Distraction Osteogenesis of the Fibula to Correct Ankle Valgus in Multiple Hereditary Exostoses

Alice Chu, M.D., Crispin Ong, M.D., Eric R. Henderson, M.D., Harold J. P. Van Bosse, M.D., and David S. Feldman, M.D.

Abstract

Gradual distal fibula lengthening (DFL), in conjunction with other procedures, was used to correct ankle valgus and short fibulae in three pediatric patients with multiple hereditary exostoses (MHE). The average amount of DFL was 15 mm with a mean follow-up of 2.9 years. Final radiographs showed that all three patients had a stable ankle mortise without evidence of talar tilt or widening. In conclusion, gradual DFL has the advantage of restoring anatomy in cases of ankle valgus due to short fibulae and MHE, and may be performed in conjunction with other procedures.

Ankle valgus can occur with a number of pediatric conditions that have fibular growth arrest as the primary etiology. Congenital fibular pseudarthrosis, longitudinal fibular deficiency, multiple hereditary exostoses (MHE), post-traumatic physeal arrest, and myelodysplasia are examples in which distal fibular growth disruption can lead to unbalanced growth between the medial and lateral tibial epiphyses.[1] Severe ankle valgus is a risk factor for the development of early arthritis.[2] Regardless of fibular deformity, many investigators treat ankle valgus only with correction of the tibial angle.[3-6]

Alice Chu, M.D., and David S. Feldman, M.D., Pediatric Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, New York. Crispin Ong, M.D., Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, New York. Eric R. Henderson, M.D., Sarcoma and Connective Tissue Oncology Program, Department of Orthopaedic Surgery, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire. Harold J. P. Van Bosse, M.D., Department of Orthopaedic Surgery, Shriners Hospital for Children, Philadelphia, Pennsylvania.

Correspondence: Alice Chu, M.D., Pediatric Orthopaedic Surgery, NYU Hospital for Joint Diseases, 301 East 17th Street, New York, New York 10003; alice.chu@nyumc.org.

In normal ankles, the distal fibula has a number of known functions. Lambert measured static forces at the mortise and deduced that the distal fibula is responsible for weightbearing one-sixth of the axial load.[7] The fibula also serves to stabilize the talus. It acts as a secondary stabilizer against talar tilt, both as a lateral restraint and through its articular congruity during ankle range of motion. Distal tibial development is dependent on fibular growth, and restricted distal fibular growth can be associated with restrained lateral distal tibial growth and the development of a valgus ankle.

The purpose of this study was to examine the effect of gradual distal fibular lengthening (DFL) for the treatment of ankle valgus in three patients with MHE.

Materials and Methods

Between January 1, 2004, and March 31, 2006, three patients with MHE were treated with gradual DFL for valgus ankle with a short fibula. This Institutional Review Board approved study involved the retrospective review of charts and radiographs.

Charts were reviewed for age at time of surgery, other procedures, duration of lengthening, duration of fixator use, and length of follow-up. At final follow-up visit, patients' ankles were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) clinical rating system.

Using radiographs taken before, during, and after the fibular lengthening procedure, the following data were recorded for three pediatric patients: 1. anatomic lateral distal tibial angle (aLDTA), 2. ankle mechanical axis (when standing radiographs were available), 3. fibular station (Malhotra),[8] 4. epiphyseal wedging, 5. sagittal tibial tilt, 6. talar tilt, 7. presence or absence of open growth plates, 8. talocrural angle,[5] 9. osteochondroma location, and 10. amount of fibular lengthening. When possible, standing views were used.

All patients had proximal tibiofibular screw fixation and a distal fibular, transverse suprasyndesmotic osteotomy with

Chu A, Ong C, Henderson ER, Van Bosse HJP, Feldman DS. Distraction osteogenesis of the fibula to correct ankle valgus in multiple hereditary exostoses. Bull Hosp Jt Dis. 2016;74(4):249-53

placement of uniplanar external fixation (mini EBI rail, Zimmer Biomet, Parsippany, NJ), with or without excision of osteochondromas. Two to three 3.0 mm half pins were placed distal and proximal to the suprasyndesmotic osteotomy. Lengthening was stopped when the Malhotra station had normalized or when further lengthening did not improve distal fibular alignment. After lengthening and consolidation of the regenerate bone, the external fixator was removed.

