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Locked Versus Nonlocked Plate Fixation For Hallux MTP Arthrodesis

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ABSTRACT

Background: **Dorsal plate fixation is used commonly for arthrodesis of the hallux first metatarsophalangeal (MTP) joint. Custom dorsal plates incorporating locking technology have been developed recently for applications in the foot to provide relative ease of application and theoretically superior mechanical properties. The purpose of this study is to compare the radiographic and clinical outcomes of patients undergoing hallux MTP joint arthrodesis using a locked plate, or a nonlocked plate.** ***Materials and Methods:*** **We compared consecutive patients who underwent hallux MTP arthrodesis for a variety of diagnoses with either a precontoured locked titanium dorsal plate (Group 1) or a precontoured, nonlocked stainless steel plate (Group 2). All patients were evaluated with radiographs, visual analog pain scale, American Orthopaedic Foot and Ankle Society (AOFAS) hallux score, and a detailed patient satisfaction survey.** ***Results:*** **There were 73 feet in Group 1 and 107 feet in Group 2. There was a trend toward a higher nonunion rate in Group 1 compared to Group 2. When considering only patients without rheumatoid arthritis (RA), the union rate was significantly higher in Group 2 compared to Group 1. Hardware failure and the overall complication rate was equivalent between the two Groups.** ***Conclusion:*** **As locked plate technology continues to gain popularity for procedures in the foot, it is important that clinical outcomes are reported. Locked titanium plates were associated with higher nonunion rates. Improved plate design, patient selection, and an understanding of plate biomechanics in this unique loading environment may optimize future outcomes for hallux MTP arthrodesis.**

Level of Evidence: III, Retrospective Comparative Study

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INTRODUCTION

Several fixation techniques have been described for arthrodesis of the hallux first metatarsophalangeal (MTP) joint.[1−4,16,19] Dorsal plate fixation is used commonly since it offers superior strength and sagittal plane rigidity, allowing early weightbearing and potentially higher union rates.[3,9,14] We recently reported on our results in 107 feet with nonlocked dorsal plate fixation for MTP arthrodesis.[7] Modern dorsal plates incorporating locking technology have been developed recently for applications in the foot to provide relative ease of application and theoretically superior mechanical properties.[15,20] Very few clinical results have been reported with locked plates in the foot.

The purpose of the present study was to compare the radiographic and clinical outcomes of patients undergoing hallux MTP joint arthrodesis using a compression screw and one of two dorsal plate constructs for internal fixation: a low profile precontoured dorsal titanium locked plate (Group 1), or a nonlocked dorsal, precontoured stainless steel plate (Group 2). We hypothesized that patients with locked plates (Group 1) would provide superior union rates compared to patients with the less rigid nonlocked plates (Group 2).

MATERIALS AND METHODS

We identified and retrospectively evaluated consecutive patients treated with hallux MTP arthrodesis with cup and domed reamer joint preparation and dorsal plate fixation between March 2005 and October 2008. Institutional review board approval and informed consent was obtained from each patient. Patients treated with intercalary bone block grafting were excluded. Revision cases were included in the analysis. Patients were contacted and asked to return for clinical and radiographic followup. Minimum followup for inclusion in the study was 6 months. All patients had undergone hallux MTP arthrodesis for a variety of diagnoses (Figure 1 and

Fig. 1: Radiographs of patient with advanced Hallux Rigidus.

Table 1: Preoperative Diagnoses

Diagnosis	Group 1 ($n = 73$)	Group 2 ($n = 107$)
Hallux valgus	29	58
Hallux valgus revision	24	21
Hallux rigidus/arthritis*	12	13
Non-union	5	5
Hallux varus	2	6
Neuromuscular	1	4

*Hallux Rigidus/Arthritis include patients with advanced degenerative or inflammatory arthritic changes in the MTP joint.

Table 1). All procedures were performed by one of four foot and ankle fellowship-trained orthopaedic surgeons.

Operative technique

The operative technique used was equivalent for all four surgeons. Anesthesia included a regional block with sedation or general anesthesia. A thigh or ankle tourniquet was used for all cases.

