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Original Research

Callus Distraction Versus Single-Stage Lengthening With Bone Graft for Treatment of Brachymetatarsia: A Systematic Review

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ABSTRACT

Brachymetatarsia deformity is a cosmetically displeasing anomaly that can become physically symptomatic. The surgical techniques most commonly used to repair the anomaly include single-stage lengthening with a bone graft, callus distraction, or a combination of bone grafting and callus distraction. A systematic review of the published data was performed to compare the outcomes of these 3 surgical procedures. A total of 61 studies reporting the use of callus distraction or single-stage lengthening, or both, for the treatment of brachymetatarsia were included in the present review. The incidence of major postoperative complications after callus distraction, single-stage lengthening, and the combination procedure was 49 (12.62%), 13 (3.72%), and 3 (33.33%), respectively. The number of minor complications with callus distraction, single-stage lengthening, and the combination procedure was 152 (39.18%), 55 (15.76%), and 1 (11.11%); the mean percentage of the original length achieved was 37.36%, 25.98% and 36.00%; and the mean length achieved was 17.5, 13.2, and 14.0 mm, respectively. The healing index (mo/cm) and healing time was 2.31 and 16.04 weeks, 1.90 and 9.35 weeks, and 3.93 and 14.62 weeks for callus distraction, single-stage lengthening, and the combination procedure, respectively. Our findings indicate that the callus distraction technique is associated with greater length gained but results in greater complication rates and requires almost twice the time to heal. Single-stage lengthening with a bone graft was associated with fewer complications and faster healing times than callus distraction but with lesser gains in length. From the information reported in the studies we reviewed, the prevalence of bilateral brachymetatarsia was 44.52%, and the female/male ratio was 13.7:1. Both of these findings seem to contradict the usual data given (72% for bilateral brachymetatarsia and a female/male ratio of 25:1).

Brachymetatarsia is a rare, sometimes painful, deformity that is frequently a source of aesthetic dissatisfaction for individuals with the condition. It has been defined as the presence of ≥1 metatarsal >5 mm proximal to the parabolic arch of the metatarsal heads (1,2). The incidence reported has varied greatly, with an incidence anywhere from 1:625 to 1:4586 (3,4). It occurs more often in females (female/male ratio of 25:1) and most often in the fourth metatarsal (4–7); 72% of cases are bilateral (4). The cause can be congenital, idiopathic, posttraumatic, or secondary to disease processes such as pseudohypoparathyroidism, malignancy, Down syndrome, Albright's hereditary osteodystrophy, diastrophic dwarfism, and Turner syndrome (8).

A number of surgical techniques have been used to correct this deformity, including slide osteotomy, transpositional osteotomy, scarf osteotomy, syndactylization, single-stage lengthening with a bone graft, and callus distraction (9–15). Recent studies have indicated that the most commonly used techniques are single-stage lengthening with a bone graft, callus distraction, or a combination of callus distraction and bone grafting. Because the deformity is rare, most reports have been of small case series. To our knowledge, no systematic reviews or meta-analyses of the published data comparing the techniques have been published, and no evidence is available regarding which of these will be associated with the most satisfactory outcomes. We undertook a systematic review of the published data to compare the outcomes of the common surgical techniques. A secondary aim was to record and evaluate the demographic data and incidence of brachymetatarsia to compare these data with the oft-reported values.

Materials and Methods

All 3 of us (M.D.J., D.M.P., S.A.R.) extracted data from medical reports. Each report was reviewed by ≥2 of us independently. The data collected from the reports were then reconciled, and any discrepancies were resolved by the third author reviewing the report. A search of the published biomedical data was performed using the

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Table 1
Etiology of brachymetatarsia among 457 patients

Gender	Congenital (n)	Clubfoot (n)	Post-traumatic (n)
Male	26 (83.9)	3 (9.7)	2 (6.5)
Female	423 (99.3)	2 (0.5)	1 (0.2)

Data in parentheses are percentages.

bibliographic databases PubMed and Medline®, with "brachymetatarsia" as the keyword, for publications from January 1945 to December 2014. A total of 75 studies was initially found. Our inclusion criteria were studies in the English language reporting on patients treated surgically with callus distraction, single-stage lengthening with a bone graft, or a combination of the 2 methods. The exclusion criteria were studies that only described the surgical techniques, those with no report of the surgical procedures on patients, and those that described other surgical methods of treatment. The total number of studies that met the inclusion criteria was 61. Of the 61 studies, 27 discussed callus distraction (7,15–39), 29 discussed single-stage bone lengthening (1,4,5,11,14,40–63), 3 discussed a combination of the 2 techniques (64–66), and 2 reported on patients who had undergone callus distraction surgery or single-stage lengthening (67,68). These reports were classified into 3 groups according to the procedure: callus distraction, bone grafting, or a combination of the 2.

From these reports, the following data were recorded: gender, age, metatarsal affected, etiology, complications, healing time in weeks, healing index (month/cm), percentage of the original length achieved, length achieved in millimeters, initial procedure performed, additional procedures performed because of complications, graft donor site, and follow-up length in months. For the data we collected, we defined major complications as those that required additional surgery to alleviate the problem. Minor complications were defined as those successfully treated without surgery. The percentage of original length achieved was defined in the studies as the difference between the length of the metatarsal before and after surgery, divided by the original length of the metatarsal. In nearly all of reports, the original length of the metatarsals was not specified, instead the percentage of original length was reported. All the data were not present in every report; however, all the information provided was recorded.

