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Original Research

First Tarsometatarsal Joint Fusion for Hallux Valgus Deformity: A Retrospective Comparison of Two Fixation Constructs Regarding Initial Maintenance of Correction and Complications: Traditional Crossing Screw Fixation Versus Dorsomedial Locking Plate and Intercuneiform Compression Screw

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ABSTRACT

Various fixation constructs exist to address hallux valgus when performing a first tarsometatarsal joint arthrodesis. The goal of this present study is to compare complication rates, and degree and maintenance of angular correction between a dorsomedial locking plate with intercuneiform compression screw construct versus traditional crossing solid screw fixation construct. The plate plus intercuneiform compression screw construct fixation utilized a combined sagittal saw and curette method of joint preparation while the crossed screw fixation group utilized a curette and bur technique. A retrospective review was conducted of consecutive patients who underwent a midfoot fusion using either constructs. Sixty four total feet in 56 patients were enrolled in the study. Twenty four consecutive patients (32 feet) who underwent a midfoot arthrodesis using the locking plate and intercuneiform fixation were fully fused (100%) by 10 weeks postoperatively, with no incidents of nonunion and one deep vein thrombosis event. Thirty two consecutive patients (32 feet) who underwent midfoot arthrodesis with crossing screw fixation had 2 nonunion events, one that was asymptomatic and the other that required a revision midfoot fusion. There was a statistically significant improvement from the pre-operative intermetatarsal angle, hallux abductus angle compared to the 10 week and 1 year radiographs ($p < .05$) for the entire cohort for both fixation constructs. There was a statistically significant increase in American College of Foot and Ankle Surgery first ray scores from pre-op to 1 year follow-up for both fixation constructs. Overall, the dorsomedial locking plate plus intercuneiform compression screw fixation construct better maintains Intermetatarsal angle (IMA) correction at midterm follow-up compared to the traditional crossing screw construct. Both cohorts overall demonstrate similar fusion rates at 10 weeks, nonunion events, incidences of broken hardware, hardware removal, deep vein thrombosis, neuritis at 1 year postoperatively, and hallux varus.

First tarsometatarsal joint (TMTJ) arthrodesis has become a strong and diverse procedure, being utilized in the context of post traumatic arthritis, degenerative joint disease, first ray hypermobility, trauma, midfoot instability, pes planus, as well as hallux abductovalgus deformity (HAV). For HAV, arthrodesis has established itself as a well-known and powerful procedure. The surgeon is able to address the center of rotational deformity, as well as provide stability to the midfoot, which is thought to aid in maintaining correction and prevent recurrence long-term. The first TMTJ arthrodesis was first described by Albrecht in 1911 specifically for the treatment of HAV (1). Paul Lapidus then made the procedure more famous a couple of decades later by reporting on it in 1934 (2). Historically the reported non-union rate with Lapidus has ranged from 3.3% to 12%. A recent systematic review by Crowell et al in

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2018 supports the lower end of the range, reporting a non-union rate of 3.61% out of 443 procedures (3).

In attempts to improve outcomes, different fixation techniques have been employed. Most surgical constructs include some combination of interfragmentary screws with or without fixed angle locking plates (4-9). Few constructs reported address intercuneiform instability and its possible impact on recurrence. There has been a greater focus on instability of the midfoot, along with surgical procedural modifications to address this with the Lapidus procedure. Intercuneiform instability, though, has received little attention within the literature. Weber et al described the clinical use of an intermetatarsal splay test to assess transverse plane instability before first metatarsocuneiform fusion (10). In the fourth of a series of 5 research studies looking at the biomechanics of the first ray, Roling et al demonstrated that there is greater stability through the first ray when the first metatarsocuneiform joint arthrodesis was augmented with intercuneiform fusion. Further midfoot instability was mitigated via this technique, as the naviculocuneiform joint motion also decreased with this augmentation (11).

Feilmeier et al measured the change in Intermetatarsal angle (IMA) of 12 cadaveric feet with first TMTJ fixation upon application of 15 pounds of both transverse and coronal force with an additional screw deployed individually in differing orientations. They found that the addition of an intermetatarsal screw predictably reduced the first metatarsal instability in both the transverse and sagittal plane (12). This study, however, did not study the IMA change with the addition of an integrated screw traversing the first metatarsal base, medial cuneiform and intermediate cuneiform. In 2015, Fleming et al studied the prevalence of midfoot intercuneiform instability via intraoperative hook test. Upon fixation of the first TMTJ, they utilized a bone hook around the lateral portion of the first metatarsal and applied medial directed force in attempts to distract the joint between the medial and intermediate cuneiform. If widening of the IMA was appreciated upon intraoperative radiograph evaluation, transverse plane intercuneiform instability was documented. They found 28 of 38 (73.68%) subjects had intercuneiform instability (13).

