Double column osteotomy for correction of residual adduction deformity in idiopathic clubfoot

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ABSTRACT

INTRODUCTION Adduction of the forefoot is the most common residual deformity in idiopathic clubfoot. The 'bean-shaped foot', which is a term used to describe a clinical deformity of forefoot adduction and midfoot supination, is not uncommonly seen in resistant clubfoot.

SUBJECTS AND METHODS Fifteen children (20 feet) with residual forefoot adduction in idiopathic clubfeet aged 3–7 years were analyzed clinically and radiographically. All of the cases were treated by double column osteotomy (closing wedge cuboid osteotomy and opening wedge medial cuneiform osteotomy) with soft tissue releases (plantar fasciotomy and abductor hallucis release), to correct adduction, supination and cavus deformities. Pre-operative measurements of certain foot angles were compared with their corresponding postoperative values.

RESULTS A grading system for evaluation of the results using a point scoring system was suggested to evaluate accurately both clinical and radiographic results after a follow-up period of an average of 2.3 years. Eight feet (40%) had excellent, eight (40%) good, three (15%) fair, and one (5%) poor outcome. There was no major complication. There was significant improvement in the result ($P > 0.04$).

CONCLUSIONS Double column osteotomy can be considered superior to other types of bone surgeries in correction of residual adduction, cavus and rotational deformities in idiopathic clubfoot.

KEYWORDS

Forefoot adduction – Double column osteotomy – Idiopathic clubfoot

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Adduction of the forefoot is the most common residual deformity in clubfoot. The 'bean-shaped foot' is a term used to describe a clinical deformity of forefoot adduction and midfoot supination.¹ It may cause functional disability; very often the parents state that the foot looks the same as before the initial treatment, despite the fact that the hindfoot is fully corrected and only the forefoot adduction is what remains.²

The possible factors contributing to the deformity are either residual talo-navicular subluxation³ or residual metatarsus varus.⁴ The medial column of the foot is shorter than the lateral column in case of forefoot adduction.

The most dependable radiographic findings are weight-bearing radiography of the foot showing the talo-first metatarsal angle TFMA1⁵ and calcaneo-fifth metatarsal angle CFMA⁶ in the anteroposterior radiograph as indicators of adduction. The most reliable measures of hindfoot varus are anterior and lateral talocalcaneal angles (TCA1

and TCA2), respectively.⁵ The talo-first metatarsal angle on weight-bearing lateral radiograph TFMA2 is recorded to give an indication of supination and cavus.⁶

Nevertheless, forefoot adduction may be present alone or in combination with other deformities. In such cases, the protocol of management will be the same but associated with treatment of such deformities. Hindfoot varus deformity can be treated by complete subtalar release and/or lateral closing wedge calcaneal osteotomy.

The aim of this work was to establish a protocol for diagnosis and treatment of residual fixed forefoot adduction deformity in idiopathic clubfoot, and to evaluate the results of double column osteotomy (closing wedge cuboid osteotomy and opening wedge medial cuneiform osteotomy, *i.e.* lateral column shortening with medial column lengthening)⁷ in correction of the foot deformity, pain relief, tolerability to orthoses, and overall patient/parent satisfaction. The procedure was combined with soft tissue releases (plantar fas-

ciotomy and abductor hallucis release). A grading system for evaluation of the results, using point scores, was suggested which can accurately evaluate both the clinical and the radiographic improvement.

Subjects and Methods

Twenty cases (feet) in 15 children, who presented to the National Institute of Neuromotor System between September 2005 and September 2006 with residual forefoot adduction deformity after previous surgical treatment for idiopathic clubfeet, were operated upon and followed-up for at least a period of 2 years.

Inclusion criteria

Moderate-to-severe residual fixed (rigid) forefoot adduction, midfoot supination, and cavovarus deformities in children between 3–7 years of age with idiopathic clubfeet were chosen.

