Brachymetatarsia: A Classification for Surgical Treatment

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A B S T R A C T

Brachymetatarsia is a congenital osseous and soft tissue deformity of a ray(s) of the foot. Because there is no particular consensus of methodology of lengthening for brachymetatarsia, the authors introduce a comprehensive anatomic classification and a surgical guide to treatment of each classification type. This classification combines the number of the metatarsal(s) affected and the letter(s) indicating the type of brachymetatarsia deformity (A = axial deficiency of the metatarsal, B = bowing of the metatarsal, C = congruency of metatarsal phalangeal joint). This study reviewed of 300 brachymetatarsals in 166 patients. Fifty of the 166 (30%) patients had bilateral brachymetatarsia. Of the 300 metatarsals with brachymetatarsia, 64 (21%) were first metatarsals, 22 (7%) were second metatarsals, 28 (9%) were third metatarsals, 12 (4%) were fourth metatarsals, and 174 (58%) were fifth metatarsals. Classification types that were found was a total of 165 (55%) type A, a total of 72 (24%) type AB, a total of 39 (13%) type AC, and a total of 18 (6%) type ABC. A total of 16 (10%) male and 150 (90%) female patients were evaluated. The mean preoperative amount of shortening of the metatarsal was 15 mm (range, 4-20 mm), as determined by the preoperative metatarsal parabola deficiency, equating to 30% of the preoperative metatarsal length. Brachymetatarsia is a complex congenital deformity which until now has not been critically analyzed. This study outlines a comprehensive brachymetatarsia classification system which provides an accurate diagnosis of the deformity and offers a surgical treatment algorithm.

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Brachymetatarsia is a complex osseous and soft tissue deformity of a ray(s) of the foot. A ray consists of the metatarsal and the corresponding phalangeal bones in combination. A congenital brachymetatarsia is deficiency of metatarsal length along with the corresponding short phalangeal bones, whereas a traumatic induced metatarsal growth plate disturbance has normal length phalanges. Brachymetapody is when there is more than one metatarsal short in a foot. Clinically the brachymetatarsia ray will have a shorten toe that sits more dorsal on the foot than the adjacent toes and which greater amounts of shortening cause a deeper plantar skin crease (1).

The anatomical position of the congenital short metatarsal is directly related to the lack of complete development at the growth plate. The growth plates of the lesser metatarsals are located in the neck and the growth plate of the first metatarsal is located in the base. Thus, brachymetatarsia of the first metatarsal has a greater effect on the sagittal plane position of the metatarsal, whereby the first metatarsal is declined in the sagittal plane more than the lesser metatarsals. The reason for the increase in the first metatarsal declination as compared to a lesser metatarsal is that the plantar soft tissues and muscular tethers the growth of the metatarsal thereby pulling the first metatarsal more plantar. The technique for lengthening the first metatarsal defers from the lesser metatarsals in that the first metatarsal is lengthened along the plantar plane of the foot and the lesser metatarsals along the metatarsal declination. The lesser metatarsal brachymetatarsia can have sagittal plane declination of the head whereas the shaft is of normal declination. Therefore, the lesser metatarsals are lengthened parallel to the longitudinal axis (1,2).

Many surgical techniques have been attempted for acute and gradual metatarsal lengthening. These include only placing half pins in the metatarsal, placing half pins in the metatarsal and an axial toe pin, placing pins in the metatarsals and half pins in the toe, half circular frame constructs, plating of the acute lengthening, acute shortening of the longer metatarsals (1-4). Many published manuscripts outline the potential complications associated with lengthening metatarsals and the treatment of these complications (1-6).

