

Proximal abduction–supination osteotomy of the first metatarsal for adolescent hallux valgus: a preliminary report

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Abstract

Background Surgical treatment of adolescent hallux valgus has been a challenging intervention because of high rates of postoperative recurrence. The purposes of this study were to describe a proximal abduction–supination osteotomy of the first metatarsal and prospectively review preliminary results of this procedure for correction of adolescent hallux valgus.

Methods Eleven patients (12 feet) who had had a proximal abduction–supination osteotomy of the first metatarsal combined with a distal soft-tissue procedure to correct an adolescent hallux valgus deformity were prospectively reviewed clinically and radiologically. The average duration of follow-up was 22 months. The average age at the time of surgery was 17 years.

Results The mean score on the Japanese Society for Surgery of the Foot standard rating system for hallux improved significantly, from 62.0 points preoperatively to 99.2 points postoperatively ($p = 0.002$). All patients were satisfied and would choose to have the same procedure again. The mean hallux valgus angle decreased significantly, from 32.3° preoperatively to 12.2° postoperatively ($p = 0.002$); mean intermetatarsal angle decreased significantly from 14.0° preoperatively to 6.2° postoperatively ($p = 0.002$). No feet had postoperative recurrence of hallux valgus (a hallux valgus angle $\geq 20^\circ$). There were no occurrences of nonunion or transfer lesions.

Conclusions The clinical and radiological results of this study demonstrate that a proximal abduction–supination osteotomy with a distal soft-tissue procedure, which

described in this study, achieved significant correction of an adolescent hallux valgus deformity, significant improvement in pain and function, and reduction in rate of recurrence.

Introduction

Adolescents with a mild hallux valgus deformity have been managed with nonoperative treatment, including modification of shoe wear or orthoses [1, 2]. Surgical treatment had been indicated for patients who have symptomatic moderate-to-severe hallux valgus when conservative treatment had failed. Many surgical procedures for correction of adolescent hallux valgus have been described in the literature, and surgical outcomes have been reported with various success rates [3–15]. However, surgical treatment of adolescent hallux valgus has been a challenging intervention because of the high rate of postoperative recurrence [5–9, 11]. Risk factors for recurrence following a proximal crescentic metatarsal osteotomy include uncorrected pronation deformity of the first metatarsal and incomplete reduction of the sesamoids [16, 17]. Therefore, we devised a proximal abduction–supination osteotomy of the first metatarsal in order to reduce these risk factors for recurrence. The purposes of this study were to describe the surgical technique and to prospectively review the results of this procedure for treatment of symptomatic adolescent hallux valgus.

Patients and methods

Our institutional review board approved this study, and informed consent was obtained from each patient. Between

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March 2007 and July 2011, 11 consecutive female patients (12 feet) who had symptomatic adolescent hallux valgus deformity were treated with a proximal abduction–supination osteotomy of the first metatarsal combined with a distal soft-tissue procedure. Adolescent hallux valgus was defined as the onset of deformity in the teen years or earlier, and hallux valgus surgery at the age of ≤ 22 years. The average age at surgery was 17 (range 13–22) years. In two patients (two feet) who had surgery at the age of 20 and 22 years, onset of deformity occurred at the age of ≤ 12 years. Therefore, these two patients were considered as having adolescent hallux valgus. All feet had the closed epiphysis of the first metatarsal at the time of surgery. In two feet, a medial closing-wedge osteotomy of the proximal phalanx (Akin procedure [18]) was added. All procedures were performed by one of the authors. The average duration of follow-up was 22 (range 12–36) months. No patients were lost to follow-up. All patients underwent clinical and radiological assessment preoperatively and at the time of the most recent follow-up.

Indication for a proximal abduction–supination osteotomy combined with a distal soft-tissue procedure was symptomatic hallux valgus deformity (hallux valgus angle $\geq 30^\circ$ or an intermetatarsal angle $\geq 12^\circ$). Conservative treatment, including modification of shoe wear, nonsteroidal anti-inflammatory medications, or arch supports, had failed for all patients. Patients were excluded from the study if they had rheumatoid arthritis, osteoarthritis of the first metatarsophalangeal joint, or other inflammatory diseases or if they had had an operation on the affected foot.

