CHAPTER 15

THE SAGITTAL-Z OSTEOTOMY AND ITS EFFECT ON FIRST METATARSOPHALANGEAL JOINT RANGE OF MOTION WHEN USED TO LENGTHEN THE FIRST METATARSAL

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The sagittal-z osteotomy is an extremely versatile procedure that may be utilized for numerous derangements of the first metatarsal. It is fairly easy to perform, and may correct deformities of the first metatarsal in multiple planes.[1] It has been used by Camasta and Chang with success for metatarsus primus elevatus or metatarsus primus equinus, as well as correction of a long or short metatarsal.[2] Viegas[3] has utilized the sagittal-z osteotomy of the first metatarsal for advanced grade I and conventional Grade II hallux limitus with a 73% success rate. Kissel and Mistretta[4] utilized this procedure as an alternative joint preservation approach to hallux limitus. Chang had reported 32 cases with 86% good results after 2 year follow-up.[5] Iatrogenic or congenitally shortened metatarsals may at times need to be lengthened in order to rebalance the weight-bearing parabola.

However, no one has yet to determine how much acute lengthening can be performed with the sagittal-z osteotomy taking into account soft tissue constraints. Another issue is how the range of motion of the first metatarsophalangeal joint is affected. Lengthening of the metatarsal may lead to an increase in tension at the metatarsophalangeal joint level, subsequently creating a symptomatic hallux limitus. Banks[6] relates that the two ways to overcome this problem is to plantarflex the distal aspect of the osteotomy or to perform a cheilectomy at the metatarsophalangeal joint. Also, with an acute lengthening such as the sagittal-z, soft tissues may not as readily adapt in comparison to a slow lengthening obtained with callous distraction techniques. The purpose of this study therefore is to quantify the amount of acute lengthening obtained with the sagittal-z osteotomy of the first metatarsal and to also evaluate the effect it may have on range of motion of the metatarsophalangeal joint.

MATERIALS AND METHODS

Ten freshly frozen cadavers were utilized for this experiment. First metatarsophalangeal plantarflexion as well as dorsiflexion were measured with a goniometer prior to dissection. All measurements were recorded and then later compared to motion of the first metatarsophalangeal joint post sagittal-z osteotomy. Dissection of the first ray was uniform, using a dorsomedial incisional approach carried over the first metatarsophalangeal joint to the level of the first metatarsocuneiform joint. A dorsal linear capsular and periosteal incision was then created with reflection of the periosteum that is needed to perform the bone cuts. The first metatarsophalangeal joint was exposed, however no extensor tendon lengthenings were performed.

Prior to the osteotomy, the length of the first metatarsals were measured and recorded. Two guide wires were placed perpendicular to the long axis of the metatarsal. One was placed distally and one proximally, making sure the distance between the wires measured 3 centimeters. This would ensure that the osteotomy was made in a strict sagittal plane with the same length of the mid-diaphyseal osteotomy and adequate room for 2 screw fixation. The osteotomy was made utilizing a sagittal power saw. The distal hemiosteotomy was made laterally, while the proximal hemiosteotomy was made medially. The distal fragment was then manually distracted maximally in a proximal to distal direction to obtain lengthening of the first metatarsal, yet making sure that no sagittal plane translation or swivel was achieved. Once maximum distraction was allowed secondarily to soft tissue constraints, the osteotomy was clamped using a bone clamp. Next, rigid stable fixation of the osteotomy was obtained utilizing two 2.7 mm screws from medial to lateral. The length of the first metatarsals were then recorded and compared to the original length. The soft tissue layers were reapproximated and then the first metatarsaophalangeral range of motion was measured again, specifically looking at dorsiflexion and plantarflexion.

RESULTS

From the 10 cadaveric specimens, the maximum amount of acute lengthening obtained with the sagittal-z osteotomy of the first metatarsal was 8.8 mm. The average amount of lengthening was 8.1 mm. First

Table 1

	Pre "Z" Length	Post "Z" Length	Pre "Z" MPJ Df/Pf	Post "Z" MPJ Df/Pf	Net Length Gained	% loss Df/Pf
Metatarsal (1)	6.44 cm	7.12 cm	64 / 21	45 / 18	6.8 mm	29.7/14.3
Metatarsal (2)	7.08 cm	7.79 cm	47 / 16	28 / 12	7.1 mm	41.4/25
Metatarsal (3)	7.50 cm	8.35 cm	32 / 11	14 / 8	8.5 mm	56.3/28.3
Metatarsal (4)	6.72 cm	7.48 cm	52 / 18	35 / 14	7.6 mm	32.7/23.3
Metatarsal (5)	5.96 cm	6.84 cm	62 / 20	43 / 16	8.8 mm	31.7/20.0
Metatarsal (6)	6.60 cm	7.33 cm	18 / 5	8 / 3	7.3 mm	55.6/40.0
Metatarsal (7)	5.95 cm	6.68 cm	40 / 17	17 / 13	7.3 mm	57.5/23.6
Metatarsal (8)	6.05 cm	6.70 cm	55 / 22	30 / 15	6.5 mm	45.5/31.9
Metatarsal (9)	6.67 cm	7.42 cm	46 / 18	22 / 14	7.5 mm	52.2/23.3
Metatarsal (10)	6.23 cm	6.82 cm	67 / 24	37 / 19	5.9 mm	44.8/20.8
					Avg: 8.1	44.7/25.1