A dorsal or dorsomedial longitudinal incision was used to approach the first MTP joint. The extensor hallucis longus tendon was retracted laterally and a longitudinal capsulotomy was made. Osteophytes were excised and a medial eminence resection was performed with a microsagittal saw if necessary. A 1.6-mm Kirschner wire was then centered on the metatarsal head and advanced proximally into the diaphysis. A cannulated domed reamer (Wright Medical, Arlington, TN) was then selected with a diameter approximating the size of the metatarsal head. The entire MT head was released (medially, laterally, plantarly) in order to allow for use of the reamer. The reamer was placed over the Kirschner wire and the metatarsal head was reamed down to bleeding subchondral bone.

Reaming of the proximal phalanx was performed in a similar fashion using a cup shaped reamer over a 1.6-mm Kirschner wire. The proximal phalangeal base was released (medially, laterally, plantarly) in order to allow for use of the reamer. Care was taken not to shorten the first ray. Sizing started with a 14-mm diameter reamer and was sequentially increased in 2 mm increments to the size matching the metatarsal head. A Kirschner wire was also used to perforate the reamed metatarsal and phalangeal surfaces.

The phalanx was then appropriately positioned on the metatarsal based on gross inspection, fluoroscopy and the use of a foot plate to ensure plantigrade position of the hallux. Provisional fixation with a small Kirschner wire was applied from distal-lateral to proximal-medial across the arthrodesis site. The appropriate locked or nonlocked dorsal plate was then selected (Wright Medical, Arlington, TN), and applied dorsally and provisionally secured with a Kirschner wire. All plates were manufactured with 10 degrees of dorsiflexion, which was adjusted with plate benders if necessary depending on the anatomy of the patient. Plate selection (locked versus nonlocked) was at the discretion of the operating surgeon (Figure 2).

In most patients, a 3.0 mm cannulated headless lag screw (Wright Medical) was then placed over the Kirschner wire traversing the arthrodesis site. Seven patients in Group 1 and two patients in Group 2 did not have lag screws used in their fixation. The decision to use a lag screw was made by the primary surgeon at the time of the procedure. The plate was then secured with a combination of 2.7 and 3.2 mm screws, depending on the bone quality (based on osteopenia determined on radiographs or intraoperative assessment). Following surgical closure a soft compressive dressing was applied.

Postoperative protocol

The early patients in Group 2 were allowed heel weightbearing for 2 weeks in a short CAM boot or hard sole postoperative shoe and then allowed to weightbear as tolerated in the boot or hard-sole shoe. The late patients in Group 2 and all patients in Group 1 were allowed heel weightbearing for 6 weeks in a CAM boot or standard hard-sole postoperative shoe. At 6 weeks, all patients were allowed to weight-bear as tolerated in the boot or shoe and were then transitioned into a regular shoe once healing was evident on radiographs.

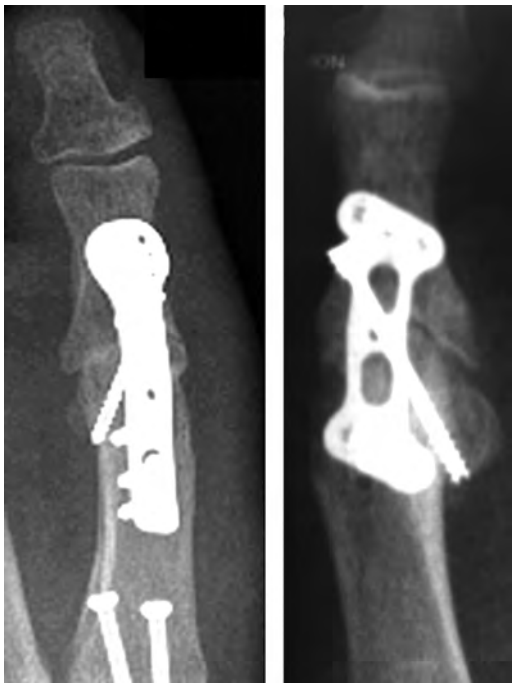

Fig. 2: Anteroposterior radiographs of hallux MTP fusion with stainless steel nonlocked plate (left) and titanium locked plate (right).

