CHAPTER **16**

EVALUATION OF FIRST METATARSOPHALANGEAL RANGE OF MOTION PRE AND POST BUNION SURGERY: A Clinical and Radiographic Correlation with Stress Lateral Dorsiflexion Views; A Retrospective Approach.

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INTRODUCTION

Very few studies have evaluated first metatarsophalangeal joint (MTPJ) range of motion (ROM) specifically both pre and postoperatively for bunion surgery. First MTPJ motion is necessary for function and cartilaginous preservation,[1] but dorsal mobility decreases with age.[2] Bryant et al[3] reviewed radiographic measurements following Austin bunionectomy but, no study has used a lateral stress radiographic view for first MTPJ dorsiflexion for clinical comparison. Multiple studies have compared pre and post range of motion (ROM) specifically for hallux rigidus[1] or hallux limitus procedures, i.e. osteotomy or bioabsorbable fixation.[4] Furthermore, no previous study has examined first MTPJ ROM in relation to the type of bunion procedure performed, be it a Keller, Austin, closing base wedge osteotomy (CBWO), or a Waterman-Green.

In a study by Ahn et al,[5] the contact surface area of the first MTPJ was greatest in the neutral position and progressively decreased with dorsiflexion. They mention that progressive degenerative arthritis is occasionally found after hallux valgus surgery, and assessing the extent of joint function is worth investigating.[5] According to Banks et al,[6] success in bunion surgery is based on establishing a congruous first MTPJ, reduction of the IMA to normal, realigning the sesamoid beneath the metatarsal head, restoring weight bearing function of the first ray, maintaining first MTPJ ROM, repositioning the hallux in rectus, and control or correction of underlying deforming factors, which we will revisit.

In this study, we will show that bunion surgery decreases first MTPJ ROM postoperatively within 1 year. Therefore, our null hypothesis is that first MTPJ ROM is not affected by bunion surgery or does not change postoperatively. Furthermore, based on other data we have collected, including first ray position, we can see how other specific factors play a role pre and post bunion surgery. We are also going to correlate radiographic stress lateral dorsiflexion views to clinical measurements of first MTPJ ROM pre and at least once postoperatively, in some cases taken at 6 weeks, 3 months, 6 months and 1 year.

METHODS

A total of 63 patients who underwent bunion surgery by one of the authors (DRG) at the San Diego Podiatry Group with preoperative stress lateral views (Figure 1) were included in the study. Excluded patients were those who had first MTPJ non-osteoarthritic conditions, dysplasias or infection involving the first MTPJ or first metatarsal bone, ulceration of the foot or ankle, significant trauma causing fracture to the first metatarsal bone or first MTPJ (preoperatively), or patients with non-ambulatory status. This study is IRB approved (4967).

Demographic data was obtained from chart review, incuding age, height, weight, body mass index, past medical history, past surgical history, and social history. Preoperative and postoperative clinical first MTPJ dorsiflexion measurements, orthotics, physical therapy

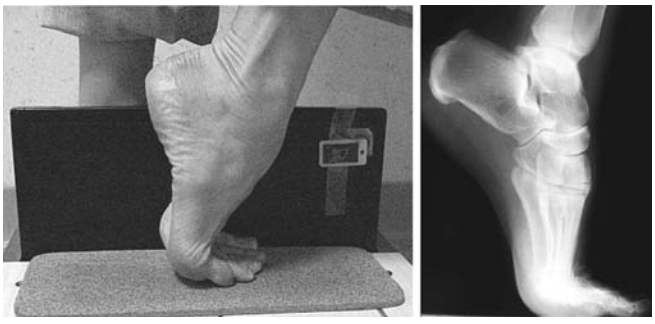

Figure 1. Stress lateral dorsiflexion view.

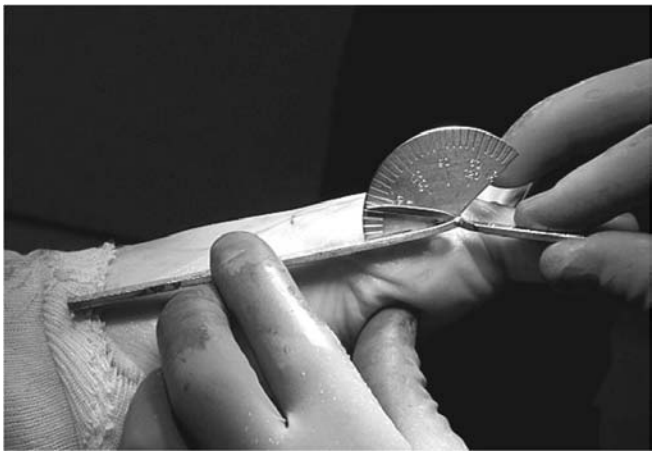

Figure 2. Intraoperative first MTPJ range of motion measurement with goniometer.

Figure 3. Nonweight bearing first MTPJ range of motion measurement with goniometer.

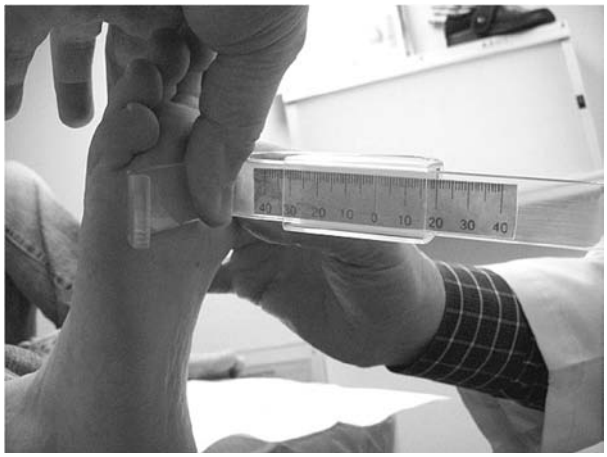

Figure 4. First ray measurement using Whitney device.

use, and complications documented in the chart were also noted.

Operative data was obtained from operative reports (dictated by a resident) and/or postoperative notes (completed by the surgeon), including first assist, diagnosis, procedure, adjunct procedures, fixation, anesthesia, preoperative antibiotics, postoperative toradol, postoperative marcaine, complications, postoperative pain medication, surgery center, first interspace dissection, postoperative shoe and weight bearing status. Intraoperative first MTPJ dorsiflexion measurements if available, were noted (Figure 2). The surgeon uses a betadine cast for post-operative dressing, and a Corex first ray cut-out in his CAM walkers. Postoperatively, patients were given interdigital spacers, Tubigrip and began range of motion exercises by 2 weeks. Patients who had a closing-base wedge osteotomy were nonweight bearing only in a CAM walker and were allowed to ambulate at 6 weeks only if osseous union was noted on radiographs.

Clinical data was obtained with 1 postoperative visit in 28 patients (34 feet), who returned for followup, conducted by the co-investigator and not the surgeon in most instances, and consents to participate in the study were obtained. Nonweight bearing (NWB) data included: first MTPJ (ROM): resting, (unassisted) DF and PF (in subtalar joint neutral) with a goniometer (Figure 3) as described by Buell,[2] quality of first MTPJ ROM: crepitus, soft tissue or osseous impingement, first ray position: assessed by first placing the subtalar joint in neutral and assessing DF and PF of the first metatarsal head relative to the lesser metatarsal heads with a Whitney biomechanical device (Figure 4), first metatarsocuneiform prominence, any toe deformities (varus/hammertoe), callus location (submetatarsal head, hallux), position of the second toe: no contact, abutting, underlying or overriding the first, and Lachman's test: dorsal translocation of second proximal phalanx by 2 mm or more relative to the second metatarsal head.[7] Weight bearing data collected included: first MTPJ DF in RCSP and NCSP, measuring to the ground with a goniometer, hallux purchase power (easy, resistant or "not moveable" ability to pull paper out from beneath patient actively plantarflexing hallux). Also, whether the patient presented with orthotics in their shoes was noted. (Worksheet 1).

