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Clinical Outcomes and Rotational Correction of First Metatarso-Cuneiform Fusion With First Metatarsal to Second Cuneiform Fixation

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Abstract

Background: The modified Lapidus procedure (first metatarso-cuneiform fusion) is a powerful technique for correcting triplanar deformity in hallux valgus. Although traditionally fixed with cross-screws (CS), growing awareness of intercuneiform stability and pronation deformity has led to fixation using a plate and first metatarsal–second cuneiform (1MT-2C) screw fixation (PS). We investigated Lapidus patient cohorts using CS vs PS fixation to understand patient-reported outcomes, angular and rotational correction, and complication rates.

Methods: We retrospectively reviewed cases of modified Lapidus for hallux valgus by a single surgeon. Patients were divided into CS or PS groups according to fixation. All patients had preoperative Patient Reported Outcome Measurement Information System (PROMIS) scores and minimum 12 months of follow-up. PROMIS scores in 6 key domains were compared within and between groups. Radiographic assessment of hallux valgus angle and intermetatarsal angle were performed on pre- and postoperative XR. Pronation of the first ray was measured on pre- and postoperative weightbearing computed tomography.

Results: We compared 42 patients with PS fixation to 43 with CS fixation. Both groups had significant improvement in hallux valgus angle and intermetatarsal angle ($P < .001$), with no difference between groups. PS patients experienced a greater correction of first metatarsal pronation, an average reduction of 11 degrees, compared to 8 degrees in the CS group ($P < .039$). Both cohorts experienced improvement in PROMIS physical function, pain interference, pain intensity, and global physical function. There were no differences in PROMIS score improvements between the cohorts. The CS group started weightbearing at 6 weeks vs 3.6 weeks for the PS group. Complication and revision rates were similar.

Conclusion: A plate and 1MT-2C screw fixation provides safe, robust fixation of Lapidus procedure and prevents instability through the intercuneiform joint. We observed similar improvement in PROMIS compared with patients treated with cross-screws. Complications did not increase despite the PS group weightbearing much earlier. PS patients achieved greater first ray rotational correction.

Level of Evidence: Level III, retrospective cohort study.

Keywords: hallux valgus, Lapidus, pronation, patient-reported outcomes, PROMIS, weightbearing CT

Introduction

Hallux valgus is a triplanar deformity involving a rotational component of the first metatarsal.[2,4] Weightbearing computed tomography (WBCT) has made it possible to assess the rotational parameters of the first ray under physiologic loading conditions, demonstrating that the first metatarsal

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in hallux valgus is pronated by 9.5 degrees on average compared with normal controls.[5,27,28] The modified Lapidus procedure is a realignment first tarsometatarsal (TMT) or first metatarso-cuneiform arthrodesis that provides 3-dimensional correction for hallux valgus.[14,18] Unlike many osteotomy procedures, the modified Lapidus procedure can reduce pronation deformity associated with hallux valgus. There is early clinical evidence that reduction of metatarsal pronation is associated with better patient-reported outcomes, as well as lower recurrence of hallux valgus deformity.[6] These findings support keen attention to rotational correction and fixation strategies that better maintain the desired reduction.

A typical method of fixation of the modified Lapidus involves 2 cross-screws lagging across the first TMT joint.[3,33] Although this technique has produced excellent clinical outcomes, nonunion, as shown in some series, remains a troubling complication that may occur in 2% to 12% of cases. [1,3,9,22–24,34] A prior study by Fleming et al[12] also suggested a high proportion of bunion patients have intercuneiform instability as demonstrated by an intraoperative hook test, and therefore recurrence of deformity may occur when fixation only involves the first TMT joint.[17] Although methods to predict and quantify which individuals have intercuneiform instability require further investigation, there is clinical interest in prophylactically preventing recurrence of hallux valgus through this site. Therefore, an alternative fixation strategy involving dorsomedial plating in conjunction with a first metatarsal–second cuneiform (1MT-2C) screw has been proposed to mitigate complications of nonunion and recurrence. This construct is biomechanically stiffer, stabilizes the plantar joint surface, and prevents drift or rotational recurrence through the intercuneiform joint.[8,10,15] Rotational alignment of the first ray achieved using 1MT-2C with dorsomedial plate has not previously been compared to traditional cross-screw fixation.

