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2020
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A radiographic assessment of the change in metatarsal length following the modified Lapidus procedure

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Medicine

Johannesburg, 2019

Declaration

I, Wessel Greeff declare that this Research Report is my own, unaided work. It is being submitted in the 'submissible' format of a paper for the Degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

……day of ……..……20…….in……

Student's contribution to article(s) and agreement of co-author(s)

I, Wessel Greeff, student number 1528723, declare that this Research Report is my own work and that I contributed adequately towards research findings published in the article(s) stated below which are included in my Research Report.

Signature of Student

……**Date**……

Name of Primary Supervisor

……

Signature of Primary Supervisor

……**Date**……

Dedication:

I would like to dedicate this research project to Laura. Without your love and support this wouldn't have been possible. Thank you for looking after your three boys.

Presentations and publications arising from the research project

South African Orthopaedic association annual congress September 2019, Durban.
Presentation for GT Du Toit prize session and Foot and Ankle free papers.

Acknowledgements

Without my family I would have never been able to complete this project.

I owe a great debt of gratitude to Dr Strydom and Dr Ferrao for their guidance and encouragement during the creation of this article. Prof Saragas has been an inspirational figure in my training and provided insight into the article.

TABLE OF CONTENTS

Declaration iii

Student's contribution to article(s) and agreement of co-author(s)……..……...iii

Dedication iv

Acknowledgements v

Presentation at congress…….……..……v

List of abbreviations…..…….……...vii

List of figures 1i

List of tables……..ix

RESEARCH REPORT

1. Abstract…….....2
2. Introduction 4
3. Materials and methods 6
4. Surgical technique 7
5. Results 8
6. Discussion 10
7. Conclusion 12

References: 18

Appendices

Appendix A: Research protocol

Appendix B: Data collection sheet

Appendix C: Foot and Ankle International authors guidelines

Appendix D: Ethics approval certificate

Appendix E: CEO letter Netcare Linksfield Hospital

Appendix F: Plagiarism/turn-it-in report cover page

List of abbreviations

AP: Anteroposterior

DMAA: Distal metatarsal articular angle

HV: Hallux valgus

HVA: Hallux valgus angle

IMA: Intermetatarsal angle

mm: Millimetres

MT: Metatarsal

MTP: Metatarsophalangeal

RML: Relative metatarsal length

TMT: Tarsometatarsal

List of tables:

Table 1: Measurements of angles in degrees and RML in mm……..…13

Table 2: Measurements and angle of RML in the MCWC sub-group (n = 19) ……...13

Table 3: Measurements and angle of RML group without MCWC (n = 13)……14

List of figures

Fig. 1: Rotational osteotomies as the Lapidus procedure can result in less RML shortening due to the correction of the deformity and relative lengthening compared to the head of the second MT……15

Fig. 2: Nilsonne/ Morton method of measuring RML……....16

Fig. 3: Pre and postoperative measurement of RML …….16

Fig. 4: Elevated first MT post modified Lapidus procedure……...17

Fig. 5: Correct first MT alignment post modified Lapidus procedure…….…..17

Research report in the format of a "submissible" paper

A radiographic assessment of the change in metatarsal length following the modified Lapidus procedure

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ABSTRACT

Background: The modified Lapidus is a surgical procedure for managing moderate to severe hallux valgus deformities, especially in the presence of first tarsometatarsal joint arthritis or hypermobility. It has good long term results, but reportedly can lead to transfer metatarsalgia due to inherent shortening of the first metatarsal.

Methods: A retrospective analysis of all adult patients who underwent a modified Lapidus procedure, during a three year period was performed. Clinical notes were evaluated to look for non-union or any other complications related to the surgery. Pre and postoperative standard weight bearing radiographs were used to establish the relative metatarsal length (RML), intermetatarsal angle (IMA), hallux valgus angle (HVA) and distal metatarsal articular angle (DMMA). A total of 69 modified Lapidus procedures were identified, with 32 included in the study.

Results: The mean pre and postoperative RML was -0.77 mm and -4.86 mm respectively. The average RML shortening due to the procedure was -4.09 ($p < 0.0001$). The mean pre and postoperative IMA was 15 and five degrees respectively ($p < 0.0001$). The mean pre and postoperative HVA was 33 and nine degrees respectively ($p < 0.0001$). One patient reported transfer metatarsalgia, which was attributed to elevation of the first metatarsal.

