



## Results of triple arthrodesis in children and adolescents

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We retrospectively evaluated 38 patients who had a total of 52 triple arthrodeses. The average age at the time of operation was 14.2 years and the mean follow-up period was 10.2 years. Results were rated good in 17 feet, fair in 28 and poor in 7.

Talonavicular pseudarthrosis was observed in two feet, residual varus deformity in four, residual valgus deformity in one, wound infections in two, and wound haematomas in six.

Better results were observed in cavovarus and planovalgus foot deformity, whereas poor results were especially seen in rigid equinovarus, calcaneo-planovalgus and equinoplanovalgus deformity. The role of supplementary operations performed prior to or concomitantly with the triple arthrodesis is crucial for correction of the deformity.

Triple arthrodesis is a reliable procedure which generally produces good and satisfactory results. Very often, it needs to be supplemented by other operations for correction of complex foot deformities, as well as for the functional improvement of the patients.

**Keywords:** triple arthrodesis ; cerebral palsy ; planovalgus ; cavovarus.

Excision of the navicular, combined with calcaneotolocuneiform and calcaneocuboid arthrodesis with posterior displacement of the foot have also been described (5). Ryerson (18) described the classic triple arthrodesis, with subtalar, talonavicular and calcaneocuboid arthrodesis. The Lambrinudi triple arthrodesis was designed in the past for the treatment of paralytic equinus deformity secondary to poliomyelitis, by resection of a bone wedge from the plantar aspect of the head and neck of the talus, to lock the talus in equinus position at the ankle, while the rest of the foot was placed in the desired degree of dorsiflexion (13), (fig 2a-b). The "beak" triple arthrodesis has also been applied for correction of severe cavus deformity, with flattening of the arch obtained by downward displacement and depression of the proximal end of the forefoot segment under the head and neck of the talus (20). Williams and Menelaus described a triple arthrodesis by lateral inlay grafting from the upper third of the ipsilateral tibia (23).

### INTRODUCTION

Triple arthrodesis was first described in 1921 by Hoke (10) who combined arthrodesis of the subtalar and talonavicular joint, by removing the head of the talus and re-inserting it after removal of its articular surfaces.

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Table I. — Preoperative foot deformities

PREOPERATIVE DEFORMITIES	
CAVUS FOOT	23
Cavovarus	17
Equinocavovarus	3
Calcaneocavus	3
MIDFOOT AND HINDFOOT VALGUS	26
Planovalgus	17
Equinoplanovalgus	4
Calcaneoplanovalgus	5
CONGENITAL TALIPES EQUINOVARUS	3

## MATERIALS AND METHODS

Written parental permission was obtained to allow the use of information held in the hospital records to be used in this review, as an Institutional Review Board (IRB) does not exist in our country.

This is a retrospective study of 52 triple arthrodeses in 38 consecutive patients. The main causative diseases were: cerebral palsy in 15 patients, Charcot-Marie-Tooth neuropathy in 6, neurological syndromes in 6, poliomyelitis in 5, congenital talipes equinovarus in 3, myelomeningocele and arthrogryposis in 2 each. The mean age at the time of operation was 14.2 years (range, 10-18) and the average follow-up period was 10.2 years (range, 2-19). The main pre-operative complaints were foot deformity, pain on standing or at rest, difficulty in gait and the presence of corns and callosities. The pre-operative foot deformities were divided into three categories, as shown in table I.

Forty-seven soft tissue and three bony procedures have been performed prior to or concomitantly with the arthrodesis (table III), while seven soft tissue and two bony procedures were performed after the index operation (tables II-IV). A modified Ryerson (18) was performed in 50 feet, and a modified Lambrinudi (13) in two.