The metatarsophalangeal joint (MTPJ) is at risk for dislocation or subluxation during lengthening of a metatarsal. Gradual metatarsal...
lengthening via callus distraction (osteogenesis) and bridging of the MTPJ is performed to control the toe position and prevent compression of the MTPJ as the soft tissue resists lengthening. This concept of bridging the adjacent joint has been utilized for decades in limb lengthening surgery in order to minimize stiffness and contracture at the adjacent joint postoperatively. Based on our review of several publication databases, including CINAHL® (Comprehensive Index of Nursing and Allied Health Literature, Elsevier Information Services, Ipswich, MA), The Cochrane Library (John Wiley & Sons, Ltd., West Sussex, England), Embase® (Elsevier B.V., Amsterdam, the Netherlands), MEDLINE® PubMed® (United States National Institutes of Health, National Library of Medicine, http://www.nlm.nih.gov/bsd/pmresources.html), ProQuest® (ProQuest, LLC, Ann Arbor, MI), and Google Scholar® (http://scholar.google.com/, Google, Inc., Mountain View, CA), the first publica-
tion to describe this technique for brachymetatarsia repair was by Lamm in 2009 (7). With greater amounts of lengthening, the joint is more susceptible to greater forces and thus increasing the risk for joint subluxation, chondrolysis, and postoperative stiffness. The farer the osteotomy from the joint, the less forces, thus a proximal metaphyseal-diaphyseal junction osteotomy is preferred. Although stabilizing the digit to the metatarsal head via axial pinning creates cartilage injury and leads to postoperative MTPJ stiffness regardless of the length of time the pin is maintained. The seniors author’s (B.M.L) technique of spanning and protecting the MTPJ was devised to prevent postoperative subluxation, stiffness, and chondrosis of the joint. In addition, this bridging fixator provides acute digital deformity correction with simultaneous joint distraction to maintain mobility of the MTPJ for the long term. The senior author (B.M.L) has previously reported successful results using this metatarsal lengthening technique with bridging of the MTPJ for correction of a short metatarsal deformity (brachymetatarsia) (7-9) (Figs. 1-3).

Lengthening of bone at the proper rate, rhythm, trajectory and protecting the surrounding soft tissues can be a challenge to even the most experience surgeons. As the amount of length needed increases so does the associated potential complications (10,11). Because there is no particular consensus of methodology of lengthening for brachymetatarsia, the authors introduce a comprehensive anatomic classification and a surgical guide to treatment of each classification type.

Classification

Throughout the senior author’s (B.M.L) experience in surgical correction of brachymetatarsia, there have been discrete types of deformity noted within the affected ray. These deformities range from purely shortened length of the metatarsal to irregularities of specific regions of the bone, including the shaft, head, and joint. Three broad categories exist: type A includes those metatarsals that are normal in all respects aside from their shortened length; type B involves angulation of the shaft of the affected metatarsal; and type C, congruency of the MTPJ which is associated with MTPJ imbalances and metatarsal head and phalangeal base irregularity. The classification system provides one number (1-5) and 3 letters (A,B,C). The number indicates which metatarsal is short or hypoplastic. For example, a number 1 would indicate the first metatarsal, and 4 would indicate the fourth metatarsal (9).

The letter A stands for Axial distance deficiency. For the lesser (2-5) metatarsals, if the axial distance or amount of shortness of the metatarsal is less than the metatarsal parabola line on an anterior posterior weightbearing radiograph this indicates the letter A. The metatarsal parabola line is drawn from the distal aspect of the second metatarsal head to the distal aspect of the fifth on an anterior posterior weight-bearing radiograph. The amount (mm) of hypoplasia or shortness is measured by the distance between the most distal portion of the hypoplastic metatarsal head drawn in line with the hypoplastic metatarsal mid-diaphyseal axis to the metatarsal parabola line. For the first metatarsal, if the axial distance or amount of shortness of the first metatarsal is more than 2 mm shorter than the second metatarsal as measured by the perpendicular distance of the most distal portion of the second to the most distal portion of the first metatarsal on an anterior posterior weightbearing radiograph this indicates the letter A. In the case of a
hypoplastic first, second, or fifth metatarsal the amount (mm) of hypoplasia or shortness is measured by the distance between the most distal portion of the hypoplastic metatarsal head to the superimposed metatarsal parabola angle/line of the opposite foot (if normal) or population normal.

The letter B stands for Bowing of the metatarsal shaft. Therefore, if the proximal and distal mid-diaphyseal lines of the metatarsal are angularly deviated than this indicates a letter B. Bowing can be noted on either the anterior-posterior (medial) or lateral radiograph (plantar). If the hypoplastic or short metatarsal shaft is bowed this indicates a letters AB (Axial distance deficiency and Bowing of the metatarsal). Bowing (B) can also be present post lengthening or fracture of the metatarsal.

The letter C stands for Congruency of the MTPJ. The deficient toe is typically raised at the MTPJ, however if the joint is misshaped, not spherical, arthritic, or dislocated this indicates the letter C. Congruency (C) of the metatarsal phalangeal joint can also occur as an altered joint position post lengthening of the metatarsal (Fig. 4).

