



# Second Metatarsophalangeal Joint Interpositional Arthroplasty Using Decellularized Human Dermal Allograft: Operative Technique

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## Abstract

Arthrodesis of an osteoarthritic second metatarsophalangeal (MTP) joint is suboptimal because of altered gait mechanics; hence, joint-preserving procedures are of value. Autograft interpositional arthroplasty is one available option with excellent results, but there are potential concerns regarding donor site morbidity and insufficiency of the autograft material. We present here an alternative technique, an interpositional arthroplasty using allograft. Our technique includes a dorsal incision and joint exposure, removal of cartilage from the metatarsal head, and interposition of human decellularized dermal allograft sutured to the metatarsal head. Allograft interpositional arthroplasty is a feasible technique and can be further investigated as an alternative procedure for patients with second MTP osteoarthritis.

**Level of Evidence:** Level V, expert opinion.

**Keywords:** second metatarsophalangeal joint, osteoarthritis, interpositional arthroplasty

## Introduction

Late-stage osteoarthritis of the second metatarsophalangeal (MTP) joint presents with pain and restricted range of motion.<sup>2</sup> Degeneration of this joint presents a unique challenge, as there are limited options for patients who fail conservative treatment. Arthrodesis leaves the second MTP joint without any range of motion, and so has the potential to result in altered gait mechanics, transfer metatarsalgia, and adjacent joint degenerative disease. Other potential treatment options include implant arthroplasty, metatarsal head resection, debridement only, and soft tissue interposition. Each of these has its own set of potential drawbacks and complications.

Autograft interpositional arthroplasty of the second MTP joint has been studied and shown to have acceptable results.<sup>2,4,10-12</sup> However, concerns discussed in the literature include donor site morbidity and potential insufficiency of the graft material leading to failure. A potential alternative to autograft interpositional arthroplasty is allograft interpositional arthroplasty. However, a technique for allograft interpositional arthroplasty for the second MTP joint has yet to be

published. The present study presents a novel technique involving removal of cartilage from the second metatarsal head combined with the use of human decellularized dermal allograft for interpositional arthroplasty of the second metatarsophalangeal joint.

