MANIPULATIONS OF THE FIRST METATARSAL IN HALLUX VALGUS SURGERY (REVISITED)

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Podiatric evolution of first metatarsal surgery has taken tremendous strides within the past twenty years. In a short period of time, we have progressed from simple soft tissue procedures to triplanar osteotomies. Part of the future growth of podiatry will be the ability to accurately and scientifically quantify our results. The mathematical concepts presented are a valuable resource to consider in the preoperative planning. If they are applied during the intra-operative stage, a more predictable postoperative result will result.

The literature is somewhat limited in addressing mathematical analysis of foot and ankle surgery. The articles available primarily discuss transverse plane manipulation of the first metatarsal in hallux valgus surgery. Although transverse plane orientation is extremely important in the evaluation of hallux valgus and first metatarsal surgery, the sagittal plane is often forgotten. Sagittal plane manipulation needs to be considered in conjunction with transverse plane changes to achieve not only a sound cosmetic result, but also a sound functional result.

REVERDIN BUNIONECTOMY

In the past, many surgeons were performing isolated Reverdin osteotomies for hallux valgus correction. Hallux limitus similar mechanically to the postoperative limitus seen with a straight translocational Austin was a common postoperative complaint. With a classic Reverdin osteotomy, the hallux and peri-articular soft tissue structures are relocated dorsally and plantarly. The first metatarsophalangeal joint is simultaneously restored to a congruous position, in effect lengthening the soft tissues crossing the joint. Unless adequate relaxation through shortening at the joint is achieved, this force increases compression and thus postoperative limitus ensues.

Analysis of the osteotomy can support the postoperative findings. (Table 1) For PASA values

TABLE 1

ANALYSIS OF METATARSAL SHORTENING IN THE REVERDIN BUNIONECTOMY

PASA	SH (mm)	WEDGE (mm)
2	0.26	0.52
4	0.52	1.04
6	0.78	1.56
8	1.04	2.08
10	1.30	2.60
12	1.56	3.12
14	1.91	3.82
16	2.07	4.14
18	2.32	4.64
20	2.57	5.14

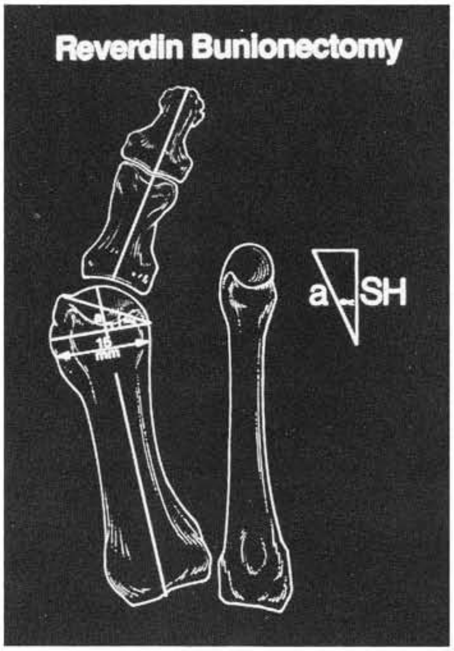

Fig. 1A

from two to twenty degrees, actual shortening at the metatarsal head can be calculated. (Fig. 1A, 1B) These values are unimpressive and in reality, the shortening seen with the Reverdin osteotomy is minimal to none. (Figs. 2, 3)

DORSIFLEXORY AND PLANTARFLEXORY WEDGE OSTEOTOMY

Dorsiflexory and plantarflexory wedge osteotomies of the first metatarsal can produce some dynamic changes within the medial column as well as the entire forefoot to rearfoot relationship. With structural changes of the medial column, the rearfoot will compensate to new forefoot positions if motion is available. This is an important consideration in the preoperative workup. Subtalar joint motion is necessary for a successful result. Utilizing our mathematical model, we have the ability to understand how much change we are affecting with our osteotomies. We can start to take the guess work out of these previously unpredictable osteotomies and effectively control the postoperative result.