Exclusion criteria

Non-idiopathic, secondary clubfoot, children below 3 years of age, hindfoot deformity, flexible (correctable) foot deformity, and relapsed clubfeet for several times were excluded.

Physical examination, original disease and treatment

The average age at the time of surgery was 4 years and 2 months (range, 3–7 years). Three patients (4 feet) were in the age group < 4 years, eight patients (12 feet) in the age group 4–5 years, and four patients (4 feet) in the age group of > 5 years. There were 11 boys (5 of them in both feet) and 4 girls. The right foot was operated upon in 10 patients and the left foot in five patients.

Pre-operative clinical evaluation

Neurological examination was done to exclude a non-idiopathic clubfoot. Assessment included evaluation of muscle tone, motor power, sensation, reflex activity, and gait.

Orthopaedic examination included the gait, the presence of deformities other than that of the foot, the components of the foot deformity, the range of motion (forefoot flexibility), and the skin condition. The foot was evaluated for forefoot adduction deformity by Bleck's method assessing the position of the forefoot with respect to the mid-line axis of the hindfoot.⁸ Forefoot adduction deformity was evident in all cases. Contracture of tibialis anterior tendon and abductor hallucis muscle was noted. Cavovarus deformity and its flexibility were assessed by Coleman's block test.⁹ The weight-bearing alignment of the hindfoot was evaluated. All cases had rigid inward deviation of the foot (*i.e.* forefoot adduction deformity) ranging from moderate to severe. Associated deformities included hindfoot varus (6 cases) and cavus (13 cases). Two cases had frank foot pain due to thickened callous and large bursa over the dorsolateral

aspect of the foot, excessive scars of previous operations or dorsal subluxation of the navicular. All cases had skin problems of thickened callous and/or scarring of previous operations.

Pre-operative radiographic evaluation

Weight-bearing anteroposterior and lateral X-ray views of ankles and feet were taken for all patients. The axis of the talus was determined by the bisector of its head and neck (*i.e.* not necessarily its body). The axis of the calcaneus was determined by the line joining its plantar most points from the tuberosity to the most distal point (*i.e.* the calcaneocuboid joint). The axes of the first and fifth metatarsals were their bisectors. In the anteroposterior view of the foot, the anterior talocalcaneal angle TCA1 or Kite's angle for varus (normally 20–40°),⁵ anterior talo-first metatarsal angle TFMA1 (normally 0° to –10°, adduction positive),⁵ and calcaneo-fifth metatarsal angle CFMA (normally 0–5°)⁶ for forefoot adduction were measured. In the lateral view of the foot, the lateral talocalcaneal angle TCA2 (normally 25–50°)⁵ and the lateral talo-first metatarsal angle or Meary's angle TFMA2 for cavus (normally 0–5°)⁶ were measured. The variable range of measures of these weight-bearing radiographic angles was recorded; and the mean calculated. The pre-operative mean anterior talocalcaneal angle TCA1 measure was 20° (range, 8–33°), mean anterior talo-first metatarsal angle TFMA1 measure 39° (range, 16–74°), mean calcaneo-fifth metatarsal angle CFMA measure 26° (range, 13–48°), mean lateral talocalcaneal angle TCA2 measure 16° (range, 0–33°), and mean lateral talo-first metatarsal angle measure 15° (range, 0–40°).

Operations

All feet underwent double column osteotomy (closing wedge cuboid osteotomy and opening wedge medial cuneiform osteotomy; Figs 1 and 2) in association with soft

Table 1 Surgery performed in relation to gender

Operation	Boys	Girls	Total
Double column osteotomy	11 (5 bilateral)	4	15 (20 feet)
Plantar fasciotomy	11 (5 bilateral)	4	15 (20 feet)
Abductor hallucis release	11 (5 bilateral)	4	15 (20 feet)
Complete subtalar release	5	1	6 (6 feet)
Calcaneal osteotomy	2	0	2 (2 feet)

Figure 1 (A) Open wedge medial cuneiform osteotomy deepened through the intermediate cuneiform without harm to the base of the second metatarsal. (B) A wedge of bone removed from cuboid with the apex directed toward the medial cuneiform cut used for medial opening wedge of the medial cuneiform 'double osteotomy'.

tissue releases (plantar fasciotomy and abductor hallucis release). In addition, six feet with fixed hindfoot varus deformity (5 boys and a girl) underwent complete subtalar release; two feet with also fixed hindfoot varus (2 boys) underwent lateral closing wedge calcaneal osteotomy (one with complete subtalar release and the other one closing wedge calcaneal osteotomy alone; Table 1).