It has been reported that intercuneiform instability can play a role in recurrence of HAV deformity, even after a first TMTJ fusion. Some surgeons will routinely employ inter-cuneiform fixation to address any possible instability present, while others do not routinely use intercuneiform fixation. A direct comparison between constructs that integrate intercuneiform stabilization versus those that do not, to our knowledge, has not been completed. We present a study that directly compares the 2 surgical techniques to evaluate the maintenance of deformity correction with the traditional crossing screw fixation construct or with a dorsomedial locking plate with intercuneiform compression screw fixation constructs. Our aim is to assess how the dorsomedial locking plate plus intercuneiform compression screw fixation construct compares to the traditional crossing screw fixation with regards to IMA, hallux abductus angle (HAA), relative metatarsal length, and complications including nonunion.

Patients and Methods

We conducted an IRB approved retrospective review using an electronic medical record (EMR) search of 64 feet in 56 patients that had undergone midfoot fusion as part of reconstructive bunion surgery with 2 solid crossing screws or a medially positioned low profile locking plate with an integrated compression screw from the medial first metatarsal into the intermediate cuneiform across the arthrodesis site. All hardware for the locking plate and compression screw were Stryker Anchorage ® CP plating system using 3.5 mm locking screws with an inset 4.1 mm partially threaded solid cross-joint screw to achieve mechanical compression. Using this fixation construct allowed the surgeon to forego the need for a separate, independent transverse screw. The obliquity of this screw being placed into the middle cuneiform also allows for the screw threads to purchase undisturbed subchondral bone of the medial intercuneiform joint.

The inclusion criteria for patients in this study were pre-operative diagnosis that were equivalent to bunion or HAV deformity and who completed their 10 week and 1 year postoperative weightbearing radiographs and first Ray American College of Foot and Ankle Surgery (ACFAS) surveys (14). Patients were excluded from this study if they were lost to follow-up, had prior first metatarsophalangeal joint surgeries, prior first TMTJ surgeries, prior or concurrent second TMTJ surgeries, prior or concurrent second metatarsophalangeal joint surgeries which would affect IMA such as a Weil osteotomy. All procedures were completed at the same institution by 2 surgeons, with one surgeon performing all the midfoot fusions using crossing screw fixation, and one separate surgeon performing all midfoot fusions utilizing the dorsomedial locking plate with an intercuneiform compression screw. There were 2 slightly different postoperative weightbearing protocols for the crossed screw fixation and the intercuneiform fixation groups. The crossed screw fixation group post-operative protocol included 6 weeks of non-weightbearing followed by 4 weeks of progressive weightbearing in a below the knee fracture walker boot. The plate plus intercuneiform fixation group post-op protocol included non-weightbearing for 4 weeks followed by progressive weightbearing in a short Controlled Ankle Walker boot for another 4 to 6 weeks.

A retrospective chart assessment for radiographic outcomes and complication rates were performed of all patients with a minimum follow-up of 1 year. Pre-operative radiographs, 10 week post-op weightbearing radiographs (earliest weightbearing films), and 1 year weightbearing radiographs were performed to calculate IMA correction, HAA, and relative metatarsal length (RML). IMA maintenance was calculated by comparing 10 week and 1 year IMA measurements within each cohort. Inter-rater reliability was not measured in this study. Pre-op and 1 year ACFAS first Ray scores were recorded.

RML of the first metatarsal was measured using a previously described technique by Nilsonne and Morton (15), which has been used to evaluate first metatarsal shortening (16). The long axis of the second MT was used as a reference. Two parallel lines perpendicular to the long axis of the second MT were drawn: the first line at the level of the distal end of the second MT head and the second at the level of the distal end of the first MT head. The distance between these lines was measured using an electronic digital caliper. A negative value was obtained if the first MT was shorter than the second MT. A positive value indicates that the first MT was longer than the second MT (Fig. 1).

The dorsomedial locking plate with the intercuneiform compression fixation construct was prepped using saw wedge resection directly across the subchondral

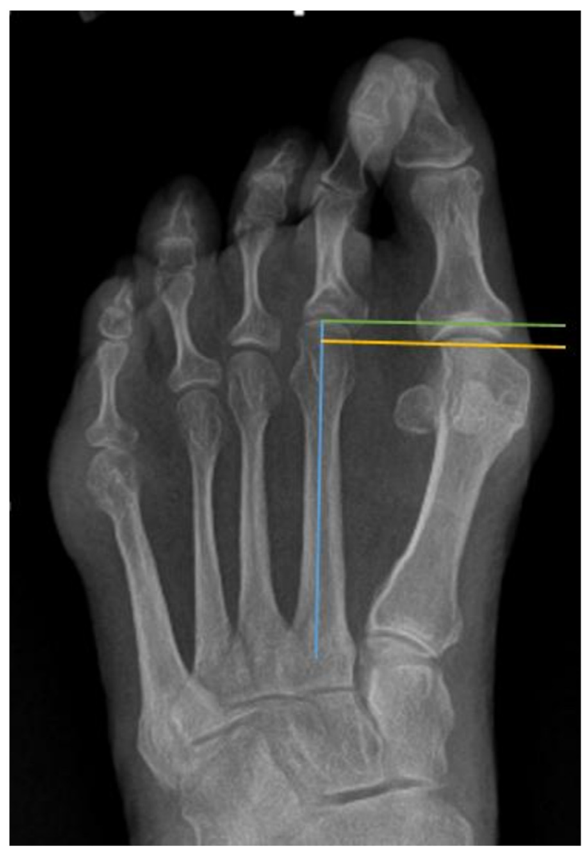

Fig. 1. Relative metatarsal length (RML) is calculated using the longitudinal axis at the distal extent of the second metatarsal bone (blue line). A line perpendicular to the distal most-protrusion of the second metatarsal is created (green line). A line that is parallel to this is constructed that courses through the distal most point of the first metatarsal (yellow line). The distance between the green and yellow line is the relative metatarsal length (RML).

