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Treatment of genua valga in children by hemi-epiphysiodesis with a percutaneous transepiphyseal screw

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Background: **Hemi-epiphysiodesis using percutaneous transphyseal screws is an established technique with good results to treat idiopathic genua valga in children. However, there is no evidence-based consensus on the optimal age for correction.**
Purpose: **This study aims to determine best age for optimal correction of the knee alignment.**
Methods : **All medical records of patients in our department treated by percutaneous hemiepiphysiodesis for idiopathic genua valga between 2007 and 2017 were reviewed. Skeletal age was determined pre-operatively. The hip-knee-ankle angle was measured on a standard frontal full leg radiograph, preoperatively, at time of removal of the screws and at skeletal maturity. The occurrence of correction loss and progression and the velocity of correction based on skeletal age were evaluated.**
Results: **A total of 164 legs were reviewed, of which 120 were followed until skeletal maturity. We perceived more insufficient valgus correction when treated at a skeletal age approximating skeletal maturity, however, also rebound valgus was noted in patients with only a short time to skeletal maturation at time of treatment. Overcorrection after screw removal was only perceived in 4.27%. A large individual variation in velocity of correction was observed.**
Conclusion: **In our study protocol with hemi-epiphysiodesis at 2 years from skeletal maturation, good results were obtained. Velocity of correction can be calculated to determine a patient specific timing for clinical and radiographical follow-up to avoid overcorrection.**
Level of evidence: **IV**

Keywords: Idiopathic genua valga, adolescents, hemi-epiphysiodesis, percutaneous screws.

INTRODUCTION

Genua vara and valga are part of the natural evolution of the lower limb alignment in children. However, a residual knee malalignment has been associated with the development and progression of knee osteoarthritis[1,2] and can predispose to meniscal tears. Therefore, it is of interest to correct a valgus or varus malalignment during childhood or adolescence[3–5]. In adolescents with remaining growth, surgical treatment can consist of permanent hemiepiphysiodesis by curettage of the physis or temporary hemi-epiphysiodesis by means of stapling, percutaneous epiphysiodesis using transphyseal screws (PETS) or tension band plating (TBP)[2,6–11]. In a study on PETS in valgus knees performed by De Brauwer and Moens, comparable results to staples were noticed, with the add on that this procedure was less invasive and results were more cosmetic[2,4].

Currently, there is no evidence-based consensus regarding the most adequate timing of temporary hemi-epiphysiodesis with PETS. The purpose of this study is to determine the best age to obtain an optimal correction of idiopathic genua valga, without recurrence, when performing hemi-epiphysiodesis with PETS.

METHODS

The medical files of all patients treated for idiopathic genua valga by a hemi-epiphysiodesis by one or two transphyseal screws in our department between 2007 and 2017 were retrospectively reviewed. Institutional ethical committee clearance and informed consent were obtained. All patients were operated under supervision of experienced paediatric orthopaedic surgeons. Patients were followed-up clinically and radiologically until skeletal maturity.

Pre-operatively, skeletal age according to Greulich and Pyle, based on an anteroposterior view of the left hand, was determined under supervision of experienced paediatric radiologists. The preferred time of treatment was 2 years from skeletal maturation, however, patients delay with presentation at later skeletal age led to a higher skeletal age at time of surgery. The HKA angle, the angle between the mechanical axis of the femur and the mechanical axis of the tibia on a standard standing anteroposterior full leg radiograph with extended knees expressed as degrees of deviation from linearity (Figure 1), was evaluated immediately before the hemi-epiphysiodesis. By convention, a valgus was noted as a positive HKA angle. To determine the level of the hemi-epiphysiodesis, the mechanical lateral distal femoral angle (mLDFA) and medial proximal tibial angle (MPTA) were evaluated preoperatively.

6.5mm fully threaded cannulated screws were placed percutaneously over a guide wire in the medial distal femoral physis and/or medial proximal tibial physis under fluoroscopic control. The entry point of the screw was the contralateral metaphysis, aiming to cross the physis at the junction of its inner and middle thirds, in the midcoronal plane[10]. One screw was used for each physis.

Postoperatively, weight bearing as tolerated was advised. None of the patients received a cast or a brace. Sport activities could be resumed after 3 weeks.

Patients were followed-up clinically and radiographically with an anteroposterior standing full leg view with the knees in extension every 3 to 6 months after surgery, depending on proximity to correction, until removal of the screw, which was performed once a physiological alignment was obtained. Further follow-up was both clinically and radiographically until skeletal maturation.