Surgical technique

Surgical technique consisted of releasing the distal soft tissues, excising the medial eminence of the first metatarsal head, plicating the medial part of the capsule, and a proximal crescentic osteotomy of the first metatarsal [19]. The medial eminence was excised minimally to preserve the distal articular surface of the first metatarsal head. The adductor hallucis tendon was then dissected from its insertion. The transverse metatarsal ligament was released, and a longitudinal incision was made in the dorsolateral capsule of the first metatarsophalangeal joint. The crescentic osteotomy was performed 1.5 cm distal to the metatarsocuneiform joint. The osteotomy was curvilinear, and the concavity of the cut was directed distally. The proximal fragment was moved medially with a elevator, and the distal fragment was abducted to achieve parallelism between the first and second metatarsals; then, the distal fragment of the first metatarsal was manually supinated (Fig. 1) so that a round, lateral edge of the first metatarsal head (a positive round sign [18]) on the dorsoplantar fluoroscopic view of the foot changed to an angular- or

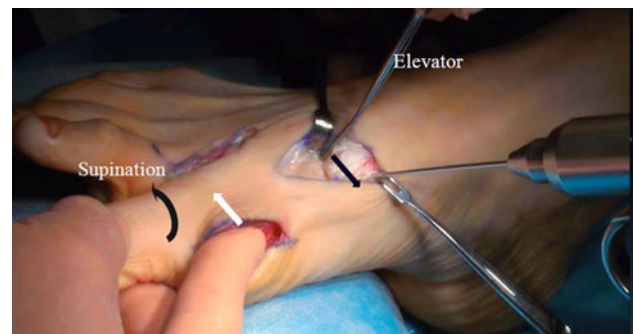


Fig. 1 Intraoperative correction of the metatarsus primus varus and pronation of the first metatarsal at the osteotomy site. The proximal fragment was pushed medially (*black arrow*) with a elevator, the distal fragment was abducted (*white arrow*) with a finger pressure applied to the medial aspect of the first metatarsal head, and the great toe, which was held with thumb and finger, was manually supinated (*curved arrow*)



Fig. 2 Intraoperative dorsoplantar fluoroscopic views. **a** Lateral edge of the first metatarsal head appearing to be round before supination of the distal fragment of the first metatarsal (*arrow*). **b** Lateral edge of the first metatarsal head appearing to be angular after supination of the distal fragment of the first metatarsal (*arrow*)

intermediate-shaped lateral edge (a negative round sign) (Fig. 2). After the desired correction was confirmed fluoroscopically, two or three crossed 1.5-mm Kirschner wires were used to fix the osteotomy site. The medial part of the capsule and the abductor hallucis tendon were plicated. If correction of the hallux valgus interphalangeus was necessary, a medial closing-wedge osteotomy of the proximal phalanx was added. Intraoperative dorsoplantar and lateral radiographs of the foot were made to evaluate the hallux

valgus angle, intermetatarsal angle, sesamoid position, and a round sign and sagittal alignment of the first metatarsal.

Postoperatively, a short-leg cast and nonweightbearing were continued for 2 weeks. Partial weightbearing in a short-leg plaster shell and active and passive extension and flexion exercises of the first metatarsophalangeal joint were then encouraged. Three weeks after surgery, patients were instructed to wear ready-made shoes with an arch support, and full weightbearing was encouraged.

Clinical assessment

Clinical assessment consisted of the Japanese Society for Surgery of the Foot standard rating system for hallux (JSSF scale) [20], metatarsalgia, range of motion of the first metatarsophalangeal joint, and patient satisfaction. The JSSF scale is a validated foot-rating system and assigns 40 points for pain, 45 points for function, and 15 points for alignment, with a possible maximum score of 100 points. The range of motion of the first metatarsophalangeal joint was measured by placing one goniometer arm parallel to the hallux and the other goniometer arm parallel to the long axis of the first metatarsal, then passively moving the first metatarsophalangeal joint from maximum flexion to maximum extension. Patient satisfaction was assessed with a questionnaire at the time of the most recent follow-up. Patients were asked whether they were satisfied or dissatisfied with the overall result of the surgery and were asked whether they would choose the same procedure again.

Radiographic examination

Dorsoplantar and lateral weightbearing radiographs were made preoperatively and at the time of the most recent follow-up. The hallux valgus angle (the angle between the longitudinal axes of the first metatarsal and the proximal phalanx) and the intermetatarsal angle (the angle between the longitudinal axes of the first and second metatarsals) were measured on the dorsoplantar weightbearing radiograph. The longitudinal axis of the first metatarsal was defined as the line connecting the center of the metatarsal head with the center of the proximal articulation according to the method proposed by Shima et al. [21]. The longitudinal axis of the proximal phalanx was defined as the line connecting the center of the proximal end of the diaphysis with the center of the distal end. The longitudinal axis of the second metatarsal was defined as a line connecting the center of the proximal end of the diaphysis with the center of the distal end. Postoperative recurrence was defined as a hallux valgus angle of $\geq 20^\circ$ at the time of the most recent follow-up.

