

Brachymetatarsia

One-stage Versus Two-Stage Procedures



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KEYWORDS

• Brachymetatarsia • Metatarsal lengthening • Metatarsalgia • Bone lengthening

KEY POINTS

- Brachymetatarsia is a deformity that usually is cosmetically displeasing and can also become a cause of pain.
- One-stage lengthening of a short metatarsal with or without autogenous or homogeneous bone grafting is a procedure that only requires a single main procedure.
- Two-stage surgery with external fixation (distraction osteogenesis) is preferred for lengthening more than 1.5 cm.
- Single-stage lengthening with a bone graft is associated with fewer complications and faster healing times than callus distraction procedures.
- Combined procedures with gradual lengthening might reduce complications.

ANATOMIC FACTORS

The metatarsal heads are aligned in a parabolic arch in a normal foot, as described by Lelievre.^{1–8} This alignment allows the 5 metatarsals to be at the same distance from the ground during weight bearing. In cases of a metatarsal shortening, the transverse metatarsal ligament is stretched, potentially altering the contact of the forefoot with the floor and possibly causing excessive pressure in the forefoot.⁹

For diagnostic purposes, brachymetatarsia is a shortening of the metatarsal superior to 5 mm. This measurement is obtained through weight-bearing radiographs of both feet. The relative length of each metatarsal can be determined by Maestro

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Fig. 1. Maestro criteria for measurement of the metatarsal length; there is a geometric progression of the lesser metatarsals by a factor of 2. Vertical red line is mid-diaphysal to the second metatarsal. Horizontal redline is perpendicular to the vertical red line and passes through the lateral sesamoid. Blue arrows show normal progression and yellow arrow a shortening of the fourth metatarsal.

criteria, with an expected decline in geometric progression of the lesser metatarsals by a factor of 2 (**Fig. 1**).¹⁰

CLINICAL PRESENTATION

Because this deformity can coexist with other skeletal and systemic abnormalities, a thorough patient physical examination is necessary. For this reason, all these patients should receive a careful multidisciplinary approach, especially when the deformity is present in patient committed with other syndromes.

Even though pain is a possible symptom, the most usual patient concern involves the cosmetic appearance the foot. In most cases, the feet are pain free and the major worry is about the appearance of the foot.⁹

However, there may be a dorsally displaced corresponding toe, which can produce callosities and make the fitting of shoes difficult. Transfer metatarsalgia is also a possible symptom, and, in long-standing deformities, further digital deviation can occur and even lead to formation of a bunion deformity (**Fig. 2**).¹¹

In all instances, the Kelikian push-up test should be performed to assess whether the metatarsal-phalangeal joint is flexible and reducible (**Fig. 3**). Its importance is that nonreducible joints need a complete capsular release, sometimes associated with extensor tendon lengthening, before any bone surgery, which implies more invasive surgery and worse foot function after treatment.¹²

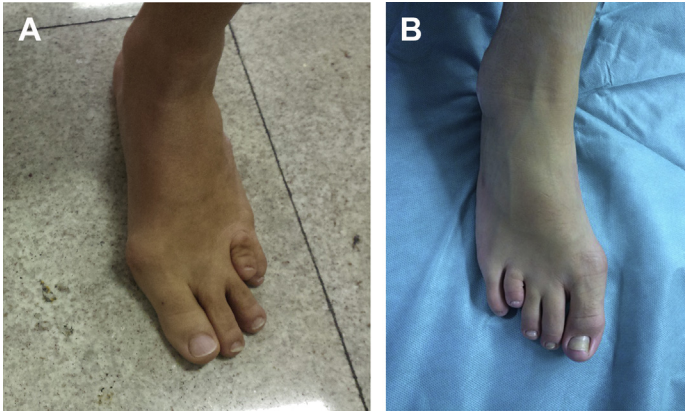


Fig. 2. (A) Dorsally displaced fourth digit. (B) Long-standing lateral deviation of the toes led to a bunion formation.

NONOPERATIVE TREATMENT

In patients with pain or callosities, the first option of treatment should embrace conservative measures such as medical insoles, orthotics, and wider toe-box shoes. Only when nonoperative measures fail to relieve pain or the main complaint is aesthetic should surgery be indicated.¹³

SURGICAL TREATMENT

Multiple acute and gradual lengthening surgical techniques have been described for correction of this type of foot deformity. All techniques try to ensure a better appearance, facilitate shoeing, or solve possible transfer metatarsalgia^{11,12}(Fig. 4).

