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ORIGINAL STUDY

Long-term outcome of chevron-osteotomy in juvenile hallux valgus

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The long-term outcome of juvenile hallux valgus treated by a modified Austin procedure was investigated. The clinical (subjective, AOFA Scores) and radiological outcome (hallux valgus angles, intermetatarsal angles, position of the sesamoid bones and metatarsal index of 15 feet in 12 patients, aged 14 years and 2 months (SD +/- 1 year 10 months) were assessed pre- and postoperatively and after 7 years and 3 months (SD +/- 3 years). A significant improvement of the hallux valgus angle and of the intermetatarsal angle was obtained, persisting until final follow–up. The mean American Orthopaedic Foot and Ankle Society hallux metatarsophalangeal-interphalangeal and AOFA-Midfoot score were 94.5 points and 85.3 points, respectively. The modified Austin procedure appears to be an effective procedure to correct a juvenile hallux valgus deformity, with long lasting improvement, no growth disturbances and good functional outcome.

Keywords : hallux valgus ; immature skeleton ; chevron osteotomy ; long-term outcome.

INTRODUCTION

The term "hallux valgus" was first introduced in 1871 by Carl Heuter for lateral angulation of the first metatarsophalangeal joint associated with metatarsus primus varus and lateral deviation of the sesamoids (*22*). Juvenile bunion is often bilateral and more frequently occurs in females. Juvenile in contrast to adult hallux valgus seldom causes pain, but may lead to shoe-fitting problems. Radiologically, the metatarsophalangeal joint is usually only minimally or not affected.

Conservative management often fails (*19*). Considerable controversy continues to exist concerning patient selection, timing and choice of surgical technique and final outcome (*7*,*8*). The chevron osteotomy procedure is recommended in less severe deformities (*2*). In skeletally immature patients the risk of recurrence after surgery seems to be higher (*3*). The aim of this study was to investigate the long-term functional and radiological outcome of a modified chevron-osteotomy procedure for the correction of juvenile bunions.

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PATIENTS AND METHODS

Patients

From the paediatric database we collected children and adolescents with primary hallux valgus deformity, surgically corrected between January 1999 and December 2009 following the technique of Austin and Levanten. Patients with secondary hallux valgus deformity (e.g. posttraumatic, cerebral palsy) were excluded. Postoperatively, an identical treatment protocol was used.

The availability of pre- and postoperative standing anteroposterior and lateral radiographs of the feet were a prerequisite for participation in this study. Approval was obtained from the local ethics committee (EK-23-507 ex 10/11). All patients matching the inclusion criteria were invited for a clinical and radiological follow-up.

Radiographs and radiographic measurements

The hallux valgus angle (HV), the intermetatarsal angle (IMT), the metatarsal index (MTI) and the position of the sesamoid bones (POS) were evaluated three times : pre- and postoperatively and at final follow-up. All radiographs were reviewed for signs of possible avascular necrosis and degenerative changes according to Kellgren (*18*).

The HV was measured according to Hardy and Clapham (*13*). The intersection of the mid shaft axis of the proximal phalanx and of the first metatarsal represents the HV. According to Thompson a HV of more than 16° was considered pathological (*27*).

The IMT was measured using the technique of Hawkins (*14*). The intersection of the midshaft axis of the first and the second ray determines the intermetatarsal angle. An angle of 10° or more on a weight-bearing radiograph is defined as pathological.

The MTI indicates the relative length of the distal ends of the metatarsals. To determine the relative metatarsal length a running arc across the ends of the second through fifth metatarsals was drawn (*5,17*). If the head of the first metatarsal surpassed this line it was defined as "long" (L). If the distal limit of the first metatarsal head touched the line, the length was defined as "neutral" (N). The first metatarsal was "short" (S) when the first metatarsal head was proximal to this line (Fig. 1).

Lateral displacement of the sesamoids and severity of hallux valgus deformity are highly correlated (*13*). The sesamoids are embedded in the tendon of the flexor hallucis brevis muscle, which inserts onto the base of the proximal phalanx. Any degree of hallux valgus tends to rotate both sesamoids along the long axis. As the sesamoids translate and rotate, the flexor hallucis brevis and flexor hallucis longus follow, thereby lateralizing their kinematic vector and accentuating the deforming forces on the proximal phalanx and the first metatarsal head (*23*).

