LONG TERM FOLLOW-UP OF THE FLAKE-AUSTIN ARTHROEREISIS (MODIFIED STA-PEG)

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INTRODUCTION

"Flatfoot" is a lay term depicting the external appearance of a low arched foot, which in some people may be normal.[1] A more explicit term is collapsing pes valgo planus. This concisely describes a pathologic state wherein abnormal motion occurs in the hind foot in the direction of pronation. There is subsequent eversion of the heel and collapse, subluxation, and flattening of the medial arch.[2-4] The vast majority of these flexible flatfeet can be controlled with functional orthotics, but the worst deformities that are recalcitrant to conservative treatment may require surgical intervention. This study was undertaken to evaluate the Smith design and Lundeen modification of the STA-peg arthroereisis procedure (Flake-Austin technique) in treating the more significant forms of collapsing pes valgo planus.

Much controversy exists regarding the treatment of collapsing pes valgo planus foot deformity in children. Many physicians and pediatricians feel that all kids have flatfeet and that they will "grow out of it". Those

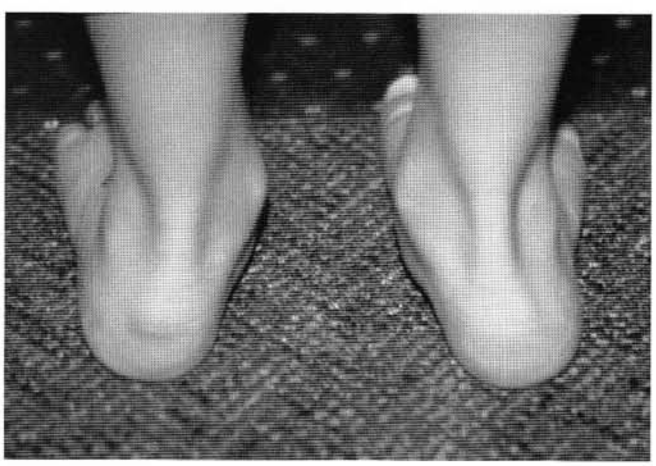


Figure 1. Posterior view of pes plano valgus foot type: everted heel, flattened arch, internally rotated leg resulting in a medially located ankle relative to the heel.

physicians without the knowledge of the devastating results of this deformity in adulthood would opt to do nothing so as to "do no harm". It is known that most kids under the age of 3-5 years of age have an under-developed neuromuscular and skeletal system. For these kids normal maturation of the arch structure with growth can be expected.[5,6] The ability to identify those kids with severe subluxing pronatory forces from those with under-developed "normal" foot types must be developed.

Clinically this can be evaluated in the standing child (Figure 1). Although there is no single clinical finding for symptomatic juvenile flatfoot condition, medial deviation of the ankle relative to the calcaneus is an excellent start. A correlation of the physical examination with positive radiographic findings is commonly used. The physical examine may include a normal appearing foot non weight bearing which collapses on weight bearing with loss of the medial arch; calcaneal valgus (heel eversion usually >6 degrees); midtarsal abduction; a positive Huebscher maneuver (toe extension of Jack); forefoot varus; and a possible gastrocnemius equinus.[1,2,6,7] In the more severe pronating child, the medial positioning of the ankle versus the everted rear foot will be significant. This will differentiate the more normal position of the ankle over the rear foot and calcaneus in spite of the foot being flat. The option of not treating these patients may be doing more harm, by condemning the individual to pain and suffering later.[1,2,3,8]

At a minimum, functional orthoses to allow as normal an osseous and soft tissue development is logical. The prime indication for performing surgery on hyperpronated feet is the presence of significant symptomatology, although this may be subtle in the growing child. In a pediatric patient, this may include those parameters outlined by Smith.[1]

These may present as persistent "growing pains," leg or night cramps, arch pain and fascitis, apophysitis, shin

Figure 2. Dorsal plantar x-ray in pronated relaxed stance position

Figure 3. Lateral x-ray in pronated relaxed stance position.

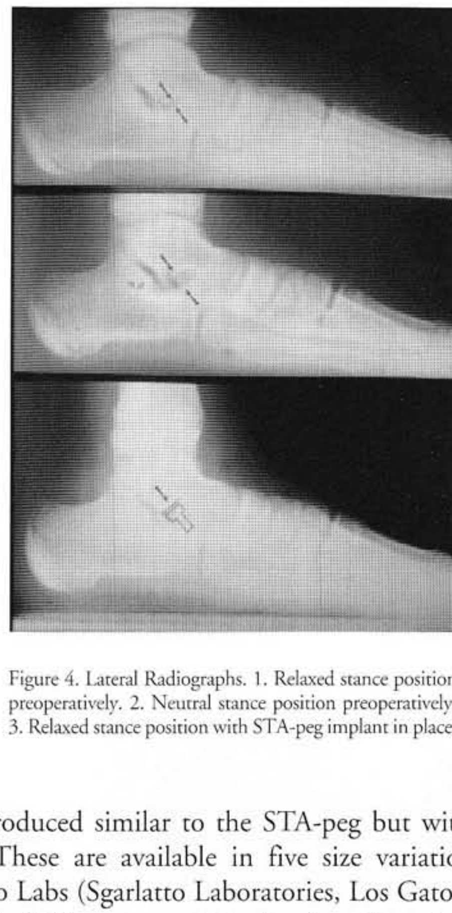


Figure 4. Lateral Radiographs. 1. Relaxed stance position preoperatively. 2. Neutral stance position preoperatively. 3. Relaxed stance position with STA-peg implant in place.

splints, low back or knee pain. These symptoms may not be expressed by the child complaining of pain but may be identified as athletic abstinence, sedentary hobby pursuits, walking intemperance. Parents may also seek attention for their children after noticing signs of abnormal foot appearance, abnormal walking patterns, or abnormal shoe wear.

Weight bearing radiographs show peritalar subluxation or an increased talocalcaneal angle on the dorsoplantar view with uncovering of the talar articular surface (positive medial deviation) (Figure 2). The lateral view shows a plantar deviation of the talus as well as "faulting" or a breach either at the naviculocuneiform or talonavicular joints (Figure 3). Neutral position x-rays are often utilized to better evaluate the flexible flatfoot (Figure 4). The dorsal plantar and lateral x-rays are taken with the foot held in a neutral subtalar joint stance position. This will help to demonstrate the flexible nature of the foot and the potential position of function postoperatively.[1,4,8,9]

Smith et al designed the subtalar arthroereisis (STA-peg) in the early 1970s. Smith and Miller presented the first reported results in 1983.[1] Lundeen described similar positive results in 1985.[10] The implant is made of an ultra high molecular weight polyethylene disk and stem. Since 1984, the peg has been available from Dow Corning Wright (Dow Corning Wright, Arlington, TN) in straight and angled version, with five size variations. (Figure 5) Recently the Lundeen Subtalar Implant (LSI) was introduced similar to the STA-peg but with longer stems. These are available in five size variations from Sgarlatto Labs (Sgarlatto Laboratories, Los Gatos, CA).