A prior retrospective study of 1MT-2C screw and plate fixation reported a high rate of union and reliable deformity correction; however, this investigation failed to evaluate patient-reported outcomes (PROs). PROs not only reflect the patient's subjective experience with functional and pain improvement but also measure physical mobility and emotional well-being.[20] The Patient Reported Outcome Measurement Information System (PROMIS) is a validated measurement tool for assessing function and symptomology following surgery, including hallux valgus correction.[16,29] A direct comparison of PROs between fixation constructs for the modified Lapidus procedure provides data that may optimize patient outcome.

This retrospective comparative cohort study assessed clinical and radiographic outcomes of the modified Lapidus procedure for hallux valgus, fixed with cross-screws (CS) vs 1MT-2C screw and dorsomedial plate, aka plate-and-screw (PS). We recorded pre- and postoperative PROMIS scores for each technique and measured changes to first ray pronation on WBCT. We hypothesized that patients undergoing plate and screw fixation would experience improved correction of deformity compared with cross-screws as measured through pronation on WBCT, but PROMIS scores would be similar between the groups.

Methods

This was a single-center retrospective study, with a protocol approved by the Foot and Ankle Registry Steering Committee at the authors' home institution. The institutional review board–approved surgical registry was retrospectively reviewed to identify all patients who underwent first TMT fusion for a primary diagnosis of hallux valgus with plate-and-1MT-2C screw (PS) fixation. All procedures were performed by the senior author, a fellowship-trained foot and ankle orthopaedic surgeon, who modified his technique from cross-screws (CS) to PS fixation in 2019 based on clinical experience. All patients were aged 18 years or older, with minimum 12-month PROMIS follow-up. Patients undergoing revision bunion surgery (n=4) or lacking preoperative PROMIS scores (n=2) were excluded, resulting in 42 patients in the PS cohort. An equal number of historical patients treated with cross-screw fixation by the senior author were identified and filtered by the same exclusion criteria. There were 43 patients included in the CS cohort.

Medical charts were reviewed for demographic data, concomitant operative procedures performed, postoperative initiation of weightbearing and complications including recurrence of deformity, hallux varus, nonunion, delayed union, painful hardware, and all reoperations. The primary outcome of PROMIS scores at least 12 months after surgery were compared to each patient's preoperative scores, collected within 2 weeks of the procedure. Postoperative PROMIS scores were collected at an average 13.3 (range 12-24) months for the CS group and 11.7 (range 10-16) months for the PS group.

Radiographic assessment involved measuring hallux valgus angle (HVA) and intermetatarsal angle (IMA) on preoperative and final postoperative AP radiographs. Pre- and postoperative WBCTs, obtained as part of the senior author's standard clinical protocol related to the patient's weightbearing progression, were used to compare rotation of the first metatarsal according to the triplanar angle of pronation (TAP) method.[2,5]

Operative Techniques and Postoperative Protocol

All patients in this study underwent first tarsometatarsal arthrodesis for hallux valgus correction. Following a lateral ligament release and medial eminence resection at the first metatarsal head, the first TMT joint was exposed. Wedge resection cuts were performed at the first metatarsal base and the distal medial cuneiform with a micro-oscillating saw in a freehand fashion to correct the intermetatarsal angle. The joint surfaces were prepared with a 1.6-mm Kirschner wire and osteotome. The first metatarsal was reduced by a manual varus, plantarflexion, and supination maneuver and secured by two 1.6-mm Kirschner wires. Satisfactory alignment was confirmed using multiplanar fluoroscopic views of the foot under simulated weightbearing conditions. Intraoperative assessment of rotation relied on the clinical appearance of the hallux nail plate, as well as sesamoid position and the metatarsal head contour on AP fluoroscopy.