## Technique

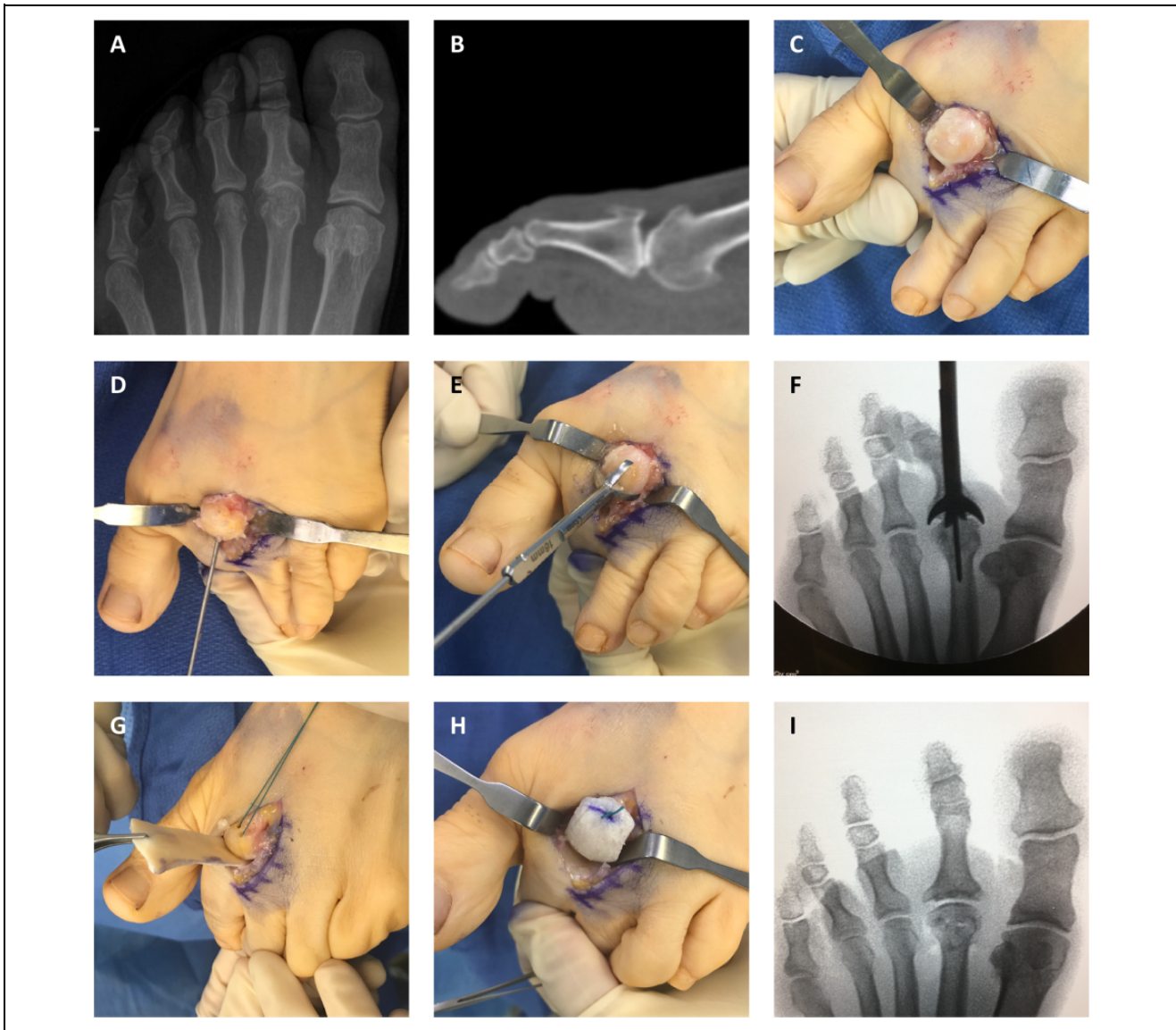
The operative technique is detailed in Figure 1. The patient is positioned supine and a calf tourniquet is placed. A longitudinal incision is made over the dorsal aspect of the second MTP joint. The extensor digitorum longus tendon is retracted laterally, the capsule incised longitudinally, and the collateral ligaments are released from the metatarsal

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**Figure 1.** Operative technique. (A) Preoperative anterior-posterior radiograph showing complete loss of second metatarsophalangeal joint space. (B) Preoperative sagittal CT cut. (C) Metatarsal head after exposure. (D) Guidewire for conical reamer placed in the center of the metatarsal head. (E) Conical reamer placed over the guidewire. (F) Anteroposterior view showing the conical reamer on the metatarsal head. (G) Graft secured to the plantar aspect of the metatarsal head. Suture runs through medial tunnel and plantar aspect of graft from dorsal to plantar, then from medial to lateral on plantar aspect of graft, and finally back through graft and lateral tunnel from plantar to dorsal. (H) Graft secured to the plantar and dorsal aspects of the metatarsal head. Medial and lateral suture ends are tied on the dorsal aspect of the graft. (I) Intraoperative fluoroscopic view showing restoration of the joint space.

neck to enable plantar dislocation. The cartilage is then removed from the metatarsal head using a conical reamer designed for first MTP joint arthrodesis (Arthrex, Naples, FL). Osteophytes are removed and a K-wire is placed in the center of the metatarsal head. The reamer that best matches the size of the metatarsal head is used to remove cartilage and a small amount of sclerotic subchondral bone. A human decellularized dermal allograft (Graft Jacket; Wright Medical, Memphis, TN) is then cut to the size of the metatarsal head. Two tunnels are then drilled through the proximal aspect of the metatarsal head from dorsal to plantar, with