In the modified Ryerson, a curvilinear incision was used over the sinus tarsi, extending from the tip of the lateral malleolus toward the talar head, to the lateral border of the extensor tendons. After the incision of the subtalar, calcaneocuboid and talonavicular capsules, arthrodesis of the joints was performed by removing bone wedges, in the above mentioned order. A preoperative drawing was made, using the contours of the lateral radiograph of the foot, to determine the size and shape of

Table II. — Additional procedures performed prior to arthrodesis

ADDITIONAL OPERATIONS PRIOR TO THE ARTHRODESIS		Preoperative deformities
Soft tissue releases	4	Cavovarus, equinocavovarus, calcaneocavus
Achilles lengthening	1	Equinocavovarus
Long extensor tendons transfer and common flexors lengthening	1	Cavovarus
Split posterior tibial tendon transfer	1	Cavovarus

Table III. — Additional procedures performed concomitantly with the index operation

ADDITIONAL OPERATIONS AT THE TIME OF THE ARTHRODESIS		Preoperative deformities
Soft tissue releases	11	Cavovarus, equinocavovarus, congenital talipes equinovarus
Tenotomies and tendon lengthenings	11	Cavovarus, equinocavovarus, planovalgus, equinoplanovalgus, congenital talipes equinovarus
Achilles tendon lengthening	8	Equinocavovarus, equinoplanovalgus, congenital talipes equinovarus
Tenodesis and tendon transfers	4	Calcaneocavus, calcaneoplanovalgus
Distal tibial hemiepiphysectomy (medial)	3	Planovalgus
Metatarsal osteotomies	3	Cavovarus, equinocavovarus
Peroneal tendon lengthening	2	planovalgus, equinoplanovalgus

the bone wedge that should be removed (fig 1a-b). The two modifications of the original technique were as follows: first, we used only a lateral curvilinear incision instead of a straight lateral incision and a second dorso-medial incision to expose the talonavicular joint, and secondly the bone wedges were removed first from the

Table IV. — Additional procedures performed after the index operation

Additional operations after the arthrodesis		Preoperative deformities
Tendon transfers	3	Cavovarus equinocavovarus
Tenotomies	3	Cavovarus equinocavovarus
Tenodesis	1	Calcaneocavus
Calcaneal osteotomy	1	Calcaneoplanovalgus
Supramalleolar varus osteotomy	1	Planovalgus

subtalar joint, so as to stabilize the hindfoot, thus resecting less bone from the talonavicular and calcaneocuboid joints.

The modified Lambrinudi procedure was performed when the foot was in marked equinus position with loss of dorsiflexion power.

In the modified Lambrinudi, instead of resecting a large bone wedge from the talus, a smaller oblique talar resection was performed, while larger bone wedges were excised from the calcaneocuboid and talonavicular joints, thus reducing the risk of talar avascular necrosis (fig 3a-b), (fig 5a-b).

A non weight bearing short leg cast was applied post-operatively for 6 weeks, and after clinical and radiological signs of progressive fusion of the arthrodesis, it was re-applied for an additional period of six weeks with partial weight bearing.

Anteroposterior and lateral radiographs in full weight bearing position were obtained at follow-up in all cases. The patients were questioned concerning the presence or absence of pain and the effects of the triple arthrodesis on their walking ability and personal satisfaction.

The foot was examined for residual or recurrent deformity and for the presence of corns and calluses. Alignment of the foot and ankle, ankle motion and stability were also noted. For the clinical assessment of the triple arthrodesis, the criteria of Angus and Cowell (2) were used.

A good result implied a foot with no or minimal deformity, no pseudarthrosis, no callosities, no or minimal pain after strenuous use, and no joint degeneration. A result was considered fair when there was pain after light use, moderate deformity or a single callosity, or pseudarthrosis and joint degeneration in the mid-foot. The result was considered poor if there was pain on

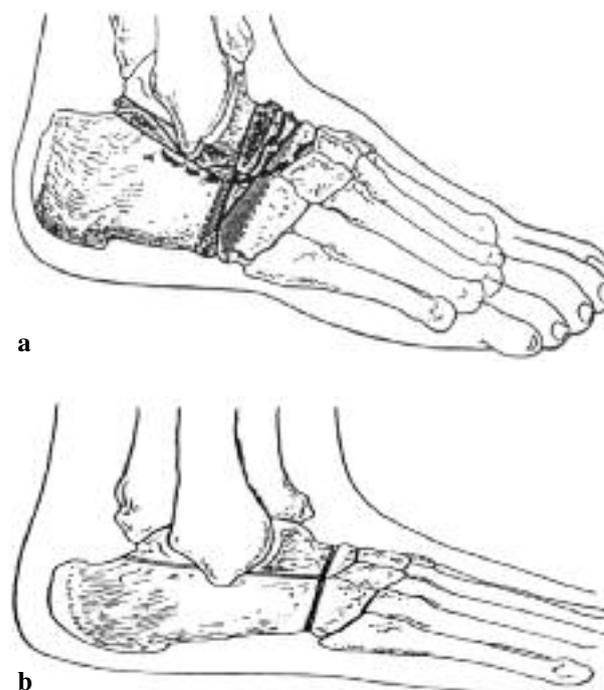


Fig. 1 (a,b). — Schematic representation of modified Ryerson technique.