At this point, techniques diverged according to the fixation construct employed. For CS patients, 2 solid cortical lag screws (DePuy Synthes, Warsaw, IN) were placed across the first TMT joint, involving 1 retrograde 4.0-mm screw and an antegrade 3.5-mm screw, forming a crossed compression screw pattern. The second smaller screw helped limit screw traffic and could be exchanged for a 4.0-mm screw if more robust purchase was desired. No fixation extended into the second cuneiform (Figure 1).

For PS patients, a guide pin was used to facilitate placement of a 4.0-mm cannulated compression screw passing obliquely from the first metatarsal base, through the medial cuneiform, into the second cuneiform (Lapifuse; Wright Medical, Memphis, TN). A dorsomedial locking plate spanning the TMT joint was positioned and secured with 2 proximal locking 3.5-mm screws. The arthrodesis site was further compressed by a cortical screw placed eccentrically through the plate. Finally, the construct was locked with 2 additional 3.5-mm screws distally (Figure 2). Following the TMT arthrodesis with either CS or PS fixation, an Akin osteotomy was performed in select cases for hallux valgus interphalangeus by the senior author's discretion. No distal metatarsal osteotomies were performed for altered distal metatarsal articular angle.

Postoperative weightbearing protocols differed according to the fixation construct employed. CS patients were always nonweightbearing for 6 weeks before gradually progressing weightbearing in a tall walking boot. For PS patients, weightbearing protocol varied according to age and additional risk factors such as overall health and bone quality. Those aged $<$40 years began weightbearing at 2 weeks while patients aged $>$50 years began weightbearing at 4 weeks. Weightbearing for patients between 40 and 50 years old was determined at the discretion of the surgeon.

Statistical Analysis

Descriptive statistics were generated for demographic variables including age and body mass index (BMI) and reported as mean and SD. The pre- vs postoperative radiographic measurements and PROMIS scores for each subject were compared using paired samples Wilcoxon test. After verifying normality by Shapiro-Wilk test, the 2 surgical cohorts were compared using Mann-Whitney *U* test for continuous variables and Pearson χ^2 test for categorical variables. Complications data were tabulated and analyzed by Fisher exact test. A multivariable linear regression was performed to determine the association of postoperative PROMIS (Physical Function [PF]) scores with postoperative pronation, HVA, IMA, and type of fixation, BMI, and preoperative PROMIS score. Statistical significance was established with an alpha value of 0.05. All analyses were performed in R, version 4.10.

Results

Demographic variables for the PS and CS Lapidus cohorts are presented in Table 1. No differences were noted between groups for age, BMI, or gender distribution. The average time (SD) of initiating weightbearing was 3.6 (1.3) weeks for the PS group and 6 (0) weeks for the CS group ($P < .01$).

The PROMIS data revealed that postoperative patients of both groups experienced improvement in PF, Pain Interference, Pain Intensity, and Global Physical Health domains, compared to their preoperative baseline (Table 2). Scores in the Global Mental Health and Depression domains did not change. The comparison of preoperative and postoperative PROMIS scores between the 2 groups did not reveal any differences. Multivariable linear regression analysis demonstrated that BMI was negatively associated with postoperative PROMIS PF scores with an effect size (standard error) of 0.65 (0.29), $P = .03$. All other variables were not correlated with final PROMIS PF.

Radiographic data revealed a similar baseline degree of deformity between the 2 groups, as evidenced by hallux valgus angle (HVA) and intermetatarsal angle (IMA) (Table 3). There was significant improvement in HVA and IMA following surgery for both groups. The final postoperative HVA and IMA measurements were also similar between the PS and CS groups. Pre- and postoperative weightbearing CT was available for 33 PS patients, at average 5.5 months postoperative, and 28 CS patients at average 3.3 months postoperative. This analysis revealed a comparable degree of rotational abnormality between the 2 groups preoperatively. Although both were significantly reduced, a greater correction was achieved with the PS construct (11 degrees) than the CS construct (8 degrees) ($P < .001$).