The shape of the lateral edge of the first metatarsal head was classified as one of three types: round (type R), angular (type A), and intermediate (type I) with the measurement

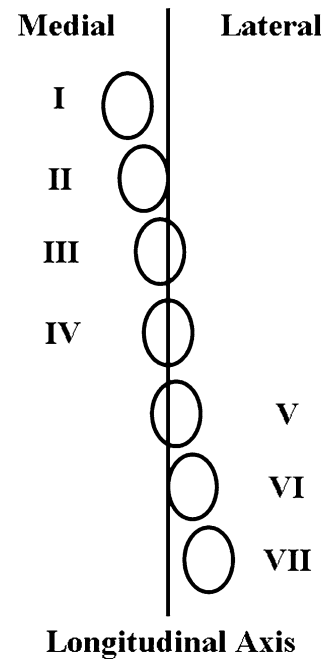


Fig. 3 Position of the medial sesamoids was classified as grade I, II, III, IV, V, VI, and VII on the basis of its relationship to the longitudinal axis of the first metatarsal

system [16]. We defined the round sign as being positive when the shape of the lateral edge was classified as type R as being negative when the shape of the lateral edge was classified as either type I or type A.

The position of the medial sesamoid in relation to a line drawn along the longitudinal axis of the first metatarsal on the dorsoplantar weightbearing radiograph was evaluated and classified as grades I, II, III, IV, V, VI, and VII according to the measurement system proposed by Hardy and Clapham [22] (Fig. 3).

The inclination angle of the first metatarsal was measured on the lateral weightbearing radiograph. The inclination angle was the angle between the longitudinal axis of the first metatarsal and the floor [16]. The longitudinal axis of the first metatarsal was defined as a line connecting the center of the proximal articular surface with the center of the distal end of the diaphysis.

Statistical analysis

Preoperative and postoperative radiological and clinical data were compared using the Wilcoxon signed-rank test. Differences with a p value < 0.05 were considered significant.

Results

The mean total JSSF score improved significantly from 62.0 points (range 49–75) preoperatively to 99.2 points

Table 1 Clinical evaluation

	Preoperative	Most recent follow-up	<i>p</i> value
JSSF score			
Pain	27.5 [30] (20–30)	39.2 [40] (30–40)	0.002
Function	32.5 [32] (29–37)	45 [45]	0.002
Alignment	1.3 [0] (0–8)	15 [15]	0.001
Total	62.0 [62] (49–75)	99.2 [100] (90–100)	0.002
ROM of the 1st MTP joint			
Extension (°)	70.4 (55–90)	67.1 (50–80)	0.526
Flexion (°)	27.1 (10–45)	21.7 (10–40)	0.219

Values are mean [median] (range)

JSSF Japanese Society for Surgery of the Foot standard rating system for hallux, ROM range of motion, MTP metatarsophalangeal

Table 2 Pre- and postoperative radiographic measurements

	Preoperative	Most recent follow-up	<i>p</i> value
Hallux valgus angle (°)	32.3 (28–38)	12.2 (9–17)	0.002
Intermetatarsal angle (°)	14.0 (11–18)	6.2 (3–9)	0.002
Inclination angle (°)	16.9 (13–21)	16.9 (10–21)	0.886

Values are given as the mean (range)

(range 90–100) at the most recent follow-up ($p = 0.002$) (Table 1). Three patients (three feet) had had metatarsalgia preoperatively. There were no feet with metatarsalgia at the most recent follow-up.

Mean extension and flexion of the first metatarsophalangeal joint are shown in Table 1. There were no significant difference in mean extension and flexion between preoperative and the most recent follow-up evaluations ($p = 0.526$ and 0.219 , respectively). All patients were satisfied with the overall results of this procedure and stated they would have the same procedure again. Results of the radiographic measurements are shown in Table 2. Preoperative hallux valgus and intermetatarsal angles significantly decreased at the most recent follow-up ($p = 0.002$, $p = 0.002$). All feet had a hallux valgus angle of $\leq 17^\circ$ and an intermetatarsal angle $< 10^\circ$ at the most recent follow-up. No significant difference was observed in mean inclination angle of the first metatarsal between preoperative and the most recent follow-up evaluations ($p = 0.886$).

