

FIRST METATARSOPHALANGEAL JOINT FUSION WITH MINIMAL FIXATION

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First metatarsophalangeal (MTP) joint fusion has been an operative technique utilized as both primary treatment as well as a revisionary one for pathology involving the first MTP joint.¹⁻⁹ Many papers have attempted to investigate the ideal combination of joint resection techniques and fixation configurations to provide maximum stability to aid arthrodesis.¹⁰⁻²¹ Fixation techniques have spanned the entire gamut of alternatives from simple pin fixation to compression techniques with multiple cross screws to more complex fixation constructs utilizing a plate and screws.

FIRST MTP JOINT ARTHRODESIS

First MTP joint arthrodesis may be recommended as a primary procedure or one of revision in cases of prior surgery. It is this latter group that this paper will address. Bunion surgery although generally performed with predictably good outcomes occasionally may encounter complications including recurrent deformity, development of hallux varus, and chronic joint pain with or without arthrosis or infection. Arthrodesis is valuable in cases of first MTP joint reconstruction where bone loss or length deficit of the first metatarsal may need to be addressed. This is particularly a concern in patients who present with failed first MTP joint implant surgery. Revisionary surgery of the first MTP joint is also performed in patients who have undergone prior surgery for hallux rigidus but experience chronic joint pain from the arthrosis that may be present.

SHORT HISTORY: FIXATION OF FIRST MTP JOINT FUSION

According to Kelikian, the foot is designed primarily to sustain weight, stability of the joints takes precedence over movement.²² He further describes several foot surgeons in the 1800s and 1900s who report satisfaction with unintentional stiffness at the first MTP joint following various types of surgical procedures. He attributes premeditated ankylosis of the first MTP joint for hallux valgus to Wyeth (1887) and later Clutton (1894) who contended that ankylosis in an ideal position would produce a permanent and very satisfactory result.²²

Duncan McKeever is generally associated with the

modern era of first MTP joint arthrodesis but interestingly he also describes unintentional ankylosis in one of his patients that had undergone bilateral bunion surgery.²³ The patient had an infection and postoperative stiffness. The patient preferred the result and he also felt that the foot that suffered the complication actually seem to function better. It is from these observations of McKeever and Glissan before him that led to the orthopedic community to embrace first MPJ arthrodesis in the mid-20th century. Crumble (1956) and Stamm (1957) recommended alternative procedures to joint fusion unless presented with hallux rigidus and gross arthritic change to the joint.²²

Interestingly, some of the earliest techniques of McKeever and his colleagues included attempts at rigid internal fixation utilizing metallic screws or external fixation.²² Some of these early descriptions of surgical technique recommended a position of fusion so as to fit within a shoe with an appropriate amount of abduction and extension at the first MTP joint. McKeever advised 15-20° of extension in men and 15-25° or upwards of 35° of extension in women no doubt attempting to fuse the great toe in a position of extension so that a female patient could still wear her high heeled shoes.^{22,23} Today, we recognize that this should be much less a consideration.

Certainly, whenever possible a more conservative joint preservation type of procedure is preferred. In all cases, the patient's pathology should warrant a joint destructive procedure.²⁴ It is in this patient population that first MTP joint arthrodesis be considered. First MTP joint arthrodesis is generally the procedure of choice as salvage for all other complications of first MTP joint surgery or trauma, short of hallux amputation or other extreme measures. It is in this pretense that this discussion of first MTP joint arthrodesis precedes.

Specifically over the last two decades, surgeons have trended towards rigid internal fixation with either multiple screws or plate and screw fixation constructs. Successful arthrodesis of the first MTP joint has been described utilizing a wide variety of techniques of internal and external fixation, all of which may have their place in various instances.^{7,8} Patients undergoing revisionary surgery particularly in situations with a bone loss may require supplemental bone grafting. It is in these patients

that fixation with a plate and screws have become most popular following the recommendations of Coughlin.^{21,25,26} Somehow though, surgeons then proposed plate fixation as a primary modality for fixation of first MTP joint fusion whether primary or revisionary in nature. Today, surgeons possess a large number of alternative fixation designs with many companies providing so-called anatomic plates designed specifically for either primary or revisionary first MTP joint arthrodesis. The proposition of this paper is to illustrate that techniques of minimal fixation may also provide very rigid fixation and be more advantageous over techniques of plate and screw fixation.

