and peroneal spastic flatfoot.

Lundeen reported his results from 49 patients, 96 feet, with an average 46-month follow up after implanting the STA peg device. Seventy eight percent reported *good* results (resolution of symptoms and deformity), 19% reported *fair* results (resolution of symptoms, but residual deformity), and 3% reported *poor* results (residual symptoms and deformity).

Tompkins reported on 41 feet in 23 patients treated with the Smith STA peg. He noted a mean decrease in the talar declination angle from 41.73° to 22.26°. Ninety-five percent of his patients were asymptomatic after 1 month. Tompkins categorized his patients as optimum, satisfactory, or unsatisfactory. Twenty-four (58.4%) of patients had optimum results, (defined as patients who were asymptomatic and had calcaneal stance position $< 2°$ valgus, subtalar joint motion $> 30°$, medial longitudinal arch present without mechanical support, and mild or no abnormal radiographic changes). Fifteen (36.6%) of his patients had satisfactory

Table 1. RESULTS OF STA PEG PROCEDURES OF 46 PATIENTS (90 FEET), FROM 1983–1996. ALL RESULTS ARE BASED ON SURGICAL CASES IN WHICH THE STA PEG WAS THE ONLY PROCEDURE PERFORMED

Patient	Age	Foot	Preop Pain	Preop RCV	Postop Pain	Postop RCV	Complications
1	10	R	6	13	0	1	0
		L	6	13	0	2	0
2	6	R	8	15	0	2	0
		L	7	13	0	2	0
3	9	R	5	11	0	2	0
		L	3	13	0	1	0
4	11	R	6	10	1	1	0
		L	6	9	0	1	0
5	11	R	9	14	0	2	1*
		L	6	12	0	2	0
6	9	R	5	16	0	2	0
		L	5	12	0	1	0
7	8	R	6	10	0	1	0
		L	5	10	0	1	0
8	7	R	9	3	0	1	0
		L	5	8	0	2	0
9	9	L	8	8	0	0	0
10	9	R	8	14	0	1	0
		L	7	12	0	2	0
11	10	R	9	15	0	0	0
		L	8	12	0	1	0
12	12	R	7	14	0	2	0
		L	7	12	0	2	0
13	11	R	8	7	0	1	0
14	13	R	6	9	0	1	0
		L	5	13	0	1	0
15	10	R	7	16	1	1	0
		L	7	12	0	1	0
16	9	R	7	12	0	2	0
		L	4	12	0	2	0
17	9	R	6	15	0	2	0
		L	4	12	0	2	0
18	10	R	9	14	0	2	0
		L	7	13	0	0	0
19	11	R	5	13	0	1	0
		L	4	12	0	3	0
20	12	R	9	13	0	1	0
		L	8	12	0	1	0
21	8	R	8	7	0	2	0
		L	8	6	0	0	0
22	7	R	7	12	0	2	0
		L	7	8	0	2	0
23	6	R	5	17	0	2	0
		L	5	15	0	1	0
24	9	R	6	14	0	2	0
		L	5	12	1	0	0
25	13	R	6	7	0	2	0
		L	5	6	0	0	0
26	11	R	9	12	0	2	0
		L	6	14	0	1	0

Table 1. RESULTS OF STA PEG PROCEDURES OF 46 PATIENTS (90 FEET), FROM 1983–1996. ALL RESULTS ARE BASED ON SURGICAL CASES IN WHICH THE STA PEG WAS THE ONLY PROCEDURE PERFORMED *Continued*

Patient	Age	Foot	Preop Pain	Preop RCV	Postop Pain	Postop RCV	Complications
27	12	R	8	13	0	2	0
		L	8	12	0	2	1**
28	10	R	8	13	0	2	0
		L	7	12	0	1	0
29	12	R	6	8	0	2	0
		L	6	7	0	1	0
30	8	R	6	16	0	2	0
		L	6	15	0	3	0
31	6	R	4	17	0	2	0
		L	4	15	0	3	0
32	12	R	5	14	0	1	0
		L	4	12	0	1	1***
33	11	R	6	10	0	2	0
		L	6	9	0	2	0
34	10	R	8	13	0	1	0
		L	7	12	0	1	0
35	11	R	8	10	0	2	0
		L	6	10	0	2	0
36	11	R	6	16	0	0	0
		L	5	14	0	1	0
37	7	R	6	12	0	2	0
		L	6	11	0	1	0
38	9	R	5	15	0	2	0
		L	5	15	0	1	0
39	13	R	9	14	0	3	0
		L	8	11	0	2	0
40	10	R	6	5	0	2	0
		L	6	5	1	2	0
41	12	R	5	8	0	2	1****
		L	6	9	0	2	0
42	11	R	5	12	0	2	0
		L	5	11	0	3	0
43	10	R	6	12	1	2	0
		L	7	15	0	1	0
44	10	R	9	16	0	2	0
		L	9	17	0	2	0
45	11	R	6	7	0	1	0
		L	5	5	0	0	0
46	9	R	5	10	0	1	0
		L	6	9	0	1	0
Averages:	9.9		6.4	11.7	0.1	1.5	4.4%

Table key:
Pain was rated on a scale of 0 to 10
RCV = Resting Calcaneal Valgus
Complications:
*superficial wound dehiscence
**7 months postop, patient dislocated implant caused by trauma, and implant was subsequently removed. Patient also developed ganglion cyst at incision site.
***superficial wound dehiscence
****prolonged swelling, resolved after 4 months

results. These patients were asymptomatic, but had calcaneal stance < 5° valgus, moderate arch with or without the use of mechanical support, subtalar joint range of motion > 20°, and moderate radiographic changes. Unsatisfactory results were persistent pain or stiffness, lack of correction requiring repeat surgery, or severe pathological radiographic changes. Tompkins related that 2 (4.9%) patients had unsatisfactory results.

From 1983 to 1996, the authors performed arthroereisis using the STA peg on 46 patients for a total of 90 feet (Table 1). In each of the cases included in this study, the STA peg arthroereisis was the only procedure performed. The average age of patients included in this study was 9.9 years (range 6 to 13 years). Preoperatively, resting calcaneal stance position averaged 11.7° of calcaneal valgus. Pain was rated on a scale ranging from 0 to 10, where 0 was no pain, and 10 was maximum pain. The pain rating ranged from 4 to 9, with an average of 6.4. Following STA peg arthroereisis without any additional procedures, resting calcaneal stance position averaged 1.5°. The postoperative pain rating averaged 0.1 (range 0 to 1). There was a complication rate of 4.4%. Two patients had postoperative wound dehiscence that healed uneventfully. One patient had prolonged swelling, lasting approximately 4 months before completely resolving. The last complication involved a traumatic incident that occurred 7 months after surgery. After twisting her ankle, the patient dislocated the STA peg. It was subsequently removed. This patient also developed a ganglion cyst at the incision that necessitated excision.

Even in the older child, these results show a high rate of success when using the STA peg as an isolated procedure. All of the patients in this study underwent conservative care preoperatively, consisting of orthotics, strengthening exercises, and the use of appropriate shoe gear. It was only after conservative care failed to relieve their symptoms that the STA peg arthroereisis was used to treat their symptomatic hypermobile flatfoot.

While there are many procedures for addressing the pediatric pes valgo planus, the STA peg procedure has proven to be a biomechanically sound procedure for addressing this deformity. This procedure has been used for over 20 years with high efficacy and few complications.

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