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Complications of distraction osteogenesis in brachymetatarsia: Comparison between the first and fourth brachymetatarsia

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ABSTRACT

BackgroundRecently, distraction osteogenesis has been widely used to treat brachymetatarsia. However, few papers have compared complications associated with this treatment. The purpose of the present study was to compare the complications between the first and fourth brachymetatarsia treated by distraction osteogenesis.

MethodsWe performed distraction osteogenesis to 83 metatarsals in 41 patients between 1999 and 2012. A total of 30 metatarsals received treatment for the first metatarsal (Group A) while 53 metatarsals received treatment with the fourth metatarsal (Group B).

ResultsThe complication rate in Group A (40%) was higher than that in Group B (18.9%). Those who had high percentage of lengthening gain were more likely to have complications. A cut-off value for lengthening gain developing complication was 41.3%.

ConclusionComplication incidence after distraction osteogenesis was increased when lengthening gain was more than 41.3% for brachymetatarsia. In the 1st metatarsal lengthening, the most common complication was stiffness. In contrast, complications of the 4th metatarsal lengthening were pin-track infection and angular deformity.

1. Introduction

Brachymetatarsia is a rare foot disease with too short metatarsal bone due to congenital or developed condition [1]. Several surgical options have been described for the treatment of brachymetatarsia. Gradual distraction osteogenesis is the most widely used one for operative correction [2–4] because it allows the lengthening of the metatarsal while giving adequate time for the soft tissue to adapt to the lengthened bone. Complications associated with treatment of distraction osteogenesis have been well documented [5,6]. However, few reports have compared the complications of the first and the fourth brachymetatarsia by distraction osteogenesis. The objective of this study was to compare the outcomes including complications between the first and the fourth brachymetatarsia treated by distraction osteogenesis.

2. Patients and method

The distraction osteogenesis surgery were performed in 45 patients with 89 metatarsals for the 1st and the 4th brachymetatarsia in our hospital from January 1999 to December 2012. This retrospective study was approved by the Ethics committee. Only patients who were followed up for more than 1 year were included in this study. A total of 41 patients were enrolled in this study, including 5 men and 36 women. Their average age was 17.9 years. A total of 18 patients (30 metatarsals) received treatment of distraction osteogenesis for the first metatarsal (Group A) while 32 patients (53 metatarsals) received distraction osteogenesis treatment for the fourth metatarsal (Group B). Metatarsal lengthening by distraction osteogenesis was performed on 17 patients who had both first and fourth brachymetatarsia. The average age was 17 years in Group A and 18.5 years in Group B. The average duration of follow-up was 42.2 months in Group A and 31.3 months in Group B. There was no significant difference in demographics (sex, age, follow-up duration) between the two groups (Table 1). Pre- and post-operative radiographs were evaluated to determine lengthening gain (Fig. 1), healing time and index, hallux valgus angle (HVA) (Fig. 2), inter-metatarsal angle (IMA) (Fig. 1), metatarsal inclination

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Table 1
Demographic characteristics of patients (min–max).

Variable	Group A (1st)	Group B (4th)	p-Value
Sex (N) male/female	3/15	2/30	0.56
Age (year)	17 (10–31)	18.5 (11–56)	0.41
Follow-up (month)	42.2 (12–147)	31.3 (12–91)	0.19
Patients (metatarsal)	18 (30)	32(53)	

angle (MIA) (Fig. 3), and malalignment angulation of metatarsal bone and point of malalignment (Fig. 4). If the malalignment angulation of metatarsal bone was greater than 15° and there was pain, it was regarded as complication. Hallux valgus angle was considered complication when it was beyond 20°. Complications such as metatarsophalangeal stiffness, metatarsal malalignment, metatarsophalangeal joint dislocation and osteoarthritis, pin-track infection, and nonunion were also evaluated. All statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC) and R 3.2.1 (Vienna, Austria; http://www.R-project.org/). Wilcoxon singed rank test was used to determine differences in radiologic measurements between preoperative X-ray and post-operative X-ray. *P* values of <0.05 were considered statistically significant. ROC curve was used to identify cut-off value for increased complications following length extension.

