ORIGINAL CLINICAL ARTICLE

Grice arthrodesis in the treatment of valgus feet in children with myelomeningocele: a 12.8-year follow-up study

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Abstract

Purpose Neurological deficit resulting in the lack of motor control in children with myelomeningocele often leads to a valgus position of the feet and ankles, usually in combination with planovalgus and pronation of the forefoot. The purpose of the study was to evaluate long-term patient satisfaction and clinical effects in ambulating children with lumbosacral myelomeningocele after having performed a Grice arthrodesis of a valgus unstable foot. The clinically most relevant radiographic measurements, such as the frontal and lateral talo-calcaneal angles, were used to evaluate the anatomical effects of the surgery, whereas the main research question was to reveal the patient satisfaction and usefulness of the procedure.

Methods The modified Grice–Green extraarticular subtalar arthrodesis was performed by the same surgeon on one standing and 22 walking patients (12 female) with lumbosacral myelomeningocele and valgus instability during the period 1985–1999. Twelve patients had bilateral surgery, giving a total of 35 operated feet. The patients attended a thorough check-up at a mean of 12.8 years (standard deviation [SD] $\pm$ 3.2, range 7.7–20.2 years) after surgery. The mean age at surgery was 6.6 years (SD $\pm$ 1.8) and at follow-up 19.4 years (SD $\pm$ 3.8). Functional parameters, such as walking ability, pain and skin problems, and the need for braces and supportive orthopaedic shoes were noted at the follow-up interview. The parents were interviewed along with the patients in order to obtain all of the necessary information. Loaded radiographs in the lateral and frontal planes were taken of both feet and ankles pre-operatively and at follow-up, except for pre-operative radiographs in six patients that were not loaded and, thus, not included, except for the assessment of ankle valgus. Ankle valgus was assessed from lateral and frontal views of the ankle on a scale from grade 0 to grade 3 according to Malhotra. Frontal and lateral talo-calcaneal angles were measured for the assessment of subtalar varus or valgus. Lateral talo-first-metatarsal (Meary's) angles were measured to investigate the longitudinal arches of the feet.

Results The mean lateral talo-calcaneal angle was reduced significantly ($P < 001$) from 55.1° (SD $\pm$ 8.9) to 38.8° (SD $\pm$ 8.1). The mean frontal talo-calcaneal angle was reduced from 24.7° (SD $\pm$ 9.7) pre-operatively to 16.6° (SD $\pm$ 6.3) at follow-up ($P < 0.001$). The mean lateral talo-first-metatarsal angle improved significantly from −16.1° (SD $\pm$ 24.7) pre-operatively to 0.9° (SD $\pm$ 15.1) at follow-up ($P = 0.0015$). The calcaneal pitch did not change significantly. In general, ankle valgus worsened during follow-up time, but not significantly ($P = 0.113$). The visual analogue scale (VAS) score of patient satisfaction improved significantly from 3.7 (SD $\pm$ 1.7) prior to surgery to 7.2 (SD $\pm$ 1.5) at follow-up ($P < 0.005$). Nineteen patients (83%) were satisfied with the surgery and would thus recommend the procedure.

Conclusions Based on the radiological findings and patient satisfaction, the patients participating in this study benefited from having had Grice arthrodeses performed on their valgus unstable feet. The results indicate good long-term correctional effect on valgus deformity after Grice arthrodesis, as the talo-calcaneal and talo-first-metatarsal angles improved significantly. A great majority of the patients were content with the surgery, and none claimed that any residual deformity was the cause for any reduced ability to ambulate.

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Introduction

Neurological deficit resulting in the lack of motor control in children with myelomeningocele often leads to a valgus position of the feet and ankles, usually in combination with planovalgus or pronation of the forefoot. This deformity may be difficult to correct by orthoses alone, and surgical correction may be needed to enable the child to walk. Difficulties in finding suitable shoes are typical. Pain produced by extreme foot deformity and orthoses is sometimes present. Pressure sores can easily occur in the insensate foot, and correction of a foot deformity to avoid such pressure sores may be necessary. The neurological condition deteriorates during childhood in some cases due to complications from tethered cord releases, hydrocephalus treatment and scoliosis corrections, and the neurological status cannot in all cases be regarded as non-progressive.

