

Hallux Metatarsophalangeal Joint Arthrodesis Using Dome-Shaped Reamers and Dorsal Plate Fixation: A Prospective Study

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ABSTRACT

Background: Many techniques exist for arthrodesis of the first metatarsophalangeal (MTP) joint, as well as, indications for each method. The purpose of this study was to determine the results of one method using dome-shaped reamers to prepare the joint surfaces and a low-profile dorsal titanium plate for internal fixation. To date, no prospective studies have reported patient outcomes of arthrodesis of the first MTP joint using this technique. **Methods:** Fifty patients (54 feet) had first MTP joint arthrodesis from January, 2004, through January, 2005. All patients were evaluated preoperatively for underlying pathology, pain, function, and radiographic findings. First MTP joint arthrodesis was fixed with a dorsal titanium plate with preset valgus and dorsiflexion after the joint surfaces were prepared with matching male and female dome-shaped power reamers to achieve congruous cancellous bone surfaces. At a minimum of 1-year followup, patients returned for postoperative evaluation. In addition to evaluation of pain, function, and radiographic findings, patients were asked how long they remained off work, how long swelling persisted, and whether the hardware caused symptoms. **Results:** Forty-nine of 53 patients returned for followup at an average of 16 months after surgery. American Orthopaedic Foot and Ankle Society (AOFAS) scores improved significantly ($z = -6.301, p > 0.01$) from an average of 51 points preoperatively (range 24 to 97) to 82 points postoperatively (range 47 to 90). Pain scores at final followup demonstrated a significant improvement ($z = -6.154, p > 0.01$) from a mean of 6.3 to a mean of less than 1 point on the visual analog pain scale. Time off work averaged 3 weeks, while swelling persisted for an average of 11 weeks. Thirty-five feet in 32 patients (66%) were rated as excellent, 16 feet in 16 patients (30%) were rated as good, and two feet (4%) in one patient were rated as fair, with none reporting a

poor result. There were four nonunions (8%), with one being a fibrous union having no progression of deformity. Three of four patients with a nonunion reported a good result subjectively with the fourth reporting a fair result. **Conclusions:** The 96% satisfaction rate in 49 patients indicates that first MTP joint arthrodesis with a low-profile contoured dorsal titanium plate and crossed lag screws after joint preparation with dome-shaped reamers is both reliable and reproducible. The union rate was high (92%), and the revision rate was low (4%).

Key Words: Metatarsophalangeal Joint Arthrodesis; Outcomes; Technique

INTRODUCTION

Arthrodesis of the first metatarsophalangeal (MTP) joint has proven to be a valuable procedure for the treatment of multiple abnormalities of the great toe.^{1,2,4-14,16-19,21,24-27} Common indications include severe hallux valgus, hallux rigidus, inflammatory arthritides, neuromuscular disorders, and failure of other first MTP joint procedures. Proper joint preparation of the distal first metatarsal and proximal phalangeal joint surfaces coupled with secure fixation of the bony surfaces remain essential to achieving the desired outcome.^{1-14,16-27} Pain relief, deformity correction, and improved function are the most frequent goals of this procedure. We hypothesized that fixation with a precontoured dorsal plate would ensure proper alignment of the first MTP joint arthrodesis after joint preparation with dome-shaped reamers.

MATERIALS AND METHODS

All subjects participating in this study received a thorough explanation of the risks and benefits of inclusion and gave informed consent. Approval from the institutional review board was obtained before the initiation of the study.

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Inclusion Criteria

The indication for surgery was intractable pain isolated to the first MTP joint region, associated with either arthritis or a hallux valgus deformity that was unrelieved by shoe modifications, nonsteroidal anti-inflammatory medications or modification of activities. Contraindications to first MTP joint arthrodesis were infection at the operative site, moderate or severe interphalangeal joint arthritis, and severe osteopenia.

Between January, 2004, and January, 2005, 50 patients (54 feet) were enrolled prospectively in the study based on the presence of first MTP joint disease for which MTP joint arthrodesis was scheduled.

Preoperative Evaluation

The initial evaluation included evaluation of the underlying disease process, preoperative pain rating, functional capacity evaluation, and AOFAS hallux MTP joint scale grading. A physical examination also was conducted to evaluate gait, ability to toe rise, pronation of the hallux, and interphalangeal joint motion.