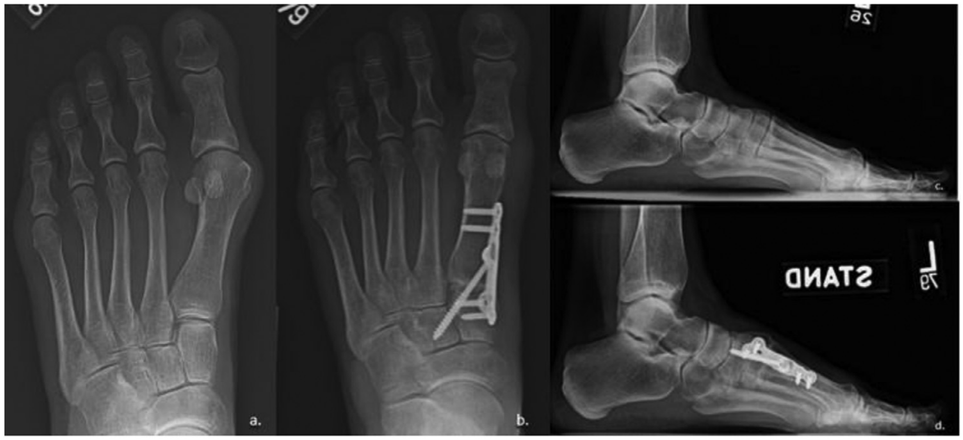

Fig. 2. Pre-op weightbearing AP (*A*) and 1 year (*B*) weightbearing AP radiograph shown above, as well as pre-op (*C*) and 1 year (*D*) lateral radiographs demonstrating stable locking plate lapidus fixation with inter-cuneiform fixation and osseous fusion at the first tarsometatarsal joint line. An anatomic dorsomedial locking plate using non-locking and locking screws was used for fixation, in addition to a compression screw from the first metatarsal into the intermediate cuneiform. Sagittal saw resection was used at the base of the first metatarsal for joint preparation. A curette was used to prep both the medial aspect of the second metatarsal base and lateral aspect of the medial cuneiform distally. IMA is well maintained at 1 year with relative metatarsal length loss within normal limits for a lapidus procedure.

bone plate of the base of the first metatarsal (Fig. 2). A curette was used to prep the second metatarsal base and medial cuneiform. The first metatarsal was purposely translated slightly plantarly on the medial cuneiform to compensate for the amount of shortening that occurs with bone resection. A partially threaded screw within our plate and compression screw fixation cohort was utilized for several purposes. It allows for a significant amount of compression across the fusion site, which is evident intraoperatively by clinically observing tightening of the fusion site with placement of the compression screw. This partially threaded screw placed into the middle cuneiform also allows for the screw threads to purchase undisturbed subchondral bone on both sides of the medial intercuneiform joint. This is especially advantageous in an instance of suboptimal bone quality. The obliquity of the compression screw may also place increased compression across the lateral portion of the first TMTJ based on the direction of compression forces along the screw's vector. Care is taken when placing this compression screw to not violate the second TMTJ and the screw is placed under fluoroscopic visualization to ensure this. Correction in all 3 planes was obtained with manual reduction and the use of a tenaculum between the first and second metatarsal heads to maintain reduction, which was confirmed with fluoroscopy. A separate pin was utilized as a joystick for frontal