Therefore, for example, if a patient has a short fourth metatarsal, bowing of the metatarsal shaft, and an incongruent MTPJ this patient would be classified as a 4ABC.

Treatment for a 4A

Two options are available, acute lengthening with bone graft or gradual lengthening via the percutaneous distraction osteogenesis (PDO) with external fixation named the PDO technique. Acute lengthening can be performed in patients with a small amount of hypo-aplasia or shortening of the metatarsal and is usually performed under 1 cm. Autograft or allograft implantation with plate and screw fixation is utilized. Gradual lengthening (PDO technique) employs an external fixator with 4 half pins in the metatarsal, and

Fig. 2. Clinical postoperative dorsal view photograph of successfully lengthened fourth brachymetatarsia. Note the spanning of the fourth metatarsophalangeal joint and the controlled position of the fourth digit.

Fig. 3. A postoperative anterior-posterior view radiograph of lengthened fourth brachymetatarsia in the consolidation phase of treatment. Note normotrophic bone regenerate formation of the fourth metatarsal and the distraction/spanning of the fourth metatarsophalangeal joint with the fourth digit in anatomic position.
2 half pins in the proximal phalanx spanning and protecting the MTPJ (7). When lengthening greater than 15 mm, this construct may need to include additional axial pin stabilization of the interphalangeal joints (IPJ) of that digit.

**Treatment for a 4AB**

The PDO external fixator technique (axial lengthening (A)) with an acute realignment osteotomy (bowing of metatarsal correction (B)). The percutaneous osteotomy of the metatarsal would be performed at the CORA (Center of Rotation Angulation) or apex of the deformity and then acutely realigned so the distal and proximal axes of the metatarsal coincide. The PDO external fixator technique would be performed having 4 half pins in the metatarsal, and 2 half pins in the proximal phalanx spanning and protecting the MTPJ.

**Treatment for a 4B**

The percutaneous acute realignment osteotomy of the metatarsal would be performed at the CORA (Center of Rotation Angulation) or apex of the deformity and then acutely realigned so the distal and proximal axes of the metatarsal coincide. An external fixator or internal fixation can be used to stabilize the osteotomy.

**Treatment for a 4BC**

The percutaneous acute realignment osteotomy of the metatarsal (bowing of metatarsal correction (B)) would be performed at the CORA (Center of Rotation Angulation) or apex of the deformity and then acutely realigned so the distal and proximal axes of the metatarsal coincide. Internal fixation or an external fixator can be used to stabilize the osteotomy. The MTPJ (congruency of MTPJ (C)) would be relocated through manual reduction, soft tissue release/balancing, osseous realignment or joint resurfacing in revision cases. An external

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**Fig. 4.** Lamm brachymetatarsia classification.
fixator is used to maintain joint neutral position when the joint is stiff. The PDO external fixator technique would have 4 or 2 half pins in the metatarsal, and 2 half pins in the proximal phalanx spanning and distracting the MTPJ. Joint distraction of 4-6 mm would be maintained for 6-12 weeks.

Treatment for a 4AC

The PDO external fixator technique (axial lengthening (A)) with realignment of the MTPJ (congruency of MTPJ (C)). The MTPJ would be relocated through manual reduction, soft tissue release/balancing, osseous realignment or joint resurfacing in revision cases and the joint affixed within the fixator at the neutral position. Soft tissue rebalancing may include the medial, lateral, plantar or dorsal capsule. The PDO external fixator technique would have 4 half pins in the metatarsal, and 2 half pins in the proximal phalanx spanning and distraction of the MTPJ.

Treatment for a 4C

The MTPJ would be relocated through manual reduction, soft tissue release/balancing, osseous realignment or joint resurfacing in revision cases and the joint affixed within the fixator at the neutral position. The PDO external fixator technique would have 4 or 2 half pins in the metatarsal, and 2 half pins in the proximal phalanx spanning and distracting the MPJ. Joint distraction of 5 mm would be maintained for 8 to 12 weeks.

