Lateralizing calcaneal osteotomy performed with a percutaneous burr results in a significantly lower increase in tarsal tunnel pressure

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Abstract

Background: Tarsal tunnel syndrome is well-documented following lateralizing calcaneal osteotomy to manage varus hindfoot deformity. Traditionally, calcaneal osteotomy is performed with an oscillating saw. No studies have investigated the effect of alternative surgical techniques on postoperative tarsal tunnel pressure. The purpose of this study was to investigate the difference in tarsal tunnel pressures following lateralizing calcaneal osteotomy performed using a high-torque, low-speed “Minimally Invasive Surgery” (MIS) Shannon burr versus an oscillating saw.

Methods: Lateralizing calcaneal osteotomy was performed on 10 below-knee cadaveric specimens. This was conducted on 5 specimens each using an oscillating saw (Saw group) or MIS burr (Burr group). The calcaneal tuberosity was translated 1 cm laterally and transfixed using 2 Kirschner wires. Tarsal tunnel pressure was measured before and after osteotomy via ultrasound-guided percutaneous needle barometer. Mean pre/post-osteotomy pressures were compared between groups. Differences were analyzed using Student’s t-test.

Results: The mean pre-procedure tarsal tunnel pressure was 25.8 mm Hg ± 5.1 mm Hg in the Saw group and 26.4 mm Hg ± 4.3 mm Hg in the Burr group (p=0.85). The mean post-procedure pressure was 63.4 ± 5.1 in the Saw group and 47.8 ± 4.3 in the Burr group (p=0.01). Change in tarsal tunnel pressure was significantly lower in the Burr group (21.4 ± 4.5) compared to the Saw group (37.6 ± 12.5) (p=0.03). The increase in tarsal tunnel pressure was 43% lower in the Burr group.

Keywords: Hindfoot; Calcaneus; Osteotomy; Tarsal tunnel; Deformi

INTRODUCTION

The tarsal tunnel is located at the lower medial hindfoot and contains the tendons of the Flexor Hallucis Longus (FHL), Flexor Digitorum Longus (FDL), and Tibialis Posterior (TP). The tarsal tunnel roof is composed of the flexor retinaculum which originates on the tibia and inserts into the medial calcaneal tuberosity. Within the tarsal tunnel the neurovascular bundle, composed of the tibial nerve and posterior tibial artery/vein, is bordered by the FDL anteriorly and the FHL posteriorly [1].

Calcaneal osteotomies are one of the primary surgical techniques for management of hindfoot deformity. Varus hindfoot deformities may be corrected using a lateralizing calcaneus osteotomy. During this, the calcaneal tuberosity is shifted laterally and the flexor retinaculum is effectively tightened, causing a narrowed space within the tarsal tunnel and increase in tarsal tunnel pressure [2]. Prior authors have shown that lateralizing calcaneal osteotomies reduce the volume of the tarsal tunnel, and thus may cause tibial nerve compression and tarsal tunnel syndrome. It has previously been demonstrated that inversion and eversion of the foot and ankle cause a decrease in the volume of the tarsal tunnel which subsequently results in an increase in the tarsal tunnel pressure; this increase in pressure contributes to tibial nerve entrapment and subsequent tarsal tunnel syndrome [2].

Tarsal tunnel syndrome was reported in 1960 by Kopell and Thompson, and was further described in 1962 by both Keck and Lam as a syndrome characterized by paresthesia and pain in the distribution of the tibial nerve [3-5]. Without appropriate management, sometimes requiring surgical decompression, the disease can progress and ultimately result in irreversible damage. The long-term sequala include sensory loss, muscle weakness, and muscle atrophy [4].

Halm *et al*. examined the change in pressure within the tarsal tunnel in relation to the degree of calcaneal tuberosity lateralization. They hypothesized that the pressure would change in accordance with increasing lateralization. Their cadaveric study demonstrated increasing pressures within the tarsal tunnel occurred with increasing lateralization of the tuberosity; the highest pressures occurred with the greatest magnitude of lateralization, which was 12 mm. Additionally, they demonstrated that flexor retinaculum release significantly lowered the pressures within the tarsal tunnel at all degrees of lateralization [6].