Table 2: Patient Demographic Data

	Group 1	Group 2	*p* value
Age (years)	61.5 ± 10.2	61.4 ± 10.8	NS
Gender M/F	8/65	30/77	NA
Pre-op VAS	72.1	67.8	NS
Concurrent procedures	65.7%	71.0%	NS

NS, no significant difference between groups; NA, not applicable.

Patient demographic data are reported in Table 2. Postoperative evaluation included weightbearing radiographs, physical examination, preoperative and postoperative visual analog pain scale (VAS, range, 0 to 100), postoperative American Orthopaedic Foot and Ankle Society (AOFAS) hallux score, and a detailed patient questionnaire that included a patient satisfaction survey. Radiographs were assessed for hardware failure and evidence of union. All perioperative complications were recorded. All chart and radiographic review was performed by a blinded, independent examiner (orthopaedic surgeon).

Statistics

Standard descriptive statistics were calculated including means, ranges, frequency, and percentages. A Kolmogorov-Smirnov test for normality was performed and the data was found not to be normally distributed. A Wilcoxon Signed Rank test was used to determine the statistical differences between preoperative and postoperative pain levels, IP arthritis grade, and the HVA. A chi-square or Fisher's exact test was used to determine statistical associations between union and failure, union and hardware pain, union and complication rate, and union and primary versus revision procedure. All tests were performed at an *a priori* significance level of 0.05.

RESULTS

We identified a total of 243 feet in 228 patients who had undergone first MTP arthrodesis by the method described. Thirty-three patients were lost to followup. Twenty-nine patients had inadequate followup. One patient died of causes unrelated to surgery. Thus, at a minimum followup of 6 months, a total of 180 feet in 169 patients were available for inclusion. There were 73 feet (69 patients) with a precontoured locked titanium dorsal plate (Group 1) and 107 feet (100 patients) with a precontoured, nonlocked stainless steel plate (Group 2). Patient demographic data and preoperative VAS scores were equivalent (Table 2).

Radiographic outcomes

There was a trend toward a higher nonunion rate in the locked plate group (Group 1) compared to the nonlocked plate group (Group 2) (16 of 73 [22.8%] versus 13 of 107 [11.4%]; $p = 0.064$). When patients with the diagnosis of rheumatoid arthritis (RA) were removed from the analysis, union rate was significantly higher in Group 2 (93.1%) compared to Group 1 (78.8%) when considering only patients without RA (Figure 3, $p < 0.05$). Also, the nonunion rate was significantly lower in Group 2 (6.9%) compared to Group 1 (21.2%) in non-RA patients ($p < 0.05$). When considering only patients with RA, there was no difference in union rates between Group 1 (80.0%) and Group 2 (77.1%) ($p > 0.05$). There was also no difference in nonunion rates or union rates between Groups in patients greater than 60 years of age.

Hallux valgus angle was corrected to $11.5 + 2.5$ in Group 1 versus $18.7 + 2.6$ in Group 2, ($p < 0.05$). Dorsiflexion angle of the MTP joint was equivalent between the

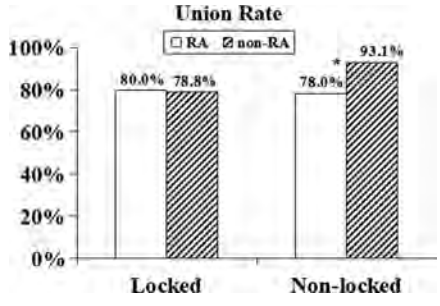

Fig. 3: Union rates (reported as a percent of overall patients in the group) for each group divided into patients with and without rheumatoid arthritis. *, $p < 0.05$