Treatment for a 4ABC

The PDO external fixator technique (axial lengthening (A)) with an acute realignment metatarsal osteotomy (bowing of metatarsal correction (B)) and MTPJ relocation (congruency of MTPJ (C)). The percutaneous osteotomy of the metatarsal would be performed at the CORA (Center of Rotation Angulation) or apex of the deformity and then acutely realigned so the distal and proximal axes of the metatarsal

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**Fig. 5.** Clinical preoperative photograph of a congenital short third metatarsal on the right. Note the deep plantar crease beneath the third metatarsal head.
coincide. The MTPJ would be relocated through manual reduction, soft tissue release/balancing, osseous realignment or joint resurfacing in revision cases and the joint fixed within the fixator at the neutral position. The PDO external fixator technique would be 4 half pins in the metatarsal, and 2 half pins in the proximal phalanx spanning and protecting the MTPJ.

This classification combines the number of the metatarsal(s) affected and the letter(s) indicating the type of brachymetatarsia deformity (A = axial deficiency of the metatarsal, B = bowing of the metatarsal, C = congruency of MTPJ) which guides the surgeon to the appropriate surgical treatment plan. Additionally, the Lamm brachymetatarsia classification system provides accurate diagnosis of the deformity and offers a surgical treatment algorithm for primary and revision brachymetatarsia (Figs. 5-20).

The purpose of this study was to report a new classification of brachymetatarsia based on the review of 300 brachymetatarsals in 166 patients. In this series of patients, the authors reviewed the initial clinical and radiographic presentation to determine anatomical patterns for a classification. This classification also provides a surgical guide for treatment based on the senior author’s (B.M.L.) experience from results of these aforementioned patients.

**Patients and Methods**

A retrospective review of 300 consecutive brachymetatarsals in 166 patients was performed. All medical records and radiographs of patients were reviewed from July 1, 2016 to January 1, 2021. An IRB approval was obtained via MetroWest Medical Center (IRB#2019-114). The following parameters were obtained through medical record review: race, state of record, age, sex, height, weight, diagnosis. The United States Centers for Disease Control and Prevention (https://www.ncbi.nlm.nih.gov/books/NBK219754/, accessed 08/31/2021), and the National Institutes of Health, define race as an arbitrary classification based on physical characteristics; a group of persons related by common descent or heredity. Races include: 1) American Indian or Alaska
Native, 2) Black or African American, 3) White, 4) Native Hawaiian or Pacific Islander, 5) Asian, and 6) Other.

A thorough evaluation of weightbearing pre- and postoperative anteroposterior and lateral view radiographs. All radiographs were measured on a PACS system, Change Healthcare Radiology SolutionsTM, by each of the 2 authors twice and averaged to determine the length or angle. All radiographic angles and measurements were averaged and reported.

On the anterior-posterior radiograph, the metatarsal parabola angle and metatarsal length were recorded. The brachymetatarsal length was determined by recording the metatarsal parabola angle measured by the intersection of the line from the distal first metatarsal to the distal second metatarsal and the line from the distal second metatarsal to the distal fifth metatarsal. The brachymetatarsal length was determined by measuring from the distal articular surface of the involved metatarsal to the reference parabola line in a line along the anatomic axis of the metatarsal involved. If any one of the reference metatarsals (first, second, or fifth) was involved, population normal measurements of 142.5° and 2 mm (the first metatarsal shorter than the second metatarsal) were used for the metatarsal parabola angle (12).

On the anterior-posterior radiograph, the position of the MTPJ was recorded. A line connecting the most medial and lateral points of the articular surfaces of the head of the metatarsal and a second line connecting the most medial and lateral points of the base of the proximal phalanx of the respective digit. The intersection of these two lines was evaluated and if the lines were parallel, the digit was deemed congruent. If the two lines intersected outside the joint, the digit was deemed subluxated. If the lines intersected within the joint, the digit was deemed dislocated (12).

On the anterior posterior view, the anatomic axis of the involved metatarsal was drawn and if no deviation from the mid-diaphyseal line occurred, the metatarsal was deemed to be normal, but if an intersection of the prox and distal axis occurred, the metatarsal was deemed to be deviated medially or laterally and the angle measured.

Joint space was determined on the anteroposterior view by measuring the distance between the center point of the distal articular surface of the metatarsal and the center point of the proximal articular surface of the proximal phalanx of the corresponding digit.