Operative techniques

CUBOID LATERALLY BASED CLOSING WEDGE OSTEOTOMY

Through a lateral incision, the cuboid bone was exposed. A laterally based wedge was removed from the cuboid with a sharp osteotome. The size of the wedge was measured according to the predetermined amount of the cuboid cut to correct the forefoot adduction deformity.

MEDIAL CUNEIFORM OPENING WEDGE OSTEOTOMY

Through a medial incision, the abductor hallucis was reflected plantarward. A vertical osteotomy of the medial cuneiform was made with a sharp osteotome. The foot was manipulated by bringing the midfoot and forefoot into abduction, correcting the adduction and supination deformity. The osteotomy site of the medial cuneiform was opened with an osteotome or a lamina spreader. The wedge of bone taken from the cuboid bone was inserted into the medial cuneiform with the base of the wedge straight medially. Two smooth Kirschner wires were used to fix the foot in the corrected position (in 10 feet), a pin through the cuboid, starting from the calcaneus and the other one through the first web space into the medial cuneiform. Intra-operative C-arm image was of help to assess the correction of the bony deformity and the position of pins.

COMPLEMENTARY PROCEDURES

Complete subtalar release was performed in 6 feet with

Figure 2 Drawing of the foot showing the wedge removed from the cuboid (A) inserted in the medial cuneiform (B).

fixed hindfoot varus. Calcaneal closing wedge osteotomy was performed in two feet with fixed hindfoot varus.

Postoperative care

A well-padded non-weight-bearing below knee plaster of Paris (POP) cast was applied in almost all feet, with the exception of cases in which Achilles tendon lengthening was performed in which case an above-knee (POP) cast was applied. It was advisable to split the cast in the immediate postoperative period to avoid the complications of oedema. The wound was checked at 2 weeks; sutures were left in place and a better fitting, non-weight-bearing cast was applied. The K-wires were removed at 6 weeks and a weight-bearing cast was applied till radiographic evidence of bony union, usually at 8 weeks. Plastic ankle/foot orthosis (AFO) was worn to prevent relapse. AFOs were used for a minimum of 12 months whether after bony procedures alone or bony with soft-tissue procedures, till the child was able to perform active abduction and/or pronation of the forefoot. Types of AFO and their methods of use were not a part of the current study.

Postoperative evaluation

A period of at least 6 weeks of gait training was instructed to all feet. All feet were assessed clinically and radiographically and a grading system, with a total score of 20 marks, was suggested. Clinical evaluation included the presence or absence of pain (2 marks), forefoot adduction (2 marks), varus heel (1 mark), supination (1 mark), cavus (1 mark), tolerability to orthosis (2 marks), and patient/parents satisfaction (1 mark). Radiographic evaluation included the degree of correction of the angle measures by comparing

the postoperative measures with those of the pre-operative, giving the anterior talo-calcaneal angle (TCA1) measure (2 marks), the anterior talo-first metatarsal angle (TFMA1) measure (2 marks), the calcaneo-fifth metatarsal angle (CFMA) measure (2 marks), the lateral talocalcaneal angle (TCA2) measure (2 marks), and the lateral talo-first metatarsal angle (TFMA2) measure (2 marks). The feet were graded into four categories as excellent with a total score of 19–20, good with a total score of 16–18, fair with a total score of 10–15, and poor with a total score < 10 (Appendix).

