DOI: https://doi.org/10.30795/jfootankle.2025.v19.1859

Original Article

Outcomes of plated metatarsophalangeal joint fusions without transarticular screw fixation

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Abstract

Objective: Evaluate the outcomes of metatarsophalangeal (MTP) arthrodesis performed with plate-only fixation.

Methods: A retrospective observational study was conducted on 68 patients submitted to MTP arthrodesis with plate fixation between June 2021 and December 2023. The primary outcome measure was the Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function (PF) score, evaluated preoperatively and postoperatively in patients who received a locking-compression plate or locking plate. Secondary outcomes included complication rates and the duration of follow-up.

Results: The mean patient age was 64.0 years, with a body mass index of 28.5 kg/m^2. The minimal clinically important difference of PROMIS-PF scores was achieved by 30.9% of patients. The complication rates were low, with no cases of malunion and only 2 (2.9%) nonunions. Patients who received a locking-compression plate had higher postoperative PROMIS-PF scores compared to the locking plate group (46.4 vs. 42.3, p = 0.038), and a greater percentage of these patients experienced improvement in PROMIS-PF postoperatively (71.4% vs. 42.5%, p = 0.035).

Conclusions: Both locking-compression and locking plates for MTP joint arthrodesis without transarticular screws are effective, with a low complication rate. These outcomes were comparable to those of prior studies evaluating screw-only and plate and screw fixation constructs. Longer follow-up studies are required to enable direct comparison of outcomes across the alternative arthrodesis techniques.

Level of Evidence III; Retrospective, Case-control study.

Keywords: Metatarsophalangeal joint; Arthrodesis; Postoperative complication; Bone plates; Patient Reported Outcome Measures.

Introduction

First metatarsophalangeal (MTP) joint arthrodesis is a surgical procedure commonly performed to alleviate pain and improve function in patients with severe arthritis or hallux rigidus[1,2]. These conditions often result in significant discomfort and impaired mobility, severely affecting patients' quality of life[3]. The primary goal of first MTP arthrodesis is to provide pain relief and restore functional ability by permanently achieving arthrodesis, thereby eliminating motion and reducing inflammation and pain[4].

Traditionally, first MTP arthrodesis has utilized screw fixation, either alone or combined with plates, due to its simplicity and reliability[5]. However, the emerging practice of using plate fixation alone, without transarticular screws, is gaining popularity at our institution and may offer comparable outcomes. Previous studies have similarly found functional and patient satisfaction improvements with plate and screw methods, prompting a reevaluation of the necessity and cost-effectiveness of transarticular screws[6-9]. Locking plates provide enhanced stability by creating a fixed plate-screw

Study performed at the Luminis Health Anne Arundel Medical Center, Annapolis, MD, USA.

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How to cite this article: Rana P, Brenna JC, Johnson AH, Owens S, Friedmann E, Spirt AA, et al. Outcomes of plated metatarsophalangeal joint fusions without transarticular screw fixation. J Foot Ankle. 2025;19(2):e1859.

construct that is more rigid and advantageous, especially with softer bone. The objective of this study is to evaluate the patient-reported and clinical outcomes of patients submitted to first MTP arthrodesis using locking or locking-compression dorsal plates without a transarticular compression screw. We hypothesized that patients submitted to plate-only fixation would experience outcomes similar to those previously described in patients submitted to screw-only or plate and screw fixation. This study examined a retrospective cohort of 68 patients, focusing on improvements in physical function as measured by the Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function (PF) scores, complication rates, and the overall efficacy and safety of the procedure. Understanding these outcomes is essential for refining surgical techniques and improving patient care in those suffering from severe first MTP joint conditions.

Methods

Study population

This study was exempt from review by the institutional review board because it was a retrospective review of existing medical records. A retrospective observational study of 68 patients submitted to first MTP arthrodesis with low-profile locking MTP plates (Low Profile Titanium Pre-Contoured Plate, Arthrex Inc., Naples, FL, USA) or locking-compression MTP plates (MaxForce MTP Plate, Arthrex Inc., Naples, FL, USA) from June 2021 to December 2023 was performed. Surgeries were performed by three board-certified orthopedic surgeons with fellowship training in foot and ankle surgery. All patients underwent plate-only fixation without the use of a transarticular compression screw. Patients were excluded from the study if they did not complete the PROMIS-PF survey at baseline and at least once postoperatively.