3. Operative techniques

In all cases, corticotomy was performed on the following screw fixation using a unilateral external fixator (External Fixator CK_s Mini Digitus U&I Corporation, Kyonggi-Do, South Korea). A 3 mm diameter screw was used for the first metatarsal on medial aspect and a 2.3 mm diameter screw was used for the fourth metatarsal on dorsolateral aspect. We used two screws each proximally and distally (Fig. 5). When the metatarsal lengthens along the anatomical axis, cavus deformity can be worse. Therefore, all screws were inserted at the first metatarsal at the same level on horizontal plane. Attention was paid to the 5th tendon across the metatarsal when performing screw fixation to the 4th metatarsal. The distraction rate and rhythm were adjusted based on radiological or clinical condition of the patient. Basically, distraction was performed 0.25 mm three times a day from one week after the surgery and X-ray follow up was performed every week. We

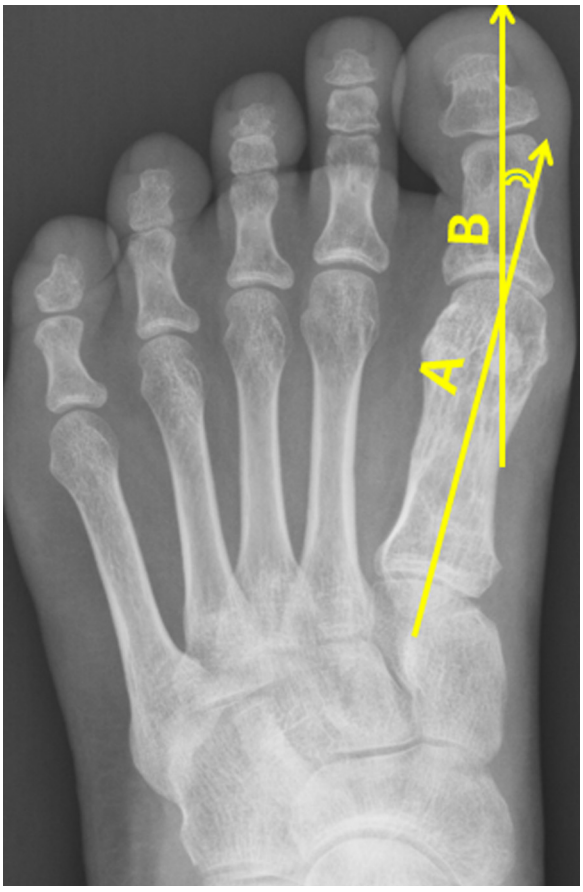

Fig 2. Hallux valgus angle was obtained on pre-operative standing foot x-ray. If hallux valgus angle exceeded 20 degrees, it was regarded as a complication. HVA (Hallux valgus angle) = ∠A & B.

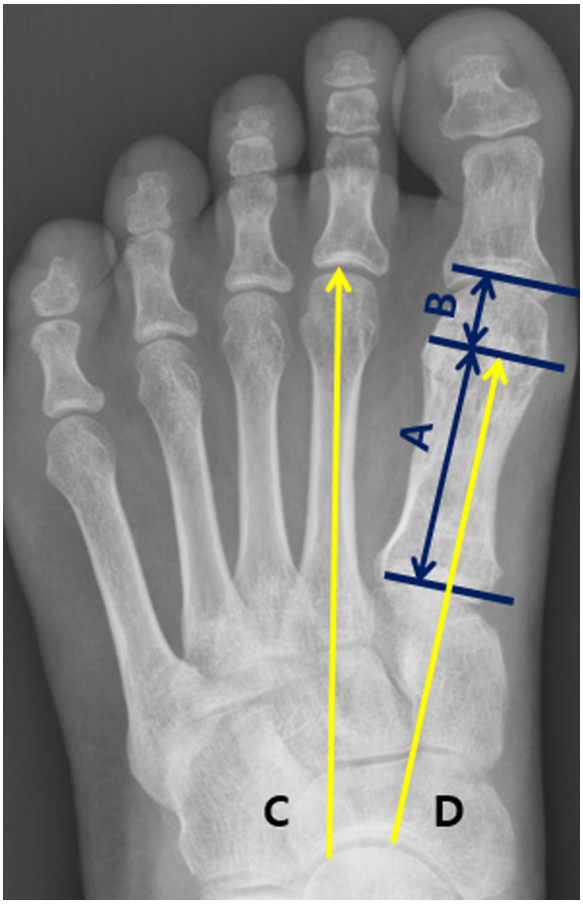

Fig. 1. Lengthening gain and metatarsal angle were obtained on pre-operative standing foot x-ray. Lengthening gain(%) = 100 * B /A IMA (internmetatarsal angle) = ∠C&D.