Intra-observer and interobserver variability were studied. Twenty feet were examined and scored independently by four observers. On a separate occasion, two of the observers repeated the assessments of the same feet in the absence of information from the initial observations. The chance corrected and weighted kappa statistics for observer agreement, both for inter-observer and intra-observer variability demonstrated satisfactory repeatability of the foot grading system. The overall intra-observer mean weighted kappa was $\chi_w = +0.68$ (range SE $\chi = 0.012$ –0.052) and the overall interobserver mean weighted kappa was $\chi_w = +0.55$ (range SE $\chi = 0.011$ –0.043).

Results

The fifteen children (20 feet) were followed-up for a mean period of 2 years and 4 months (range, 2.0–2.5 years).

Pain disappeared in the postoperative gait training and physiotherapy period in 18 feet. Only two feet had mild pain. Non-mechanical pain, as that at the site of sutures or K-wires, was of no significance as it was short-term and disappeared spontaneously. The degree of forefoot adduction improved in 16 feet (Fig. 3). Only four feet had residual adduction < 5° at the last follow-up. The reasons were due to severe pre-operative forefoot adduction (2 feet), medial tethering due to postoperative scarring (3 feet), failure to maintain correction (1 foot), complete slip of the graft (2 feet), and/or residual hindfoot varus (2 feet). The varus heel improved in five out of eight feet. Residual cavus remained in only four feet. The range of motion (forefoot flexibility) was improved in 15 feet as compared with the pre-operative rigid deformed state. The other five feet remained rigid but plantigrade. There was better tolerability to the foot orthosis in three feet, while all other feet showed no complaints of the footwear. In 16 feet, the patient and/or the parent were satisfied due to the disappearance of pre-operative pain or discomfort, the correction of the foot deformity, better footwear, and the overall improvement of the gait. Only in four feet were the patient and/or the parents dissatisfied because of mild pain and/or residual forefoot adduction < 5°.

The radiographic weight-bearing angle mean measures improved in the 20 feet. The mean anterior talocalcaneal

Figure 3 Clinical evaluation. (A) Pre-operative bilateral relapsed idiopathic clubfeet: right, fixed forefoot adduction, supination, and cavus; left, fixed forefoot adduction, hindfoot varus, cavus. (B) Two year postoperative, full correction of both feet.

angle (TCA1) measure was 26° (range, 15–40°) postoperatively as compared with 20° (range, 8–33°) preoperatively. That of the anterior talo-first metatarsal angle (TFMA1) was 7° (range, –10° to 25°) postoperatively as compared with 39° (range, 16–74°) pre-operatively. That of the calcaneo-fifth metatarsal angle (CFMA) was 9° (range, 10–20°) postoperatively as compared with 26° (range, 13–48°) pre-operatively. That of the lateral talo-calcaneal angle (TCA2) was 21° (range, 0–30°) postoperatively as compared with 16° (range, 0–33°) pre-operatively. That of the lateral talo-first metatarsal angle (TFMA2) was 11° (range, 0–29°) postoperatively as compared with 15° (range, 0–40°) pre-operatively (Table 2 and Fig. 4).

There was no major complication. Superficial skin sloughing occurred in two feet and deep wound infection in one foot; all were controlled by debridement, dressing, and antibiotic administration for two weeks and were followed-up for 24 months without recurrence. Slipping of the graft occurred in two feet; one extruded from the K-wire, and the other was not originally fixed by K-wires. K-wire migration

Table 2 Pre- and postoperative radiographic angle measures

Angle	Mean measurements ± SD (degrees)	
	Pre-operative	Postoperative
TCA1	20 ± 9.2	26 ± 12.3
TFMA1	39 ± 8.9	7 ± 2.1
CFMA	26 ± 6.3	9 ± 3.4
TCA2	16 ± 8.4	21 ± 9.4
TFMA2	15 ± 4.6	11 ± 2.2

occurred in one foot. Three feet had flat-topped talus and one talar avascular necrosis. No foot showed medial wedging graft collapse. Complication rate was only 15%; because only three feet had these complications, namely wound infection, slipping of the graft, residual deformity, and flat topped talus.