Routine standing anteroposterior and lateral radiographs were obtained and were evaluated for first interphalangeal joint arthritis, first metatarsocuneiform joint arthritis, the hallux valgus angle, the 1–2 intermetatarsal angle, and first MTP joint dorsiflexion angle (Figure 1). Arthritis at the hallux interphalangeal joint was graded on Fitzgerald's¹⁰ 4-point scale as adapted by Coughlin.⁷ Grade I is assigned to a joint with no degenerative changes, grade II is early degeneration with less than 1 mm of joint narrowing, grade III demonstrates 1 to 2 mm of joint space narrowing, and grade IV is severe degenerative changes. The metatarsocuneiform joint also was graded on a 4-point scale as described by Coughlin.⁹ Grade I is a normal joint, grade II is mild degeneration demonstrating less than 0.5 mm of joint space narrowing, grade III is 1 mm of joint space narrowing, and grade IV is severe degenerative changes.

Preoperative Data

Hallux rigidus was the most common diagnosis, occurring in 16 patients (17 feet), followed by hallux valgus in 15 (16 feet), rheumatoid arthritis in nine (11 feet), failure of prior first MTP joint procedure in five (five feet), hallux varus in three (three feet), and neuromuscular disorder in one (one foot). The average age of the patient population at surgery was 61 (range 39 to 79) years. Four patients had bilateral disease: two had rheumatoid arthritis in the cohort of 49 pts. (53 feet) (Figure 1), and one each had hallux valgus and hallux rigidus. Each patient was asked to rate his or her pain on a 10-point visual analog pain scale (0 points for no pain, 10 points for severe pain). In addition to the visual analog pain scale, patients also were asked to subjectively rate their pain as being none, mild, moderate, moderately severe, or severe. One point was given for no pain, and 1 point was added for rating up to 5 for severe pain. The visual analog pain scale ratings averaged 6.3 (range 0 to



Fig. 1: Preoperative radiograph with hallux valgus angle of 44 degrees, and 1–2 intermetatarsal angle of 18 degrees as measured by midaxial reference lines.

10), while the subjective pain score averaged 3.6 (range 1 to 5). Functional capacity limitations were graded on a 1-point to 5-point scale. On this scale 1 was no limitations, 2 was mild, 3 was moderate, 4 was significant, and 5 was housebound. The scores averaged 2.2 (range 1 to 4), indicating mild limitations. The AOFAS hallux MTP joint scale uses a 100-point system to evaluate the foot with 40 points awarded for pain, 45 points for function, and 15 points for alignment. The average preoperative score was 51 (range 24 to 97) points. Gait evaluation demonstrated 32 patients with normal gait, four with a slight limp, 12 with a moderate limp, and one with a severe limp. Thirty-three of 49 patients were able to demonstrate a toe rise on the affected extremity, 15 were unable to toe rise, and one had no response recorded. Pronation was graded on a 4-point scale. A score of 1 on this scale indicated no pronation, 2 represented mild pronation, 3 was moderate pronation, and 4 was severe pronation. The average score was 2 with a range of 1 to 4. Total first interphalangeal joint motion averaged 47 (range 3 to 85) degrees.

On the standardized preoperative weight-bearing radiographs, the average preoperative score for interphalangeal joint arthritis was 1.4 (range 1 to 3), and for metatarsal cuneiform joint arthritis was 1.3 (range 1 to 4). The mean preoperative hallux valgus angle was 20 degrees on the anteroposterior radiographs (range –22 to 44 degrees). The mean 1–2 intermetatarsal angulation measured 13 (range –0.5 to 24) degrees.

