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The management of brachymetatarsia

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We treated 35 brachymetatarsal rays of 18 feet in 12 patients by one-stage lengthening with interpositional bone grafts or by gradual lengthening with callotasis combined with shortening of the adjacent metatarsals and phalanges. Definition of the two parabolas which connect the metatarsal heads and the tips of the toes, and recognition of three patterns of metatarsal length, were helpful guides in treatment. In total, 36 excisions of the phalanges and/or the metatarsals were undertaken. The mean shortening was 8 mm.

The radiological results were satisfactory. The mean values were as follows: one-stage lengthening, length gain, 1.3 cm; healing index, 1.3 months/cm; percentage increase, 30%; gradual lengthening, length gain, 2.0 cm; healing index, 2.0 months/cm; percentage increase, 50%.

Associated shortening of an adjacent bone can avoid the disadvantages of one-stage lengthening which may not achieve target length and can result in neurovascular complications. Reduction of the target length enables the surgeon to carry out one-stage instead of gradual lengthening. It also shortens the length of treatment in the group undergoing callotasis and improves cosmesis.

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Brachymetatarsia is diagnosed when one metatarsal ends 5 mm or more proximal to the parabolic arc.[1] It usually occurs in a single metatarsal, and the fourth ray is most frequently affected. The causes of brachymetatarsia may be congenital, post-traumatic, postsurgical, or linked to specific disease processes such as Down's syndrome, Apert's syndrome, Albright's osteodystrophy, sickle-cell anaemia, diastrophic dwarfism, and poliomyelitis.[1-3] Brachymetapody, when there are multiple abnormally short metatarsals, is a serious cosmetic problem.[1,4]

Despite potential complications, the surgical correction of brachymetatarsia tends to favour lengthening procedures. One-stage lengthening with an interpositional bone graft and gradual lengthening by callotasis are the two techniques most widely used.[1,2,5-8] In evaluating a patient with brachymetatarsia, numerous variables must be assessed, including the number of rays affected, the amount of lengthening required, the method of lengthening, the possibility of combined adjacent shortening, the sources of bone grafts, the options for internal and external fixation, soft-tissue contracture, and the tension of the skin.

Our aim was to evaluate the feasibility of combined lengthening and shortening of adjacent metatarsal and phalangeal bone using the parabola formed by the tips of the toes (Fig. 1) and three metatarsal types (Fig. 2) as guides.[9]

Patients and Methods

We studied 35 examples of brachymetatarsia in 18 feet (12 patients) which we had treated by either one-stage lengthening with an interpositional bone graft (five patients with a unilateral fourth ray and one with unilateral fourth and fifth ray brachymetatarsia), or gradual lengthening by callotasis (five patients with bilateral first and fourth ray brachymetatarsia). The study also included one patient with first, third, fourth, and fifth metatarsal involvement on both feet treated by second metatarsal and proximal phalangeal shortening. All patients were treated by combined adjacent metatarsal or phalangeal shortening (Table I). Because of the relatively young age of the patients in our study, the primary reason for surgical correction was cosmetic rather than functional. Before operation, four patients complained of problems with hygiene in the area of the recessed fourth web. One had a plantar keratosis beneath the fourth toe which gave mild discomfort, but her major concern was cosmetic. In one patient the problem was caused by injury, 11 had congenital conditions. There were nine females and three males. The mean period of follow-up was three years.

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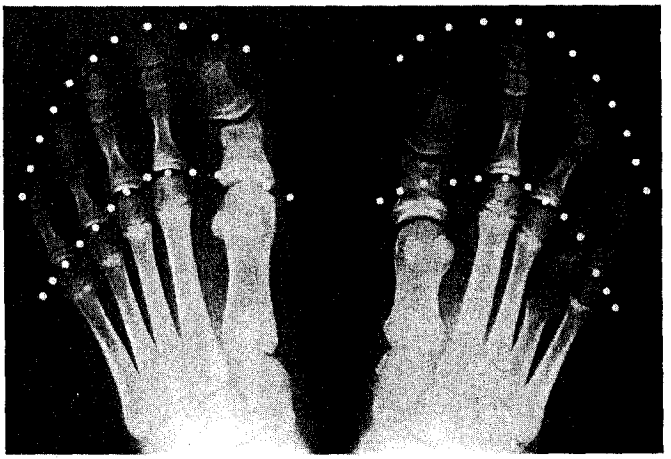

Fig. 1

AP radiograph of both feet. The right foot shows first- and fourth-ray brachymetatarsias and the left has a normal parabola.