The extraarticular subtalar arthrodesis was originally designed by Grice in the treatment of children with polio [1] and was widely used some decades ago [1–4]. Recently, other corrective surgical procedures have been more commonly used, such as the medial sliding osteotomy of the calcaneus [5, 6] and the calcaneal lengthening osteotomy [7–9].

The Grice procedure has, since the eradication of polio, been more commonly used in the treatment of spastic valgus deformity seen in patients with spastic cerebral palsy [1, 10]. The operation is found to be a demanding one, even among experienced surgeons [1, 11–14], but it is a major advantage that it does not affect further bone growth or necessitates the resection of local bone. The procedure has also been used in children with myelomeningocele [15, 16], which typically has concomitant valgus instability of the ankles, and correcting the subtalar joint addresses, in many cases, only part of the problem. Adequate pre-operative radiographs of both the feet and ankles are of the essence to locate the cause of the valgus instability.

The purpose of the study was to evaluate long-term patient satisfaction and radiological and clinical effects in walking children with myelomeningocele after having performed a Grice arthrodesis of a valgus foot. The clinically most relevant radiographic measurements, such as the frontal and lateral talo-calcaneal angles, were used to evaluate the anatomical effects of the surgery, whereas the main research question was to reveal the patient satisfaction and usefulness of the procedure.

Patients and methods

A modified Grice–Green extraarticular subtalar arthrodesis was performed on 22 walking patients and one standing patient with lumbosacral myelomeningocele and foot valgus instability during the period 1985–1999. The patients were identified retrospectively from hospital and personal archives. Eight patients declined to participate and two patients had died due to causes unrelated to their foot deformities, hence, 23 patients (12 female) attended a thorough check-up at a mean of 12.8 years (standard deviation [SD] ± 3.2, range 7.7–20.2 years) after surgery. The mean age at surgery was 6.6 years (SD ± 1.8) and at follow-up 19.4 years (SD ± 3.8). Twelve patients had bilateral surgery, giving a total of 35 operated feet. Sixteen patients had significant planus deformity (lateral talo-first-metatarsal angles <1°) and one patient had significant cavus deformity (lateral talo-first-metatarsal angle >35°) at the time of surgery.

Pre-operatively, six patients were walking independently without orthoses, 14 patients were walking with orthoses, two patients were walking with support and orthoses, and one patient was capable of standing with orthoses and support. Prior to surgery, 14 patients (61%) used special orthopaedic supportive shoes, two patients experienced foot pain and six patients had skin problems due to pressure sores.

All patients had been operated in the exact same manner by the same experienced surgeon. Concomitantly, nine patients (13 feet) had anterior tibial tendon transfers to the Achilles tendon to improve plantar flexion power, three patients (four feet) had Achilles lengthening procedures and one patient had a bilateral transfer of the anterior tibial tendon to the dorsum of her feet to improve foot balance and to correct forefoot supination. In one foot, tenotomy of both the posterior and the anterior tibial tendon was performed to improve forefoot balance and position.

Two patients (three feet) had anterior tibial tendon transfers to the Achilles tendon and two patients had derotational tibial osteotomies at other points of time.

Nineteen patients in this series (83%) had hydrocephalus treated with ventriculoperitoneal shunts and 17 patients had tethered cord releases, in some cases with significant reduction in neurologic function over time.

Surgical technique of the modified Grice–Green procedure used in the study

An oblique dorso-lateral incision was made over the sinus tarsi of the foot. The underlying extensor brevis muscle, along with local fatty tissue, was dissected from the bone and retracted distally. All remaining soft tissues were

excised from the sinus tarsi. A double cortical graft harvested from the proximal lateral part of the tibia was placed into small channels in the calcaneus and talus made by an osteotome at the same time as the foot was held in slight plantar flexion and supination. The varus–valgus position of the heel was assessed on clinical examination intraoperatively. The grafts were placed in a vertical position in line with the tibia. Any additional bone graft was impacted into the sinus tarsi. Additional fixation was not used. After wound closure, a circular short leg cast was applied for 12 weeks until healing. The patients were usually allowed to partially weight-bear after 8 weeks (Fig. 1). The patients were advised to use orthoses according to the individual patient's needs and comfort, but no general recommendations were given.