Results

The patients were 10, 13, and 14 years old (Table 1). All were male and skeletally immature preoperatively. Patients' presenting complaints were presence of deformity and pain with excessive ambulation or running. On clinical examination, no ankle instability was found. All had planovalgus foot appearance with difficulty on toe rise. The mean duration of follow-up was 2.9 years (range: 2.3 to 4.0 years) and at the final visit, two out of the three were skeletally mature. The average amount of DFL was 15 mm (range: 12 mm to 21 mm). The average time spent in the fixator was 3 months. Standing leg length radiographs were performed in all patients, and other deformities, such as knee valgus, were corrected.

Patients 1 and 3 had no other procedures. In patient 2, percutaneous screws were placed for medial tibial hemiepiphysiodesis and syndesmosis fixation. Nine months after placement, when satisfactory distal tibial correction was obtained, the medial tibial screw was removed. Both the hemiepiphysiodesis and the fibular lengthening contributed to this patient's ankle valgus correction.

The mean aLDTA increased from 78.3° to 80.3° after fibular lengthening and was 83.7° at follow-up. The mean talocrural angle improved from 89.7° to 82.3° postoperatively and was 82.6° at follow-up. Similarly, improvement in the Malhotra station was found at the postoperative time point. All three patients had solid distal syndesmostic synostoses at final follow-up. The two patients who did not have a screw hemiepiphysiodesis of the medial distal tibia showed mild improvement (2° and 3°) in the aLDTA between the postoperative and follow-up times (Fig. 1). Patient 2, who did have a screw hemiepiphysiodesis, had a final aLDTA of 88°, improving 6° in 9 months (Fig. 2). None of the patients had talar tilt before, during, or after lengthening. Patient 2 had mild talar lateralization prior to surgery, which corrected during fibular lengthening. The mean AOFAS score at follow-up was 94.3, with two of the three patients scoring 100. Two patients had pre- and postoperative full length standing films allowing for measurement of their ankles' mechanical axis: patient 2 showed improvement from 72° to 80° and patient 1 from 70° to 73°. Minimal change was found in the amount of epiphyseal wedging, while the sagittal tibial tilt increased an average of 6.7° (range: 1° to 11°). None of the patients experienced complications related to the procedures.

Discussion

Valgus ankle deformity can occur with or without fibular shortening. Possible causes can be divided into primary (congenital fibular pseudarthrosis, spina bifida, cerebral palsy, hemophilic arthropathy, fibular physeal arrest, tibiofibular synostosis before skeletal maturity, longitudinal fibular deficiency) and compensatory mechanisms (secondary to deformities above or below the ankle joint).[5,9-11]

Primary childhood ankle deformities, in association with fibular shortening, illustrate that fibular and tibial development are closely related. In normal ankles, the average percentage of longitudinal growth from the proximal tibia (57%) is slightly, but significantly, lower than that of the proximal fibula (61%).[12] Beals and Skyhar reported that the distal tibia-fibular physis distance was 0.4 cm before age

Table 1 Radiographic Outcome Measures

	Patient 1 (10 year old)			Patient 2 (13 year old)			Patient 3 (14 year old)		
	Preop	Postop	Follow-up	Preop	Postop	Follow-up	Preop	Postop	Follow-up
aLDTA	73°	75°	78°	79°	82°	88°	83°	84°	85°
Ankle Mechanical Axis	70°	N/A	73°	72°	80°	N/A	N/A	N/A	81°
Fibula Station (Malhotra)	II	0-I	I	III	II	III	I	0	N/A
Epiphyseal Wedging (mm)	7	6	6	10	11	9	2	3	N/A
Sagittal Tibial Tilt	76°	75°	84°	82°	83°	N/A	82°	89°	93°
Talar Tilt	0°	1°	0°	0°	2° to 3°	1°	0°	3°	0°
Open Physis	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Talocrural Angle	90°	78°	84°	92°	86°	83°	87°	83°	81°
AOFAS Score	—	—	83	—	—	100	—	—	100
Osteochondroma Location	Distal tibia/ fibula	s/p excision	s/p excision, fused	Distal tibia/ fibula	No excision	Tibia/ fibula fusion	Distal tibia/ fibula	s/p excision	s/p excision

aLDTA = anatomic lateral distal tibial angle; AOFAS = American Orthopaedic Foot and Ankle Society.

