First Metatarsophalangeal Arthrodesis for Severe Bone Loss

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KEYWORDS

- Metatarsophalangeal joint • Arthrodesis • Bone loss
- Hallux valgus

Severe bone loss of the first metatarsal is a challenging problem for foot and ankle surgeons. The bone loss of the first metatarsophalangeal (MTP) joint may be related to an infection, rheumatoid arthritis–related destruction, and in most cases iatrogenic because of previous hallux valgus or hallux rigidus surgery. Numerous procedures for hallux valgus and rigidus correction have been proposed in the literature, causing various complications, such as hallux varus, first MTP joint instability, infection, recurrent hallux valgus, and avascular necrosis (AVN). A first MTP joint arthrodesis is often the method of choice to salvage this situation.[1–3]

With minimal to moderate bone loss, hallux MTP joint arthrodesis is performed in situ, accepting a slight shortening of the hallux. In the authors' opinion, the slight shortening creates minimal cosmetic concerns and affords satisfactory functional improvement in most cases. Furthermore, the morbidity and risk of complications after in situ fusion is less than after bone block distraction fusion.

When previous surgeries have led to bone loss and shortening of the proximal phalanx or first metatarsal, especially in cases after failed joint implants, prior resection arthroplasty (such as the Keller-type arthroplasty), and revision arthrodesis for healed malunions or nonunions, it is necessary to restore the length of the great toe (**Figs. 1** and **2**).[4] Significant changes of the length of the first ray have a clinical significance, as the first ray, along with the fifth ray and the calcaneus, forms a tripod for weight bearing. Changes in the length of the first ray can cause critical alterations in the biomechanics of the foot, which could potentially allow for partial weight-bearing points of contact.[5] The first ray has been found to support at least one-third of the

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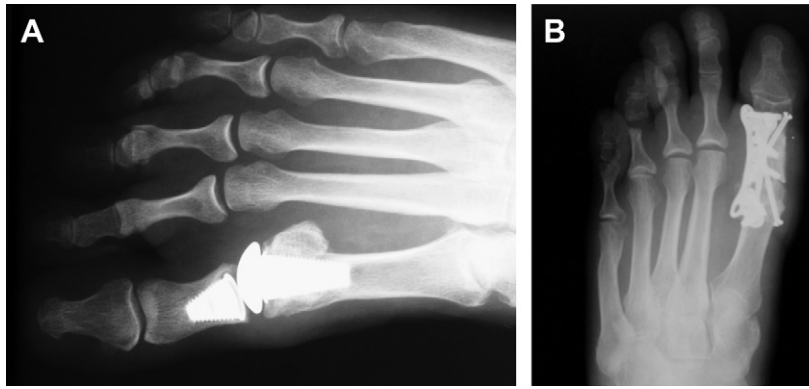

Fig. 1. (*A*) Anteroposterior radiograph of a patient with failed first MTP joint arthroplasty caused by implant malposition. (*B*) A bone block fusion was performed as salvage procedure.

forefoot weight during the stance phase of gait.[6] Furthermore, approximately 40% to 60% of the body weight passes through the first MTP joint and great toe during normal gait.[7] During athletic activities, these forces can approach 2 to 3 times the body weight, especially with jogging and running.[8]

With marked shortening of the hallux and associated lesser metatarsalgia, an in situ hallux MTP joint arthrodesis may fail to restore satisfactory function. An interpositional structural bone graft from the iliac crest is used to restore first ray length, which, in turn, should improve the weight bearing of the first metatarsal and hallux while alleviating lesser metatarsalgia. An interpositional bone graft can accomplish the goals of restoring length and filling defects in the native bone, but making accurate flat surface cuts and achieving proper fusion may be technically difficult.[9–11] A cup-in-cone

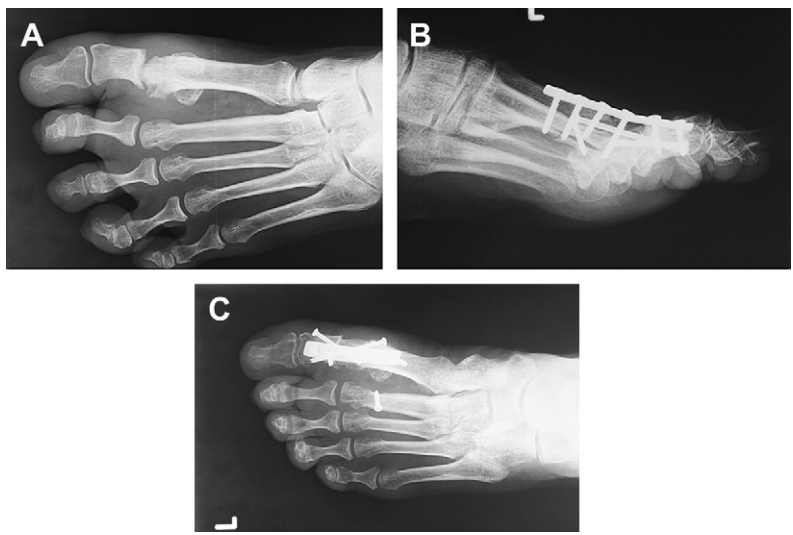

Fig. 2. (*A–C*) Radiographs of a patient after Mayo procedure. Because of severe bone loss, a bone block arthrodesis was performed.