Conclusion: In this series there was a statistically significant degree of shortening ($p < 0.05$) of the relative length of the first metatarsal, without any clinical implications. The low rate of transfer metatarsalgia following the modified Lapidus procedure could be attributed to the sagittal plane correction and stability obtained by performing a first tarsometatarsal (TMT) fusion.

Level of evidence: Level IV, retrospective case series.

Keywords: relative metatarsal length, modified Lapidus procedure, hallux valgus, transfer metatarsalgia

Introduction

Hallux valgus (HV) is a common deformity. [25] It occurs in an estimated 23% of the adult population (age 18 - 65 years) and 35.7% of patients above the age of 65 years as reported in a meta-analysis performed by Nix et al. [20] It is not exclusively a cosmetic abnormality, but affects shoe wear, causes pain and affects balance leading to gait disturbances and even falls among the elderly. [15, 24]

First tarsometatarsal joint (TMT) fusion for the correction of a HV deformity was first described by Albrecht in 1911. [10] In 1934 Lapidus described his variation of this procedure. [13] Although Lapidus was not the first to describe a first TMT fusion for the treatment of HV, this procedure and variations thereof are eponymously referred to him in the literature. The Lapidus technique described first TMT and first intermetatarsal joint fusion by suturing the joint capsule with catgut. The modern modified Lapidus procedure does not include the fusion of the intermetatarsal joint and utilises plates, screws or combinations thereof, to achieve fixation. The modified Lapidus procedure, in combination with a distal soft tissue release, has been shown to have good long term results in the treatment of moderate to severe HV deformities. [4, 8]

A reported complication of the modified Lapidus procedure is transfer metatarsalgia. [1, 3, 9, 17, 21] This is described as pain in one metatarsophalangeal joint (MPJ) due to mechanical impairment of another MPJ. [14] It is suspected that fusion of the first TMT leads to shortening of the first ray. This shortening may lead to an increased weight bearing load on the second metatarsal (MT) head and other lesser toes. The load bearing surface of the second MT head is roughly half the size of the first. [11] The transferred load and smaller area of distribution predisposes the second MT head to transfer metatarsalgia. This increase in loading force can lead to stress fractures of the lesser metatarsals. [26] Coetzee et al. found that only four out of

118 feet (3.4%) developed transfer metatarsalgia following the modified Lapidus procedure in their prospective cohort. [4] Two of the cases were thought to be due to shortening of the MT, while the other two were due to a dorsiflexed first MT.

First MT length can be measured as an absolute or as a relative metatarsal length (first MT length compared to the second MT length). Relative metatarsal length (RML) correlates to the functional length of the first MT and is believed to be more important than absolute MT length. [6]

In the author's experience we found very few patients complaining of transfer metatarsalgia after the modified Lapidus procedure was performed. In practice, the correction of the intermetatarsal angle leads to the first MT head correction along a radius of curvature rather than simple translation, meaning the rotational correction may slightly lengthens the first MT relative to the second (see Fig. 1). The relative lengthening is offset by bone loss during the procedure.

Carr and Boyd reported that up to four millimetres was an acceptable range for postoperative shortening of the first MT in HV surgery. [2] More recently, Nakagawa et al. found that a postoperative RML of -3 mm, predicted postoperative metatarsalgia (specificity 88% and sensitivity 85%). [18] The procedure investigated by Nakagawa et al. was a midshaft metatarsal osteotomy, with shortening and translation. That osteotomy being translational does not have the benefit of relative lengthening seen in rotational osteotomies such as the Lapidus. They used the Nilsonne/Morton method of measuring RML and found it easy to perform and reproducible in daily practise (see Fig. 2).

The hypothesis for this study was that the change in RML of the first MT is not significant post modified Lapidus procedure.