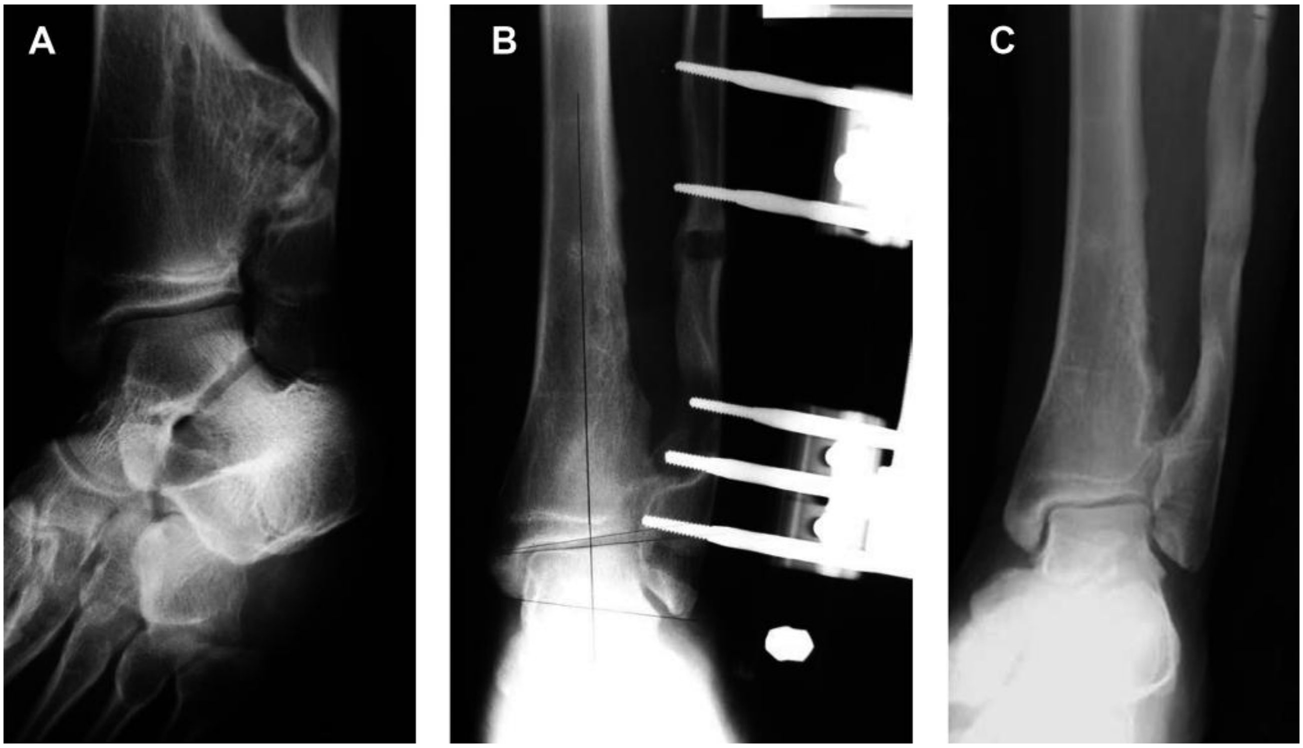

Figure 1 Preoperative (**A**), postoperative (**B**), and follow-up (**C**) radiographs show a 14-year-old boy with MHE who underwent distal fibular lengthening without medial tibial screw hemiepiphysiodesis.