one tunnel lying medially and one laterally. A no. 1 nonabsorbable suture is then passed through the medial tunnel from dorsal to plantar. Using a free needle, the plantar end of the suture is passed from dorsal to plantar through the graft. The suture is then run from medial to lateral along the plantar aspect of the graft. Again using a free needle, the end of the suture is passed from plantar to dorsal through the graft. The suture is then passed through the lateral tunnel from plantar to dorsal. The graft is tensioned appropriately across the metatarsal head, and the medial and lateral suture strands are passed through the medial and lateral aspects of

the dorsal aspect of the graft. These strands are then tied to each other on the dorsal aspect of the graft. The capsule is repaired with 2-0 absorbable suture and the skin is closed.

Postoperatively, the patient is initially heel-weight-bearing in a forefoot wrap and postoperative shoe. At 4 postoperative weeks, the patient is made weight-bearing-as-tolerated in the postoperative shoe and formal physical therapy is begun emphasizing second MTP gentle active and passive range of motion. At 8 postoperative weeks, the patient is made weight-bearing as tolerated in a regular shoe.

## Discussion

Late-stage osteoarthritis of the second MTP joint presents a unique challenge, as there are limited options for patients who fail conservative treatment.<sup>2</sup> Arthrodesis leaves the second MTP joint without any range of motion, and so has the potential to alter gait mechanics, hamper running, result in transfer metatarsalgia, and contribute to adjacent joint degenerative disease. Other potential treatment options include implant arthroplasty, metatarsal head resection, debridement only, and soft tissue interposition.

*Autograft* interpositional arthroplasty of the second MTP joint has been studied and shown to have acceptable results.<sup>2,4,10-12</sup> Lavery et al<sup>10</sup> performed a retrospective review of 9 patients with degenerative arthritis who underwent interpositional arthroplasty with MTP joint capsular material. Eight patients had improvement in symptoms, and all patients stated they would undergo the procedure again. Postoperative motion was noted to be "limited" but generally without pain or crepitus. Ozkan et al<sup>12</sup> reviewed 10 patients with Frieberg infarction who underwent second MTP joint interpositional arthroplasty with extensor digitorum brevis autograft. Nine patients described improvement in symptoms, and no patients experienced complications. Similarly, el-Tayeby described 13 cases of Frieberg infarction treated with extensor digitorum brevis autograft.<sup>4</sup> That author reported postoperative range of motion similar to preoperative levels and decreased pain at 11- to 27-month follow-up. Finally, Liao et al<sup>11</sup> describe a single case of Frieberg infarction treated with palmaris longus autograft. That patient was a soldier and reportedly had functional improvement above baseline with return to his army group and durable pain relief at 2 postoperative years. However, the authors did note that the patient complained of forearm weakness for the first 4 postoperative weeks.

Based on the above evidence, autograft interposition is a viable option for patients with second MTP osteoarthritis. Autograft presents particular advantages in being readily available and inexpensive, and it has a proven track record. The above studies also raise several reasons to consider allograft as an alternative. First, autograft reconstructions have donor site morbidity, whether using capsular material, extensor digitorum longus, palmaris longus, or any other material. For example, MTP extensor function weakness can be seen postoperatively after use of extensor tendon as

graft.<sup>4</sup> Similarly, the use of palmaris longus tendon can result in forearm weakness postoperatively.<sup>11</sup> A second concern with the use of autograft is that the graft itself can be insufficient to achieve successful interposition. For example, the use of capsular tissue for interposition has been called into question as it is often thin and affected by the same disease process, which raises concerns of durability.<sup>10,12</sup> In this context, if a reliable allograft technique could be identified, it could present certain advantages. Nevertheless, autograft is less expensive and more readily available and has an excellent track record, so comparative studies would need to be conducted to support one technique over the other.