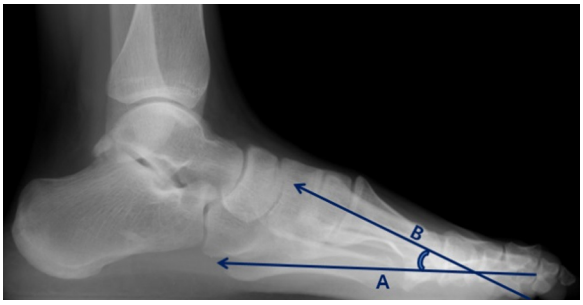

Fig. 3. Metatarsal inclination angle(MIA) was obtained on pre-operative standing foot x-ray. MIA = ∠A & B.

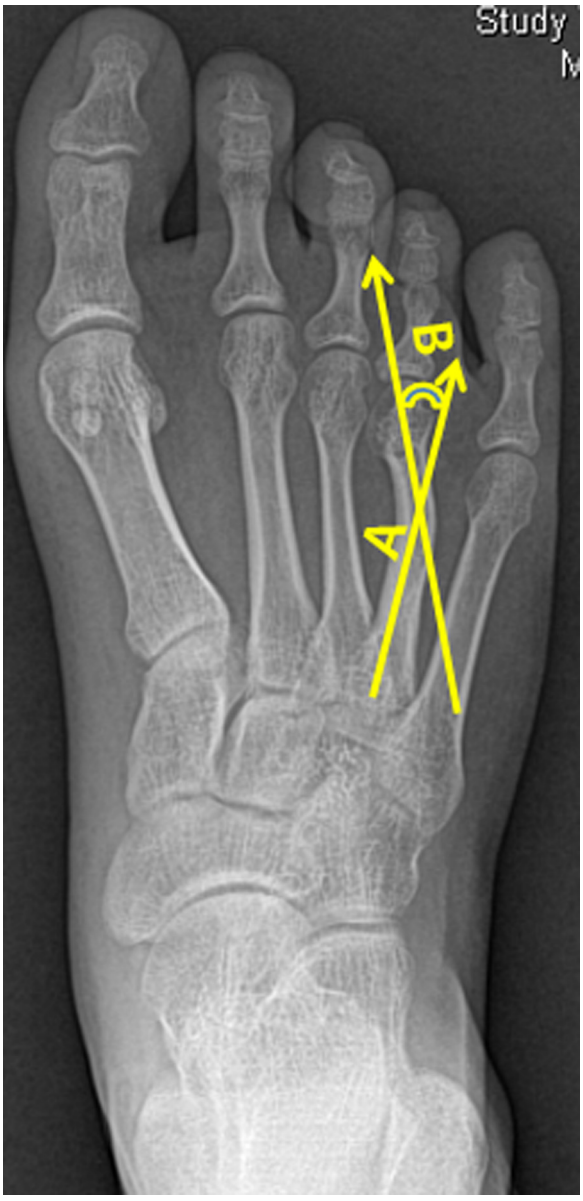

Fig 4. Malalignment angulation of metatarsal bone was obtained on post-operative standing foot x-ray. If it was greater than 15 degrees and there was pain, it was regarded as a complication.

Fig. 5. Postoperative x-ray of patients who underwent both 1st and 4th surgery.

cleaned the pin insertion site with betadine solution and used dry gauze daily.

We considered consolidation when three cortex unions were observed and there is no pain at weight bearing. All the procedures were performed by one surgeon (Shim JS).

