Modified Grice–Green subtalar arthrodesis performed using a partial fibular graft yields satisfactory results in patients with cerebral palsy

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The aim of this study was to report the experience with the use of a modified Grice–Green technique, which was performed using a partial subperiosteal fibular bone graft because of valgus unstable foot in children with cerebral palsy. Fifteen feet of 11 patients were evaluated on the basis of the appearance of the feet, clinical symptoms, and radiographic measurements. After an average follow-up duration of 24 (9–39) months, all feet showed satisfactory clinical and radiological results. Solid fusion and sustained correction took place in all feet. The gap at the donor site was bridged with new bone in all cases. No donor-site morbidity was detected. This modification of the Grice–Green technique can be used effectively in the correction of planovalgus foot in cerebral palsy. ***J Pediatr Orthop B*** **25:119–125**

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Introduction

The Grice–Green extraarticular subtalar arthrodesis procedure is considered to be a valid surgical method that improves foot alignment in the pediatric population with pes planovalgus deformity [1–4]. It was originally described to treat children with poliomyelitis [5]. However, this technique has since been used widely in the treatment of spastic pes planovalgus deformity. As the procedure is extra-articular and does not affect further bone growth, it can be used even in young children [2].

Satisfactory long-term results with the Grice–Green procedure have been reported in children with cerebral palsy [4,6–8]. However, achievement of a successful subtalar arthrodesis in these children can sometimes be challenging and several problems have been reported to occur in up to 15–33% of spastic feet undergoing this procedure. These are generally graft-related problems (independent of its source), which include delayed union or complete dissolution of the graft, fractures of the graft or donor site, technical problems with contouring of the graft to achieve adequate correction, loss of correction because of slippage of the graft, and valgus deformity of the ankle [1–3,6,9–15].

In the Grice–Green technique, the bone grafts may be obtained from the fibula, tibia, or iliac crest. These graft sources often lead to their own morbidity. The late valgus deformity of the ankle may occur because of failure of full regeneration when the graft is obtained from the ipsilateral fibula in a growing child [2,12]. In the absence of a normally growing fibula, the lateral side of the tibial epiphysis grows slower than the medial side and the tibiotalar joint may tilt into the valgus position [12]. The tibial bone graft has a relatively high risk for donor-site fracture [6,13,16]. When the distal tibial shaft is used as a graft site, there may be an acceleration of the growth of the tibia at the donor site. This accelerated growth may increase the deformity and produce an ankle valgus [13]. Failure of fusion and resorption of the graft obtained from the iliac crest have also been reported in the literature [10].

Several modifications of the type of bone graft and graft harvesting techniques with or without the use of internal fixation have been described to overcome these problems [6,17–20]. A double layer of a corticocancellous tibial graft [18], a strip of corticocancellous bone from the lateral wall of the calcaneus [19,20], an osteoperiosteal-based flap from the surface of the talus and calcaneus [17], and local bone graft with percutaneous fixation [6] are some of these modifications. Another modification of the original Grice–Green procedure is the partial subperiosteal fibular graft technique. It was first described by Faraj [21] in patients with poliomyelitis to decrease graft-site morbidity. He described the use of two partial fibular bone blocks placed across the subtalar joint and reported only minor complications in two children. Therefore, he stated that partial fibular subperiosteal bone grafts were not associated with any major biomechanical sequelae of the ankle and foot.

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To our knowledge, this is the first report on the use of the same technique, which was performed by obtaining only one partial subperiosteal fibular bone graft in patients with cerebral palsy. The aim of the present study was to evaluate the radiological and clinical results of this modified technique.