Radiographic study was done preoperatively as well as at least once postoperatively, on all dates where lateral stress dorsiflexion views were taken, by the same investigator using the same goniometer for measurements. Views evaluated include: dorsoplantar (DP), medial oblique (MO), lateral (lat) foot views and lateral stress DF (at the first MTPJ) view (Figures 5-7), taken in the standard fashion by two office staff personnel but using the same machine. The DP view was assessed for: first metatarsal length and width, shape of first metatarsal head

Worksheet 1

Physical Exam **#:** _____

Date of Examination:_____ **Surgeon:** _____

Date of Surgery: _____ **Examiner:** _____

Extremity: ☐ Right ☐ Left

NWB Exam

1st MTPJ ROM in STJN: Resting position _____ °DF / PF

DF _____°

PF _____°

1st Ray Motion in STJN: Resting position _____ mm DF / PF

Use Whitney device DF _____ mm ☐ crepitus

PF _____ mm ☐ crepitus

1st MTPJ motion:

☐ Painful DF / PF / mid / end-range

☐ Crepitus DF / PF / mid / end-range

☐ Soft tissue / osseous impingement DF / PF / mid / end-range

Presence of:

☐ 1st Met-cuneiform prominence

☐ 4th toe adducted / varus mild / moderate / severe

☐ 5th toe adducted / varus mild / moderate / severe

☐ Bunionette mild / moderate / severe

☐ Hammertoes 1 2 3 4 5

☐ Submet head callus 1 2 3 4 5

☐ Medial pinch callus hallux

☐ Sub-IPJ callus hallux

2nd toe position relative to hallux: *Weightbearing*

☐ No contact ☐

☐ Abutting ☐

☐ Underlying 1st ☐

☐ Overlying 1st ☐

☐ Positive Lachman's test

(Proximal phalanx 2mm dorsal translocation relative to 2nd metatarsal head at 2nd MTPJ)

WB Exam

1st MTPJ ROM: RCSP _____° DF

NCSP _____° DF

Hallux purchase: ☐ Easy ☐ Resistant ☐ Not Moveable

Paper can be pulled out from beneath patient's hallux without resistance (easy), with resistance, or not.

o Patient presents to clinic with orthotics inside shoes.

Figure 5A & 5B. Dorsal plantar and lateral radiographic assessment.

Figure 7. Stress lateral dorsiflexion radiograph.

and base (round, oblique or square), first and second MTPJ congruity (congruous, deviated or subluxed), signs of first MTPJ degeneration (subchondral cysts, erosions, sclerosis, joint space narrowing), metatarsus primus adductus (MPA), hallux abductus angle (HAA), metatarsal protrusion distance (bisection of the second metatarsal with lines perpendicular to the first and second at the most distal aspect of each metatarsal, measuring the distance between; positive means the first is longer, negative the second longer), hallux interphalangeus angle (HIA), tibial sesamoid position (TSP), tibial sesamoid-second metatarsal distance, second toe position (abducted, adducted or rectus), metatarsus adductus (MAA), calculation of true IMA (IMA + MAA – 15), Engle's angle (second metcuneiform), forefoot adductus (FAA), first metatarsal-calcaneal angle, talocalcaneal angle (TCA), talonavicular coverage angle,[8] and cuboid abduction angle (CAA), as described by Sangeorzan, DiGiovanni, Banks, and Christman.[6,8-10] The medial oblique view was used to evaluate for dorsiflexion of the toes.

Figure 6. Medial oblique view: Dorsiflexion of toes.

Similarly, the lateral view was assessed for: metatarsus primus elevatus (MPE), first metatarsal declination angle, talo-first metatarsal angle or Meary's angle, Seiberg Index (quantitatively measures first metatarsal position relative to the second; positive value indicates elevation),[11,12] calcaneal inclination angle (CIA), Kirby's sign, and dorsal first MTPJ lipping/spurring. The plantar reference line from which the first metatarsal declination and CIA were measured included the most inferior aspect of the calcaneal tubercle to the CCJ as described by DiGiovanni and Smith.[9] Then the weight bearing stress lateral DF view was used to measure first MTPJ DF.

Questionnaires were returned by 36 patients, for chief concern preoperative (bump, joint, motion, nerve pain), duration of preoperative bunion pain, previous treatment, work type, exercise, reason for surgery (appearance, pain, shoegear difficulty), current pain (marked on a line), preoperative limitation (none, slight, moderate, severe), satisfaction with bunion surgery, lifestyle, activity, post-operative course, and complications (Worksheet 2).

ANALYSIS AND RESULTS

The Lost to follow-up (LTFU) results are as follows: n = 77 feet in 63 patients at baseline; n = 66 feet in 54 patients (14.46% LTFU) at 6 weeks postoperative; n = 69 feet in 56 patients (11.8% LTFU) at 1 year postoperative; and n = 55 feet in 42 patients (33.61% LTFU) at 2 years postoperative.

Worksheet 2

PATIENT QUESIONNAIRE

Main concern before having foot surgery:
- ☐ Bump pain
- ☐ Joint pain
- ☐ Limited motion
- ☐ Nerve pain
- ☐ Other: _____

Duration of Bunion pain *before surgery:* _____ (months) _____ (years)

Previous treatment: ☐ Orthotics other:_____

Work:
- ☐ Sedentary
- ☐ Desk Work
- ☐ Standing Job
- ☐ Heavy Duty

Exercise:
- ☐ No Exercise
- ☐ Occasional Exercise
- ☐ Regular Exercise

In order of importance, using a scale of 1-5 (1 = not important, 5 = very important), please designate the reason **why you decided to have surgery.**
_____ Appearance
_____ Pain
_____ Inability to wear all shoe types

Mark on the following line your current level of pain:
No pain_____Worst pain possible

Before your bunion surgery how did your foot pain limit your daily activities?
- ☐ I had no pain with normal activities.
- ☐ I had slight or occasional pain, no compromise in activities.
- ☐ I had moderate pain, slight effect on activities.
- ☐ I had pain with serious limitation of activities.
- ☐ I had severe pain with total limitation of activities.

*Please circle a number on a **scale of 1 to 10,** with 10 being very UNsatisfied:*

1. How satisfied are you with your bunion surgery? 1 2 3 4 5 6 7 8 9 10
2. Would you make the **same decision** again, knowing your outcome after surgery turned out as it did? ☐ Yes ☐ No
3. If you would not have made the same decision again, what would you do have done differently?

_____

Please *circle* a number on a **scale of 1 to 10,** with 10 being the worse pain imaginable:

4. How much was your **pain level before** bunion surgery? 1 2 3 4 5 6 7 8 9 10

Please *circle* a number on a **scale of 1 to 10,** with 10 being NOT improved at all:

5. How improved is your lifestyle after bunion surgery? 1 2 3 4 5 6 7 8 9 10
6. Do you feel you are able to do **more or less activities** now, compared to before surgery? ☐ More ☐ Less
7. Please indicate if you have ever had a **bunion** on L / R foot: ☐ Right ☐ Left
8. If you had bunions on both feet, which foot was worse? ☐ Right ☐ Left
9. Please indicate on which foot/feet you had bunion surgery: ☐ Right ☐ Left
10. If you have a bunion on the other foot and have not had surgery on it, would you **consider having the same procedure** done to your other foot? ☐ Yes ☐ No
11. Did you do exercises of your big toe joint after surgery? ☐ Yes ☐ No
12. Did you put weight on your foot immediately after surgery? ☐ Yes ☐ No
13. Are you **currently wearing orthotics?** ☐ Yes ☐ No
14. If you are wearing orthotics, do you have any **padding/modifications on your orthotics** (if you look on top or underneath it)? ☐ Yes ☐ No
15. Did you have any **complications** (unexpected results) from surgery? ☐Yes ☐No
16. If you did have unexpected results from your surgery, what were they?

_____

Did you have any **falls or traumatic injuries after your surgery** that significantly increased your pain level more than a few days? ☐ Yes ☐ No

Table 1 shows only the statistically significant results of paired nonparametric null hypothesis tests, comparing median averages for a number of variables at baseline and at specific points in the postoperative period. The level of statistical significance was set at $P \leq 0.05$. Since the null hypothesis states there is no difference between the measurements at the different time periods, $P < 0.05$ showed a statistically significant difference likely due to bunion surgery.

The results from Table 1 show significant improvement in first MTPJ congruity, significant reduction in the first IMA (5°), HAA (7°), TSP (2 positions) and lateral stress dorsiflexion (15°) on average at 6 weeks postoperative. The 6° significant increase in forefoot adduction angle could be as a result of guarding or supinating the foot during the x-ray at 6 weeks postoperative. Shortening of the first metatarsal as expected, was indicated by 2 mm decrease in first metatarsal length and 2.5 mm decrease in first metatarsal protrusion distance at 6 weeks postoperative and similarly at 1 year postoperative (3 mm reduction for both values). Of note, in some variables the statistical significance is not meaningful (not clinically important), such as in the cuboid

Table 1

COMPARISON OF PREOPERATIVE TO POSTOPERATIVE MEASUREMENT AT 6 WEEKS, 1 AND 2 YEARS POSTOPERATIVE

(N = 77 feet in 63 patients at baseline, median overall follow-up = 22.5 [range 9 to 52] months).