The complications in the PS group included 1 nonunion that was revised at 7 months postoperatively and 3 delayed unions that healed with the use of a bone stimulator or teriparatide, as confirmed on repeat CT scan. In addition, there was 1 case of hallux varus and 2 patients with painful hardware who had elective hardware removal at 8 and 16 months. Despite no formal preparation of the intercuneiform joint, no loosening or hardware breakage occurred involving the 1MT-2C screw. The CS group had 1 nonunion

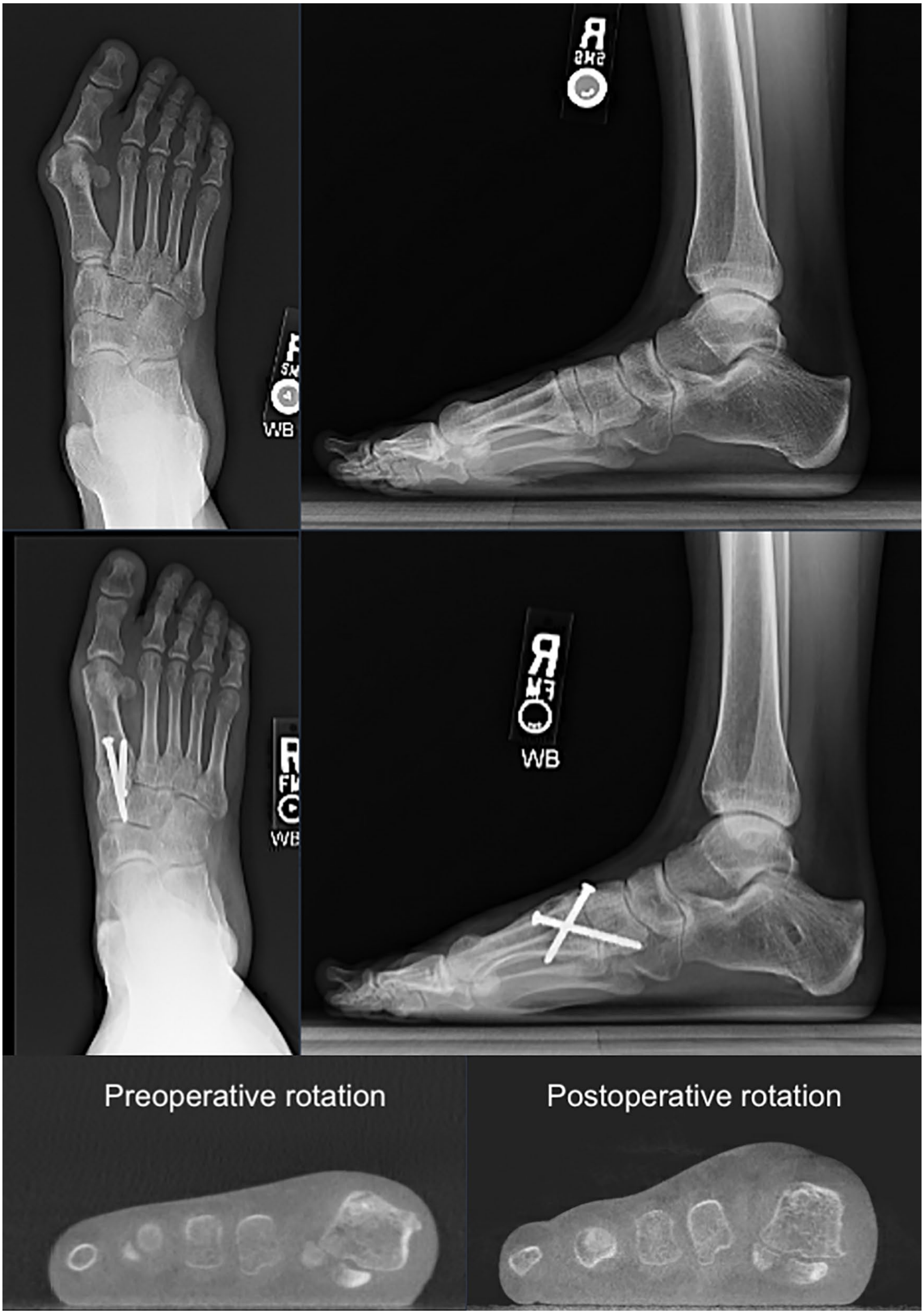

Figure 1. Pre- and postoperative radiographs for case example of hallux valgus fixed with cross-screws. Bottom: First metatarsal rotation evaluated on weightbearing CT pre- and postoperatively.