CASE 1

Case 1 involves a 47-year-old white woman with a history of diabetes mellitus and multiple prior foot surgeries. She had undergone 4 prior surgeries of the first MTP joint, right foot including bunionectomy with hallux osteotomy, revisionary bunionectomy with metatarsal osteotomy, cheilectomy, incision and drainage of wound infection, and resection joint arthroplasty. There was some concern that she may have had prior osteomyelitis. Her current problem involved chronic joint pain as well as malposition of the toe with varus malposition and medial hallux irritation.

Her radiographs showed what appeared to be some type of resection arthroplasty procedure at the first MTP joint with the absence of articular surfaces from both the proximal phalanx as well as first metatarsal head. The hallux was shortened and adducted and showed a loss of toe purchase. The first metatarsal was also short but her bone quality appeared good. Complicating this patient's situation was very poor quality of the dorsal and medial skin and soft tissues from the multiple prior surgeries and infection.

Recommendation for revisionary surgery with first MTP joint fusion appeared logical but the poor quality of her skin and soft tissues did not lend itself to the usual standard operation of bone grafting with dorsal plate fixation. Any attempts at lengthening the first ray segment would stretch and place the already tenuous skin and subcutaneous tissues in a further compromised position. The bone quality appeared adequate but due to these other limitations, alternative fixation constructs were explored. This was early in the author's experience with nitinol thermoplastic compression staples in 2001 and arthrodesis was proposed but with limited surgical exposure and fixation.

She underwent salvage arthrodesis of her first MTP joint with an autogenous interpositional bone graft taken from her ipsilateral calcaneus. At no point during the surgery was there any evidence of old or active infection. Good bone quality could be appreciated. The surgical technique involved limited dorsal exposure of the first MTP joint with freshening of

adjacent bone margins. The procedure was performed under radiographic guidance with an external distractor placed to provide for joint distraction and lengthening of the great toe. The bone graft was inserted and initial fixation accomplished with a Kirschner-wire. Following radiographic evaluation, definitive stabilization with a single large nitinol bone staple placed from dorsal to plantar spanning the arthrodesis site and bone graft was performed.

A large 2 x 3 mm nitinol thermoplastic staple was utilized with a staple back of 20 mm and 20 mm legs. The distal leg was modified with reduction of the length of the distal leg due to the more shallow depth of the proximal phalangeal base. The staple was energized and compression obtained. Immediate postoperative radiographs showed minor irregularities between the graft and bone interface but good position and correctional deformity as well as improvement of hallux length.

This patient was treated postoperatively with two weeks of nonweight bearing followed by 6 weeks of partial weight bearing on axillary crutches and a short-leg walker brace. Radiographs were obtained throughout the postoperative course to monitor her healing progress (Figure 1). Progressive filling-in and remodeling of both the proximal and distal osseous interface could be appreciated.

The patient gradually progressed to full weight bearing in a diabetic type rocker-bottom shoe. She is now more than 8 years postoperative and did undergo removal of the staple at 3 years postoperative. Radiographs showed complete bony consolidation and incorporation of the bone graft. Remodeling of the osseous contours may be appreciated in the long-term radiograph at five years post arthrodesis.



Figure 1A. Preoperative deformity of the patient described in case 1.



Figure 1B. Two-week postoperative radiograph showing the position of the nitinol staple and interpositional bone graft.



Figure 1C. AP radiograph at 1 year postoperative.



Figure 1D. The 3-year postoperative radiograph shows not only complete incorporation but remodeling of the fusion site.



Figure 1E. Lateral radiograph at 3 years postoperative showing that his staple has been well tolerated without loosening or any resorptive changes. Note the 4 cortice purchase of the staple.



Figure 1F. The long-term arthrodesis at 5 years postoperative and 2 years post removal of the nitinol staple.

CASE 2

Case 2 involves a woman who had undergone prior surgery for hallux rigidus at a university hospital by a foot and ankle orthopedic surgeon. She initially underwent a cheilectomy of the first MTP joint but had difficulties with continued joint pain from the early postoperative period. Subsequently, a revisionary procedure was performed with proximal phalangeal base resection and membrane-type interpositional arthroplasty.

She continued to have pain in and around the first MTP joint as well as having lesser metatarsalgia. She also had a shortened hallux due to prior bone resection or Keller type arthroplasty. She possessed a good bone density although numerous metallic bone anchors had been inserted during the prior surgeries. She was an active individual with significant limitation of activities and her choice of footwear restricted due to chronic first MTP joint pain. First MTP joint arthrodesis with interpositional bone graft was recommended in an effort to relieve her chronic pain, stabilize the hallux, and restore length to the great toe. She underwent the procedure with autogenous calcaneal bone graft. Minimal bone resection from the first



Figure 2A. Case 2 preoperative AP radiograph showing a failed membrane interpositional arthroplasty with numerous retained bone anchors.