Operative Technique

The operative technique for first MTP joint arthrodesis was similar for all patients involved in the study. Other simultaneous forefoot procedures totaled 171, for an average

of three procedures per foot (range 0 to 10), but only the first MTP joint was evaluated in the study. Anesthesia consisted of a regional block augmented with sedation or general anesthesia and was individualized for each patient. A dorsal longitudinal incision was used to expose the first MTP joint. The extensor hallucis longus tendon was retracted laterally, and the dorsal joint capsule was incised longitudinally, exposing the medial and lateral aspects of the joint. Marginal osteophytes were removed with a rongeur before joint preparation. A 0.062-in Kirschner wire was then inserted into the center of the metatarsal head and directed proximally. A cannulated power reamer was selected with a diameter equivalent to the metatarsal shaft diameter and was then used to shape the metatarsal head in a dome-shaped fashion (Hallu©-Ream, Integra Life Sciences Inc, Plainsboro, NJ) (Figure 2). The Kirschner wire was removed and used to perforate the metatarsal head in multiple areas to increase the bony surface area available for fusion and to stimulate bleeding. A 0.062-in Kirschner wire was then inserted into the center of the proximal phalanx and directed distally. Successively larger cannulated dome-shaped male reamers were then used over the Kirschner wire to prepare the proximal phalanx (Figure 3). The smallest reamer was used first to penetrate the subchondral cortex before increasing the reamer size. The final reaming was done with a reamer of the same diameter as the metatarsal reamer to optimize bony contact. The Kirschner wire was then removed and used to penetrate the proximal phalanx in a similar fashion to the metatarsal head. The two bony surfaces were approximated and stabilized with crossed 0.062-in Kirschner wires with the hallux in dorsiflexion of 15 degrees and valgus of 10 to 15 degrees. Neutral rotation also was set at this stage. An appropriately sided right or left precontoured six-hole dorsal titanium plate was then selected. The plate has preset valgus of 10 degrees and dorsiflexion of 10 degrees (Figure 4). The plate has a small hole that accepts a Kirschner wire to temporarily secure it to the bone before screw fixation. Spin screws of 2.7 mm or 3.0 mm were used to secure the plate to the bone. The crossed Kirschner wires were then removed and replaced by a screw crossing from distal-medial to proximal-lateral (Figure 5). Intraoperative fluoroscopy was used to evaluate alignment during the procedure. The skin was closed in a routine fashion. The forefoot was wrapped in a postoperative compression dressing over the forefoot and changed on a biweekly basis.

Postoperative Course

Patients were seen within 48 hours, and a gauze and tape compression dressing with a great toe spica wrap was applied. Taping of the great toe continued for 12 weeks after surgery. Physical and radiographic examinations were performed at followup visits. Patients were instructed on proper weightbearing on the heel and the lateral border of the foot if no other lateral forefoot procedure was done at the time of the initial surgery. A postoperative shoe was



Fig. 2: The metatarsal head reamer is cannulated to fit over a 0.062-in Kirschner wire.



Fig. 3: The proximal phalanx reamer also is cannulated to fit over a 0.062-in Kirschner wire.

worn using this technique of ambulation for 12 weeks after surgery.

Followup Evaluation

Forty-nine of 50 (98%) patients (53 feet) were successfully contacted and returned for followup evaluation including physical and radiographic examination at an average of 16 (12 to 24) months after surgery. The 43 women and six men had an average age of 62 (40 to 80) years. One patient (one foot) had moved from the area during the study period and was unavailable for followup. Patients were again evaluated regarding pain, ambulatory capacity limitations, time off work, length of postoperative swelling, presence of symptomatic hardware, gait evaluation, ability to toe rise, hallux pronation, and interphalangeal joint motion. An

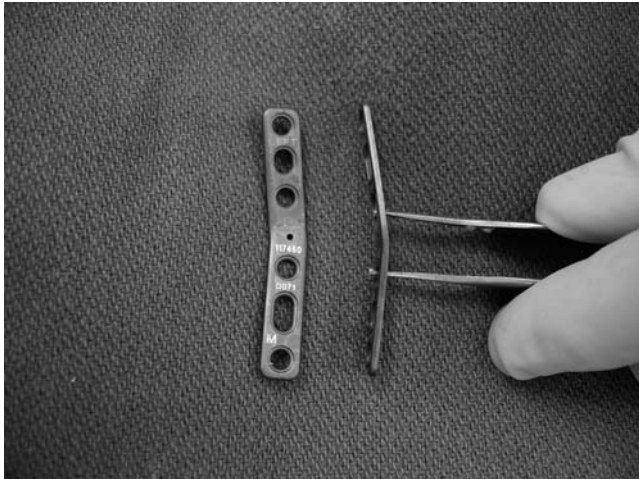


Fig. 4: A left six-hole plate with preset 10 degrees valgus and 10 degrees dorsiflexion.



