First MTP Joint Distraction Arthrodesis With Cancellous Autograft and Bridge Plating: A Novel Surgical Technique to Restore Maximum Length

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Abstract: A novel technique used in a small series of patients is presented that describes a management option for the difficult situation of hallux metatarsophalangeal pathology with associated first-ray shortening and transfer lesions. Distraction arthrodesis was performed using proximal tibial cancellous autograft and locked plating to achieve an average of 10.6 mm length restoration with all patients showing radiographic signs of union by the eighth postoperative week and resolution of transfer metatarsalgia. This novel technique shows promise for reliable outcomes in a variety of historically difficult clinical situations such as inflammatory arthritis and salvage arthrodesis.

Level of Evidence: Diagnostic Level 4. See Instructions for Authors for a complete description of levels of evidence.

Key Words: metatarsophalangeal arthrodesis, distraction arthrodesis, bridge plating, cancellous autograft, technique

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LEARNING OBJECTIVES

After completing this activity, the learner should be better able to:

1. Select and recognize patient-specific indications for revision hallux metatarsophalangeal joint surgery.
2. Identify patients at risk of complications from revision hallux metatarsophalangeal joint surgery.
3. Understand the aims of a novel surgical technique.

HISTORICAL PERSPECTIVE

Arthrodesis of the first metatarsophalangeal (MTP) joint is a commonly performed salvage procedure with predictable outcomes in the treatment of end-stage hallux rigidus and failed hallux valgus surgery. Previous authors[1–3] have also reported on first MTP arthrodesis with structural bone graft in the instance of significant shortening of the first ray. Although good results have been reported with this technique, it necessitates the harvest of iliac crest bone graft (ICBG) or the use of structural allograft in combination with costly osteoinductive biologics.

It can additionally be challenging to contour the structural graft precisely to regain the maximum length while achieving appropriate axial and sagittal plane alignment, and even more challenging to achieve consistent union at the 2 primary bone-healing interfaces. Although union rates for primary arthrodesis of the first MTP joint have been reported at up to 100%,[4] nonunion rates for first MTP arthrodesis using structural autograft or allograft range from 13% to 31%.[2,3]

Distraction arthrodesis using cancellous autograft and bridge plating offers greater restoration of length through the arthrodesis site and greater forgiveness in achieving proper axial and sagittal plane alignment, while obviating the need for ICBG harvest or the use of expensive biological additives by exploiting the patient's inherent biology for osteoinduction and osteoconduction.

To our knowledge, there have been no previous reports of first MTP distraction arthrodesis with proximal tibial cancellous autograft and locked bridge plating. This novel technique provides relative stability to the arthrodesis construct, which, by definition, promotes secondary bone healing much like the use of locked plating in comminuted metadiaphyseal long-bone fractures. In our experience, restoration of up to 12 mm of length has been achieved successfully without any nonunions.

INDICATIONS AND CONTRAINDICATIONS

Although the indications and the contraindications are similar to those reported previously for traditional first MTP

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arthrodesis techniques, this technique is especially useful in the setting of significant first-ray shortening necessitating restoration of length.

Specific indications for this technique include failed hemiarthroplasty or total joint arthroplasty, failed hallux valgus surgery with first-ray shortening, first metatarsal head osteonecrosis with first-ray shortening, failed silastic arthroplasty, or posttraumatic hallux rigidus with first-ray shortening. Although there is no defined amount of shortening that would indicate this procedure, we have used this technique for situations in which subchondral plates of the metatarsal head and/or the proximal phalanx are absent, combined with transfer metatarsalgia clinically.

Contraindications for this technique include end-stage hallux rigidus without first-ray shortening, active infection, or the inability to obtain sufficient cancellous autograft.

PREOPERATIVE PLANNING

Preoperative planning includes a thorough history and physical examination, and standard weight-bearing radiographs of both feet. Clinical evaluation should include the assessment of the ankle joint range of motion and heelcord flexibility, the assessment of the skin and the soft tissue envelop surrounding the first MTP joint, including any previous incisions, interphalangeal joint motion of the great toe, the presence or the absence of angular deformity or contractures through the first MTP joint, and the extent of first-ray shortening relative to the contralateral side.

Radiographic evaluation includes the presence or the absence of indwelling implants, the presence or the absence of angular deformity through the first MTP joint, the presence or the absence of osteonecrosis of the first metatarsal head, and the extent of first-ray shortening relative to the contralateral side.