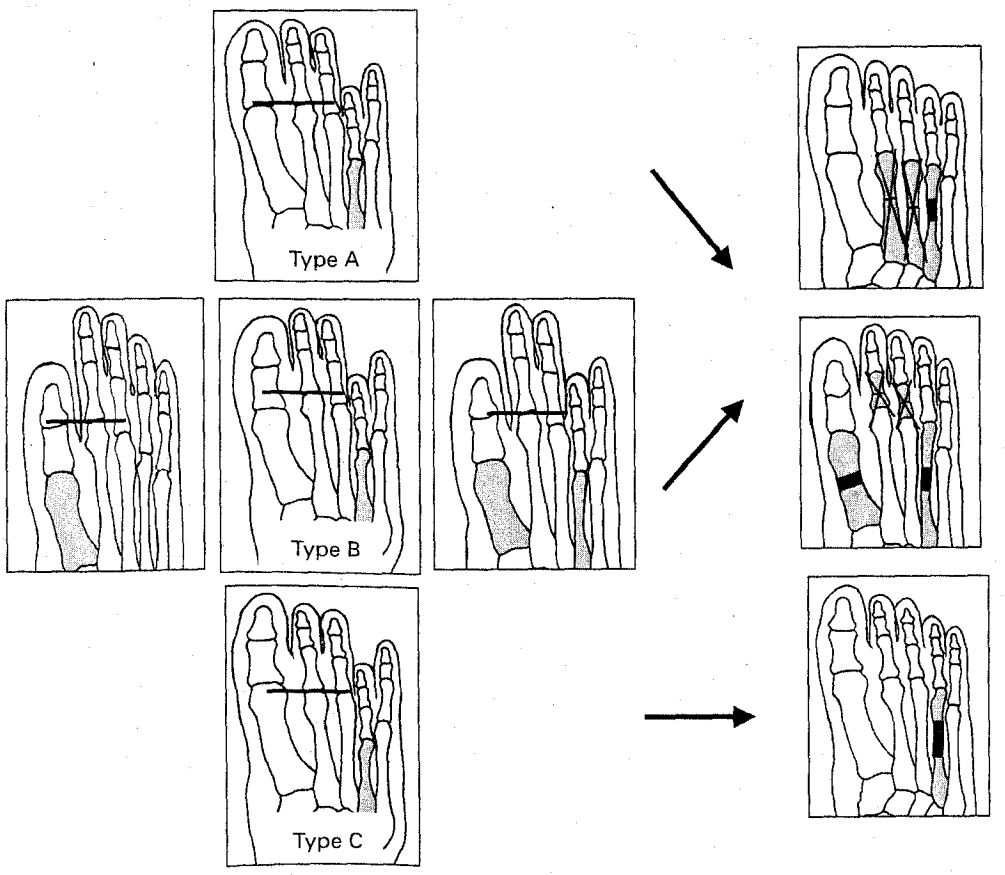

Fig. 2

Diagram of the three metatarsal types in a normal foot. The first metatarsal is equal (index plus-minus: type A), shorter (index minus: type B), or longer (index plus: type C) in length to the second. The shortening of the bones adjacent to the brachymetatarsia of the first, fourth, and combined first and fourth rays is indicated.

Table I. Details of treatment of 12 patients with brachymetatarsia who underwent adjacent phalangeal or metatarsal shortening