1, but increased to 1.0 cm by age 12.[13] This produces the appearance of downward migration of the lateral malleolus as well as gradual decreasing valgus of the distal tibia. The lateral distal tibial angle averages 80° at birth, increases to 84° by age 1 year, and is approximately 90° by age 10.[14] Some investigators believe that the tibial and fibular physeal relationship is dynamic. Makin stated that the distal physis initially predominates in both the tibia and fibula. At differing times (50% overall length of the tibia; 30% of the fibula), the proximal physis assumes the majority of growth.[11] It seems likely that there is an intricate feedback between the rates of physeal growth in both bones. Distal tibial epiphyseal wedging, in which the lateral distal tibial epiphysis grows more slowly than the medial distal tibia, can occur after any type of insult to distal fibular growth.[9,14,15] Increased tibial forces during lengthening for patients with fibular hemimelia can lead to varying amounts of growth arrest in the lateral distal tibial physis.[16]

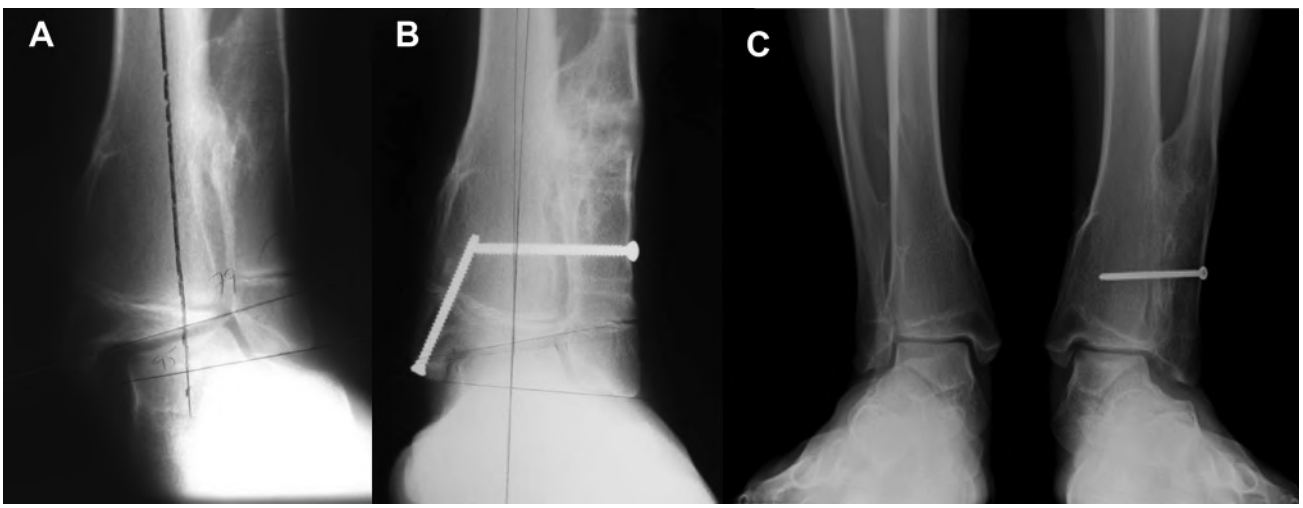

Figure 2 Preoperative (**A**), postoperative (**B**), and follow-up (**C**) radiographs show a 13-year-old boy with MHE who underwent distal fibular lengthening with medial tibial screw hemiepiphysiodesis.

Ankle valgus can occur in 54% of patients with MHE.[17] In 23 patients with distal tibial or fibular osteochondromas, the tumors in 11 patients (48%) caused deformation of the distal tibia.[18] Takikawa and coworkers found in 33 patients (62 ankles) that severe ankle valgus occurred more often in males with exotoses in lateral distal tibia and medial distal fibula.[19]

When left untreated, the natural history of tibiotalar tilt is an increased likelihood of joint degeneration. In 38 adults with MHE and untreated ankle valgus, patients with radiographic signs of osteoarthritis had a significantly increased level of tibiotalar tilt. Forty percent reported activity limitations secondary to ankle pain.[20]