One-Stage Procedures

One-stage procedures are those that realize an acute lengthening of the metatarsal. In 1969, McGlamry and Cooper¹⁴ first described the lengthening of a short metatarsal in

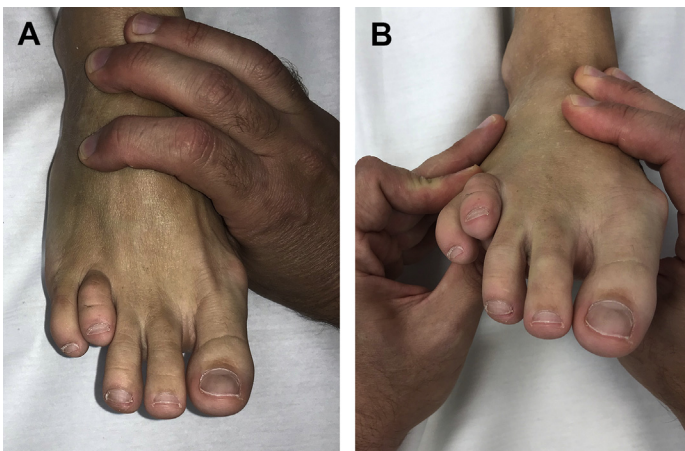


Fig. 3. (A) Dorsally displaced fourth digit. (B) The Kelikian push-up test showing a nonreducible joint.

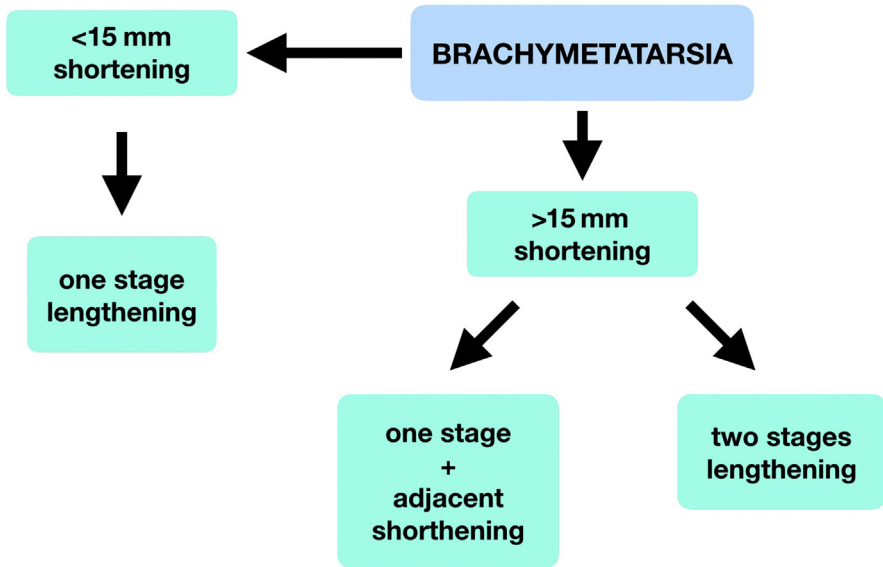


Fig. 4. Algorithm of surgical treatment of brachymetatarsia.

a single surgery using bone graft from the calcaneus to fill the gap obtained after the osteotomy site was acutely spread apart.

Since then, several acute lengthening techniques have been described in procedures using various sites of autogenous bone grafts, allografts, synthetic materials, sliding osteotomies, and many different internal fixation materials.¹³

The main disadvantage of these type of procedures is the limitation of the capacity to lengthen the bone. Acute lengthening has a greater risk when more than 15 mm of gain is attempted, because a large neurovascular stretch done at once might compromise the viability of the toe because of vasospasm. In addition, the soft tissue is placed at great tension, predisposing the patient to metatarsophalangeal dislocations or later joint rigidity.^{13,15–17}

When the amount of lengthening is not feasible by interposition bone graft surgery, the usual alternative is to consider associated shortening of adjacent bones. In many instances, by realizing the shortening of adjacent metatarsals and phalanges, the surgeon is able to achieve the targeted parabola, without the need of an external fixator for long periods, making the whole process more comfortable and faster for the patient and reducing associated risks of 2-stage surgery. This benefit is especially useful when brachymetatarsia affects the first metatarsal, because surgeons can easily diminish the lateral rays, needing a smaller 1-stage procedure.¹⁷

There is no exact amount of shortening recommended in these cases. The amount should be enough that the lengthening needed is less than the limit of a 1 stage procedure (1.5 cm). Extreme shortening must also be done carefully so that vascular compromise is not an issue.^{9,13,17}

Sliding osteotomies

In 1984, Marcinko and colleagues¹⁸ described a Z-shaped sliding osteotomy to treat posttraumatic shortening. The main advantage of this technique is the reduced necessity to use some form of bone graft, thus reducing donor site morbidity and tissue

scaring, which is of great value because the main purpose of the surgery is cosmetic improvement.¹⁹

When some sort of graft is needed, adjacent metatarsal bone is usually the most favorable donor site. However, sliding osteotomies have very few complications and good functional and cosmetic results²⁰ (Fig. 5).