Figure 2. Pre- and postoperative radiographs for a case example of hallux valgus fixed with first metatarsal–second cuneiform screw and dorsomedial plate. Bottom: First metatarsal rotation evaluated on weightbearing computed tomography pre- and postoperatively.

Table 1. Demographic Data.

	PS (n = 42)	CS (n = 43)	*P* Value
Sex, female/male	36:6	39:4	>.05
Age, y, mean	54	57	>.05
Body mass index, mean	25.9	24.8	>.05
Time to weightbearing, wk, mean ± SD	3.6 ± 1.3	6 ± 0	**<.01**
Follow-up, mo, mean	12	12	>.05

CS, cross-screw; PS, plate and first metatarsal-second cuneiform screw.
Boldface indicates significance.

Table 2. Average PROMIS Outcome Scores.[a]

Domain	PS	CS	*P* Value
Physical Function			
Preoperative	47.60	49.20	.93
Postoperative	53.10	53.10	.94
P value	**.04**	**.002**	
Pain Interference			
Preoperative	53.70	54.30	.23
Postoperative	50.60	51.00	.83
P value	**.03**	**<.001**	
Pain Intensity			
Preoperative	45.70	49.90	.13
Postoperative	40.50	40.50	.88
P value	**.04**	**<.001**	
Global Physical Health			
Preoperative	47.70	47.70	.79
Postoperative	54.10	54.10	.96
P value	**<.001**	**.001**	
Global Mental Health			
Preoperative	53.30	53.30	.79
Postoperative	54.65	50.80	.15
P value	.06	.27	
Depression			
Preoperative	48.50	46.10	.92
Postoperative	45.60	48.10	.33
P value	.42	.77	

Abbreviations: CS, cross-screw; PROMIS, Patient Reported Outcome Measurement Information System; PS, plate and first metatarsal-second cuneiform screw.
[a]Boldface indicates significance.

Table 3. Preoperative and Postoperative Radiographic Results by Group.[a]

	Preoperation	Postoperation	*P* Value
HVA			
PS	29.6	8.1	**<.001**
CS	30.3	9.6	**<.001**
P value	.75	.53	
IMA			
PS	14.2	5.8	**<.001**
CS	16.2	5.5	**<.001**
P value	.17	.92	
Pronation[b]			
PS (n=33)	37.0	26.0	**<.001**
CS (n=28)	38.0	30.0	**.001**
P value	.64	**.04**	

Abbreviations: CS, cross-screws; HVA, hallux valgus angle; IMA, 1-2 intermetatarsal angle; PS, plate and first metatarsal-second cuneiform screw.
[a]All values are in degrees, unless otherwise noted. Boldface indicates significance.
[b]Pronation was calculated by the triplanar angle of pronation.

with screw backout that was revised at 2 months, 1 hallux varus complication, and 1 case of painful hardware. There were no statistical differences observed in the incidence of complications (Table 4).

Discussion

The original Lapidus procedure involved first TMT fusion as well as fusion between the first and second metatarsal bases, fixated with catgut suture.[21] Over time, the Lapidus procedure has undergone numerous modifications and the modern, modified Lapidus with cross-screw fixation is an isolated first TMT arthrodesis, which remains associated with complications of nonunion and deformity recurrence.[19,24,34] Although the original metatarsal base fusion procedure is rarely performed, the concept of stabilization between the first and second rays may still be relevant. An alternative fixation construct involving 1MT-2C screw and dorsomedial plate fixation has been proposed to mitigate complications by stabilizing the intercuneiform joint without formally preparing the joint for fusion.[33] Our study compared this fixation construct to cross-screws for hallux valgus correction performed by 1 senior foot and ankle surgeon. We found the plate and screw technique was safe and effective, with comparable patient-reported outcomes to cross-screws and a low incidence of complications. Both methods yielded excellent angular correction, but the plate and screw technique offered greater reduction and maintenance of first metatarsal pronation.

Table 4. Complications Data and Sequelae.