Using the grading system for evaluation, eight feet (40%) had excellent, eight (40%) good, three (15%) fair and one (5%) poor outcome. There was significant improvement in the result ($P > 0.04$).

Discussion

In treated clubfeet, forefoot adduction and supination were the most common persistent deformities present in 95% of the feet.

According to Tarraf and Carroll,¹ these deformities resulted from undercorrection at the time of the primary operation. The possible factors contributing to the deformity were either residual talonavicular subluxation⁵ or resid-

ual metatarsus varus (metatarsal adduction).⁴ Steyler and Van der Walt¹⁰ proposed internal tibial torsion; however, the very existence of internal tibial torsion in clubfoot was refuted by other authors.^{11,12} Berman and Gartland¹³ in 1971 and Lowe and Hannon⁴ in 1973 suggested metatarsal deformity; however, it was probably a consequence of persistent forefoot adduction rather than the cause. Metatarsal osteotomies were described first by Steyler and Van der Walt¹⁴ in 1966 and were indicated when the adduction deformity originates distal to the navicular. Fried¹⁵ in 1959 proposed the tibialis posterior muscle. Despite this muscle having a possible indirect action over the forefoot, it was more apt to cause a hindfoot varus. Proposing the direct muscular action, the abductor hallucis was the only muscle capable of causing adduction of the forefoot, as suggested by Thomson¹⁶ in 1960 and Otremski *et al.*¹⁷ in 1987; however, this muscle was not contracted in all of the children in the current study at the time of surgery. Turco¹⁸ in 1971 believed that forefoot adduction was caused by overcorrection of the hindfoot, whereas Dwyer¹⁹ in 1963 suggested that residual varus of the hindfoot caused medial deviation of the forefoot. Lack of correction of the midfoot (the talonavicular, the calcaneocuboid, or both) might cause forefoot adduction.^{5,12} Although adequate talonavicular correction was obtained in all of the children in the current study, in some instances there was probably a persistent subluxation of the calcaneocuboid joint. This could be seen in patients who had the primary soft tissue release by the 'hockey-stick' incision. However, the adduction deformity was not more severe in these patients than in those who had the Cincinnati incision, as reported by Nimityongskul *et al.*²⁰

At the stage before the double osteotomy, a simple release of the calcaneocuboid joint would not be enough to correct the adduction of the forefoot. Other soft tissue releases to correct forefoot adduction such as the classic tarsometatarsal mobilisation described by Heyman *et al.*²¹ in 1958, received much criticism in the literature. Kendrick *et al.*²² in 1970 and Stark *et al.*²³ in 1987 reported the risk of degenerative arthritis associated with this technique. Beyond that, Carroll¹² did not recommend this procedure because the tarsometatarsal joints were not the site of the deformity.

The principle of an elongated lateral column associated with a shortened medial column was crucial in dealing with residual forefoot adduction, Evans²⁴ was acknowledged as the author of this principle, but his proposal of re-establishing the balance between the two columns by the calcaneocuboid fusion might cause a reverse deformity with an abducted foot. Lichtblau²⁵ in 1973 suggested a resection of the anterior end of the calcaneus as a method of avoiding this complication. However, this would act on only one of the sides of the deformity, as with procedures that lengthen the medial column described by Fowler² in 1959, and

Hoffman *et al.*²⁶ in 1984. They described an opening wedge osteotomy of the medial cuneiform but that did not easily address the rotational deformity. Talar neck osteotomy was proposed by Ozeki *et al.*²⁷ in 1994; which had an increased vascular risk. Medial column lengthening also had an additional problem because it required harvesting bone graft from another site.