Operative technique

The most commonly used approach for first MTP arthrodesis was the dorsal longitudinal incision, medial to the extensor hallucis longus tendon over the hallux MTP joint[1]. However, in cases where there was significant dorsal scarring of the hallux, a medial incision was used as an alternative. Sharp dissection was performed down through the skin and subcutaneous tissue, and the capsule was incised in line with the skin incision. This approach ensures adequate exposure of the joint while minimizing trauma to the surrounding tissues.

Joint preparation

Subperiosteal dissection and release of the collateral ligaments were performed to allow proper positioning of the cup and cone reamers from the Arthrex hallux MTP arthrodesis plating system (Arthrex, Inc., Naples, FL, USA). The spherical cup-and-cone articular surface preparation technique, known for its precision and reliability, was employed in this procedure. While alternative techniques, such as peg and socket configurations or planar cuts, are available and well-documented, the cup-and-cone method was selected for its superior alignment and surface matching[1,10]. Reaming was performed to the level of bleeding subchondral bone, and additional fenestration of the first metatarsal head and the base of the proximal phalanx was accomplished using Kirschner-wire drill holes.

Fixation technique

For fixation, either an Arthrex arthrodesis locking or locking-compression plate was chosen at the surgeon's discretion and provisionally secured to the bone with BB-Taks (Arthrex, Inc., Naples, FL, USA). In the locking plates, the distal part of the plate was then fixed securely, followed by the placement of a proximal compression screw. In the locking-compression plates, the distal end was secured with multiple locking screws, and a compression jig was used to compress through the MTP joint arthrodesis site. Bone reamings are utilized as graft material to enhance the fusion process in both cohorts. Notably, no transarticular screws were used in any of these cases.

Independent variables

The independent variables of interest included age, body mass index (BMI), race, American Society of Anesthesiologists (ASA) score, history of rheumatoid arthritis, prior MTP surgery, hallux rigidus grade, additional procedures performed, and plate type.

Outcome measures

The outcomes of interest were baseline PROMIS-PF, postoperative PROMIS-PF, improvement in PROMIS-PF, achievement of the minimal clinically important difference (MCID) between baseline and postoperative PROMIS-PF achievement, malunion, nonunion, reoperation, and duration of follow-up. The PROMIS-PF is a validated tool used to assess patients' self-reported physical abilities and health status, providing a standardized way to gauge the effectiveness of medical interventions. The PROMIS-PF MCID was defined as a 5-point improvement from baseline, using the ½ standard deviation method, in alignment with prior studies[11,12].

Statistical analysis

Descriptive statistics were performed to evaluate the demographics, surgeries performed, and outcomes for all MTP arthrodesis patients. For all descriptive statistics, the data were presented as mean ± standard deviation or n (%). Univariate analysis, including Chi-square testing for categorical measures and 2-sided independent samples t-testing for continuous measures, was performed to compare outcomes between locking and locking-compression plates. Statistical analysis was performed in RStudio (Boston, MA, USA), and statistical significance was assessed at $p < 0.05$.

Results

The patients' mean age was 64.0 ± 10.8 years, with a BMI of 28.5 ± 5.4 kg/m^2. Only six patients (1.0%) were not white, and only five (7.4%) had a history of rheumatoid arthritis. Most patients had an ASA score of 2 (69.1%) or 3 (26.5%), and 15 (22.1%) had a prior first MTP surgery, 13 (86.7%) of which were a bunionectomy or cheilectomy. Additionally, five patients (7.4%) had a hallux rigidus grade of 2, 41 (60.3%) had a grade of 3, and 22 (32.4%) had a grade of 4. An Arthrex Maxforce locking-compression plate was used in 28 (41.2%) MTP arthrodesis, and 19 (27.9%) of patients had additional procedures performed (Table 1).