Materials and methods

A retrospective review of the records and X-rays of patients who underwent a modified Lapidus procedure was performed. The study included all adults (age 18 years and older) between July 2015 to April 2018 done at the same orthopaedic foot and ankle unit. During the study period 69 modified Lapidus procedures were performed among 53 patients. Out of these 23 patients, 32 feet, were included in the study group. Seventeen feet were excluded due to simultaneous second MT procedures. The procedure on the second MT affected the length of the second MT and subsequently affected the RML of the hallux. A further 19 feet were excluded due to missing or inadequate X-rays or follow up visits.

All patient records were assessed for documented complications.

Pre and postoperative full weight bearing AP radiographs without magnification were used. These were done in accordance to the international standard protocol. [22, 23] All radiographs were measured manually by the author. Intermetatarsal angle (IMA), hallux valgus angle (HVA) and distal metatarsal articular angle (DMMA) were measured according to the international standard technique. [7]

RML of the first metatarsal was measured using the technique described by Nilsonne and Morton. [16, 19] The long axis of the second MT was used as a reference. Two parallel lines perpendicular to the long axis of the second MT are drawn: the first line at the level of the distal end of the second MT head, the second at the level of the distal end of the first MT head. The distance between these lines was measured using an electronic digital calliper. A negative value was obtained if the first MT was shorter than the second MT. A positive value indicates that the first MT is longer than the second MT (see Fig. 3).

Surgical technique

The procedure is performed with the patient in a supine position and pneumatic tourniquet applied to the thigh

A distal soft tissue release is performed first through a dorsal incision in the first web space. This includes sequential release of the adductor hallucis tendon, sesamoid suspensory ligament and the lateral capsule. This is followed by a bunionectomy through a medial skin incision and an L-shaped capsulotomy. The modified Lapidus procedure is then performed through a three to four centimetres incision dorsally over the first TMT joint. The extensor hallucis longus tendon is retracted medially. A capsular incision is made and the joint is carefully exposed. The MT cut is made perpendicular to the long axis of the first MT (in all the planes) at the level of the subchondral plate. The medial cuneiform articular surface is then resected perpendicular to the long axis of the second metatarsal in the frontal and sagittal planes, creating a lateral closing wedge. By doing this the first metatarsal will be almost parallel to the second metatarsal once the fusion site is reduced, thus correcting the IM angle. Both joint surfaces are then fenestrated using a 2.5 mm drill bit to allow for the access of marrow elements into the fusion site. The two joint surfaces are reduced while dorsiflexing the hallux and engaging the windlass mechanism, to ensure plantarflexion of the first metatarsal. It is very important to never elevate the first MT. Once reduction is obtained, two guidewires for the cannulated screws are used to provisionally fix the position. Adequate correction of the IM angle and positioning of the guide wires is confirmed under image intensification. The fusion site is compressed and fixed with two 4.7 mm cannulated headless compression screws (Acutrak 2, Acumed, USA). A distal medial closing wedge chevron osteotomy (MCWC) and Akin osteotomy are added when indicated. The MCWC is performed in cases with a high distal metatarsal articular angle (DMAA). The Akin

osteotomy is performed for correction of hallux valgus interphalangeus and pronation of the hallux. The capsule is repaired using Vicryl and the wound is closed in layers.

Due to the medial cuneiform cut being perpendicular to the second MT more bone loss is expected than in other techniques where the cartilage might only be denuded. A closing wedge cut has the advantage of allowing the first MT to be nearly parallel to the second MT, leading to less shear strain across the fusion site and a reliable reduction of the IMA.

Results

The average age of the study group was 43 years (20 to 68 years). Nineteen of the patients were females and four were males. Thirteen patients (56%) underwent bilateral hallux valgus corrections. Nine of the patients (39%) had bilateral modified Lapidus procedures. The remaining four patients (17%) had a proximal opening wedge osteotomy on the contralateral foot. The indications for a modified Lapidus procedure within this series included 28 feet with hypermobility of the first TMT joint, with a moderate or severe HV deformity, three severe hallux valgus deformities and two hallux valgus deformities with osteoarthritis of the first TMT joint. Nineteen feet (59%) underwent an ipsilateral distal MCWC of the MT. Twenty eight feet (88%) underwent an ipsilateral Akin osteotomy. Seventeen feet (53%) had both an Akin and distal MCWC performed.