Methods

Modified Grice–Green extraarticular subtalar arthrodesis was performed on 15 feet (four bilateral, four right feet, three left feet) of 11 patients with cerebral palsy between the time period May 2011 and May 2014. There were six girls and five boys, three of whom were spastic quadriplegics (five feet), six were spastic diplegics (eight feet), and two were spastic hemiplegics. All patients had a valgus hindfoot deformity secondary to spasticity that was correctable passively. The average age of the patients at the time of surgery was 10.7 (range 6–15) years. Motor skills were assessed using the Gross Motor Function Classification Scale (GMFCS) [22]. Three (27.3%; two hemiplegics – GMFCS level I, one diplegic – GMFCS level II) patients were able to walk independently without orthoses and support, six (54.5%; five diplegics – GMFCS level III, one quadriplegic – GMFCS level III) patients were able to walk with support, and two (18.2%; two quadriplegics – GMFCS level IV) patients were capable of standing with orthoses and support, but were unable to walk. All patients experienced foot pain and three (two quadriplegics, one diplegic) patients had skin problems because of pressure sores. Before the subtalar arthrodesis procedure, multiple tendon release for five (three quadriplegics, two diplegics) patients had been performed to control muscle imbalance and multiple botulinum toxin injections for six (three quadriplegics, three diplegics) patients had been administered to control the spasticity. All patients received the physiotherapy-rehabilitation protocol during their operative period.

Anteroposterior (AP) and lateral weight-bearing radiographs were taken of both feet and ankles preoperatively. Radiological assessment consisted of five parameters in accordance with angular measurements that were directly associated with the deformity [8,23,24]. These angles were AP and lateral talocalcaneal, AP and lateral talus-first metatarsal, and calcaneal pitch angles. Ankle valgus was evaluated by assessing the level of the fibular growth plate relative to the ankle joint on frontal ankle radiographs according to Malhotra *et al.* [25]. Preoperatively, the distal fibular epiphyseal line was located between the talar plateau and the distal tibial epiphysis (grade 1) in all feet. All radiographic measurements were performed by the second author (A.T.) independently and the mean values of all measured angles were used for evaluation.

Before the operation, we discussed with the parents the potential risks and benefits of this modified technique. All patients had been operated in the supine position by the same surgeon (M.G.). Under a tourniquet control, a 5 cm oblique skin incision centered over the sinus tarsi was applied to the lateral portion of the foot. After passing through the subcutaneous layer, the cutaneous branch of the sural nerve, peroneal tendons, and extensor digitorum brevis were found and retracted. The superficial peroneal nerve may cross the most anterior part of the incision and therefore should also be protected. Anterior and posterior capsula of the subtalar joint were visualized and left intact. The sinus tarsi was visualized and cleaned from the soft tissues. Then, plantar flexion and inversion were applied to the foot. The calcaneus was held inverted out of its valgus position under the talus and dorsiflexion of the foot was attempted. In three patients (four feet; 26.6%), calcaneus could not be brought out of equinus; therefore, lengthening of the aponeurosis of the gastrocnemius was performed using the Vulpius procedure.