Functional parameters, such as walking ability, pain and skin problems, and the need for orthoses and special orthopaedic shoes, were noted at the follow-up interview. The parents were interviewed along with the patients in order to obtain all of the necessary information. The visual analogue scale (VAS), using a scale from 1 to 10, where 1 was the poorest and 10 was the best possible score, was used to monitor patient satisfaction regarding foot function and cosmetics. Information regarding the neurological diagnosis and concomitant diseases were noted from the patients' charts. At the very end of each interview, the patients were asked if they would recommend the arthrodesis operation to other children with similar problems.
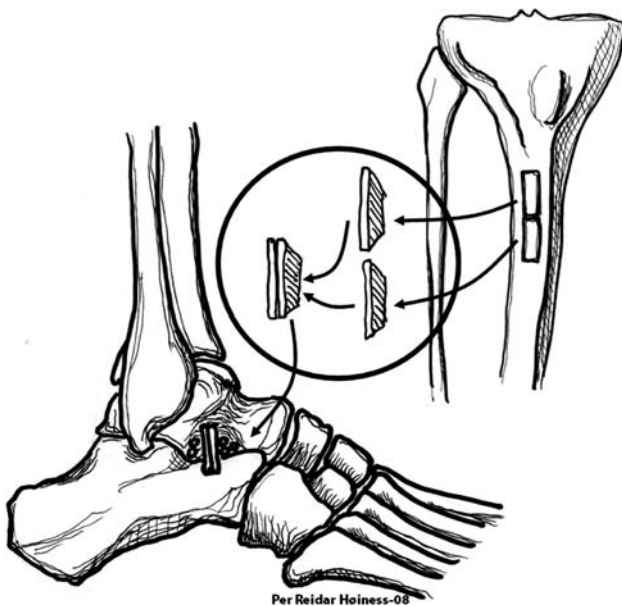
In principle, loaded radiographs in the lateral and frontal planes were taken of both feet and ankles pre-operatively and at follow-up. However, the pre-operative radiographs of six patients (nine feet) were not loaded and, thus, not included in the statistical evaluation, except for the assessment of ankle valgus. Ankle valgus was assessed according to Malhotra et al. [17] on a scale from grade 0 to grade 3, even on non-weight-bearing films, by assessing the level of the fibular growth plate relative to the ankle joint on frontal and lateral views (Fig. 2). Grade 2 ankle valgus was considered to be moderate and grade 3 severe [17].

The main radiographic measurements were the frontal and lateral talo-calcaneal angles, as these have previously been proven to be a valid means of assessing subtalar varus or valgus [2, 10, 18, 19]. Additionally, lateral talo-first-metatarsal angles (Meary's angles) were measured to investigate the longitudinal arches of the feet, as a cavus foot deformity typically develops in some of these patients. Highly positive values would indicate a cavus deformity, as opposed to negative values, which would indicate a rocker-bottom deformity and, possibly, pronation of the foot. In addition, the calcaneal pitch was measured.
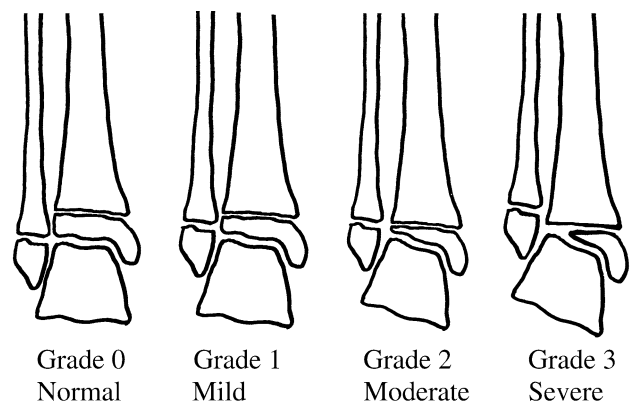
Normal values and ranges were used as described by Malhotra et al., Vanderwilde et al. and Davids et al. [17–19], as shown in Table 1.