All patients had clinical and radiological signs of union at 12 weeks. The mean preoperative RML was -0.77 (range, -7.2 to 4.56) mm and postoperative RML was -4.86 (range, -14.8 to 0.6) mm. The mean RML change was statistically significant ($p < 0.0001$), with a mean shortening of -4.11 mm. The mean pre and postoperative IMA was 15 (range, 11 to 20) and five (range, 2 to 12) degrees respectively. The mean pre and postoperative HVA was 33

(range, 16 to 46) and nine (range, three to 25) degrees respectively. The mean pre and postoperative DMAA was 16 (range, four to 26) and nine (range, 2 to 17) degrees respectively (see Table 1)

To establish if any of the preoperative measurements or angles predicted the amount of RML change obtained with the modified Lapidus procedure, the Pearson Correlation coefficient was calculated. This measure sets out to assess the linear correlation between two variables, with the outcome having a value between +1 and −1. A value of one is total positive linear correlation, with a value greater than zero indicating a positive association; thus, an increase in the value of one variable will result in an increase in the other variable. A value of zero indicates that there is no linear correlation or no association between the two variables, and −1 is total negative linear correlation.

This measure will highlight whether any preoperative angles or measurements has a high likelihood of predicting shortening of the RML that is considered higher than the norm. The correlation between the change in postoperative RML and the preoperative RML was -0.4. The correlation between the change in postoperative RML and the preoperative HVA was -0.15. The correlation between the change in postoperative RML and preoperative IMA was 0.3. According to these correlation calculations, none of the preoperative measurements had a strong correlation with the degree of RML change. Thus, none of these values was likely to predict excessive shortening of the first metatarsal.

The distal MCWC osteotomy group had a mean change in RML of -3.82 (see Table 2) and the group without a distal closing wedge osteotomy mean change in RML was -4.49 (see

Table 3). One patient developed signs of transfer metatarsalgia at final follow-up. These patient's x-rays were re-evaluated and the first MT was found to have been elevated by the procedure (see Fig. 4).

Discussion

Hallux valgus deformity remains a common but complex condition in foot and ankle surgery. The foot and ankle surgeon needs to have an array of procedures to address each specific deformity and patient. It is important to understand each surgical procedure's potential limitations and complications. The modified Lapidus procedure has good long term outcomes, but is reserved for specific indications. RML shortening resulting in transfer metatarsalgia is a concern, but both the amount of shortening as a result of the procedure and the correlation of RML and transfer metatarsalgia have not been well establish in the literature.

Our initial hypothesis was that the RML would not be shortened significantly due to the rotational correction achieved with this procedure. The medial cuneiform cut perpendicular to the long axis of the second MT adds to bone loss and potential shortening. The authors, however, believe that this technique adds to the stability of the fusion, decreases the rate of non-unions, leads to a reliable IMA correction and limits recurrence of the deformity.

In this series the modified Lapidus procedure did lead to a significant amount of shortening of the first MT according to published standards. On average the amount of shortening was 4.09 mm relative to the second metatarsal. Bednarz et al. estimated the amount of shortening in their series as four millimetres, but did not describe the technique of measuring the length.

[1] They found no correlation between the amount of shortening and postoperative transfer metatarsalgia.

Other authors have described measuring intraoperative metatarsal length and doing second metatarsal shortening osteotomies to avoid potential transfer metatarsalgia. Schmid and Krause suggested performing a shortening osteotomy on the second MT if the shortening following the modified Lapidus procedure exceeds 10 mm. [22] Coetzee suggested not to perform the Lapidus procedures if the first MT was 15 mm shorter than the second, preoperatively, due to the risk of transfer metatarsalgia. [4]

Comparing our results with the findings of Nakagawa et al. (that a -3 mm RML increases the risk of transfer metatarsalgia), 18 out of 32 (56%) feet had a postoperative RML less than -3 mm. Only one of these patients reported transfer metatarsalgia. The low rate of transfer metatarsalgia postoperatively in the literature would suggest that shortening alone is not the cause for transfer metatarsalgia. [4, 12] Our patient with transfer metatarsalgia was found have an elevated first MT post-surgery. The authors believe that sagittal plane alignment of the first MT after the modified Lapidus procedure might be more important than the RML. With the first metatarsal stabilised in the correct amount of plantar flexion the tripod mechanism is maintained and transfer metatarsalgia prevented. It is important to make sure intraoperatively that the first MT is appropriately plantar flexed (see Fig. 5). Further research looking at the sagittal position of the first metatarsal in patients with transfer metatarsalgia is needed.