VARIABLE	PREOPERATIVE	POSTOPERATIVE		P-VALUE*
First Metatarsal Length	65 (57, 74)	63 (55, 70)		0.0027
Congruity of First MTPJ	Deviated	Congruous		0.0067
First Intermetatarsal Angle (°)	13 (4, 21)	8 (-3, 14)		0.0006
Hallux Abductus Angle (°)	22 (2, 52)	14 (-10, 30)	6 wks; N=66ft in 54pt (14.46% LFTU†)	0.0006
First Met Protrusion (mm)	-2 (-9, 6)	-4.5 (-10, 5)		0.0002
Tibial Sesamoid Position	4 (0, 7)	2 (0, 6)		0.0030
Tibial Ses – 2nd Met (mm)	31 (4, 40)	31 (24, 40)		0.0189
Forefoot Adductus Angle (°)	8 (-4, 23)	14 (-4, 24)		0.0446
Cuboid Abductus Angle (°)	10 (0, 34)	10 (0, 27)		0.0119
Calc Inclination Angle (°)	22 (12, 42)	22.5 (14, 32)		0.0028
Lateral Stress DF Angle (°)	66 (20, 98)	50 (20, 66)		0.0005
First Met Length (mm)	65 (57, 74)	62 (53, 69)		<0.0001
Congruity of 1st MTPJ	Deviated	Deviated		0.0023
First Intermetatarsal Angle (°)	13 (4, 21)	10 (4, 20)	1 Yr; N=69ft in 56pt (11.8% LFTU†)	0.0009
Hallux Abductus Angle (°)	22 (2, 52)	14 (0, 30)		<0.0001
First Met Protrusion (mm)	-2 (-9, 6)	-5 (-12, 2)		0.0003
Tibial Sesamoid Position	4 (0, 7)	3 (0, 6)		<0.0001
True Intermetatarsal Angle (°)	14 (5, 28)	13 (5, 23)		0.0019
1st Met-Calcaneal Angle (°)	20 (7, 38)	19 (0, 39)		0.0159
Dorsal 1st MTPJ Osteophytosis	None	None		0.0339
First Metatarsal Length (mm)	65 (57, 74)	61 (52, 72)		0.0006
1st Met Midshaft Width (mm)	12 (10, 44)	13 (10, 15)		0.0006
Shape of First Metatarsal Head	Oblique	Square	2 Yr; N=55ft in 42pt (33.61% LFTU†)	0.0469
First Intermetatarsal Angle (°)	13 (4, 21)	10 (0, 15)		0.0052
Hallux Abductus Angle (°)	22 (2, 52)	8 (-22, 28)		0.0005
First Met Protrusion (mm)	-2 (-9, 6)	-5 (-12, 5)		0.0017
Tibial Sesamoid Position	4 (0, 7)	3 (0, 6)		0.0252
True Intermetatarsal Angle (°)	14 (5, 28)	11 (0, 18)		0.0171
Dorsal 1st MTPJ Osteophytosis	None	None		0.0455

**Wilcoxon signed ranks paired-sample test*
^MTPJ = metatarsophalangeal joint
†LTFU = lost to follow up

abduction and calcaneal inclination angles. At 1 year postoperative, there remains a reduction of the first IMA (3°), HAA (7°) and TSP (1 position). And at 2 years, the hallux valgus deformity correction is also maintained with again reductions in the first IMA (3°), HAA (14°, skewed due to hallux varus case), and TSP (1 position), as well as true IMA (3°). However the lateral stress DF is not significantly reduced (2°) on average for both 1 and 2 years postoperative.

Significant change of satisfaction postoperatively in relation to independent variables are shown in Table 2, using count and percentage for categorical data, and median/range for continuous numeric variables. Table 2 shows that use of a blood thinner as a listed medication and having a psych disorder (anxiety, depression or ever seeking help for psychiatric issues) were associated with increased patient satisfaction postoperatively, and the median preoperative HAA was statistically significantly greater in the group of patients that failed to be satisfied after the intervention. For purposes of clinically meaningful data, the blood thinner (being that no one had DVT/PE) and psych disorder may be confounded, as shown by further regression analysis. Patients with high HAA preoperative had greater deformity, perhaps implying higher expectation with decreased satisfaction. Of note, no statistical significance between satisfied and not satisfied patients was found with the median lateral stress DF value, as with all other variables recorded (age, gender, BMI, obesity, previous foot surgery, number of meds, birth control pill use, tobacco/caffeine/alcohol use, other components of past medical history, year of surgery, surgical procedure, intraoperative variables, and all other radiographic variables). We used nonparametric null hypothesis tests, the Wilcoxon rank-sum test for binary variables with only 2 possible endpoints (i.e. yes/no in regard to a characteristic), or the Kruskall-Wallis test for variables with more that 2 possible endpoints (i.e. neutral, abducted or adducted second toe).

Table 3 shows only those independent variables that statistically significantly influenced the outcome…a satisfied patient following the operation. Logistic regression model analysis was performed for every independent variable to show this. Odds ratio (OR) > 1 indicates the independent variable increased the likelihood of the outcome, and OR ratio < 1 decreases the likelihood of the outcome. If the 95% confidence interval (95% CI) does not cross 1 (a ratio = 1), then the association is statistically significant.

According to Table 3, the following independent variables statistically significantly increased the likelihood of subjective satisfaction postoperative: regular exercise, anxiety/depression, weight-bearing job, preoperative limited motion, TSP <3 at 1 year postoperative, and increased AP view TCA 1 year postoperative. Our interpretation is as follows: patients who regularly exercise (versus occasional or never) and have a weight-bearing job (versus desk or sedentary) may be more motivated for exercising the joint postoperative or had worse preoperative symptoms due to their increased level of activity. Patients with anxiety/depression requiring seeking help at some point in their lifetime may again be a confounding factor to increased satisfaction, or may be related to decreased level of expectations preoperative. Those who had a preoperative complaint of limited motion/stiffness were more satisfied postoperative due to improved motion. TSP <3 at 1 year postoperative, indicative of maintained correction of deformity is logical to increased satisfaction postoperative. Also, patients with increased AP view TCA 1 year postoperative or increased rearfoot pronation, may have had greater preoperative deformity, resulting in greater satisfaction from improvement.

Also in Table 3, the following independent variables

Table 2

PREVALENCE (PROPORTION [%] FOR CATEGORICAL VARIABLES, OR MEDIAN AND RANGE FOR CONTINUOUS NUMERIC VARIABLES) OF BASELINE AND INTRA-OPERATIVE RISK FACTORS BY SATISFACTION*

with the results of the operation (N = 77 feet in 63 patients, median overall follow-up = 22.5 [range 9 to 52] months)

VARIABLE	SATISFIED	NOT SATISFIED	*P*-VALUE^
Blood Thinner	4 (22.22%)	2 (4.55%)	0.0340
Psych disorder	8 (44.44%)	8 (18.18%)	0.0334
HAA (°)	18.5 (2, 33)	22 (6, 52)	0.0402

** "Satisfied" defined as the patient being subjectively satisfied with results of operation.*

^The Wilcoxon rank-sum (Mann Whitney U) 2-sample test was used to test the equality of unmatched pairs, and the Kruskal-Wallis equality-of-population rank test was used to test the hypothesis that several (>2) samples were from the same population.

Table 3

UNIVARIATE LOGISTIC REGRESSION

(generalized estimation equation), dependent variable = patient subjectively satisfied with the results of the surgery (N = 77 feet in 63 patients, median overall follow-up = 22.5 [range 9 to 52] months)

VARIABLE	ODDS RATIO	95% CONFIDENCE INTERVAL
Chief Complaint Including Stiff Joint	11.6	1.124918, 119.6176
Weight Bearing (>4h continuous) Job	7.1795	1.519747, 33.93919
Psychological Disorder	3.6	1.079253, 12.00831
Regular Exercise (vs never/occ)	48.5333	10.26676, 229.4281
1° Increase Preop HAA	.9276598	.8674388, .9920615
1° Increase Preop Engle's Angle	.9095931	.8289399, .9920615
1° Increase 3-Month Postop HAA	.8765779	.7819443, .9826645
1° Increase 1-Yr Postop HAA	.8195337	.6992227, .9605458
1° Increase 1-Yr Postop SI	.9413551	.8903062, .995331
1° Increase 1-Yr Postop AP TCA	1.089663	1.008047, 1.177886
1° Increase 1-Yr Postop TSP < 3	4.42	2.173314, 89.708

Table 4

MULTIPLE VARIABLE LOGISTIC REGRESSION

(generalized estimation equation), dependent variable = patient subjectively satisfied with the results of the surgery (N = 77 feet in 63 patients, median overall follow-up = 22.5 [range 9 to 52] months)*