The double osteotomy addresses the problem by lengthening the medial column using the wedge resected from the lateral column. It affects both sides of the deformity permitting a better correction than an isolated procedure in just one column. The indication for the correction of forefoot adduction by the double osteotomy should above all be clinical. A radiographic study (anteroposterior and lateral weight-bearing radiography of the foot) was imperative not only to document the amount of adduction but also to rule out any other deformities such as medial deviation of the metatarsals that would show a severe adduction deformity or a medial subluxation of the navicular. The six feet with fixed hindfoot varus were added to the current study; however, they were a complementary part of the results in the fact that their correction had not eventually corrected the residual fixed forefoot adduction. Therefore, they are considered as if they were pre-operatively corrected and only what remains was the fixed forefoot adduction.

Kose *et al.*²⁸ in 1999 reported a transcuneiform osteotomy with closing cuboid and opening cuneiform osteotomies in 10 feet with adduction and supination deformities and another three patients with cavovarus feet. Their results were similar to those of the current study, with reliable correction of adduction and supination.

The amount of correction of the adduction obtained in the current study, measured by the anterior talo-first metatarsal angle and calcaneo-fifth metatarsal angle (25°) was better than that reported by Shoemaker *et al.*²⁹ with the same procedure (18°). They had patients with metatarsus adductus with no previous surgical history, unlike the relapsed clubfeet in the current study. Also, the results of the current study were better than those obtained by McHale and Lenhart² reported in 1991, whose average correction was (9°), probably because they had patients with inadequate correction of the hindfoot with a low talocalcaneal index.

If the deformity is not severe enough to cause functional problems, it would be better to wait until the child is old enough to do the double osteotomy. It would be important that the medial cuneiform ossification centre be well formed (usually older than 3 years). The chronological age of cuneiform ossification was justified radiographically before choosing the appropriate age for surgical interference. Lourenco *et al.*,³⁰ in 2001, stated that surgery is advocated in children older than age 4 years, or when the medial cuneiform ossific nucleus is well developed.

The scoring system in the current study is a recently invented one similar in idea to the international rating system of Bensahel *et al.*³¹ supported by the International Club Foot Study Group (ICFSG) which ranges from 0–60 points, the latter expressing the worst result. Four groups of results are mentioned as excellent, good, fair and poor. The outcome evaluation should be performed at 6 years old and at the end of the growth. In the current study, the patients were < 6 years of age and consequently below maturity; therefore, that outcome evaluation was not applicable.

The current study suggested that a clinically satisfactory result was more likely to occur than radiographically satisfactory one. These clinical radiographic results had been previously mentioned by Wynne-Davies³² and Lowe and Hannon,⁴ as they observed more radiographic than clinical deformities in operated clubfeet.

While the debate over treatment of forefoot adduction continues with the use of external fixators^{33,34} and other types of tarsal osteotomies,³⁵ the double osteotomy approach has produced excellent results, with a straight foot and no indication of a need for further aggressive intervention.

Conclusions

Clinically, all residual clubfeet have significant forefoot adduction either alone or in combination with other deformities. The indications for surgery in these cases are moderate-to-severe fixed (rigid) forefoot adduction deformity in children between 3–10 years of age intolerant to footwear/orthoses with or without pain. The operation is not suitable for non-idiopathic clubfoot, secondary clubfoot with severe soft-tissue abnormalities, children below 3 years with immaturity of the cuneiform ossification, those with flexible (correctable) foot deformity using orthotic treatment or soft tissue procedures, and repeated relapsed clubfoot with unsuitable skin condition for multiple incisions.

Double column osteotomy (combined cuboid/cuneiform osteotomy) is a safe operation, which allows satisfactory correction of residual forefoot adduction deformity in previously treated idiopathic clubfeet. It is advisable in place of other types of bony surgery in correction of the adduction, cavus and rotational deformities in idiopathic clubfoot.