Hypermobility of the first TMT is a controversial cause of HV deformities; some researchers argue that this hypermobility may be a result of the deformity rather than the cause. [5] By eliminating this hypermobility with the fusion, this sagittal stability of the first ray probably decreases the incidence of transfer metatarsalgia.

In this cohort, adding a distal MCWC osteotomy to the modified Lapidus procedure did not result in further shortening of the RML.

Conclusion

Shortening of the first MT is a concern in any hallux valgus surgery. The amount of first MT shortening which is clinically significant for the modified Lapidus procedure has not been established in the literature. In this study the mean shortening was found to be 4.09 mm, which is statistically significant but had no clinical sequela. The authors believe that sagittal alignment is an important factor in preventing transfer metatarsalgia.

Table 1: Measurements of angles in degrees and RML in mm

Total (n = 32)	Preoperative Mean	Range	Postoperative Mean	Range	Average Change
RML in mm	-0.77	-7.2 to 4.56	-4.86	-14.8 to 0.6	-4.09
IMA in degrees	15	11 to 20	5	2 to 12	-10
HVA in degrees	33	16 to 46	9	3 to 25	-22
DMAA in degrees	16	4 to 26	9	2 to 17	-7

Table 2: Measurements and angle of RML in the MCWC sub-group (n = 19)

	Preoperative Mean	Range	Postoperative Mean	Range	Average Change
RML in mm	-1.33	-7.2 to 0.38	-5.16	-14.8 to 4.41	-3.82
IMA in degrees	16	11 to 20	5	2 to 8	-11
HVA in degrees	33	26 to 38	10	3 to 21	-19
DMAA in degrees	17	4 to 26	8	2 to 18	-8

Table 3: Measurements and angle of RML group without MCWC (n = 13)

	Preoperative Mean	Range	Postoperative Mean	Range	Average Change
RML in mm	0.06	-3.22 to 4,56	-4.41	-7.5 to 0.6	-4.47
IMA in degrees	14	11 to 20	6	2 to 12	-8
HVA in degrees	32	16 to 4	7	3 to 25	-25
DMAA in degrees	16	4 to 26	10	2 to 17	-6