THE SURGICAL TECHNIQUE

- The patient is placed supine on the operating room table, and a pneumatic tourniquet is placed high on the ipsilateral thigh. A nonsterile bolster is placed beneath the ipsilateral hip where necessary. The involved limb is prepped and draped, ensuring exposure of the limb proximal to the knee joint.
- A standard dorsal approach to the hallux MTP is performed. Deep dissection continues through the extensor hallucis longus tendon sheath along the medial border of the tendon. An arthrotomy is performed, and subtotal capsulectomy and synovectomy is completed. The collateral ligaments are released to afford maximum joint exposure. Removal of any previous implants or fixation is performed when applicable.
- The plantar plate is released off the proximal phalanx where needed to facilitate maximum joint distraction.
- Surfaces of the first metatarsal and the proximal phalanx within the first MTP joint are denuded of residual articular cartilage or fibrous debris with a small osteotome or a sharp periosteal elevator. The joint is irrigated and the bony surfaces are drilled with a 2.0-mm drill bit to promote subchondral bleeding.
- The first MTP joint is provisionally distracted with a medium AO lamina spreader to the desired amount, and the extent of the bony defect is estimated.
- The proximal tibia is exposed anteromedially, distal to the knee joint line and overlying the pes insertion. A cortical window is created with an osteotome, and the appropriate amount of proximal tibial cancellous autograft is harvested and preserved on the back table. The cortical window is replaced, and the wound is closed in a layered manner.
- With the laminar spreader applying maximum distraction, provisional alignment is assessed both clinically and under fluoroscopic control. The autograft is placed at the arthrodesis site, and manually packed while ensuring contact of the cancellous autograft with both bony surfaces (Fig. 1).
- A 2.7-mm locking compression plate is selected and provisionally placed traversing the first MTP joint to ensure balanced fixation proximally and distally. The plate is first secured to the proximal phalanx with a 2.7-mm cortical screw placed immediately distal to the first MTP joint, followed by a 2.7-mm locking screw through the distal most screw hole in the plate.
- Additional length can be obtained where necessary through additional distraction with the laminar spreader. The plate is then secured provisionally to the first metatarsal with a 2.0-mm Kirschner wire through the distal portion of one of the proximal screw holes within the plate.
- Provisional alignment is again assessed both clinically and radiographically. Weight-bearing alignment is simulated by applying pressure to the plantar aspect of the foot with the lid of the screw caddy and a mallet while obtaining a lateral fluoroscopic view of the ankle and the foot. We consider optimal first MTP joint alignment to be slight valgus and symmetric to the contralateral side in the anterior-posterior plane, and slight dorsiflexion in the sagittal plane such that a finger breadth will easily slide between the distal phalanx and the flat plate. This position should allow sufficient compensatory IP joint motion to facilitate a heel-to-toe gait.
- With proper provisional alignment confirmed, the plate is then secured to the first metatarsal with a 2.7-mm cortical screw placed immediately proximal to the first MTP joint. A 2.7-mm locking screw is placed through the proximal most screw hole within the plate. An additional 2.7-mm locking screw may be placed between the 2 proximal screws where necessary (Fig. 2).
- Final clinical and radiographic alignment is confirmed as described above. The extensor hallucis longus tendon sheath is closed meticulously with a 2-0 absorbable suture, followed by a running horizontal mattress skin closure with a 3-0 monofilament suture. A soft toe-spica type dressing and low-top fracture boot is applied.

RESULTS

The senior author has performed this technique on 6 patients. Each patient presented with a different first MTP pathology with significant associated first-ray shortening and transfer metatarsalgia.

Case 1

A 34-year-old man, 6'5" and 250 lbs, presented with a failed first MTP hemiarthroplasty and shortening-dorsiflexion first metatarsal osteotomy performed elsewhere. There was no history of wound-healing difficulties or infection; there was a 10-degree arc of motion in the first MTP joint. Standing radiographs showed a grossly loose prosthesis positioned in the excessive valgus and 12 mm of first-ray shortening (Figs. 3A, B). Intraoperatively, end-stage chondral changes on the first metatarsal head were noted and cultures were negative. Nine months' postoperative standing radiographs demonstrated

maintained alignment and radiographic evidence of arthrodesis union (Figs. 4A, B).

Case 2

A 63-year-old woman with a history of a failed bunion correction elsewhere presented with a 15-degree arc of motion in the first MTP joint. Standing radiographs revealed 10 mm of first-ray shortening and sclerotic changes to the first MT head suggestive of osteonecrosis, which was confirmed intraoperatively.