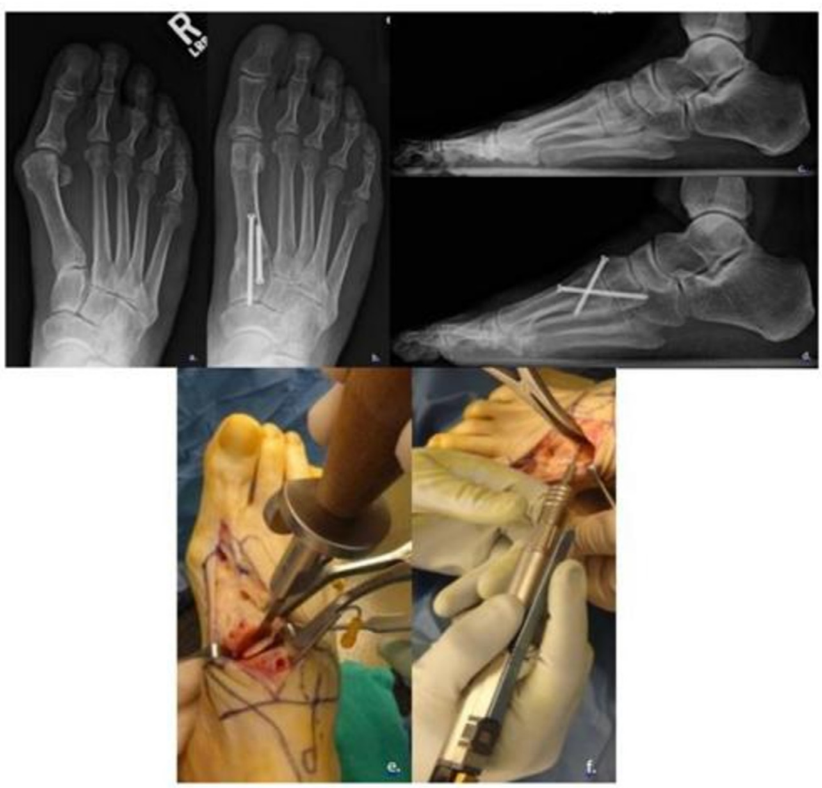

Fig. 3. Pre-op (*A*) and 1 year (*B*) weightbearing AP radiographs, and initial pre-op (*C*) and 1 year (*D*) lateral radiographs demonstrating stable 2 screw Lapidus fixation with solid osseous fusion demonstrated at the firt tarsometatarsal joint line. The joint is prepped using a flexible osteotome (*E*) first at the base of the first metatarsal with use of a joint distractor at the lateral tarosmetatarsal joint for adequate exposure, followed by the use of a straight currette. The burr (*F*) is used to remove the subchondral bone plate and to make final angular adjustments prior to fixation.

Table 1
Combined demographics

	Traditional Crossed Screw Fixation	Dorsomedial Locking Plate with Intercuneiform Compression Screw	Significance ($p \leq .05$)
Sample size	32 Patients, 32 feet	24 Patients, 32 feet	
Average age in years	59 (43-70)	48 (28-73)	p = .44
Males	3 (9.4%)	3 (13%)	X^2 = 0.14
Females	29 (91%)	21 (88%)	p = .71
Laterality: Right	16 (50%)	19 (59%)	X^2= 0.57
Laterality: Left	16 (50%)	13 (41%)	p = .45
Former smoker	1 (3%)	4 (17%)	p = .06
Osteoporosis	2 (6%)	1 (4%)	p = .34

plane correction when necessary.

First ray length-preserving joint preparation via a curette and bur technique was used for the traditional crossed-screw fixation construct (17) (Fig. 3). This construct did not utilize fish scaling. Instead, the flexible osteotome removed cartilage, the burr removed subchondral bone and the subchondral bone plate was fenestrated using a 2.0 mm drill. Planar correction was obtained using manual reduction after osseous remodeling with the burr, and confirmed with fluoroscopy. Manual reduction was used to hold and maintain correction in all 3 planes while the fixation was placed. A k-wire was used for temporary fixation prior to the final placement of the partially-threaded screws. Both techniques involved an intra-operative evaluation of frontal plane alignment to assess for appropriate planar correction.

Osteoporosis was defined as a patient's bone density being 2.5 standard deviations or more below the mean on dual-energy x-ray absorptiometry. Former smokers were defined as those individuals who had reported smoking at least 100 cigarettes in their life, and not currently smoking. EMR data was used to determine prior dual-energy x-ray absorptiometry scan within the last 3 years to determine qualification for osteoporosis, and cigarette smoking information was also taken from their EMR. Listwise deletion was used to address any missing data. Nonunion was assessed using weight-bearing Anterior-Posterior (AP) radiographs at 10 weeks and at 1 year follow-up. A nonunion was defined as having a visible radiolucency at the first TMTJ with minimal or no callus present assessed on AP, oblique, and lateral radiographs and had pain at the fracture site with or without full weightbearing. If a visible radiolucency at the first TMTJ was visualized on 2 of the 3 radiographic views, this was considered a nonunion. Fusion was defined by the absence of pain or tenderness at the fracture site on weight-bearing, the absence of pain on palpation at the site of fracture, or the ability to weight bear and no visible radiolucency at the first TMTJ on 2 of the 3 radiographic views. If a patient did not meet 1 or more criteria for a clinical union, the patient was documented to have a non-union.

Data analysis was performed with a focus on data type and distribution using descriptive statistical methods. Continuous variables were reported in terms of the mean and reported range (minimum, maximum range). Categorical variables were described in terms of frequency counts and percentages. For demographic data the percentages were calculated using the number of patients rather than total number of feet. To determine if surgical correction was maintained, the first weight-bearing AP radiographs at 10 weeks were compared to the 1 year weight-bearing AP radiographs. To determine the overall correction, the 1 year postoperative measurement was compared to the pre-operative measurement. To determine statistically significant differences between the pre-operative, 10 week, and 1 year measurements, one way analysis of variance was performed. Each mean pre-operative, 10 week, 1 year, and change calculations were compared between the 2 fixation constructs using the 2-tailed t test for significance. Tukey simultaneous confidence intervals were utilized as the post hoc tests. Separate statistical analysis was performed to determine if any significant difference existed between cohorts. Wilcoxon signed rank test was used to address clustering effects of duplicated data. Statistical significance was defined by using a 95% confidence interval ($p \leq .05$).