VARIABLE	ODDS RATIO	95% CONFIDENCE INTERVAL
Age 40-49 Yr	.0003594	.0001511, 2.577618
Age 50-59 Yr	.0210047	.0017579, 1.923967
Age > 60 Yr	6.770992	.8619746, 17.65562
Male Sex	.0339451	.0263056, 2.438703
CC Including Stiff Joint	2.00422	1.377254, 3.809861
WB (>4h continuous) Job	1.068644	.1964484, 7.008854
Psychological Disorder	8.137308	.7704306, 11.35878
Regular Exercise	70.99417	.9872338, 284.9274
1° Increase Preop HAA	.3313129	.2008348, 1.180473
1° Increase Preop Engle's	.0725035	.0007493, 2.800219
1° Increase 3-Mo P.O. HAA	.8640653	.4902967, 1.094805
1° Increase 1-Yr P.O. HAA	.7888972	.6895134, .8236398
1° Increase 1-Yr P.O. SI	.4458846	.3769812, .8498051
1° Increase 1-Yr P.O. AP TCA	2.685496	.8322224, 19.028423
1° Increase 1-Yr P.O. TSP < 3	.065317	.0007366, .5639719

**Multiple variable inclusion criteria of univariate logistic regression P ≤0.01 or variable considered clinically important.*

statistically significantly decreased the likelihood of subjective satisfaction postoperative: increased preoperative HAA, increased preoperative Engle's angle, increased HAA 3 months and 1 year postoperative, and increased Seiberg's Index 1 year postoperative. Increased preoperative HAA and Engle's angle with the more dissatisfied patients postoperative may be due to higher expectations in the patients with greater deformity. Increased postoperative HAA indicative of recurrence of deformity (versus undercorrection), is logically associated with decreased patient satisfaction. Increased Seigberg's Index 1 year postoperative may result in a less satisfaction from limited first MTPJ motion.

Since patients are actually influenced by many independent variables, the multiple variable regression model (Table 4) is considered clinically more important

than the univariate analyses (Table 3). The independent variables in Table 4, were isolated from a logistic regression model that included all variables (fully adjusted) statistically significant in the univariate analyses at the 10% level ($P \leq 0.1$), as well as age category and gender (deemed clinically important by statistician), and proved to be statistically significant (multiple variables statistically significantly increased the odds (likelihood) of patient subjective satisfaction postoperative). These variables include: preoperative stiffness, increased 1 year postoperative HAA, SI, and TSP < 3. Since these variables are repeated from the univariate analysis, the same interpretation applies.

So, the surgeries that were performed were more likely to result in a satisfied patient if the patient had stiffness in the preoperative phase; if the first MTPJ remained balanced, as measured by the HAA at 1 year postoperative, if the first metatarsal was not elevated at 1 year postoperative, and if the TSP was 1-3 at 1 year postoperative. So, it seems important to perform surgery that clinically and statistically significantly improved alignment (Table 1), and held up over time (Tables 3 and 4).

Demographic data showed average age of 53.3 years (range 23-88 years) with the highest number of patients in their 50s (22/63; 34.9%). Average BMI was on the low side of overweight at 25.7 (range 17 to 39) overall, averaged 25.2 in patients with HAV (with or without HL) and 27.8 in patients with HL only. These results are comparable to a BMI of 26.2 in a study by Bryant et al[13] in HAV patients. The majority of patients were female (83%, 52/63) and there was no prevalence to right or left side (49% and 51%), as found in the literature. In Table 5 are the variables which later proved significant.

Operative data showed June, August and November as the most prevalent months, 2006 had the most (39.2%, 29/74 feet) surgeries, and the first assists correlating with the most prevalent year (MW & AH). The majority of the diagnosis was hallux abducto valgus (60.8%, 45/74 feet), the majority of procedures was Austin (43.2%, 32/74), the majority had no adjunct procedures (60.8%, 45/74), absorbable pin fixation the most prevalent (39.2%, 29/74), one number of fixation (59.5%, 44/74 feet), majority were MAC anesthesia (83.8%, 62/74), no preoperative antibiotic (75.7%, 56/74), Toradol injection postoperative (91.9%, 68/74), Marcaine injection postoperative (95.9%, 71/74), no complications intraoperatively (86.5%, 64/74), postoperative Vicodin (67.6%, 50/74), no postoperative NSAID (78.4%, 58/74), location at the Mercy Pavilion (55.4%, 41/74), no cartilage degeneration (70.3%, 52/74), no lateral capsulotomy (66.2%, 49/74), fibular sesamoid ligament release (60.8%, 45/74), no adductor tendon release (74.3%, 55/74), half had medial capsulorrhaphy, majority had no flexor hallucis brevis lateral head release (85.1%, 63/74), a surgical shoe (78.4%, 58/74) and fully weight bearing postoperatively (70.3%, 52/74). The operative diagnosis and procedural detail is listed in Table 6. Although the hallux maneuver could effect a lateral capsulotomy via a tear in the lateral capsule.

Dorsiflexion of the first MTPJ was greater clinically than radiographically on all preoperative evaluations and most postoperative evaluations (the same at 6 months), on average values (Table 7). Patients with hallux abducto valgus had greater dorsiflexion values perioperatively than patients with hallux limitus. Dorsiflexion values decreased immediately postoperative and showed gradual increase with values exceeding preoperative values on average (Chart 1). Hallux limitus patients had an average 15° clinical increase in DF (51° to 66° at 2 year followup) and 17° radiographically (46° to 63° at 4 year followup).

Table 5

DEMOGRAPHIC DATA

VARIABLE	AVERAGE	RANGE
Age (Yr)	53.3	23-88
BMI	25.7	17-39
Side: *Right*	49% (36/74)	
Side: *Left*	51% (38/74)	
Sex: *Female*	83% (52/63)	
Sex: *Male*	17% (11/63)	
Blood thinner	9.5% (6/63)	
Psych Disorder	25% (16/63)	

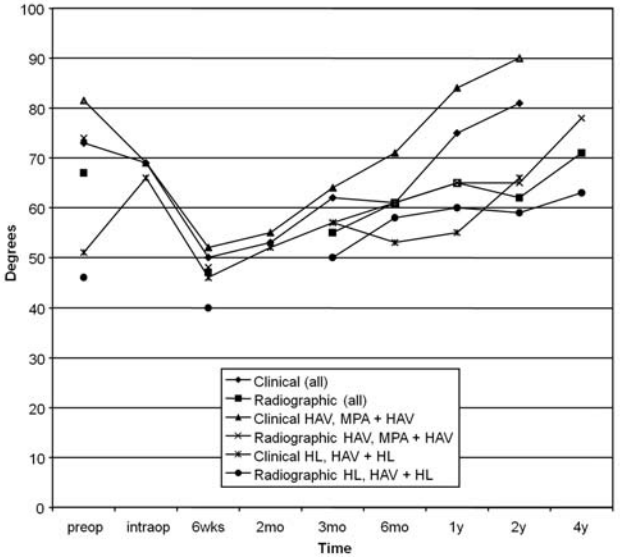

Chart 1.

Table 6

OPERATIVE DETAIL

DIAGNOSIS	FEET	PATIENTS
HAV	60.8% (45/74)	60.3% (38/63)
HAV + MPA	13.5% (10/74)	14.3% (9/63)
Hallux Limitus	18.9% (14/74)	17.5% (11/63)
HAV + HL	6.8% (5/74)	7.9% (5/63)
Exostosis 1st met	1.4% (1/74)	0.1% (1/63)
PROCEDURE		
Austin	43.2% (32/74)	12.7% (28/63)
Mod McBride + CBWO	14.9% (11/74)	15.9% (10/63)
Keller	14.9% (11/74)	14.3% (9/63)
Mod Green-Waterman	13.5% (10/74)	14.3% (9/63)
Modified McBride	4.1% (3/74)	4.8% (3/63)
Mod Waterman-Laird	2.7% (2/74)	3.2% (2/63)
Implant + Mod McBride	1.4% (1/74)	0.1% (1/63)
Silver	1.4% (1/74)	0.1% (1/63)
Modified Austin	1.4% (1/74)	0.1% (1/63)
1st Exostectomy	1.4% (1/74)	0.1% (1/63)

Hallux valgus patients had an 8.5° increase clinically in DF (81.5° to 90° at 2 year followup), and 4° radiographically (74° to 78° at 4 year followup), which corresponds exactly to the overall increase in DF measurements. One patient with exostosis of the first metatarsal head throughout was excluded from the dorsiflexion and range of motion data.

We also looked at the most prevalent procedures and stratified average dorsiflexion measurement peri-operatively, as seen in Table 8. The 6 week postoperative radiographic dorsiflexion was significantly decreased in the Austin (by 30°), CBWO (by 29°), and Keller (by 35°) groups but increased by 4° in the Green Waterman procedure group. It was interesting to note that although not statistically significant, all of these most prevalent procedures clinically decreased at 6 weeks except for the Green Waterman, and at 1 year only the Keller increased clinically, and both the Keller and Green Waterman increased radiographically with dorsiflexion measurements.

