Extra-articular dorsal closing-wedge osteotomy to treat late-stage Freiberg disease using polyblend sutures: technical tips and clinical results

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Abstract

Purpose The purpose of this study was to evaluate the clinical outcomes regarding the dorsal wedge osteotomy fixed using a polyblend suture and describe the usefulness of this fixation method for the treatment of Freiberg disease.

Methods The subjects consisted of 13 feet from 13 cases suffering from Freiberg disease that underwent extra-articular dorsal closing-wedge osteotomy using a polyblend suture. The average age was 31.7 (range 13–72) years. The average follow-up period was 17 (range 14–24) months. Regarding image findings, time to bone union and metatarsal shortening was reviewed. The investigation was carried out using the range of motion (ROM), visual analog scale (VAS), and Japanese Society of the Surgery of Foot lesser toe scale (JSSF score) in the MTP joint before surgery and at the latest follow-up.

Results Calluses under the metatarsal head were not observed in any cases. The mean metatarsal shortening was 2.33 ± 2.07 mm at follow-up. The bone union required an average of 8.4 ± 0.8 weeks. The average ROM of dorsal flexion improved from $37.2 \pm 5.3^\circ$ before surgery to $73.6 \pm 9.9^\circ$ at latest follow-up ($p < 0.0001$). The average ROM of plantar flexion improved from $16.0 \pm 10.1^\circ$ before surgery to $19.5 \pm 8.6^\circ$ at latest follow-up ($p = 0.35$). The average VAS significantly improved from 75.3 ± 8.5 before surgery to 4.9 ± 4.2 at latest follow-up ($p < 0.0001$). The average JSSF score significantly improved from 67.3 ± 9.4 points before surgery to 98.8 ± 3.0 points at the latest follow-up ($p < 0.0001$).

Conclusion Extra-articular dorsal closing-wedge osteotomy using a polyblend suture was carried out to treat Freiberg

disease. The bone union was observed in all cases with improved clinical results. Fixation using a polyblend suture was considered to be useful.

Keywords Freiberg disease · Polyblend suture · Closing-wedge osteotomy · Metatarsal

Introduction

Freiberg disease, which was first reported in 1914, involves osteonecrosis of the metatarsal head, and it is characterized by pain, bloating, and articular inflammation of the metatarsophalangeal (MTP) joint. Although the cause of Freiberg disease remains unclear, injury, continued stress, and vascular insufficiency have been reported [1]. Treatments for this disease consist primarily of conservative therapy, such as activity restriction and using orthoses or casts. Surgical treatment is typically only performed when conservative therapy fails. Although various operative procedures, including resection arthroplasty, joint debridement, osteotomy, and osteochondral transplant, have been reported, no consensus regarding the best surgical approach has been reached to date [2–12]. Gauthier and Elbaz reported good results for dorsal intra-articular closing-wedge osteotomy procedures regardless of the disease stage [4].

Various methods have been reported for fixing osteotomy sites. In the report by Gauthier and Elbaz, cerclage wire was used to fix the osteotomy site [4]; however, tendinitis occurred in the extensor tendon, and wire removal was required. Kinnard used an absorbable suture, but these types of sutures are reportedly too weak for fixing [8]. Chao used a temporal cross-pinning of Kirschner wire (K-wire) for fixation [3]. Although the procedures associated with this method are simple, the removal of metal objects is required, and early

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range of motion (ROM) training cannot be conducted. Lee et al. have reported a fixing method using absorbable poly-L-lactic acid (PLLA) pins [9]. Although no inflammatory foreign-body reactions occurred in the Lee et al. study, PLLA pins have been reported to increase the risk of these reactions and are thus problematic for intra-articular use.