Our mathematical model is identical to the model presented previously. The osteotomy performed at the Podiatry Institute is oblique with the proximal cut oriented 45 degrees from the metatarsal cuneiform joint. The apex is situated

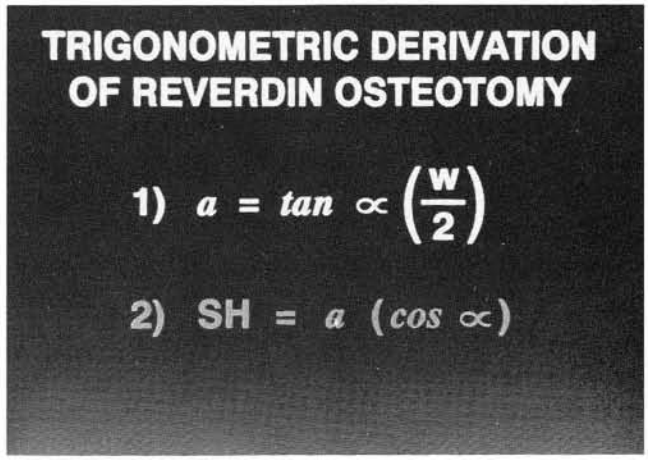

Fig. 1B. Derivation of actual shortening with the Reverdin osteotomy for correction of proximal articular set angle.

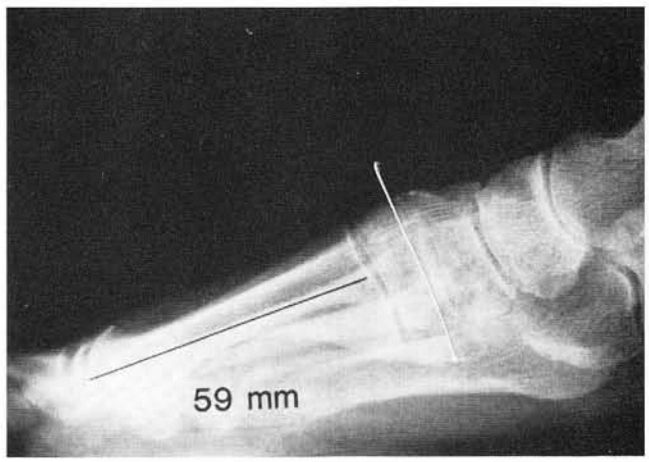

Fig. 2. Preoperative radiograph of Reverdin procedure first metatarsal length. Moderate PASA is corrected with minimal shortening achieved, resulting in decreased first MPJ motion.

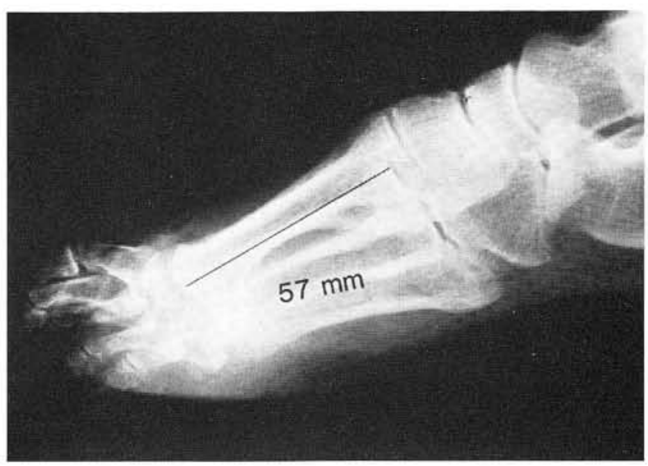

Fig. 3. Postoperative radiograph of Reverdin procedure first metatarsal length.

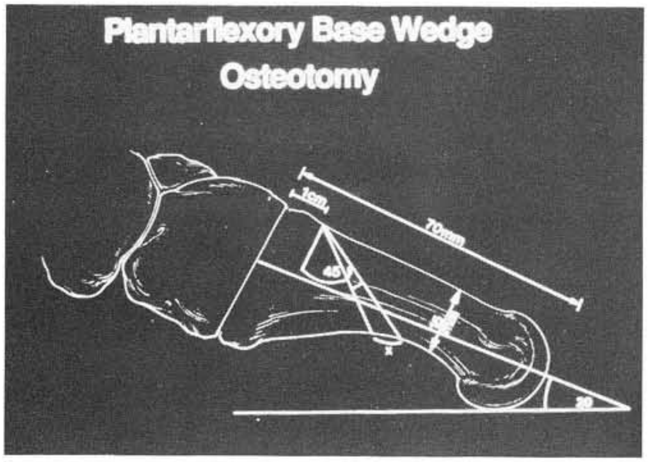

Fig. 4. Mathematical model for analysis of the DFWO/PFWO. Note the distance "x" on the plantar cortex corresponding to the wedge removed.