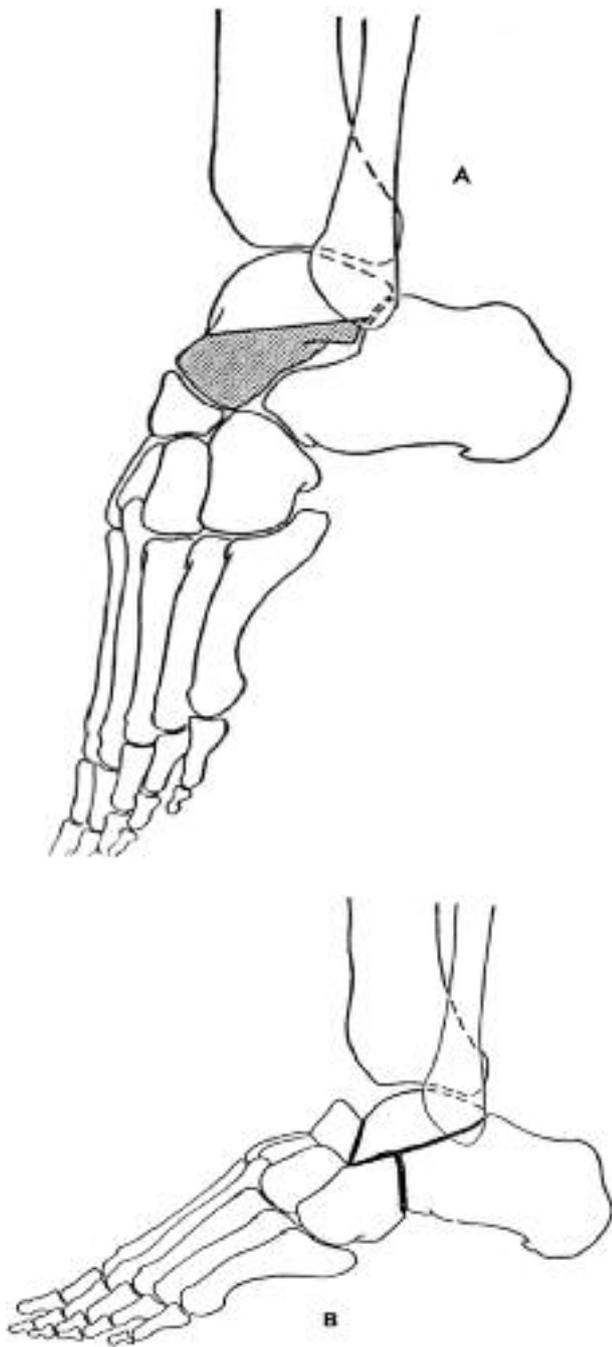
standing or at rest, severe deformity, multiple callosities or pseudarthrosis and severe joint degeneration.

The goal of this study was to evaluate the outcome of triple arthrodesis relative to preoperative foot deformities.