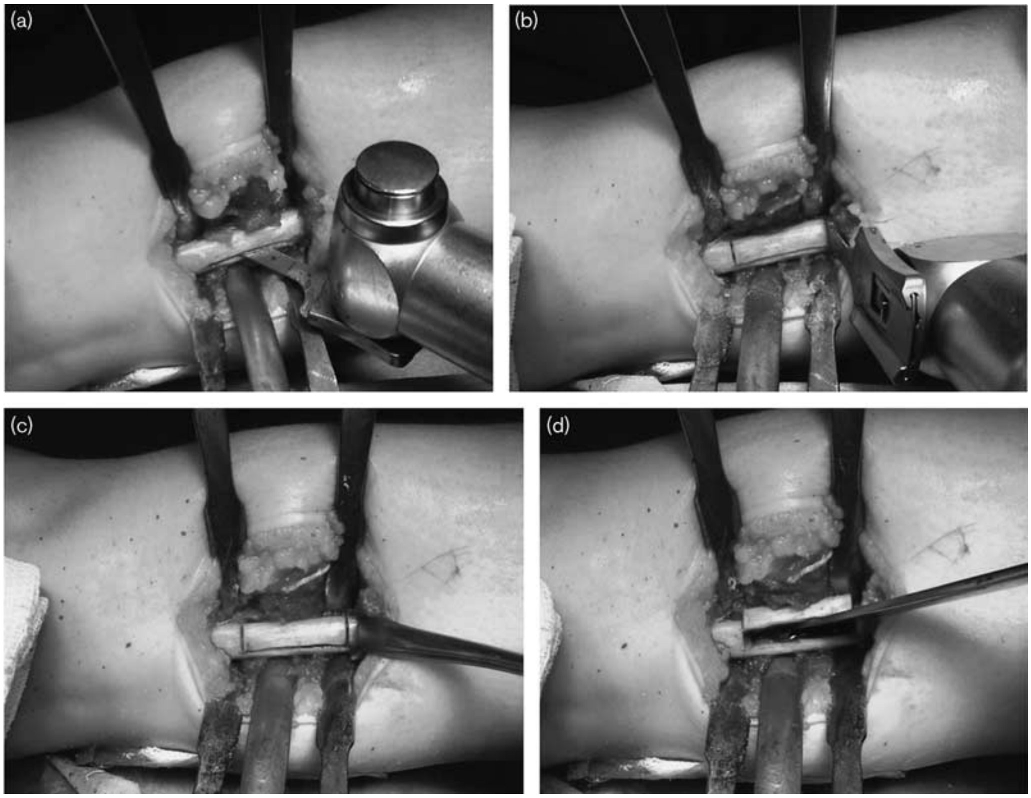
The graft bed was prepared by performing a thin osteotomy. Osseous blocks were removed from the undersurface of the talus (roof of the sinus tarsi) and the top of the calcaneus (floor of the sinus tarsi) and the length of the graft to be applied was determined. The ipsilateral fibula was used as the donor of the graft. A 5–6 cm lateral longitudinal incision was applied over the distal third of the fibula. After passing through the subcutaneous layer, a subperiosteal strut graft was obtained from the junction of the middle and distal third of the fibula above the syndesmosis. Fibular osteotomy was carried out using an oscillating saw by respecting the periosteum in each case (Fig. 1). Care was taken to obtain a 2/3 semicircular partial fibular graft with an intact posterior cortex of the fibula (Fig. 2).

The graft was placed into its bed in the sinus tarsi extraarticularly while forcing the subtalar joint into the varus position. Attention was paid to ensure that the long axis of the graft was parallel to the long axis of the tibia while the ankle was held in a neutral position (Fig. 3). The varus–valgus position of the heel was assessed on clinical examination intraoperatively. No internal fixation was needed in any of the cases after locking the graft at its slots. The tourniquet was deflated and hemostasis was ensured. The incisions were closed in a standard manner with subcuticular absorbable sutures.

Postoperatively, all feet were immobilized in circular short leg casts and the patients were usually allowed to partially weight-bear after 4 weeks. The short leg casts were continued until early incorporation of the bone graft was visible on the lateral weight-bearing radiographs of the foot. The positive bony union was considered in patients with union of the graft to both the talus and the calcaneus on the lateral radiographs. If graft union was observed in only one of them, it was considered a partial union. After removal of the casts, the patients were advised to use orthoses according to the individual patient's needs and comfort, but no general recommendations were provided.