Complications were found in 31 patients, and those found in greater than one patient included: stiffness, subsecond metatarsal head pain, second toe pain, second hammertoe discomfort, immediately postoperative infection (in 3 cases, defined as increased redness/swelling/drainage/tenderness than would be expected postoperative[14] all of which resolved on oral antibiotic therapy and did not require reoperation), sinus tarsitis, recurrence of bunion, hypertrophic scar, pain/aching of feet, numbness, and cramping. Complications found in only one patient each included: subfibular sesamoid pain, arch pain, subfourth metatarsal head pain, subsecond and third metatarsal head ulcer, floppy second, neuroma (second and third interspaces), hallux varus (Figure 8), delayed healing, which resolved after several months of external bone stimulator, avascular necrosis of the second metatarsal head, reaction to glue and shifting of fixation (Table 7).

Figure 8. Postoperative complication: hallux varus.

Radiographic data showed, on the AP view: an average loss of 4mm first metatarsal length (6.5 to 6.1cm), no change in width (1.3cm), no predominance of metatarsal head shape, majority incongruous first MTPJ (67.6%, 48/71 feet), no predominance of narrowing at the first MTPJ, majority of square first metatarsal base (83%, 59/71), average IMA which decreased preoperative then increased but not to preoperative value (12.3° to 10.9°), dramatic decrease in the HAA by two-thirds on average (22.0° to 7.3°), no predictable change in HIA (average 11.8° preoperative), decrease by 1.8mm of metatarsal protrusion distance of the first relative to the second (-2.3 to -4.1mm), a decrease in the tibial sesamoid position of 4.7 to 3.4 on average, majority congruous 2nd MTPJ preoperatively (73.2%, 52/71), no predictable change in MAA (average 15.6 preoperative), similar decrease and then increase in true IMA like IMA on average (15° to 14.1°), slight increase in Engle's angle longterm (23.4° to 25.6° average), no predominant change in FAA (8.5° preoperative average), postoperative decrease then increase in first metatarsal-calcaneal angle

Table 7

DORSIFLEXION MEASUREMENTS OF THE 1ST MTPJ

1st MTPJ ROM (mean)	Clinical (all)	Radiograph (all)	HAV, + MPA (clinic)	HAV, + MPA (radiographic)	HL, + HAV (c)	HL, + HAV (r)
Preop DF	73°	67°	81.5°	74°	51°	46°
Preop PF	23°	No data	23°	No data	21°	No data
Intraop DF	69°	No data	69°	No data	66°	No data
Intraop PF	25°	No data	25°	No data	26°	No data
6wk PO DF	50°	47°	52°	48°	46°	40°
6wk PO PF	13°	No data	15°	No data	10°	No data
2mo PO DF	53°	No data	55°	No data	52°	No data
2mo PO PF	7°	No data	7°	No data	8°	No data
3mo PO DF	62°	55°	64°	57°	57°	50°
3mo PO PF	14°	No data	14°	No data	14°	No data
6mo PO DF	61°	61°	71°	61°	53°	58°
6mo PO PF	9°	No data	9°	No data	7°	No data
1y PO DF	75°	65°	84°	65°	55°	60°
1y PO PF	15°	No data	11°	No data	24°	No data
2y PO DF	81°	62°	90°	65°	66°	59°
2y PO PF	15°	No data	21°	No data	6°	No data
4y PO DF	No data	71°	No data	78°	No data	63°

Table 8

STRATIFICATION OF PATIENTS BY PREVALENT PROCEDURES: DORSIFLEXION AND TOTAL ROM MEASUREMENTS; CLINICALLY (RADIOGRAPHICALLY)

PROCEDURE (#feet)	PRE DF	TOTAL	6WK DF	TOTAL	1 YR DF	TOTAL
Austin (32)	91° (79°)	114°	51° (49°)	55°	88° (66°)	98°
CBWO (11)	72° (73°)	93°	44° (44°)	53°	72° (63°)	93°
Keller (12)	55° (55°)	84°	54° (20°)	58°	65° (68°)	89°
Green-Wtr (11)	41° (46°)	52°	42° (50°)	53°	37° (55°)	56°

(average 20.3° preoperative) (and CAA, average 10.6° preoperative) similar to IMA, and no predictable change in TCA (average 31.2° preoperative) nor talo-navicular coverage angle (average 17.5° preoperative).

On the medial oblique view, the majority of toes were dorsiflexed (81.4%, 57/70). On the lateral view, the metatarsus primus elevatus (average 62.0%, 44/71 majority elevated) and Sieberg's index (average 1.1 mm preoperative, with dorsal position of the first metatarsal is positive[11] did not show considerable change, no predictable change in the first metatarsal declination angle (average 17.4° preoperative) nor Meary's angle (average 10.6° preoperative), CIA (average 23.2° preoperative), TDA (average 26.7° preoperative), lateral TCA (average 49.8° preoperative), Kirby's sign (stayed majority positive, or obliteration of sinus tarsi 85.9% preoperative), and medial border of tibial-sesamoid to second metatarsal bisection also did not change (average 3.0 cm preoperative). Dorsal lipping was present in 73.2% (52/71) preoperative and diminished dramatically postoperative (<10%). The cyma line was anterior in the majority 64.8% (46/71) preoperative and had no predictable change postoperative. The second toe position was majority rectus preoperative 55.1% (38/39) also with no predictable change postoperative (Table 10).

When separated into hallux abducto valgus and

Table 9

COMPLICATIONS

Stiffness	3	4.10%
Sub 2nd Metatarsal Head Pain	3	4.10%
2nd Toe Pain	3	4.10%
2nd Hammertoe Discomfort	3	4.10%
Immediate Postop Infection	**3**	**4.10%**
Sinus Tarsitis	2	2.70%
Recurrence of Bunion	**2**	**2.70%**
Hypertrophic Scar	2	2.70%
Pain/Aching of Feet	2	2.70%
Numbness	2	2.70%
Cramping	2	2.70%
Sub Fibular Sesamoid Pain	**1**	**1.40%**
Arch Pain	1	1.40%
Sub 4th Metatarsal Head Pain	1	1.40%
Sub 2nd & 3rd Metatarsal Head Ulcer	**1**	**1.40%**
Floppy 2nd Toe	1	1.40%
Neuroma (2nd & 3rd Interspaces)	1	1.40%
Hallux Varus	**1**	**1.40%**
Delayed Healing	**1**	**1.40%**
Avascular Necrosis of 2nd Metatarsal Head	**1**	**1.40%**
Reaction to Glue	1	1.40%
Shifting of Fixation	**1**	**1.40%**

hallux limitus, the radiographic data showed: a predominance of round head shape 40.3% (35/62) in the HAV group, and majority square head shape in the HL group (71.4%, 10/14), a predominance of subluxed first MTPJ in the HAV group (47.4%, 27/57) and a majority of congruous first MTPJ in the HL group (92.9%, 13/14) preoperative, majority no DJD of the first MTPJ preoperative in the HAV group (80.7%) and the reverse in the HL group (majority had DJD 85.7%, 12/14). Similarly, a majority did not have narrowing of first MTPJ in the HAV group (59.6%, 34/57) and did in the HL group (85.7%, 12/14). The shape of the base was majority square in both groups (87.7%, 50/57 in HAV and 64.3%, 9/14 in HL group). The average IMA was abnormal in the HAV group (13.1°) and on the upper edge of normal on the HL group (8.8°). The HAV group had a decrease followed by an increase to preoperative value postoperative, whereas the HL group had not much change in the IMA. The HAA was similarly abnormal in the HAV group (24.8° average) and normal in the HL group (10.6°) however both decreased and remained decreased postoperatively. The HIA did not show predictable change in either group, nor did the tibial sesamoid to second metatarsal distance (3.0 cm in both), MAA (16.1° HAV, 13.5° HL preoperative average), Engle's (23.6° HAV, 22.9° HL), first metatarsal-calcaneal angle (21.5° HAV, 15.6° HL preoperative average), TCA (31.0° HAV, 32.0° HL), TN coverage angle (17.8° HAV, 16.1° HL average preoperative), or CAA (10.4° HAV, 11.5° HL preoperative average). The TSP was abnormal for the HAV group (average 4) and normal in the HL group (average 2), and dropped to normal (average 3) postoperative in the HAV group and did not change in the HL group. The congruity in the second MTPJ was majority congruous in both groups (74.1%, 43/58 in HAV, 73.3%, 11/15 in HL) pre and postoperative. The second toe position was majority rectus in both groups as well (51.8% HAV, 69.2% HL). In the HAV group, the true IMA decreased postoperative then increased back to its preoperative value longterm, whereas the HL group did not show much change. FAA seemed to increase postoperative in both groups.