The STA-peg was originally placed into the floor of the sinus tarsi in such a manner that the leading edge of the posterior facet of the talus would glide up onto the disc to block the forward progression and depression of the body of the talus. This would prevent excessive pronation (Figure 6). Those patients with an increased subtalar joint axis and a transverse planar dominant foot type would have a tendency for the talus to glide up over the STA-peg implant, lessening its affect when placed using this traditional Smith technique.

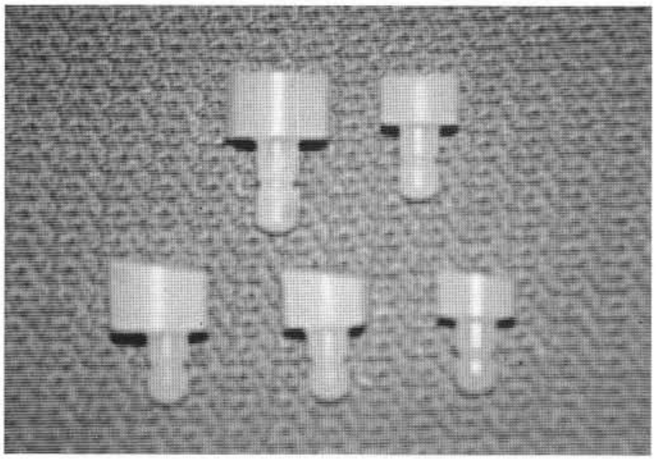


Figure 5A. STA-Peg sizes.

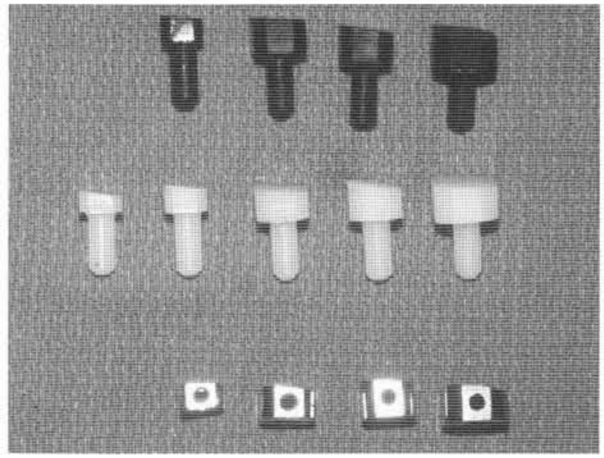


Figure 5B. Lundeen Subtalar Implants (LSI).

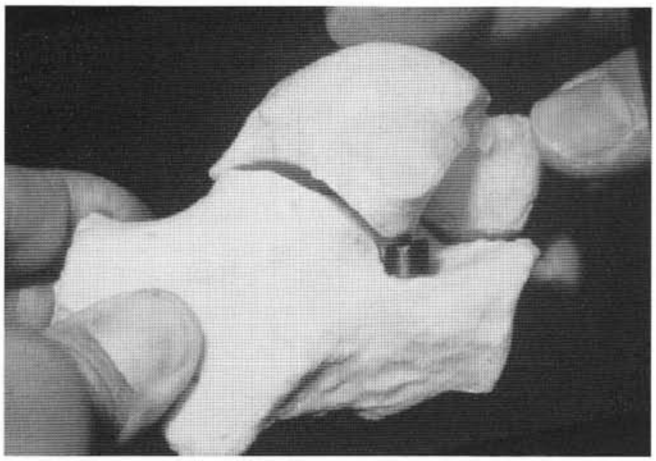


Figure 6. Model of right talus and calcaneus with the STA- peg perpendicular in the sinus tarsi. This blocks the forward progression of the lateral talar facet as it rides up on the STA-peg in pronation.

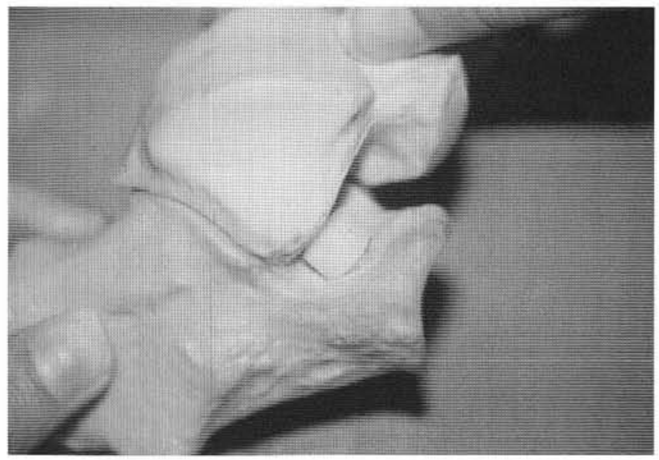


Figure 7. Model of right talus and calcaneus with the STA-peg angled in the calcaneus so that the surface of the peg abuts the leading wall of the posterior face of the talus in a flush manner in pronation.

Flake and Austin[2,3] have modified the placement of the implant. They placed the STA-peg in the sinus tarsi so that the flat surface of the disc will allow the most flush approximation to the lateral leading wall of the posterior facet of the talus. This usually is approximately a 45 degree angle (Figure 7). This not only prevents forward progression but also prevents adduction and depression of the talus on the calcaneus. The Flake- Austin technique would especially block the adduction rotation of the talus in the transverse planar dominant foot type.[2,3,11]

MATERIALS AND METHODS

Medical records of 125 patients treated for juvenile collapsing pes valgo planus Representing 250 STA-peg type operations have been performed by authors DG and EF since 1982. More recently, the Lundeen Subtalar Implant (LSI) modified STA-pegs with the longer stems have been utilized. A parent /patient questionnaire was sent to patients with at least one-year follow-up. Forty-four patients responded; 23 males and 21 females representing 87 STA-peg procedures. Ages at the time of surgery ranged from 4-20 years with an average of 9 years old. The follow-up period ranged from 1-16 years with an average of 6.5 years.

Six patients had ancillary procedures. Three patients had 4 kidner procedures, 1 patient had bilateral TALs and 2 patients had 3 McBride bunionectomies and epiphyseal staplings.