On the anterior-posterior radiograph, the first intermetatarsal angle was recorded. We measured the length of the proximal phalanx of the affected metatarsal based on the anteroposterior view radiograph. The length was measured from the center of the distal to proximal articular surfaces. On the lateral view, the metatarsal declination was determined by the angle formed from the intersection of the anatomic axis of the involved metatarsal and the ground.

Fig. 7. Clinical preoperative photograph of a congenital short fourth metatarsal on the left and third metatarsal on the right. Note the elevation and shortening of the respective brachymetatarsia digit. A bunion (hallux abductovalgus) on both feet is forming as the hallux and lesser toes drift laterally due to the unopposed brachymetatarsia digit is dorsally displaced.
Results

Brachymetatarsia was identified in 166 patients for a total of 300 metatarsals. One hundred sixteen of 166 (70%) patients had a primary diagnosis of brachymetatarsia, 26 of 166 (16%) patients had associated congenital deformity, 10 of 166 (6%) patients had iatrogenic deformity, and 14 of 166 (8%) patients failed previous acute metatarsal lengthening with bone grafting. Fifty of the 166 (30%) patients had bilateral brachymetatarsia. Of the 300 metatarsals with brachymetatarsia, 64 (21%) were first metatarsals, 22 (7%) were second metatarsals, 28 (9%) were third metatarsals, 12 (4%) were fifth metatarsals, and 174 (58%) were fourth metatarsals. Classification types that were found was a total of 165 (55%) type A, a total of 6 (2%) type B, a total of 72 (24%) type AB, a total of 39 (13%) type AC, and a total of 18 (6%) type ABC.

Fig. 8. Clinical preoperative photograph of a congenital short fourth metatarsal on the left and third metatarsal on the right. Note the elevation and dorsal displacement of the respective brachymetatarsia digit.

Fig. 9. Clinical preoperative side view photograph of a congenital short fourth metatarsal on the left and third metatarsal on the right. Note the elevation and dorsal displacement of the respective brachymetatarsia digit and lack of fourth digit purchase during static stance.
the classification type A only a total of only 18 (6%) metatarsals where shorter than the 10 mm axial discrepancy.

The mean patient age was 30 years (range, 4-65 years). The most common race treated was White (55%), Black or African American (40%), Asian (5%). More than 70% of the patients came from another state or country. A total of 16 (10%) male and 150 (90%) female patients were treated. The mean height and weight was 160 cm and 63 kg, respectively.

The overall mean lesser metatarsal length was 50 mm. The mean preoperative amount of shortening of the metatarsal was 15 mm (range, 4-20 mm), as determined by the preoperative metatarsal parabola deficiency, equating to 30% of the preoperative metatarsal length. The mean preoperative first intermetatarsal angle was 8° (range, 0-19°). The mean preoperative first metatarsal length for males was 44.50 mm compared to females with 43.29 mm. The mean metatarsal parabola angle measured was 142° (range, 124-173°). The mean lesser proximal phalanx length was 18 mm, whereas the mean hallux (first proximal phalanx) length was 23 mm. Finally, the mean joint space was 1.5 mm (range 0-2.5 mm). Medial or plantar angulation or bowing (type B) occurred in 96 (32%) metatarsals with an mean of 10° (3-15°).

A review of the preoperative lateral view radiographs revealed 57 (19%) of lesser metatarsal phalangeal joints were either greater than 50% subluxed or dislocated, with the exception that all the short first metatarsal phalangeal joints were congruent. The declination of the lesser brachymetatarsals was in line with the adjacent metatarsals (mean 15° (range, 8-22°)). However, brachymetatarsia of the first metatarsal had an increased declination angle compared with the adjacent metatarsals. The mean short first metatarsal declination was 35° (range, 30-37°).

Fig. 10. Preoperative weightbearing left foot. AP view radiograph of a congenitally short fourth metatarsal. Note the mid-shaft bowing (type B) in the medial direction of the fourth metatarsal. Classification 4AB type on the left.
Discussion

The goals of metatarsal lengthening are to improve foot function, restore the metatarsal parabola for weightbearing, allow for a greater selection of shoe gear, and improve pedal cosmesis. Lengthening metatarsals like limb lengthening requires extensive knowledge of congenital deformities, a great understanding of external fixation, and a comprehensive approach. The advent of this classification system allows for a better understanding and a recommended surgical treatment guide for brachymetatarsia based on the senior author’s (B.M.L.) experience.