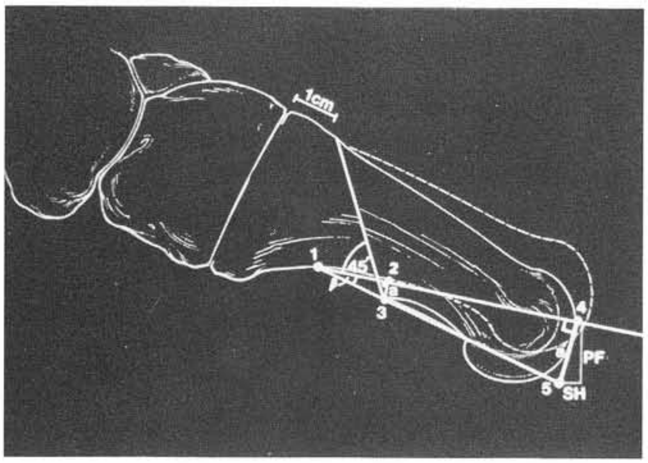

Fig. 5. Similar triangles applied to the model to determine the result of base a'. This is summated from a plantar-flexion (PF) and shortening (SH) vector.

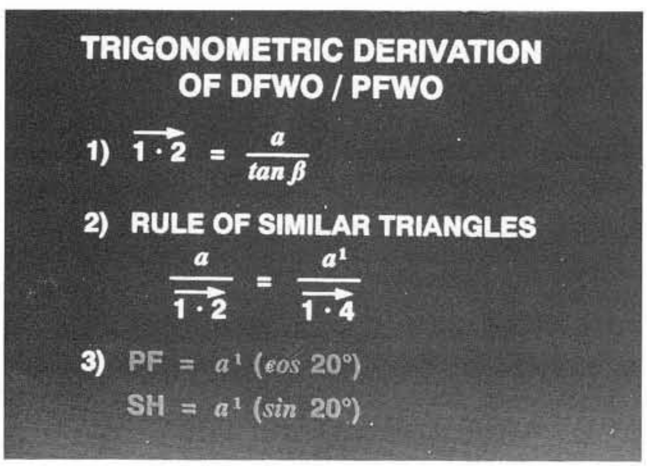

Fig. 6. Derivation of plantarflexion and shortening vectors in millimeters.

one centimeter distal to the joint. (Fig. 4) The oblique osteotomy has proven to be stable with the two screw fixation technique. In essence, this is a closing base wedge osteotomy rotated 90 degrees to the sagittal plane. Using trigonometric analysis based on our model, we know how much plantarflexion/dorsiflexion the osteotomy will provide as well as shortening. The analysis actually produces a resultant vector which is summated from a plantarflexory/dorsiflexory vector and a shortening vector. By measuring the wedge distance on the cortical bone for the proximal and distal osteotomy (x), we can accurately control the sagittal plane orientation of the metatarsal. (Figs. 5, 6) (Table 2)

When we pass the saw blade through the proximal and distal osteotomy, we are effectively making a 2mm wedge resection. This already changes the sagittal plane position of the metatarsal 3.62mm. A six millimeter wedge will affect a one centimeter change in the metatarsal. Depending on the preoperative clinical and radiographic exam, we can determine the sagittal plane manipulation desired and achieve the surgical result.

LAPIDUS ARTHRODESIS

The Lapidus procedure (first metatarsal-cuneiform fusion) affords both dynamic transverse and sagittal plane manipulation. Just by bringing the osteotomy one centimeter proximal and changing the orientation of the osteotomy from oblique to transverse, we affect the metatarsal head more

TABLE 2

ANALYSIS OF PLANTARFLEXORY OSTEOTOMIES

WEDGE	B	PF (mm)	SH (mm)
1mm	1.84	1.82	0.67
2mm	3.58	3.62	1.32
3mm	5.19	5.18	1.89
4mm	6.71	6.72	2.45
5mm	8.13	8.17	2.97
6mm	9.46	9.60	3.49
7mm	10.71	10.91	3.97
8mm	11.88	12.18	4.43
9mm	12.99	13.37	4.87
10mm	14.01	14.50	5.28