RADIOGRAPHIC METHODS

The radiographic evaluation included preoperative, post-operative DP (AP) and lateral radiographs. Angles on the DP included: talocalcaneal (Kite's) angle, calcaneal cuboid angle, talar 1st metatarsal angle, metatarsal

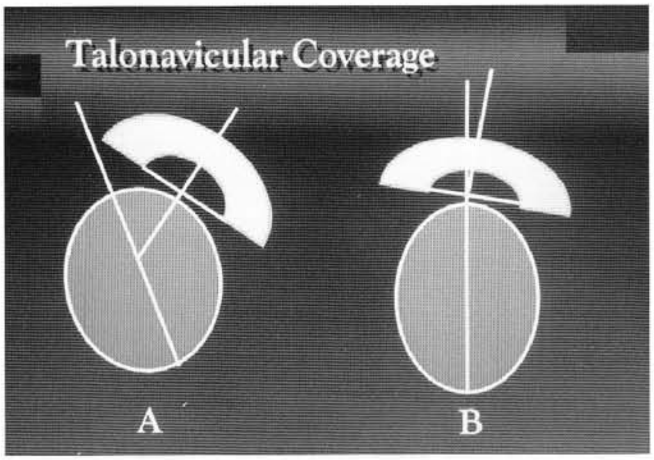


Figure 8. Talonavicular coverage angle

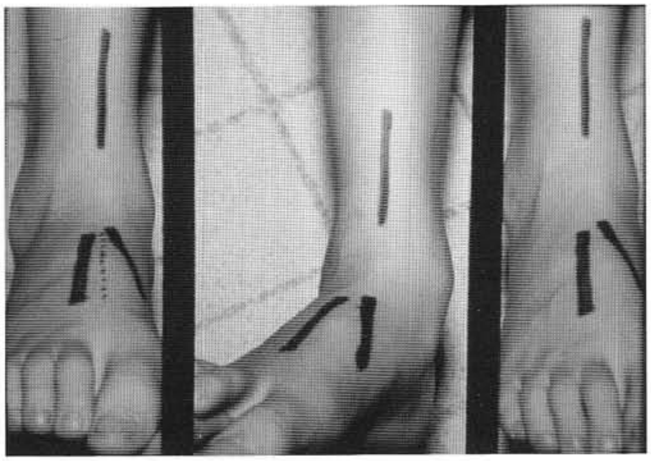


Figure 9. A. Foot in neutral subtalar joint position. The leg line is drawn on the distal anterior aspect of the leg. The foot line is an extension of the leg line in the neutral position. B. Foot in maximally pronated subtalar joint position. The foot line is an extension of the leg line in the maximally pronated position. C.The dotted line is an extension of the leg line with the foot mildly pronated. This is the desired position to hold the foot with the STA-peg.

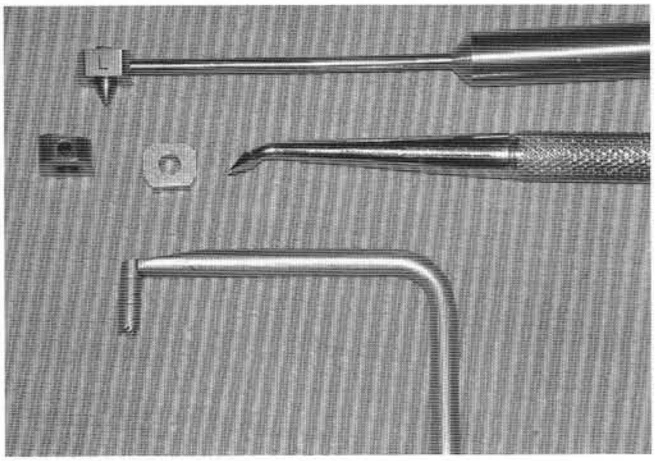


Figure 10. Instruments: A. Template with metal spike in central hole attached to the handle. B. Template heads (with capacity to screw into handle) that equal disk shapes for LSI implants. There is a central hole for the awl if necessary. C. Awl for deepening hole for implant stems. D. Right angled trephine precisely equal to stem size.

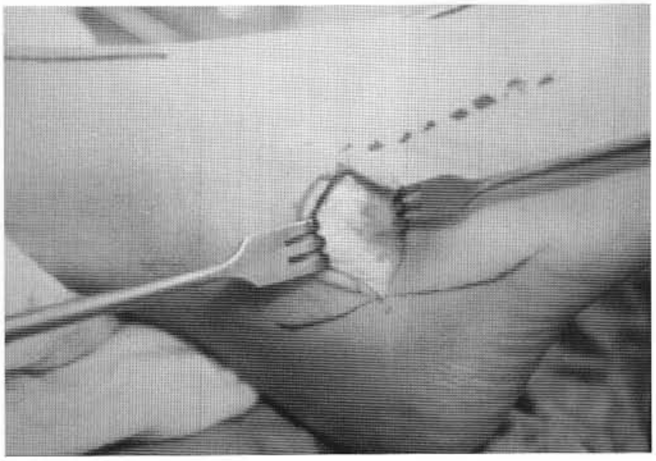


Figure 11. Ollier incision made along the skin lines over the lateral sinus tarsi between the intermediate dorsai cutaneous nerve and the peroneal tendons on a right foot. The foot is to the right and the leg is to the left.

adductus angle, forefoot adductus and the talar navicular coverage angle. (Figure 2)

An angular measurement was used in this study for the talonavicular coverage angle (Figure 8). The longitudinal axis of the talus was drawn. A line was then drawn connecting the edges of the articular surface of the navicular. A perpendicular line was then drawn bisecting the midline of the articular surface line. The angle formed by the longitudinal axis of the talus and the perpendicular bisection of the navicular articular surface was considered the talonavicular coverage angle.

Measurements taken from the lateral x-ray included the calcaneal inclination angle; talar declination angle; lateral talocalcaneal angle; navicular height; and sinus tarsi occlusion (Kirby sign)[12] (Figure 3). Sinus tarsi occlusion is a radiographic change that can indicate abnormal pronation. This measured the distance between the leading edge of the posterior facet of the talus and the superior aspect of the floor of the calcaneus in the resting calcaneal stance position. When this distance was 0, the sinus tarsi was occluded demonstrating a maximally pronated subtalar joint and a positive Kirby sign.

Thirty-three children for a total of 66 feet had preoperative and postoperative x-rays available for review. There were 14 females and 19 males ranging in age from 4-17 years old with and average age of 8 years. The follow up period was from 1-13 years with an average of 4.5 years. Fifteen of these children representing 30 feet were available for biomechanical evaluation. Results and comments concerning biomechanical findings will be directed toward postoperative results. This was due to inconsistent preoperative data.

SURGICAL PROCEDURE

Alignment markers are mapped out by drawing a straight line on the anterior aspect of the leg. The line is extended on to the dorsum of the foot with the foot in neutral position. A second line is extended on to the dorsum of the foot with the foot in a maximally pronated position. When evaluating the size and location of the STA-peg, pronation against the implant should allow the foot to line up between these two lines (Figure 10). This will allow some pronation while eliminating excessive pronation. Over correction should be avoided or postural symptoms such as lateral heel pain, and jolting gait pattern may ensue. Consequently, some mild amount of under correction is expected to remain postoperatively. This procedure is not intended to result in a perfectly normal appearing foot but a better functioning foot.