There are advantages of acute lengthening with bone grafting including no external fixation and in certain patients maybe preferred. Acute lengthening has disadvantages including use of bone graft, donor site for autograft, internal fixation, acute compression of the joint cartilage, larger incision, and a period of non-weightbearing. Thus, for metatarsal lengthening of 10 mm or more, acute lengthening is not recommended. Furthermore, in this study only 18 of 300 (6%) metatarsals were measured to be less than 10 mm preoperatively.

Staged lengthening, which is a limb lengthening technique used to increase a bone length in a staged fashion, thereby obtaining bone lengthening in one treatment and a year or so later the bone lengthening is repeated on the same bone to gain even more length, in order to maximize the length gained without risking soft tissue injury. Staged metatarsal lengthening is a technique employed by the senior author (B.M.L.). In patients with a type A classification, the most common type (55%), and the desired axial length needed is greater than 15 mm, a 2 stage lengthening protocol can be utilized. The 2-stage lengthening
would decrease the amount of lengthening needed by splitting the treatment into 2 lengthenings. The advantage of this technique is to minimize the MTPJ stiffness thereby improving function. Therefore an adolescent (age 10–16 years old) lengthening can achieve approximately 15mm of length followed by a second lengthening for the remaining metatarsal length required at or after osseous maturity. Thus, for example if the required lengthening is 22 mm than the patient can undergo a 15mm adolescent lengthening followed by a 7 mm lengthening at or after maturity. This method of staged lengthening is similar to other congenital lengthenings like fibular and tibial

Fig. 12. Preoperative weightbearing right foot. Lateral view radiograph of a congenitally short third metatarsal. Note the mid-shaft bowing (type B) in the plantar direction of the third metatarsal. Note the extended 3rd metatarsophalangeal joint, which indicates a type C or non-Congruency of joint. Classification 3ABC type on the right.

Fig. 13. Preoperative weightbearing left foot. Lateral view radiograph of a congenitally short fourth metatarsal.
hemimelia as well as congenital femoral deficiency in which the amount of lengthening is limited by the surrounding soft tissues. The goal is to obtain lengthening while maintaining function (10).

With the use of advanced imaging, the understanding of brachymetatarsia has grown especially when analyzing the C (congruency of the MTPJ) classification. Routinely, the metatarsal phalangeal joint is 50% subluxed or dislocated dorsal. The shape of the metatarsal head and base of the proximal phalanx identified on plain radiographs is not well visualized thus advanced imaging (CT and MRI) is very helpful. The joint can vary and if not spherical or in an abnormal osseous position the

Fig. 14. Clinical preoperative photograph of a congenital short third and fourth metatarsal on the bilaterally. Note the elevation and shortening of the respective brachymetatarsia digits 3 and 4.

Fig. 15. Clinical preoperative photograph of a congenital short third and fourth metatarsal on the bilaterally. Note the medial drift of the fifth digit and the lateral drift of the second digit.
success of the final lengthening outcome is affected. Advanced imaging is extremely helpful for planning of initial surgical treatment and also for revisional surgical treatment of brachymetatarsia.

The revisional surgical cases can be represented by the aforementioned classification as the metatarsal length maybe short, correct, or too long. These revision brachymetatarsia cases are complex and challenging as the deformity remains in the form of bowing of the metatarsal (type B) and/or the incongruity of the MTPJ (type C). Commonly, when the MTPJ is not protected or the toe is pinned axially across the MTPJ, the MTPJ becomes stiff and/or dislocated. This postoperative resultant toe malposition or stiffness results in a classification type C.

Revisional surgery is patient specific but care must be taken to ensure maintenance of neurovascular status and restoration of the joint position, joint space and toe function. Typically, MTPJ distraction is employed for 8 to 12 weeks together with deformity correction of osseous lengthening or shortening via acute or gradual methods as well as osseous realignment.

Traumatic etiology of a hypoplastic metatarsal can occur from a childhood growth plate injury. This is identified as the phalanges of the affected toe are not shorter than the adjacent lateral toe. Hand (brachymetacarpia) and foot (brachymetatarsia) combined hypoplasia can also occur and were seen in 10 patients (3%) in this series. In most cases, the hands are treated at a separate surgical operation, due to the need for the hands for crutches or a walker post metatarsal lengthening surgery.