Polyblend sutures (FiberWire suture; Arthrex Inc., Naples, FL, USA) have sufficient strength for fixing, and they have been used for suturing the meniscus of the knee joint, for fractures of the tibial intercondylar eminence, and for suturing rotator cuff tears in the shoulder joint [13–21]. We have been using polyblend sutures to fix osteotomy sites since 2008. In this study, we investigated bone union and the clinical results of cases in which the osteotomy site was fixed using polyblend sutures. The usefulness of this fixing method was also investigated, as was the utility of operative procedures using polyblend sutures.

Subjects and methods

Patients

This study was approved by the Institutional Review Board of our university and was performed in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki. The subjects consisted of 13 individuals (four men and nine women) with late stage Freiberg disease (stage III to V), each of whom underwent an extra-articular dorsal closing-wedge osteotomy using polyblend sutures between 2008 and 2011. The average age of the study population was 31.7 years (range, 13–72). Using the disease stages described by Smillie, three cases were in stage III, five cases were in stage IV, and five cases were in stage V [1]. The average follow-up period was 17 months (range, 14–24 months).

Operative techniques

All surgeries were conducted with the patient in a supine position under general anaesthesia using an air tourniquet. A longitudinal approach was used to expose the metatarsal head. The free body inside the joint was extracted to excise the inflammatory synovium and the spur in the metatarsal bone. Burr holes were made using 0.035-in K-wire 5-mm proximal and 5-mm distal from the osteotomy site in the neck of the metatarsal bone. An 18-gauge cannula was then implanted in the distal burr hole. After passing a 3–0 nylon suture inside the cannula (Fig. 1a), the cannula was extracted, leaving the nylon suture in place. A polyblend suture was then passed inside the burr hole using the nylon suture as a guide (Fig. 1b, c). Next, the same procedure was performed in the proximal burr hole (Fig. 1d) and the back of the metatarsal bone neck was excised by approximately 5–7 mm (Fig. 1e). The distal side was pushed

from the bottom of the metatarsal head for dorsal flexion. The osteotomy site was fixed in place with a polyblend suture using the figure eight suturing method (Fig. 1f, g). Splint immobilization was maintained for one week after surgery, and weight-bearing training commenced following the removal of the splint. The transition to full weight-bearing occurred over a period of three weeks, and ROM training was commenced two weeks after surgery if there was no pain.

Evaluation of patients and operative parameters

For each clinical evaluation, an objective evaluation was conducted using the Japanese Society of the Surgery of the Foot (JSSF) lesser toe scale (JSSF score) and visual analogue scale (VAS) [22, 23]. The ROM in the MTP joint was measured before and after surgery. Postoperative radiographs were obtained during follow-up appointments at two, four, eight, 12, and 16 weeks and at six and 12 months after surgery and yearly thereafter until the last follow-up. Radiographic union was defined as the appearance of bridging trabeculae across the osteotomy site. In addition, morphological changes in the metatarsal head were also evaluated. Regarding the occurrence of brachymetatarsia after surgery, the second or third metatarsal bone length (A) and the first metatarsal bone length (B) were measured upon X-ray imaging during the load prior to surgery and at the latest follow-up. The amount of shortening prior to and following surgery was measured using the following formula in accordance with the report by Lee et al. [9] (Figs. 2).

$$\text{Metatarsal shortening} = A_{\text{preoperation}} \times \left(B_{\text{postoperation}} / B_{\text{preoperation}} \right) - A_{\text{postoperation}}$$

Regarding the radiographs, synostosis was confirmed, and two board-certificated orthopaedists specializing in foot and ankle surgery evaluated any changes in the epiphysis.

Statistical analysis

Paired t tests were used to compare the clinical evaluations prior to and following surgery. The threshold of significance was set at $P < 0.05$.