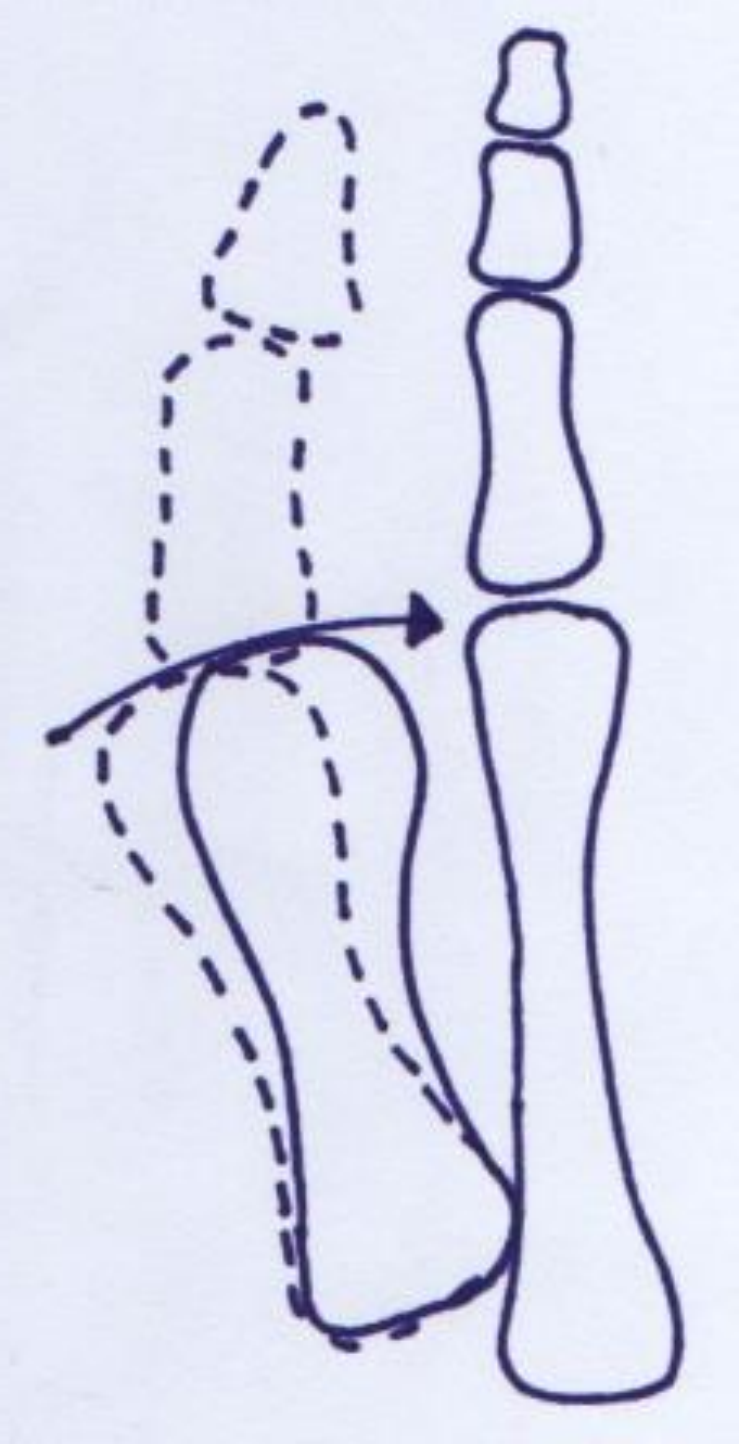


Fig. 1: Rotational osteotomies as the Lapidus procedure can result in less RML shortening due to the correction of the deformity and relative lengthening compared to the head of the second MT



