Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Temporary screw epiphyseodesis of the first metatarsal for correction of juvenile hallux valgus

C. Schlickewei[1]
K. Ridderbusch[2,3]
S. Breyer[2,3]
A. Spiro[2,3]
R. Stücker[2,3]
M. Rupprecht[2,3]

Abstract

Purpose Juvenile hallux valgus deformity (JHVD) is rare but may be associated with symptoms or deformities that require surgical treatment. Literature recommends waiting to perform surgical treatment until maturity. However, if conservative treatment is not sufficient and the children's psychological or physical suffering is particularly severe, earlier surgical treatment should be considered. The aim of this study was to evaluate the safety and efficiency of temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal as a new treatment option for JHVD during growth age.

Methods Between June 2011 and November 2017, 33 patients (24 girls, nine boys; 59 feet) with a JHVD were treated by temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal. At the time of surgery mean age was 11.1 years SD 1.4 (8 to 15). Patients were followed clinically and with standing, weight-bearing radiographs of the feet in two planes.

Results In all, 22 patients (39 feet) were included into this study. Mean follow-up was 27.8 months SD 9.9 (12 to 58). The hallux valgus angle changed from 26.5° SD 6.6° preoperatively to 20.2° SD 6.2° ($p < 0.001$) at time of follow-up. The intermetatarsal angle changed from 14.1° SD 5.4° to 10.5° SD 2.9° during this time ($p < 0.01$). In two patients (three feet) the screws were removed before the JHVD was fully corrected due to local tenderness over the screw head. In two patients screw migration away from the growth plate was observed, resulting in no further deformity correction in one patient and increasing deformity in the other patient. No other complications were seen.

Conclusion Temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal seems to be an effective, safe, technically easy and minimally invasive early treatment option to correct JHVD in children with particularly severe suffering. Due to the individual correction rate, frequent follow-up visits are recommended until skeletal maturity.

Level of Evidence IV

Cite this article: Schlickewei C, Ridderbusch K, Breyer S, Spiro A, Stücker R, Rupprecht M. Temporary screw epiphyseodesis of the first metatarsal for correction of juvenile hallux valgus. *J Child Orthop* 2018;12:375-382. DOI: 10.1302/1863-2548.12.170208

Keywords: juvenile hallux valgus; screw epiphyseodesis; hallux valgus angle; intermetatarsal angle

Introduction

Juvenile hallux valgus deformity (JHVD) is defined as a varus deviation of the first ray metatarsal and valgus deviation of first proximal phalanx in skeletally immature patients. The literature describes an incidence appearance of 1.6%, while girls are affected five times more often than boys.[1,2] Different reasons are discussed as a cause of an increasing malalignment of the first ray. Most common are an intermetatarsal angle (IMA) > 14°, a hypermobility of the medial tarsometatarsal joint, an oblique position of the tarsometatarsal joint and a pigeon toe in early childhood.[2,3] In addition, the presence of an os intermetatarseum may be associated with the JHVD. A familial occurrence is described in up to 90% of cases.[4,5] If symptoms occur, complaints do not always correlate with the severity of the deformity. However, in most cases a significant valgus deformity of the first ray is evident. To evaluate JHVD a complete analysis of gait, alignment and function of the entire lower extremity as well as standing, weight-bearing radiographs of the feet in two planes are necessary.

Nonoperative treatment options like insoles and hallux valgus splints do exist. While the use of insoles has been shown to be inefficient,[6] the use of splints at night may be helpful during the early stages of the JHVD.[7] For significant

[1] Department of Trauma-, Hand-, and Reconstructive Surgery, University Medical Center Hamburg-Eppendorf, Hamburg Germany
[2] Department of Pediatric Orthopaedics, Altonaer Children's Hospital, Hamburg, Germany
[3] Department of Orthopaedics, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

Correspondence should be sent to M. Rupprecht, Department of Pediatric Orthopaedics, Altonaer Children's Hospital, Bleickenallee 38, 22763 Hamburg, Germany.
E-mail: mrupprec@uke.de

deformities only surgical management is effective. However, immobilization with restricted weight-bearing for a significant time and recurrent deformity needs to be taken in account. Until now, there is no agreement about the ideal surgical procedure, and many authors recommend postponing any operative intervention until maturity.[8,9] In some cases, however, this may not be possible due to severe complaints and increasing deformity. In addition to soft-tissue surgery, a variety of different osteotomies, either proximal or distal or combined, have been proposed.[10-15] Few reports focusing on permanent epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal for correction of the JHVD[16-18] and only one study reporting on temporary stapling.[19] To the best of our knowledge, this is the first report on screw hemiepiphyseodesis to correct JHVD during growth age.