Attention is then directed to the lateral aspect of the foot where the intermediate dorsal cutaneous nerve and peroneal tendons are identified and marked. The sinus tarsi is then identified and palpated. A modified Ollier incision following the skin lines is made staying between the anatomic markers (Figure 11). Dissection is performed in layers. The deep fascia is identified and a "V" shaped incision is made through it. The vertical incision follows the lateral-leading wall of the talus and the more horizontal incision follows the floor of the sinus tarsi (Figure 12). The deep fascia is then reflected and the fat plug is identified and removed.

The lateral leading wall of the talus, the floor of the calcaneus and the posterior facet of the subtalar joint should be identified (Figure 13). The sinus tarsi ligament deep in the wound is preserved as much as possible.

A template, which has a medium and a small size consistent with the widths of straight STA-peg, is then utilized to determine the proper size of the implant. The template is placed flush against the lateral-leading wall of the talus and the foot is maximally pronated. The

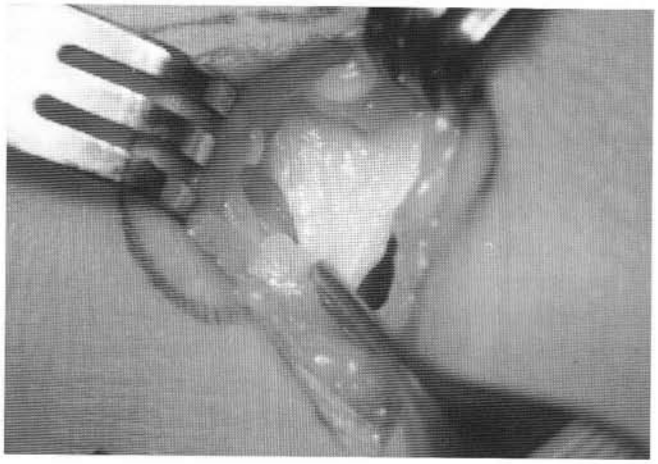


Figure 12. The deep fascia is identified and an "V" shaped incision is made. The vertical incision follows the lateral- leading wall of the talus and the more horizontal incision follows the floor of the sinus tarsi.

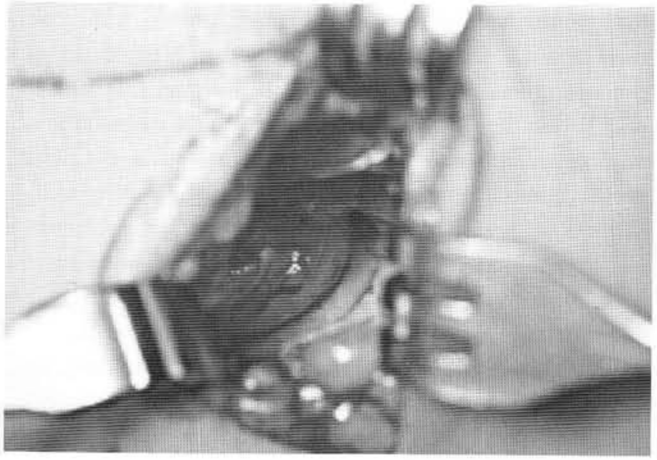


Figure 13. Sinus tarsi cleared off exposing the calcaneal floor of the sinus tarsi and the leading wall of the talus.

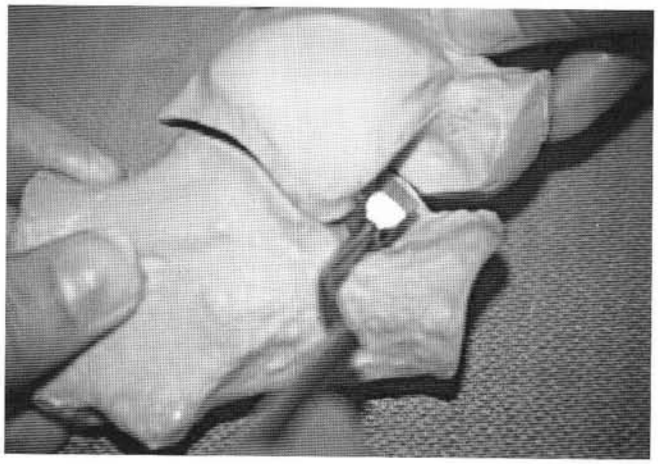


Figure 14. The template of various sizes is held flush against the leading wall of the talus in the sinus tarsi. The foot position is checked in front while the subtalar joint is maximally pronated against the template to insure proper size of the implant.

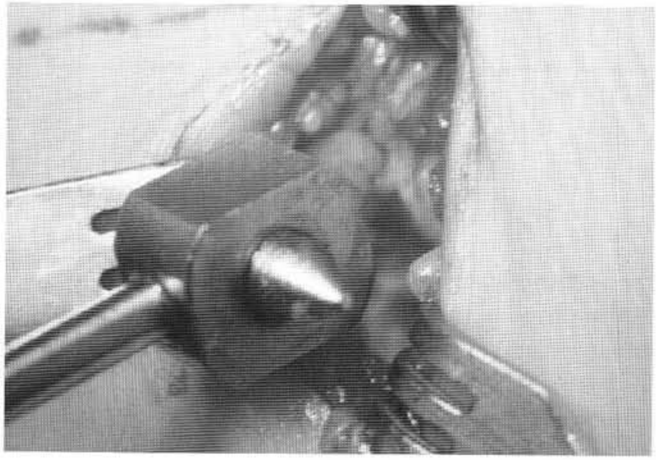


Figure 15. The template with the metal spike in the center is inserted. The subtalar joint is pronated against the template to determine the location and direction of the stem hole. The hole is then deepened with the awl.

alignment markers are then checked to assure the appropriate amount of correction has been achieved. The foot is then supinated and the template is replaced with one that has a metal sharp point filling the hole of the template (Figure 15). The appropriate point for insertion of the stem of the implant is marked on the calcaneal floor of the sinus tarsi by pronating the subtalar joint against the template (Figure 14). The template is then removed and the hole is widened and deepened with a sharp awl and curved hemostat or curette. A right-angled trephine is used to deepen the hole to allow for proper size and depth of the stem (Figure 16). A spacer is then seated into the calcaneus for a trial fitting (Figure 17).

The lateral-leading wall of the talus must be flush with the flat disk portion of the implant when the foot is maximally pronated (Figure 18). The angled implant is often utilized to get this flush fit. Once the appropriate size implant is determined, the sizer is removed and the implant is seated. The amount of excess pronation is eliminated, but supination remains available.