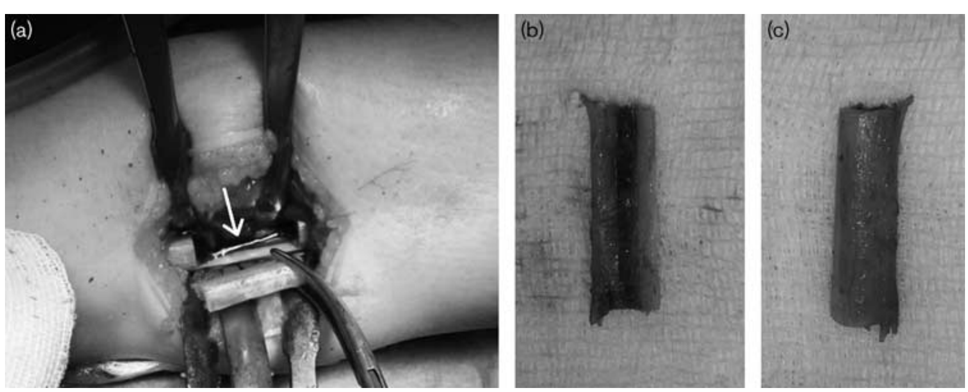
The patients were followed regularly at monthly intervals up to 3 months, every 3 months up to 12 months, and

Fig. 1



Fibular osteotomy applied using an oscillating saw (a–d).

Fig. 2



Care is taken to leave the posterior cortex (white arrow) of the fibula intact (a). Figure shows a 2/3 semicircular partial fibular bone graft (b, c).

every 6 months up to the last visit. The same angles were measured on the immediate postoperative and final follow-up radiographs. In addition, graft position against the weight-bearing axis of the tibiotalar joint and regeneration and integrity of the fibular donor site were also assessed. If the proximal end of the graft was angled anterior to the weight-bearing axis, it was termed anterior placement and if the proximal end lay posterior to the axis (perpendicular to the subtalar movement), it was termed posterior placement. Alignment of the graft was termed neutral if it was perpendicular to the floor.

Functional parameters such as walking ability, pain and skin problems, and the need for orthoses and special

Fig. 3

Alignment of the graft that is placed into its slots in the sinus tarsi.

orthopedic shoes were noted at the follow-up interview. The parents were interviewed along with the patients to obtain all of the necessary information and a questionnaire recommended by Jeray *et al.* [6] was used to assess the subjective outcome of the procedure (Table 1). Written informed consent form and written parental permission were obtained for all patients.

Results

The average follow-up period was 24 (range 9–39) months. Postoperative recovery was uneventful without infection in any of the cases. One superficial skin necrosis under a cast was the only immediate postoperative complication.

On the final follow-up, the mean talocalcaneal angle decreased from 41.3° (31°–63°) to 25.7° (21°–32°) and from 44° (35°–58°) to 28.6° (23°–33°) in frontal and sagittal planes, respectively. The mean AP and lateral talus-first metatarsal angle decreased from 22.1° (10°–44°) to 6.5° (4°–11°) and from 18.2° (8°–40°) to 6.4° (3°-–15°), respectively. The mean calcaneal pitch angle increased from 10.4° (3°–17°) to 16.9° (12°–21°). Preoperative ankle valgus remained unchanged for all applications (Table 2).

The casts were removed at the seventh week (range 6–9) on average postoperatively. All grafts were stable and solid fusion with sustained correction occurred in all feet. Thirteen (86.6%) feet had neutral alignment of the graft, whereas two (13.4%) had posterior alignment. The gap at the donor site showed complete fibular regeneration in all procedures. In two feet (13.4%), 5° valgus angulation of the distal fibula was detected on the coronal plane without any upward migration of the lateral malleolus. There were no angulations on the sagittal plane in any of the patients (Fig. 4).

Cosmetic foot appearance and walking ability were markedly improved, whereas preoperative complaints were reduced in all patients. This was also confirmed by the parents. On the final follow-up, the average age of the patients was 12.4 (range 8–17) years. Nine (81.8%) patients were still walking, seven (64%) of whom required no support. GMFCS levels of four diplegic patients, who were able to walk with support (GMFCS level III) preoperatively, upgraded to level II. GMFCS levels of the remaining patients were unchanged. Of those unable to walk, two patients were still able to stand with orthoses and support. Six patients required orthopedic shoes. Ten (91%) of the 11 patients (13 feet) were satisfied with the surgical procedure and one (9%) patient (two feet) was dissatisfied (Table 1). This patient was quadriplegic (GMFCS level IV) and his parents were not satisfied with the outcome, although clinical appearance and radiographic results were satisfactory.