This study sought to evaluate our experience with temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal as a new treatment option for JHVD and to address the following questions:

1. Is temporary medial screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal safe and efficient in the surgical treatment of JHVD?
2. How much correction can be achieved?
3. What is the complication rate?
4. Which follow-up intervals should be recommended?

Materials and methods

Inclusion criteria

Only patients with a JHVD treated by temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal were included in the study. Indication for surgery was an insufficiently conservative treatment result combined with psychological or physical problems. Preoperatively, all included patients complained about pain and tenderness over the first metatarsophalangeal joint. Other requirements for inclusion were a complete clinical and radiographic analysis and a minimum follow-up of 12 months. All included patients were followed clinically and with standing, weight-bearing radiographs of the feet in two planes.

Patients close to skeletal maturity with less than two years of growth or with a hallux valgus angle (HVA) < 18° were not offered treatment by epiphyseodesis. Children with no complaints were recommended a surgical correction after skeletal maturity. Patients with intermittent documentation or additional trauma had to be excluded during the study.

Operative technique and perioperative management

The operation was performed with the child supine on a radiolucent table. Under fluoroscopic guidance the epiphyseal plate of the first ray metatarsal was localized. A 1 cm longitudinal skin incision was made slightly distal to the epiphyseal plate and the outer cortex of the metatarsal was identified by blunt dissection. Then, a Kirschner (K)-wire was advanced across the lateral margin of the epiphyseal plate into the lateral epiphysis of the first ray metatarsal. The correct position was controlled by fluoroscopy in two planes. A cannulated ∅ 3.0-mm screw with partial thread was inserted (Fig. 1). The thread had to pass the proximal epiphyseal plate by three turns at least. The screw head was countersunk into the surface of the metatarsal bone to avoid irritation with shoe wear. The K-wire was removed, the wound irrigated and closed. For bilateral complaints, surgical treatment was performed on both sides, due to the minimally invasive procedure and minimal postoperative pain. Mobilization was performed immediately after the operation under weight-bearing. Although preoperative, conservative therapy had not been sufficient to reduce pain and discomfort, additional postoperative treatment with night-time splints were performed to protect the wounds at night, to address the soft tissue and to support the epiphyseodesis.

Radiographic analyses

All radiographs were obtained with standing, weight-bearing radiographs of the feet in two planes. To evaluate the outcome of the HVA, the IMA, the proximal metatarsal articular angle in the anteroposterior plane (PMAA-AP), the proximal metatarsal articular angle in the lateral plane (PMAA-L), the length of the first (MTL-I) and second metatarsal (MTL-II) and the metatarsal length ratio (MTLR) were analyzed preoperatively and during latest follow-up. The HVA was determined by measuring the angle between the long axes of the first proximal phalanx and first metatarsal (Fig. 2a), the IMA was determined by measuring the angle between the long axis of first and second metatarsals (Fig. 2b). The PMAA-AP was created by the intersection of two lines, one line bisected the diaphysis of the first metatarsal, the other line connected the margins of the proximal articular surface of first metatarsal (Fig. 2c). Values > 90° were described as valgus alignment (valg), values < 90° as varus alignment (var). The PMAA-L was determined on the standing lateral radiograph of the foot in a similar way (Fig. 2d), with values > 90° described as dorsiflexion (dor) and values < 90° as plantarflexion (pla). The MTL-I and MTL-II were calculated as the distance from the distal to the proximal articular surface, bisecting the diaphyses of each metatarsal (Fig. 2e). The MTLR was the ratio of the length of the first and second metatarsals (a:b; Fig. 2e).