The toes were overwhelming majority dorsiflexed in the medial oblique view for both groups (80.3%, 45/56 HAL, 85.7%, 12/14 HL). Metatarsus primus elevatus was present in the majority throughout in both groups (preoperative 85.7%, 12/14 HAV and 78.6%, 11/14 HL). The Seiberg's index likewise indicated dorsal position of the first metatarsal head in both groups throughout, with a higher value on average in the HL group (1.8 mm preoperative) versus half the value for HAV group (0.9 mm) and showed little change postoperative. There was no change in first metatarsal declination angle with similar average values between the groups (preoperative 17.6° HAV, 16.4° HL), as with Meary's angle (10.5° HAV, 11.1° HL), CIA (23.0° HAV, 23.9° HL, average preoperative), and TDA (26.5° HAV, 27.7° HL preoperative average). Kirby's sign was also overwhelming positive in both groups with no change postoperative (84.2%, 48/57 HAV, 86.7%, 12/15 HL). The cyma line was similarly anterior in the majority of both groups also with little change postoperative (64.9%, 37/57 HAV, 64.3%, 9/14 HL). Also unsurprisingly, dorsal first MTPJ lipping was not evident in the majority of HAV patients (87.7%, 50/57) and was evident in the HL group (85.7%, 12/14).

Results from the 36 patients who returned questionnaires included a prevalence of chief complaint in combination of bump pain, joint pain and limited motion (35.4%, 12/34), average duration of symptoms preoperative 73.6 months (mode 24 months; comparable to 63.6 months in Coughlin and Jones study,[15]), half had no previous treatment, and the majority had desk work (53.8%, 14/26), the majority exercised regularly (69.7%, 23/33), the majority ranked cosmesis on the lower end of importance, the majority ranked pain as high importance in reason

Table 10

RADIOGRAPHIC DATA

VARIABLE		PREOP	PO 6WK	PO 3MO	PO 6MO	PO 1YR	PO 2YR	PO 4YR
Length (cm)	Average	6.5	6.2	6.2	6.2	6.1	6.1	6.1
	Range	5.7-7.4	5.5-7.0	5.3-7.3	5.3-7.4	5.3-6.9	5.2-7.2	5.6-7.0
Width (cm)	Average	1.3	1.3	1.3	1.2	1.2	1.3	1.2
	Range	1.0-1.6	1.0-1.7	1.0-1.6	1.1-1.6	1.1-1.6	1.0-1.5	1.1-1.4
Congruity 1st	Congruous	32.4% (23/71)	68.8% (28/43)	65.1% (28/43)	56.7% (17/30)	48.3% (14/29)	50% (8/16)	37.5% (3/8)
MTPJ	Deviated	29.6% (21/71)	12.5% (2/16)	25.6% (11/43)	36.7% (11/30)	41.4% (12/29)	31.3% (5/16)	62.5% (5/8)
	Subluxed	38.0% (27/71)	18.8% (3/16)	9.3% (4/43)	6.7% (2/30)	10.3% (3/29)	18.8% (3/16)	0% (0/8)
IMA (°)	Average	12.3	6.8	9.4	10.4	10.5	8.9	10.9
	Range	4-21	-3-14	4-16	1-17	4-20	0-15	6-17
HAA (°)	Average	22.0	14.7	12.8	12.8	14.2	10.5	7.3
	Range	2-52	-10-30	0-39	2-26	0-30	-22-28	-4-30
HIA (°)	Average	11.8	12.3	13.8	12.9	11.8	15.7	9.4
	Range	0-28	9-23	0-30	0-23	0-26	2-29	2-18
Met Protrus Dist (mm)	Average	-2.3	-3.8	-4.1	-4.8	-5.0	-4.0	-4.1
	Range	-9-6	-10-5	-11-2	-11-2	-12-2	-12-5	-9-6
TSP	Average	4.7	3.6	3.8	3.7	3.9	3.6	3.4
	Range	1-7	1-7	1-7	1-7	1-7	1-7	1-6
MAA (°)	Average	15.6	17.0	16.1	15.4	14.9	14.9	15.7
	Range	6-30	9-30	5-26	4-28	6-28	6-20	6-28
True IMA (°)	Average	15	11.7	12.4	13.1	12.8	10.7	14.1
	Range	5-28	-2-19	4-23	2-24	5-23	0-15	8-23
Engle's Angle (°)	Average	23.4	27.0	23.4	22.8	23.5	25.6	25.6
	Range	8-36	12-40	8-36	14-38	15-36	16-38	16-39
FF Add Angle (°)	Average	8.5	12.4	9.0	10.0	9.3	9.5	8.9
	Range	-4-23	-4-24	-4-26	-6-26	-5-26	-4-26	-4-26
AP TCA (°)	Average	31.2	32.3	30.6	31.0	27.4	31.4	36.7
	Range	4-62	18-64	6-68	6-66	4-61	7-64	17-54
TN Angle (°)	Average	17.5	14.8	16.2	17.5	15.8	15.9	19.7
	Range	2-50	6-47	1-44	0-42	0-48	-20-46	2-40
Cuboid Abd (°)	Average	10.6	10.9	9.9	9.6	11.0	10.2	13.2
	Range	0-34	0-27	2-26	1-30	0-27	2-19	4-26
Met Primus Elevatus	No	38.0% (27/71)	10.0% (4/21)	34.7% (17/49)	39.5% (15/38)	44.1% (15/34)	36.8% (7/19)	33.3% (3/9)
	Yes	62.0% (44/71)	81.0% (17/21)	65.3% (32/49)	60.5% (23/38)	55.9% (19/34)	62.2% (12/19)	66.7% (6/9)
Seiberg's Index (mm)	Average	1.1	1.5	1.0	0.7	0.6	0.6	0.8
	Range	-3-4	0-5	-3.5-4	-5.5-3.5	-3-5	-3-5	-2-3
Calc Inclin Angle (°)	Average	23.2	23.2	24.2	24.1	22.3	22.0	23.4
	Range	12-42	14-32	14-42	16-47	10-38	13-38	14-35
Dorsal Lip	No	26.8% (19/71)	88.9% (16/18)	98.0% (48/49)	97.2% (35/36)	97.0% (32/33)	94.4% (17/18)	77.8% (7/9)
	Yes	73.2% (52/71)	11.1% (2/18)	2.0% (1/49)	2.8% (1/36)	3.0% (1/33)	5.6% (1/18)	22.2% (2/9)
Tib-ses to 2nd met (cm)	Average	3.0	3.1	3.1	3.1	3.0	3.1	3.1
	Range	2.2-4.0	2.4-4.0	2.3-4.0	2.7-3.5	2.6-3.9	2.4-3.9	2.8-3.9

for surgery (76.9%, 20/26), and the majority ranked shoegear difficulty also as high importance for surgery (51.9%, 14/27). The mode for current pain marked on a 114 mm line was 0 (or no pain), with average 20.3 mm (17.8% of line). The majority had pain with serious activity limitation prior to surgery (52.8%, 19/36), the majority were on the high side of satisfied with the surgery (top 3 rank: 58.4%, 21/36), and 91.7% would make the same decision again (33/36). The majority ranked preoperative pain 5 to 8 out of 10 (79.4%, 27/34), majority of lifestyle improved postoperative very much (top 3 rank: 62.9%, 22/35) however 3 patients (8.6%) did indicate that their lifestyle was not at all improved postoperative. A total of 75% could do more activities now than preoperative (24/32), 68.6% (24/35) had ever had a bunion on the left side, and 88.6% (31/35) on the right, and the ones having both sides indicated majority the left side as worse (52.3%, 11/21). There was a fair distribution of having had surgery on right, left or both sides, and two-thirds would consider surgery to the contralateral if they only had surgery on the one side. There were 88.6% that exercised their great toe joint postoperative (31/35), and the majority indicated they were not weight bearing immediately postoperative (57.1%, 20/35). The majority indicated that they were wearing orthotics (51.4%, 18/35) but no padding/modifications (64%, 16/25). 76.5% denied having any complications or unexpected results from their surgery (26/34) and no one experienced any falls or injuries postoperatively (100%, 35/35) (Table 11).

Results from the 28 patients who returned for physical exam (34 feet), were an average of 25.7 months postoperative (range 9-52), 27.3° dorsiflexed resting first MTPJ position, 62.9° first MTPJ DF nonweight bearing, 20.9o PF, 93.1% first ray rested plantarflexed position at average -2.3mm, average first ray DF 5.0 mm, PF 7.4 mm, no first ray crepitus in 100%, and no pain on first MTPJ ROM in 91.2% (31/34); 11.8% (4 patients) had crepitus on PF of first MTPJ with 2 in the mid-range and 2 in the end-range, 17.6% (6 patients) had soft tissue impingement first MTPJ on PF and 8.8% (3 patients) on DF, 2 in the end-range. One patient had first MTPJ osseous impingement in DF and PF and 38.2% (13 patients) had a prominent first metatarsocuneiform joint proliferation, which was palpable. A total of 26.4% (9/34) had adductovarus of the fourth toe, a majority 79.4% (27/34) had adductovarus of the fifth toe, majority 52.9% (18/34) had a bunionette, 26.5% (9/34) had hammertoe of the second, 17.6% (6/34) of the third, 41.2% (14/34) of the fourth, and 67.6% (23/34) of the fifth. Calluses beneath the metatarsal heads was found under the first in 2 patients (5.9%), under the second in 14 patients (41.2%), under the third in 4 patients (11.8%), under the fourth in 3 patients (8.8%) and under the fifth in 8 patients (23.5%). There were 11 patients that had a medial pinch callus on the hallux (32.3%) and 10 patients had a subIPJ callus on the hallux (29.4%).