Surgery for ankle valgus includes supramalleolar osteotomy, medial tibial hemiepiphysiodesis, fibular-Achilles tenodesis, fibular lengthening, and distal tibiofibular synostosis.[5] The most appropriate operation may vary depending upon etiology. For example, in the treatment of isolated congenital pseudarthrosis of the fibula, distal fibular osteosynthesis produced better results than tibiofibular synotosis.[21] Several investigators have stated that simple exostosis excision does not improve alignment in MHE.[17,18,22] In nine patients who underwent tumor excision, medial tibial hemiepiphysiodesis with staples, or fibular lengthening procedures, only the five ankles that had hemiepiphysiodesis or fibular lengthening, or both, showed valgus correction.[22]

In patients with open growth plates, medial tibial hemiepiphysiodesis is a minimally invasive way to correct the tibiotalar angle. It has been described using a single 4.5 mm screw, staples, or surface epiphysiodesis.[3-6] The rate of ankle valgus correction after medial malleolar screw placement has been calculated to be 0.59° per month, and reversal of the growth arrest is possible after screw removal.[5] Despite the ability of hemiepiphysiodesis to improve the tibiotalar angle and the mechanical axis measurement, no appreciable change was found in fibular station or the amount of tibial epiphyseal wedging.[5,6]

The necessity of fibular lengthening in addition to tibial correction is unknown. Many investigators believe that ankle valgus is well treated by addressing the tibia alone.[3-6] Very few case series of fibular lengthening in children have been reported.[23] However, in patients with unstable ankle fractures, the distal fibula plays an important, secondary role in maintaining joint stability.[24] The abnormal growth biomechanics associated with having a short fibula, leading to distal tibial epiphyseal wedging and tibial tilt, can be addressed with a fibular lengthening procedure. Snearly and Peterson's case series included an 11-year-old girl treated only with acute fibular lengthening (17 mm) and Achilles lengthening. At follow-up of 29 months, the tibial angle had decreased by 14°.[22] Acute fibular lengthening through step-cut osteotomies or bone graft would circumvent the many problems and length of fixator time associated with distraction osteogenesis, though it would add new ones such as the potential for non-union and hardware retainment. Whether gradual or acute, fibular lengthening has the benefit of restoring more normal ankle anatomy, which will improve the biomechanics of stance and gait (talar stability and allocation of axial forces). In skeletally immature patients with remodeling potential, a normal force distribution will facilitate tibial correction. As in all gradual deformity correction, the timing should be shortly before bone maturity to decrease recurrence.

In conclusion, distal fibula lengthening is an accepted practice in cases of adult deformity[25] and may have supplemental benefits in children who can remodel tibial deformity. It should be performed concurrently with tibial correction and is indicated in cases of ankle deformity with fibular shortening. Normal distal fibular anatomy is known to have an important role in ankle stability and biomechanics. The decision to perform distal fibular lengthening should be made after all potential advantages, and disadvantages are fully discussed with the patient and family.