Case 3

A 65-year-old man with nondiabetic peripheral neuropathy and multiple other medical problems presented with significant swelling, erythema, and mild pain after minor trauma. There was no history of gout or signs of infection. Initial radiographs showed destructive changes of the first MTP joint suggestive of neuroarthropathy. The patient had persistent mechanical pain, limited radiographic healing, and 8 mm of first-ray shortening despite several months of boot immobilization and protected weight-bearing. A large gouty tophus and osteonecrosis of the first metatarsal head were identified intraoperatively.

Case 4

A 61-year-old woman with a history of end-stage hallux rigidus presented with a chronic first MTP arthrodesis nonunion. The patient had undergone an attempted first MTP arthrodesis elsewhere, which was complicated by a deep infection, and was further treated with multiple debridements, hardware removal, and placement of an antibiotic-laden methylmethacrylate spacer several months previously. The patient exhibited minimal first MTP motion. Standing radiographs showed the antibiotic spacer and 11 mm of first-ray shortening. Intraoperative cultures were negative and there was no clinical evidence of residual infection.

Case 5

A 58-year-old woman presented with a history of a failed first MTP hemiarthroplasty performed elsewhere. She exhibited a 20-degree dorsiflexion contracture at the first MTP joint with a painful hypertrophic callus underlying the first metatarsal head, and transfer metatarsalgia. Standing radiographs revealed a loose hemiarthroplasty and 11 mm of first-ray shortening.

Case 6

A 52-year-old male laborer, 6'1" and 270 lbs, presented after a shortening distal first metatarsal osteotomy performed elsewhere for apparent hallux rigidus. Standing radiographs revealed a healed distal metatarsal osteotomy and 12 mm of first-ray shortening, as well as a second metatarsal stress fracture.

All 6 patients had clinical and radiographic evidence of arthrodesis union at an average of 8 weeks postoperatively. Although CT scanning of the arthrodesis site may allow more detailed information regarding the union, we do not regularly obtain advanced imaging for this purpose unless the clinical and radiographic evidence of union is not convincing. In addition, metal artifacts might make appropriate investigation of a union difficult in this scenario. An average of 10.6 mm of length restoration of the first ray was achieved through the arthrodesis. There were no infections, no complications at the arthrodesis site, and no complications related to the cancellous autograft donor site. All 6 patients are now fully weight-bearing in a regular shoe without pain, and have returned to their previous level of activity. The most recent follow-up was a 9-month postoperative clinic visit for cases 1 to 4 and a

FIGURE 1. The autograft is placed at the arthrodesis site, and packed manually while ensuring contact of the cancellous autograft with both bony surfaces

FIGURE 2. The 2.7-mm locking compression plate is applied and secured with a combination of cortical and locking screws once appropriate orientation of the joint is confirmed.

FIGURE 3. Preoperative standing AP (A) and lateral (B) radiographs demonstrate a grossly loose prosthesis positioned in the excessive valgus and 12 mm of first-ray shortening in a patient with a failed first metatarsophalangeal hemiarthroplasty and shortening-dorsiflexion first metatarsal osteotomy.

FIGURE 4. Nine-month postoperative standing AP (A) and lateral (B) radiographs demonstrate maintained alignment and radiographic evidence of arthrodesis union.

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3-month postoperative clinic visit for cases 5 and 6. None of these patients have any radiographic suggestion of implant compromise. Transfer metatarsalgia has resolved in all 6 patients.

DISCUSSION

The use of locked plating in first MTP arthrodesis has been investigated with varying results[5,6]; however, the proposed indication for locked plating has not been studied. This technique provides an effective and reliable option when confronted with the difficult situation of first MTP pathology with associated first-ray shortening and transfer lesions. Although we have used this technique in a limited number of patients with short-term follow-up data, we have had significant success in achieving union in varied settings that have proven to be difficult historically, such as inflammatory arthritis and salvage arthrodesis.

There have been 2 large case series published that evaluated the fusion rate in first MTP fusion with effective lengthening using a structural graft. Myerson et al[2] presented a series of 24 patients who had undergone this procedure using structural autografts in 16 patients (ICBG = 15 and distal tibial = 1) and femoral head allografts in 8 patients. They reported nonunion in 5/16 structural autograft patients with 3 of these occurring at the distal end of the graft and 2 at the proximal end. Malhotra et al[3] have recently published a similar series of 25 feet in 24 patients who underwent the aforementioned procedure with autologous ICBG. Three feet went on to nonunion and required additional procedures. Of note, an average first-ray lengthening of 4.4 mm (0 to 8 mm) and 13 mm (0 to 29 mm) were reported in the Malhotra and the Myerson studies, respectively.