The literature lacks large studies showing 1-stage lengthening with sliding osteotomies. Most work involves case reports with no complications and good functionality; none show large gains.^{18,21–23}

Singh and Dudkiewicz²⁴ described a prospective cohort series of sliding osteotomies to treat metatarsalgia resulting from iatrogenic first metatarsal shortening. They operated on 16 patients with transfer metatarsalgia after shortening from a Wilson osteotomy to treat hallux valgus. Good pain relief was shown when more than 8 mm of lengthening was obtained.

Bone grafting

Various donor sites for grafts (tibia, iliac bone crest, calcaneus, autologous metatarsal, and so forth) have been reported in this modality of treatment (Fig. 6).^{15,25,26} All have shown the same limitations: diminished capacity to lengthen the metatarsal and donor site morbidity, for which a promising alternative is the use of homologous bone.¹³

In a systematic review realized by Jones and colleagues,²⁷ analyzing 349 feet that underwent acute lengthening with bone graft, the mean size gain was 13.3 mm. There was a faster healing index (centimeters per month) and fewer complications than in callus distraction surgery.

Giannini and colleagues¹³ used homologous metatarsal bone to graft and acutely lengthened 41 feet. Radiographically, the mean gain was 13 mm, with a 23% increase in size. Overall, no complications were present and full bone union was achieved in every patient.

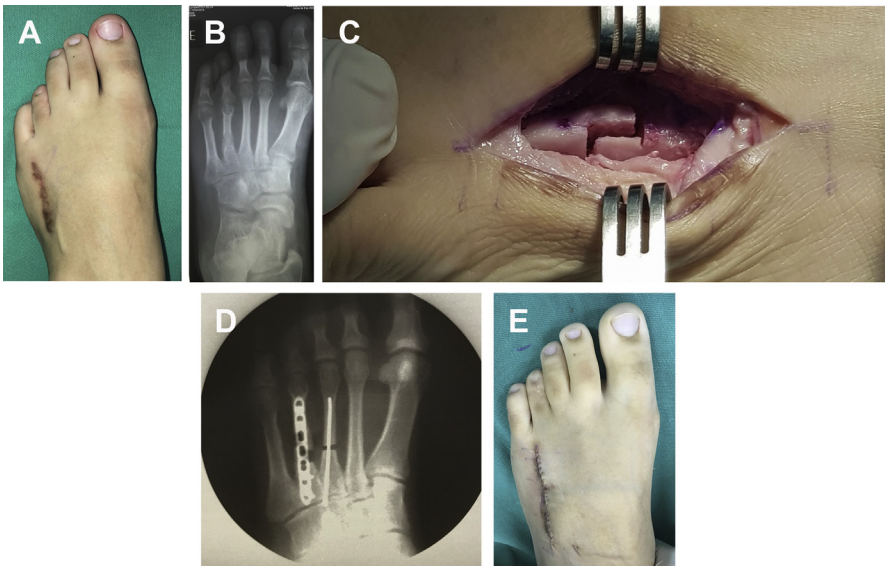


Fig. 5. (A) Fourth metatarsal brachymetatarsia with shortening after a failed attempt at gradual lengthening. (B) Preoperative radiography. (C) Step sliding osteotomy. (D) Plate/screw fixation of the lengthening and shortening of the third metatarsal. (E) Postoperative clinical result.



Fig. 6. (A) Shortening of the third metatarsal, with consequent pain under second ray and claw toe. (B) Preoperative radiograph. (C) Lengthening trough bone spreader and (D) clinical result.

