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ORIGINAL STUDY

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Long-term outcome of extraarticular subtalar arthrodesis in children with cerebral palsy using modified Grice technique

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The purpose of the study is to describe and analyse long-term results of the modified Grice procedure with specially prepared pre-shaped autograft from iliac crest. 54 patients (101 feet) who underwent modified Grice procedure, were retrospectively analysed. Before and after the surgery, talocalcaneal (TC) angle and calcaneal inclination (CI) angle were measured and compared with post-operative values. Furthermore, AOFAS score was assess pre-and postoperatively as well as the subjective evaluation of the patients or their parents. Detailed analysis was performed separately for patients with different forms of CP. Postoperatively, TC angle and subjective assessment decreased, and CI angle and AOFAS score increased significantly compared to pre-operative values. The significant difference was observed among different CP groups in all observed parameters. Severe complications were not observed. The modified Grice procedure with specially prepared pre-shaped autograft showed promising long-term results.

Key words: subtalar arthrodesis; cerebral palsy; foot deformities; pes equinus.

INTRODUCTION

Juvenile cerebral palsy (CP) is non-progressive neurological disease, which origin is in perinatal brain tissue changes as a response on hypoxy or bleading damage in perinatal period. It represents a large group of childhood movement and posture disorders and patients diagnosed with CP present with progressive musculoskeletal malformations due to the muscle spasm, muscle strength imbalance, bone abnormalities and joint capsule relaxations *(1)*. A recent meta-analysis run by Oskoui et al. has stated the constant overall prevalence of CP - 2.11 per 1,000 live births *(2)*, despite the changes in antenatal and perinatal care.

The equinovalgus deformity represents the most common deformity of the feet in patients with CP. It arises from the simultaneous contracture of triceps surae muscle and imbalance of muscle groups producing inversion and eversion movements, mainly peroneal muscles. The initially unrestricted deformity gradually changes the shape of bones of the child´s foot and leads to the collapse in

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Table 1. — General patient´s characteristics

Demographic data of population	
Number of patients	54
Gender	32 boys (59%)/ 22 girls (41%)
Number of feet which underwent surgery	101
Laterality	51 right feet/50 left feet
Average age	8 years 2 months
Average follow-up	9 years 5 months
Forms of CP	30 patients (56%) – diparetic 13 patients (24%) – quadruparetic 7 patients (13%) – hemiparetic 4 patients (7%) - triparetic

The table provides general information about the population which was enrolled in the study. The values are express as mean or as and percentage (%).

subtalar joint, so the foot position progress into the abduction and eversion in the joint. Although conservative treatment with orthoses and casting for the mild deformity can be initially used, it doesn´t lead to the definite stabilisation of the condition and due to the progression of deformity, surgical treatment is often required.

In children older than 6 years without fixed contractures, the most commonly used procedure for stabilization of the feet is the extraarticular subtalar arthrodesis described by Grice, who first applied this technique in patients with poliomyelitis after their skeletal development was complete *(3)*. Throughout the years, this technique was used also for different conditions besides poliomyelitis, such as spina bifida, congenital vertical talus, talocalcaneal coalition, myelodysplasia, idiopathic pes planovalgus and cerebral palsy *(4,5,6,7)*. This surgery can be performed simultaneously with procedures on soft tissues and tendons in indicated cases *(2,4,8,9,10)* we reviewed 17 (26 feet. Many modifications of the original Grice technique were already described *(5,11)*. In patients included in our study, standard Grice procedure was modified in terms of using the specially pre-shaped double cortical bone graft harvested from the iliac crest inserted in the sinus tarsi.

The aim of the study was to evaluate the long-term subjective and objective assessments of modified Grice procedure in children with CP who underwent the treatment in our institution.

MATERIALS AND METHODS

Between 2003 and 2010, 54 patients with CP who underwent modified Grice procedure in our institution, were retrospectively analysed and included in the study. The main pre-operative symptoms were the deformity, foot pain, gait disturbance and skin irritation. The inclusion criteria were: patients with CP, failure of conservative treatment, absence of fixed contractures of the feet, children age of more than 6 years, complete documentation and the informed consent of parents.