Case	Age (yr + mth)	Gender	Site	Gain in length (cm)	Target length (cm) using toe-tip (metatarsal head) parabola	Healing index (month/cm)	Increase (%)	Donor site*	Bone graft*	Shortening site (toe)	Amount of bone shortening (cm)	Expected decrease of treatment period	Complication*	Results (R/L foot)
One-stage lengthening (n = 7)														
1	12 + 1	M	L 4th	1.4	2.1 (1.9)	1.3	*30*	MT	Diaphysis	2nd, 3rd MT, 2nd PP	0.9, 0.9, 0.8	-		
			L 5th	1.2	2.1 (1.8)	1.3	*30*	MT	Diaphysis			-		/Excellent
2	12 + 5	F	L 4th	1.3	2.1 (1.9)	1.3	*20*	PP	Diaphysis	2nd, 3rd PP	0.8, 0.8	-		/Excellent
3	15 + 5	F	R 4th	1.2	2.2 (1.9)	1.2	*30*	PP	Diaphysis	2nd, 3rd MT	0.7, 0.7	-		Excellent/
4	16 + 3	M	R 4th	1.3	2.1 (1.8)	1.3	*30*	MT	Diaphysis	2nd MT‡‡, 5th PP	0.8, 0.8	-	Cartilage erosion (Kirschner wire)	Excellent/
5	24 + 11	M	L 4th	1.3	2.1 (2.0)	1.3	*40*	Ilium	MP joint	2nd PP	0.8	-	Painful pseudarthrosis	/Good
6	26 + 1	F	L 4th	1.4	2.3 (2.0)	1.4	*40*	MT	Diaphysis	2nd, 3rd MT	0.9, 0.9	-		/Excellent
	Mean			1.3	2.1 (1.9)	1.3	*30*				0.8			
Callotasis (n = 20)														
7	10 + 9	F	R/L 1st	2.1/2.2	2.6 (2.2)/2.7 (2.2)	2.1/1.6	*60/60*	-	-	Both 2nd, 3rd PP	0.8, 0.8	1.7/1.3		Good/
			R/L 4th	2.2/2.2	3.0 (2.8)/2.9 (2.8)	1.7/1.8	*50/50*	-	-	Both 2nd, 3rd PP		1.4/1.4		Excellent
8	12 + 1	F	R/L 1st	2.2/2.1	3.0 (2.7)/2.9 (2.7)	1.9/1.9	*60/40*	-	-	Both 2nd, 3rd PP	0.9, 0.9	1.7/1.7	Hallux valgus	Fair/
			R/L 4th	1.5/1.5	2.5 (2.4)/2.6 (2.4)	2.4/2.3	*40/50*	-	-	Both 2nd, 3rd PP		2.2/2.1		Good
9	13 + 9	F	R/L 1st	2.4/2.1	3.2 (2.9)/3.1 (2.7)	1.9/1.7	*60/70*	-	-	Both 2nd, 3rd PP	0.7, 0.7	1.3/1.2	1st MP joint stiffness	Good/
			R/L 4th	2.1/2.1	2.9 (2.8)/3.0 (2.7)	1.7/1.5	*40/40*	-	-			1.2/1.1		Fair
10	15 + 6	F	R/L 1st	2.1/2.2	2.9 (2.7)/2.9 (2.6)	1.9/2.0	*60/40*	-	-	Both 2nd, 3rd PP	0.8, 0.8	1.5/1.6		Good/
			R/L 4th	2.2/2.1	3.0 (2.8)/2.9 (2.8)	2.4/2.3	*50/50*	-	-			1.9/1.8		Excellent
11	19 + 8	F	R/L 1st	1.5/1.5	2.2 (2.0)/2.3 (2.0)	2.5/2.4	*30/40*	-	-	Both 2nd, 3rd PP	0.8, 0.8	2.0/1.9	Callotasis breakage	Excellent/
			R/L 4th	1.5/1.5	2.5 (2.4)/2.6 (2.4)	2.0/2.0	*50/30*	-	-			1.6/1.6		Good
	Mean		1st and 4th	2.0	2.8 (2.5)	2.0	*50*				0.8	1.6		
			1st	2.0	2.8 (2.4)	2.0	*50*					1.6		
			4th	1.9	2.8 (2.5)	2.0	*50*							
Shortening only (n = 8)														
12	12 + 0	F	L 1st, 3rd, 4th, 5th	-	1.8		-	-	-	2nd MT & PP	1.0, 0.8			Excellent/
			R 1st, 3rd, 4th, 5th	-	1.8		-	-	-	2nd MT & PP	1.0, 0.8			Excellent
	Mean				1.8						1.8			

*PP, proximal phalanx; MT, metatarsal; MP, metatarsophalangeal

Table II. Basic rules for shortening the adjacent bones for patients with brachymetatarsia

Brachymetatarsia	Increase (%)	Target length (cm)	Treatment options	Desirable postoperative metatarsal type
1st ray	*< 40*		Gradual lengthening	Type A or B can minimise metatarsophalangeal joint stiffness
	≥ 40		Adjacent bone shortening and gradual lengthening	
4th and other rays		L < 1.5	One-stage lengthening with bone graft (iliac bone)	
		L ≥ 1.5	Target length < 1.5 cm after adjacent bone shortening → one-stage lengthening with bone graft (iliac or excised bone)	Type C can reduce the percentage increase and target length
			Target length ≥ 1.5 cm after adjacent bone lengthening → gradual lengthening	

The clinical results were assessed as follows: excellent (improved cosmetic and functional results), good (improved cosmetic and unchanged functional results), and fair (improved cosmetic but poor functional results). Difficulty in walking on tiptoe or any limitation of daily activities was assessed as poor function.