Statistical analysis

This was carried out with the SPSS statistical package (Version 17.0, SPSS Inc., Chicago, Illinois). Descriptive statistics were given as mean ± SD and range (minimum to

JOURNAL OF CHILDREN'S ORTHOPAEDICS

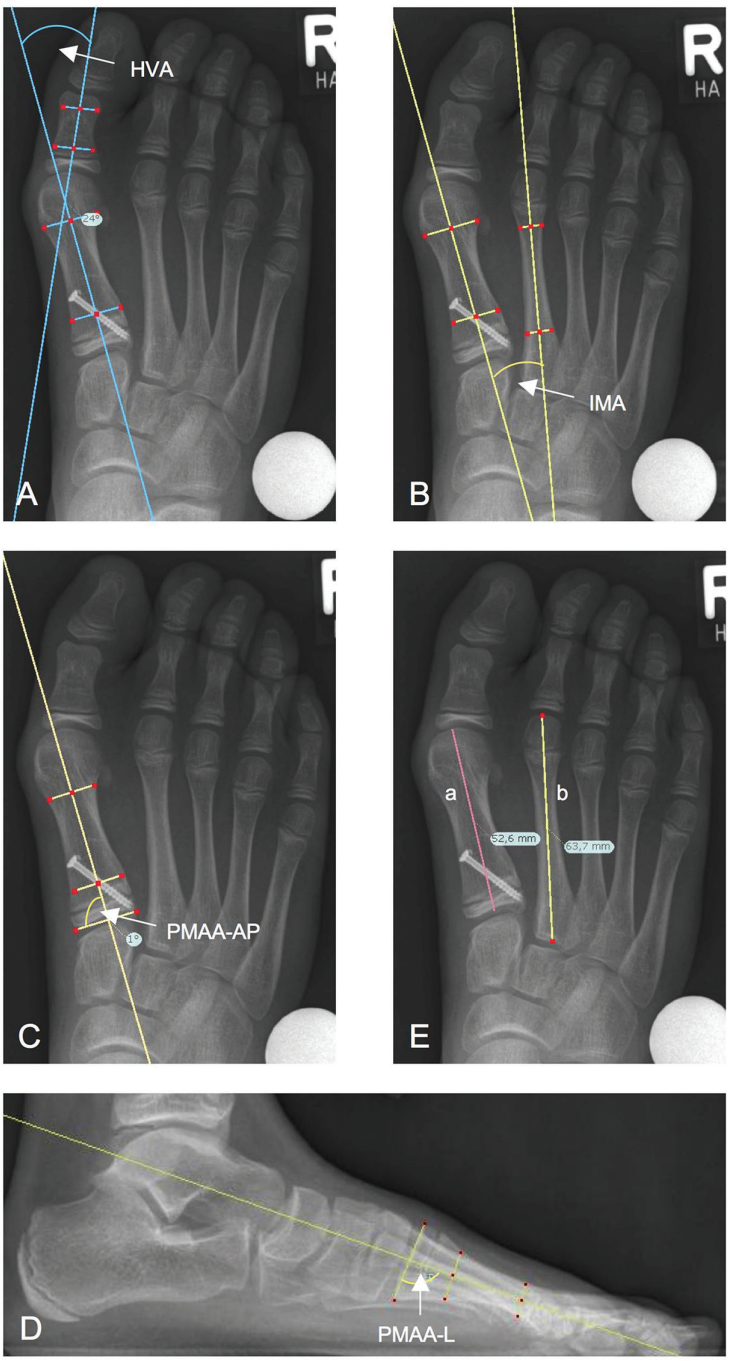

Fig. 1 Case series. Plain standing radiographs of the right foot of an 11-year two-month-old girl with juvenile hallux valgus deformity: (**a**) preoperative; (**b**) 13 months after screw-epiphyseodesis.

maximum). The Student paired *t*-test was applied to compare pre-treatment and post-treatment values. Statistical significance was assigned to p-values < 0.05.

Results

In all, 22 patients fulfilled the inclusion criteria. A total of 39 feet were affected (20 right; 19 left). The operative procedure was performed bilaterally in 17 patients, and on one side in five patients. At time of surgery the mean age was 11.1 years SD 1.5 (8 to 15). The mean follow-up was 27.8 months SD 9.9 (12 to 58). All patients had resumed their daily activities. By the time of follow-up, ten JHVD (six patients) had been fully corrected and the screws were removed. In all, 11 patients had to be excluded due to intermittent documentation (moving of the family to

Fig. 2 Radiographic analyses: (**a**) hallux valgus angle (HVA); (**b**) intermetatarsal angle (IMA); (**c**) proximal metatarsal articular angle anteroposterior in the anteroposterior plane (PMAA-AP); (**d**) proximal metatarsal articular angle in the lateral plane (PMAA-L); (**e**) metatarsal length ratio (MTLR).

another city, external further treatment, compliance) or additional trauma (Table 1).