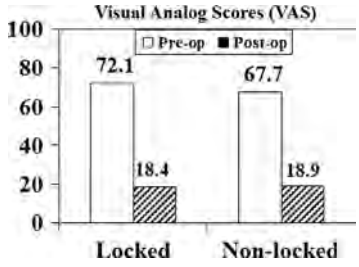

Fig. 4: Preop and postop VAS scores. There was no difference in VAS score between groups preoperatively or postoperatively.

two groups ($19.5 + 5.7$ in Group 1, $19.6 + 5.8$ in Group 2, $p > 0.05$). Hardware failure was equivalent between the two Groups (8/73 [10.9%] versus 11 of 107 [10.3%]). We identified two of 107 (1.9%) patients in Group 1 and seven of 73 (9.5%) patients in Group 2 who did not have a lag screw. Both patients in Group 1 resulted in union and two of the seven patients in Group 2 resulted in union.

Clinical outcomes

The overall complication rate was equivalent between the two groups (34.2% in Group 1 versus 28.9% in Group 2). There was no increase in complications in patients with RA (35.5% in Group 1 versus 29.6% in Group 2). AOFAS scores were equivalent between the two Groups ($80.7 + 11.6$ in Group 1 versus $79.6 + 11.2$ in Group 2). VAS scores significantly improved by 48.8 points in Group 1 and by 53.7 points in Group 2 (Figure 4). Number of patients reporting improved physical activity was equivalent between Groups (54.8% in Group 1 versus 59.8% in Group 2). Patient satisfaction was equivalent between the two Groups (82.2% in Group 1 versus 83.2% in Group 2), as was improvement in shoe wear.

DISCUSSION

We found a trend toward an increased nonunion rate in patients undergoing hallux MTP arthrodesis with a titanium dorsal locked plate compared to those treated with traditional stainless steel nonlocked plating. When evaluating only patients without RA, the nonunion rate is significantly higher in the locked plate group. Clinical outcomes and patient satisfaction were equivalent between the two groups. Possible explanations for the lower union rate with locked plating include a diminished ability to obtain sufficient interfragmentary compression with the locked plate design and the inferior rigidity of the titanium plate used in this study compared to the stainless steel plate.

Published results of hallux MTP fusions using dorsal plating have yielded mixed results. Bennett et al.[1] evaluated 95 consecutive patients who underwent dorsal plate fixation in addition to a crossed lag screw. They used a titanium plate with 2.4-mm screws. The nonunion rate was 15% and all failures included plate or screw breakage. Gaucher and Coughlin[9] reported their results in 49 consecutive patients who underwent hallux MTP arthrodesis with a nonlocked titanium dorsal plate with 2.7- and 3.0-mm screws. They reported an 8% nonunion rate with improved AOFAS scores and high satisfaction. Most of their failures were at the bone/screw interface. Our recently reported results[7] demonstrated a 12.1% nonunion rate in patients undergoing arthrodesis with a nonlocked stainless steel dorsal plate. Although our postoperative protocol is the same for patients regardless of the implant used, it is likely that the mechanical properties of the titanium plates used in Group 2 differ from those used in Group 1. Thus, it is possible that our relatively early transition out of a post-op shoe may have contributed to the higher non-union rate in Group 2.

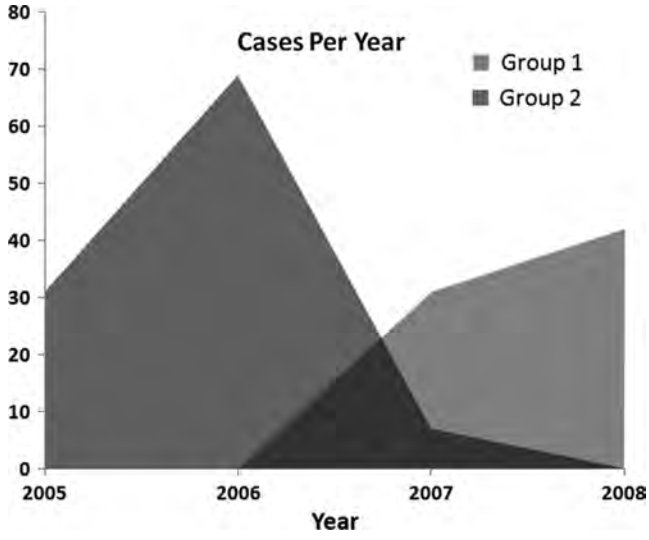

Fig. 5: Numbers of patients in each group by year during the study period.