Fig. 2: Nilsonne/Morton method of measuring RML

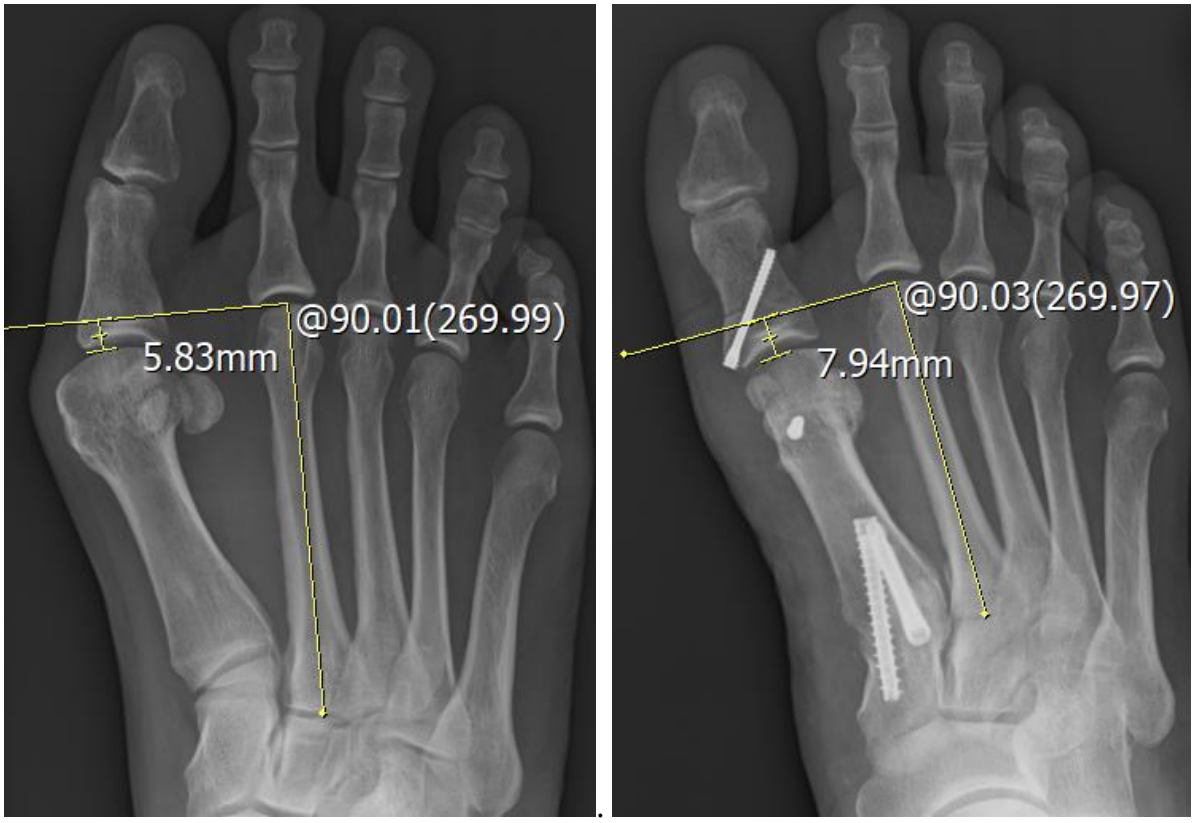


Fig. 3: Pre and postoperative measurement of RML

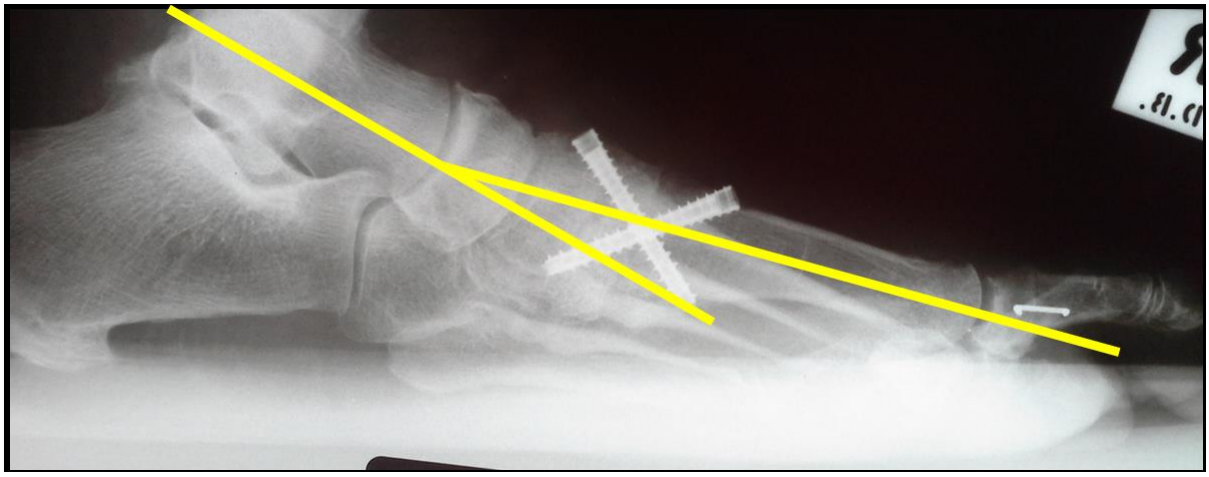


Fig. 4: Elevated first MT post modified Lapidus procedure



Fig. 5: Correct first MT alignment post modified Lapidus procedure

References

1. Bednarz PA, Manoli A, 2nd. Modified lapidus procedure for the treatment of hypermobile hallux valgus. *Foot & ankle international* 2000;21(10):816-21. doi: 10.1177/107110070002101004.
2. Carr CR, Boyd BM. Correctional osteotomy for metatarsus primus varus and hallux valgus. *The Journal of bone and joint surgery American volume* 1968;50(7):1353-67.
3. Catanzariti AR, Mendicino RW, Lee MS, Gallina MR. The modified Lapidus arthrodesis: a retrospective analysis. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 1999;38(5):322-32.
4. Coetzee JC, Wickum D. The Lapidus procedure: a prospective cohort outcome study. *Foot & ankle international* 2004;25(8):526-31.
5. Coughlin MJ, Jones CP. Hallux valgus and first ray mobility. A prospective study. *The Journal of bone and joint surgery American volume* 2007;89(9):1887-98. doi: 10.2106/jbjs.f.01139.
6. Coughlin MJ, Jones CP, Viladot R, et al. Hallux valgus and first ray mobility: a cadaveric study. *Foot & ankle international* 2004;25(8):537-44.
7. Coughlin MJ, Saltzman CL, Nunley JA, 2nd. Angular measurements in the evaluation of hallux valgus deformities: a report of the ad hoc committee of the American Orthopaedic Foot & Ankle Society on angular measurements. *Foot & ankle international* 2002;23(1):68-74. doi: 10.1177/107110070202300114.
8. Faber FW, van Kampen PM, Bloembergen MW. Long-term results of the Hohmann and Lapidus procedure for the correction of hallux valgus: a prospective, randomised trial with eight- to 11-year follow-up involving 101 feet. *The bone & joint journal* 2013;95-b(9):1222-6. doi: 10.1302/0301-620x.95b9.31560.
9. Gerard R, Stern R, Assal M. The modified Lapidus procedure. *Orthopedics* 2008;31(3):230-6.
10. GH. A. The pathology and treatment of hallux valgus. *Russ Vrach* 1911;10(14).
11. Goldberg A, Singh D. Treatment of shortening following hallux valgus surgery. *Foot and ankle clinics* 2014;19(2):309-16. doi: 10.1016/j.fcl.2014.02.009.
12. Kopp FJ, Patel MM, Levine DS, Deland JT. The modified Lapidus procedure for hallux valgus: a clinical and radiographic analysis. *Foot & ankle international* 2005;26(11):913-7.