Preoperatively, the mean PROMIS-PF score was 42.8 ± 6.1, and postoperatively, the mean PROMIS-PF score was 44.0 ± 7.6. Additionally, 37 (53.6%) patients saw improvement in PROMIS-PF scores postoperatively, while 21 (30.9%) achieved MCID. There were no patients with a malunion postoperatively, and only two (2.9%) had a nonunion postoperatively. Three (4.3%) patients had a reoperation. The mean follow-up was 13.8 months (median 12 months) after surgery (Table 2).

Table 3 details the patients with nonunion and reoperation. All patients had pre-contoured locking Arthrex plates, and none were MaxForce locking-compression plates. Two male patients, aged 71 and 79, experienced nonunion with no evidence of hardware loosening or failure on computed tomography (CT) scans. The 71-year-old patient's condition was complicated by an autoimmune disorder, and it is questionable if the nonunion was aseptic or septic. The 79-year-old patient displayed hardware loosening without signs of infection. Three patients required reoperation due to different etiologies. The 71-year-old male, with advanced hallux rigidus (grade 4), underwent hardware removal due to nonunion. The CT scans confirmed that there was no hardware loosening or failure, and no signs of infection were observed. The other two patients, females aged 55 and 37, both underwent hardware removal due to persistent pain despite achieving successful fusion. Both showed no signs of hardware failure or loosening on their CT scans.

Table 1. Patient characteristics and surgery details

Measure	All patients (n = 68)
Age	64.0 ± 10.8
BMI	28.5 ± 5.4
Non-white race	6 (1.0)
ASA score	
1	2 (2.9)
2	47 (69.1)
3	3 (26.5)
4	1 (1.5)
Rheumatoid arthritis	5 (7.4)
Prior MTP surgery	15 (22.1)
Bunionectomy/Cheilectomy	13 (86.7)
Arthroplasty/Hemiarthroplasty	2 (13.3)
Hallux rigidus grade	
2	5 (7.4)
3	41 (60.3)
4	22 (32.4)
Additional procedures performed	19 (27.9)
Locking plate	28 (41.2)

Data are expressed as mean ± SD or n (%). ASA: American Society of Anesthesiologists; BMI: Body mass index (kg/m2); MTP: Metatarsophalangeal.

Discussion

This study demonstrates that first MTP joint arthrodesis using plate-only fixation without a transarticular screw improved the patient-reported physical function and comparable outcomes as previously reported using screw-only and plate and screw fixation. The plate-only procedure exhibited a low complication rate, with no instances of malunion and a 2.9% nonunion rate, which underscores the efficacy and safety of plate-only first MTP arthrodesis. Additionally, the reoperation rate was relatively low at 4.3%. In comparison to patients treated with locking plates, those receiving locking-compression plates reported higher levels of physical function postoperatively and were more likely to report improvement on the PROMIS-PF survey—further, none of the patients receiving a locking plate experienced complications.

The 2.9% nonunion rate observed in our study is in alignment with prior studies reporting nonunion rates of 0% to 23% after first MTP arthrodesis[13-16]. In a systematic review of 2,800 primary and revision first MTP arthrodesis, an overall nonunion rate of 5.4% and implant removal rate of 8.5% was reported[17]. Kumar et al.[13] found a 98% fusion rate with plate and screw methods, and other studies have shown a 1.5%-3.7% nonunion rate in hallux rigidus fusion with plate and compression screw[14]. Our study contributes to this body of evidence by demonstrating that plate-only fixation, without the use of transarticular screws, achieves comparable results, providing surgeons with flexibility in choosing the method best suited to their patients' needs. Nonunion and reoperation after first MTP joint arthrodesis are influenced

Table 2. Patient-reported and clinical outcomes

Outcome	All patients (n = 68)
Baseline PROMIS-PF	42.8 ± 6.1
Postop PROMIS-PF	44.0 ± 7.6
Improved PROMIS-PF postoperatively	37 (53.6)
Achieved PROMIS-PF MCID postoperatively	21 (30.9)
Malunion	0 (0.0)
Nonunion	2 (2.9)
Reoperation	3 (4.3)
Follow-up months	13.8 ± 10.5

Data are expressed as mean ± SD or n (%). PROMIS: Patient-Reported Outcomes Measurement Information System; PF: Physical function; MCID: Minimal clinically important difference.