Complications and revision operations

During this study no wound infection, treatment-related fractures or perioperative implant failures were seen. No premature epiphyseal plate closure had developed. Due to tenderness over the head of the screw, premature screw removal and proximal metatarsal osteotomy in combination with a lateral soft-tissue release was performed in two patients (three feet). In two cases (two feet) the screws grew out of the epiphysis, leading to progression of the JHVD in one patient. (Figs 3a and 3b) In one case, the screw broke during removal and was left *in situ* (Figs 3c and 3d, Table 1).

Radiographic analysis

The preoperative average HVA was 26.5° SD 6.6°. At the time of follow-up, the mean HVA was significantly reduced to 20.2° SD 6.2° ($p < 0.001$). Compared with the initial HVA, the temporary epiphyseodesis resulted in a mean correction of 5.5° SD 7.4°, according to an average rate of correction of 0.17° SD 0.35° per month. Due to screw migration an increasing HVA during follow-up was seen in one case. The mean IMA improved significantly from 14.1° SD 5.4° preoperatively to 10.5° SD 2.9° at time of latest follow-up ($p < 0.01$). The mean difference was 4.0° SD 5.4°, the mean rate of correction per month was 0.12° SD 0.20° (Table 1). The average PMAA-AP was 1.1° varus SD 5.3° before operation and 1.0° valgus SD 5.5° at the time of follow-up ($p = 0.06$). The PMAA-L changed from 5.2° dorsal

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Table 1 Study population, intermetatarsal angle (IMA) and complications

Patient	Gender	Side	Age at surgery (yrs)	Time to follow-up (mths)	Pre-operative IMA (°)	Follow-up IMA (°)	Complication
1	F	R	11.8	28	9	8	
		L	11.8	28	12	10	
2	F	R	12.5	40	23	16	Premature screw removal
		L	12.5	40	28	18	Premature screw removal
3	F	R	10.1	41	13	8	Screw migration
		L	10.1	41	15	11	
4	F	R	8.9	32	14	10	
5	M	R	10.1	58	33	11	
6	F	R	12.5	31	12	7	
		L	12.5	31	11	9	
7	F	R	10.1	28	18	11	
		L	10.1	28	16	11	
8	F	R	11.2	32	18	14	Premature screw removal
		L	11.2	32	22	16	
9	F	R	10.9	35	10	8	
		L	10.9	35	11	8	
10	M	R	12.1	34	20	11	
		L	12.1	34	15	8	
11	M	L	12.8	18	13	9	
12	M	R	11.5	22	11	8	
13	F	R	10.6	12	10	16	
		L	10.6	12	9	10	
14	F	R	8	25	12	9	
		L	8	25	18	11	
15	M	L	11.9	22	11	7	
16	F	R	10.1	22	10	8	
		L	10.1	25	12	10	
17	F	R	11.9	20	13	7	
		L	11.9	20	9	6	
18	F	R	10.3	17	11	9	
		L	10.3	17	8	10	
19	F	R	11.3	28	8	7	
		L	11.3	28	10	11	
20	F	R	11	22	12	16	Screw migration
		L	11	22	11	16	
21	F	R	15	28	16	12	
		L	15	28	14	13	
22	F	R	9.2	22	16	7	Screw breakage
		L	9.2	22	17	9	

SD 2.1° to 4.4° dorsal SD 2.4° (p = 0.06). No significant change of metatarsal ratio occurred over time (Table 2).

Discussion

The JHVD is rare. Symptoms range from cosmetic problems, tenderness over the first metatarsal joint, pressure sores, to significant pain at rest and during walking. Conservative management is controversial and operative management is challenging, associated with complications and recommended after skeletal maturity. A high rate of recurrence of the deformity after various reconstructive procedures has been reported in the literature.[20-25] Schwitalle et al[14] reported unsatisfactory results after the McBride procedure in 29% (five out of 17 feet) and after Mitchell osteotomy in 19% (three out of 16 feet). Other authors report a recurrent deformity after the McBride procedure in 29% to 75%, and after Mitchell osteotomy in 19% to 30%.[9,14,21,25] Waiting until maturity to perform surgery may not be acceptable for many children and families due to particularly severe psychological or physical suffering. In these selected cases early operative treatment has to be considered to reduce the complaints, making the temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal an attractive treatment option.