	PS	CS	*P* Value
Nonunion	1; revision at 7 mo postoperation	1; revision at 2 mo postoperation	NS
Delayed nonunion	3; 2 healed with bone stimulator, 1 with Forteo	0	NS
Hallux varus	1; hardware removal at 10 mo postoperation	1; no surgical intervention	NS
Painful hardware	2; hardware removal at 8 and 16 mo postoperation	1; no surgical intervention	NS

Abbreviations: CS, cross-screws; NS, nonsignificant; PS, plate and first metatarsal–second cuneiform screw.

Prior investigations of compression screw and locking plate fixation for the modified Lapidus have suggested positive results. Langan et al[20] reported a case series of 62 patients that underwent hallux valgus with 1MT-2C screw and plate fixation, without a comparison cohort. They found improved intermetatarsal angle and hallux valgus angle on plain radiographs with only 2 to 3 degrees of correction lost over time. Only 2 patients had symptomatic recurrence requiring revision, and 2 nonunions occurred for a union rate of 96%. DeVries et al[8] compared cross-screws and a locking plate with or without a compression screw for hallux valgus. Compression screw placement into the second cuneiform was not consistently performed, but they found a lower rate of nonunion (2% vs 8%) and earlier weightbearing in the locking plate patients. We observed 1 nonunion in each group, resulting in a nonunion rate of 2% that was consistent with these prior studies. Existing biomechanical data suggest that a dorsal locking plate with lag screw is more stable than crossing lag screws across the first TMT joint.[11] Furthermore, a 1MT-2C screw is shown to reduce sagittal plane mobility of the first ray more than isolated TMT fixation.[13]

Patients in both cohorts experienced significant improvement in several PROMIS domains. Physical function improved by 5.5 points in PS patients and 3.9 in CS patients to a *t* score of 53 postoperatively, which reflects a level of function higher than the population average of 50. Concurrently, the pain intensity and pain interference were both reduced. These findings are consistent with previously reported PROMIS outcomes after modified Lapidus for hallux valgus.[30] A key clinical difference between the 2 groups was the time to weightbearing. The PS patients initiated weightbearing on average at 3.6 weeks, which was approximately half the time of the CS group. Historically, a period of immobilization up to 6 weeks is recommended following modified Lapidus to allow for bony consolidation. Several studies have retrospectively reported success with earlier weightbearing, but high-quality evidence is lacking. The 6-week period indeed poses a considerable challenge for patients.[8] With enhanced biomechanical stability, a plate and screw fixation construct offers the advantage of weightbearing as early as 2-3 weeks postoperatively and thereby faster restoration of mobility and function.[25,31] We observed equivalent final PROMIS scores between groups, suggesting that assessment of PROMIS at the 1-year time point may fail to capture early gains due to patient's weightbearing and return to activity. Regardless, the earlier weightbearing progression in the PS group was not associated with higher rates of radiographic or clinical nonunion.

The key advantage of the modified Lapidus procedure is its ability to achieve triplanar correction of hallux valgus through the first tarsometatarsal joint.[7,34] This study is the first to compare the effect of 1MT-2C fixation on IMA and HVA parameters, as well as rotation of the first metatarsal measured on WBCT. Our results revealed that both forms of fixation achieved excellent correction of coronal plane deformity; however, we identified a unique difference in the degree of pronation correction—the PS group had on average 11 degrees of rotational correction compared with 8 degrees among CS patients. As understanding of the 3-dimensional deformity of hallux valgus has increased, so has interest in assessment and clinical correlation of first ray rotation.[26,28,32] Conti et al[7] used an alternative computer-aided 3-dimensional method of measuring pronation after modified Lapidus, fixed by crossing screws. Their average preoperative (29 degrees) and postoperative (20 degrees) pronation angles were lower than observed in our study, but the magnitude change of –8.8 degrees was similar to our CS cohort. A follow-up study by the same investigators revealed that the computer-aided pronation measurements were indeed skewed lower than the triplanar angle of pronation (TAP) method we utilized.[5] The difference observed between the 2 fixation methods is attributed to the addition of the first metatarsal-second cuneiform (1MT-2C) screw, which secures and maintains the reduction achieved at time of surgery. In the cross-screw construct, acute or subacute instability at the intercuneiform joint may lead to some loss of rotational correction over time.