Results

Overall there were 56 total patients with 64 feet included in the study, with 32 patients (32 feet) in the traditional crossed screw fixation construct group and 24 patients (32 feet) in the dorsomedial locking plate with intercuneiform compression screw fixation construct group. The average age in years was 59 (43-70) for the traditional crossed screw fixation construct group and 48 (28-73) for the locking plate plus intercuneiform compression screw fixation construct group. There were 3 (9%) males and 29 females (91%) in the traditional crossed screw fixation construct group, and 3 (12%) males and 21 females (88%) in the dorsomedial locking plate with intercuneiform compression screw fixation construct group. There were 16 right (50%) and 16 left feet (50%) in the crossed screw fixation group and 19 right (59%) and 13 left (41%) feet in the dorsomedial locking plate plus intercuneiform screw fixation group. There was 1 former smoker (3%) and 2 included subjects with osteoporosis (6%) in the traditional crossed screw fixation construct group and 4 former smokers (17%) and 1 individual with osteoporosis (4%) in the dorsomedial locking plate plus intercuneiform compression screw fixation construct group. There was no statistically significant ($p < .05$) detectable difference in frequencies of former smokers, osteoporosis when comparing the 2 fixation constructs (Table 2).

Dorsomedial Locking Plate with Intercuneiform Compression Screw Fixation Construct (Tables 1 and 2)

24 consecutive patients underwent midfoot arthrodesis with the locking plate plus intercuneiform screw fixation. There were no nonunion incidences, with all (32/32) patients fully fused at 10 weeks post-

Table 2
Mean radiographic and survey outcomes for dorsomedial locking plate with intercuneiform compression screw (n = 32)

	Pre-op	10 wk	1 y	Significance ($p \leq .05$)
IMA (range)	14.3° (10°-19°)	5.9° (4°-9°)	6.7° (5°-9°)	<.001*
HAA (range)	29.9° (12°-46°)	14.6° (3°-27°)	14.9° (3°-28°)	<.001*
ACFAS first Ray scores (range)	43 (12-59)		96 (84-100)	<.001
	Pre-op	10 wk	Change in length	Significance ($p \leq .05$)
RML (mm)	2.8 (-2.8 to 7.8)	6.4 (0.5-12.3)	3.6 (0.3-6.9)	<.001

Abbreviations: HAA, hallux abductus angle; IMA, 1-2 intermetatarsal angle; RML, relative metatarsal length in millimeters.
IMA Measurements: F- Ratio 177.5 with a p-value <.001 which denotes a statistically significant difference at $p < .05$. Post-ad hoc studies were conducted through Tukey simultaneous confidence intervals. The Tukey HSD p-value was: <.001 between Pre-op and 10 weeks; <.001 between Pre-op and 1 year; p = .23 between 10 weeks and 1 year.
HAA Measurements: F- Ratio 35.06 with a p-value <.001 which denotes a statistically significant difference at $p < .05$. Post-ad hoc studies were conducted through Tukey simultaneous confidence intervals. The Tukey HSD p-value was: <.001 between Pre-op and 10 weeks; <.001 between Pre-op and 1 year; p = .40 between 10 weeks and 1 year.
* Statistically significant when comparing pre-op measurements with both 10 weeks and 1 year outcomes. When comparing the change between 10 weeks and 1 year IMA and HAA outcomes, the results were not statistically significant.

Table 3
Mean radiographic and survey outcomes for traditional crossing screw fixation outcomes (n = 32)

	Pre-op	10 wk	1 y	Significance ($p \leq .05$)
IMA (range)	14.6° (10°-20°)	6.5° (5°-9°)	7.8° (5°-10°)	<.001*
HAA (range)	30° (21°-42°)	10.4° (3°-28°)	12° (3°-28°)	<.001*
ACFAS first ray scores (range)	48 (18-69)		84 (60-100)	<.001
	Pre-op	10 wk	Change in length	Significance ($p \leq .05$)
RML (mm)	3.4 (0-12)	3.3 (0-10)	0.16 (0-8)	.84

Abbreviations: HAA, hallux abductus angle; IMA, 1-2 intermetatarsal angle; RML, relative metatarsal length in millimeters.
IMA Measurements: F- Ratio 103.1 with a p-value <.001 which denotes a statistically significant difference at $p < .05$. Post-ad hoc studies were conducted through Tukey simultaneous confidence intervals. The Tukey HSD p-value was: <.001 between Pre-op and 10 weeks; <.001 between Pre-op and 1 year; $p = .29$ between 10 weeks and 1 year.
HAA Measurements: F- Ratio 125.9 with a p-value <.001 which denotes a statistically significant difference at $p < .05$. Post-ad hoc studies were conducted through Tukey simultaneous confidence intervals. The Tukey HSD p-value was: <.001 between Pre-op and 10 weeks; <.001 between Pre-op and 1 year; $p = .36$ between 10 weeks and 1 year.
* Statistically significant when comparing pre-op measurements with both 10 weeks and 1 year outcomes. When comparing the change between 10 weeks and 1 year IMA and HAA outcomes, the results were not statistically significant.