4. Results

The mean lengthening gain was 21 mm (53%) in Group A and 17.6 mm (36.3%) in Group B. The mean healing index was 66 days/cm in Group A and 69.6 days/cm in Group B (Table 2). The mean malalignment angulation of metatarsal bone was 0° in Group A and varus 4.85° in Group B without symptoms. Two metatarsal bones were valgus angulation (15.4°, 5.7°) in Group B. The point of metatarsal bone malalignment included middle portion (14 metatarsals) and distal portion (11 metatarsals) in Group B. The angular deformity did not occur in the proximal portion. It only occurred in the middle and distal portions without clinical significance. HVA was significantly changed 6.68–14.04° in Group A. IMA was changed 7.71–10.36° in Group B. MIA was changed 29.4–24.6° in Group A (Table 3). The complication rate in Group A (40%) was higher than that in Group B (18.9%). Lengthening gain, malalignment angulation of metatarsal bone, and complication rate were significantly ($p < 0.05$) different between the two groups. Total numbers of complications were 22 (Table 4). The most common complication was metatarsophalangeal joint (MPJ) stiffness which occurred in 6 metatarsal bones in Group A. In Group B, angular deformity and pin-track infection were the most common complications. Hallux valgus, pin-track infection, and nonunion were observed in Group A. In case of nonunion, union was obtained by internal fixation using plate and auto iliac bone graft (Fig. 6). MPJ dislocation and MPJ osteoarthritis were observed in Group B. In case of MPJ dislocation, trans-articular fixation of Kirschner wire was performed and kept for one month (Fig. 7). All pin-tract infection cases were recovered by intravenous antibiotics and meticulous daily dressing. Those with high percentage of lengthening gain were more likely to have complications. A cut-

Table 2
Lengthening index (min–max).

Variable	Group A (1st)	Group B (4th)	p-Value
Final lengthening (mm)	21 (11.1–30.3)	17.6 (9.5–26.6)	0.0027
Lengthening gain (%)	53 (28–75.5)	36.3 (15.6–62.1)	<0.0001
Healing index (days/cm)	66 (38.1–159.1)	69.6 (31.4–132.8)	0.4716

Table 3
Preoperative and postoperative radiologic parameters (min–max).

	Group A (1st)		p-Value	Group B (4th)		p-Value
	Pre OP.	Post OP.		Pre OP.	Post OP.	
HVA	6.68 (0.3–27.5)	14.04 (1.5–39.3)	<0.0001	17.89 (4.1–28.5)	17.45 (5.9–33.8)	0.262
IMA	8.08 (0.76–16.6)	8.15 (0.76–13.3)	0.905	7.71 (0.1–13.8)	10.36 (5.2–16.7)	<0.0001
MIA	29.4 (16.6–34.9)	24.6 (19–36.2)	<0.0001	23.38 (14.3–36.9)	23.88 (18.3–30.7)	0.078

Table 4
Complications during distraction osteogenesis on 1st and 4th brachymetatarsia.

	Group A (1st)	Group B (4th)
Complications (n, metatarsal)	12 (40%)	10 (18.9%)
MPJ stiffness	6	0
Hallux valgus	3	0
Non-union	1	0
Pin-track infection	2	4
Angular deformity	0	4
MPJ osteoarthritis	0	1
MPJ dislocation	0	1

off value for lengthening gain developing complication was 41.3%. Its sensitivity and specificity were 0.73 and 0.62, respectively. The area under the curve was 0.733 (Fig. 8). According to these results, patient with lengthening gain of 41.3% and above will have more chance to develop complications.

5. Discussion

Several surgical technique have been used for the treatment of brachymetatarsia [3,4,7]. One-stage lengthening has advantage in that it does not require external fixator. However, it also has several disadvantages with limitation of length gain and problem of donor site. Shortening osteotomy also has cosmetic limitation. On the other hand, gradual distraction osteogenesis is a good surgical option in brachymetatarsia. It has been used widely [2–4].

In many papers, healing index of distraction osteogenesis is different. The healing index of the 1st brachymetatarsia ranges from 60.0 to 98.0 days/cm. The healing index of the 4th brachymetatarsia ranges from 43.4 to 82.0 days/cm [2–4,8,9]. Choi et al. have suggested that the 1st metatarsal is higher than 4th metatarsal in healing index [4]. However, Oh et al. and Kim et al. have suggested that there is no significant difference in healing index between the 1st and 4th metatarsal [2,8]. Wada et al. and our previous paper have suggested 4th metatarsal is higher than the 1st metatarsal in healing index [3,9]. This study also revealed that the healing index of 4th metatarsal was higher than the 1st, although the difference between the two was not statistically significant. Recently, several complications of distraction osteogenesis in brachymetatarsia have been reported. MTP joint stiffness is the most common complication [5–7]. Hallux valgus and cavus deformity were found in treatment of the 1st brachymetatarsia in this study. On the other hand, MTP joint subluxation was found in treatment of the 4th brachymetatarsia.