The studies included in the present review were generally poor in quality. Only 2 were level III studies (67,68) and the rest were level IV and V (7,15–66). Owing to the relatively poor quality level of the studies, only a systematic review with descriptive outcomes could be completed.

Results

The total number of patients was 457, with a mean age of 21.7 (range 2 to 55) years. Surgery was performed on 683 feet and 761 metatarsals. Brachymetatarsia was present in 10 additional metatarsals that had not been operated on because they were asymptomatic, bringing the total to 771 affected metatarsals. Some of the studies reviewed did not report data for all categories; however, all data reported in the studies were recorded. Thus, all 457 patients and 771 metatarsals were not represented in each of the categories.

Brachymetatarsia occurred bilaterally in 44.52% of the patients. Of the 457 patients, 426 (93.22%) were female, and 31 (6.78%) were male, for a ratio of 13.7:1 (Table 1). The most common etiology for the brachymetatarsia in all the patients was congenital. The etiologies among the males included congenital in 26 (83.87%), clubfoot in 3 (9.67%), and post-traumatic in 2 (6.45%). Among the females, the etiology was congenital in 423 (99.30%), clubfoot in 2 (0.46%), and post-traumatic in 1 (0.23%; Table 2). None of the patients were reported to have brachymetatarsia in association with other disease processes in the studies reviewed. The metatarsal most commonly affected was the fourth metatarsal, with 559 cases (72.50%). In descending order, the next most commonly affected metatarsal was the first metatarsal in 149 (19.33%); the third metatarsal in 45 (5.84%); the second metatarsal in 10 (1.30%), and the fifth metatarsal in 8 (1.04%; Table 3).

Table 2
Patient demographics (N = 457 patients)

Variable	All Groups Combined
Overall total (n)	
Patients	457
Feet	693
Metatarsals	771
Age (y)	
Mean	21.7
Range	2 to 55
Gender	
Male	31 (6.8)
Female	426 (93.2)

Data in parentheses are percentages.

Table 3
Prevalence of metatarsals affected by brachymetatarsia (N = 771 metatarsals)

Metatarsal Affected	n (%)
Fourth	559 (72.5)
First	149 (19.3)
Third	45 (5.8)
Second	10 (1.3)
Fifth	8 (1.0)

The complications in each of the 3 groups were compared with those in the other groups. Within the bone graft group (n = 349 metatarsals), 13 (3.72%) had major complications, 55 (15.76%) had minor complications, and 281 (80.52%) had no complications. In the callus distraction group (n = 388 metatarsals), 49 (12.62%) had major complications, 152 (39.18%) had minor complications, and 188 (48.45%) had no complications. In the combination group (n = 9 metatarsals), 3 (33.33%) had major complications, 1 (11.11%) had minor complications, and 5 (55.56%) had no complications (Table 4)

The reported complications associated with each surgical technique varied among the groups. The callus distraction group had the most complications overall, with metatarsophalangeal joint (MTPJ) stiffness and decreased range of motion, pin tract infection, and metatarsal malalignment/malunion the most common. For the bone graft group, the most common were decreased MTPJ range of motion, metatarsal angulation, and dorsal elevation of the toes. For the combination treatment group, MTPJ subluxation, hallux valgus, and delayed bone graft incorporation were the most common (Table 5).

The percentage of the original length achieved in the bone graft group (n = 238 metatarsals) was a mean of 25.98% (range 19% to 57%), in the distraction group (n = 354 metatarsals) was a mean of 37.36% (range 13.5% to 70%), and in the combination group (n = 6 metatarsals) was a mean of 36.00% (range 12% to 68%). The mean increased length of the metatarsal after the procedure in the bone graft group (n = 348 metatarsals) was 13.2 (range 3.5 to 22) mm. The mean increased length in the callus distraction group (n = 389 metatarsals) was 17.5 (range 8 to 40) mm and in the combination group (n = 9 metatarsals) was 14.0 (range 6 to 36) mm. The healing time was a mean of 9.35 (range 5 to 14) weeks in the bone graft group (n = 299 metatarsals), 16.04 (range 7.3 to 68) weeks in the callus distraction group (n = 383 metatarsals), and 14.62 (range 8 to 23) weeks for the combination group (n = 9 metatarsals). The healing index was calculated as the healing time in months divided by length gained in centimeters. The bone graft group (n = 297 metatarsals) had a mean healing index of 1.90 (range 1.0 to 3.8) mo/cm. The callus distraction group (n = 383 metatarsals) had a mean healing index of 2.31 (range 0.9 to 8.5) mo/cm. The combination group (n = 9 metatarsals) had a

Table 4
Complication rates for all 3 surgical groups (N = 746 metatarsals)

Complication	Callus Distraction Group (n = 388)	Bone Graft Group (n = 349)	Combination Group (n = 9)
Major	49 (12.62)	13 (3.72)	3 (33.33)
Minor	152 (39.18)	55 (15.76)	1 (11.11)
None	188 (48.45)	281 (80.52)	5 (55.56)

Data in parentheses are percentages.