All radiographic measurements were performed by both authors independently, and the mean values were used for the statistical analysis.

Paired t-tests and non-parametric tests were used for the statistical evaluation.

Results

At the time of follow-up, 16 patients were walking independently, of which seven patients used orthoses. Three

Fig. 1 The Grice–Green procedure. Two cortical bone blocks are harvested from the lateral proximal part of the tibia and inserted into the tarsal tunnel. Implants for fixation are usually not necessary

Fig. 2 Classification of ankle valgus according to Malhotra et al. [17]. The degree of ankle valgus is determined based on the level of the fibular growth plate

Table 1 Normal means and ranges of the radiological angles used in the study

Radiological angle	Mean angle	Assessment
Lateral talo-calcaneal angle	49° (range 36°–61°)	Hind foot varus/valgus
Frontal talo-calcaneal angle	25° (range 11°–35°)	Hind foot varus/valgus
Lateral talo-first-metatarsal angle	13° (range 1°–35°)	Cavus/planus foot
Calcaneal pitch	17° (range 5°–32°)	Plantar flexion hind foot

Table 2 Clinical and radiological findings prior to surgery and at follow-up

	Pre-operative mean value (range, SD)	Follow-up mean value (range, SD)	P-value
Satisfaction (VAS)	3.7 (0–8, SD ± 1.7)	7.2 (3–10, SD ± 1.5)	<0.005
Ankle valgus grade 0	10	9	–
Ankle valgus grade 1	14	11	–
Ankle valgus grade 2	10	9	–
Ankle valgus grade 3	1	6	–
Lateral talo-calcaneal	55.1° (39–72, SD ± 8.9)	38.8° (23–54, SD ± 8.1)	<0.001
Frontal talo-calcaneal	24.7° (6–51, SD ± 9.8)	16.6° (0–28, SD ± 6.3)	<0.001
Lateral talo-first-metatarsal	−16.1° (−64 to 38, SD ± 24.7)	0.9° (−36–35, SD ± 15.1)	0.0015
Calcaneal pitch	17.6° (−9 to 36, SD ± 11.9)	16.1° (−15–30, SD ± 10.7)	0.25

patients were walking with crutches and orthoses, one patient was walking with crutches without orthoses and three patients used a wheelchair only. The orthoses used were the Ferrari-type orthoses and, in a few instances, plain ankle foot orthoses (AFO).

The incidence of foot problems were reduced at the follow-up check-up, at which six patients used specially made supportive shoes (26%), one patient had foot pain and five patients had skin problems.

The VAS score of patient satisfaction improved significantly from 3.7 (SD ± 1.7) prior to surgery to 7.2 (SD ± 1.5) at follow-up ($P < 0.005$). Nineteen patients (83%) were satisfied with the surgery and would, thus, recommend the procedure. Two patients (three feet) had residual valgus unstable feet due to valgus instability at Chopart's joint, but none of these patients had related complaints.

Ankle valgus on pre-operative radiographs demonstrated grade 0 in 10 feet, grade 1 in 14 feet, grade 2 in 10 feet and grade 3 in one foot. At follow-up, ankle valgus had generally worsened, as grade 0 was found in nine feet, grade 1 in 11 feet, grade 2 in nine feet and grade 3 in six feet. This change in ankle valgus was, however, not significantly different ($P = 0.113$). The VAS score was higher in patients with moderate/severe ankle valgus (grade 2/3) compared to those with none/low grade (grade 0/1) ankle valgus (7.4 vs. 7.1, $P = 0.542$).