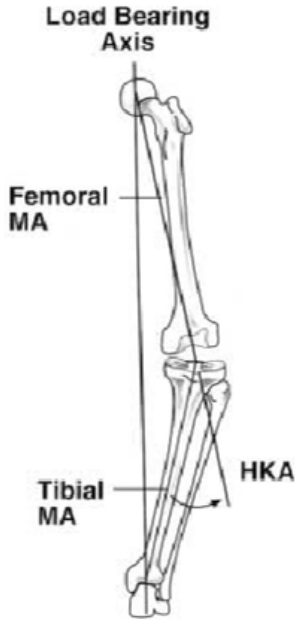

Fig. 1 — Mechanical axis and measurement of the hip-knee-ankle angle as the angle between the femoral and tibial mechanical axis.

Skeletal age, HKA angle - at time of hemi-epiphysiodesis, screw removal and skeletal maturation - and timing of screw placement, screw removal and skeletal maturation was recorded from the clinical files. All data were collected in an excel file and excel functions were used for calculations. Time interval between screw placement, screw removal and skeletal maturation and velocity of correction as degrees of correction (HKA angle at time of screw removal – HKA angle at time of hemi-epiphysiodesis) per month was calculated.

The aim of this study is determining the best age to obtain an optimal correction. Therefore, a definition of a good correction needed to be formulated. Siboni et al. found in a population study with 269 males and 317 females a mean HKA angle for a normal adult male knee as 1.00° ± 2.52° (SD) and the mean HKA angle for a normal adult female knee as 0.3° ± 2.46° (SD)[12]. We divided patients into 3 subgroups based on the obtained HKA angle at skeletal maturation. A good final correction was described as the mean HKA angle ± SD described by Siboni et al.[12] Since the SD is 2.52° and 2.46° for males and females respectively, a large interval of respectively 5.04° and 4.92° is considered as a good correction. To avoid a large interval for moderate correction variating up to 10° of the mean HKA angle, we used a cutoff of 1° based on the study of Cicuttini et al., which demonstrated an influence in cartilage loss for each degree[3]. A poor correction was defined as a correction to more than the mean HKA angle ± (2* SD + 1°). This is an overcorrection to more than 4.52° varus in boys and 3.16° varus in girls or a recurrent valgus more than 2.52° in boys and 3.76 in girls.

RESULTS

In total, 164 valgus legs were treated, 84 legs in 45 boys and 80 legs in 46 girls. In 34 legs, a PETS was placed in the distal femur and proximal tibia, of which 11 male legs and 15 female legs were followed-up until skeletal maturation. 120 legs, 63 male and 57 female legs, were treated at the distal femur alone and 9 legs were treated at the proximal tibia alone (Table I). Of these last 2 groups, respectively 48 male and 47 female legs and 1 male and 2 female legs were

followed-up until skeletal maturation. In 1 girl treated bilaterally with a femoral and tibial PETS and in 1 boy treated bilaterally with a femoral PETS, skeletal age was not determined before treatment. These 2 patients were excluded (Table I). In 5 patients, 3 of them treated at both femoral and tibial level and 2 treated only with a femoral transepiphyseal screw, a redo hemi-epiphysiodesis because of an overcorrection to a varus malalignment. These patients were evaluated separately.

Evaluating the magnitude of the valgus angulation and skeletal age at time of surgery, no correlation was found (Figure 2).

In the legs treated with a combined femoral and tibial hemi-epiphysiodesis, a good correction was obtained in 92%, respectively 90.91% for boys and 92.86% for girls, a moderate correction in 4%, none in boys and 7.14% for girls, and a bad correction in 4% or in 9.09% of all boys (Table II). The boy with a bad final HKA angle was treated at a skeletal age of 14.5 years and had insufficient correction at time of screw removal and skeletal maturation. The girl with a moderate final HKA angle was treated at a skeletal age of 13 years. At time of screw removal, a varus alignment of 1° was measured, with additional varisation to 2.4° after screw removal.

93 femoral PETS were included in this study. In 64.52%, 60.09% in boys and 68.09% in girls, a proper final HKA angle was obtained. In 19,35%, respectively 19.57% and 19.15%, moderate corrections were obtained and in 16.13%, respectively 19.57% and 12.77%, bad corrections were measured at skeletal maturation (Table II).