Discussion

The aim of the treatment of pes planovalgus deformity in patients with cerebral palsy is to achieve a painless and plantigrade foot that has an as normal as possible hindfoot alignment. The Grice–Green procedure can correct symptomatic planovalgus feet. Together with physiotherapy and orthotic use, it can also improve ambulation [8,26]. In the present study, significant angular correction and solid fusion were achieved in all feet. The number of patients who were able to walk independently increased from three (27.3%) to seven (64%) during the postoperative period. The overall satisfaction rate of the patients/parents was 91%.

Lancaster and Pohl [16] reviewed 36 extra-articular arthrodeses of 21 patients retrospectively to ascertain

Table 1 Clinical results obtained from the questionnaire on patients'/parents' satisfaction [6]

Questions	Response (*n*) No	Response (*n*) Yes	Patients (%)	Feet (%)
Does your child's foot/feet look better now than it did before surgery?	1	10	91	86.6
Was the surgery worth it?	1	10	91	86.6
Would you have this surgery again for the same condition?	1	10	91	86.6
If your child had pain before surgery, has this been improved since surgery?	–	11	100	100
Are you pleased with the outcome of your child's foot/feet?	1	10	91	86.6

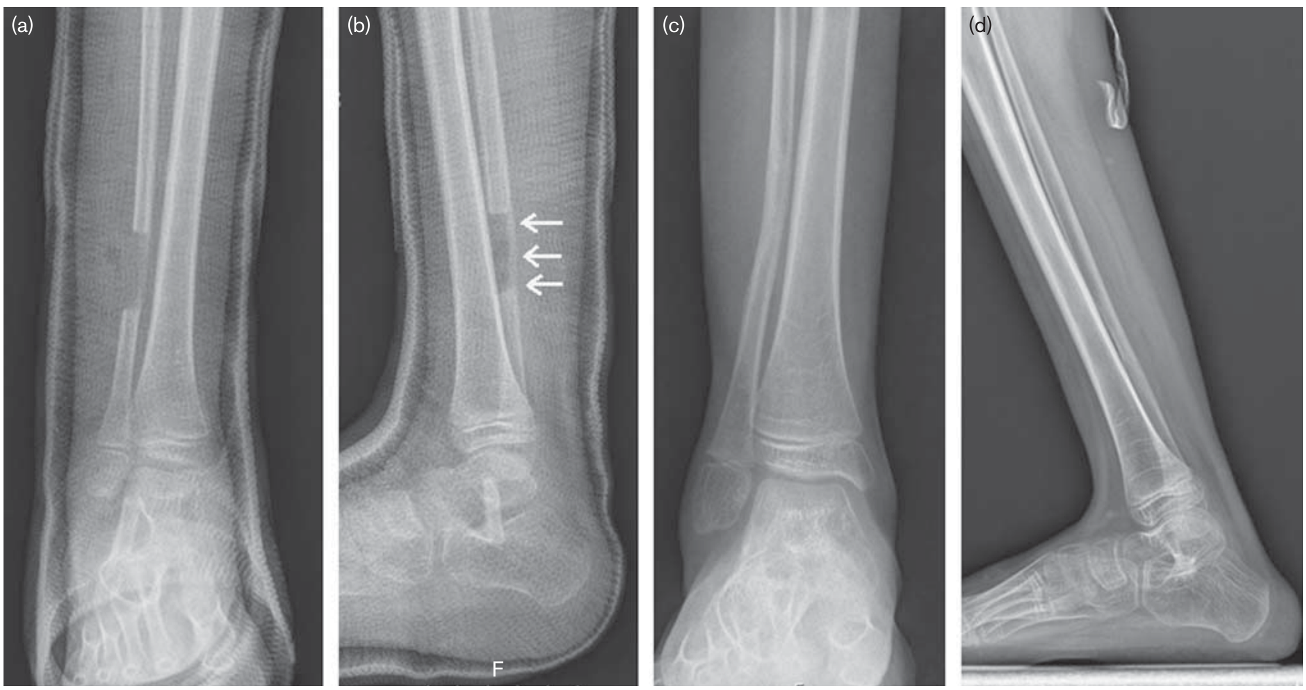
n, number of patients.