Figure 2 illustrates the stages of sesamoid position : in stage 0 the overlap of the medial sesamoid in relation to the longitudinal axis of the first metatarsal is 0%, in stage 1 less than 50%, in stage 2 between 50 and100% and in stage 3 over 100%.

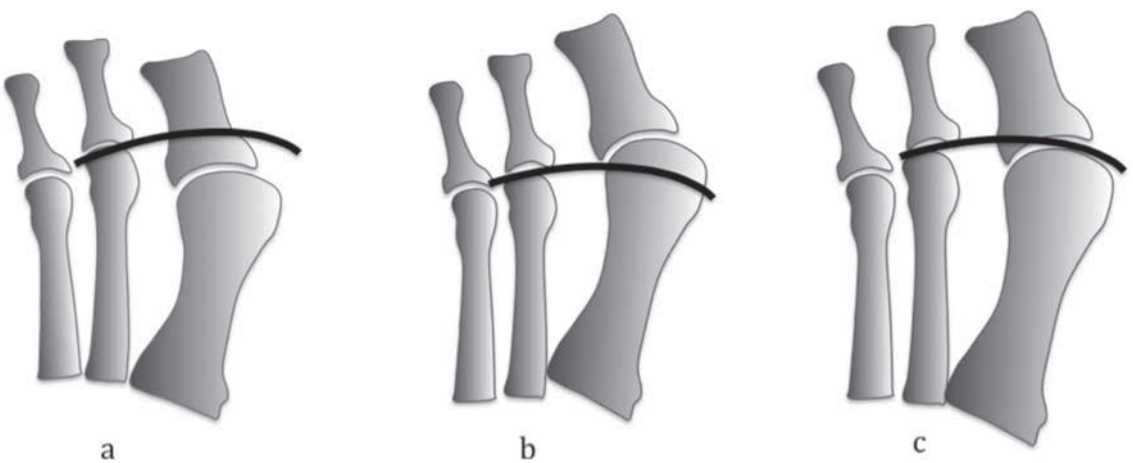

Fig. 1. — Different types of the metatarsal index (MTI) are presented. This index indicates the relation of the length of the second to the first metatarsal. Figure 1a shows a short first metatarsal (S), 1b a long first metetarsal (L) and 1c shows equal length of the first and second metatarsal (N)

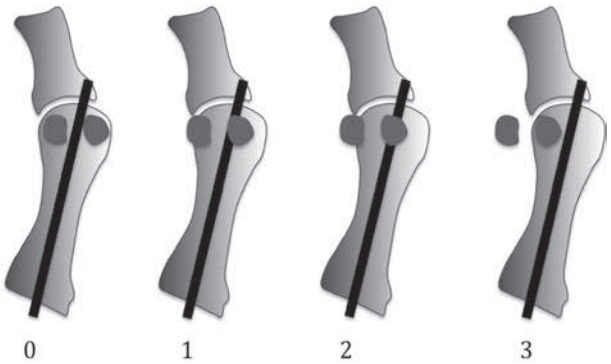

Fig. 2. — The position of the sesamoids in relation to the mid-shaft axis of the first metatarsal as well as their lateral deviation is presented according to Smith *et al* (25) ; stage 0 : 0%, stage 1 : < 50%, stage 2 : 50-100% and Stage 3 : > 100%.

Indication for surgery

Conservative treatment included the wear of comfortable shoes with insoles and a sufficiently spacious toe box to avoid rubbing or lateral pressure on the great toe. Surgery was indicated for a HV of more than 16° and a IMT of more than 10° when discomfort persisted and conservative treatment failed. We did not operate on patients without pain, only claiming the cosmetic appearance of their foot, because the expectations in these patients are often unrealistically high.

Operative technique

A tourniquet was used in all patients. A dorso-medial slightly curved skin incision was used. In contrast to the original procedure by Austin, the abductor muscle was always detached. A 60° V-shaped distally capsular based flap was created, followed by removal of the medial eminence. The adductor muscle was released intra-articularly by sharp dissection. In some patients this was achieved by a second skin incision at the first web space allowing adequate exposure of the adductor insertion. From medial to lateral a V-shaped osteotomy with distal apex was performed in the cancellous bone of the metaphysis of the first metatarsal. The capital fragment was shifted laterally by thumb pressure. In difference to Austin (2), the fragments were fixed using either a K-wire, Ethibond-pins (Johnson&Johnson Ethicon®) or one or more micro screws (Titanium cortical screw 18 mm, 2 mm in diameter). The remaining medial projection of the shaft was equalised to the contour of the metatarsal neck by saw. The wound was closed in layers after medial capsulorhaphy.