## RESULTS

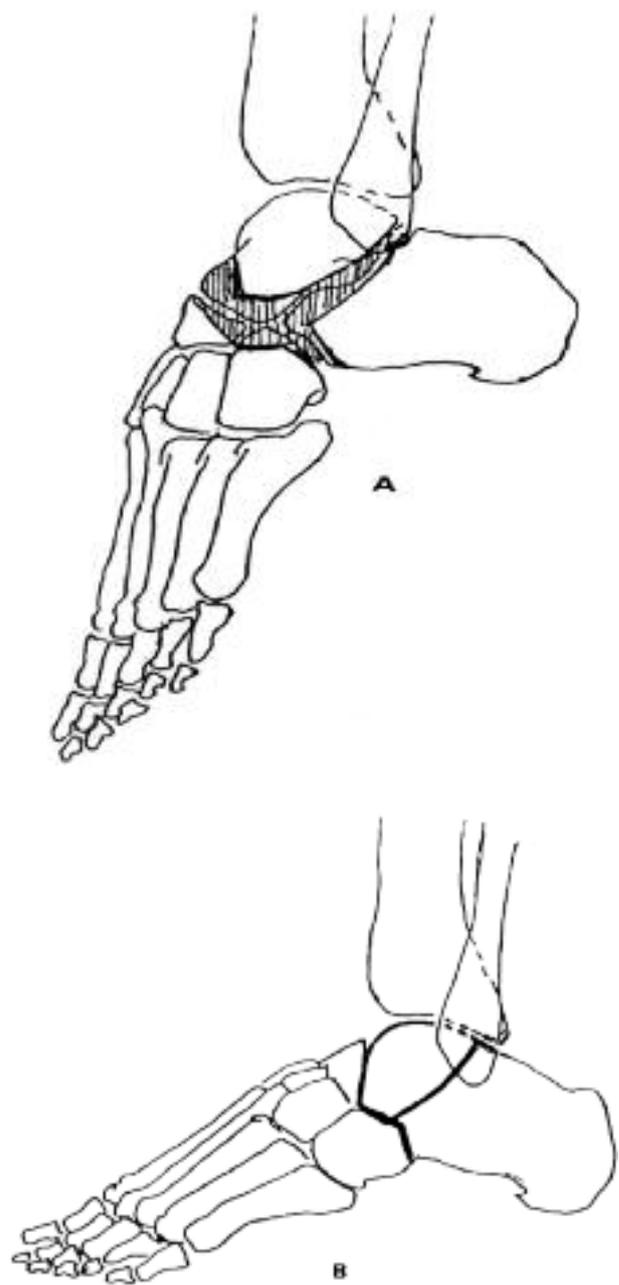
Seventeen feet (32.6%) were graded as good, 28 as fair (53.8%), and poor results were present in seven feet (13.4%) (table V). Talonavicular pseudarthrosis was observed in two feet. In one foot with tarsal coalition, talonavicular revision was performed 18 months after the arthrodesis. Following the revision, the patient complained of moderate pain after light use. In a second foot, with cavovarus deformity, the talonavicular pseudarthrosis was revised 10 months after the index operation with full recovery of symptoms.

Residual varus deformity was observed in 4 feet. The first patient (2 feet), with cavovarus deformity,



*Fig. 2 (a,b).* — Schematic representation of Lambrinudi technique.

presented bilateral residual heel varus of  $4^\circ$ . The second patient (2 feet) with a similar foot deformity had bilateral residual heel varus of  $5^\circ$  on the left foot and  $10^\circ$  on the right.



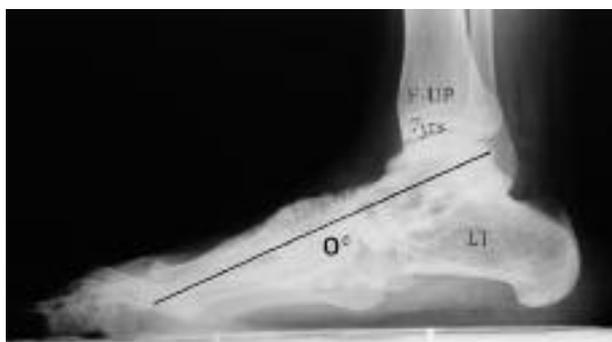
*Fig. 3 (a,b).* — Schematic representation of modified Lambrinudi technique.

Delayed wound infection was observed in both feet of a patient with cavovarus deformity who was treated with oral antibiotics.

Degenerative changes of the ankle were observed in two feet with planovalgus deformity ; a bilateral



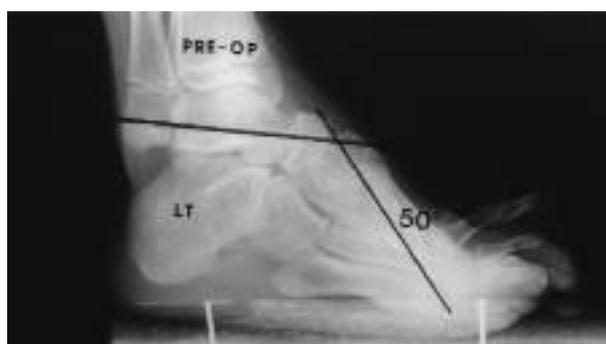
**Fig. 4a.** — Preoperative radiograph of a left cavovarus foot. The causative disease was Charcot-Marie-Tooth neuropathy. Méary angle on lateral weight-bearing view was 42°.