It is worthwhile to consider the extensive background work that has been conducted to develop and understand this graft material and its ability to become populated with host fibroblasts, incorporate into the host, and regenerate tissue. Bondioli et al<sup>1</sup> describe the chemophysical decellularization method applied to allogenic human-derived dermis, which involves separation of cadaver epidermis from the dermis using an electric dermatome, treatment in a series of decellularization solutions, irradiation with gamma-rays (100 Gy), and finally storage in nitrogen vapor at  $-180$  to  $-190$  °C. These authors demonstrate that the decellularization process results in a material with high levels of transforming growth factor-beta 1 and proliferative tissue matrix. In *in vitro* assays, the allograft significantly increases the proliferation rate of L929 fibroblasts in comparison with controls. Implantation in rats and subsequent retrieval at various time points up to 90 days reveals macroscopically visible neocapillaries feeding the graft material, a thin fibrous capsule consisting of fibroblasts, reorganizing collagen fibrils, and macrophages existing within the membrane material. CD68 cells (cells of the monocytic phagocyte and osteoclast lineage) are distributed at the implant periphery. By 30 days after implantation, a complete fibroblast colonization of the graft material is routinely achieved, and by 90 days the tissue has undergone significant reorganization compared with that originally implanted. Taken together, these findings provide evidence for graft incorporation, host infiltration, and the potential for tissue regeneration.

The primary alternatives to interposition for management of late-stage second MTP joint degenerative disease include implant arthroplasty, resection arthroplasty, osteotomy, and arthrodesis.<sup>3,6-8,13</sup> Implant arthroplasty using a silicone implant can result in improved pain, function, and shoe-wear; however, there are concerns regarding the rate of complications including transfer metatarsalgia, infection, synovitis, implant failure, and fracture.<sup>3,6,13</sup> We could not find good support for this procedure in the current literature. Reports of resection arthroplasty are limited to toes with major sagittal plane deformity or rheumatoid disease.<sup>7,8</sup> However, because resection arthroplasty removes the weight-bearing function of the second toe, it is believed to be high risk for development of transfer metatarsalgia.<sup>3,5</sup> Osteotomies that dorsiflex the distal aspect of the second

metatarsal are reasonable alternatives for joints with cartilage remaining on the plantar aspect of metatarsal head; however, they are less likely to result in pain relief for patients with global joint disease.<sup>3</sup> Arthrodesis of the second MTP joint reliably relieves pain derived directly from an osteoarthritic MTP joint. However, it fixes the second MTP joint in position, potentially altering gait mechanics. Although data specific to arthrodesis of the lesser MTP joints for osteoarthritis are sparse,<sup>9</sup> one might anticipate difficulties with both running and the use of high-heeled shoes. Relatedly, the alteration of gait could potentially result in either transfer metatarsalgia or adjacent joint degenerative disease.

There are several directions for future research on this topic. The first involves achieving a better understanding of how human dermal allografts incorporate and what factors can be altered to achieve a greater likelihood of graft incorporation and joint space preservation. The second direction for future research involves evaluations of outcomes from this and related allograft techniques, including comparisons to autograft techniques and potentially other techniques such as arthrodesis.

A technical topic of discussion is our use of a metatarsal head reamer to prepare the host metatarsal head, which can result in shortening of the second metatarsal if subchondral bone is taken with the cartilage. Care must be taken to balance the desire to create space for the graft with the need to avoid overshortening of the metatarsal. In some cases, we did recognize metatarsal shortening on postoperative radiographs, in which case more bone may have been taken than necessary. Care must be taken when using reamers to prevent overshortening, and the use of curettes to remove cartilage would be an alternative technique with less risk of shortening.

## Conclusion

Potential treatment options for second MTP osteoarthritis include arthrodesis, implant arthroplasty, metatarsal head resection, debridement only, and soft tissue interposition. Although authors have published good results with autograft interpositional arthroplasty techniques, there are concerns regarding donor site morbidity and autograft durability. We publish here a novel technique for allograft interpositional arthroplasty of the second metatarsophalangeal joint. Allograft interpositional arthroplasty is a feasible technique and can be further investigated as an alternative procedure for patients with second MTP joint osteoarthritis.

## Declaration of Conflicting Interests


The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

## Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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