Fig. 5: An implanted dorsal six-hole plate with insertion of a crossed lag screw.

American Orthopaedic Foot and Ankle Society (AOFAS) score was obtained at the final evaluation, and patients were asked to rate their satisfaction with the procedure using a previously published scale.⁶ An excellent result is given when the patient reports no problems, is very satisfied, has mild or no pain, and walks without difficulty. A good result denotes few problems, mild pain, walks without difficulty or with mild difficulty, but would still have the surgery. A fair result is when there is moderate pain, some difficulty with walking, and the patient has reservations about the success of surgery. A poor result is continued pain, little improvement in walking, and the patient regrets having had surgery.

Radiographs were obtained and evaluated and measured for angular correction, and for the presence of arthritis at the interphalangeal and metatarsocuneiform joints and union of the arthrodesis.

RESULTS

Subjective Evaluation

Of the 49 patients who returned for followup evaluation, 32 (65%) rated their final outcome as excellent, 16 (33%) as good, and one as fair. The patient with a fair result had rheumatoid arthritis and had both feet operated on at different times during the time frame of the study and rated both feet as fair. This patient also had a Hoffman procedure on the lesser metatarsals. The arthrodesis on one side failed to unite and migrated into 32 degrees of valgus with loosening of the hardware. This patient continues to have swelling that is equal to the amount of swelling present before surgery. Revision surgery has been planned but has not yet been scheduled.

AOFAS scores at final followup (Table 1) improved from a preoperative mean of 51 points to an average of 82 points (range 47 to 90). This improvement was statistically significant ($z = -6.301, p > 0.01$).

Visual analog pain scores improved from a mean of 6.3 points preoperatively to less than 1 point (range 0 to 7 points) at final followup (Table 1). Subjective pain ratings were no pain in 31 (63%) feet, mild pain in 17 feet (32%), moderate pain in four feet, and moderate-to-severe pain in one foot. One patient reported no pain in one foot and mild pain in the other. One patient who reported moderate pain in one foot and moderate to severe pain in the other had a nonunion on one side. Ambulatory capacity improved from a preoperative mean of 2.2 points to an average of 1.3 points (range 1 to 4 points).

The average time taken off work was 3 weeks. Subjects who were retired were eliminated from this calculation. Swelling resolved at an average of 11 weeks after surgery. Only one person had swelling of the hallux at 1 year after surgery. This patient had rheumatoid arthritis and experienced swelling before surgery.

Objective Evaluation

Physical Examination

Pronation of the hallux was present in 32 patients before surgery. This improved in all but three patients after surgery.

Table 1: Results of physical and subjective evaluation

	Preoperative	Postoperative	P value
AOFAS ¹	51 points	82 points	<0.01
VAS ²	6.3 points	0.64 points	<0.01
Pain	3.6 points	1.5 points	<0.01
Ambulation	2.2 points	1.34 points	<0.01
IP motion ³	47°	45°	0.745

¹AOFAS hallux-MTP joint score; ²visual analog scale; ³interphalangeal joint motion.

One of these three patients had a revision surgery involving a derotational osteotomy through the mid-portion of the proximal phalanx after plate removal and reported improved appearance and diminished pain with ambulation. The final AOFAS score for this patient was 77 points and the final subjective rating was good. The other two patients had mild pronation. One had a final AOFAS score of 90 points, and rated the overall outcome as good. The other patient had a nonunion of the fusion site with loose hardware (Figure 6, A) that required revision surgery (Figure 6, B).

Radiographic Examination

Radiographs were assessed for arthritis of the interphalangeal and metatarsocuneiform joints and for fusion of the MTP joint. The amount of degeneration on initial radiographs was minimal in most patients.^{7,9,10} Before surgery the arthritis scores for the interphalangeal joint averaged 1.4 (range 1 to 3) points and for the metatarsocuneiform joint 1.3 (range 1 to 4) points (Table 2). At final followup, the average score for the interphalangeal joint was 1.7 (range 1 to 4) points and for the metatarsocuneiform joint 1.3 (range 1 to 4) points. One foot progressed from a grade 1 at the interphalangeal joint to grade 4 at final followup. This was due to a technical error that caused the plate to extend past the interphalangeal joint. The AOFAS score was 77, and final rating was good despite mild pain at the interphalangeal joint. The metatarsocuneiform joint was unchanged in this foot. Thirteen feet had single-grade worsening at the interphalangeal joint and three at the metatarsocuneiform joint. No patient noted any pain associated with the metatarsocuneiform joint.