All patients included in this study underwent a preoperative conservative therapy attempt with a change of footwear, individual insole adjustment and hallux valgus splints. Nevertheless, the children and the parents reported persistent complaints that not only caused pain, but also led to varying levels of mental stress (cancelled holidays, abandonment of hobbies or regular absence on school sports). Only in these cases with particularly severe psychological or physical suffering surgery was contemplated.

No perioperative complications occurred. No wound infection or over correction was seen. No premature epiphyseal plate closure or permanent fusion by formation of a bar was detected. All patients resumed their daily activities. In two cases, the screw had to be removed before full correction of the deformity was accomplished.

Fig. 3 Complications: (**a**) postoperative; (**b**) the screw grew out of the epiphysis; (**c**) postoperative; (**d**) the screw broke during removal and was left *in situ*.

Both patients reported a tenderness on palpation over the slightly prominent head of the screw leading to a necessitating implant removal. None of the remaining 20 patients complained about local pain during sports activities or walking long distances. Migration of the screw was seen in two feet (two of 39, 5%), clarifying the need of conscientious follow-up investigations.

In this series, 27.8 months after screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal a significant reduction of the HVA had occurred (26.5° to 20.2°) with a correction rate of 0.2° per month. Seiberg et al[19] noted similar results after lateral epiphyseal stapling and modified McBride bunionectomy. In these patients the HVA decreased with an average of 19.6° (initial decrease

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Table 2 Radiographic results

	Preoperative	Follow-up	Difference	Change/month	p-value
HVA (°)	26.5 SD 6.6	20.2 SD 6.2	5.5 SD 7.4	0.17 SD 0.35	<0.001*
(range)	(14 to 42)	(9 to 38)	(-9 to 21)	(-0.75 to 0.95)	
IMA (°)	14.1 SD 5.4	10.5 SD 2.9	4.0 SD 5.4	0.12 SD 0.20	<0.01*
(range)	(8 to 33)	(6 to 16)	(-6 to 22)	(-0.5 to 0.41)	
PMAA_AP (°)	1.1 var SD 5.3	1.0 val SD 5.5	2.8 SD 5.6	0.13 var SD 0.24	0.06
(range)	(16var to 11val)	(14var to 14val)	(16var to 5val)	(0.73var to 0.18val)	
PMAA-L (°)	5.2 dor SD 2.1	4.4 dor SD 2.4	0.1 SD 0.5	0.01 pla SD 0.03	0.06
(range)	(1dor to 9dor)	(1pla to 9dor)	(1pla to 1dor)	(0.05pla to 0.06dor)	
MTL-I (cm)	5.7 SD 0.7	5.9 SD 0.6	0.2 SD 0.6	0.01 SD 0.03	0.10
(range)	(4.3 to 7.0)	(5.1 to 7.1)	(-1.4 to 0.9)	(-0.07 to 0.08)	
MTL-II (cm)	6.5 SD 0.9	6.9 SD 0.8	0.2 SD 0.8	0.01 SD 0.02	<0.05*
(range)	(4.6 to 8.3)	(5.7 to 7.1)	(-1.8 to 1.0)	(-0.07 to 0.04)	
MTL-Ratio	0.9 SD 0.1	0.9 SD 0.1	0.01 SD 0.05	---	0.11
(range)	(0.8 to 1.0)	(0.8 to 1.1)	(-0.13 to 0.10)	---	

HVA, hallux valgus angle; IMA, intermetatarsal angle; PMAA-AP, proximal metatarsal articular angle in the anteroposterior plane; PMAA-L, proximal metatarsal articular angle in the lateral plane; MTL-I, length of the first metatarsal; MTL-II, length of the second metatarsal; MTL-ratio, metatarsal ratio; VAR, varus; val, valgus; dor, dorsiflexion; pla, plantarflexion

was 10.7° with an additional 8.9° occurring over time), the IMA with an average of 6.6° (initial decrease was 2.7° with an additional 3.9° occurring over time). Davids et al[16] reported an improvement of the HVA in nine of 11 feet, and of the IMA in seven of 11 feet after ablating the lateral physis of the metatarsal using a drill. No sagittal plane malalignment or shortening of the first metatarsal in relation to the second were seen in our cases. Similar to our study, Davids et al[16] reported that permanent hemiepiphyseodesis of the great toe metatarsal did not result in significant sagittal plane malalignment or shortening of the first metatarsal.