operatively. IMA was 14.3° (10°-19°) pre-operatively, 5.9° (4°-9°) at 10 weeks, and 6.7° (5°-9°) at 1 year. HAA pre-operatively was 29.9° (12°-46°), 14.6° (3°-27°) at 10 weeks, and 14.9° (3°-28°) 1 year post-op. The mean ACFAS first Ray score was 43 (12-59) pre-operatively and 96.1 (84-100) at 1 year. The RML pre-operatively was 2.8 (-2.8 to 7.8), and at 1 year was 6.4 (0.5-12). The mean difference in RML between pre-op and 10 weeks was 3.6 mm (0.3-6.9). There was a statistically significant improvement in IMA and HAA pre-operatively compared to both 10 weeks and 1 year ($p < .001$). There was a statistically significant improvement in ACFAS first Ray Scores pre-operatively and 1 year ($p < .001$). Comparing the mean IMA and HAA at 10 weeks and 1 year was not statistically different. There was a statistically significant increase in RML between the initial pre-op measurements and at 10 weeks ($p < .001$).

One patient sustained a deep vein thrombosis (DVT) that occurred within the initial 6 week post-operative period, who was placed on rivaroxaban. There was one incidence of asymptomatic broken hardware which did not require revision or removal. There were no incidences of hallux varus that developed in the post-op period. There was 1 incidence of a crush injury that occurred at 1 year where the patient continued to have ongoing pain and sensitivity, however the patient did not need to undergo a revision surgery. There was 1 incidence of neuritis at 1 year follow-up. (Table 5)

Crossing Screws Without Intercuneiform Fixation Construct (Tables 1 and 3)

Thirty two consecutive patients without inter-cuneiform fixation. Ninety one percent of (30/32) patients were fused at 10 weeks post-operatively. IMA was 14.6° (10°-20°) pre-operatively, 6.5° (5°-9°) at 10 weeks, and 7.8° (5°-10°) at 1 year. HAA was 30° (21°-42°) pre-op, 10.4° (3°-28°) at 10 weeks, and 12° (3°-28°) 1 year follow-up. The mean ACFAS first Ray scores was 48 (18-69) pre-operatively and 84 (60-100) at 1 year. The RML pre-op was 3.4 (0-12), and 3.3 (0-10) at 10 weeks. The mean length lost at 1 year was 0.16 mm (0-8). There was a statistically significant improvement in IMA and HAA pre-operatively compared to both 10 weeks and 1 year ($p < .001$). There was a statistically significant improvement in ACFAS first Ray Scores pre-operatively and 1 year ($p < .001$). Comparing the mean IMA and HAA at 10 weeks and 1 year was not statistically significant. There was a statistically significant increase in RML between the initial pre-op measurements and at 10 weeks ($p < .001$).

There was 1 incidence of symptomatic nonunion that required local bone grafting without further treatment at the first MPJ surgical site 4 months after the initial surgery. There was 1 incidence of asymptomatic nonunion with broken hardware that did not require revision surgery. There were no incidences of DVTs, or hallux varus development at 1 year follow-up. There were 3 patients who complained of ongoing neuritis symptoms at 1 year that did not require additional surgery (Table 5).

Construct Comparison Outcomes (Table 4)

The mean pre-op IMA between the 2 fixation constructs was not statistically significant ($p = .06$). The mean IMA at 10 weeks ($p < .001$) and 1 year ($p = .02$) were statistically lower in the dorsomedial locking plate plus intercuneiform compression group. The mean HAA pre-op between the 2 constructs was not statistically significant ($p = .94$), however at 10 weeks ($p < .001$) and 1 year ($p < .001$) the traditional crossed screw fixation group had better maintained lower angles. At 1 year post operatively the dorsomedial locking plate plus compression intercuneiform screw group had statistically higher mean scores ($p < .001$).The ACFAS first Ray Scores at 1 year were higher in the dorsomedial locking

Table 4.
Construct comparison analysis

	Traditional Crossed Screw Fixation	Dorsomedial Locking Plate With Intercuneiform Compression Screw	Significance ($p \leq .05$)
IMA Pre-op (range)	14.6° (10°-20°)	14.3° (10°-19°)	.066
IMA 10 wk (range)	6.5° (5°-9°)	5.9° (4°-9°)	<.001
IMA 1 y (range)	7.8° (5°-10°)	6.7° (5°-9°)	.017
Change in IMA Improvement Pre-op to 10 Weeks (range)	8.1° (4°-21°)	7.7 (3.6°-13°)	.61
Change in IMA 10 wk to 1 y (range)	1.3° (1°-3°)	0.7° (0°-4.6°)	.681
HAA Pre-op	30° (21°-42°)	30° (11°-46°)	.941
HAA 10 wk	10.4° (3°-28°)	14.6° (3°-27°)	<.001
HAA 1 y	12.0° (3°-28°)	14.9° (3°-28°)	<.001
ACFAS first Ray Score 1 y	83 (60-100)	96 (84-100)	<.001
Pre-op RML (mm)	3.4 (0-12)	2.8 (-2.8 to 7.8)	.472
10 Week RML (mm)	3.3 (0-10)	6.4 (0.5-12.3)	<.001
Change in RML (mm)	0.16 (0-8)	3.6 (0.3-6.9)	<.001