Disclosure Statement

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References

1. Dias LS. Valgus deformity of the ankle joint: pathogenesis of fibular shortening. J Pediatr Orthop. 1985 Mar-Apr;5(2):176-80.
2. Takikawa K, Haga N, Tanaka H, Okada K. Characteristic factors of ankle valgus with multiple cartilaginous exostoses. J Pediatr Orthop. 2008 Oct-Nov;28(7):761-5.
3. Beals RK, Shea M. Correlation of chronological age and bone age with the correction of ankle valgus by surface epiphysiodesis of the distal medial tibial physis. J Pediatr Orthop B. 2005 Nov;14(6):436-8.
4. Burkus JK, Moore DW, Raycroft JF. Valgus deformity of the ankle in myelodysplastic patients. Correction by stapling of the medial part of the distal tibial physis. J Bone Joint Surg Am. 1983 Oct;65(8):1157-62.
5. Davids JR, Valadie AL, Ferguson RL, et al. Surgical management of ankle valgus in children: use of a transphyseal medial malleolar screw. J Pediatr Orthop. 1997 Jan-Feb;17(1):3-8.
6. Stevens PM, Belle RM. Screw epiphysiodesis for ankle valgus. J Pediatr Orthop. 1997 Jan-Feb;17(1):9-12.
7. Lambert KL. The weight-bearing function of the fibula. A strain gauge study. J Bone Joint Surg Am. 1971 Apr;53(3):507-13.
8. Malhotra D, Puri R, Owen R. Valgus deformity of the ankle in children with spina bifida aperta. J Bone Joint Surg Br. 1984 May;66(3):381-5.
9. Frick SL, Shoemaker S, Mubarak SJ. Altered fibular growth patterns after tibiofibular synostosis in children. J Bone Joint Surg Am. 2001 Feb;83-A(2):247-54.
10. Hsu LC, Yau AC, O'Brien JP, et al. Valgus deformity of the ankle resulting from fibular resection for a graft in subtalar fusion in children. J Bone Joint Surg Am. 1972 Apr;54(3):585-94.

11. Makin M. Tibio-fibular relationship in paralysed limbs. J Bone Joint Surg Br. 1965 Aug;47:500-6.
12. Pritchett JW. Growth and growth prediction of the fibula. Clin Orthop Relat Res. 1997 Jan;(334):251-6.
13. Beals RK, Skyhar M. Growth and development of the tibia, fibula, and ankle joint. Clin Orthop Relat Res. 1984 Jan-Feb;(182):289-92.
14. Wiltse LL. Valgus deformity of the ankle: a sequel to acquired or congenital abnormalities of the fibula. J Bone Joint Surg Am. 1972 Apr;54(3):595-606.
15. Shapiro F, Simon S, Glimcher MJ. Hereditary multiple exostoses. Anthropometric, roentgenographic, and clinical aspects. J Bone Joint Surg Am. 1979 Sep;61(6A):815-24.
16. Choi IH, Lipton GE, Mackenzie W, et al. Wedge-shaped distal tibial epiphysis in the pathogenesis of equinovalgus deformity of the foot and ankle in tibial lengthening for fibular hemimelia. J Pediatr Orthop. 2000 Jul-Aug;20(4):428-36.
17. Pierz KA, Stieber JR, Kusumi K, et al. Hereditary multiple exostoses: one center's experience and review of etiology. Clin Orthop Relat Res. 2002 Aug;(401):49-59.
18. Chin KR, Kharrazi FD, Miller BS, et al. Osteochondromas of the distal aspect of the tibia or fibula. Natural history and treatment. J Bone Joint Surg Am. 2000 Sep;82(9):1269-78.
19. Taniguchi K. A practical classification system for multiple cartilaginous exostosis in children. J Pediatr Orthop. 1995 Sep-Oct;15(5):585-91.
20. Noonan KJ, Feinberg JR, Levenda A, et al. Natural history of multiple hereditary osteochondromatosis of the lower extremity and ankle. J Pediatr Orthop. 2002 Jan-Feb;22(1):120-4.
21. Martus JE, Johnston CE 2nd. Isolated congenital pseudoarthrosis of the fibula: a comparison of fibular osteosynthesis with distal tibiofibular synostosis. J Pediatr Orthop. 2008 Dec;28(8):825-30.
22. Snearly WN, Peterson HA. Management of ankle deformities in multiple hereditary osteochondromata. J Pediatr Orthop. 1989 Jul-Aug;9(4):427-32.
23. Rozbruch SR, DiPaola M, Blyakher A. Fibula lengthening using a modified Ilizarov method. Orthopedics. 2002 Nov;25(11):1241-4.
24. Chu A, Weiner L. Distal fibula malunions. J Am Acad Orthop Surg. 2009 Apr;17(4):220-30.
25. Roberts C, Sherman O, Bauer D, et al. Ankle reconstruction for malunion by fibular osteotomy and lengthening with direct control of the distal fragment: a report of three cases and review of the literature. Foot Ankle. 1992 Jan;13(1):7-13.