Correction of Brachymetatarsia with Transpositional Metatarsal Osteotomies

The authors present a case history that illustrates their surgical procedure to correct congenital hypoplastic metatarsals. The literature is reviewed, and surgical alternatives are discussed. Treatment consisted of transpositional osteotomies performed between the fourth and fifth metatarsals with good results.

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Brachymetatarsia is an aberrent condition in which a metatarsal, usually the fourth, is short and hypoplastic. Most often congenital, this abnormality usually results in a contracted and cosmetically unacceptable fourth digit. The condition most often is seen bilaterally and affects females to males in a ratio of 25:1. The deformity is usually not seen at birth, but becomes evident when the child is between 4 and 15 years old (1). It can be associated concurrently with short metacarpals (brachymetacarpalia) (2).

Although the underlying etiology is unknown, Kite (3) believes that "shortening is caused by premature fusion of the epiphyseal line at the distal end of the metatarsal." Although a hereditary pattern has been observed in some families, the condition can also evolve through iatrogenic or traumatic means (4).

Hypoplastic metatarsals have been found in conjunction with some pathologic disorders, such as pseudohypoparathyroidism, pseudo-pseudohypoparathyroidism, Turner's syndrome, Albright's hereditary osteodystrophy, Down's syndrome and others. Early union of epiphyses from accumulation of x-ray exposures had been reported, as well as contributing factors from chromsomal abnormalities such as trisomy 21 (5). The signs and symptoms will vary with the patient. In a young female, the chief complaint is usually cosmetic, as the patient becomes self-conscious when her foot is exposed while walking barefooted or when wearing open-toed shoes.

Metatarsal shortening can cause the involved toe to overlap the adjacent toe. This can result in contracture of the extensor tendons, flexor tendons, and overlying skin. The contracture or overlapping may cause irritation with pain and discomfort when wearing a closed-toe shoe. The short metatarsal can also cause excessive loading of adjacent metatarsals (three and five) with resultant plantar keratoses (4, 6). Although the diagnosis of a short metatarsal is clinically apparent, the final diagnosis is made on the basis of radiographic findings.

Review of Treatment

Management of brachymetatarsia can be divided into conservative and surgical approaches. Conservative treatment, although not advocated, consists of padding and accomodative devices in the shoe. However, this will not relieve the cosmetic or underlying anatomic problems.

Surgical management is the treatment of choice, and, over the years, many different techniques have been developed. Kelikian et al (7) proposed syndactylization of the fourth and fifth digits to accomplish straightening of the contracted toe, but this did little to provide functional improvement or cosmetic relief.

McGlamry and Cooper (4) incorporated an inlaid calcaneal bone graft at midshaft of the metatarsal, and used Kirschner wire for fixation. This procedure was later modified by Scheiner and Chamas (8), who added a Z-plasty skin incision, and Jimenez (9), who used an autogenous tibial graft. Kaplan and Kaplan (10) obtained autogenous grafts from the proximal diaphysis of an adjacent metatarsal and transplanted it to the affected metatarsal using monofilament wire fixation in a three-hole technique. Urano and Kobayashi (1) used variations of Jinnaka's interpositional technique of a spindle-shaped bone graft to fuse the metatarsophalangeal complex in an attempt to lengthen the metatarsal. Biggs *et al.* (11) proposed using an autogenous bone graft from the distal diaphysis of an adjacent metatarsal and achieved fixation with Kirschner wire.

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et al. (12) interposed a Calnan-Nicole implant to as a spacer in the metatarsophalangeal joint. Mero (13) offered another surgical technique by intering the fourth and fifth metatarsal heads (transected the anatomical necks) and fixated them with Kirschr wire, while Marcinko *et al.* (14) used a modification the Giannestras step-down procedure to elongate a ost-traumatic brachymetatarsia. More recently, Walr and Pressman (15) reported the use of the minixternal fixation device to stretch the soft tissue structures and allow lengthening of a short metatarsal.