At followup, 39 of the 53 feet had the same arthritic grade at the interphalangeal joint as before surgery, 50 had the same grade at the first metatarsocuneiform joint as before surgery.

The hallux valgus and the 1–2 intermetatarsal angles were measured on the initial and final followup radiographs (Table 3). The mean preoperative hallux valgus angle of 20 degrees was improved to a mean of 13 (range 1 to 32.5) degrees. The mean preoperative 1–2 intermetatarsal angle of 13 degrees was reduced to a mean of 10 (range 2 to 18) degrees at final followup. Both of these changes were statistically significant ($z = -3.553$, $p < 0.01$ for the hallux angle, and $t = 5.139$, $p < 0.01$ for the 1–2 intermetatarsal angle). The dorsiflexion angle of the hallux metatarsophalangeal joint averaged 24 degrees at final followup. During the course of the study there were no delayed unions and four nonunions.

Table 2: Radiographic measurement of interphalangeal (IP) and metatarsocuneiform (MC) degeneration

	Preoperative	Postoperative	P value
IP joint	1.4 points	1.7 points	<0.01
MC joint	1.3 points	1.3 points	0.083

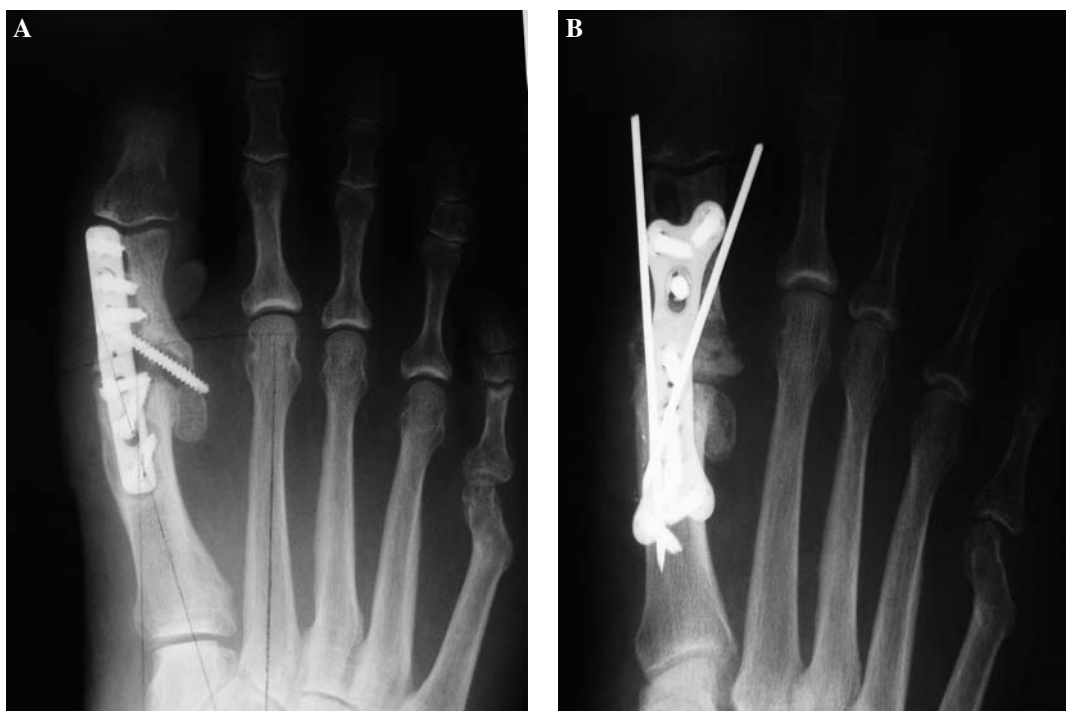


Fig. 6: A, Symptomatic fibrous union with loosening of the hardware. B, After revision surgery with proximal tibial bone grafting and revision plating.