Figure 2B. The 6-week postoperative AP radiograph



Figure 2C. Lateral 6-week postoperative view showing a 10 mm interpositional autogenous bone graft and staple fixation.

MTP joint area was prepared and a 10 mm bone graft inserted. Two of the 4 previously implanted bone anchors were noted at the time of surgery and removed.

Fixation was accomplished with a single large nitinol thermoplastic staple, 25 x 20, W23 staple placed in a dorsal to plantar manner. Again, the distal leg of the staple was cut short due to the osseous height of the proximal phalangeal base. The wound healing was uneventful. Postoperatively, she was treated in a short-leg walking brace for 8 weeks with initial touch weight bearing for 2 weeks with axillary crutches followed by partial weight bearing. Thereafter, she was allowed to transition to normal shoes and gradually progressed to full activities. Complete bony consolidation ensued by three months postoperatively (Figure 2). She was a slender individual and the staple was palpable following maturation of the soft tissues. The staple was removed at 6 months postoperatively.

CASE 3

Case 3 is a 65-year-old woman with diabetes mellitus and history of prior foot surgery. She had undergone prior bunion and hammertoe surgery on the left foot with complications mainly associated with recurrent postoperative deformities and painful interdigital lesions. She showed a recurrent hallux valgus deformity with abduction contractures of the lesser toes. Radiographs revealed lateral luxation of the base of the hallucal proximal phalanx with evidence of prior malposition of hallucal osteotomy. A poor joint space and attempted capsule repair with intra-osseous bone anchor still showed deformity. There was evidence of prior arthroplasty at the PIPJ of the second and third toes and medial subluxation of base of proximal phalanx on the respective metatarsal heads. Her main complaint was an



Figure 2D. The one year postoperative radiograph following removal of the staple.

interdigital lesion between the second and third toes. She was a prior smoker with sensory disturbances associated with her diabetes but intact protective sensation and good vascular status.

Such severe deformity was present at the first MTP joint that arthrodesis seemed the only viable option regarding salvage of hallux position. Revisionary surgery was proposed and included first MTP joint fusion and hammertoe repair with second and third MTP joint arthroplasty as well as shortening of the fourth toe with diaphysectomy. The area of study included first MTP joint fusion with realignment between the hallux and first metatarsal segment. Articular resection was performed with soft tissue release although no attempt was made to find the previously inserted bone anchor. Fixation was accomplished with 2 compression bone staples, a large staple placed from dorsal to plantar and a second smaller staple placed from medial collateral as a second point of stabilization. The lesser toes and MTP joints were stabilized utilizing pLLA absorbable pins following arthroplasty.

Postoperatively, this patient was allowed to bear weight on the surgical foot in a below knee walking boot that she wore for 6 full weeks postoperatively and gradually transitioned into standard shoes thereafter. Healing of the first MTP joint fusion was relatively uneventful although she did require removal of the absorbable pins from the third and fourth toes at 3 months postoperatively.



Figure 3A. The presenting AP radiograph of the patient in case 3 shows recurrent hallux valgus deformity with lateral subluxation of the base of the proximal phalanx despite hallucal osteotomy and bone anchor stabilization of a capsular repair.



Figure 3B. Postoperative radiograph at 6 weeks.



Figure 3C. Six months postoperative view shows consolidation of the first MTP joint fusion without resorption and maintenance of position.

CASE 4

Case 4 involves a 46-year-old woman who also had a history of multiple foot surgeries by a foot and ankle orthopedic surgeon several years prior. She initially underwent a Chevron type bunionectomy with recurrence of deformity and postoperative lesser metatarsalgia. The surgeon elected to perform lesser metatarsal osteotomy of the second and third metatarsal, within a year postoperative of the initial surgery. She returned with continued difficulties and a third surgical intervention was recommended. A fourth metatarsal osteotomy was performed with repair of nonunion second and third metatarsals. She was also placed in an electrical bone growth stimulator.

She subsequently came under my care with reports of chronic pain and swelling of the right foot. Clinical examination showed significant recurrent hallux valgus deformity and a large dorsal subcutaneous bony prominence in the area of the mid-shaft of the second metatarsal. She complained of generalized pain throughout the right forefoot and described continued difficulties with her feet over the past 3 years despite 3 prior foot surgeries.