Case Review

A 22-year-old white female presented to St. Anne's Hospital-West with the chief complaint of a dorsally contracted fourth toe on her right foot. The shortened toe became evident when the patient was 7 years old. The toe had become more dorsally contracted and was now a source of constant irritation in enclosed shoes, catching on her socks. She also related a feeling of unsteadiness when placing her weight on the ball of her right foot. Secondarily, the patient was concerned with the cosmetic appearance of her shortened/contracted toe and a painful bump on the dorsomedial aspect of her right foot (Fig. 1). Approximately 2 years earlier, the patient had a previous consultation with an orthopedic surgeon who recommended surgical correction of her problem by syndactylization of her fourth and fifth toes.

Physical examination of the right foot revealed a dorsally contracted fourth digit that was floppy. Plantarly, the third and fifth metatarsal heads were prominent, as exhibited by diffuse submetatarsal tylomas and a mild skin cleft beneath the fourth metatarsal head. The third and fifth toes slightly overlapped the fourth digit. A hallux abducto valgus deformity was present with pain-free range of motion at the first metatarsophalangeal joint (MPJ). Radiographically, the fourth metatarsal, as well as the proximal phalanx, appeared shortened, altering the appearance of a normal metatarsal parabola (Fig. 2). Additionally, adaptive changes were noted at the head of the fourth metatarsal and base of the proximal phalanx, as evidenced by decreased bone density on either side of the MPJ, indicating pathologic changes in the joint. The remainder of the

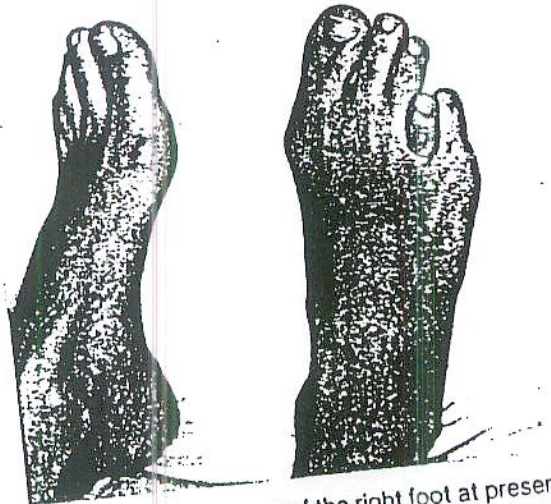

Figure 1. Clinical appearance of the right foot at presentation, demonstrating shortened (brachymetatarsia) fourth digit.

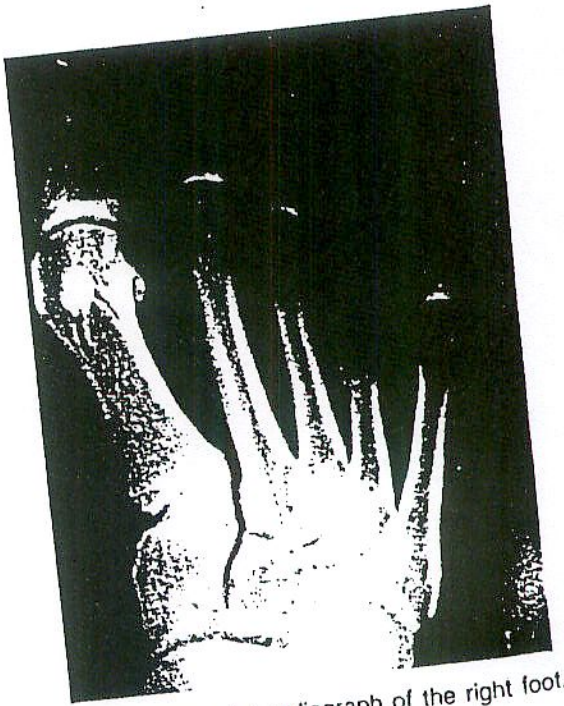

Figure 2. Anteroposterior radiograph of the right foot, demonstrating shortened fourth metatarsal.

medical history and physical examination was normal for the age and sex of the patient. Preoperative laboratory values were normal, and the patient was found to be a satisfactory surgical candidate.