Results

Clinical outcomes

The average JSSF score improved from 67.3 ± 9.3 points before surgery to 98.8 ± 3.0 points at the time of the latest follow-up observation ($P < 0.0001$) (Table 1). The average VAS significantly improved from 75.3 ± 8.5 before surgery to 4.9 ± 4.2 at latest follow-up ($P < 0.0001$). The ROM improved from an average dorsal flexion of $37.2 \pm 5.3^\circ$ before

Fig. 1 The photographs of saw bone show the dorsal part of the metatarsal for osteotomy. **a** An 18-gauge cannula was implanted in the distal hole and a 3–0 nylon suture was passed inside the cannula. **b** A #2 polyblend suture was passed inside the loop of nylon suture. **c** The polyblend suture was passed inside the distal hole. **d** The polyblend suture was passed inside the proximal hole using the same technique of distal hole. **e** The dorsal wedge osteotomy was performed. **f** The plantar portion of the metatarsal head was rotated and fixed with a polyblend suture. **g** The osteotomy site was fixed in place with a polyblend suture using the figure eight suturing method

surgery to $73.6 \pm 9.9^\circ$ at the latest follow-up appointment ($P < 0.0001$). Plantar flexion improved from an average of $16.0 \pm 10.1^\circ$ to an average of $19.5 \pm 8.6^\circ$ at the time of the last follow-up ($P = 0.35$). In addition, pain upon walking and running improved in all cases. None of the athletes experienced pain, and a level of sports activity above the pre-operative level was achieved. Moreover, no transfer metatarsalgia cases were observed. In addition, no cases of floating-toe deformities were observed following osteotomy (data not shown).

Radiographic outcomes

The average metatarsal bone length had shortened to 2.33 ± 2.07 mm at the time of the latest follow-up appointment (Table 1). Bone union required an average of 8.4 ± 0.8 weeks (range, seven to ten weeks). No joints exhibited changes in osteoarthritis (OA) in the MTP joint at the latest follow-up. Moreover, no progression of osteonecrosis was observed in any of the examined cases (Fig. 3).

Fig. 2 A standard X-ray illustrating the method used to measure the length of the second metatarsal. Lines A and B are drawn along the longitudinal axis of the metatarsals. Metatarsal shortening was calculated using the following equation: Metatarsal shortening = $A_{\text{preoperative}} \times (B_{\text{postoperative}}/B_{\text{pre-operative}}) - A_{\text{postoperative}}$

Fig. 3 A 14-year-old boy with Freiberg disease (Case 1). **a** A pre-operative radiograph revealed marked flattening of the metatarsal head and degenerative arthrosis with narrowing of the joint (Smillie stage IV). **b** The metatarsal head had been completely remodeled two years after the operation

Discussion

Metatarsal dorsal closing-wedge osteotomy for Freiberg disease is a surgical technique that aims to recover the congruity of the joints of the normal articular surface at the bottom of the metatarsal head. We performed intra-articular debridement, spur excision, and extra-articular metatarsal dorsal closing-wedge osteotomy for Freiberg disease, and good results were obtained. To date, good results have been reported for both intra-articular and extra-articular cases using metatarsal dorsal closing-wedge osteotomy. Gauthier and Elbaz reported 53 cases of intra-articular closing-wedge osteotomy in 1979 [4].

They used cerclage wire to fix the osteotomy site. According to their report, pain persisted in only one of the 53 cases. However, the use of cerclage wire has been associated with tendinitis in the extensor tendon. Accordingly, removal of the cerclage wire is required following bone union. Kinnard et al. used an absorbable suture to fix the intra-articular closing-wedge osteotomy site [8], but fixation using absorbable sutures is relatively weak and is thought to cause a loss of reduction and/or synostosis failure [9]. Chao et al. reported temporal cross-pinning using K-wire in 13 cases [3]. Although this simple technique leads to strong fixation, there are problems associated with infection, migration, and friction of soft tissues. Moreover, the wire needs to be removed before weight-bearing and ROM training. Lee et al. also reported cross-pinning using K-wire in 13 cases and noted that bone union was obtained following an average of seven weeks [10]. Lee et al. performed a fixing method using absorbable pins for intra-articular closing-wedge osteotomy and observed bone union after an average of ten weeks [9]. Although delayed healing was observed in one of the 13 cases examined, the authors reported that the other patients recovered well and were able to enjoy recreational activities within four months. However, because of the relatively weak fixing force of a single absorbable pin, multiple pins were required.