The second toe position nonweight bearing was 50% abutting and 50% no contact to the hallux, WB was majority no contact with the hallux (57.1%, 8/14), and Lachman's test was positive in 7 patients (20.6%). The average first MTPJ DF in RCSP was 21.1° (range 6-43°), and increased to average 32.2° in NCSP (range 6-62°). Majority of patients had resistance or "not moveable" paper from beneath their hallux (for purchase power; 64.7%, 22/34), and only 30.3% (10 patients) presented to the office with orthotics in their shoes. However, the results from the physical exam postoperative were not statistically significant. Table 12 shows a few of these results.

Table 11

PATIENT QUESTIONNAIRE RESULTS

Chief Complaint	Bump Pain	29.4% (10/34)
	Joint Pain	14.7% (5/34)
	Limited Motion	0% (0/34)
	Combination	**35.3% (12/34)**
	Nerve Pain	5.9% (2/34)
	Other	14.7% (5/34)
Type of Work/ Job	Sedentary	3.8% (1/26)
	Desk Work	**53.8% (14/26)**
	Standing Job	34.6% (9/26)
	Heavy Duty	7.7% (2/26)
	None	0% (0/26)
Exercise	None	3.0% (1/33)
	Occasional	27.3% (9/33)
	Regular	**69.7% (23/33)**
How Satisfied	**1 = Very satisfied**	**30.6% (11/36)**
	2	16.7% (6/36)
	3	11.1% (4/36)
	4	0% (0/36)
	5	8.3% (3/36)
	6	5.6% (2/36)
	7	11.1% (4/36)
	8	8.3% (3/36)
	9	2.8% (1/36)
	10 =V. Unsatisfied	5.6% (2/36)

Table 12

POSTOP PHYSICAL EXAM RESULTS

	AVERAGE	RANGE
# Months PO	**25.7**	9-52
Resting 1st MTPJ Position	**27.3° DF**	10-45° DF
NWB 1st MTPJ DF	**62.9°**	23-110°
NWB 1st MTPJ PF	**20.9°**	5-45°
Resting 1st Ray Position:	Dorsiflexed	6.9% (2/29)
	Plantarflexed	**93.1% (27/29)**
Resting 1st Ray Value	**-2.3mm**	-6-5
1st Ray DF	**5.0mm**	-2-16
1st Ray PF	**7.4mm**	0-13

DISCUSSION

Among our statistically significant data on average, at 6 weeks postoperative, the IMA decreased by 5 degrees, the HAA decreased by 7 degrees, and the TSP decreased by 2 positions showing evidence of deformity correction. The stress lateral dorsiflexion was significantly decreased at 6 weeks and this is the only time it was significantly changed. As far as procedures, the only significant increase in dorsiflexion was at 6 weeks radiographically in the Green Waterman group (by 4°). At 1 year, the IMA decreased by 3 degrees, the HAA decreased by 7 degrees, and the TSP decreased by 1 position, also indicating deformity correction. Similarly at 2 years, the IMA decreased by 3 degrees, the HAA decreased by 14 degrees and the TSP decreased by 1 position, again maintenance of realignment. Patient satisfaction appeared to be significantly associated with regular exercise, weight bearing job, improved postoperative TSP, IMA and HAA as expected. And patient dissatisfaction associated with: higher preoperative HAA and Engle's angle, higher postoperative HAA and Seiberg's index as expected for recurrent deformity.

Most patients have bunion surgery in their 50s with a female prevalence,[6,15] possibly due to increased laxity, in their 40's in the study by Bryant et al[3] and Deenik.[16] but almost equal incidence in second through fifth decades in Coughlin and Jones study.[15] For an average preoperative IMA of 12.3°, it is not surprising that an Austin was the most prevalent (43.2%, 32/74) procedure.

We found that postoperatively, dorsiflexion values both clinically and radiographically using the stress lateral dorsiflexion view: significantly diminished at 6 weeks and acceptance of our null hypothesis that first MTPJ ROM is not affected by bunion surgery. Values were higher throughout in hallux valgus than in hallux limitus patients. In contrast, a study by Goforth et al[17] found after Austin bunionectomy, a 7.2° decrease over 5 years compared with at 18 months postoperative, in first MTPJ ROM.

A total of 65° to 75° dorsiflexion at the first MTPJ is necessary for gait,[2] which was available preoperatively on all hallux valgus patients only (81.5° clinically, 74° radiographically, averages), and not available in hallux limitus patients (51° clinically, 46° radiographically, averages). However postoperativey, both hallux valgus and clinically only hallux limitus patients achieved motion necessary for gait (HAV: 90° clinically, 78° radiographically; HL: 66° clinically, 63° radiographically, averages), however less than 60° will cause joint jamming[2] which was not the case radiographically in the hallux limitus group. Buell et al[2] found that patients with first ray pathology showed 10° less motion than the required 65° to 75°. Furthermore Coughlin and Jones[15] found that neither magnitude of hallux valgus preoperative angular deformity nor increasing age had any association with degree of first MTPJ ROM. Preoperative DF (81.5°) and PF (23°) for hallux valgus patients clinically were higher than that of Coughlin and Jones study, 60° and 19° respectively. Coughlin and Jones[15] also found a significant increase in first ray mobility in hallux valgus patients compared with their control.

Compared with the literature, the 15° clinical increase in first MTPJ DF in hallux limitus patients in this study more than doubles the 6° in patients who underwent Waterman-Green by Laakmann et al but only half of Derner et al[1] who achieved 33° DF improvement with their halllux rigidus plantarflexory shortening procedure (34.4 month average followup).

Among the complications, the postoperative infection rate of 4.10% was within the cited rate 2-4% for bunion surgery[4] and was defined as any increase in redness, swelling, warmth or drainage than would be expected postoperative all of which resolved on 5 days of oral antibiotics. Overall complications post bunion surgery range from 7.1 to 16%, which this study also falls in range at 14.9%, if we consider only the true complications (postoperative infection, recurrence, subfibular sesamoid pain, subsecond and third ulcer, hallux varus, delayed healing, avascular necrosis, and fixation shifting).

The patient with AVN of her second metatarsal head was treated with arthroplasty, likely secondary to her advanced age (78 years). The patient with hallux varus was also the one with delayed healing improved by bone stimulator with nonweight bearing status, and may both be due to overcorrection in addressing her abnormally

large pronation forces (Meary's of 32°, CAA 10°, HAA 30°, TSP 6, true IMA 15°, MAA 16°, Engle's angle 34° and FAA 0° preoperative).

The patient whose fixation shifted was taken to the O.R. 9 days postoperative for ORIF with resolution. Coughlin and Jones[18] had recurrence in 6 of 127 feet (4.7%) after proximal crescentic osteotomies, Deenik et al[16] had 9% recurrence after Austin and Scarf bunionectomies, both higher than our rate of 2.7%. The patient who developed ulcerations subsecond and third metatarsal heads healed within the following months, and was also a diabetic with neuropathy (also had a stitch abscess which healed within 1 month). However a study by Bryant et al[13] showed no influence of medial and central metatarsal forefoot pressure distribution and should not increase the metatarsalgia after Austin bunionectomies, though when it does occur, attributed to first metatarsal shortening. This patient indeed had shortening of 5mm at 2 years postoperative, though the procedure was McBride and total implant.