If the implant is not secure and moves in the calcaneus or if the dorsal aspect of the implant is not flush with the lateral-leading wall of the talus, methyl methacrylate may be needed to secure this position. This is usually not required. Care should be taken not to have excessive methyl methacrylate in the sinus tarsi. The wound is then flushed with normal saline and is closed in layers. It is important that no soft tissue is interposed between the seating of the implant and the calcaneus or interposes between the talus and the disk aspect of the implant.

Many times ancillary procedures are required. Children with a gastrocsoleus equinus require a tendoAchillies lengthening. Children with significant gastronemius equinus require a gastrocnemius recession. Older children with severe pronating forces leading to subluxation may need reconstruction of the medial arch. Depending upon the age of the patient and amount of deformity, additional soft tissue and or bony auxiliary procedures may need to be performed.

POSTOPERATIVE CARE

The postoperative care consists of immediate weight bearing in a surgical shoe and compressive dressing for two weeks if the Flake-Austin STA-peg procedure is done as an isolated procedure. Early range of motion is started and the patient may return to a soft-soled shoe in two weeks. Peroneal longus strengthening exercises are also started. The patient is told not to run or jump for three months and normal vigorous sports activity can start in six months.

SUBJECTIVE RESULTS

Two questions were asked concerning patient satisfaction. The first question asked if chief complaints were satisfactorily resolved (Table 1). Ninety percent (40/44) of the patients were over 70% improved. Two of the 44 patients, felt that their signs and symptoms were over 50% improved. Another two patients felt that their signs and symptoms were less than 50% improved. These two patients included one patient whose arch pain and pain with walking and standing remained unresolved. The second patient denied any pain in her feet but complained that her hammertoes had worsened since her surgery.

The second question asked about overall satisfaction (Table 2). Forty-two of 44 stated they were pleased with their STA-peg implants and would recommend the procedure. Two patients stated they were displeased with the procedure and were the same two patients that felt that their symptoms were less than 50 percent improved. These were the only two patients that would not recommend the procedure.

Table 1

CHIEF COMPLAINTS SATISFACTORILY RESOVLED

Very strongly, agree (90% or more improved)	32(72%)
Strongly agree (70% improved)	8 (18%)
Agree (50% improved)	2 (5%)
Disagree (less than 50% improved)	2 (5%)
Strongly disagree (minimal improvement, worse)	0

Table 2

OVERALL SATISFACTION

Very pleased (would highly recommend)	32(70%)
Pleased (would recommend)	10(25%)
Displeased (would not recommend)	2(5%)

In the subjective questionnaire, the patient indicated what signs and symptoms were present preoperatively and postoperatively. This is indicated, in Table 4, which gives the percent of specific signs and symptoms preoperatively and postoperatively. The symptoms ranged from night cramps, arch pain, pain with walking or standing, to lower back and/or knee pain. The signs ranged from resistance to prolonged walking, fallen arches, inability or lack of desire to participate in sports, abnormal shoe wear to clumsiness. These signs and symptoms were then rated as severe, moderate or mild. In our study, the percent of complaints were drastically decreased. Of the 277 preoperative subjective signs and symptoms that were reported 111 were rated as severe, 112 moderate and 54 as mild. Postoperatively, 106 subjective signs and symptoms were reported with only 6 being severe, 31 moderate and 69 mild (Table 3). Thus, over 87% of the preoperative signs and symptoms were reduced or eliminated.

Dramatic improvements in subjective signs and symptoms postoperatively were recorded (Table 4). Of the 111 severe signs and symptoms reported preoperatively, 107 had reduced postoperatively with 28 reducing to mild, 15 reducing to moderate and 64 reducing to no symptoms at all. Four signs and symptoms remained severe in 3 patients. Two patients stated their feet remained severally flat but denied any pain with activity. One patient complained of arch pain, and pain with walking and standing that never resolved. This is one of the two patients whose symptoms were not reduced by at least 50%.

Table 3

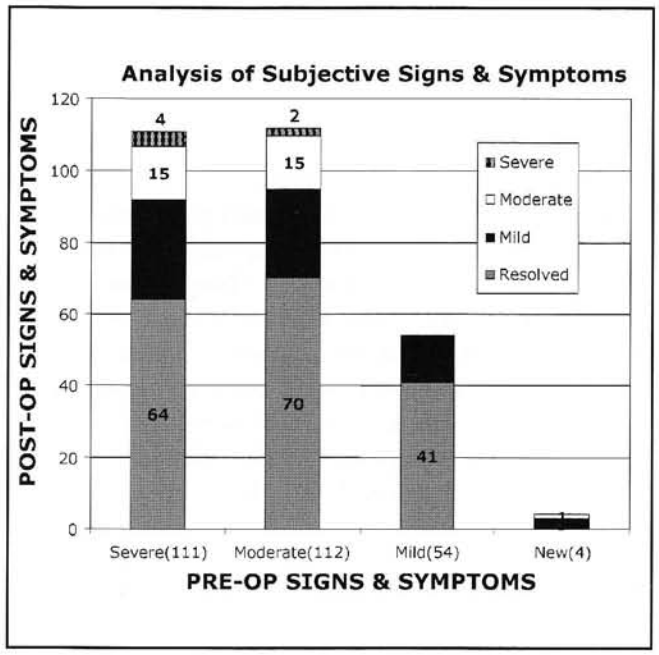
PATIENT QUESTIONAIRE

Signs & Symptoms	Preoperatively	
Postpone		
Night cramps	51%	14%
Pain walking / standing	78%	34%
Fallen Arches	90%	36%
Lower Back and/ or knee pain	63%	26%
Resistant to prolonged walking	87%	34%
Inability or lack of desire To participate in sports	73%	17%
Abnormal shoe wear	92%	19%
Decreased coordination	73%	24%
Arch pain	75%	17%
Total Symptoms	**Pre-op= 277**	**Post-op= 106**

One hundred and twelve subjective signs and symptoms were initially reported as moderate with 110 reducing or remaining the same. Two moderate symptoms increased to severe and represents two patients. These two patients both had initially complained of mild arch pain that had resolved and were pain free for several years. Both are young men that have been active in sports. The first patient is 12 years postoperative, and recently started high school wrestling doing a considerable amount of running at workouts. He states he notices the pain after long workouts.

The second patient is 16 years postoperative and was very active in highschool sports without problems. The patient is currently working as an auto mechanic and states his arches will ache after long days on his feet. Both of these patients initially used orthoses post-operatively but had since grown out of them and had not returned to their surgeon for another pair. Both patients were referred back to their podiatric physician for orthoses.

Table 4



*Severe signs or symptoms remaining unresolved three patients:** Two patients denied pain but complained their feet remained flat. One continued to have pain while walking and standing.