101 subtalar arthrodesis using modified Grice procedure were performed – in 47 patients (87%) bilaterally (simultaneously during one surgery or separately), in 4 patients (7%) on the right and in 3 patients (6%) on the left foot, respectively. The population consisted of 32 (59%) boys and 22 (41%) girls. The average age at the time of surgery was 8 years 2 months (range 6 years 1 months – 16 years 4 months). 30 patients (56%) presented with diparetic form, 13 (24%) patients with quadruparetic form, 7 (13%) patients with hemiparetic form and 4 patients (7%) with triparetic form of CP. The average time of follow up was 9 years 5 months. (Tab 1).

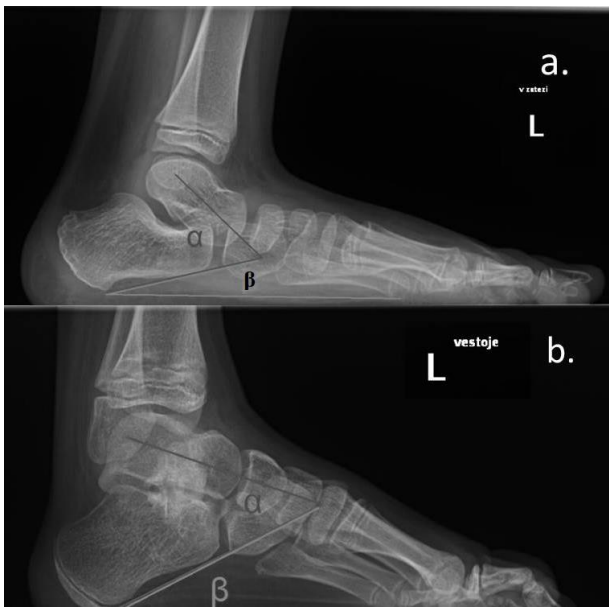

Figure 1. — The measurements of TC and CI angle.
The measurements of TC angle (α) and CI angle (β). The upper X-ray (a.) represents the pre-surgery assessment – shows the condition 5 months before the operation. The lower X-ray the assessment after the modified Grice procedure with the auto-graft incorporated - shows the condition of the same foot 1 year 2 months after the operation. Girl (I.M.) was 7 years 5 month at the time of surgery.

All patients were clinically evaluated before the surgery. The examination consisted mainly of the assessment of heel position and the possibility to correct the deformity passively. Furthermore, weightbearing x-ray of foot was obtained (dorso-plantar and lateral projection) and the lateral talocalcaneal angle (TC angle) (normal range 35-50°) and the calcaneal inclination angle (CI angle) (angle between the long axis of heel bone and the surface) (normal range 20-30°) were measured by the same author (Jiří Jochymek) (Figure 1). The clinical and radiological evaluations were performed prior to surgery and at follow-up.

Furthermore, the patient or their parents filled out the simple questionnaire of subjective assessment of foot deformity (1 excellent, 2 very good, 3 good, 4 satisfactory, 5 unsatisfactory). Eventually, the condition was assessed using the American Orthopaedic Foot and Ankle Society Score (AOFAS) *(12)*, which evaluates walking, pain, daily activity limitations, and limitation of foot movement using

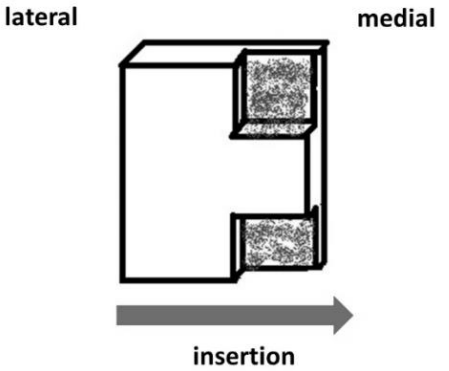

Figure 2. — The schematic shape of the auto-graft
The auto-graft was taken from the iliac crest, pre-shaped in a way that the upper medial and lower medial portions were reduced to mono-cortical components allowing better and more stable placement.

9 questions (0-100 points) (Table 2). The clinical and radiological evaluations as well as subjective evaluations were performed prior to surgery and at follow-up.

Unified surgery technique was used in all patients. First, the double cortical bone autograft was harvested. Small incision above the iliac crest was performed, then periosteum was separated, and double cortical graft was cut with its length of 3 cm and width of 2 cm, followed by iliac crest apophysis and origin of gluteal muscles reinsertion.