In the male group, moderate corrections were noted in legs treated at skeletal age 14 and 14.5 years: 3 legs skeletal age 14 and 1 leg skeletal age 14.5 had insufficient valgus correction at time of screw removal, while respectively 3 and 2 legs had a rebound valgus alignment. In girls, moderate corrections were noted along all skeletal age groups with both persistent valgus and rebound valgus alignment.

One boy treated at a skeletal age of 13 years and 1 boy skeletal age 14 years had an overcorrection of more than mean HKA angle – 1SD – 1° after screw removal despite neutral alignment at screw removal, defined as a bad correction. 6 male legs treated at a skeletal age of 14 years and had an insufficient correction more than HKA angle + 1SD + 1° at time of screw removal, 1 leg treated at a skeletal age 15 years had a rebound valgus alignment after screw removal to a HKA-angle more than mean + 1SD + 1°.

Bad correction in female knees were observed seen in 2 girls treated at skeletal age 12 years with

Table I. — . inclusion of valgus legs.

	84 male legs			80 female legs			total
	femur + tibia	femur	tibia	femur + tibia	femur	tibia	
	16	63	4	18	57	5	164
Exclusion criteria							
Loss of follow-up	5	15	3	3	10	3	39
No bone age		2		2			4
Legs included	11	46	1	13	47	2	121

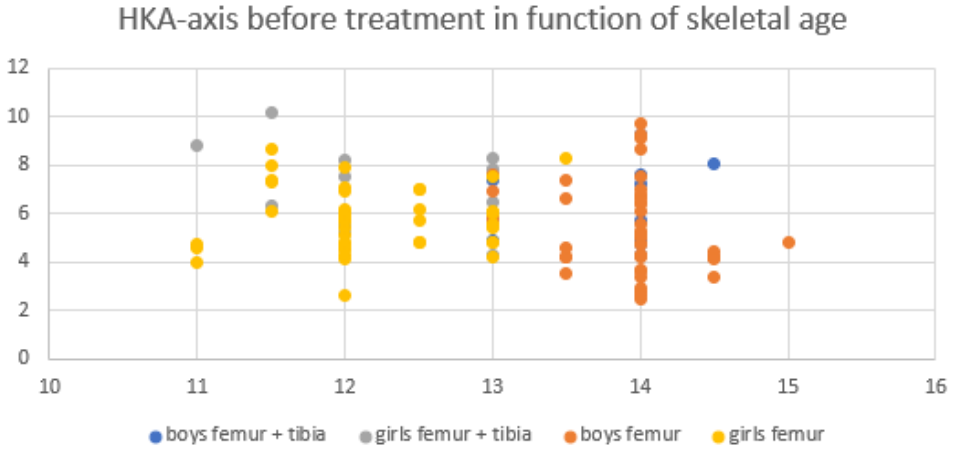

Fig. 2 — HKA-axis at time of start of treatment in function of skeletal age. No correlation was found between timing of treatment and the magnitude of the vlgus angulation.

Table II. — Results of hemi-epiphysiodesis in function of skeletal age in patients treated with a hemi-epiphysiodesis for valgus correction. For moderate and bad results, number of legs in indicated respectively in parentheses.

Male femoral and tibial hemi-epiphysiodesis						
Skeletal age	Number of legs	Good final HKA-axis	Insufficient correction	Overcorrection	Rebound valgus	Overcorrection after screw removal
13	1	1 (100%)				
13.5						
14	8	8 (100%)				
14.5	2	1 (50%)	1 (0+1) (50%)			
Total	11	10 (90.91%)	1 (0+1) (9.09%)			
Male femoral hemi-epiphysiodesis						
Skeletal age	Number of legs	Good final HKA-axis	Insufficient correction	Overcorrection	Rebound valgus	Overcorrection after screw removal
13	4	3 (75%)				1 (0+1) (25%)
13.5	6	6 (100%)				
14	30	17 (56.67%)	9 (3+6) (30%)		3 (3+0) (10%)	1 (0+1) (3.33%)
14.5	5	2 (40%)	1 (1+0) (20%)		2 (2+0) (40%)	
15	1				1 (0+1) (100%)	
Total	46	28 (60.09%)	10 (4+6) (21.74%)		6 (5+1) (13.04%)	2 (0+2) (4.35%)