reamer used for contouring the interpositional graft may help to provide proper thickness of the graft to gain length of the great toe.[4]

Sources for structural interposition bone block arthrodesis include the following:

1. Structural allograft (usually contoured from a donor femoral head or iliac crest) or
2. Structural autograft (typically obtained from the patient's iliac crest or lateral aspect of the calcaneus).

Ipsilateral anterior iliac crest harvesting is ideal for foot and ankle surgery because this site is readily accessible in the patient positioned supine on the operating table.

Several methods have been described for contouring the interpositional graft. The authors' method of choice is the ball-and-socket technique, which affords 3 advantages over flat cuts or a conical preparation.

PATIENT HISTORY

The patient's major complaint is pain in the first MTP joint region and/or at the lateral aspect of the forefoot caused by pathologic force distribution during the stance phase of gait (lateralization of center of pressure). The patient's history includes failed primary hallux valgus surgery (especially in cases of previous resectional arthroplasties) or failed primary MTP fusion and total joint alloarthroplasty.[12]

The physical examination should include assessment of the neurovascular status, hallux position, shortening of the first ray, range of motion of the first interphalangeal (IP) joint, and pain and crepitus with range of motion of the hallux. Forefoot pronation and supination with regards to the first ray should be noted.[13] Instrumented examinations like the dynamic plantar pressure analysis could be used to objectively assess abnormalities of the stance phase of gait. In addition, the site of bone graft harvesting (iliac crest, lateral aspect of the calcaneus, proximal tibia) should be inspected for unanticipated soft tissue concerns.

NONOPERATIVE TREATMENT

Nonoperative treatment options include the use of forefoot support provided by custom-made insoles to unload the lesser metatarsal heads. However, for the severely shortened first ray, this treatment option might often be insufficient.

PREOPERATIVE PLANNING

Weight-bearing anteroposterior (AP)- and lateral-view radiographs are taken. In case of residual hallux valgus deformity, the hallux valgus angle and intermetatarsal angle should be assessed in the AP plane. An external oblique view can add information about the amount of the osseous defect.[13] In addition, magnetic resonance imaging of the forefoot might be useful to assess the amount of necrotic bone in cases of AVN of the first metatarsal head.

Preoperatively, it has to be decided if a structural femoral head of iliac crest allograft or an iliac crest autograft will be taken. Both procedures have specific advantages and disadvantages. Theoretically, there is the possibility of transmission of disease and malignancy when using a structural allograft. However, Myerson and colleagues[14] reported no case of transmission of disease in an investigation of structural allografts for foot and ankle surgery. The risk of autologous iliac bone graft is donor site morbidity, including local hematoma, local infection, and local nerve irritation.[15]

A preoperative drawing may help to determine the approximate amount of bone resection and the length of the graft that is required.

SURGICAL TECHNIQUE

The patient is placed in the supine position on the operating table. The procedure should be performed without a tourniquet to assess the vitality of the bone intraoperatively.

Regardless of existing scars, a standard dorsal approach is recommended. This approach allows adequate exposure of the MTP joint and avoids damage of the medial dorsal cutaneous nerve, which is difficult to identify in the scar tissue.[16] The skin incision starts about 4 cm proximal to the first MTP joint and extends to the first IP joint (**Fig. 3**). Depending on the amount of shortening and presence of cock-up deformity, the flexor hallucis longus tendon is retracted laterally or cut in a Z shape to facilitate exposure to the MTP joint. In case of cock-up deformity, it is necessary to lengthen this tendon.

The joint capsule and the soft tissue coverage of the metatarsal and the phalanx are incised longitudinally straight down to the bone and then opened as an envelope. Subperiosteal preparation is mandatory to ensure sufficient release from the lateral soft tissue and scar adhesions. Only the plantar aspect is left intact to preserve the blood supply to both bones. Osteophytes and remaining soft tissue adhesions are removed at this point. After this, the big toe is brought into maximal plantarflexion.