Song et al. [10] have reported that MTP joint stiffness is the most common complication when lengthening gain is over 40%. When lengthening gain is under 40%, angular deformity and pin track infection are the most common complications [10].

In our study, complication rate in the 1st metatarsal was significantly higher than that in the 4th. MTP joint stiffness was the most common complication in treatment of the 1st brachymetatrsia similar to results of previous studies. However, for distraction osteogenesis in the 4th brachymetatarsia, the most common complications were angular deformity and pin-track infection.

Several studies have tried to reduce the incidence of complication during distraction osteogenesis. Oh et al. have used a Kirschner wire to fix the interphalangeal and

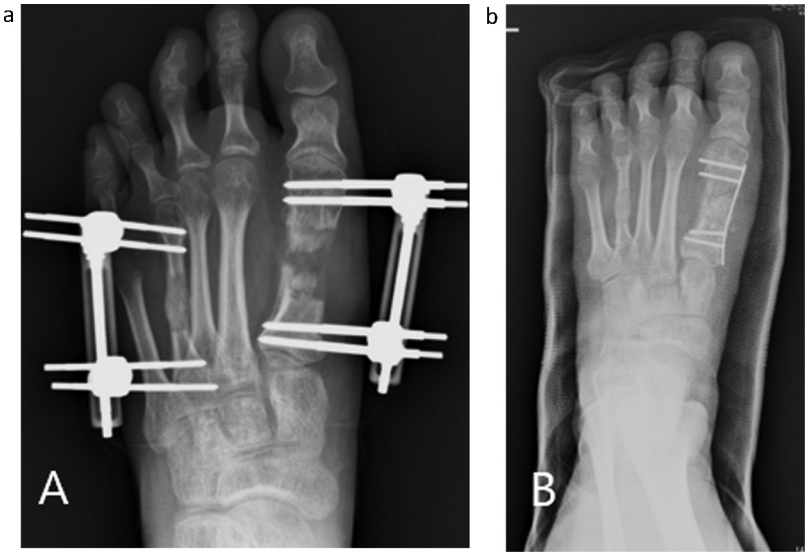

Fig 6. A- Non-union occurred in 1st metatarsal after distraction osteogenesis on 1st and 4th brachymetatarsia. B- Plating and auto-bone graft were performed on nonunion site of 1st metatarsal bone.