In this study, polyblend sutures were used for fixation following extra-articular dorsal closing-wedge osteotomy. The ROM of the MTP joint dramatically improved following surgery. ROM training was possible at an earlier stage than is feasible using fixation by K-wire, absorbable pins, or absorbable sutures without friction with soft tissues. Based on these data, the use of polyblend sutures for fixation is considered effective.

Table 1 Details of 13 patients with Freiberg disease and follow-up results

Case	Age (years)	Sex	Side	Smillie stage	Preop JSSF	Postop JSSF	Preop VAS	Postop VAS	Metatarsal shortening (mm)	Preop DF	Postop DF	Preop PF	Postop PF	Union (weeks)
1	14	M	L	IV	54	100	74	14	4.27	31	70	12	22	8
2	72	M	L	V	77	100	62	4	4.69	33	79	32	18	8
3	20	F	L	IV	68	100	84	5	−0.58	40	80	5	18	8
4	53	F	L	V	77	95	76	0	0.34	38	63	0	20	9
5	65	F	L	V	77	90	82	5	−0.30	28	52	0	22	10
6	16	F	L	IV	54	100	82	10	5.89	42	82	25	42	7
7	59	F	R	V	68	100	56	6	2.97	33	65	14	8	9
8	26	F	R	III	68	100	78	9	4.72	45	84	22	8	9
9	13	M	L	IV	82	100	82	5	0.53	32	71	12	16	8
10	13	F	L	III	64	100	82	2	2.17	38	72	22	15	8
11	18	F	L	II	64	100	68	4	2.11	43	85	15	25	8
12	28	M	R	II	54	100	76	0	2.00	42	84	24	24	9
13	15	F	R	III	68	100	77	0	1.53	39	70	25	15	8

JSSF The Japanese Society of the Surgery of the Foot, VAS visual analogue scale, DF dorsiflexion, PF plantarflexion, M male, F female, L left, R right

The occurrence of a floating toe accompanying dorsal flexion of the metatarsal head is one problem that has been associated with extra-articular dorsal closed-wedge osteotomies. Several published studies have reported the floating toe phenomenon, but no such instances were observed in this study. This lack and the early ROM training are likely because no reductions in the ROM of the plantar flexion were observed in this study.

The transfer metatarsalgia is another problem with this osteotomy. In the present study, the metatarsalgia was not observed. Usually the elevation of the metatarsal head has occurred. This is because of the reduced loading on the metatarsal head.

Kinnard and Lirette performed intra-articular dorsal closed-wedge osteotomies to treat 15 cases of late-stage Freiberg disease [8]. They reported that the average amount of brachymetatarsia observed following surgery was 2.5 mm. The average amount of brachymetatarsia following surgery in our study was also 2.5 mm. Moreover, neither transfer metatarsalgia accompanying shortening of the metatarsal bone nor floating toe was observed in the present study. Thus, it appears that the amount of shortening of the metatarsal bone accompanying osteotomy in our study was controlled without any problems.

There are several limitations associated with our case series. First, this study was retrospective and not comparative. However, we kept very careful records at each visit according to a strict protocol. Second, the number of participants was too small to draw any definitive conclusions. As a result, additional prospective and long-term follow-up studies with more patients and control groups will be required to elucidate the efficacy of extra-articular dorsal closing-wedge osteotomy using polyblend sutures for the treatment of Freiberg disease.

In conclusion, extra-articular dorsal closing-wedge osteotomy of the metatarsal using polyblend sutures is considered to be an effective and useful operative procedure for Freiberg disease. This technique improves joint congruence and is capable of obtaining good synostosis without the association of any complications.

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