Our radiographic biomechanic analysis show that an increased pronation is seen with hallux valgus patients, indicated with the abnormally high values in IMA, HAA, TSP, Engle's angle, first metatarsal-calcaneal angle, CAA, TCA, TN coverage (on AP and lateral views), Meary's angle, TDA, abnormally low FAA, positive Kirby's sign (obliteration of the sinus tarsi) and anterior break in the Cyma line (lateral view), consistent with the literature.[6,13,15,19] The hallux abducto valgus patients also had a predominance of round head shape, consistent with the literature,[15] as well as predominance of subluxed first MTPJ not present in the HL group, indicative of adaptive changes associated with increased pronatory forces. One patient had an old previous Lisfranc-dislocation injury which could have predisposed her to residual medial column instability.[6] However it is important to note certain values that did not change before and after surgery, such as the tibial sesamoid to second metatarsal bisection, indicating that the sesamoids are not moving but the metatarsal head relative to the sesamoids. The MAA and CIA did not change between measurements, indicating that these are structural angles and are not affected by pronation or supination. Although abnormally high MAA has been associated with increased predisposition to hallux valgus,[6,19] a study by Coughlin and Jones[15] found no correlation between increased HAA preoperative and MAA. In this study, the MAA was on average within the normal range 10 to 20 degrees, similar to Bryant study.[19] Second toe instability is also thought to increase progression the hallux valgus deformity and play a role in recurrence postoperative.[6] In lateral view measurements, the TCA = TDA + CIA proved true as described by DiGiovanni.[9] We chose not to measure PASA and DASA since cartilaginous deviation cannot be adequately assessed on radiographs, especially in round metatarsal heads.[16]

With hallux limitus, initial limitation of joint motion restricted potential for gaining motion. This may explain why perioperative hallux abducto valgus patients had higher dorsiflexion values both clinically and radiographically than hallux limitus patients. Metatarsus primus elevatus based on Seiberg's index (relationship of the first to second metatarsal dorsal cortices on the lateral view) was present in both HAV and HL groups, however the magnitude was much greater as indicated by Seiberg's index in the HL group, consistent with the limited joint motion of hallux limitus patients. Similarly, specific joint adaptations were found in the majority exclusively in the HL group, including the dorsal first MTPJ lipping (lateral view), majority of narrowing of the first MTPJ, and majority had first MTPJ DJD as well. There is controversy as to whether a long or short metatarsal length is associated with hallux valgus,[19] however in our study we found a relatively similar preoperative first metatarsal length 6.5cm in HL (6.51cm) and HAV (6.48cm). Bryant[19] also found a correlation with broader first metatarsal width to hallux valgus, and in our study the HAV group (1.31cm) had again a relatively similar average value 1.3cm to the HL group (1.27cm).

Bryant et al[3] looked at the HAA, IMA, metatarsal protrusion distance and TSP following Austin bunionectomy, however they excluded patients with hallux limitus or DJD in their study. They also found significant reduction in these parameters, with an average shortening of 4 mm for metatarsal protrusion distance, much greater than in our study of 1.8 mm. Their TSP reduced an average of 2.2 positions, whereas in our study reduced 1.3 positions, which could be due to our not releasing the conjoint adductor tendon in 74.3% of cases, and due to the fact that their study looked only at the Austin bunionectomy. Faber et al[20] had a TSP reduction of 1 position for both Hohmann and Lapidus procedures.

Also in Bryant et al,[3] the mean reduction in HAA was 14.3°, and was comparable to our study of 14.7° overall and 15.6° in hallux valgus patients. In their 2005 study, Bryant et al[13] found a mean decrease in HAA of 17.8°, in IMA 7.1°, and metatarsal protrusion distance 5.4 mm in hallux valgus patients after Austin bunionectomy, compared with our study's decreases postoperative in HAV patients as: HAA 15.6°, IMA 4.2° (at 2 years) and metatarsal protrusion distance 1.8mm, to normal values (in Table 1). Coughlin and Jones[18] found greater reductions in HAA and IMA of 20° and 9.1°, respectively, Deenik et al[16] of 13.3° and 3.9° after Austin

bunionectomy, 20.7° and 8.0° for Hohmann, 20.1° and 7.9° for Lapidus bunionectomies by Faber et al.[20] Goforth et al[17] found maintenance of correction for HAA, IMA and sesamoid position at 5 years post-Austin bunionectomy.

Bryant et al[19] looked at radiographic measurements in hallux valgus and hallux limitus patients, as well as a control group, they found significantly higher IMA, HAA, metatarsal protrusion distance and metatarsal width in the hallux valgus group, and significantly higher HIA in the hallux limitus group. They found no significant relationships in the lateral view between the two groups. Similarly, Coughlin and Jones[15] discussed the notion of decreased HIA in hallux valgus due to less resistance in transverse plane deformity than hallux rigidus patients. In our study, the hallux limitus patients also had increased HIA values compared to the hallux valgus patients perioperatively.

From the sample of patients who returned questionnaires, the majority were satisfied with their surgery (58.5%), were able to do more activities postoperative (75%) and would make the same decision again (91.7%), comparable to literature range 77-97%.[20] The majority also indicated that they performed exercises at their great toe joint postoperative (88.6%). A study by Connor and Berk[21] found that continuous passive motion significantly improved first MTPJ DF for iatrogenic hallux limitus (using a T300 Toe CPM device minimum 4 hours/day for 28 days) by 27%, even when delayed 6 months after hallux valgus surgery. From the physical exams performed on average 26 months postoperative, patients had adequate ROM of the first MTPJ (63° DF, 21° PF) for gait, a lack of stiffness of the first ray (total excursion 12.4 mm average, up to 9 mm considered normal[15]), and 91.2% no pain on motion. Coughlin and Jones[15,18] showed that preoperative HAA and increased first ray mobility had no statistically significant difference, likewise severity of preoperative HAA was not associated with pes planus. Our total first ray range of motion postoperative was 12.4mm and according to the senior author is closer to 16° preoperative – we will see the result in the following prospective study. A majority had adequate hallux purchase power, consistent with superior results. A third did have a medial pinch callus and sub IPJ hallucal callus, indicative of continued pronatory and abduction forces.[6] Bryant et al[13] attributed decreased medial plantar hallucal callus after bunion surgery to their findings of decreased hallucal peak pressures after Austin bunionectomies in hallux valgus patients. The increased first MTPJ DF in NCSP compared to RCSP can be attributed to higher functional position.

Sources of bias include the few times where the surgeon made clinical measurements, and accuracy in use of the standard goniometer in radiographic measurements, since the average reduction in IMA is typically 3.2 to 9.3° (4) and in this study was 1.1o for the true IMA and 1.4° for the IMA overall, but specifically for HAV patients: 4.2° (13.1° to 8.9°) IMA, and 4.9° (15.7° to 10.8°) true IMA, which still falls in the expected range. Similarly, the HAA dropped 14.7° overall, also slightly less than the expected range 14.8-17.6°, however specifically in the HAV group dropped 15.6° (24.8° to 9.2°). The unavailability of preoperative clinical dorsiflexion values and consistent postoperative clinical dorsiflexion measurements as well as intraoperatively, were limitations with regards to the retrospective nature of the study. Another limitation in comparing the hallux valgus and hallux limitus patients is the small amount of the latter group (55 versus 19 patients), and short followup as proved by the Goforth et al study.[17] There are likely some inaccuracies in comparing radiographic measurements between these periods, unless, as a rule, the patients were in the angle and base of gait for all of the radiographs (which is probably the case before surgery, and at any time after 6 weeks postoperative).

In many patients orthotics were recommended, but perhaps due to cost factor (usually up to $400), patients were deterred from obtaining them. Patients who had orthotics preoperative did not get new orthotics postoperative in most instances, likely cost was a factor. Although over half of the patients who returned questionnaires indicated that they wore orthotics in their shoes, but only a third presented to the office with orthotics in their shoes for a physical exam. The idea of using orthotics to help control pronatory forces[6] should be used not only as conservative management pre-operatively, but postoperatively since the patient is not cured of abnormal pronation post-bunion surgery. The corex first-ray cut-outs used by the surgeon postoperative also helps improve first MTPJ motion.[6]

Based on this study, we plan to investigate prospectively the dorsiflexion measurements for a comprehensive preoperative as well as 6 weeks, 3 months, 6 months and 1 year postoperative close followup on bunion patients, again assessing radiographic and clinical outcomes. We also plan to use the Bristol Foot Score for a foot health assessment in the prospective study.

Using the stress lateral view, dorsiflexion at the first MTPJ does diminish significantly at 6 weeks post bunion surgery, in all but the Green-Waterman procedure where it significantly increased. There was no statistically significant decrease in dorsiflexion at 1 year post bunion surgery both clinically and radiographically, requiring acceptance of our null hypothesis. The stress lateral

dorsiflexion measurement radiographically was across the board slightly less than the nonweight bearing clinical measurement, though not statistically significant. Among the dorsal bunion or hallux limitus patients, values were less than the hallux abducto valgus patients at all perioperative measurements. Hallux valgus patients had increased pronatory factors, hallux limitus patients had increased degenerative disease, on radiographic analysis. Patients with hallux abducto valgus tend to have a more pronatory foot type, consistent with the literature. Gheluwe et al performed a dynamic study that could not definitely conclude that a retrograde midtarsal pronation does occur after heel lift in hallux limitus patients.[22]

As expected, increased HAA and TSP postoperative leads to decreased patient satisfaction due to recurrence of deformity (vs. lack of enough correction). This study also suggests that there is a measureable connection (correlation) between subjective outcome and certain radiographic measurements. Increased patient satisfaction was also associated with preoperative stiffness, weight bearing job and patients who regularly exercise or higher activity patient. A further prospective study is warranted for more complete pre and postoperative assessments, not only of first MTPJ but also first ray mobility.

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