Female femoral and tibial hemi-epiphysiodesis						
Skeletal age	Number of legs	Good final HKA-axis	Insufficient correction	Overcorrection	Rebound valgus	Overcorrection after screw removal
11	1	1 (100%)				
11.5	2	2 (100%)				
12	4	4 (100%)				
12.5						
13	7	6 (85.71%)				1 (1+0) (14.29%)
Total	14	13 (92.86%)				1 (1+0) (7.14%)
Female femoral hemi-epiphysiodesis						
Skeletal age	Number of legs	Good final HKA-axis	Insufficient correction	Overcorrection	Rebound valgus	Overcorrection after screw removal
11	3	2 (66.67%)			1 (1+0) (33.33%)	
11.5	5	3 (60%)	1 (1+0) (20%)		1 (1+0) (20%)	
12	22	17 (77.27%)	1 (1+0) (4.55%)		2 (2+0) (9.10%)	2 (0+2) (9.10%)
12.5	6	5 (83.33%)	1 (1+0) (16.67%)			
13	10	5 (50%)	3 (1+2) (30%)		2 (1+1) (20%)	
13.5	1		1 (0+1) (100%)			
Total	47	32 (68.09%)	7 (4+3) (14.89%)		6 (5+1) (12.76%)	2 (0+2) (4.26%)

overcorrection after screw removal, in 3 out of 15 girls treated at skeletal age 13 years of which 2 had insufficient correction and 1 a rebound valgus alignment, and in 1 out of 3 girls treated at skeletal age 13.5 years with insufficient correction.

Only 3 patients treated with a tibial PETS were included in this study, of which only 1 girl obtained a neutral alignment at time of skeletal maturation. Since the small size of this group, this was not further evaluated.

As previously mentioned, an important overcorrection was observed during follow-up after hemi-epiphysiodesis in another 5 legs, requiring redo hemi-epiphysiodesis in the lateral physis to correct varus alignment. In 3 patients, 1 boy skeletal age 14 years and 1 girl skeletal age 12 years treated with a femoral and tibial PETS and 1 boy skeletal age 14 years treated at femoral level, an overcorrection was noticed within the first 6 months after the screw

Table III. — Legs needed redo hemi-epiphysiodesis to correct overcorrection to a varus malalignment.

	Skeletal age	Level of TEPS	Time to screw removal (days)	Time between screw removal and redo surgery (days)	Time between primary surgery and redo surgery (days)
Overcorrection during follow-up after screw-insertion					
Boy 1	14	femur			203
Boy 2	14	femur + tibia			138
Girl 1	11	femur + tibia			168
Overcorrection after screw removal					
Boy 3	13	femur + tibia	112	832	944
Girl 1	12	femur	205	33	238

insertion, requiring an immediate correction of the varus alignment. In all 3 patients, first radiographical full leg control was performed after 6 months. The 2 boys were followed-up clinically every 3 months, the girl only had a follow-up 1 month and 6 months postoperatively. In 2 patients, a girl skeletal age 11 years treated with a femoral PETS and a boy skeletal age 13 years treated with a combined femoral and tibial PETS, overcorrection to varus was noticed after screw removal in the follow-up until skeletal maturity, requiring hemi-epiphysiodesis to correct varus. In the girl, a correction to 2° of valgus was noticed after 3 months with a progression to a varus malalignment at 6 months after the first operation. In the boy, a rapid correction of 7.4° to a neutral alignment was noticed 3 months after the hemi-epiphysiodesis. To evaluate this phenomenon, we calculated the velocity of correction (°/month) for each leg in each group and noticed a more rapid correction (above 1.19°/month) for these 5 patients compared with the other 3 groups (Figure 3).

DISCUSSION

The effectiveness and safety of PETS for hemi-epiphysiodesis in genua vara and valga was described by De Brauwer and Moens in 2008[4]. Because of the advantage of a shorter operative time, length of hospital stay and return to full activity compared with TBP,[2,13] as well the appearance of hypertrophic scaring and incisional pain in TBP[2], PETS is used as the standard treatment in idiopathic coronal malalignment for adolescent boys and girls with remaining growth in our centrum. However, the optimal age to use this technique has not been reported.

A good correction was noted more in male legs treated at skeletal age 13.5 years and female legs 12.5 years. However, this groups were only small compared to the groups with 2 years of growth remaining.