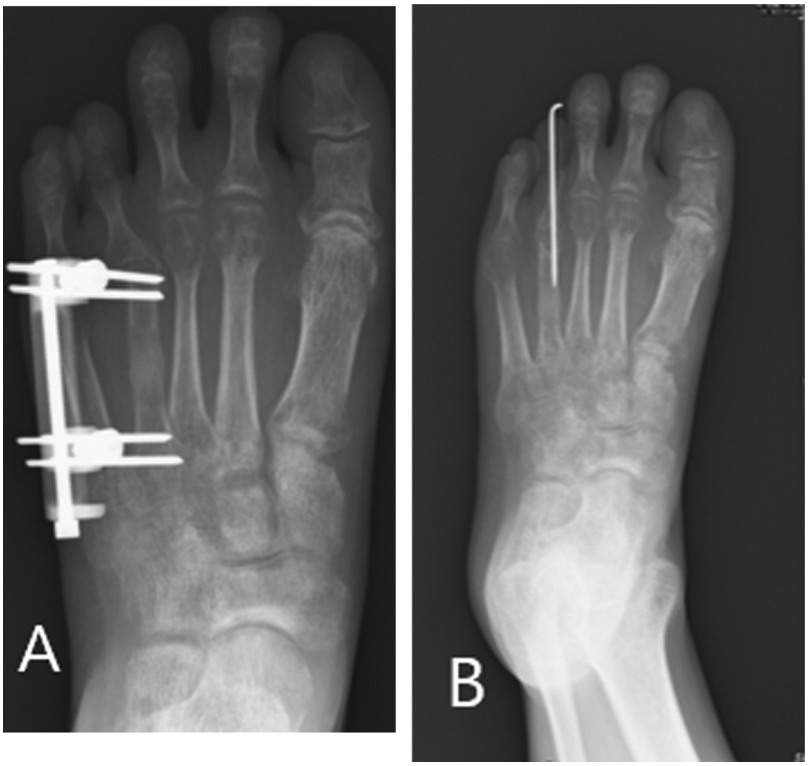

Fig. 7. A -Dislocation of 4th MPJ during distraction osteogenesis on 4th brachymetatarsia. B- After distraction osteogenesis, transarticular fixation was performed using Kirschner wire.

metatarsophalangeal joints to prevent subluxation and stabilize the joints [8]. However, this procedure is likely to cause MPJ stiffness. Early removal of the Kirschener wire failed to prevent stiffness of MPJ [6]. Therefore, Lamm et al. [11] have used bridging external fixator across the MPJ to prevent joint stiffness following gradual distraction osteogenesis with Kirschner wire across the joint. According to them, an external fixator consisting of six half-pins was used to stretch MPJ during distraction osteogenesis on metatarsal bone. They have reported that this procedure has shown good results [11].

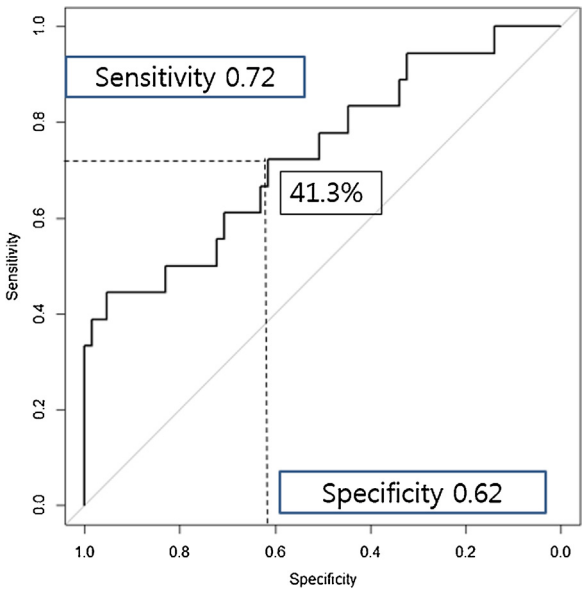

Fig 8. ROC curve for lengthening gain (%).

Unfortunately, no studies have compared the incidence of complications between Kirschner wire and additional external fixator. Nevertheless, both procedures can be used as surgical options. Using the temporary pinning or additional external fixator method shown above is expected to reduce complications.

Our study has several limitations. First, only one conventional external fixator was used without considering the above surgical options. Another limitation of our study was that we did not distinguish between bilateral cases and unilateral cases. In our study, there were 25 bilateral brachymetatarsia patients and 17 patients had both 1st and 4th brachymetatarsia simultaneously. Thus, there was a difference in operation time depending on the position and bilaterality. In addition, we did not rule out differences in factors that could lead to postoperative complications such as hematoma and pain. Patients who underwent surgery on both sides were in severe pain. They presumably had delayed joint movement.

According to our study results, more attention needs to be given when performing distraction osteogenesis for brachymetatarsia with lengthening gain of more than 41.3%. When performing lengthening in 1st metatarsal bone and 4th metatarsal bone, scrupulous care is necessary for MPJ stiffness and hallux valgus in 1st metatarsal bone and angular deformity and pin-track infection in 4th metatarsal bone. If more cases can be collected and studied in a divided subgroup, it will provide more helpful information on clinical treatment of brachymetatarsia.

Conflict of interest

Each author certifies that his or her institution has approved the human protocol for this investigation, all investigations have been conducted in conformity with ethical principles of research, and informed consent for participation in the study has been obtained.

Each author certifies that he or she has no commercial associations that might pose a conflict of interest in connection with the submitted article.

This study was performed at Sungkyunkwan University School of Medicine, Korea.

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