As a second step, longitudinal skin incision was applied to the lateral portion of the foot through subtalar joint with sinus tarsi located in the centre. The underlying cutaneous branch of sural nerve, peroneal tendons, and extensor digitorum brevis were identified and retracted. The soft tissues located in sinus tarsi were excised as well as adjacent cartilage surfaces of the talus and calcaneus. Afterwards, the varus-valgus position of the heel was assessed by manipulation intraoperatively. Plantar flexion and inversion were applied, and calcaneus was rotated to its normal position under the talus, so the correction of valgus deformity was achieved. Next, the small osteotomies parallel to the long axis of tibia with resection of bony blocs were performed at the level of talus and calcaneus in line with the sinus tarsi and the double cortical graft was placed strictly vertically. Prior to insertion, the graft was adjusted in a way that the cortex of the graft was

Table 2. — AOFAS score system

Ankle-Hindfoot Scale	
I. Pain	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
II. Function	
Activity limitations, support requirement	
No limitations, no support	10
No limitation of daily activities, limitation of recreational activities, no support	7
Limited daily and recreational activities, cane	4
Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
Maximum walking distance, blocks	
Greater than 6	5
4-6	4
1-3	2
Less than 1	0
Walking surfaces	
No difficulty on any surface	5
Some difficulty on uneven terrain, stairs, inclines, ladders	3
Severe difficulty on uneven terrain, stairs, inclines, ladders	0
Gait abnormality	
None, slight	8
Obvious	4
Marked	0
Sagittal motion (flexion plus extension)	
Normal or mild restriction (30°and more)	8
Moderate restriction (15-29°)	4
Severe restriction (less than 150°)	0
Hindfoot motion (inversion plus eversion)	
Normal or mild restriction (75% - 100% normal)	6
Moderate restriction (25% - 74% normal)	3
Marked restriction (less than 25 normal)	0
Ankle-hindfoot stability (anteroposterior, varus – valgus)	
Stable	8
Definitely unstable	0
III. Alignment	
Good, plantigrade foot, midfoot well aligned	15
Fair, platigrade foot, some degree of midfoot malallignment observed, no symptoms	8
Poor, nonplantigrade foot, severe mallgnment, symptoms	

The table describes the tool for assessment of foot and ankle conditions called the American Orthopedic Foot and Ankle Society Score (AOFAS). Each tool is comprised of nine questions and cover three categories: pain, function and alignment. These are all scored together for a total of 100 points.

shortened at both sides (proximal and distal) (Figure 2). This adjustment allowed better placement and incorporation of the graft into the grooves in talus and calcaneus. The precise insertion mentioned above allowed to achieve stable correction because it eliminated the bending forces which could cause the failure of graft and stabilisation in subtalar joint. Before suturing the wound by layers, the implanted graft was laid around with the rest of cancellous bone. After the surgery, short plaster cast was

applied for 2x 6 weeks. Xray was performed at the 2nd postoperative day, the next one after cast removal at the beginning of verticalization and one year after surgery. The last X-ray was performed during the last check-up of patients in our institution.

Descriptive statistics for population was expressed as a mean (range minimal – maximal values) for continuous variables, while categorical variables were reported in percentage (%). Normal distribution of the data was tested by Shapiro-Wilk test. Paired sample t-test was used to compare TC and CI angles before and after surgery for all feet, while Mann-Whitney test was used to compare the angles for the right and left feet separately. The same tests were used for comparison of subjective assessment of the outcome of therapy and for AOFAS score. Furthermore, Kruskal-Wallis for used to compare the differences among the patients with different form of cerebral palsy. All p values were 2 sided and a p value below 0,05 was considered statistically significant. Data analysis was conducted with SPSS version 20.0 (SPSS INC, Chicago, IL, USA).

RESULTS

The average pre-operative value of TC angle was 50,4° (19,8°-69,1°) for all feet and separately 49,2° (23,5-68,7°) for right and 52,8° (19,8-69,1°) for left feet. After the surgery, the value decreased to 35,7° (14,3°-50,3°) for all feet, 33,7° (16,5°-47,5°) and 38,4° (14,3°-50,3°) for right and left feet, respectively (Figure 3).

The average pre-operative measurement of CI angle was 9° (-5,5°-26°) for all patients, 9,8° (-3,5°-6°) for right feet and 8,1° (-5,5°-19,2°) for left feet. The CI increased after the surgery to 13,1° (3°-37,2°) in average for all the feet, 14,8°(5,5°-37,2°) and 12,5°(3°-25,5°) for right and left feet, respectively (Figure 3).