Table 2 Radiological outcomes of patients

	Preoperative	Postoperative	At the latest follow-up
AP TCA	41.3° ± 8.5° (31°–63°)	26.4° ± 4.3° (20°–35°)	25.7° ± 2.6° (21°–32°)
Lateral TCA	44° ± 7.3° (35°–58°)	28.4° ± 4.7° (20°–35°)	28.6° ± 3° (23°–33°)
AP TFM	22.1° ± 9.4° (10°–44°)	6.2° ± 2.2° (3°–11°)	6.5° ± 2° (4°–11°)
Lateral TFM	18.2° ± 11.6° (8°–40°)	6.9° ± 4.2° (4°–18°)	6.4° ± 3.5° (3°–15°)
CPA	10.4° ± 3.9° (3°–17°)	17.4° ± 3.7° (12°–23°)	16.9° ± 2.7° (12°–21°)
Ankle valgus according to Malhotra *et al.* [25]	All in grade 1	All in grade 1	All in grade 1

Values are given as the mean and SD, with the range in parentheses.
AP, anteroposterior; CPA, calcaneal pitch angle; TCA, talocalcaneal angle; TFM, talus-first metatarsal angle.

Fig. 4



Immediate postoperative AP (a) and lateral (b) radiographs of a 9-year-old diplegic female patient. White arrows show the intact posterior cortex of the ipsilateral fibula. The gap at the donor site shows complete regeneration at the 18th month postoperative radiographs and solid fusion has been achieved. Valgus angulation (5°) on the coronal plane has been detected without any upward migration of the lateral malleolus (c, d).

long-term results and to identify the better grafting material: tibial corticocancellous bone or a fibular strut graft. All patients had flexible planovalgus deformities because of various etiologies. Satisfactory results (fusion, no pain, and correction of the deformity) were achieved in 83.3% of patients and unsatisfactory results (residual pronation, marked pronation, or graft resorption) were achieved in 16.7%. They concluded that the fibular strut graft had a better overall success rate, fewer complications, easier acquisition, and achieved union where the tibial corticocancellous bone graft failed.

The use of a partial subperiosteal fibular graft in the Grice–Green procedure has been described previously by Faraj [21]. He applied an extraarticular subtalar arthrodesis, which was performed by obtaining a partial subperiosteal bone graft from the middle third of the ipsilateral fibula and compared the results of full versus partial bone grafts in patients with residual poliomyelitis. He described the use of two bone blocks placed across the subtalar joint and reported minor complications in two of 12 children who had a partial fibular graft. The fibular graft site did not regenerate well in one child and another child developed a valgus deformity of the ankle. He reported that partial subperiosteal fibular bone grafts were not associated with any major biomechanical sequelae of the ankle and foot, whereas full fibular grafts had 75% adverse sequelae including failure of the fibula to regenerate at the donor site and distinct ankle valgus deformity with an average 3 mm upward migration of the lateral malleolus. However, he also reported that the limb in the residual stage of polio was weaker than that in normal patients or in patients with cerebral palsy as the paralysis was flaccid. Therefore, use of a partial fibular bone graft after reduction of the subtalar joint should be enough to control the abnormal muscle pull around the foot in spastic conditions once the arthrodesis has occurred. Shortening of the Achilles tendon may be masked in patients with cerebral palsy because of the medial displacement and subtalar subluxation. Unless this is detected and lengthened before the arthrodesis, the tight Achilles tendon will pull the calcaneus backwards and the bone graft placed across the subtalar joint may then slip out. Therefore, the reduction of the subtalar joint will be lost [21,27]. In the present study, lengthening of the aponeurosis of the gastrocnemius using the Vulpius procedure was performed in three patients (four feet; 26.6%) before the arthrodesis procedure to control the Achilles tendon spasticity.