Discussion

Radiographically, adaptive changes were evident at the fourth MPJ, both in the proximal and distal aspects of the joint. Upon surgical dissection, it was noted that the fourth metatarsal head and base of the proximal phalanx appeared avascular, as indicated by a bluish color to the bone. The articular cartilage, although present, was eroded dorsally and presented as being soft and discolored. These changes could be attributed to a lack of normal weightbearing and dorsal subluxatory pressure.

The increased plantar declination of a short or hypoplastic metatarsal, in an attempt to maintain weightbearing, has the same effect on the toes as a plantarflexed deformity of a metatarsal. The proximal phalanx is forced into a dorsiflexed position at the MPJ, and the joint structures adapt to that position. As a result of the lack of normal joint function at the fourth MPJ, compressive forces were diminished at the articular interface. This decrease in compressive force is manifested clinically by a decreased concentration of trabeculations and by dimineralization of bone. This finding was substantiated on x-ray by areas of radiodensity in the fourth metatarsal head and base of the proximal phalanx.

It had become obvious by the plantar metatarsal three and five tylomas, and the skin cleft under the fourth metatarsal, that there was little to no weightbearing at the fourth metatarsal head. Studies performed by Eberhart *et al.* (16) at the University of California, show that vertical ground reactive forces reach two peaks of intensity (exceeding the force of body weight) during the stance phase of gait. First, at the end of the contact period during which the body weight is supported on one foot, and again during early propulsion.

After heel lift, the metatarsals unload from lateral to medial. With little to no weightbearing under the fourth metatarsal head in a foot with brachymetatarsia, a "tripod effect" is created. Loss of stability under the fourth metatarsal transfers a greater propulsive load to the third and fifth metatarsals, and they must bear an excessive load throughout propulsion. Shear and vertical forces of up to 125% of body weight cannot be dispersed, and the forefoot becomes traumatized in those areas bearing an inordinate share of the load, manifesting itself in hyperkeratoses and painful metatarsalgia.

Accordingly, the transpositional osteotomy used in this case presentation was specifically designed to:

1. Lengthen the fourth metatarsal while modifying the plantar declination angle, and
2. Maintain an even weightbearing parabola without shortening the fifth metatarsal.

Giving consideration to the fact that the fourth MPJ was not a healthy joint, it was decided to transpositionalize the fifth metatarsal shaft and head in an attempt to restore function at the joint; specifically weightbearing and stability for the fourth toe. Although the fourth metatarsal head, when transpositionalized to the fifth ray was not as readily functional at the MPJ, it was not as critical for the fifth toe, as that toe is not as active in ground purchase at propulsion as are the other lesser toes.

The osteotomy sites were preplanned in design through the use of templates, to optimize bone-to-bone contact by maintaining at least a 50% overlap of bone surfaces when the desired lengthening was achieved. It is important to note that although it was necessary to elongate the periosteal envelope of both metatarsals at their plantar aspect in order to encompass the lengthened osteotomies, the envelopes were meticulously maintained in order to decrease postoperative periosteal proliferation that could possibly lead to bony bridging. By transpositionalizing portions of the fourth and fifth metatarsal shafts, each segment also acted as a complete autogenous bone graft, instead of the allografts that had been described previously in a number of surgical approaches. Obvious advantages are that with the autogenous grafts, viable cells are available at the graft site in order to set the stage for osteogenesis, along with a framework to maintain optimum vascularity in an area that already had a compromised neurovascular status. Both of these factors established a favorable environment to minimize the potential for a nonunion at the graft site.