13. Lapidus PW. Operative correction of the metatarsus varus primus in hallux valgus. *Surg Gynecol Obstet* 1934;58(183-191):16.
14. Maceira E, Monteagudo M. Transfer metatarsalgia post hallux valgus surgery. *Foot and ankle clinics* 2014;19(2):285-307. doi: 10.1016/j.fcl.2014.03.001.
15. Mann RA. Disorders of the First Metatarsophalangeal Joint. *The Journal of the American Academy of Orthopaedic Surgeons* 1995;3(1):34-43.
16. Morton DJ. Structural factors in static disorders of the foot. *The American Journal of Surgery* 1930;9(2):315-328. doi: https://doi.org/10.1016/S0002-9610(30)91100-2.
17. Myerson M. Metatarsocuneiform arthrodesis for treatment of hallux valgus and metatarsus primus varus. *Orthopedics* 1990;13(9):1025-31.
18. Nakagawa S, Fukushi J, Nakagawa T, Mizu-Uchi H, Iwamoto Y. Association of Metatarsalgia After Hallux Valgus Correction With Relative First Metatarsal Length. *Foot & ankle international* 2016;37(6):582-8. doi: 10.1177/1071100716634792.
19. Nilsonne H. Hallux Rigidus and Its Treatment. *Acta Orthopaedica Scandinavica* 1930;1(1-4):295-303. doi: 10.3109/17453673008991145.

20. Nix S, Smith M, Vicenzino B. Prevalence of hallux valgus in the general population: a systematic review and meta-analysis. *Journal of foot and ankle research* 2010;3:21. doi: 10.1186/1757-1146-3-21.
21. Sangeorzan BJ, Hansen ST, Jr. Modified Lapidus procedure for hallux valgus. *Foot & ankle* 1989;9(6):262-6.
22. Smith RW, Reynolds JC, Stewart MJ. Hallux valgus assessment: report of research committee of American Orthopaedic Foot and Ankle Society. *Foot & ankle* 1984;5(2):92-103.
23. Srivastava S, Chockalingam N, El Fakhri T. Radiographic measurements of hallux angles: a review of current techniques. *Foot (Edinburgh, Scotland)* 2010;20(1):27-31. doi: 10.1016/j.foot.2009.12.002.
24. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *The New England journal of medicine* 1988;319(26):1701-7. doi: 10.1056/nejm198812293192604.
25. Vanore JV, Christensen JC, Kravitz SR, et al. Diagnosis and treatment of first metatarsophalangeal joint disorders. Section 1: Hallux valgus. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons* 2003;42(3):112-23. doi: 10.1053/jfas.2003.50036.
26. Zechman J. Stress fracture of the second metatarsal after Keller bunionectomy. *The Journal of foot surgery* 1983;23(1):63-65.