Patients with diparetic form of the CP show the best improvement in x-ray parameters (TC angle, CI angle) compared to other form of CP (Table 3).

The average score of subjective assessment provided by the patients or parents was 4,5 (2-5). After the surgery, the score decreases to 2,5 (1-4) in average. The best improvement was also seen in patients with diparetic form of CP (Table 4).

Preoperative evaluation of AOFAS score showed the mean value of 46,2 points (19-80) and after the surgery, the improvement was observed by increasing the score to 81 points (50-93) in average. No patient presented with decreasing the score after the surgery compared to preoperative value. In 2 patients, the AOFAS score remained constant before and after surgery (54 and 65 points, respectively). In AOFAS assessment, the most often improvement was observed in the pain improvement category (62% of patients) and gait improvement category (58%). Furthermore, the biggest improvement was seen in patients with diparetic form of CP (45,7 points before the surgery and 83,3 points after the surgery) compared to other forms when assessing AOFAS score (Table 4).

None of the patients presented with severe complication after the surgery. Only one patient was

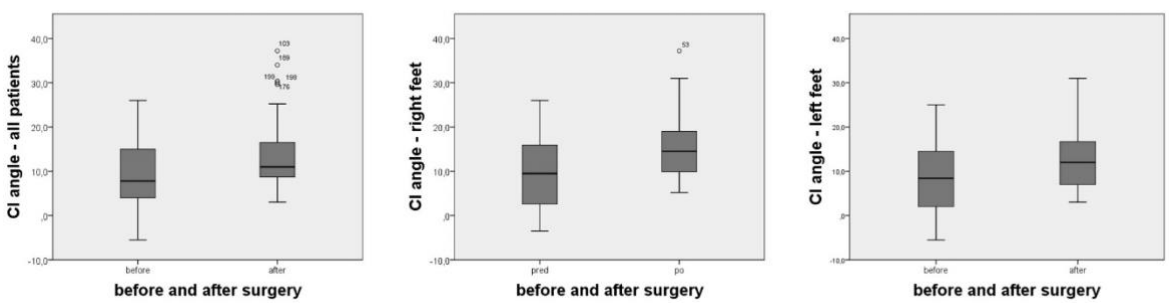

Figure 3. — The TC angle and CI angle changes
The boxplot grafts demonstrating the change between the initial values and the final values of TC angle and CI angle, assessed for all feet and right and left feet separately.

Table 3. — The comparison of talocalcaneal angle (TC angle) and calcaneal inclination angle (CI angle) in patients with different form of cerebral palsy

	Diparetic	Quadruparetic	Hemiparetic	triparetic	p
TC angle initial	47°(20,7°-63,2°)	54,2°(24,7°-7,1°)	50,2°(22,9°-9,1°)	52,8°(19,8°-4,1°)	.125
TC angle final	29,1°(14,3°34,2°)	40,1°(17,8°-0,3°)	38,4°(20,5°-45°)	36,4°(16,5°-2,8°)	.232
TC angle difference	17,9°	14,1°	11,8°	16,4°	.047
p	.025	.001	.001	.012	
CI angle initial	9,2°(-5,5°-26°)	9°(1°-22,1°)	8,0°(-2°-16,1°)	10,5°(3°-19,8°)	.256
CI angle final	18,2°(3°-37,2°)	12,4°(2°-28,1°)	11°(2°-31,7°)	12,9°(4°-30,5°)	.080
CI angle difference	9°	3,4°	3°	2,4°	.001
p	.02	.001	.014	.005	

The statistical analysis showed significant difference in terms of improvement of TC and CI angles for each group of different form of CP. Furthermore, the TC and CI angles changes were statistically significantly different among these groups.

Table 4. — The difference of the subjective assessment and AOFAS score before and after surgery in different CP groups of CP patients

		Diparetic	Quadruparetic	Hemiparetic	Triparetic	p
Subjective assessment	Initial score	4(2-5)	4,8(2-5)	4,3(2-5)	4,5(2-5)	.526
	Final score	2(1-4)	3,5(1-4)	3,1(1-4)	2,9(1-4)	.688
	difference	2	1,7	1,2	1,6	.002
	p-value	.001	.012	.025	.021	
AOFAS	Initial score	45,7(22-80)	50,5(20-75)	47,1(19-78)	45,5(19-80)	.547
	Final score	83,3(50-93)	76,2(50-88)	82,4(52-90)	81,5(54-90)	.588
	difference	37,6	25,7	35,3	36	.012
	p-value	.001	.005	.001	.001	

The statistical analysis showed significant difference in terms of improvement of subjective assessment and AOFAS for each group of different form of CP. Furthermore, the subjective assessment and AOFAS score changes were statistically significantly different among these groups.

treated for the minor superficial defect at the area of subtalar stabilisation.