Postoperative management

Immediately after surgery an Acrylastic® dressing (BSN Medical) was used in order to keep the big toe medialized. A full weight bearing below knee cast was applied for 6 weeks postoperatively. Perioperative antibiotics were given and an antithrombotic therapy was recommended until cast removal. After cast removal, patients were provided shoe inlays. Standing postoperative radiographs were taken within the first three months after operation.

Scores

For all patients at follow-up the AOFAS – Score was used. No radiological parameters are included. The AOFAS clinical rating scales have the potential advantage of being applicable to a wide variety of foot and ankle disorders (26). The total score in the AOFAS scoring scales ranges from 0 to 100, with higher scores indicating lesser impairment. In this study, the midfoot score (MS) and the AOFAS hallux metatarsophalangeal-interphalangeal scale (HMIS) were completed at follow-up (16).

The AOFAS midfoot score (MS) considers pain (40 points), alignment (10 points) and function (50 points). Function includes activities of daily living, walking distances and footwear requirements. The HMIS assesses pain (40 points), alignment (15 points) and function (45 points) of the forefoot.

Cosmesis

Patients were asked to grade the appearance of the forefoot between normal, mildly, moderately and severely altered due to possible recurrence of the hallux valgus.

Statistics

According to the Kolmogorov-Smirnov-test the data were normally distributed. For comparing the radiological data measured before and after operation, an ANOVA with Scheffe's post hoc test was performed and a p-value of < 0.05 was considered statistically significant. Clinical data and scores are presented in means with ranges and standard deviations.

RESULTS

Twenty patients met the inclusion criteria of whom 12 patients (15 feet ; 3 feet in 2 boys and 12 feet in 10 girls) completed follow-up. Mean age at operation was 14 years and 2 months (SD +/- 1 year and 10 months ; range 11 years and 8 months - 17 years and 3 months). At the time of operation the growth plate of the first metatarsal was near closure in 7 of the 15 (46%) feet. An oblique medial cuneiform bone, predestining to hallux valgus, was found in 8 feet. The mean time between operation and follow-up was 7 years and 3 months (SD +/- 3 years ; range : 2 years and 2 months - 11 years and 2 months). Postoperatively there were no wound or pin complications nor did any superficial or deep infection occur.

At follow-up, the radiographs showed neither degenerative changes nor mal-unions. The HV angle significantly improved ($p < 0.001$) with a preoperative mean of 31.5° (SD +/- 8,6 ; range 14-45) and a postoperative mean of 14.4° (SD +/- 4.6 ; range 7-22) (Fig. 3). The IMT significantly improved ($p < 0.001$) from a preoperative mean of 13.2° (SD +/- 2.1 ; range 10-17) to a postoperative mean of 6.1° (SD +/- 2.1 ; range 4-10). Both, HV angle and IMT were unchanged when comparing immediate postoperative to final follow-up values (HV $p = 0.83$; IMT $p = 0.48$).

The details of the changes of the MTI from pre-, postoperative to follow-up are presented in Table I. Forty seven per cent of the feet had an unchanged MTI, 40% had a shortened MTI and 13% an increase of the MTI when comparing preoperative to follow-up findings.

In 12 feet of the 15 feet, the position of the sesamoids was improved, in 2 feet unchanged and in one foot the sesamoids were lateralized. At long-time follow-up, 7 feet showed deterioration compared to the postoperative position, in 7 feet the position of the sesamoids remained unchanged and in one foot the position improved. Preoperatively and at follow-up none of the feet showed degenerative changes. Detailed information is presented in Table I.

Three patients (five feet) experienced mild pain at weather changes. One patient (two feet) was limited in recreational activities, but not in activities of daily living. All patients regained unlimited walking. One female patient (1 foot) preferred flat shoes and only 2 patients (2 feet) regularly wear their inlays. Walking surface was no problem in 11 patients (14 feet), 1 patient (2 feet) complained of mild pain when walking on stony terrain or climbing hills.