The hypoplastic fourth metatarsal was nonweightbearing, despite having an increased angle of plantar declination. By interposing the fourth and fifth distal metatarsal segments, and adjusting the capital fragments in the sagittal plane, it was possible to restore a more normal metatarsal declination to the fourth metatarsal and assure that both the fourth and fifth metatarsal heads would be weightbearing on the same transverse plane as the other two lesser metatarsal heads. The first metatarsal already had been accommodated by its transposition during the procedure to correct the hallux abducto valgus deformity.

Many of the previously described surgical procedures attempted to recreate a metatarsal parabola. However, by using a segment of the fifth metatarsal to elongate the fourth ray, the fifth ray was shortened, and the

created parabola often was severely affected at the lateral column. If an allograft was used to lengthen the fourth metatarsal, enough length was never achieved to make the parabola functional. By interposing the fourth and fifth metatarsal shafts, in this case, it was possible to create a totally new parabola that was more nearly normal rather than to try and make the fourth and fifth metatarsal heads conform to an already pathological parabola.

The chief disadvantage of this selected procedure was potential morbidity, due to the necessity for fixation of both metatarsals, and the resultant possibility of elevatus occurring in two metatarsals. Additionally, both metatarsal segments were handled out of the surgical site, which could have increased the chances for infection. However, in these authors' opinion, the previously discussed advantages outweighed the disadvantages in comparison to the other surgical alternatives.

Surgical Procedure

The selected procedures for the right foot were planned as follows: Silver bunionectomy/Hohmann osteotomy using 2.7-mm cortical screw fixation to correct the hallux abducto valgus/metatarsus primus elevatus deformity, and sliding transpositional osteotomies of the fourth and fifth metatarsals with fixation to correct the brachymetatarsia. The patient was placed on the operating table in the supine position. After general anesthesia was administered, the patient's right foot and leg were prepared, and draped in the usual sterile manner. Hemostasis was obtained with a pneumatic ankle tourniquet inflated to 300 mm. Hg. Attention was then directed to the dorsomedial aspect of the right foot where a Silver bunionectomy/Hohmann osteotomy was performed using a 2.7-mm cortical screw to achieve fixation.

Prior to surgery, correction of the brachymetatarsia of the fourth metatarsal and contracted fourth digit were carefully planned out using templates. The angle of the oblique sliding osteotomy was determined to provide the desired lengthening of the fourth metatarsal and still maintain approximately 50% bone-to-bone contact between the proximal and distal fragments. Additionally, since the fourth and fifth metatarsals were going to be transposed with each other, the cuts had to be at the same angle so as not to create any adductus or abductus of either metatarsal.

Attention was then directed to the dorsum of the right foot overlying the fourth and fifth metatarsals. The incision was carefully planned out in order to mobilize skin for reduction of the contracture of the fourth toe, and for the gain in length that was necessary to correct for the shortened position. A V-Y skin plasty incision was made, with the apex of the V proximal, and the base distal. In order to gain the necessary exposure at the base of the metatarsal, the proximal end of the incision was then extended in a linear fashion.

A full-thickness flap was carefully maintained on either side of the incision, but particularly on the V section of the skin plasty. The flap was then gently reflected distally to gain exposure to the fourth and fifth metatarsophalangeal joints. Superficial bleeders were clamped and ligated as necessary, with care taken to preserve and retract all superficial nerves. The extensor digitorum longus tendon to the fourth digit was identified and a Z-plasty was performed. The tendon was then tagged on both ends using 4-0 Nylon and reflected from the wound, to be sutured together in a lengthened position at the closure of the case. The extensor digitorum brevis tendon to the fourth digit was tenotomized.

Exposure was then gained to the fourth metatarsophalangeal joint and shaft of the fourth metatarsal. A linear longitudinal incision was made into the joint capsule and periosteum along the dorsum of the metatarsal, over its entire length. The periosteum was then carefully reflected both medial and lateral, using a periosteal elevator, with care to preserve and maintain the periosteal envelope. The medial and lateral collateral ligaments at the head of the fourth metatarsal were identified and carefully dissected free.