**Fig. 4b.** — Radiograph after 7 years follow-up shows a Méary angle of 0°. The operations performed concomitantly with the triple arthrodesis were plantar soft tissue release, split posterior tendon transfer, and extensor tendons transfer to the neck of the metatarsals.

supramalleolar varus osteotomy was performed due to ankle instability. Degenerative changes were observed in the midfoot joints of three planovalgus and one cavovarus foot. Wound haematomas were observed in six feet.

Better results were observed in cavovarus and planovalgus foot deformities whereas a poor result was observed in three calcaneoplanovalgus and two equinoplanovalgus deformities and one rigid equinovarus which was treated primarily with plantar soft tissue releases (table V).



**Fig. 5a.** — Preoperative lateral radiograph of a left calcaneocavus foot in a patient with sequelae from poliomyelitis.



**Fig. 5b.** — Radiograph 5 years after a modified Lambrinudi triple arthrodesis, which was performed concomitantly with soft tissue plantar release, flexor tenotomies with extensor tendons transfer and 1<sup>st</sup> metatarsal osteotomy. A calcaneal osteotomy was performed 12 months after the triple arthrodesis to correct a severe hindfoot varus.

## DISCUSSION

It is generally recommended that a triple arthrodesis should not be performed too early (3,6,16) although it has been suggested as an alternative to talectomy, as well as at any time after the appearance of the ossific nucleus of the navicular (7,9). Seitz and Carpenter (19) reported a 57% incidence of residual deformity following triple arthrodesis in their series, with planovalgus foot presenting the worst prognosis. We did not observe residual heel valgus after correction of planovalgus foot deformity. One foot with preoperative cavovarus deformity presented a postoperative heel valgus angulation of 10°.

Table V. — Results according to clinical criteria of Angus and Cowell

	RESULTS	
GOOD	17	32.6%
Cavovarus	9	
Planovalgus	5	
Equinocavovarus	1	
Equinoplanovalgus	1	
Congenital talipes equinovarus	1	
FAIR	28	58.3%
Planovalgus	12	
Cavovarus	8	
Calcaneocavus	3	
Equinocavovarus	2	
Calcaneoplanovalgus	2	
Congenital talipes equinovarus	1	
POOR	7	13.4%
Calcaneoplanovalgus	3	
Equinoplanovalgus	2	
Planovalgus	1	
Congenital talipes equinovarus	1	

It is generally accepted that correction of a planovalgus deformity is technically more demanding than correction of a cavus deformity, with respect to excision of the medially-based bone wedge (fig 7a-b). The difficulty will increase if there is a concomitant calcaneal deformity. These deformities should be treated aggressively because they may progress rapidly with growth, as the calcaneal tuberosity becomes horizontally aligned under the calcaneus and it may require an additional calcaneal osteotomy to correct the deformity.

In our series, out of 18 planovalgus deformities, 5 presented a good result (27.8%) while 12 (66.7%) had a fair result.

Three factors that lead to a high rate of pseudarthrosis are lack of internal fixation, poor bony apposition and early weight bearing (6,16,24). Two feet in our cases presented a talonavicular pseudarthrosis (3.8%) and were revised 18 and 10 months respectively after the index operation,



Fig. 6a. — Preoperative lateral radiograph of a right cavovarus foot in a cerebral palsy patient.

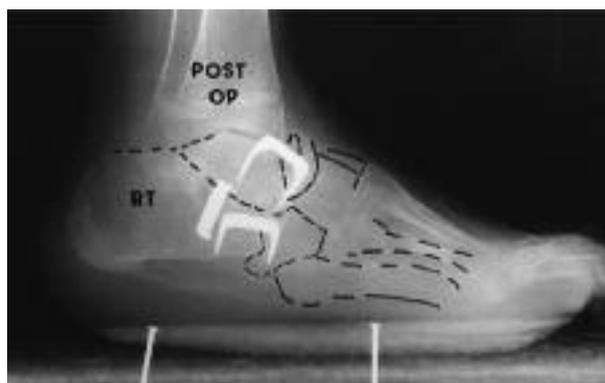


Fig. 6b. — Radiograph 6 years after plantar soft tissue release and triple arthrodesis.