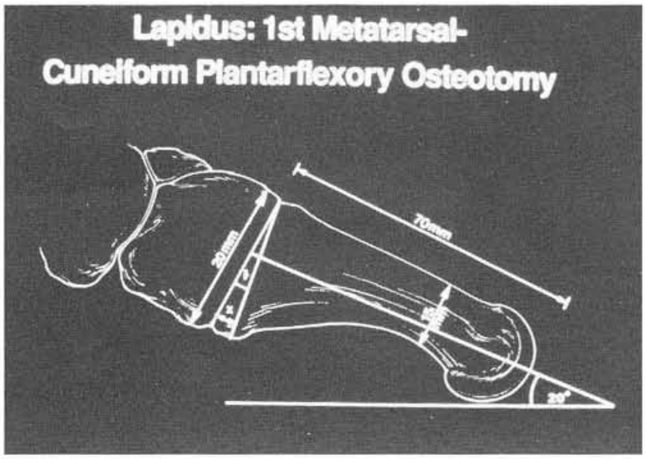

Fig. 7. Similar model for analysis of the Lapidus fusion. Note the apex is transverse and one centimeter more proximal..

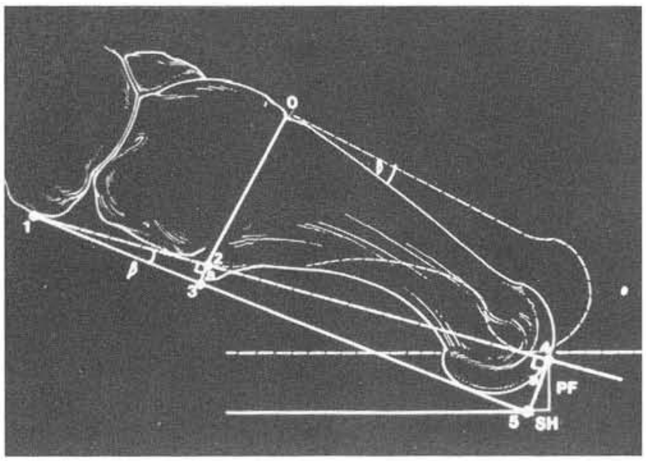

Fig. 8. Similar triangles applied to the Lapidus model with the same resultant vectors.

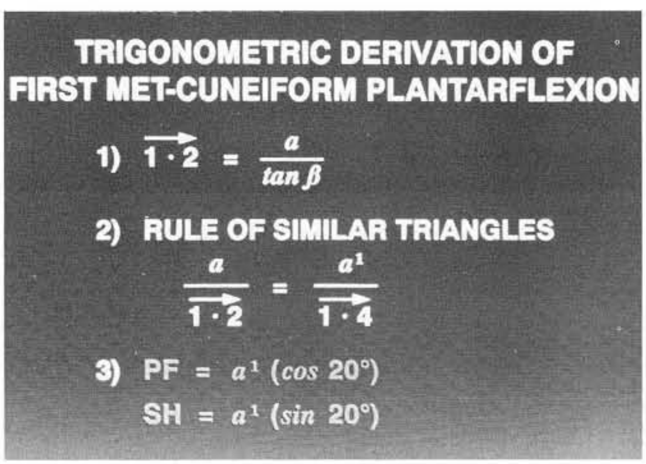

Fig. 9. Derivation of plantarflexion and shortening vectors in millimeters.

TABLE 3

ANALYSIS OF THE LAPIDUS FUSION

WEDGE	B	PF (mm)	SH (mm)
1mm	2.86	3.31	1.20
2mm	5.71	6.68	2.43
3mm	8.53	10.08	3.67
4mm	11.31	13.52	4.92
5mm	14.04	17.04	6.20
6mm	16.70	20.57	7.47
7mm	19.29	24.13	8.78
8mm	21.80	27.78	10.10
9mm	24.23	31.41	11.43
10mm	26.57	35.11	12.78

dramatically for every millimeter of wedge resection. (Fig. 7) The trigonometry is similar to the previous example yet the results are more dramatic. (Figs. 8, 9) (Table 3)

A 2mm wedge with the Lapidus now effectively changes the metatarsal position 6.68mm. A 6mm wedge in this situation will change the metatarsal position 20.57mm or 2.057cm. Awareness of how dynamic the changes can be is essential for both surgical control as well as for avoiding overzealous correction.

Bibliography

Cain TD, Boyd D: Defining the Limits of the Modified Austin Bunionectomy. In DiNapoli R (ed): *Reconstructive Surgery of the Foot and Leg, Update 90*. The Podiatry Institute Publishing, Tucker, p. 128-134, 1990.