Distribution of the position of the medial sesamoids is shown in Table 3. All feet were classified as grade V or greater preoperatively. Ten feet (83 %) were classified as grade IV or less, and the remaining two as grade V at the most recent follow-up. The mean sesamoid position improved significantly from 5.8 (median 6, range 5–7) preoperatively to 3.3 (median 3, range 2–5) at the most recent follow-up ($p = 0.002$).

Table 3 Distributions of sesamoid position and shape of the lateral edge of the first metatarsal head

	Preoperative	Most recent follow-up
Sesamoid position		
Grade II	0	2
Grade III	0	6
Grade IV	0	2
Grade V	5	2
Grade VI	4	0
Grade VII	3	0
Shape of the lateral edge		
Type A	0	7
Type I	1	4
Type R	11	1

Distribution of the shape of the lateral edge of the first metatarsal is shown in Table 3. Preoperatively, the round sign was positive for 11 feet and negative for one foot (type I). At the most recent follow-up radiographs, the round sign was positive for one foot and negative for 11 (type A or I) (Fig. 4).

There was no recurrence of hallux valgus in any patients. There were no occurrences of nerve injury, infection, delayed wound healing, delayed union, or non-union. At the most recent follow-up, no painful transfer lesions and no hallux varus developed in any patient.

Discussion

Many authors reported on the results of a distal metatarsal osteotomy for correction of mild-to-moderate hallux valgus deformity with various success rates in adolescents [3, 4, 7, 9, 11]. Canale et al. [9] reviewed the long-term results of the Mitchell procedure for treating adolescent hallux valgus and reported that a poor result in ten (20 %) of 51 feet were associated with recurrence of the hallux valgus deformity. Zimmer et al. [7] reported the results of chevron osteotomy for correction of adolescent hallux valgus and found that five (14 %) of 35 feet had subjective recurrence postoperatively. Peterson et al. [10] reviewed the results of a double osteotomy of the first metatarsal for adolescent moderate-to-severe hallux valgus and reported a satisfactory result in 13 (87 %) of 15 feet, although the two failures occurred due to technical problems that resulted in a postoperative hallux varus deformity. There is little available information on the results of a proximal osteotomy of the first metatarsal for correction of a hallux valgus deformity in adolescents [11, 14]. In this study, we describe a proximal abduction–supination osteotomy to correct adolescent hallux valgus and prospectively review the results of this procedure.



Fig. 4 A 17-year-old girl with a moderate hallux valgus deformity. **a** Preoperative dorsoplantar weightbearing radiograph demonstrating a hallux valgus angle of 33°, an intermetatarsal angle of 13°, a grade VI position of the medial sesamoids, and a round-shaped lateral edge of the first metatarsal head (a positive round sign). **b** Preoperative lateral weightbearing radiograph demonstrating an inclination angle of the first metatarsal of 18°. **c** At the 27-month follow-up,

dorsoplantar weightbearing radiograph demonstrating a hallux valgus angle of 9°, an intermetatarsal angle of 5°, a grade III position of the medial sesamoids, and an intermediate-shaped lateral edge of the first metatarsal head (a negative round sign). **d** Lateral weightbearing radiograph demonstrating an inclination angle of the first metatarsal of 17°

Our radiological results show that postoperative hallux valgus angle was $<17^\circ$ and postoperative intermetatarsal angle $<10^\circ$ in all feet; there was no recurrence of hallux valgus. Therefore, our surgical procedure could provide satisfactory correction for adolescent hallux valgus.

Several authors have reported that the rate of the excellent and good results has ranged from 69 to 93 % following a distal osteotomy, a proximal osteotomy, or a double osteotomy of the first metatarsal for adolescent hallux valgus, although there were various assessment tools among the literature [3, 4, 7, 9, 10, 13–15]. In our study, all patients were assessed using JSSF scale as a validated foot-rating system [20] preoperatively and at the time of the most recent follow-up. The mean total JSSF score improved significantly from 62.0 points preoperatively to 99.2 points postoperatively ($p = 0.002$); postoperative JSSF score was ≥ 90 points in all patients. Therefore, clinical results of our study are comparable with previously reported clinical results.