**Fig. 7a.** — Preoperative lateral radiograph of a right planovalgus foot in a cerebral palsy patient.



**Fig. 7b.** — 4 yrs postoperative radiograph after triple arthrodesis.

giving fair and good results. The joints were internally fixed with staples and a short-leg cast was applied postoperatively for 12 weeks.

Achilles tendon lengthening should be performed prior to or concomitantly with the arthrodesis, so as to minimize the amount of bone that should be resected and thus to decrease the risk of avascular necrosis (2,4,15). We did not observe avascular necrosis, even in those feet with preoperative equinus deformity.

Degenerative changes of the ankle were observed in two feet (3.8%) with planovalgus deformity, and a bilateral supramalleolar varus osteotomy had to be performed due to ankle instability. Degenerative arthritis of the midfoot joints was observed in four feet (7.6%) three with planovalgus and one with cavovarus deformity, causing mild pain during gait.

Table VI. — Results according to the causative disease

	GOOD	SATISFACTORY	POOR
Cerebral palsy	7	12	3
Charcot-Marie-Tooth	3	4	—
Poliomyelitis	2	5	—
Myelomeningocele	—	1	2
Arthrogryposis	2	—	—
Club foot	1	1	1
Others	2	5	1

High incidences of degenerative changes have been reported in the past (3,17), but recent papers reported that severe degenerative arthritis of the midfoot was rarely noted 18 years after surgery, and osteoarthritis of the ankle and foot was not a common problem 20 years after triple arthrodesis (21).

Adelaar *et al* (1) found asymptomatic radiographic changes of osteoarthritis of the midfoot and ankle after 20 years follow-up. Degenerative changes are probably observed because of the force distribution to the ankle and midfoot joints after the subtalar, talonavicular and calcaneocuboid joints have been fused. Poor bony contact at the midtarsal joint, can result in pseudarthrosis or recurrence of the deformity (3,8,11).

In our series significant pain was found only in association with pseudarthrosis, and mild pain was present only in cases with degenerative joint changes. We observed that seven feet in patients with progressive neuromuscular disease had good and fair results, but the number is small compared to the overall sample (fig 4a-b). Only two previous studies reported good results in progressive neuromuscular diseases (12,14).

The overall long-term results of triple arthrodesis in patients who have peripheral neuropathy are poor, because the motor loss is irreversible and progressive, and muscle balance cannot be achieved. These patients do not retain normal proprioception and sensation and thus the articular surfaces are more likely to be damaged (22).

Soft-tissue procedures should be performed prior to the arthrodesis, when the foot is immature and the deformity is not so rigid. Tendon transfers can

be used when there is an identifiable muscle imbalance, especially in younger patients with a flexible deformity. Principles of tendon transfer should be followed, particularly in correcting the fixed deformity first and transferring only those tendons from muscles having adequate motor strength.

One of the most common procedures that we performed in a cavus foot deformity was the extensor digitorum tendons transfer to the metatarsal heads, so as to address the anterior pes cavus, with concomitant flexor tendons tenotomy for the correction of claw toe deformity. Split tibialis posterior tendon transfer was performed to correct the hindfoot varus in flexible deformities. Plantar soft tissue release was the most common soft tissue procedure in cavus and equinovarus deformity, comprising the first step prior to or during the index operation. This release constitutes a keystone procedure in lengthening the shortened base of the foot and its contribution to the successful outcome of the correction of the deformities cannot be overemphasized (fig 6a-b). In midfoot and hindfoot valgus, the most common procedures performed prior to or concomitantly with the index operation was lengthening of the Achilles and peroneal tendons. It should be performed prior to or at the same time as the triple arthrodesis, otherwise a large amount of bone has to be resected, and any attempt to correct the deformity by bony resection alone, may result in avascular necrosis of the talus.

Regardless of age, tendon balancing procedures are necessary and with adequate surgical correction, the triceps surae muscle lever arm function improves.

The role of additional operations performed prior to the index operation is crucial in younger patients with flexible deformities in early stages of a progressive neuromuscular disease, as the foot balance can be restored, until the deformity becomes rigid and the need for a triple arthrodesis becomes inevitable.

## CONCLUSION

Triple arthrodesis is a reliable procedure which generally produces good and fair results. Very often however it must be supplemented by other

operations in order to correct complex foot deformities.

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