Radiographs now 3 years post original surgery date showed recurrent bunion deformity with obliquity of the first metatarsal first cuneiform joint as well as nonunion of the second, third and fourth metatarsals with broken screws were noted. Osteotomies were performed in mid-shaft areas and significant dorsal displacement of the distal portion of second metatarsal was evident radiographically. Clinically, a



Figure 4A. The patient in case 4 had undergone free prior surgeries. Her presenting AP radiograph illustrates the recurrent hallux valgus deformity as well as lesser metatarsal nonunions.



Figure 4B. One month postoperative radiograph shows the first MTP joint fusion performed with tabletop bone resection and fixated with nitinol bone staples.

dorsal subcutaneous bony prominence in the area of the second metatarsal shaft was apparent. A splay-foot type of deformity was present. Her complaints seem to stem from weight bearing with multiple metatarsal nonunions and malunion combined with recurrent hallux valgus with resultant lesser metatarsalgia. Dorsal subcutaneous bony prominence of second metatarsal also made wearing shoes difficult and made insertion of any orthotic or any in-shoe modifications difficult.

This patient was a long-term smoker and cessation was emphasized. She did utilize a bone stimulator in the past and this was reinstated. Surgical considerations involved realignment of her forefoot and healing of nonunion, multiple metatarsals. Revisionary bunionectomy with first MTP joint fusion, repair of second metatarsal nonunion with exostectomy, bone graft, and internal fixation was recommended. It was felt that if the first and second metatarsals and medial column could be stabilized that healing of the third and fourth metatarsal nonunion could be accomplished with the use of postoperative immobilization and electrical bone stimulation.

Surgery was performed as described above with bone grafting, realignment of the second metatarsal, and plate stabilization as well as first MTP joint arthrodesis with staple fixation. Staple fixation with nitinol thermoplastic compression staples was performed (Figure 4). A staple specifically designed for first MTP joint fusion is now



Figure 4C. Radiograph at 6 months postoperative shows consolidation of fusion site without absorption as well as healing of lesser metatarsal nonunions.

available and utilized. This 2 mm rectangular staple possessed a 18 mm back with a 18 mm length proximal leg and a 15 mm distal leg.

Surgery and the postoperative course was uneventful. Postoperative care included nonweightbearing with actuary crutches for 6 weeks followed by the use of a

below-knee walker for a total of 3 months postoperatively. The patient was compliant with the postoperative course and showed very nice healing of the first and second metatarsals and progressive consolidation of the third and fourth. She did utilize the electrical bone growth stimulator for a full 3 months postoperative. She did well with resumption of normal activities and footwear.



Figure 5A. Illustrates the difficulty assessing union at the arthrodesis due to the presence of a large plate.

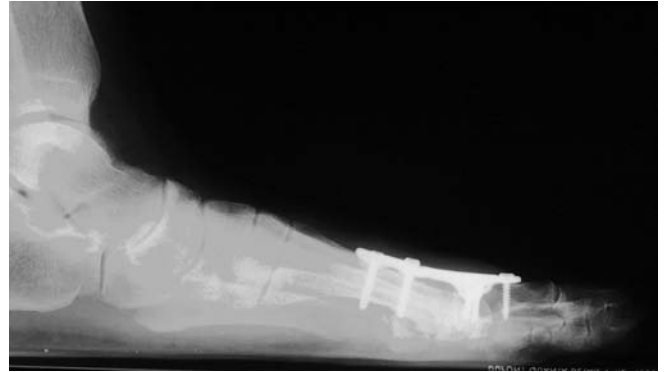


Figure 5B. This was also one of the earlier designs of an anatomic plate.



Figure 5C. A smaller and thinner maxillofacial plate that fractured at 3 months postoperative first MTP joint fusion performed with an autogenous bone graft.

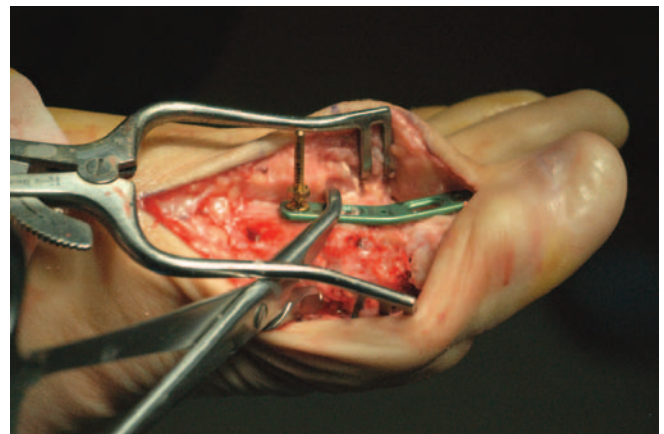


Figure 5D. A version of the modern anatomic plate design for primary fusion.