The prevalence of brachymetatarsia has been report to be as frequent as 1 in less than 1000 to one in 2500 births (3). The genetics of the brachymetatarsia is not fully understood. Brachymetatarsia is a congenital deformity whereby congenital deformities are known to be a random genetic mutation. A hereditary component of this condition is

![Clinical preoperative photograph of a congenital short third and fourth metatarsal on the bilaterally. Note the dorsally displacement of both the third and fourth digits.](image)
not known to be linked, but has been seen by the senior author (B.M.L.).
(Figs. 21-23).

A recent study that reviewed 62 articles on brachymetatarsia found the mean female to male ratio was 10:1, which is similar to our study that showed a ratio of 9:1 (13). In that same study, the authors found the prevalence of bilateral brachymetatarsia was 47%, whereas we found it to be 38% of our patients (13). Of the 300 brachymetatarsals studied, the majority were fourth metatarsals 174 (58%).

Bunion or hallux abductovalgus can be present in combination with brachymetatarsia and was seen in 68 patients (41%) in our series. The adjacent toes through the MTPJ transversely angulate into the space where the short toe resides. Similarly as the lesser toe drifts or angulates laterally toward the short toe space the big toe also laterally angulates creating or exacerbating a bunion. Bunion deformity is typically correct simultaneously with metatarsal lengthening either with internal or external fixation methods. The senior author (B.M.L.) has combined minimally invasive bunion correction with percutaneous metatarsal lengthening. Unlike the bunion deformity, the adjacent toe drift or transverse angulation of the lesser toes typically self-corrects with the metatarsal lengthening surgery but on occasion an adjacent toe MTPJ capsulotomy to correct the transverse plane deformity is performed. Also associated tenotomy or open tendon lengthening on initial metatarsal lengthening surgeries are not warranted, which again is comparable to the limb lengthening literature where gradual tendon distraction is the preferred treatment.
Fig. 18. Preoperative weightbearing left foot. AP view radiograph of a congenitally short third and fourth metatarsal. Note the mid-shaft bowing (type B) in the plantar direction of the third metatarsal. Classification 3AB, 4A type on the left.

Fig. 19. Preoperative weightbearing left foot. AP view radiograph of a congenitally short third and fourth metatarsal. Note the mid-shaft bowing (type B) in the plantar direction of the third metatarsal. Classification 3AB, 4A type on the left.
The limitations of this study include: like all patient-oriented research reports, ours has a number of methodological shortcomings that could threaten the validity of our observations, including selection biases, since one surgeon’s practice was used as the source of the cases measured; measurement biases related to using radiographic features and digital software to identify anatomic landmarks and measure distances and angles, despite the lack of intra- and inter-rater reliability coefficients for statistical correlation for these measurements; and, despite making recommendations for treatment based on the proposed classification system, and knowing that the senior author (B.M.L.) has treated brachymetatarsia patients for over 20 years, no data outcomes for radiographic measurement or pain or subjective outcomes is presented in this report, and the surgical outcomes based on categorization has not yet been explored.

In conclusion, brachymetatarsia is a complex congenital deformity which until now has not been critically analyzed/classified. This is the first study to provide a clearer understanding of the anatomical variations that occur with brachymetatarsia. This study outlines a comprehensive classification system to guide the surgical treatment of brachymetatarsia. Still the experience of the surgeon in bone lengthening, external fixation, and foot and ankle surgery remains paramount for the successful treatment of this complex congenital deformity.

Fig. 20. Preoperative weightbearing right foot. AP view radiograph of a congenitally short third and fourth metatarsal. Note the dorsally extended fourth metatarsophalangeal joint, which indicates a type C or non-Congruency of joint. Classification 3A, 4AC type on the right.

Fig. 21. Clinical preoperative photograph of mother and son with brachymetatarsia. Mom (on the left side of the photo) has a left congenital short fourth metatarsal and her son has bilateral congenital short third and fourth metatarsal.
Fig. 22. Clinical preoperative photograph of father and son with brachymetatarsia. Father (on the left side of the photo) has a right congenital short first metatarsal and his son has bilateral congenital short first metatarsals.

Fig. 23. Clinical preoperative photograph of mother and daughter with brachymetatarsia. Mom (on the right side of the photo) has a left congenital short fourth metatarsal and her daughter has bilateral congenital short fourth metatarsals.
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References