Table 3. Details of patient complications

Patient Age/Sex	Plate type	Hallux rigidus grade	Arthritis grade	Etiology of outcome	Patient risk factors
Nonunion					
71 y.o. Male	Low profile Titanium standard Pre-contoured (Locking)	4	4	CT shows no hardware loosening or failure Questionable aseptic versus septic Autoimmune disorder	Elevated BMI Smoker
79 y.o. Male	Low profile Titanium standard Pre-contoured (Locking)	3	3	CT showing hardware loosening No signs of infection	Elevated BMI Smoker
Reoperation					
71 y.o. Male	Low profile Titanium standard Pre-contoured (Locking)	4	4	Hardware removal due to nonunion CT shows no hardware loosening or failure No signs of infection	Elevated BMI Smoker
55 y.o. Female	Low profile Titanium petite Pre-contoured (Locking)	2	2	Hardware removal due to pain No hardware loosening or failure Successful fusion	None
37 y.o. Female	Low profile Titanium petite Pre-contoured (Locking)	2	2	Hardware removal due to pain No hardware loosening or failure Successful fusion	None

BMI: Body mass index; CT: Computed tomography.

by a range of patient-specific and surgical factors. Key modifiable risk factors significantly associated with nonunion after foot and ankle arthrodesis include a higher BMI, tobacco use, diabetes mellitus, thyroid dysfunction, parathyroid disease, and vitamin D abnormalities[18]. Specifically, higher body weight and increased preoperative hallux valgus angle slightly raised the likelihood of nonunion in first MTP arthrodesis[19]. Nonunion is also more frequently reported among males, those with comorbidities, higher grades of osteoarthritis, and greater postoperative dorsiflexion of the great toe[20]. Patients with inflammatory diseases can achieve successful fusion; however, they may take longer to achieve clinical and radiographic union compared to patients without inflammatory disease[21]. Surgical factors such as moderate to severe hallux valgus and under-correction of more than 25 degrees at the first MTP joint significantly increased the risk of nonunion or delayed union[22]. Diabetes further heightened nonunion rates, underscoring the need for careful management of diabetic patients undergoing surgery[23]. Finally, postoperative residual hallux valgus deformity was an independent risk factor for nonunion, highlighting the importance of achieving proper alignment during surgery[24].

Multiple previous studies have evaluated the benefits of first MTP arthrodesis for pain relief, functional improvement, and patient-reported outcomes[3,7]. In the study by Dayton et al.[25], 98.3% of patients were able to walk at a normal pace postoperatively, and 95% reported that loss of motion in their big toe did not affect their daily function after MTP arthrodesis. Another study of 60 patients by Chraim et al.[26] highlighted that 90% of patients were either satisfied or very satisfied after treating their hallux rigidus with fusion at a mean follow-up of 47 months. Even patients with a history of cheilectomy, who tend to have worse physical function both preoperatively and postoperatively, can achieve similar improvements in PROMIS scores compared to patients without such a history[27]. Various factors may influence these results; Andrews et al.[28] found that resilience, as measured by the Brief Resilience Scale, independently affects patient-reported outcomes, including PROMIS-PF scores. In our study, similar results were observed in patient-reported outcomes. Across the population, patients presented with relatively high levels of preoperative physical function, as demonstrated by a mean PROMIS-PF score of 42.8, which is within one standard deviation of the general adult population normative value of 50[29]. This is in alignment with a prior study reporting mean baseline PROMIS-PF scores of 44.4 in patients undergoing primary first MTP arthrodesis[27]. Given the high levels of baseline function in the population and the relatively short follow-up period, we observed modest improvements in PROMIS-PF scores postoperatively, with approximately 54% of patients reporting improvement. Notably, patients treated with locking-compression plates demonstrated higher postoperative PF scores and higher rates of improvement than those receiving locking plates—an observation that, to our knowledge, has not been previously reported. In light of this trend and the finding that no patients in the locking-compression plate group experienced postoperative complications or reoperations, our data suggest there may be a slight benefit to using locking-compression plates in plate-only MTP arthrodesis constructs.