DISCUSSION

Complications of first MTP joint surgery does occur with the most frequent being recurrent deformity. Joint malalignments may occur and may be accompanied by chronic joint pain and/or arthrosis. Less frequently but still a prominent consideration is that of osseous malalignment with or without joint subluxation and pain. First MTP joint surgery may be complicated in cases of bone defects as a result of prior resection arthroplasty, avascular necrosis, or inadvertent shortening due to the surgical intervention and healing process.

These cases involve middle-aged female patients who each had undergone 1 to 5 prior surgeries. In case 1 recurrent surgical attempts were made to relieve first MTP joint pain. Case 2 illustrated failure to relieve joint symptoms associated with hallux rigidus. Hallux rigidus is often treated with cheilectomy and patients with continued joint pain generally go on to implant arthroplasty or fusion. This surgeon following a failed cheilectomy attempted an interpositional membrane arthroplasty which did not improve her clinical symptoms.

Two cases, (3 and 4) involved hallux valgus repair with recurrent deformity following surgery. Case 4 is an instance of the surgeon being oblivious to the etiology of her postoperative lesser metatarsalgia due to recurrent deformity. Instead, he attempted to perform multiple metatarsal osteotomies versus admitting to his failure to correct the original deformity. His misadventures were further complicated with multiple metatarsal nonunions and requirement for additional surgeries.

Each of us may experience complications but revisionary surgery is generally more complicated than the original surgical intervention. A thoughtful evaluation of the failed initial procedure as well as considerations for repair must be performed. The patient should possess adequate bone density for the anticipated procedures and the patient must show commitment to the required postoperative course for a successful outcome. First MTP joint arthrodesis is a preferred procedure to provide “finality” to many difficult clinical problems. Salvage of the myriad of complications from prior first MTP joint surgery may be achieved with revisionary fusion. Clinical success is dependent upon bony consolidation in a position of clinical tolerability. The ideal position of fusion is a well aligned great toe parallel to the second toe with enough extension to allow the great toe to sit just lightly touching the ground with

normal weight bearing. There should be no axial rotation within the hallux. Finally, bone union should be achieved in a predictable and timely manner.

These case presentations show the utility of nitinol thermoplastic staples as a form of minimal yet very rigid internal fixation of a first MTP joint arthrodesis even in the presence of bone grafting. The nitinol staple placed in a dorsal to plantar manner provides a great deal of stability across the entire fusion interface. Immediate intraoperative compression is achieved with energizing the staple while compression is continuously maintained while implanted due to the thermoplastic properties of the nitinol material and body temperatures.

Dorsally placed plates do not provide compression and may even yield tension across the plantar portion of the arthrodesis with or without weight bearing considerations. Large and often thick plates may provide sufficient stability but are often prominent subcutaneously and will cause irritation unless removed at some point post-operatively. Difficulties may be encountered regarding evaluation of bone healing and consolidation of the fusion site due to the presence of the metallic hardware and the inability to visualize the surgical site on radiographs, (Figure 5). Thin plates from maxillofacial systems have been utilized but are not of sufficient strength to withstand forces in the foot across the first MTP joint and implant breakage may be encountered.²⁷ Newer plate systems specifically designed for first MTP joint fusion are helpful but the position of the hallux relative to the first metatarsal is dictated by the design of the plate and little variation is possible by the surgeon.

CONCLUSION

Nitinol bone staples are available in a variety of sizes that allow matching of an appropriate size piece of fixation hardware with the patient’s osseous anatomy. Nitinol staples have been shown to be of sufficient strength and size to provide rigid internal fixation for a wide variety of situations and has been particularly useful for first MTP joint arthrodesis. Fusion of this joint may be a primary procedure or one of revision. Salvage arthrodesis of the first MTP joint with or without a bone graft of up to 10 mm in length may be stabilized utilizing nitinol bone staples. Good rigid compression fixation may be accomplished with very impressive bone healing achieved as illustrated in the above cases.

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