The optimal pronation correction for hallux valgus remains poorly understood. Previous reports suggest that hallux valgus patients have 9.5 degrees of increased rotation compared to controls, but it is difficult to predict if surgical correction to "normal" will yield the best outcome.[5] Conti et al[6] investigated the relationship between patient related outcomes and pronation. Patients who had a decrease in pronation had on average 7-point higher PROMIS physical function scores than those with unchanged or increased pronation. In a subgroup analysis, they found patients with more than 8 degrees of pronation change had lower gains in PROMIS PF, compared to moderate correction ranging 2 to 8 degrees. In our study, both patient cohorts saw a decrease in first ray rotation, yet the PROMIS physical function scores between groups were comparable. We hypothesize that because this study was not designed to assess specifically for pronation-associated outcomes, it may have been underpowered to detect a difference. Furthermore, we noted variability in the final pronation angle. Without a clear goal for corrected pronation and lack of subgroup analysis, it is difficult to determine if the greater pronation correction *on average* in the PS group had a positive or negative effect on PROs.

This study was subject to several limitations. The PS group was compared to a historical cohort of CS patients. No randomization of the fixation construct was possible because of the retrospective nature of the study; however, all procedures were performed by a single surgeon with a standardized protocol for lateral ligament release, joint preparation, and reduction maneuver. Nevertheless, we could not control for exact forces applied by the surgeon in his reduction technique or account for changes to pronation correction as a result of the surgeon's greater awareness of rotational deformity. Our senior author has extensive experience with more than 500 cases of Lapidus bunion correction with CS fixation prior to switching his clinical practice to PS fixation, but a learning curve may still exist. We also lack longitudinal WBCT data on the CS patients that could definitively attribute loss of reduction through the intercuneiform joint that occurred after bony union of the TMT joint. Further investigation involving randomization of fixation method would reduce the possibility of surgeon-related bias.

One nonunion occurred in each group, there were 3 delayed unions in the PS group, which were diagnosed by WBCT on average 19 weeks after surgery. There were fewer postoperative WBCTs available for the CS group than the PS group (28/43 vs 33/42), which was due to lack of insurance authorization for the scans, despite clinical justification and peer-to-peer review, when available. The increased reliance on plain radiographs among the historical CS cohort may have failed to identify cases of asymptomatic delayed union. Although a prospective institutional review board study would be preferred to collect consistent imaging data, we do not expect any missed cases of nonunion among those without postoperative WBCT if clinical symptoms such as pain and swelling were not present. Ultimately, we detected a statistical difference in pronation between the fixation methods but failed to correlate it with a difference in PROMIS score. Additional research is needed to improve our understanding of the clinical significance of pronation and determine the degree of correction that optimizes clinical outcome.

Conclusion

In this series, the modified Lapidus procedure (first metatarso-cuneiform fusion) provided satisfactory correction of hallux valgus deformity and ability to address abnormal pronation of the first ray. Although classic crossing lag screws have been effective, alternate fixation constructs aim to minimize nonunions and deformity recurrence, as well as promote earlier return to activity. The 1MT-2C screw with dorsomedial locking plate is a construct that spans the intercuneiform joint, reducing the potential for loss of reduction, especially rotation of the first metatarsal. We observed similar improvement in patient-reported outcomes compared with a group of patients with cross-screw fixation. Complications did not increase despite the PS group weightbearing a few weeks earlier. Analysis of available WBCT images revealed a greater magnitude of pronation correction among PS patients, but subtle changes to surgeon technique and attention to pronation must be considered as a source of bias. These findings suggest that plate and 1MT-2C screw fixation is safe and effective, with the ability to achieve more rotational correction.

Ethical Approval

Ethical approval for this study was obtained from Hospital for Special Surgery institutional review board (2013-038).

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Scott J. Ellis, MD, reports consulting fees; payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events; and participation on a data safety monitoring board or advisory board from Stryker/Wright Medical. ICMJE forms for all authors are available online.

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