The mean lateral talo-calcaneal angle was reduced significantly from 55.1° (SD ± 8.9) to 38.8° (SD ± 8.1) ($P < 0.001$). The mean frontal talo-calcaneal angle was significantly reduced from 24.7° (SD ± 9.7) pre-operatively to 16.6° (SD ± 6.3) at follow-up ($P < 0.001$). The

mean lateral talo-first-metatarsal angle improved significantly from −16.1° (SD ± 24.7) pre-operatively to 0.9° (SD ± 15.1) at follow-up ($P = 0.0015$). The average calcaneal pitch decreased slightly from 17.6° (SD ± 11.9) pre-operatively to 16.1° (SD ± 10.7) at follow-up ($P < 0.25$) (Table 2).

The foot length at follow-up was, on average, 188 mm (SD ± 15.6) vs. 186 mm (SD ± 15.7) when comparing the operated and the non-operated feet in the unilateral cases, thus, they were not significantly different ($P = 0.59$).

No infections were seen post-operatively.

Only one arthrodesis failed to heal, but the patient had no symptoms and were satisfied (Fig. 3).

Discussion

When Grice introduced the extraarticular arthrodesis of the subtalar joint in 1952 [1, 20], it was originally devised to treat children with polio. The procedure has later been widely used in the treatment of spastic valgus instability and in paralytic disorders. As the procedure is extraarticular and does not disturb bone growth, it is applicable even in young children. It is, therefore, regarded as being well suited in the correction of valgus instability in children with myelomeningocele (Fig. 4). Long-term results in patients with cerebral palsy have been somewhat variable [4, 21, 22], but Bourelle et al. [10] reported good long-term results in 23 children with cerebral palsy who had had Grice arthrodeses performed, and so have others [23, 24]. The natural course of valgus unstable feet in children with

Fig. 3 Graft resorption and apparent lack of subtalar fusion 9 years after Grice extraarticular subtalar arthrodesis. The patient had no complaints and the foot appeared to be valgus stable

myelomeningocele with respect to foot deformity, function or patient satisfaction has not been reported previously and is not further investigated in this study. The evaluation of corrective foot surgery in myelomeningocele children is further complicated by the neurological deterioration commonly occurring in these patients, often due to tethered cord and subsequent releases [25–28].

Patient selection and the indications for surgery in this study were based on the clinical judgement of valgus instability of the feet combined with an evaluation of the overall situation of the child, such as walking ability, and not solely on radiographic measurements or any other objective parameter. The selection of these patients was based on the judgement of an experienced orthopaedic surgeon who performed all of the surgical procedures in this study.

When assessing function and patient satisfaction at follow-up, walking ability could not be used as a valid parameter, as a great number of myelomeningocele patients tend to worsen in time due to the natural course of their neurological condition. Some patients also experience loss of neurology and ability to walk secondary to release operations for tethered cord [25, 27]. Moreover, a great number of patients chose to use a wheelchair, as they found themselves more mobile using a wheelchair rather than walking with crutches and orthoses. This may explain why there was no significant difference in the incidence of foot pain, pressure sores and the need for special supportive shoe wear. At our clinic, there is no rigid recommendation regarding the use of orthoses, as the use of orthoses depends on the degree of usefulness and tolerance in each individual patient.

The use of the VAS scale for the assessment of patient satisfaction may be challenging, especially in children. Misconceptions and misinterpretations are possible, and

the information in this study was, thus, partly dependent upon information and assessments given by the parents. In general, the assessment of the child's foot deformity prior to surgery and at follow-up was given jointly by the parents and the patients.

Four patients were reluctant to recommend the Grice–Green arthrodesis, as they claimed that their long-term results did not compensate for the post-operative pain and discomfort. One of these patients was reluctant to evaluate any benefit he may have had from the surgery, as he had experienced severe neurological loss of function following several operations for tethered cord.

Radiographic measurements change in a child's growing foot [18], and were, thus, expected to change regardless of any foot surgery or any other non-operative treatments that might have been instituted. Severely valgus unstable feet are, however, not likely to correct spontaneously and, thus, the findings that were made at the follow-up check-up were most probably due to the corrective surgeries and, perhaps, combined with the use of orthoses.