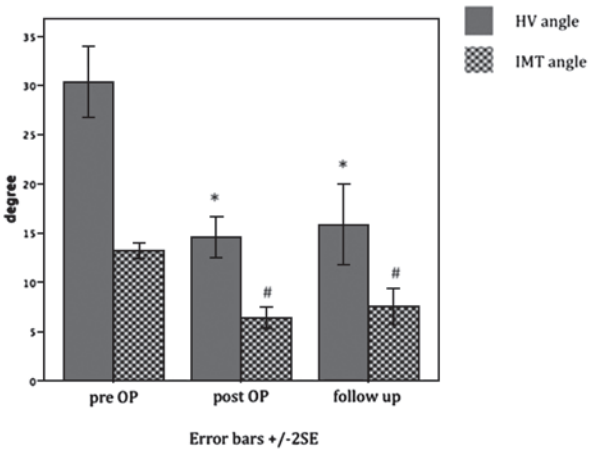

Fig. 3. — HV angle and IMT angle are presented as means and standard errors. Postoperatively both angles were significantly improved. Improvement persisted after 7 years (* $p < 0.05$ vs pre-OP HV ; # $p < 0.05$ vs pre-OP IMT).

The average AOFA-Midfoot–score was 85.3 points (SD +/- 4.9 ; range 73-95). The mean AOFAS - HMIS was 94.5 points (SD +/- 7.7 ; range 73-95). The functional capacity, which was measured by summing the scores for six different aspects of functional performance, averaged 48.1 points for the HMIS and 36.4 points for the MS. Detailed information is presented in Table II.

Most patients were satisfied with the cosmetic outcome of their feet and assessed it as normal or mildly altered (11 patients ; 13 feet). Only one female patient found her two operated feet moderately altered after operation due to the scars.

DISCUSSION

The aetiology of juvenile hallux valgus is complex. Predestining factors are pes planus, female sex, an oblique medial cuneiform bone, metatarsus primus varus, a longer first metatarsal

Table I. — Detailed data of the patients including sex, the operated foot, age at operation, time to follow-up examination, the positions of the sesamoid bones and the MTI at three different time points

Patient	Sex	Side	Age at OP (y,m)	Follow-up (y,m)	POS			MTI		
					preOP	postOP	Follow-up	preOP	postOP	Follow-up
1	m	right	14y 8m	11y 2m	2	1	2	N	N	S
2	m	right	12y 6m	11y 1m	3	2	2	L	N	N
		left	12y 6m	11y 1m	3	3	2	N	N	L
3	f	right	11y 8m	10y 5m	1	0	0	N	S	S
		left	12 y 11m	9y 2m	0	0	0	S	S	S
4	f	left	12y 6m	9y 3m	3	0	1	N	N	N
5	f	left	15y 7m	8y	1	2	2	L	S	S
6	f	right	15y	6y 3m	3	0	2	S	N	S
		left	14y	7y 3m	3	2	2	S	S	S
7	f	left	17y 3m	5y 5m	2	0	0	L	L	L
8	f	left	13y 3m	5y 5m	1	0	1	N	N	N
9	f	right	16y 1m	4y 10m	2	0	1	N	S	S
10	f	right	12 y 8m	4y 2m	3	2	2	N	S	S
11	f	right	15y 2m	3y 3m	3	0	3	N	N	N
12	f	left	17y 3m	2y 2m	2	0	3	S	N	N

POS = Position of Sesamoids ; MTI = Metatarsal Index.
N = equal first and second metatarsal ; L = long first metatarsal and S = short first metatarsal.
Average age 14 yrs 2 mths ; SD : 1 yr 3 mths
Average FU : 7 yrs 3 mths ; SD : 3 yrs.

and hypermobility of the metatarsocuneiform joint (*6*). A positive family history is associated with a significant earlier onset of bunions and mostly girls inherit the disorder from their mothers (*11*). However, the exact mode of transmission is unknown.

A hallux valgus is designated as "juvenile" in individuals who are 20 years old or younger because bone growth, cartilage moulding and soft tissue changes are relatively plastic until that age (*10*). Deformity worsens between ages 16-20 due to the final growth spurt with increased weight and external compression (*10*). Patients in this age group have a marked awareness of their bodies and the deformity and are more inclined to demand treatment. Conservative management of the deformity in adolescents is prone to fail because the desire to wear certain types of shoes and insoles generates great concern. The decision for surgery therefore is frequently taken. The risk of recurrence seems to be higher in juvenile patients after surgical correction (*24*).