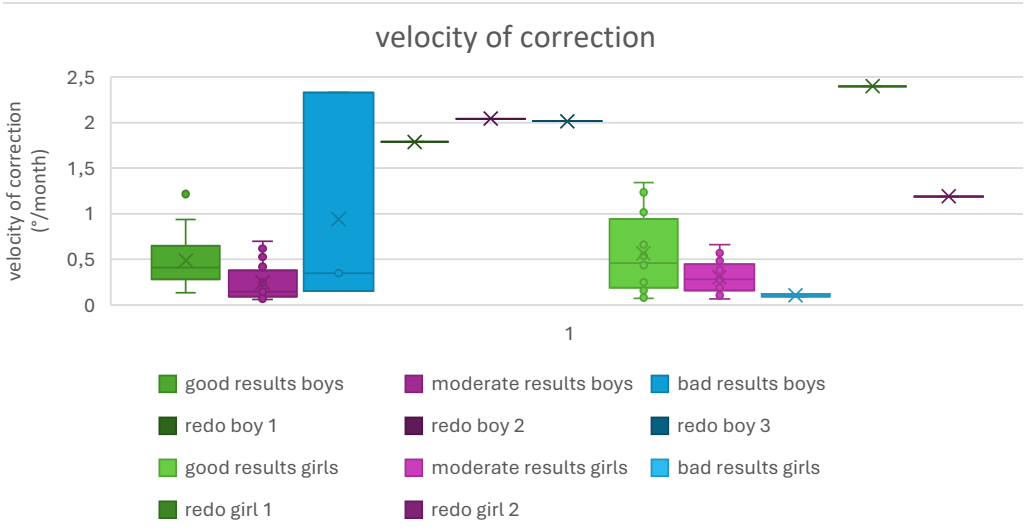

Fig. 3 — Velocity of correction. In the patients who needed a redo hemi-epiphysiodesis to correct a varus malalignment, a higher velocity of correction was perceived. In the group of boys with bad correction, 1 boy treated at skeletal age 13 years had a velocity of correction of 2.32°/month, while the other 2 had a velocity of correction of less than 0.35°/month.

Moderate or bad corrections were primary valgus malalignment, both rebound valgus as well as insufficient correction at time of screw removal. We were not able to notice a difference in function of skeletal age at time of treatment considering rebound valgus of insufficient correction. In 5 patients out of the 117 patients (4.27%) treated with a femoral or combined femoral and tibial PETS, an overcorrection to a varus alignment more than mean HKA angle – SD – 1° after screw removal was measured at skeletal maturation despite a follow-up every 6 months between removal of the screw and skeletal maturation. This confirm that a PETS is relatively harmless to the physis.

In 5 patients, overcorrection to varus was noticed during follow-up, requiring a revision surgery. Comparing the velocity of correction in these patients with the other 3 subgroups, a more rapid correction was noticed, despite a comparable skeletal age at time of treatment. This can be used as a determinant for time interval for clinical and radiographical follow-up.

Limitations of this study are its retrospective design and the use of a frontal standing full leg radiograph for our measurements, in which the HKA angle might be influenced by the rotational position of the lower extremity. Nevertheless, this method is well validated in the literature and has excellent intra- and interobserver reliability[14-16]. Additionally, the rotation position of the lower extremity was controlled by positioning the legs with the patella facing forward. All measurements were performed by a single observatory, which assure consistency but can also introduce a systematic bias. A third limitation is the fact that most of the patients were operated at the same age, as the current practice at our department is to correct alignment in boys at age 14-14.5 years and in girls at age 12-12.5 years, regardless the extend of valgus deviation. This could have accounted for a selection bias. This limitation is not so easy to overcome, as it is ethically not feasible to perform a randomized controlled trial with the patients randomized for age. Skeletal age was not measured at time of screw removal. This can be included in further research since this can give new insights to the evolution of malalignment correction after screw removal.

CONCLUSIONS

The use of PETS for hemi-epiphysiodesis in genua valga is a reliable and effective procedure.

We obtained good corrections in our treatment protocol with hemi-epiphysiodesis at time of 2 years of growth remaining. However, overcorrection to varus malalignment as well as rebound valgus is noticed along all skeletal age groups, with a large variation in velocity of correction. We recommend a strict clinically and radiographically follow-up every 3 months, but also after screw removal, a proper follow-up until skeletal maturation is advised to detect rebound valgus or progressive varus early and treat if necessary. Evaluation of the velocity of correction 3 months after hemi-epiphysiodesis can be useful to determine a patient specific follow-up interval.

Conflict of interest: The Authors declare that there is no conflict of interest.

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