The importance of muscle balancing the foot has been reported repeatedly [4, 10]. In our series, a great number of additional surgical procedures were performed, including anterior tibial tendon transfers, Achilles tendon lengthenings and derotational tibial osteotomies. The influence that these procedures may have had on the on the long-term outcome is difficult to assess, but, most likely, they have had a favourable effect.

Pre-operative radiographs demonstrated ankle valgus grade 0 in ten patients, grade 1 in 14 patients, grade 2 in ten patients and grade 3 in one patient. This finding was quite consistent with Malhotra's own findings [17]. The mean pre- and post-operative ankle valgus increased from grade 1.1 to 1.3, but the difference was not statistically significant ($P = 0.113$). Moderate or severe ankle valgus (grade 2/3) increased from 31% of all cases pre-operatively to 43% post-operatively. Even though late ankle valgus is well recognized as a cause of clinical failure [2–4, 11, 12, 14, 29], it proved not to be of clinical importance in our series, as the mean patient satisfaction VAS score was higher in patients with moderate/severe ankle valgus compared to those with none/insignificant (grade 0/1) ankle valgus (7.20 vs. 7.05).

Two patients had recurrent valgus instability in three feet. One patient had moderate valgus instability at Chopart's joint in her left foot, and her ankle was positioned neutrally. She had little discomfort and was helped sufficiently with a medial support in the shoe. The other patient had bilateral valgus feet and also a significant ankle valgus deformity which had increased from grade 2 to grade 3 post-surgery. He had developed considerable neurological deficits after repeated tethered cord releases, lost walking

Fig. 4 Example of the course of the foot after a Grice arthrodesis was performed in a 5-year-old girl. The radiographs were taken: **a** prior to surgery, **b** post-operatively and **c** at 13 years follow-up. The fourth toe was amputated due to a pressure sore

ability and there was, thus, no indication for any salvage procedures, such as triple arthrodeses, of his feet.

Lateral and frontal talo-navicular radiographs are suited for assessing hind foot varus/valgus [18, 19] and, to some degree, planus deformity (Fig. 5). In this series, the mean frontal talo-calcaneal angle was reduced by 8.1° ($P < 0.001$) and the mean lateral talo-calcaneal angle was reduced from 55.1° to 38.8°, thus, reducing hind foot valgus significantly ($P < 0.001$). Although 13 patients had radiological measurements indicating slight hind foot varus (lateral talo-calcaneal angle <36° or frontal talo-calcaneal angle <11°) at follow-up, there were no cases of significant hind foot varus deformity upon clinical assessment in our series. The follow-up hind foot measurements were, on average, within the normal ranges as found by Vanderwilde et al. and Davids et al. [18, 19], and well in line with the clinical findings and patient satisfaction.

Cavus/planus position of the foot and alignment of the hind foot vs. the forefoot can be assessed on the basis of the lateral talo-first-metatarsal angle [18, 19, 30]. The greater the lateral talo-first-metatarsal angle, the more planus is the mid foot. In this series, the mean talo-first-metatarsal angle was significantly reduced from 16.1° to −0.9° ($P = 0.0015$), thus, demonstrating considerable correction of planus deformity of the mid foot following Grice arthrodesis.

A key issue of the Grice procedure has been to preserve further growth of the foot, and Bourelle et al. found no difference in shoe size when comparing the operated with the un-operated feet [10]. Bourelle et al.'s finding was confirmed in our series of 11 unilaterally operated feet with no significant difference in foot length when comparing with the non-operated side as measured on lateral radiographs (188 vs. 186 mm, $P = 0.59$).

There have been reports on pseudarthrosis, failure of fixation or fracture of the graft in up to 15–31% of spastic feet [12, 14], and graft resorption has been reported to occur in up to 33% of patients undergoing the Grice procedure [14, 22, 23, 31]. There was no negative effect on the clinical outcome in the only case of graft resorption and pseudarthrosis in this series (Fig. 6). Additional screw fixation has still not been found to be necessary in our clinic.