Preoperative plan for bone shortening. We used an anteroposterior (AP) radiograph to determine the site for bone shortening after analysis of the relationship of the metatarsals and phalanges based on the curves of the two parabolas (Fig. 1). The toe-tip parabola is important for cosmetic improvement and the metatarsal head parabola for functional improvement. The metatarsal head has an important weight-bearing function during walking, especially at toe off. The three metatarsal types in a normal foot must be considered in the preoperative plan according to their length (Fig. 2).[9]

The basic concept of a preoperative plan for the bone shortening procedure is summarised in Table II. For example (Fig. 2), in first-ray brachymetatarsia, second and third metatarsal or proximal phalangeal shortening can reduce the target length and the percentage increase of the first metatarsal to 40% or less. Postoperatively, the metatarsal type B is preferable to type A or type C in order to reduce complications associated with excessive bone lengthening. In a fourth-ray brachymetatarsia, shortening the second and third metatarsals is possible in both metatarsal types A and B, thereby changing them into metatarsal type C after operation. In preoperative metatarsal type C, one-stage or gradual lengthening can be carried out without adjacent bone shortening because of the relationship of the short second metatarsal to the first in this type. In combined first- and fourth-ray brachymetatarsias, shortening of the second and third metatarsal or the proximal phalanx can reduce the amount of the target length and the percentage increase.

The same concept can be applied to bone shortening in other forms of brachymetatarsia. In a patient with a single long metatarsal and phalanx (case 12), shortening can be undertaken in both the metatarsal and the proximal phalanx. In certain patients with a single long metatarsal and a concomitant short proximal phalanx, adjacent phalangeal shortening will be required after metatarsal shortening to establish a smooth parabola of the tips of the toes.

Methods of lengthening. In the one-stage lengthening procedure, the osteotomies were gradually distracted with a small bone spreader while the ray was fixed with an intramedullary Kirschner wire (0.16 cm) to decrease surrounding soft-tissue tension. After achieving a satisfactory metatarsal parabola, one or two temporary transverse Kirschner wires were passed through the distal portion of the distracted metatarsal to the adjacent metatarsals. They stabilised the space for the bone graft and plate fixation. In gradual lengthening by callotasis, all patients had lengthening of the extensor tendon by Z-plasty. Two distal and proximal mini-half pins were inserted into the distal and proximal metaphysis, the cuneiform, or the cuboid. Distraction proceeded at the usual rate of 0.5 or 0.75 mm/day in two or three steps after seven to ten days.

We undertook gradual lengthening in all first-ray brachymetatarsias. In other rays, the selection of the method of lengthening was based on a target length determined by tracing an AP radiograph of the foot and carrying out the several possible adjacent bone-shortening procedures on this model (Table II). We performed a one-stage lengthening with an interpositional bone graft in a patient with fourth brachymetatarsia when the target length after adjacent bone shortening was less than 15 mm. We used resected bone from the adjacent metatarsal, the proximal phalanx, or bicortical iliac bone for a bone graft in the acutely distracted gap in the middle of the metatarsal. Gradual lengthening by callotasis was chosen for patients in whom the target length, even after adjacent bone shortening, was 15 mm or more.

Other procedures. The superfluous skin after phalangeal shortening can be remodelled without cosmetic complications. A wedge-shaped triangular excision at the level of the interdigital web area can provide cosmetic improvement.

and hallux valgus, which can occur when the increase in length is more than 40%.[12,13] These complications were encountered even when using a soft-tissue release and/or fixation by Kirschner wires through the metatarsophalangeal joint during distraction.

In our study (Table II), the percentage increase of 40% is a reliable guide to avoid complications such as metatarsophalangeal joint stiffness in first-ray brachymetatarsia. The tendency for joint stiffness was evident around the percentage increase of 50%. Hallux valgus occurred in patients with an increase of more than 50%. In other rays, the use of target length, before and after adjacent bone shortening, was a convenient guide for evaluating the need for shortening and the amount required, as well as in deciding which method of lengthening should be applied. A target length of more than 15 mm may require adjacent bone shortening. One-stage lengthening could be undertaken safely when the target length was less than 15 mm. Gradual lengthening by callotasis was required when the target length was 15 mm or more, even after shortening of bone.

We recommend shortening of an adjacent bone in the treatment of brachymetatarsia in order to reduce the period of treatment and to avoid complications. The amount of lengthening should be limited to less than 50%, preferably 40%, of the original length of the bone in any digit, especially the first because of its functional importance. We believe that less lengthening provides a better functional outcome.

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