Abbreviations: HAA, hallux abductus angle; IMA, 1-2 intermetatarsal angle; RML, relative metatarsal length in millimeters.

Table 5
Complication rates

	Traditional Crossed Screw Fixation	Dorsomedial Locking Plate with Intercuneiform Compression Screw
Fusion at 10 wk	30/32 (91%)	32/32 (100%)
Nonunion events	1 Symptomatic nonunion, underwent revision surgery 4 months later (local bone grafting without further treatment at the first MPJ surgical site) 1 Asymptomatic nonunion with broken hardware, no revision surgery	None
Broken hardware	1 incidence of broken hardware (asymptomatic nonunion listed above)	1 incidence of asymptomatic broken hardware, no revision
Hardware removal	0	0
DVT	None	1 incidence of DVT who was placed on rivaroxaban, did not progress to a PE
Neuritis at 1 y	3	1
Hallux varus	None	None

plate with intercuneiform compression screw fixation cohort ($p < .001$). There was no statistically detectable difference in the mean pre-op RML between the 2 groups ($p = .473$). The 10 week RML ($p < .001$) and RML change between pre-op ($p < .001$) and 10 week ($p < .001$) radiographic measurements were statistically higher in the dorsomedial locking plate plus intercuneiform compression fixation group.

Discussion

The reported postoperative recurrence rate of hallux valgus varies widely with reports ranging from 3% to 73% and few studies differentiate between symptomatic and asymptomatic recurrence (18-20). Bock et al reported a recurrence rate of 30% at an average follow-up of 10.3 years with 93.5% of those patients being asymptomatic in their recurrence. Chong et al reported a recurrence rate of 9.9% in 199 patients at an average follow-up of 5.2 years and stated that 25.9% of the patients reported dissatisfaction with their outcome (19). A Cochrane review of hallux valgus surgery reported that 25% to 33% of patients expressed dissatisfaction after bunion surgery (21). Recurrence of deformity makes the assumption that the operation did correct the deformity. Surgeons may be hesitant to fully correct hallux valgus deformity for fear of over-correction, leaving the patient with a negative IM angle and possible hallux varus. Failure to correct the IMA to less than 10° is a risk factor for recurrence of HAV deformity. Less obviously, residual deformity may be related to an elevated distal metatarsal articular angle.

Roukis and Landsman had previously discussed first ray motion with the windlass mechanism with the “dynamic Hicks test,” by dorsiflexing the hallux and evaluating first ray function during propulsion. They believed that there was no instability if the medial column motion returns to a normal state with their Hicks test, theorizing that hypermobility of the medial column may be stabilized through the windlass mechanism during gait and through the peroneus longus (22). We did not perform intraoperative midfoot/intercuneiform stress examinations in either of the cohorts in our study, as there is not a clinically proven and validated technique to objectively assess for intercuneiform instability. However, we assume that intercuneiform instability is present based on prior studies demonstrating a high incidence (13). Intercuneiform instability and screw orientation have previously been studied in a study by Feilmeier et al, with the first to second metatarsal fixation demonstrating consistent reduction in instability, and first metatarsal to middle cuneiform fixation having intermediate results. They concluded that the findings of their study strengthen the notion that first ray instability is complex and involves the tarsal and metatarsal articulations at multiple levels outside of the TMTJ alone (23).

The purpose of using the intercuneiform screw within the dorsomedial locking plate fixation construct in our study was not for additional deformity correction beyond the saw wedge resection, as this would be insufficient to make up for inadequate deformity correction. Alternatively, anchoring a screw into the second metatarsal base instead of into the intermediate cuneiform may act as an anchor for stability and subsequently lead to less deformity recurrence. Intermetatarsal screw fixation was not evaluated in our cohort comparison. Based on prior surgeon experience with utilizing the intermetatarsal screw from the first metatarsal base into the second metatarsal base, this was more likely to fail than a screw placed from the first metatarsal base into the intermediate cuneiform. In an instance where intercuneiform instability may not be present, our study supports that there are not increases in hardware failure using a partially threaded screw from the medial first metatarsal into the intermediate cuneiform when compared to traditional crossing screw fixation. Further studies are needed to compare the hardware failure rates between an intercuneiform fixation and intermetatarsal fixation construct.