Alternative methods of arthrodesis, such as the use of fully threaded compression screws and low-profile locking plates, have been compared in terms of biomechanical properties. One study indicated that fully threaded compression

screws had similar plantar gapping and load-to-failure compared to low-profile locking plates, but with significantly more stiffness[26], which may contribute to poorer patient satisfaction. However, when comparing low-profile contoured locking plates with single intraarticular compression screws, patients suffered from greater stiffness in the screw group[30], further defending the performance of plate-only arthrodesis. In general, studies have shown no clinical difference in time to fusion, fusion rates, or biomechanical differences between plate and screw techniques[30,31]. However, the choice between locking and non-locking plates remains a contested issue. Locking plates are designed to provide greater stability and may reduce the risk of hardware failure. Non-locking plates, while offering flexibility during bone healing, may present a higher risk for complications in certain patient populations. Haimes et al.[16] performed a comparison of non-locking semi-tubular plates and pre-contoured locking plates and found no significant difference in revision rates, questioning the necessity of more expensive locking plates. Hunt et al.[11], however, found that locked titanium plates resulted in a higher nonunion rate compared to non-locking stainless steel plates in patients without rheumatoid arthritis. Additionally, Bass and Serikonda[32] found higher fusion rates with locking plates in males, although overall fusion rates did not differ significantly between the two plate types. Although the majority of patients may achieve similar results with either type of plate, certain patient populations may benefit from a personalized selection. A unique aspect of our study is the evaluation of compression vs. traditional plates within the locking plate category. Our data suggest that locking compression plates might be associated with fewer complications compared to traditional locking plates without compression when not using a transarticular screw. Further research is needed to evaluate outcome differences between these alternative locking plate systems, especially given the increased cost of locking compression plates.

The primary limitation of this study is its small sample size, which may affect the statistical power and generalizability of the findings. The retrospective nature of the study also introduces potential biases, such as selection bias and recall bias, which can impact the accuracy and reliability of the results. Additionally, the study was conducted at a single institution, limiting the applicability of the results to broader populations. Furthermore, only patients completing both pre- and postoperative PROMIS surveys were included, adding to selection bias. Moreover, the time to follow-up was variable across the population, and no minimum follow-up period was required, potentially biasing both the clinical and patient-reported outcomes observed. These factors should be considered when interpreting the findings, and future research should include larger, multicenter cohorts to validate these results and enhance their generalizability.

Conclusion

Patients undergoing first MTP arthrodesis using plate-only fixation without a transarticular screw experienced low complication rates, including a 2.9% nonunion rate and a 4.3% reoperation rate. These outcomes were comparable to previous studies evaluating screw-only and plate and screw fixation constructs, demonstrating the safety of the plate-only approach. Longer follow-up studies are required to enable direct comparison of outcomes across the alternative arthrodesis techniques.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PR *(https://orcid.org/0000-0002-9898-2844) Interpreted results of the study, wrote the paper, participated in the reviewing process, approved the final version; JCB *(https://orcid.org/0000-0003-2923-3740) Interpreted results of the study, wrote the paper, participated in the reviewing process, approved the final version; AHJ *(https://orcid.org/0000-0001-6903-7731) Planned the activities that led to the paper, participated in the reviewing process, approved the final version; SO *(https://orcid.org/0009-0000-4550-3515) Participated in the reviewing process, approved the final version; EF *(https://orcid.org/0000-0003-0432-0100) Conceived the activities that led to the paper, participated in the reviewing process, approved the final version; AAS *(https://orcid.org/0009-0007-8992-569X) Conceived the activities that led to the paper, participated in the reviewing process, approved the final version; JJT *(https://orcid.org/0000-0002-5591-8033) Planned the activities that led to the paper, interpreted the results of the study, participated in the reviewing process, approved the final version; DJK *(https://orcid.org/0009-0008-1429-1140) Conceived the activities that led to the paper, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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