As determined by templates preoperatively, the osteotomy of the fourth metatarsal was planned in an oblique fashion from distal medial to proximal lateral, through the entire diaphysis of the fourth metatarsal. An oscillating bone saw was used to perform the through-and-through osteotomy. The distal portion of the metatarsal, including the metatarsal head, was then carefully freed of its remaining attachments to the plantar periosteum, removed from the wound, and placed in a saline-soaked gauze.

Through the same incision, attention was directed to the fifth metatarsophalangeal joint and fifth metatarsal, where a linear incision was placed over the joint capsule and extending proximally, the entire length of the fifth metatarsal. The periosteum was then carefully reflected off the metatarsal, both medial and lateral. Again, as determined by preoperative templates, a similar type osteotomy was performed on the fifth metatarsal as was performed on the fourth metatarsal, with the angle of the cut being oblique and extending from proximal lateral to distal medial. The osteotomy of the fifth metatarsal was not quite the entire length of the diaphysis of the metatarsal, so that a smaller distal portion of the metatarsal was removed. With completion of the osteotomy, the fifth metatarsal was carefully freed of its

remaining plantar attachments to the periosteum and muscle attachments in the sheath of the fourth metatarsal, a V-type incision was made into the soft tissue structures, and with traction placed distally on the fourth toe, the soft tissue was lengthened, and tension released. Prior to insertion of the capital fragment, traction on the fourth toe was able to create a gain of approximately 1 cm. in length, which was the preoperative goal. The fifth metatarsal head/shaft was then withdrawn from saline, and a 0.045-inch Kirschner wire was driven through the metatarsal head, completely exiting out the shaft, prior to insertion into the wound. This provided a future guide hole for alignment of both sides of the osteotomy. The Kirschner wire was then retrograded through the phalanges of the fourth toe and out the distal tip of the toe. The section of the fifth metatarsal was then placed onto the same Kirschner wire as it exited the base of the proximal phalanx, and placed into the periosteal envelope of the fourth metatarsal (Fig. 3).

The distal fragment was carefully matched with the remaining base of the fourth metatarsal, traction was maintained on the fourth toe, and the osteotomy was positioned in order to gain the necessary length. The 0.045-inch Kirschner wire was then advanced proximally into the base of the fourth metatarsal and cuboid for stability. A small amount of gapping was noted at the osteotomy site, and it was determined that cerclage wiring would be necessary to maintain good bone-to-bone contact of the osteotomy. A single strand of 26-gauge monofilament wire was doubled over, passed around the osteotomy site, and tightened upon itself. Good closure and apposition of the osteotomy site was noted.

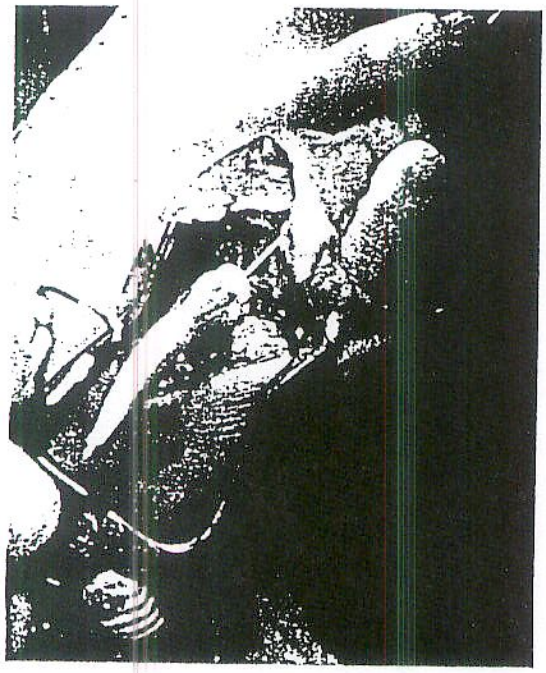

Figure 3. The fifth metatarsal head/shaft on a 0.045-inch Kirschner wire being placed into the periosteal envelope of the fourth metatarsal.