When reviewing complication rates between the 2 cohorts, there were no incidences of hardware removal despite one incidence of broken hardware in both cohorts. There were no nonunion events, or incidences of broken hardware in the dorsomedial locking plate plus intercuneiform compression screw fixation cohort with all 24 patients fused at 10 weeks. Neither cohort had incidences of hallux varus. Both cohorts overall demonstrate similar fusion rates at 10 weeks, nonunion events, incidences of broken hardware, hardware removal, DVT, neuritis at 1 year, and hallux varus.

The lapidus procedure successfully holds IMA stable over time, a finding by Coetzee and Wickum that is supported by our statistically insignificant IMA comparing the 10 week and 1 year postoperative results among both crossed screw and intercuneiform fixation groups (24). A 2021 Long et al study reviewed the radiographic success of a modified Lapidus bunionectomy with both intercuneiform and intermetatarsal fixation. They found the modified Lapidus improved postoperative IMA and HAV angles from pre-operative measurements with reasonable outcomes, however there was no direct comparison group (25). It is difficult to ascertain whether the intercuneiform or the intermetatarsal fixation in this study independently prevented recurrence of the bunion deformity based on the IMA and HAV measurements.

The crossed screw fixation for first metatarsocuneiform arthrodesis in a Cohen et al article demonstrated higher mean maximum load to failure rate compared to a standard locking plate, which was attributed to compression across the metatarsocuneiform joint using partially threaded cannulated screws (26). A study by Gruber et al saw no difference in load to failure or stiffness between a dorsomedial locking plate with medial cuneiform cannulated compression screw and 2 crossed cannulated screws (27). In our study, the IMA measurement in the dorsomedial locking plate plus intercuneiform compression fixation construct group was statistically lower, meaning the IMA was better maintained at midterm follow-up comapred to the crossing screw cohort. This would be consistent with the Long et al study suggesting that the intercuneiform fixation does play a role in the maintenance of the IMA through 1 year follow-up. Our data shows that, although there was an amount of correction lost when comparing IMA at 10 weeks and 1 year, IMA remained within historically normal limits. Both constructs lost nearly equivalent amounts of correction from 10 weeks to 1 year follow-up. ACFAS first Ray Scores however were statistically higher in the dorsomedial locking plate plus intercuneiform screw fixation cohort at 1 year follow-up, however both cohorts had an overall statistical increase in ACFAS first Ray Scores from pre-operatively to 1 year. HAA was statistically lower at 10 weeks and 1 year in the traditional crossed screw fixation cohort, which we attribute to medial capsular ligament repair completed in this cohort that shifts the toe alignment to a more rectus position.

The dorsomedial plate plus intercuneiform compression fixation construct cohort, utilizing straight saw cuts for first TMTJ preparation, had a statistically significantly higher RML at 1 year compared to the crossing screw group with curette and bur joint preparation. Additionally, the difference in RML between the 2 groups was statistically significant ($p < .05$). Our authors infer that the curette and bur technique maintains first metatarsal length and metatarsal parabola. The straight saw cut technique with the intercuneiform and plate fixation did have a larger amount of first ray length loss compared to the traditional crossing screw construct, however the documented values are well within the normal published amounts of first metatarsal length loss with a Lapidus procedure.

There were 2 slightly different postoperative weightbearing protocols for the crossed screw fixation and the intercuneiform fixation groups. The crossed screw fixation group necessitated 6 weeks of non-weightbearing followed by 4 weeks of progressive weightbearing in a Controlled Ankle Walker boot. The intercuneiform fixation group's weightbearing protocol relied on the compression technology of the plate to safely weight bear the patients earlier at 4 weeks followed by progressive weightbearing for another 4 to 6 weeks depending on their clinical exams. It is possible that in the crossed screw fixation group, the 10 week radiographs may be not represent true weight-bearing. However, there was not a statistically significant difference between the 10 week radiographic IMA and HAV angles between groups.

In conclusion, limitations of our study include retrospective nature, short follow-up, and a relatively small cohort. There are benefits as well as limitations to having a single surgeon performing either procedure. Additionally we did not assess inter-rater reliability in this study. As a result of very similar results for both constructs, we are unable to neither confirm nor deny whether or not addressing intercuneiform instability plays a direct role in recurrence of deformity or if further studies are necessary. Overall, both cohorts maintained IMA correction from 10 weeks to 1 year postop. Both cohorts had an increase in ACFAS first Ray Scores from pre-op to 1 year follow-up. Both cohorts had improvement of HAA from pre-op to 10 weeks and between the 10 weeks and 1 year follow-up. The RML was statistically lower in the traditional crossing screw fixation cohort, although both cohorts were within a normal range of first ray length lost. The locking plate plus intercuneiform compression fixation construct may better prevent loss of IMA deformity correction at midterm follow-up. Both cohorts overall demonstrate similar fusion rates at 10 weeks, nonunion events, incidences of broken hardware, hardware removal, DVT, neuritis at 1 year, and hallux varus. The study supports that the dorsomedial locking plate plus intercuneiform compression screw fixation is a safe and efficacious surgery with comparable complications to the extensively studied cross screw fixation construct.

IRB Approval (HealthPartners Institute Institutional Review Board, Bloomington, MN)

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