DISCUSSION

In children of 6 years of age and older, with the severe form of equino-valgus deformity without fixed contractures, the extraarticular subtalar stabilisation described by Grice is considered as an optimal treatment option. Its suitability for the paediatric patients consists of extraarticular approach realized by sinus tarsi fusion when the growth of the talus and calcaneus are not blocked. There are several studies which proved the satisfactory long-term results *(4,5)*.

Nevertheless, some modifications have been presented to eliminate the potential complication. These modifications are mostly connected with the autograft harvesting site or the preparation of the graft. The most common modification of the classic Grice procedure is the harvesting graft from the fibula. Hsu *(11)* and Paluska and Blount

(13) observed valgus of the ankle after harvesting the fibular graft due to lack of regeneration of fibula resulting in pseudarthrosis. The ankle valgus is one of the main cause of the clinical failure of the procedure reported in the literature *(11,13)*. Some authors used tibial graft and observed the overgrowth of the tibia and valgus tilting of the tibial platfond *(3,14)*.

The other option how to treat the deformity is the Batchelor technique, first described by Brown et al. *(15)*, when the graft was harvested from the fibula and placed in the sinus tarsi. This technique is nonextraarticular and high rates of non-union were reported due to usage of one cortical graft. The modification of this technique was described by Dennyson and Fulford *(16)*. They used the screw in the same location as a fibular graft in Batchelor technique and additionally, the cancellous bone was inserted in the sinus tarsi. Although reported high rate of fusion, the problems with the screw, such as screw sclerosis leading to non-union, may be encountered *(16)*. Furthermore, combination of the technique was presented by Hsu et al. *(11)*. They combined the classic approach of Grice technique with Batchelor procedure and the combined the advantages of both techniques. Although they observed solid fusion in 96% of cases, the procedure was performed only on 25 feet.

We have many years of good experience with the use of bone graft from the pelvis. The post-operative course is not burdened by a significant painful reaction after harvesting of bone graft. Postoperative pain is alleviated by commonly used analgesics. The length of hospitalization is not extended. In accordance with recent literature even the actual course of autograft healing is certainly more favourable than course of the allograft healing.

The Grice procedure is performed by many authors after several previous multi-level surgeries when the muscle balance is compensated *(17,18,19)* 56 boys. It can be combined with soft tissues surgeries, especially the most popular is the combination with the Young procedure, consisting of tibialis anterior tendon transposition into the pre-drilled hole in the navicular bone *(2,10)* based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses.

There are several complications encountered with the Grice procedure or its modification reported in the literature. One of the major complication is graft resorption, independent of its source, occurring up to 33% of the patients *(8,19,20)*, although it doesn't necessarily lead to the recurrence of the deformity because of the fibrosis at the location of the resorbed graft *(4)*. In our study, no graft resorption was observed that is in accordance with the study of Keats et al. *(21)* and Lancaster et al. *(5)*. Furthermore, no other graft related complications, such as migration or the breakage were not observed as well. To prevent the complication mentioned above, we pre-shaped the graft in the way as it is described above. It allowed precise placement and firm anchoring in the talus and calcaneus without any artificial fixation material. In our opinion, the shape of the graft was responsible for the good long-term outcomes without any severe complications.

Assessing radiological parameters, average TC angle and IC angle showed significant changes comparing pre-operative and post-operative measurements. The statistical analysis revealed that the best improvement was seen in patients with diparetic form of CP. We believe, that the main reason is the best radiological values of pre-operative measurement compared to patients with the other forms of CP. This presumption needs to be confirmed in the further orthopaedic and neurological observational studies.

Some studies assess the procedure successfulness mechanistically focusing mainly on radiological evaluation *(8,21)*. Although this study also closely analysed radiological parameter, from the clinical experience it is known that overall outcome after the surgery, evaluated both by the patients and the orthopaedic surgeon, doesn´t always correlate with the radiological findings, especially when evaluating TC angle. Because of it, this study analysed not only objective x-ray parameters, but additionally critically assessed the outcomes of the treatment according AOFAS criteria. This comprehensive evaluation incorporates also subjective assessment of the patient or the parents.