Fractures and overgrowth at the donor site have been described but were not found at the clinical examination of the patients in this study. However, no specific investigations were performed to reveal any growth deformity secondary to graft harvesting from the proximal tibia. At our clinic, we still prefer to use tibial grafts for this procedure, as we have found it to be quite practical and we have not experienced any of the negative effects mentioned above.

Degenerative changes in adjacent joints are frequently found in patients with gross foot deformities, regardless of treatment. Only one out of the 23 patients in this series experienced foot pain, mainly due to clavus formation and occasional pressure sores.

Mosca [9] demonstrated good results using the calcaneal lengthening osteotomy in a mixed group of patients suffering from myelomeningocele and cerebral palsy, and

Fig. 5 Lateral view of a Grice arthrodesis pre-operatively, post-operatively after union and at 9 years follow-up

Fig. 6 Patient unhappy with their left foot due to valgus instability at Chopart's joint 9 years after Grice–Green arthrodesis

metatarsal angles improved significantly. A great majority of the patients were content with the surgery, and none claimed that any residual deformity was the cause for any reduced ability to ambulate.

The results of this study indicate that the Grice arthrodesis is a safe and sufficient method to correct foot valgus deformity in children with myelomeningocele, with a low incidence of complications and satisfactory long-term results.

Torosian and Dias [5] showed good results using the medial sliding osteotomy of the calcaneus in 27 myelomeningocele patients. Both of these procedures and the Grice arthrodesis seem to be suitable for children, and the choice of surgical procedure will depend upon the evaluation of each valgus foot and the preference of the surgeon.

In conclusion, based on the radiological findings and patient satisfaction, the patients participating in this study benefited from having had Grice arthrodeses performed on their valgus unstable feet. The Grice arthrodesis proved to have a good long-term correctional effect on planovalgus deformity, as both lateral talo-calcaneal and talo-first-

References

1. Grice DS (1952) An extra-articular arthrodesis of the subastragalar joint for correction of paralytic flat feet in children. J Bone Joint Surg Am 34A(4):927–940
2. Aronson J, Nunley J, Frankovitch K (1983) Lateral talocalcaneal angle in assessment of subtalar valgus: follow-up of seventy Grice-Green arthrodeses. Foot Ankle 4(2):56–63
3. De Leon-Falewski G (1973) Modified Grice operation for correction of paralytic plano-valgus feet. Int Surg 58(1):52–55
4. McCall RE, Lillich JS, Harris JR, Johnston FA (1985) The Grice extraarticular subtalar arthrodesis: a clinical review. J Pediatr Orthop 5(4):442–445
5. Torosian CM, Dias LS (2000) Surgical treatment of severe hindfoot valgus by medial displacement osteotomy of the os calcis in children with myelomeningocele. J Pediatr Orthop 20(2):226–229. doi:10.1097/00004694-200003000-00018
6. Rathjen KE, Mubarak SJ (1998) Calcaneal-cuboid-cuneiform osteotomy for the correction of valgus foot deformities in children. J Pediatr Orthop 18(6):775–782. doi:10.1097/00004694-199811000-00015
7. Noritake K, Yoshihashi Y, Miyata T (2005) Calcaneal lengthening for planovalgus foot deformity in children with spastic cerebral palsy. J Pediatr Orthop B 14(4):274–279
8. Doğan A, Albayrak M, Akman YE, Zorer G (2006) The results of calcaneal lengthening osteotomy for the treatment of flexible pes planovalgus and evaluation of alignment of the foot. Acta Orthop Traumatol Turc 40(5):356–366

9. Mosca VS (1995) Calcaneal lengthening for valgus deformity of the hindfoot. Results in children who had severe, symptomatic flatfoot and skewfoot. J Bone Joint Surg Am 77(4):500–512

10. Bourelle S, Cottalorda J, Gautheron V, Chavrier Y (2004) Extra-articular subtalar arthrodesis. A long-term follow-up in patients with cerebral palsy. J Bone Joint Surg Br 86(5):737–742. doi:10.1302/0301-620X.86B5.14170