Locked plate technology has evolved in an effort to overcome the limitations associated with conventional plating methods, particularly for fracture fixation in osteopenic bone and periarticular fractures.[8,13,20] The recent advent of locked plates for use in the foot combined with the perceived advantages of locked plate technology[6] was the impetus for our transition from a nonlocked plate to the available locked plate (Figure 5). Use of locked plating for fusions in the foot offers the theoretical advantage of superior angular and axial rigidity while minimizing screw loosening.[11,15] However, the biologic and mechanical goals are different for fusions than for fracture fixation as interfragmentary compression is crucial to achieve arthrodesis. These differences are especially true in the forefoot where shear loads are prevalent. The overall stability provided by the locked plate system across the fracture site becomes dependent on the amount and direction of load applied and the mechanical properties of the plate itself.

There is presently a paucity of mechanical data on locked plating in the foot. Scranton et al.[15] evaluated locked lapidus arthrodesis plates. They found a higher load to failure in the

lapidus plate compared to 4.0-mm lag screws alone. Klos et al.[11] demonstrated, in a cadaver model, that a medial locking plate with adjunct compression screw was superior to two crossed screws for lapidus fusion. However, clinical data on use of locked plates in the foot is exceedingly limited. Sorensen et al.[17] reported radiographic union in 20 of 21 patients undergoing lapidus arthrodesis using a locked plate with protected weightbearing allowed at 14 days postoperatively. The majority of the cases were augmented with bone graft or bone marrow aspirate. The authors did not report clinical outcomes and there was no control group. Subgroup analysis of patients with the diagnosis of RA demonstrated that nonunion rates were no different in patients with RA in either group. Activity levels and use of corticosteroids and other immunomodulatory medications can impact bone healing and fusion rates in patients with RA. These factors can vary considerably between patients, depending on disease severity, and may be a contributor to this unexpected variability in union rates. However, information on medications and activity levels was not included in our data collection for the RA patients in the present study. In addition, we found no significant difference in complications in RA patients versus non-RA patients. Still, patients with RA should be counseled about their increased risk of nonunion. The nonunion rates in patients with RA in the present study are slightly higher than those of previous studies (0% to 16%).[5,10,12,18]

Subgroup analysis of patients over 60 years of age demonstrated that nonunion rates were no different between groups despite presumably have relatively poor bone quality in patients over age 60. This suggests that locked plates, while preferred in management of periarticular and long bone fractures in osteoporotic bone, may not lead to improved union rates in osteoporotic patients undergoing first MTP arthrodesis. Since we did not obtain bone mineral density studies on patients over 60 years of age, it is plausible that there was not a significant difference in bone quality in these patients compared with younger patients.

Limitations of this study include those inherent to a retrospective cohort study. We are also limited by the lack of preoperative AOFAS hallux scores. In addition, the plates used in the two groups are comprised of different materials (titanium locked plates versus stainless steel) and the difference in plate rigidity is unknown. Thus, it is difficult to determine the influence of plate material vis a vis locked plate technology on union rates. Further controlled studies are underway to help clarify this issue. We allow early heel weightbearing which may be different than previously reported fixation methods (i.e., crossed screws) where prolonged nonweightbearing is implemented.

As locked plate technology continues to gain popularity for procedures in the foot, it is paramount that clinical outcomes and biomechanical characteristics are established. Compared to a traditional nonlocked plate, we found that a titanium locked plate used for hallux MTP arthrodesis was associated with a trend toward higher nonunion rates and a significantly higher nonunion rate in patients without rheumatoid arthritis. In the future, improved plate design, patient selection, and an understanding of plate biomechanics in this unique loading environment may optimize outcomes for arthrodesis of the hallux MTP joint and other joints in the foot.

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