Ankle valgus is another cause of clinical failure in the Grice–Green procedure, with an incidence ranging between 23 and 50% [1–3,8,9,12,14,15,23]. It can be assessed indirectly from the standing AP view of the ankle using the method described by Malhotra *et al.* [25]. This method consists of evaluating the relationship between distal tibial and fibular growth plates. There is a correlation between the extent of shortening of the fibula and the severity of wedging of the distal tibial epiphysis leading to ankle valgus [21,25,28]. Underdevelopment of the fibula is often observed in paralyzed limbs, leading to ankle valgus [29]. In most cases, ankle valgus is present before stabilization, but tends to deteriorate after arthrodesis [1,2,14]. Delayed fibular regeneration and fibular pseudoarthrosis could be responsible for the late ankle valgus because nonunion of the fibula causes elevation of the lateral malleolus. To avoid this problem, harvesting of the graft from the middle third of the fibula is recommended by ensuring that the periosteum is protected [12,15].

Faraj [21] reported that a complete long fibular graft (more than 3 cm) resulted in proximal migration of the lateral malleolus, especially when obtained from the distal third of the fibula. A partial subperiosteal fibular bone graft obtained from the middle third of the fibula, in contrast, was found not to be associated with biomechanical disturbance. We also conclude that failure of regeneration of the fibula is uncommon following a partial fibular bone graft that is obtained from the middle-distal third of the fibula. Although we detected 5° valgus angulation of the distal fibula in two feet (13.4%) postoperatively, it did not cause any upward migration of the lateral malleolus and, therefore, we conclude that the valgus position of the fibula was not associated with any additional angular changes in the ankle joint.

Previous reports [1,3,6,8,10,12,26] have shown that resorption of the graft does not necessarily lead to recurrence of the deformity because there is sufficient fibrosis to maintain the alignment of the subtalar joint. Whereas a slight hindfoot valgus in patients with cerebral palsy is tolerable without lack of function, overcorrection should be avoided. However, the proper placement of the bone graft across the subtalar joint is very important for stability and preservation of correction of the planovalgus foot deformity [4]. If this is not done correctly, pseudoarthrosis of the graft and significant hindfoot valgus recurrence can occur [1,3,26]. The graft should be placed perpendicular to the floor in neutral alignment or with the proximal part of the strut slightly posterior to the weight-bearing axis as recommended by Grice [1,5]. Anterior placement should be avoided. In the present study, 13 (86.6%) feet had neutral alignment of the graft, whereas two (13.4%) had posterior alignment. Besides the usage of a partial fibular bone graft, we conclude that proper placement of the bone graft could also be an explanation for the absence of recurrence of the deformity in our cases.

The technique described in the present study is a modification of the original Grice–Green procedure. In addition, a more distal site for harvesting of the bone graft and use of only one partial fibular graft for a different clinical patient group are main differences from the study of Faraj [21]. Although conclusive statistical analysis of the results could not be carried out because of the small number of feet in the present study, we are convinced that this modified technique can be performed easily and gives a greater assurance of solid fusion and adequate correction of the planovalgus feet in cerebral palsy. All patients in the present study had a valgus hindfoot deformity secondary to spasticity that was correctable passively. In other words, all feet were flexible. Therefore, we conclude that the results were related only with flexible planovalgus feet. On the basis of the radiological results and patients'/parents' satisfaction, the patients participating in the present study benefited from modified Grice–Green arthrodeses performed on their flexible planovalgus foot deformity.

Conclusion

This modification of the Grice–Green subtalar extra-articular arthrodesis can eliminate graft-site morbidity and related complications caused by bone taken from the fibula completely and can be used easily and effectively in the correction of flexible planovalgus foot deformity in patients with cerebral palsy.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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