11. Scott SM, Janes PC, Stevens PM (1988) Grice subtalar arthrodesis followed to skeletal maturity. J Pediatr Orthop 8(2):176–183

12. Moreland JR, Westin GW (1986) Further experience with Grice subtalar arthrodesis. Clin Orthop Relat Res 207:113–121

13. Pollock JH, Carrell B (1964) Subtalar extra-articular arthrodesis in the treatment of paralytic valgus deformities. A review of 112 procedures in 100 patients. J Bone Joint Surg Am 46:533–541

14. Ross PM, Lyne ED (1980) The Grice procedure: indications and evaluation of long-term results. Clin Orthop Relat Res 153:194–200

15. Aronson DD, Middleton DL (1991) Extra-articular subtalar arthrodesis with cancellous bone graft and internal fixation for children with myelomeningocele. Dev Med Child Neurol 33(3):232–240

16. Gallien R, Morin F, Marquis F (1989) Subtalar arthrodesis in children. J Pediatr Orthop 9(1):59–63

17. Malhotra D, Puri R, Owen R (1984) Valgus deformity of the ankle in children with spina bifida aperta. J Bone Joint Surg Br 66(3):381–385

18. Vanderwilde R, Staheli LT, Chew DE, Malagon V (1988) Measurements on radiographs of the foot in normal infants and children. J Bone Joint Surg Am 70(3):407–415

19. Davids JR, Gibson TW, Pugh LI (2005) Quantitative segmental analysis of weight-bearing radiographs of the foot and ankle for children: normal alignment. J Pediatr Orthop 25(6):769–776. doi:10.1097/01.bpo.0000173244.74065.e4

20. Grice DS (1955) Further experience with extra-articular arthrodesis of the subtalar joint. J Bone Joint Surg Am 37A(2):246–259

21. Hamel J, Kissling C, Heimkes B, Stotz S (1994) A combined bony and soft-tissue tarsal stabilization procedure (Grice-Schede) for hindfoot valgus in children with cerebral palsy. Arch Orthop Trauma Surg 113(5):237–243. doi:10.1007/BF00443810

22. Guttmann GG (1990) Subtalar arthrodesis in children with cerebral palsy: results using iliac bone plug. Foot Ankle 10(4):206–210

23. Jeray KJ, Rentz J, Ferguson RL (1998) Local bone-graft technique for subtalar extraarticular arthrodesis in cerebral palsy. J Pediatr Orthop 18(1):75–80. doi:10.1097/00004694-199801000-00015

24. Alman BA, Craig CL, Zimbler S (1993) Subtalar arthrodesis for stabilization of valgus hindfoot in patients with cerebral palsy. J Pediatr Orthop 13(5):634–641

25. Hudgins RJ, Gilreath CL (2004) Tethered spinal cord following repair of myelomeningocele. Neurosurg Focus 16(2):E7. doi:10.3171/foc.2004.16.2.8

26. Mazur JM, Menelaus MB (1991) Neurologic status of spina bifida patients and the orthopedic surgeon. Clin Orthop Relat Res 264:54–64

27. Bowman RM, McLone DG, Grant JA, Tomita T, Ito JA (2001) Spina bifida outcome: a 25-year prospective. Pediatr Neurosurg 34(3):114–120. doi:10.1159/000056005

28. Sarwark JF, Weber DT, Gabrieli AP, McLone DG, Dias L (1996) Tethered cord syndrome in low motor level children with myelomeningocele. Pediatr Neurosurg 25(6):295–301. doi:10.1159/000121143

29. Hsu LC, Jaffray D, Leong JC (1986) The Batchelor-Grice extra-articular subtalar arthrodesis. J Bone Joint Surg Br 68(1):125–127

30. Davis LA, Hatt WS (1955) Congenital abnormalities of the feet. Radiology 64(6):818–825

31. Engström A, Erikson V, Hjelmstedt A (1974) The results of extra-articular subtalar arthrodesis according to the Green-Grice method in cerebral palsy. Acta Orthop Scand 45(6):945–951