A number of complications may occur when performing epiphyseodesesis in an immature patient, like damage to the epiphyseal plate, implant failure and over correction. Therefore, close follow-up visits are strongly recommended, especially because a wide range of correction rates per month (in our series for the HVA mean 0.2° up to 0.95°) and for the IMA (mean 0.12° up to 0.4°) was seen in our patients. The optimal time of screw removal after achieving full correction should not be missed and an over correction into a hallux varus has to be prevented. If the screw has to be removed before epiphyseal plate closure, further follow-ups are necessary to detect a possible rebound phenomenon. So far, no recurrence could be detected. At this time, we do not have enough data to give a precise recommendation regarding the optimal timing of the screw epiphyseodesis. Previous studies suggest that adequate longitudinal growth to achieve significant correction by hemiepiphyseodesis is present in girls up to ten years of age and boys up to 12 years of age.[26-28] Due to the rather low correction rate per month an early epiphyseodesis seems reasonable.

For all patients we prescribed night-time splints to protect the wounds at night, to address the soft tissue and to support the epiphyseodesis, although preoperative, conservative therapy had not been sufficient. Since the splint is not compromising the epiphyseodesis we recommend the splint to achieve the best possible treatment result.

Defined in accordance with the literature we only recommend the operative therapy of the JHVD in cases with severe psychological or physical complaints. The shape of the deformity itself did not correlate with the complaints and should not be considered as indication for surgery alone. To recommend temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal for all patients with JHVD, larger cohort studies are required.

In comparison with the already existing operative methods, our first described method of temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal leads to an improvement of the JHVD in all followed up cases. Reduction of preoperative complaints was achieved in all patients. A clear advantage is the minimally invasive surgical therapy with a significantly reduced complication rate compared with the existing operative methods, which allows bilateral operative care with immediate postoperative weight-bearing.

As a limitation of the study the median follow-up period of 28 months must be stated. Older studies regarding the treatment of JHVD reported increasing patient dissatisfaction and a rising recurrence rate over the time. For our study, we cannot report in detail an increasing patient dissatisfaction or a rising recurrence rate, even after 58 months. Nevertheless, these results have to be proven in longer term and larger cohort studies. A further limitation represents the absence of a clinical evaluation tool.

In summary, the results confirm the positive effect of the temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal on the HVA in patients with JHVD and ongoing severe psychological or physical complaints after conservative therapy attempts.

Conclusion

Temporary screw epiphyseodesis of the lateral epiphyseal plate of the first ray metatarsal seems to be a sufficient,

technically simple, minimally invasive and safe treatment option for the JHVD. Due to the individual correction rate, regular clinical and radiological follow-ups should be carried out until the patient reaches skeletal maturity. To confirm the long-term outcome, and the rate of recurrence after screw removal, and to define the optimal timing for the screw epiphyseodesis, larger cohort studies are required.

Received 20 December 2017; accepted after revision 27 May 2018.

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical approval: All procedures and investigations performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration.

Informed consent: Informed consent was not required due to the retrospective nature of this work.

ICMJE CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. **Cole AE.** Foot inspection of the school child. *J Am Podiatry Assoc* 1959;49:446-454.

2. **Kilmartin TE, Barrington RL, Wallace WA.** Metatarsus primus varus. A statistical study. *J Bone Joint Surg [Br]* 1991;73-B:937-940.

3. **Grace D, Delmonte R, Catanzariti AR, Hofbauer M.** Modified lapidus arthrodesis for adolescent hallux abducto valgus. *J Foot Ankle Surg* 1999;38:8-13.

4. **Hardy RH, Clapham JC.** Observations on hallux valgus; based on a controlled series. *J Bone Joint Surg [Br]* 1951;33-B:376-391.