References

1. Tarraf YN, Carroll NC. Analysis of the components of residual deformity in clubfeet presenting for reoperation. *J Pediatr Orthop* 1992; **12**: 207–16.
2. McHale KA, Lenhart M. Treatment of residual clubfoot deformity-the 'bean-shaped' foot-by opening wedge medial cuneiform osteotomy and closing wedge cuboid osteotomy: clinical review and cadaver correlations. *J Pediatr Orthop* 1991; **11**: 374–81.
3. Main BJ, Crider RJ. An analysis of residual deformity in clubfeet submitted to early operation. *J Bone Joint Surg Br* 1978; **60**: 536–43.
4. Lowe LW, Hannon MA. Residual adduction of the forefoot in treated congenital clubfoot. *J Bone Joint Surg Br* 1973; **55**: 809–13.
5. Simons G. Analytical radiography in the progressive approach in talipes equinovarus. *Orthop Clin North Am* 1978; **9**: 187–206.

6. Pohl M, Nicol RO. Transcuneiform and opening wedge medial cuneiform osteotomy with closing wedge cuboid osteotomy in relapsed clubfoot. *J Pediatr Orthop* 2003; **23**: 70–3.
7. Raymond TM, Stuart LW. *Morrissey Atlas of Pediatric Orthopedic Surgery*, 4th edn. Philadelphia, PA: Lipincott Williams Wilkins, 2006; 927–56.
8. Bleck EE. Developmental orthopaedics III: Toddlers. *Dev Med Child Neurol* 1982; **24**: 533–55.
9. Paulos L, Coleman SS, Samuelson KM. Pes cavovarus: review of a surgical approach using selective soft tissue procedures. *J Bone Joint Surg Am* 1980; **62**: 942–53.
10. Steytler JCS, Van der Walt ID. Correction of resistant adduction of the forefoot in congenital clubfoot and congenital metatarsal varus by metatarsal osteotomy. *Br J Surg* 1966; **53**: 558–60.
11. Swann M, Lloyd-Roberts GC, Catterall A. The anatomy of uncorrected clubfeet. *J Bone Joint Surg Br* 1969; **51**: 263–9.
12. Carroll NC. Clubfoot. In: Morrissey RT. (ed) *Lovell and Winter's Pediatric Orthopedics*, 3rd edn. Philadelphia, PA: JB Lippincott, 1990; 927–56.
13. Berman A, Gartland JJ. Metatarsal osteotomy for the correction of adduction of the fore part of the foot in children. *J Bone Joint Surg Am* 1971; **53**: 498–506.
14. Penny JN. The neglected clubfoot. *Techn Orthop* 2005; **20**: 153–66.
15. Fried A. Recurrent congenital clubfoot: the role of the tibialis posterior in etiology and treatment. *J Bone Joint Surg Am* 1959; **41**: 243–52.
16. Thomson SA. Hallux varus and metatarsus varus. *Clin Orthop* 1960; **16**: 109–18.
17. Otremski I, Salama R, Khemosh O, Wientroub S. Residual adduction of the forefoot. *J Bone Joint Surg Br* 1987; **69**: 832–4.
18. Turco VJ. Surgical correction of the resistant clubfoot. One-stage posteromedial release with internal fixation: a preliminary report. *J Bone Joint Surg Am* 1971; **53**: 477–97.
19. Dwyer FC. The treatment of relapsed clubfoot by the insertion of a wedge into the calcaneum. *J Bone Joint Surg Br* 1963; **45**: 67–75.
20. Nimiityongskul P, Anderson LD, Herbert DE. Surgical treatment of clubfoot: a comparison of two techniques. *Foot Ankle* 1992; **13**: 116–24.
21. Heyman CH, Herndon CH, Strong JM. Mobilization of the tarsometatarsal and intermetatarsal joints for the correction of resistant adduction of the fore part of the foot in congenital clubfoot or congenital metatarsus varus. *J Bone Joint Surg Am* 1958; **40**: 299–309.
22. Kendrick RE, Sharma NK, Hassler WL, Herndon CH. Tarsometatarsal mobilization for resistant adduction of the fore part of the foot. *J Bone Joint Surg Am* 1970; **52**: 61–70.
23. Stark JG, Johanson JE, Winter RB. The Heyman–Herndon tarsometatarsal capsulotomy for metatarsus adductus: results in 48 feet. *J Pediatr Orthop* 1987; **7**: 305–10.
24. Evans D. Relapsed clubfoot. *J Bone Joint Surg Br* 1961; **43**: 722.
25. Lichtblau S. A medial and lateral release operation for clubfoot. *J Bone Joint Surg Am* 1973; **55**: 1377–84.
26. Hoffman AA, Constine RM, McBride GG, Coleman SS. Osteotomy of the first cuneiform as treatment of residual adduction of the fore part of the foot in clubfoot. *J Bone Joint Surg Am* 1984; **66**: 985–90.
27. Ozeki S, Yasuda K, Lisaka H. The results of talar neck osteotomy in resistant congenital clubfoot. In: Simons GW. (ed) *Club foot*. New York: Springer, 1994; 351–9.
28. Rathjen KE, Mubarak SJ. Calcaneal-cuboid-cuneiform osteotomy for correction of valgus foot deformities in children. *J Pediatr Orthop* 1998; **18**: 775–82.
29. Shoemaker PL, Anderson DJ, Blair VP, Anderson AM. Combined lateral column shortening and medial column lengthening of severe forefoot adductus. In: Simons GW. (ed) *Club foot*. New York: Springer, 1994; 412–6.
30. Lourenco AF, Dias S, Zoellick DM, Sodre H. Treatment of residual adduction deformity in clubfoot: the double osteotomy. *J Pediatr Orthop* 2001; **21**: 713–8.
31. Bensahel H, Kuo K, Duhaime M. Outcome evaluation of the treatment of clubfoot. *J Bone Joint Surg Br* 2002; **84** (Suppl III): 297.
32. Wynne-Davies R. Talipes equinovarus: a review of eighty-four cases after completion of treatment. *J Bone Joint Surg Br* 1964; **46**: 464–76.
33. Grill F, Franke J. The Ilizarov distractor for the correction of relapsed or neglected clubfoot. *J Bone Joint Surg Br* 1987; **69**: 593–7.
34. Watts H. Gradual midfoot distraction for the treatment of severe adductus deformity in children with clubfeet after multiple prior operations. In: Simons GW. (ed) *Club foot*. New York: Springer, 1994; 275–81.
35. Gupta AK. Treatment of residual clubfoot deformity. *J Pediatr Orthop* 1993; **13**: 408–9.