The limitation of the study is that the procedure was performed by different paediatric orthopaedic surgeons throughout the years. Furthermore,

patients are checked only until the 18 years of age so the next follow up is provided by the different orthopaedic institution. On the other hand, relatively long follow up and big number of patients included in the analysis are the strongest part of the study.

CONCLUSION

The results of the study were in accordance with majority of authors when using Grice extraarticular subtalar stabilisation as a primary option and core procedure to correct not-fixed equinovalgus feet in patients with CP. The modification of the autograft from the iliac crest appeared to be the key point in achieving good results and preventing complications.

REFERENCES

1. Miller F. Cerebral Palsy-Section I, Part 11: Knee, Leg and Foot. 2004. NY, Springer.
2. Oskoui M, Coutinho F, Dykeman J, et al. An update on the prevalence of cerebral palsy: a systematic review and meta-analysis. Dev Med Child Neurol. 2013;55:509-519.
3. Grice DS. An extra-articular arthrodesis of the subastragalar joint for correction of paralytic flat feet in children. J Bone Joint Surg Am. 1952;34A:927-940.
4. Bourelle S, Cottalorda J, Gautheron V, et al. Extra-articular subtalar arthrodesis. A long-term follow-up in patients with cerebral palsy. J Bone Joint Surg Br. 2004;86:737-742.
5. Lancaster SJ, Pohl RO. Green-Grice extraarticular subtalar arthrodesis: results using a fibular graft. J Pediatr Orthop. 1987;7:29-33.
6. Smith JB, Westin GW. Subtalar extra-articular arthrodesis. J Bone Joint Surg Am. 1968;50:1027-1035.
7. Tohen A, Carmona J, Chow L, et al. Extra-articular subtalar arthrodesis. A review of 286 operations. J Bone Joint Surg Br. 1969;51:45-52.
8. Guttmann GG. Subtalar arthrodesis in children with cerebral palsy: results using iliac bone plug. Foot Ankle. 1990;10:206-210.
9. Leidinger B, Heyse TJ, Fuchs-Winkelmann S, et al. Grice-Green procedure for severe hindfoot valgus in ambulatory patients with cerebral palsy. J Foot Ankle Surg Off Publ Am Coll Foot Ankle Surg. 2011;50:190-196.
10. Senaran H, Yilmaz G, Nagai MK, et al. Subtalar fusion in cerebral palsy patients: results of a new technique using corticocancellous allograft. J Pediatr Orthop. 2011;31:205-210.
11. Hsu LC, Jaffray D, Leong JC. The Batchelor-Grice extra-articular subtalar arthrodesis. J Bone Joint Surg Br. 1986;68:125-127.
12. Kitaoka HB, Alexander IJ, Adelaar RS, et al. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15:349-353.
13. Paluska DJ, Blount WP. Ankle valgus after the Grice subtalar stabilization: the late evaluation of a personal series with a modified technic. Clin Orthop. 1968;59:137-146.
14. Grice DS. Further experience with extra-articular arthrodesis of the subtalar joint. J Bone Joint Surg Am. 1955;37A:246-259.
15. Brown A. A simple method of fusion of the subtalar joint in children. J Bone Joint Surg Br. 1968;50:369-371.
16. Hadley N, Rahm M, Cain TE. Dennyson-Fulford subtalar arthrodesis. J Pediatr Orthop. 1994;14:363-368.
17. Bollmann C, Franz A, Raabe J. The Grice-Green subtalar arthrodesis using a fibular bone graft -follow-up of 92 patients. Orthopadie Unfallchirurgie.2015;153:93-98.
18. Ettl V, Wollmerstedt N, Kirschner S, et al. Calcaneal lengthening for planovalgus deformity in children with cerebral palsy. Foot Ankle Int. 2009;30:398-404.
19. Jeray KJ, Rentz J, Ferguson RL. Local bone-graft technique for subtalar extraarticular arthrodesis in cerebral palsy. J Pediatr Orthop. 1998;18:75-80.
20. Ross PM, Lyne ED. The Grice procedure: indications and evaluation of long-term results. Clin Orthop. 1980:194-200
21. Keats S, Kouten J. Early surgical correction of the planovalgus foot in cerebral palsy. Extraarticular arthrodesis of the subtalar joint. Clin Orthop. 1968;61:223-233.