*Moderate signs or symptoms worsening to severe involved two patients:** Both patients stated that symptoms had resolved postop for several years. Both are very active young men and complain of severe arch pain after several hours of running in high-school athletics and the other after standing 10 hrs days as an automachanic. Both patients had grown out of their orthotics.

*New signs and symptoms involved two patients:** One patient was initially treated for mild arch pain to her left foot only. She denied pain to her left foot at 6 years postoperatively. She felt her feet remained flat and the implant had contributed to the progression of her hammertoes. The other patient had been asymptomatic for 9 years post-operatively until a recent ankle sprain that continues to cause lateral ankle/sinus tarsi pain.

The mild subjective signs and symptoms preoperatively also showed dramatic improvements. Of the 54 mild symptoms preoperatively, 41 resolved and 13 remained unchanged postoperatively.

Four new signs and symptoms were reported postoperatively. One patient was 12 years postop and had been symptom free being very active in high school sports up until one year prior to the examination. The patient had sprained her ankle and the lateral ankle pain had not resolved. She is further discussed under complications. The other patient reported that her hammertoes previously present before surgery had worsened. This patient was initially treated for mild arch pain to her left foot only. She denied pain to her left foot at 6 years postoperatively but felt her feet remained flat and the implant had contributed to the progression of her hammertoes. This is the second patient that did not feel that her signs and symptoms had reduced by at least 50%.

RADIOGRAPHIC RESULTS

The Kite's angle preoperatively was 23.78 degrees and 17.04 degrees postoperatively resulting in a decrease of 6.74 degrees. The talonavicular coverage angle decreased from 23.92 preoperatively to 10.12 postoperatively for a reduction of 13.80 degrees. The calcaneal cuboid angle measured 11.28 preoperatively and 8.3 postoperatively reducing almost 3 degrees. The talar first metatarsal angle went from 9.84 degrees to 3.89 pre and post operatively for a change of approximately 6 degrees. The metatarsal adductus angle had no significant change (preop 15.89, postop 15.67). The forefoot adductus angle went from 8.87 to 10.81 for an increase of almost 2 degrees (Table 5).

The talar declination angle showed a mean decrease of 4.67 degrees, decreasing from 24.50 degrees preoperatively to 19.83 degrees postoperatively. The calcaneal inclination angle as expected changed very little. Preoperatively it measured 17.23 degrees and postoperatively 17.00 degrees for a mean decrease of .23 degrees. The lateral talocalcaneal angle preoperatively was 41.61 degrees and postoperatively was 37.03 degrees decreasing 4.58 degrees. The sinus tarsi occlusion measured 3.49 mm preoperatively and 6.67 postoperatively for a change of 3.18 mm. The navicular height pre-operatively was 23.50 mm and measured 30.69 postoperatively increasing on average of 7.19 mm. (Table 6)

BIOMECHANICAL EVALUATION

One patient (discussed under complications) was found to have pain with palpation and range of motion of the subtalar/ankle joint. No patients were found to be overcorrected. Subtalar range of motion averaged 29.6 degrees (range 20- 47 degrees). Average subtalar joint-inversion was approximately 23 degrees (range 15-35 degrees). Subtalar joint-eversion averaged 6.5 degrees (range 4-12). Resting calcaneal stance position was 2.43degrees everted (range 0-5everted). (Table 7)

Table 5

RADIOGRAPHIC RESULTS, A.P.

Angles	Preop	Postop	Diff
T-C angle(Kite's)	23.78	17.04	6.74
T-N Coverage angle	23.92	10.12	13.80
C-C angle	11.28	8.34	2.44
Talar/1stMet angle	9.84	3.89	5.95
Met.Adductus angle	15.89	15.67	NC
FF. Adductus angle	8.87	10.81	1.94

Table 6

RADIOGRAPHIC RESULTS, LATERAL

Angles	Preop	Postop	Diff
Talar Declination	24.50	19.83	4.67
Calcaneal Inclination	17.23	17.00	.23
Lateral T-C Angle	41.61	37.03	4.58
Sinus Tarsi(mm)	3.49	6.67	3.18
Navicular Height(mm)	23.50	30.69	7.19

Table 7

BIOMECHANICAL EXAM RESULTS (FOLLOW-UP ONLY)

Parameter	Average/range (degrees)
Total subtalar joint ROM	29.6 (Range: 20-47)
Subtalar joint-eversion	6.5 (Range: 4-12)
Subtalar joint-inversion	22.9 (Range: 15-35)
Resting Calcaneal Stance Position	2.43 (Range: 0-5E)

Sample Size No. of Feet: 30

COMPLICATIONS

Since the introduction of subtalar implant arthroereisis, several studies have reported on the complications that may be involved in the procedure.[1,10,13,14,15,16] There were three cases with complications in our study group.

One patient developed peroneal spasm and pain after playing soccer and having a ball forcibly smack into the dorsolateral aspect of his right foot 5 months post-operatively bilateral STA-peg arthroereisis. The patient gradually developed worsening symptoms in the right foot while the left foot remained asymptomatic. When conservative measures failed to relieve the peroneal spasm on a permanent basis, exploratory surgery was done one year postoperatively. A 2mm ledge of talar bone was noted contouring to the deep border of the implant (Figure 19). The ledge of bone was removed and the implant was inspected and found to be seated well without loosening. The implant was left in place. The patient is now 10 years out from original surgery very active and happy with his implants on both feet.

Our second patient received implants in an attempt to improve painful pronatory symptoms secondary to a congenital familial malformation arthropathy. Her overall symptoms improved initially once her temporary sinus tarsi pain resolved with several sinus tarsi injections. She significantly improved her walking ability but never was able to engage in vigorous activities such as sports. Thus, she was included as a complication. Her implants were both removed 7 years later at the age of maturity. She is now 3 years out from implant removal. She states that she still has occasional sinus tarsi pain but feels that she has improved even more since the STA-pegs have been removed. She feels that the implants did help reduce her symptoms significantly and would recommend the procedure to others (Figure 20).

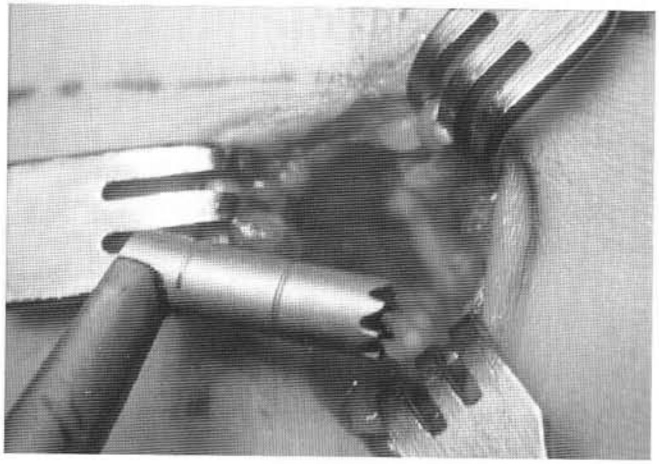


Figure 16. The stem hole is deepened and contoured to the appropriate size and direction with the right angled trephine.