DISCUSSION

Multiple retrospective studies have reported the results of first MTP joint arthrodesis,^{1,2,4-12,14,16-19,21,24-27} but to our knowledge this is the first prospective study to evaluate this procedure. Patients with a variety of underlying diagnoses, enrolled consecutively over a 1-year period, were evaluated at a minimum of 12 months after surgery. This enabled us to accurately examine the foot for multiple parameters before arthrodesis and eliminate the effects of recall bias on patient outcome.

Many techniques exist for joint preparation and instrumentation.^{1-14,16-27} A method that is easy to perform and is reproducible leads to more predictable outcomes. We chose dome-shaped reamers for preparation of the joint surface because of the ease of use and the ability to reliably produce congruous joint surfaces.⁵ Valgus angulation, dorsiflexion, and pronation of the hallux can be independently altered to produce the desired final metatarsophalangeal angulation.⁵ While flat cuts may be simple to make, the final three-dimensional angulation of the joint must be accounted for in the osteotomies to achieve the desired outcome. Changes in one plane may affect angulation in another plane. This difficulty in achieving the final desired varus and valgus, dorsiflexion and plantarflexion, and axial rotation can be minimized by dome-shaped joint preparation.

Buranosky et al.³ in a cadaver study compared arthrodeses using two crossed lag screws to a dorsal six-hole plate and interfragmentary screw compression. The first MTP joint surfaces were prepared with dome-shaped reamers before fixation. The constructs were tested to failure, and the results were quantified. The dorsal plate with a crossed lag screw construct was significantly stiffer and had a greater point of ultimate failure than did the interfragmentary screws. In addition, even when the plate bent during testing, the joint surface maintained compression as opposed to loss of fixation when the crossed screws cut through the bone.

Neufeld et al.²² compared three methods of fixation of the first MTP joint in cadaver feet. The joints were fixed with either crossed screws, dorsal plating and a crossed Kirschner wire, or two compression staples and a crossed Kirschner wire. The strongest construct was the crossed screws, the

plate fixation was second in strength second, the staples were the weakest. These results are similar to those of Politi et al.,²³ which demonstrated that a plate alone was not as stable as crossed screws, but a plate with a crossed interfragmentary screw was more stable than screws or plates alone.

To achieve bony fusion, the joint surfaces must be held in rigid apposition during the healing period. Multiple methods have been developed to achieve this rigid fixation, including Kirschner wires,^{10,12,13,17,25} Steinmann pins,^{7,17,18} screws,^{2,10,16,17,19,20,26} plates,^{1,5-9,24} cerclage wire,^{11,27} sutures,⁴ and various combinations of these methods. Several studies have demonstrated that dorsal plating with a crossed lag screw is a reliable technique.^{3,5-9,23} Politi et al.²³ demonstrated that dome-shaped joint preparation coupled with dorsal plating and a crossed lag screw was the most stable construct in synthetic bone models. Bennett et al.¹ examined hardware failures after dome-shaped joint preparation and dorsal plate fixation with a crossed lag screw. The plate used was a dorsal titanium plate (Synthes Modular Hand Fixation Set, Synthes, Paoli, PA) fixed with 2.4-mm screws. The authors evaluated 95 consecutive patients who had first MTP joint arthrodesis with this technique and plating system. Of the 95 patients, 14 had nonunions with concomitant plate or screw breakage. Based on their patient outcomes, Bennett et al.¹ concluded that these implants were not strong enough to be used for first MTP joint arthrodeses. The plate and screws also used in our study were titanium, but the diameters of the screws were 2.7 mm and 3.0 mm, which provided more strength than the 2.4-mm screws used by Bennett et al.¹ The plate we used was prebent to 10 degrees of valgus and 10 degrees of dorsiflexion and did not need to be routinely custom-contoured intraoperatively, which might lead to metal fatigue and implant failure. Neither the plate nor the screws failed in any of our patients during the followup period. The only cause of the four nonunions in our patients was loss of fixation at the bone-screw interface. For this reason, we now use 3.0-mm screws in osteopenic bone.