If a cup-in-cone reamer is used for the preparation of joint surfaces and removal of remaining cartilage tissue, a guidewire has to be inserted in the center of the metatarsal head. A ball-in-socket preparation provides the advantage of minimizing bone loss and creates the ability to alter the position of the toe after the preparation has been performed. Basically, it can be performed with spherical reamers, chisels, or a rongeur. After inserting the guidewire, the appropriately sized “female” reamer is placed over the guidewire. The reaming is performed until cancellous bleeding bone can be visualized. Then, the proximal phalanx is exposed, and a guidewire is placed in the center of the articular surface area. The “male” reamer counterpart is placed over the guidewire, and the surface is prepared in the aforementioned manner.

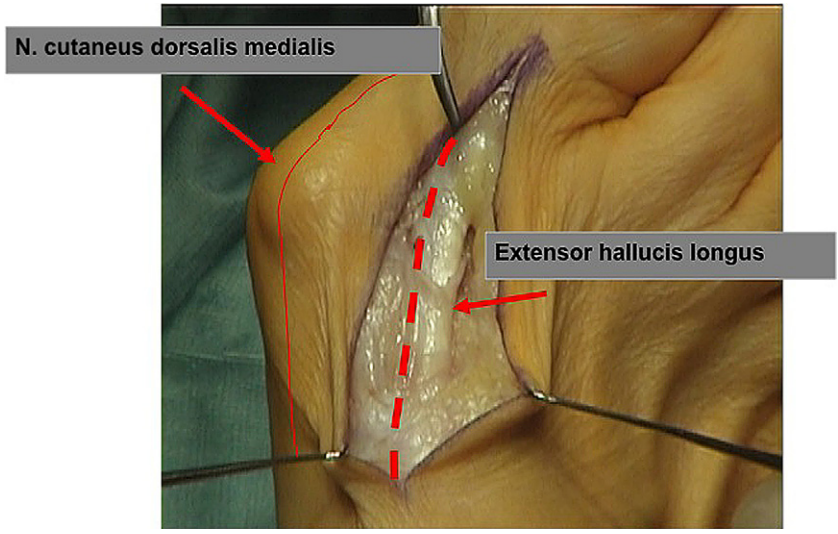

Fig. 3. Dorsal approach and anatomic landmarks of the first MTP joint.

Now, the toe can be pulled into the position of desired length, and the exact extent of the gap in the joint is measured.

The skin incision at the iliac crest is centered 3 cm posterior to the anterior superior iliac spine. The preparation of the soft tissue is performed using electrocautery for hemostasis until the periostium of the superior crest is reached. Two Hohmann retractors are introduced, and the desired segment for harvesting is marked. The length is determined by the gap created with the first MTP joint preparation. At this stage, a saw is used to osteomize the ends of the tricortical bone block. The autogenous graft is harvested, and the defect may be backfilled with allograft bone chips. After drain placement, the periostium is closed and wound closure is performed in a common manner.[15]

The graft (either autogenous or allogenous) should be secured on the back table using a forceps to be shaped into the desired length. A guidewire for the cup-in-cone reamer set is placed in the center of the graft's longitudinal axis. The graft margins are marked, and the graft ends are contoured with the reamers. Two corresponding ends are prepared to create optimal contact to the host bone (**Fig. 4**).

The molded graft is inserted in the gap between the proximal phalanx and the first metatarsal. Either a standard plate or a special revision plate is placed dorsally, and temporary fixation of the construct is performed using pins. The position of the arthrodesis is crucial. Excessive plantarflexion or dorsiflexion has to be avoided. Therefore, the lid of an instrument tray can be used to simulate the floor with weight bearing. A correct position in the sagittal plane is obtained when the tip of the toe (distal phalanx) is able to exert pressure on the ground when the patient is standing. In general, a dorsiflexion angle of 20° to 25° between the metatarsal and the phalanx