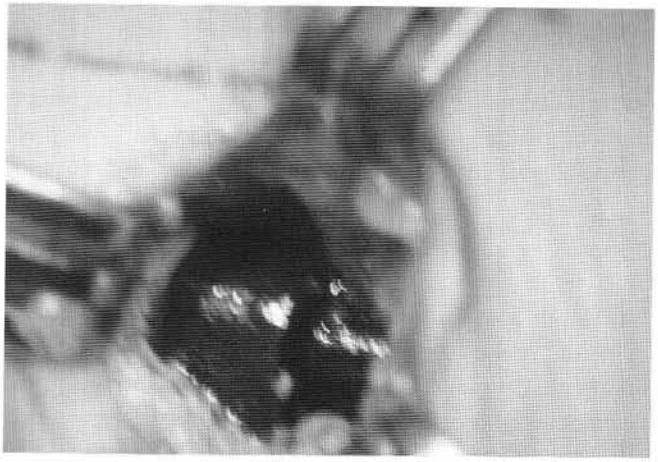


Figure 17. The STA-peg trial spacer is inserted into the floor of the sinus tarsi and the foot is maximally pronated, demonstrating a flush fit of the spacer and the leading wall of the posterior facet of the talus.

Figure 18. The trial spacer is removed and the appropriate sized implant is inserted into the floor of the sinus tarsi ensuring a flush fit against the leading wall of the talus.

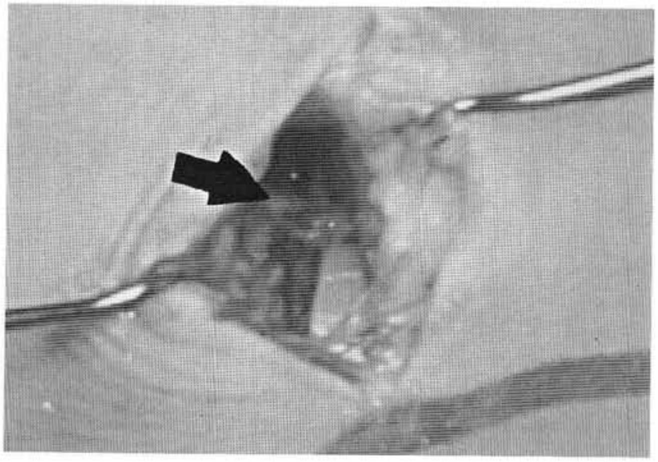


Figure 19. Complication I: Sinus tarsi with STA-peg in place. The deep talar exostosis is contoured to the dorsal deep aspect of the STA-peg which is marked with an arrow. This had led to the peroneal spasm.

The third patient is a 21-year-old female who was 9 years old when bilateral STA-pegs were placed. She has been a very active athlete throughout high school and college and was symptom free until one year ago. She relates a history of significantly spraining her left ankle, which has been recalcitrant to treatment. She complains of tenderness in the posterior lateral part of her ankle and in the sinus tarsi area with associated lateral ankle instability. X-rays show a fractured posterior process of the talus and osteophyte formation in the anterior ankle area, with mild sclerosis in the area of the STA-peg (Figure 18).

CT scan showed the implant on the symptomatic side had been impacted into the body of the calcaneus with considerable wear and small cystic formation in the talus (Figure 19). The right side showed a well-seated implant in the correct position. Recommendations were to have exploratory surgery of the posterior talar process with possible removal of the implant and debridement of synovial and bony hypertrophy. She felt the implants had made a great improvement to her physical abilities and would still recommend the procedure to others.

As stated from the subjective questionnaire, two patients said they would not recommend the STA-peg procedure to others. At the writing of this paper, both were unavailable for further questioning and physical examination.

DISCUSSION

Numerous procedures have been described for the correction of collapsing pes valgo planus. The surgical approaches include: soft-tissue procedures;[17,18] bony procedures with osteotomies;[19-25] arthroereisis procedures that affect the subtalar joint motion or axis of motion,[1,10,26-29] or a combination of the three approaches.[8,30]

The arthroereisis concept stems from Chambers who in 1946, used bone graft impacted into the anterior leading edge of the posterior facet of the calcaneus. This prevented excessive anterior displacement of the talus upon the calcaneus and limited abnormal pronation of the subtalar joint[19] The Grice procedure utilized a bone graft in the sinus tarsi to create an extra articular arthrodesis of the talus and the calcaneus.[30] Lelievre and Haraldson also placed a bone graft in the sinus tarsi to block excessive pronation.[31,39]

Baker and Hill elevated the posterior facet utilizing bone graft.[32] Selakovich elevated the sustentaculum tali with bone graft attempting to prevent the talus from adducting and plantar flexing over this area.[25]

The idea of using materials other than bone in the sinus tarsi was first described by Subotnick in 1974.[26] He fashioned conical plugs made of medical grade silastic to block excessive pronation. Prosthetics of various sizes and shapes have since been implanted (Table 7).

Smith in the early 1970s Designed the STA-peg and Lundeen later modified this device. More recently Jerry Maxwell has developed the MBA subtalar arthroereisis (MBA-Maxwell/ Arthroereisi) implant that is made of titanium and screws into the sinus tarsi to block excessive subtalar joint pronation similar to the Valenti polypropylene implant.[33,34]

Christensen et al. using a three-dimensional radiowave tracking system were able to measure individual tarsal movements in all 3 cardinal planes with and without the arthroereisis in a cadaveric study. They confirmed the effects of arthroereisis on limiting pronation and demonstrated that there are distinct independent

Table 8

ARTHROEREISIS SUBTALAR JOINT IMPLANTS HISTORY: PROSTHETIC BLOCKS

Date	Surgeon	Device
1974	Subotnick	Carved Silastic Block
1976	Smith et al.	Polyethylene STA-peg
1976	Valenti	Polyethylene threaded screw
1977	Viladot	Elastomer umbrella
1978	Samuelson	Polypropylene SS2component
1979	Lanham	Swanson hemi-implant stem
1982	Addante	Silastic silicone sphere
1983	Sgarlato	Mushroom-shaped Silastic cap
1984	Pisani	Silastic-capped screw
1985	Lundeen	Polyethylene STA-peg (design)
1995	Maxwell/Brancheau	Cannulated slotted titanium screw

Adapted from: Reconstructive Surgery of the Foot and Leg. Update '98 rotations for each tarsal bone during closed kinetic chain loading of the foot. In their series, the talus externally rotated and dorsiflexed; the navicular inverted and slightly dorsiflexed; the cuboid and calcaneus inverted.[35]

The radiographic results from our series clearly demonstrated a reduction in the pronatory signs seen on the DP (AP) and lateral radiograph. These findings are consistent with Christinson's cadaver studies. This corresponds to our radiographic series in that the calcaneal cuboid angle reduced only mildly and would not be observed significantly on x-ray with motion being predominantly inversion in the frontal plane.