In every acute lengthening, concern about soft tissues is needed to avoid joints dislocations, neuromuscular damage, and to optimize stretching capacity. Usually a Z-plasty to elongate extensor tendons, freeing the interosseous muscles, or a flexor tendon tenotomy is undertaken.^{9,13,15}

Complications

Besides a possible undercorrection, neurovascular compromise caused by acute lengthening is the main concern in 1-stage procedures; rapid stretching of the blood

vessels might lead to vasospasm.²⁶ However, recent data show that, with the proper freeing of soft tissue and respecting the limit of 15 mm of total gain, this is a rare occurrence.^{13,17}

Single-stage lengthening with bone grafting has shown a 19.48% overall rate of complications. Some loss of the range of motion of the metatarsophalangeal joint is the most common and limiting concern. Most studies also report, with less frequency, possible loss of fixation, bone graft resorption, bone deviation, joint subluxation, and graft donor site morbidity.²⁷

Two-Stage Procedure

Two-stage procedures involve some sort of osteotomy associated with concomitant bone distraction. Through callotasis, new bone is formed and the short metatarsal gains the desired length after the surgical procedure is complete.^{9,28} This technique usually is used when there is a need to overcome the limitations of 1-stage surgery, in which no more than 15 mm of lengthening is desired.¹⁷

After the osteotomy, the distraction callotasis is usually done with an external fixator at a rate of less than 1 mm/d, allowing bone growth and soft tissues to gradually accommodate, thus reducing the risk of vasospasm caused by acute stretch of the neurovascular bundle.^{29,30}

Surgical technique

Most bone distraction surgery is done with a unilateral external fixator to achieve careful placement of 2 pins in the proximal segment and another 2 in the distal segment.¹² To prevent plantar flexion of the lengthened metatarsal, the pins should be placed in a manner so that distraction is done parallel to the ground and not necessarily respecting the anatomic axis of the bone. This point is especially important in the first metatarsal, where a plantar flexion might cause an undesired varus compensatory deformity of the hind foot.³¹

Osteotomy is realized through a small dorsal incision with careful extensor tendon protection. Afterward, after a latency period of about a week (no more than 10 days to avoid premature consolidation), gradual distraction is started⁹ (**Fig. 7**). The same surgery can be executed percutaneously with a bone burr, theoretically preserving more soft tissue and causing better cosmetics.³²

Pitfalls

In contrast with long bone lengthening, distraction should be done at a slower rate in a metatarsal. When a distraction rate of 0.75 mm/d is undertaken, even though good bone formation is expected, this might be too fast for tendon stretching and can lead to joint rigidity or dislocations.³³ A distraction rate of 0.25 mm twice a day is optimal for soft tissue elongation and bone formation.³⁴

To prevent joint dislocation, besides joint stretching and tendon lengthening, surgeons can also fixate the metatarsal-phalangeal joint with a Kirschner wire that is left in the patient until the bone distraction phase is complete.³⁵ Another option is extending the fixation beyond the metatarsal-phalangeal joint and not invading it, by placing Schanz pins into the proximal phalanx throughout the process.¹¹

Complications

Two-stage procedures have a high risk of complications, with more than 50% of the surgeries being involved with some sort of problem. Major complications such as metatarsal malalignment, poor bone formation and joint dislocations occur in about 12.62% of the cases (**Fig. 8**). Postoperative joint rigidity has a 17% rate of occurrence

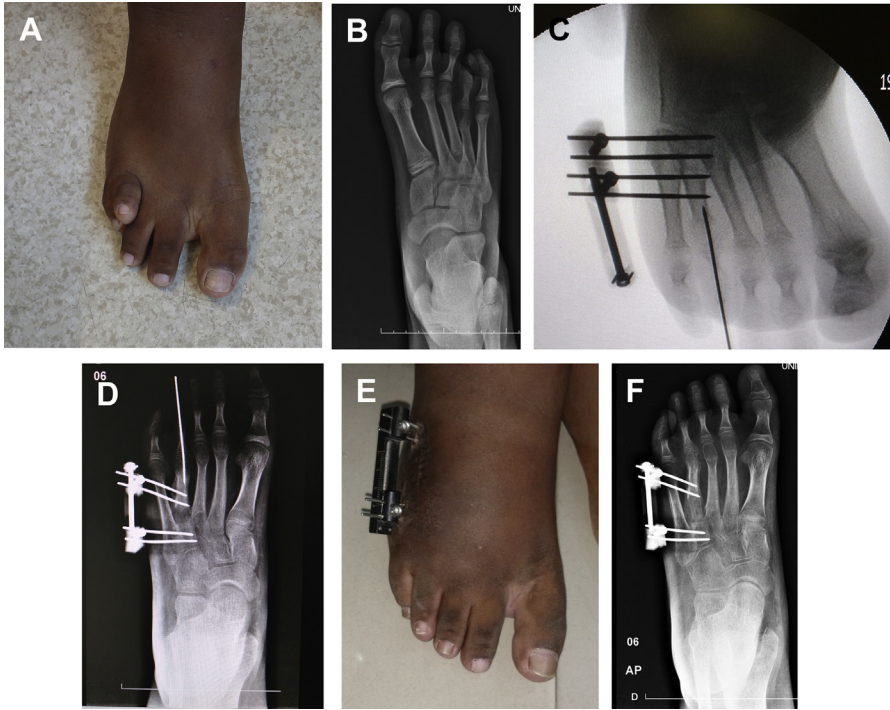


Fig. 7. (A) Fourth metatarsal shortening and (B) preoperative radiograph. (C) External fixator placement and osteotomy. (D) Lengthening of the fourth metatarsal. (E) Postoperative clinical and (F) radiological final result.