metatarsophalangeal dorsiflexion was significantly diminished, with an average loss of 44.7%. Plantarflexion was also decreased by an average of 25.1%. One cadaver had severe hallux limitus with a structural elevatus that was not addressed with osteotomy. There seemed to be a significant increase in the amount of tension placed upon the first metatarsophalngeal joint after 6 mm of distraction. The results are summarized in Table 1.

DISCUSSION

The sagittal-z osteotomy is a very versatile procedure that may correct many different types of metatarsal derangements, including metatarsal primus elevatus or equinus, as well as short or elongated metatarsals. The procedure is easy to perform and stabilize with internal fixation. Lengthening is achievable, but not without a potential cost. Distraction of the distal fragment to its maximum capacity increased tension over the first metatarsophalangeal joint region significantly, decreasing dorsiflexion and plantarflexion range of motion by an average of 44.7% and 25.1% respectively. The maximal length obtained with acute lengthening of the first metatarsal was 8.80 mm, while average gain was 8.10 mm. There was a tremendous amount of tension to the first metatarsophalangeal joint after 6.00 mm of distraction. Banks[6] relates that one may create a symptomatic hallux limitus with this procedure. There are a couple of ways to overcome this problem. One is to plantarflex the distal fragment via a "swivel" of the osteotomy and the other is to perform an adjunctive cheilectomy of the first metatarsophalangeal joint. Soft tissue constraints definitely affect the amount of possible lengthening achieved.

There are other techniques that have been utilized to lengthen either a congenital or iatrogenic short metatarsal. Traditionally, a bone graft with plate fixation has been employed for this purpose. However, grafting may require another surgical procedure to harvest the graft, which may be associated with greater risks and morbidity.

More recently callous distraction techniques, popularized by Ilizarov[7] have been utilized to obtain length. Callous distraction does allow for a more "controlled" type of lengthening, which allows soft tissue structures to more readily adapt. However, it may also be associated with its own risks and complications such as pin tract infections and premature consolidation.[8] One may also see limitation of joint motion in spite of the slower rate of lengthening.

Limitations of this study include a small sample size and the use of freshly frozen cadavers, in which some demonstrated to have poor bone quality and inelastic soft tissue structures. In addition, in some patients where previous surgery has been performed there may be scar tissue, which may preclude this amount of lengthening. This study may also help the physician in procedural selection when it comes to the surgical technique required to correct a short metatarsal. From the results of this study it would appear that acute lengthening of the first metatarsal may be limited to approximately 8.80 mm.

The restriction of first metatarsophalangeal joint range of motion that was noted in this study may not fully or accurately reproduce the effects seen in clinical

settings, although experience with the procedure has demonstrated that there is some associated loss of mobility of the first metatarsophalangeal joint that can develop intraoperatively. However, there may be adaptive changes in the soft tissues during the postoperative interval, which may allow for greater motion than that noted at the time of surgery.

REFERENCES

1. Cicchinelli LD, Camasta CA, McGlamry ED. Iatrogenic metatarsus primus elevatus: etiology, evaluation and surgical management. *J Am Podiatr Med Assoc* 1997;87:165-77.
2. Chang TJ, Camasta CA. Hallux limitus and hallux rigidus. In Banks AS, Downey MS, Martin DE, Miller SJ, editors. McGlamry's comprehensive textbook of foot and ankle surgery. 3rd Edition. Baltimore: Lippincott Williams & Wilkins, 2001; p. 679-711.
3. Viegas GV. Reconstruction of hallux limitus deformity using a first metatarsal sagittal-Z osteotomy. J Foot Ankle Surg 1998;37:204-11.
4. Kissel CG, Mistretta RP, Unroe BJ. Cheilectomy, chondroplasty, and sagittal "Z" osteotomy: a preliminary report on an alternative joint preservation approach to hallux limitus. *J Foot Ankle Surg* 1995;34:312-8.
5. Chang TJ. The sagittal z osteotomy: a retrospective study. Presented at the 55th annual scientific meeting of the American College of Foot and Ankle Surgeons, New Orleans, 1996.
6. Banks AS. The sagittal-z osteotomy. In Vickers N, editor. *Reconstructive surgery of the foot and leg, Update '95.* Tucker (GA): Podiatry Institute; 1995. p. 192-5.
7. Ilizarov GA. The tension-stress effect on the genesis and growth of tissues. *Clin Orthop Rel Res* 1989;239:263-85.
8. Saxby T, Nunley JA. Metatarsal lengthening by distraction osteogenesis: a report of two cases. *Foot Ankle* 1992;13:536-9.