Numerically the largest change occurred in the talonavicular coverage angle. This may suggest that the talonavicular coverage angle as described is a sensitive indicator of the relationship of the hind foot and the midfoot. It also suggests that the talonavicular relationship is important in the pes planus deformity. Strong radiographic evidence of dorsiflexion and external rotation of the talus with slight dorsiflexion of the navicular from the maximally pronated position closely parallels Christensen's publication. These radiographic results demonstrate that with the modified surgical placement of the STA-peg implant, the corrective movement of the tarsus occurs along the same directional supinatory parameters as published data on normal joints.[5,6,7,36-38]

Angles measured on the radiographs were both positional and structural. Positional meaning the angle measured is affected by supination and pronation of the foot. Structural, meaning that the angle measured is not affected significantly by supination and pronation of the foot.[9]

The positional angles measured on the DP (AP) radiograph that normally reduce with supination were the talonavicular coverage angle, talocalcaneal (kites angle), talar 1st metatarsal angle, and calcaneal cuboid angles. The talonavicular coverage, kite's and the 1st metatarsal angle showed the most correction. The calcaneal cuboid angle was only mildly affected. The forefoot adductus angle normally increases with supination. This angle was increased by the STA-peg. The one structural angle measured on the DP x-rays was the metatarsal adductus angle, which showed no significant change. It is interesting to note that in our study the greatest amount of correction was seen in the transverse plane versus the sagittal plane.

The positional angles and signs measured on the lateral radiograph that normally reduce with supination were the talar declination and lateral talocalcaneal angle and sinus tarsi occlusion (Kirby's Sign). Both angles and the Kirby Sign were reduced postoperatively. The navicular height is also a positional indicator that increased postoperatively as was expected. The one structural angle that was measured on the lateral radiograph (calcaneal inclination angle) remained essentially unchanged.[9]

Elftman explained the effect that the subtalar joint position had on the range of motion at the midtarsal joint.[36] He described a congruity (or parallelism) that develops between the axes of the talonavicular and calcaneocuboid joints when the subtalar joint is pronated and an incongruity (or obliquity) that develops when the subtalar joint is supinated. Thus, when the subtalar joint pronates, the midtarsal joint may unlock and allow additional midtarsal motion. When this occurs, the midtarsal joint can collapse at the midfoot with adduction of the rear foot/abduction of forefoot or eversion of the calcaneus/inversion of the leg depending on the planar dominance of the subtalar joint.

In a long-standing unlocked midtarsal joint, the rear foot (talus/calaneus) can sublux plantarly on the forefoot as the heel lifts off the ground in propulsion. This subluxation can lead to a structural decrease in the calcaneal inclination angle overtime.[11] We can see by directly affecting the subtalar joint with a prosthetic, the remaining tarsal segments were also affected causing a significant effect at the midtarsal joint.

Inversion of the calcaneus, navicular, and cuboid relative to the talus are all affecting the properties of the midtarsal joint complex and contribute to the "locking mechanism" of the midtarsal joint that results in midfoot stability in a less pronated position. The locking mechanism places the cuboid in proper alignment and provides a stable fulcrum for the peroneus longus.[36] Smith and Miller felt that correction of the subtalar joint position allows the peroneus longus to more actively

Figure 20. Complication II: X-rays showing congenital familial malformation arthropathy. Notice the irregularity of the bones.

plantarflex the first ray or at least resist dorsiflexion against ground reactive forces. Thus, in the growing child the medial longitudinal arch is maintained by reducing the forefoot supinatus/varus component. A more biomechanically stable foot will result, in adaptive soft tissue and osseous changes. This will manifest itself at skeletal maturity as a more normal appearing foot.[1,13]

There were three other patients that had complications that were not included, as they could not return for this study. In an earlier study that also demonstrated very good results,[2] there was a patient that required removal of both STA-Pegs. She had excessive range of motion and required excessive methyl methacrylate to place the implants. Synovial fluid drained periodically from the sinus tarsi area until the implants were removed. Once the implants were removed, she was no worse off than she was before the surgery. Unfortunately she was unavailable at the time of this study

Another patient was the sister of two patients that were included in the study. She has since moved to Texas. She had severely sprained ankle and dislocated one of her two implants. It was removed but fortunately she had already undergone her adolescent growth spurt. Her sisters reported that she continues to do well on both feet.

The third patient was lost to follow up when her insurance changed. I heard that she was later diagnosed with tarsal coalition and had additional surgery. At the time of the STA-peg arthroereisis procedures, she had full subtalar range of motion. The neutral position x-rays demonstrated a normal position. For over a year, her mother has indicated that she will bring her back in for evaluation when she gets a chance. However, they currently live over an hour away.

CONCLUSION

Our investigation of the Flake-Austin STA-peg arthroereisis procedure, proved to have positive results both subjectively and radiographically. The radiographic results correspond to previous publications confirming the reduction of pronatory effects of subtalar joint arthroereisis. By limiting excessive subtalar pronation in a child of skeletal immaturity, the osseous alignment of the foot will readapt in a more normal attitude. Subjectively patients were very positive about their surgery with most stating that their signs and/or symptoms had resolved or reduced and their activity level had significantly increased. One advantage of the Flake-Austin placement of the STA-peg arthroereisis procedure is that it does not involve placing the STA-peg into an articulating joint. Furthermore the Flake-Austin technique is more effective in transverse planar dominant foot types than the traditional Smith placement technique.

One cautionary note regarding patient, parent and doctor expectations. We do not strive for a perfectly normal appearing foot as we do expect a mildly under corrected foot to allow for some pronation. We do expect a better functioning foot that can be well controlled in functional orthoses. We expect the signs and symptoms to be reduced and that the foot will have a greater potential to mature into a more normal appearing foot especially when the surgery is performed prior to the adolescent growth spurt. It is important that the patients, the parents and the surgeon be on the same page pre operatively. Consequently we encourage the parents to take pictures of their child's feet preoperatively for future reference.

None of our patients where harmed by the implant. Even those two patients who felt that they were not improved significantly were not made worse by the procedure. If complications do arise, the implant is easily removed. We do recommend that the implants be removed at the age of maturity (20-22 years of age) as a precautionary measure as the very long term results of the implants are not well known. However, many patients are reluctant to have this done because they are doing so well.

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