and 8% rate of pin tract infection.²⁷ In 1 series, in which the mean amount of gain was 30%, all patients showed some loss in range of motion (120° before and 57° after surgery on average).³⁶

Most studies show that, by respecting a limit of lengthening of no more than 40% of the metatarsal original size, most complications are avoided.^{9,31,36} This finding is especially seen when subluxation is in question, with the joint being excessively stressed because of overlengthening.^{15,33}

Future Directions

As the techniques of distraction osteogenesis for bone lengthening have evolved, attempts have been made to improve the patients' experiences by reducing the time of external fixation usage. A promising alternative is plating the area after the desired length is achieved, decreasing the fixator time for the patient and guaranteeing a faster postoperative rehabilitation.³⁷ However, reports on this topic are limited, and only small series have been undertaken in diverse anatomic locations and in patients of different ages.³⁸

Another promising technique was described by Woo and colleagues,³⁹ who realized an anatomic reconstruction of fourth brachymetatarsia with 1-stage iliac bone and cartilage cap grafting. Instead of a mid-diaphysis osteotomy, the dissection and spreading was taken into the metatarsal-phalangeal joint space, reconstructing the joint and gaining length. In theory, this has the advantage that, by dissection through the joint space, it is possible to achieve a more effective release.

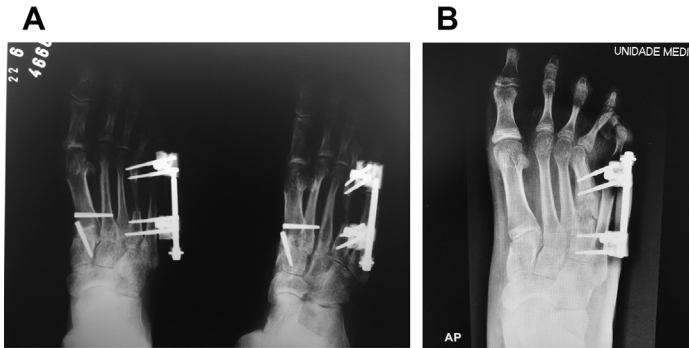


Fig. 8. (A) Poor bone formation in a gradual lengthening of the fourth metatarsal. (B) Bone malalignment and metatarsal-phalangeal joint dislocation in a fourth metatarsal gradual lengthening.

With a capsulotomy and the plantar plate incision, there is no need for a wider subperiosteal dissection, avoiding a decrease in the circulation and thus permitting wider bone spreading.

In 56 operated feet, they showed a 22.9-mm gain on average, with only 1 case of nonunion and no neurovascular complications. Thirteen patients complained of loss of range of motion but did not require secondary surgery.

Authors' Experience

The authors have a case series of 12 operated feet, with lengthening of 13 metatarsals, in which only 1 patient had a 1-stage procedure done because of having less than 1.5 cm of shortening. The remaining patients underwent gradual lengthening with monolateral external fixator.

Mostly there was a very low incidence of complication; mainly superficial pin tract infection solved with topical or oral antibiotics. In 1 case of lengthening of 2 adjacent metatarsals, the foot developed acute compartment syndrome during bone stretching and decompression was necessary. There was also a case of delayed bone formation, and since then we have tried not to exceed a bone distraction rate of 0.75 mm/d.

Whenever possible (no active pin tract infection), the authors use plating to shorten the fixator usage period.

SUMMARY

Brachymetatarsia is a rare deformity with controversial clinical presentation. Because most patients seek medical attention because of the cosmetic appearance of the foot, it is hard to decide when and how to intervene. Smaller and less aggressive procedures (most 1-stage surgeries) have a limited capacity to gain the total desired length and involves the risk of donor site morbidity. However, gradual distraction makes lengthening of more than 1.5 cm possible, but requires the use of an external fixator and the procedures cause many complications. In all instances, adjacent metatarsal shortening should be combined to diminish exposure to excessive lengthening, selecting 1-stage or 2-stage surgeries based on each patient's deformities, concerns, and clinical needs.

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