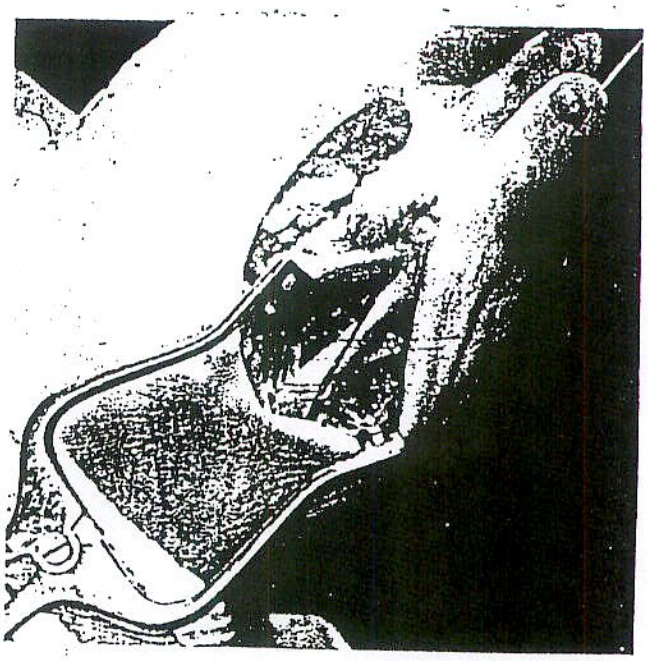

Figure 4. The fourth metatarsal head/shaft in alignment with the base of the fifth metatarsal.

The freed-up section of the fourth metatarsal was then predrilled with a 0.045-inch Kirschner wire centrally through the metatarsal shaft, as was done for the previous metatarsal. The Kirschner wire was retrograded through the phalanges of the fifth digit, and the freed-up section of the fourth metatarsal was placed onto the same Kirschner wire and into the wound so that the osteotomy site with the remaining base of the fifth metatarsal was matched up with that of the fourth metatarsal (Fig. 4). The distal fragment was carefully positioned so as to maintain the length of the original fifth metatarsal and thus achieve even weight distribution at the metatarsal heads. With these factors satisfied, the 0.045-inch Kirschner wire was advanced proximally into the base of the fifth metatarsal and cuboid. The osteotomy site was noted to gap centrally, and a strand of 26-gauge monofilament wire was placed centrally around the osteotomy site in a cerclage fashion, similar to that done on the fourth metatarsal.

Both osteotomies were noted to have better than 50% contact across the osteotomy sites, and tight fixation was present. Prior to closure, radiographic examination was obtained, and the osteotomies and placement of fixation materials were viewed and found adequate (Fig. 5).

Figure 5. Postoperative radiograph, demonstrating restoration of the metatarsal parabola.

The surgical sites were irrigated with 25% Betadine[3] solution followed by sterile saline. Two 0.25-inch silastic drains were placed in the wound, one at the proximal end of the sheath at the fourth metatarsal base and the other at the proximal end of the sheath of the fifth metatarsal base, to provide drainage after closure. The fourth metatarsophalangeal joint and periosteum of the fourth metatarsal was then maintained with simple interrupted sutures of 3-0 Dexon. The same type of closure was then performed at the joint capsule and periosteum of the fifth metatarsal. The extensor digitorum longus tendon of the fourth digit was sutured in a lengthened position, using simple and horizontal mattress sutures of 3-0 Dexon. Subcutaneous tissues were maintained with the use of horizontal mattress sutures of 3-0 Dexon. The initial V incision was then sutured as a Y with simple interrupted sutures of 5-0 Nylon, and using an apical suture at the apex of the Y. The silastic drains were left communicating at the proximal end of the incision. Regional nerve blocks were obtained in the area of the surgical site using 0.5% Marcaine.[4] A small amount of dexamethasone was injected at each surgical area. The wound was then dressed with Adaptic,[5] sterile 4 × 4's, and Kling[5] in a compressive fashion. Following release of the tourniquet, normal color and warmth returned to all aspects of the right foot, and the fourth digit in particular.