The distal metatarsal articular angle is a radiographic measurement of the orientation of the articular surface of the first metatarsal. Coughlin [11] found an increased distal metatarsal articular angle in 48 % of 60 feet with

adolescent hallux valgus. However, the distal metatarsal articular angle is not thought to be as valuable in the study of hallux valgus because the medial and/or lateral extent of the distal articular surface of the first metatarsal head is often not clearly defined on radiographs [23]. In addition, there is controversy regarding the reliability in the distal metatarsal articular angle measurement [24–27]. In our study, all but one foot had a round-shaped lateral edge of the first metatarsal head on preoperative radiographs, and the lateral articular margin of the first metatarsal head was not distinct. The rate of a round-shaped lateral edge of the first metatarsal head was 1.7 % (1/60 feet) in normal adult females and 78.3 % (47/60 feet) in adult females with hallux valgus [16]. Eleven of 12 feet (91.6 %) in adolescent hallux valgus had a round-shaped lateral edge. Therefore, a round-shaped lateral edge of the first metatarsal head may be the defining characteristic of adolescent hallux valgus. The difficulty of defining the lateral articular margin due to a round-shaped lateral edge of the first metatarsal head might have resulted in controversy regarding the reliability of the distal metatarsal articular angle measurement.

Mizuno et al. [28] described that pronation of the first metatarsal is one of the essential features of hallux valgus based on their clinical observation, and they proposed distal detorsion osteotomy of the first metatarsal. Eustace et al. [29], in a study of first metatarsal rotation and the role of pronation in hallux valgus, found that the amount of first metatarsal rotation increases as the intermetatarsal angle increases. They concluded that pronation and varus deviation of the first metatarsal are intimately related and appear to contribute to development of hallux valgus. The prevalence of the round-shaped lateral edge of the first metatarsal head (a positive round sign) was significantly greater in feet with hallux valgus than it was in normal feet [16]. From an anatomical point of view, the pronation of the first metatarsal in feet with hallux valgus may cause the shape of the lateral edge to appear round on the dorsoplantar radiograph [16]. In our study, a preoperative round sign was positive in all but one foot. However, we found that the apparent shape of the lateral edge changed from type R to type A or I under intraoperative fluoroscopy when the distal fragment was supinated after a proximal metatarsal osteotomy. In addition, a round sign was negative in most feet at the time of the most recent follow-up. Therefore, we believe that the round-shaped lateral edge of the first metatarsal head in adolescent hallux valgus might be produced on the radiograph by pronation of the first metatarsal head.

Recurrence of hallux valgus is the common complication following surgical correction for an adolescent hallux valgus deformity. The reported prevalence of recurrence deformity ranged from 0 to 61 % [3–9, 11, 12, 15]. Canale et al. [9] investigated the long-term results of the Mitchell procedure for adolescent hallux valgus and stated that the poor results were secondary to recurrence of the deformity, technical problems associated with the operation, stiffness, or an unsightly scar. Risk factors for postoperative recurrence in adult hallux valgus included postoperative round-shaped lateral edge of the first metatarsal head, postoperative incomplete reduction of the sesamoids, and a postoperative round sign can be positive when the pronation of the first metatarsal presents or recurs after surgery [16, 17]. Pronation of the first metatarsal may be a possible component of lateral displacement of the sesamoids because pronation of the first metatarsal brings dorsolateral displacement of the sesamoids at the same time. Therefore, we devised a proximal abduction–supination osteotomy in which pronation deformity of the first metatarsal can be corrected. Our radiological results showed a negative round sign and complete reduction of the sesamoids, defined as grade IV or less [17], in most patients at the most recent follow-up. We believe that these factors led to no recurrence in our study.

Our study has some limitations, including small number of patients and relatively short duration of follow-up. Surgical treatment of adolescent hallux valgus is relatively rare and has been a challenging intervention due to the high rate of complications [5–9, 11, 12]. Results of our study suggest that our surgical procedure, which can correct pronation of the first metatarsal as well as the metatarsus primus varus, has considerable potential for treating hallux valgus in adolescents. Therefore, we report the preliminary results of this procedure. Further investigations involving large number of patients, severe hallux valgus deformity (angle $\geq 40^\circ$), and longer follow-up are required to demonstrate the reliability and durability of this procedure.

In conclusion, our clinical and radiological results indicate that a proximal abduction–supination osteotomy is an effective procedure for correcting hallux valgus deformity in adolescents and could provide satisfactory correction and a low rate of recurrence.

Conflict of interest All authors declare that no grants, funds or benefits of any kind were received in support of the study.

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