For surgical correction a variety of techniques have been described. The correction involves either soft tissue, or bony procedures or a combination of both. The evidence for effectiveness of operative treatment for juvenile hallux valgus patients is very limited (*28*). This study reports the long-time outcome of Chevron osteotomy in juvenile hallux valgus. Distal soft tissue procedures alone such as the McBride procedure have been found inadequate for correction of the typical juvenile bunion. Helal *et al* reported a 46% failure rate with the McBride technique and noted that results deteriorated over time (*15*). Scranton and Zuckerman reported a 75% failure rate after 3 years in children using the McBride technique (*24*).

Distal metatarsal osteotomies are done at a safe distance to the growth plate. With a distal metatarsal oblique osteotomy Wilson (*29*) reported 88% and Helal almost 100% success rates (*15*). Many have found the Mitchell repair to be a satisfactory technique. Ball and Sullivan, however, reported a 44%

Table II. — AOFAS hallux metatarsophalangeal - interphalangeal scale (HMIS) and midfoot score (MS) according to pain, function and alignment including means, standard deviations and ranges

	HMIS			MS		
	mean	SD +/-	range	mean	SD +/-	range
Pain	34.6	5.2	30-40	36.4	5.0	30-40
Function	48.1	3.4	30-40	36.4	5.1	24-40
Alignment	11.7	3.6	8-15	12.6	3.3	8-15
Total	94.4	7.7	73-95	85.3	9.2	73-95

incidence of metatarsalgia following Mitchell osteotomy (*3*). Displacement of the small distal fragment, rotational instability, dorsiflexion or plantarflexion, malunion, non-union, shortening of an already short first metatarsal, incomplete correction and avascular necrosis are some noted complications of Mitchell osteotomy (*3,21*).

The Chevron procedure was introduced in 1968 and has gained increasing popularity over the last 20 years. Its advantages are rapid healing and increased stability even without fixation. In adults, good to excellent results are reported with a high level of satisfaction (*17,20*). The Chevron osteotomy is recommended for patients with a mild or moderate hallux valgus (*2*) with a HV angle of less than 30° and IMT of less than 13° (*4*). In this study the mean preoperative HV angle was 31.5° and the mean preoperative IMT was 13.2°. We found a significant improvement of the HV angle and the IMT postoperatively. Moreover, the angle improvement persisted after a follow-up of 7.3 years. The fact that almost half of the feet presented with an unchanged MTI supports the assumption that chevron-osteotomy in preventing excessive shortening of the first metatarsal avoids metatarsal II and III overload (*5*). However, a small loss of length cannot be avoided (*16*).

Mean age of operation in our patients was 14.2 years. The majority of operated patients were female. A girl's foot is fully grown at the age of 14 years (*1*). At age 12, a girl usually has only 0.8 cm of remaining growth potential (*8*) while in a boy with the same age the remaining growth is proximally 2.7 cm. These factors have to be kept in mind when deciding to operate a juvenile bunion. Already Coughlin and Roger recommended to consider postponement of surgery until the patient is closer to skeletal maturity (*8*) because of the significant amount of growth remaining in the proximal metatarsal epiphysis. Particularly in adolescents, bunion is known to recur over time (*20*). In eight of the operated feet the physis was still open. However, we found no significant deterioration of HV angle and IMT from operation to follow in the feet operated with open physis.

All patients had a below knee cast applied for 6 weeks postoperatively. Adhering to this strict protocol seems to be important when dealing with possibly non-compliant children and adolescents and might be one reason for the lasting improvement seen in our patients (*9*).

Zimmer *et al* (*30*) collected follow-up data after 5.5 years from a personal interview. We focused on objective clinical and radiological parameters. An additional strength of the present study is a mean follow-up of 7 years.

The retrospective nature of the study and the limited number of participants are shortcomings of the present study. Validity and reliability of the AOFA score and its inherent limited precision and small number of response intervals at each item of the scale, are still a matter of debate (*12*).

In six operated feet the position of the sesamoid bones (POS) was not completely corrected. Although there was no significant recurrence of bunion, a slight lateralisation of the sesamoid bones recurred in most feet. Residual lateral displacement of the sesamoid bones might be related to postoperative recurrence of hallux valgus. Okuda *et al* (*22*) described a significant relationship between postoperative incomplete reduction of the sesamoid bones and the recurrence of hallux valgus in adult

women. Our data show that feet with incomplete reduction of the POS had an increased HV and IMT at follow-up (data not shown).

CONCLUSION

The Chevron osteotomy according to Austin is a feasible method to correct mild to moderate juvenile hallux valgus without inducing growth disturbances. Bunion correction is maintained at long-term.

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