The low-profile design of the plate used in our patients allows the plate to be left in permanently. None of our patients required plate removal because of discomfort. When

Table 3: Radiographic examination before and after surgery regarding hallux valgus, 1-2 intermetatarsal, and dorsiflexion angles. Shortening was calculated using the arc technique described by Hardy and Clapham¹⁵ when the second or third metatarsal was not included in forefoot corrections

	HV angle	1-2 IM angle	Dorsiflexion	Shortening
Preoperative	20 degrees	13 degrees	N/A	N/A
Postoperative	13 degrees	10 degrees	24 degrees	-3.4 mm

HV = hallux valgus; IM = intermetatarsal.

questioned at final followup, four patients complained that the plate caused symptoms, but on physical examination only one of these patients had tenderness over the plate. On examination, five other patients had tenderness over the plate, but four of them were not aware of this tenderness until the followup examination. Only two plates were removed during the study. One was removed because of malrotation of the phalanx as a residual of the initial operation and not due to discomfort. This patient has done well after hardware removal and derotational osteotomy through the mid-proximal phalanx. The other plate was removed during revision surgery for a nonunion with replating of the MTP joint and bone grafting.

Time to fusion averaged 12 weeks in our patient population. Our 92% fusion rate is similar to previously reported rates.^{1,2,4-11,14,16,18,19,21,24-27} Only four nonunions occurred in the 53 feet. Three progressed into valgus, and one of these patients elected to have revision arthrodesis during the course of the study. Two of these were reported as good and one as fair. All three reported good overall outcomes. The AOFAS scores in these three patients were 62, 65, and 70. After a first MTP joint fusion, the highest possible score is 90 points because the loss of MTP joint motion constitutes a 10-point reduction in the overall score. The fourth patient with a nonunion had a stable fibrous union with maintenance of the joint space radiographically. This patient rated the final subjective result as good although the AOFAS score improved only 5 points from 57 to 62 points at final followup. Three of four patients with nonunions in this study population rated their final outcome as good, with the fourth rating his as fair. This finding is similar to that of previous studies^{4,9,13,14} that demonstrated that a pseudoarthrosis does not necessarily lead to a poor outcome.

Interphalangeal joint motion of the great toe and radiographic evidence of interphalangeal joint arthritis after arthrodesis have been evaluated in previous studies. Fitzgerald¹⁰ concluded that the first MTP joint should be placed in at least 20 degrees of valgus and reported a three-fold reduction in the incidence of interphalangeal joint arthritis when the joint was fused in greater valgus. Later, Coughlin⁷ reported that a minimum of 20 degrees of dorsiflexion at the MTP arthrodesis site substantially reduced the incidence of interphalangeal joint arthritis. The plate used in our study is precontoured with dorsiflexion of 10 degrees and valgus of 10 degrees. The dorsiflexion angle is calculated on the lateral radiograph using mid-diaphyseal reference points. While the plate itself measured 10 degrees, it is contoured to the dorsal surface of the proximal phalanx and first metatarsal. The radiographic measurement based on mid-diaphyseal reference points is 15 to 20 degrees of dorsiflexion and occurs due to the widening that occurs in the metaphyseal flare of both bones. These angles reliably produce the desired result of 20 degrees of dorsiflexion and 15 to 20 degrees of valgus.^{5-9,14,18,26} The plates can be further bent intraoperatively to accommodate unusual bony anatomy, but this was

rarely required. The dome-shaped reaming coupled with the precontoured plate allows for ease of joint alignment into the desired dorsiflexion and valgus, which we believe reduces the risk of interphalangeal joint degenerative arthritis. In our patients, there was statistically significant progression of degeneration at the interphalangeal joint of the great toe ($z = -3.638$, $p > 0.01$); however, there was no correlation between interphalangeal joint degeneration and the rating on the visual analog pain scale ($r = 0.166$, $p = 0.241$) or the final subjective rating ($r = -0.075$, $p = 0.597$). Because of the relatively short mean followup of 16 months, these numbers may not accurately represent the long-term status of arthritis at these joints.

While we have accurate followup of 98% of patients, one weakness of this prospective study is the relatively short followup period of 1 year. Degeneration of the adjacent joints may develop or increase with the passage of time but this has not been reported to be a factor in other studies;^{7,10,14} it was uncommon and rarely symptomatic in our patients. Also, the differing diagnoses of the patients add other confounding variables. Our cohorts would have been too small had we elected to use only a single diagnosis, but future prospective studies of patients with the same diagnosis would be preferable.

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