Appendix – SCORING SYSTEM

Item	Score (marks)		Item	Score (marks)	
CLINICAL EVALUATION			RADIOGRAPHIC EVALUATION		
Pain (2 marks)	Absent	2	Anterior talocalcaneal angle TCA1 (2 marks)	20–40°	2
	Mild	1		10–19°	1
	Persistent	0		< 10°	0
Adduction deformity (2 marks)	Full correction (no adduction)	2	Anterior talo-first metatarsal angle TFMA1 (2 marks)	< 10°	2
	Partial correction (adduction < 5°)	1		10° – 20°	1
	Adduction > 5°	0		>20°	0
Hindfoot varus (1 mark)	Absent	1	Anterior calcaneo-first metatarsal angle CFMA (2 marks)	< 10°	2
	Present	0		10–20°	1
Supination (1 mark)	Absent	1		> 20°	0
	Present	0	Lateral talocalcaneal angle TCA2 (2 marks)	20–50°	2
Cavus (1 mark)	Absent	1		10–24°	1
	Present	0		< 10°	0
Tolerability to orthosis (2 marks)	Optimum	2	Lateral talo-first metatarsal angle TFMA2 (2 marks)	10–20°	2
	Better	1		> 20°	1
	Intolerable	0		< 10°	0
Patient/parents satisfaction (1 mark)	Satisfied	1	Total score (20 marks)		
	Not satisfied	0		Excellent	19–20
				Good	16–18
				Fair	10–15
				Poor	< 10