The use of the tibial cancellous autograft has been shown to provide up to 5.6 mL of compressed graft volume with minimal morbidity.[7] This graft choice provides an excellent osteoconductive scaffold for callous formation and fusion. Drilling of the articular surfaces further promotes this process by increasing blood flow into the arthrodesis site. A locked plate is utilized as a bridge plate to provide relative stability. This promotes secondary bone healing by callus formation in this vascularized bed rather than relying on primary bone healing at both the proximal and the distal ends of a structural graft. We believe that this will allow for a more predictable and reliable arthrodesis and a lower rate of additional procedures related to nonunions.

POSTOPERATIVE MANAGEMENT

The patient is placed into a low top fracture boot at the time of procedure completion and is restricted to heel-down weight-bearing on the operative extremity for 8 weeks postoperatively. Sutures are typically removed at 2 weeks, and nonstanding radiographs are obtained at 5 weeks. Standing radiographs are obtained at 8 weeks postoperatively, at which point weight-bearing is typically advanced. The patient is transitioned to regular shoe wear as tolerated once able to fully weight-bear in the boot.

POSSIBLE CONCERNS AND THE FUTURE OF THE TECHNIQUE

Further research must be conducted on comparing union rates for first MTP arthrodesis using cancellous autograft with more traditional methods before recommending this method as a standard; however, this method applies well-tested orthopedic principles frequently utilized in fracture care. Comparative and randomized prospective trials are needed to establish this technique as a standard of care. A larger number of patients with a longer follow-up would allow more accurate investigation on union rates and any other possible complications. In addition, CT scanning of the arthrodesis site may provide more accurate determination of union.

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CME QUESTIONS

1. Distraction arthrodesis with cancellous autograft as described above utilizes bone-healing principles that would be seen in which of the following scenarios:

   A. Intramedullary nail fixation of a transverse, diaphyseal femur fracture
   B. Open reduction and internal fixation of a comminuted distal radius fracture
   C. Compression plating of short oblique radius and ulna fractures
   D. Closed reduction and percutaneous pinning of a supracondylar humerus fracture

2. The union rate of revision arthrodesis of the hallux metatarsophalangeal joint with structural bone graft is closest to which of the following?

   A. 30%
   B. 50%
   C. 75%
   D. 95%

3. All of the following are contraindications for distraction arthrodesis of the hallux metatarsophalangeal joint, except:

   A. Infection of the joint
   B. End-stage hallux rigidus without first-ray shortening
   C. Inflammatory arthritis
   D. Inability to obtain adequate cancellous autograft

4. The maximum compressed graft volume harvested from the proximal tibia is closest to which of the following values?

   A. 1 cc
   B. 3 cc
   C. 5 cc
   D. 10 cc

5. Which best describes the orientation in which the hallux metatarsophalangeal joint should be positioned during distraction arthrodesis?

   A. Slight valgus and dorsiflexion
   B. Slight varus and dorsiflexion
   C. Slight valgus and plantar flexion
   D. Slight varus and plantar flexion

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June 2016

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Your completion of this activity includes evaluating it. Please respond to the following questions below.

Please rate these activities (1 — minimally, 5 — completely)	1 2 3 4 5
This activity was effective in meeting the educational objectives	O O O O O
This activity was appropriately evidence-based	O O O O O
This activity was relevant to my practice	O O O O O

Please rate your ability to achieve the following objectives, both before this activity and after it: 1 (minimally) to 5 (completely)

	Pre 1 2 3 4 5	Post 1 2 3 4 5
Select and recognize patient-specific indications for revision hallux metatarsophalangeal joint surgery	O O O O O	O O O O O
Identify patients at risk of complications from revision hallux metatarsophalangeal joint surgery	O O O O O	O O O O O
Understand the aims of a novel surgical technique	O O O O O	O O O O O

How many of your patients are likely to be impacted by what you learned from this activity?
O <20% O 20-40% O 40-60% O 60-80% O >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 — definitely will not change, 5 — definitely will change)	1 2 3 4 5
	O O O O O

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In monitoring patients O	As a foundation to learn more O
In educating students and colleagues O	In educating patients and their caregivers O
As part of a quality or performance improvement project O	To confirm current practice O
For maintenance of board certification O	For maintenance of licensure O

Please list at least one strategy you learned from this activity that you will apply in practice:

_____

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