[3] Purdue Frederick Co., Norwalk, Connecticut.
[4] Winthrop-Breon, New York, New York.
[5] Johnson & Johnson, New Brunswick, New Jersey.

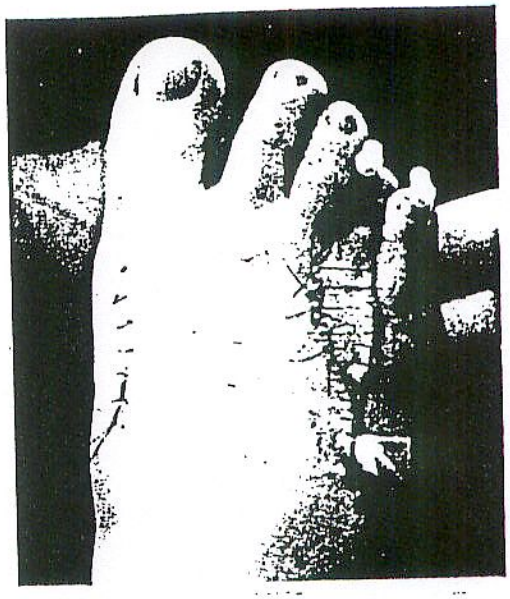

Figure 6. Clinical appearance of the foot postoperatively. An elongated fourth digit is evident.

The patient appeared to tolerate both anesthesia and the procedure well, and left the operating room with vital signs stable and neurovascular status to all toes of the right foot intact. A posterior splint was applied in the recovery room in approximately a 60° angle. Prophylactic antibiotics, Ancef,[6] 1 gm. every 8 hr., were continued postoperatively for 24 hr. (Fig. 6).

Postoperative Course

Patient was discharged from the hospital in a below-the-knee fiberglass cast and was instructed to remain nonweightbearing for approximately 8 weeks, walking with crutches. Sutures were removed in 14 days, and the apex of the V-Y skin plasty was noted to be warm, but bluish in color. The Kirschner wires were removed in 5½ weeks and the patient was placed in a lower-leg walker, continuing nonweightbearing for 2 more weeks. The apex of the V-Y skin plasty sloughed and ultimately healed by secondary intention. After all immobilization had been removed, patient was given range-of-motion exercises for the first, fourth, and fifth metatarsophalangeal joints, as well as muscle-strengthening exercises for the forefoot.

Results and Follow-Up

Preoperative radiographs demonstrated a hypoplastic fourth metatarsal with an abnormal metatarsal parabola. Radiographs taken 2 months postoperatively revealed adequate lengthening of the fourth metatarsal with reestablishment of a normal metatarsal parabola

[6] Smith Kline & French, Philadelphia, Pennsylvania.

and proper anatomical position of the fourth digit. No shortening of the fifth metatarsal was observed.

Clinical assessment of the right foot was positive in the respect that the foot had now taken on a more normal appearance. Immediately postoperatively the patient expressed her satisfaction with the cosmetic result, and after 3 months, stated her overall balance had improved considerably. However, after 5 months, the patient moved to a different state and was lost to follow-up.

Summary

The authors have presented a review of surgical approaches that have been used for the treatment of brachymetatarsia. A case report was presented in which transpositional osteotomies of the fourth and fifth metatarsals were described. The authors believe that when indicated, this approach can provide satisfactory cosmetic and psychologic results, along with relief of biomechanical symptoms.

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