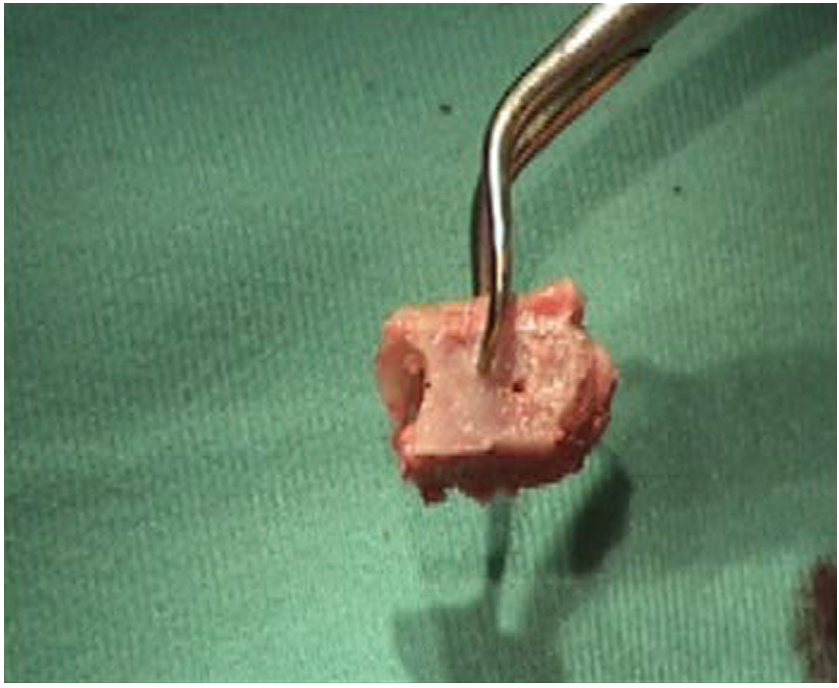

Fig. 4. A ball-in-socket preparation of autologous iliac crest bone graft.

is recommended, but the individual first metatarsal inclination angle has to be considered.[17] Excessive dorsiflexion may cause overload of the sesamoids, symptomatic irritation of the hallux in shoe, and poor cosmetic appearance, whereas excessive plantarflexion leads to symptoms during push off in the stance phase of gait and eventually to IP joint arthrosis. A varus position makes wearing shoes difficult; an excessive valgus position impinges the second toe. Therefore, a neutral to slight valgus position is recommended.

For fixation of the arthrodesis, a 3.0-mm or 3.5-mm cannulated screw is inserted from the medial aspect of the residual proximal phalanx across the graft to the lateral aspect of the residual metatarsal. The plate is secured to the construct with screws in the proximal phalanx, graft, and metatarsal. All the fixation processes are performed under fluoroscopic guidance.

A small-diameter drain is introduced, and closure of the wound is performed in a proper manner.

POSTOPERATIVE REGIMEN

Sterile dressings are applied to the wound, and the foot is placed for a total of 6 to 8 weeks in a short-leg cast that extends beyond the toes. Non–weight bearing is recommended until suture removal 2 weeks postoperatively, after which partial weight bearing until 6 to 8 weeks should be performed.

Full weight bearing can be anticipated when there is radiographic evidence of bony fusion.

RESULTS

In a retrospective study, Myerson and colleagues[10] investigated 24 patients who underwent first MTP joint arthrodesis using bone graft to restore length. All patients underwent previous surgery for correction of hallux valgus deformity or hallux rigidus, which resulted in significant bone loss. The clinical and radiographic follow-up was performed at an average of 62.7 months after surgery. In 79.1% of the patients, successful fusion was noted at a mean of 13.3 weeks after surgery and the first ray was lengthened by a mean of 13 mm. There were a total of 5 nonunions; 3 of them were symptomatic and successfully managed with further surgery. In this series, 1 deep infection and 2 superficial infections were reported. The mean American Orthopaedic Foot and Ankle Society (AOFAS) score improved from 39 points preoperatively to 79 points at follow-up.

Another study by Brodsky and colleagues[11] investigated 12 patients with salvaged first MTP arthrodesis with structural interpositional autologous iliac crest bone graft. Indication for surgery was severe bone loss after MTP joint alloplasties in 8 patients, AVN after failed hallux valgus surgery in 2 patients, nonunion after primary MTP arthrodesis in 1 patient and osteomyelitis after cheilectomy in 1 patient. The graft was augmented with a single dorsal plate in 11 cases and a dorsal and medial plate in 1 patient. At a mean of 15 weeks, arthrodesis was achieved in 11 of 12 cases. The nonunion was asymptomatic and did not need further treatment. The AOFAS score averaged 70 points at 22 months follow-up. Two cases required flap coverage for skin necrosis.

Vienne and colleagues[18] stated that the AOFAS score increased from 44 to 85 at an average follow-up of 34 months in 20 patients who underwent MTP joint arthrodesis after failed Keller-Brandes procedure. However, most patients of this study had in situ fusion and did not require interpositional bone graft. Assessment of dynamic plantar pressure distribution of these patients revealed that, biomechanically, the

MTP joint arthrodesis could not fully restore the function of the hallux but produced a significant improvement, allowing a more physiologic loading pattern under the hallux and the metatarsal head.

SUMMARY

Studies have demonstrated that shortening of the first ray can lead to symptomatic forefoot disorders, such as transfer metatarsalgia of the lesser toes.[7,19] Therefore, in cases of MTP arthrodesis, care has to be taken to avoid shortening of the first ray. In case of revisional arthrodesis with severe bone loss, interpositional bone block arthrodesis is a reliable procedure that results in good clinical and functional results.

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