5. **Piqué-Vidal C, Solé MT, Antich J.** Hallux valgus inheritance: pedigree research in 350 patients with bunion deformity. *J Foot Ankle Surg* 2007;46:149-154.

6. **Kilmartin TE, Barrington RL, Wallace WA.** A controlled prospective trial of a foot orthosis for juvenile hallux valgus. *J Bone Joint Surg [Br]* 1994;76-B:210-214.

7. **Groiso JA.** Juvenile hallux valgus. A conservative approach to treatment. *J Bone Joint Surg [Am]* 1992;74-A:1367-1374.

8. **Fuhrmann RA.** Therapy of pediatric hallux valgus. *Orthopade* 2013;42:38-44.

9. **Helal B.** Surgery for adolescent hallux valgus. *Clin Orthop Relat Res* 1981;157:50-63.

10. **Coughlin MJ. Roger A.** Mann Award. Juvenile hallux valgus: etiology and treatment. *Foot Ankle Int* 1995;16:682-697.

11. **McBride ED.** The McBride bunion hallux valgus operation. *J Bone Joint Surg [Am]* 1967;49-A:1675-1683.

12. **Mitchell LA, Baxter DE.** A Chevron-Akin double osteotomy for correction of hallux valgus. *Foot Ankle* 1991;12:7-14.

13. **Peterson HA, Newman SR.** Adolescent bunion deformity treated with double osteotomy and longitudinal pin fixation of the first ray. *J Pediatr Orthop* 1993;13:80-84.

14. **Schwitalle M, Karbowski A, Eckardt A.** Hallux valgus in young patients: comparison of soft-tissue realignment and metatarsal osteotomy. *Eur J Pediatr Surg* 1998;8:42-46.

15. **Young KW, Kim JS, Cho JW, et al.** Characteristics of male adolescent-onset hallux valgus. *Foot Ankle Int* 2013;34:1111-1116.

16. **Davids JR, McBrayer D, Blackhurst DW.** Juvenile hallux valgus deformity: surgical management by lateral hemiepiphyseodesis of the great toe metatarsal. *J Pediatr Orthop* 2007;27:826-830.

17. **Ribotsky BM, Nazarian S, Scheuller HC.** Epiphysiodesis of the first metatarsal with cancellous allograft. *J Am Podiatr Med Assoc* 1993;83:263-266.

18. **Sheridan LE.** Correction of juvenile hallux valgus deformity associated with metatarsus primus adductus using epiphysiodesis technique. *Clin Podiatr Med Surg* 1987;4:63-74.

19. **Seiberg M, Green R, Green D.** Epiphysiodesis in juvenile hallux abducto valgus. A preliminary retrospective study. *J Am Podiatr Med Assoc* 1994;84:225-236.

20. **Bonney G, Macnab I.** Hallux valgus and hallux rigidus; a critical survey of operative results. *J Bone Joint Surg [Br]* 1952;34-B:366-385.

21. **Canale PB, Aronsson DD, Lamont RL, Manoli A II.** The Mitchell procedure for the treatment of adolescent hallux valgus. A long-term study. *J Bone Joint Surg [Am]* 1993;75-A:1610-1618.

22. **Luba R, Rosman M.** Bunions in children: treatment with a modified Mitchell osteotomy. *J Pediatr Orthop* 1984;4:44-47.

23. **Mann RA, Coughlin MJ.** Hallux valgus—etiology, anatomy, treatment and surgical considerations. *Clin Orthop Relat Res* 1981;157:31-41.

24. **McHale K, McKay D.** Bunions in a child: conservative versus surgical management. *J Musculoskelet Med* 1986;3:56-62.

25. **Scranton PE Jr, Zuckerman JD.** Bunion surgery in adolescents: results of surgical treatment. *J Pediatr Orthop* 1984;4:39-43.

26. **Anderson M, Blais M, Green WT.** Growth of the normal foot during childhood and adolescence; length of the foot and interrelations of foot, stature, and lower extremity as seen in serial records of children between 1-18 years of age. *Am J Phys Anthropol* 1956;14:287-308.

27. **Anderson M, Blais MM, Green WT.** Lengths of the growing foot. *J Bone Joint Surg [Am]* 1956;38-A:998-1000.

28. **Nelson JP.** Mechanical arrestment of bone growth for the correction of pedal deformities. *J Foot Surg* 1981;20:14-16.