Traditionally, calcaneal osteotomy is performed using an oscillating saw. However, the use of a Shannon or Minimally Invasive Surgery (MIS) burr to perform minimally invasive osteotomies of the calcaneus has been growing in popularity. Guyton discussed that minimally invasive calcaneal osteotomies offer excellent mechanical correction with reliable union rates, and was associated with outcomes that are equivalent, if not superior, to open procedures with regards to safety and reliability [7]. No prior study has investigated the effect of alternative surgical techniques on postoperative tarsal tunnel pressure and the subsequent risk of tarsal tunnel syndrome following lateralizing calcaneal osteotomy. The purpose of this study was to investigate the difference in post-procedure tarsal tunnel pressures following lateralizing calcaneal osteotomy performed with an oscillating saw versus a MIS burr.

MATERIALS AND METHODS

Study procedures were conducted in a cadaveric lab using 10 fresh-frozen, below-knee specimens. Investigations were conducted by three physicians: a foot and ankle fellowship-trained Orthopaedic Surgeon, an orthopaedic surgery resident physician, and a Physical Medicine and Rehabilitation physician. Calcaneal osteotomies were performed either by the Orthopaedic Surgeon or by the Orthopaedic Surgery resident physician, under direct supervision of the Orthopaedic Surgeon. Tarsal tunnel pressure measurements were performed by the Physical Medicine and Rehabilitation physician, who has significant experience with ultrasound guided pressure measurement acquisition utilized for exertional compartment syndrome.

Lateral-to-medial, single-plane calcaneal osteotomies via a lateral approach were performed on the 10 below-knee cadaveric specimens. Osteotomies were performed on 5 specimens using an oscillating saw (Saw Group) and 5 specimens using a 3 mm straight tip MIS burr (Burr Group). The calcaneal tuberosity was translated 1 cm laterally in all specimens and then transfixed using 2 Kirschner wires. The translational measurement was confirmed using direct visualization utilizing a metal ruler measuring from the remnant calcaneus and the posterior tuberosity cortical bone. The Burr group also had a lateral approach utilized to visually ensure translation was 1 cm. Tarsal tunnel pressure measurements were collected both before and after osteotomy using a needle barometer (Intra-Compartmental Pressure Monitor System, Stryker, Mahwah, NJ) under ultrasound guidance (Figure 1). The tarsal tunnel pressure was measured along the medial calcaneal wall from within the quadratus plantae muscle belly just inferior to the FHL tendon sheath. The quadratus plantae belly was required to identify the maximum pressure measurement as needle placement otherwise within the extramuscular tarsal tunnel space allowed for fluid extravasation during trialing; thus, the quadratus plantae belly was used. This is similar to what is known about technique to perform compartment syndrome pressure measurement acquisition [8]. This was performed with percutaneous technique utilizing ultrasound guidance.

Mean pre-osteotomy, post-osteotomy, and the percent change of tarsal tunnel pressures were compared between groups. Differences were analyzed using Student's t-test. Mean percent change in pre- and post-osteotomy tarsal tunnel pressure in each group was defined as the difference in the mean post-osteotomy and mean pre-osteotomy tarsal tunnel pressures divided by the mean pre-osteotomy tarsal tunnel pressure. Statistical analyses were performed with STATA software version 14 (STATACorp, College Station, Texas). Statistical significance was defined as $p<0.05$.

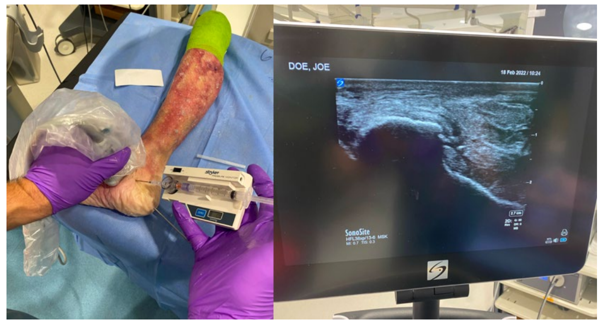

Fig. 1. Post-osteotomy tarsal tunnel pressure measurement performed under ultrasound guidance using needle barometer. Measurements performed by consultant Physical Medicine and Rehabilitation physician

RESULTS

There were 5 specimens in the Saw Group and 5 in the Burr Group. The pre- and post-osteotomy tarsal tunnel pressures in each below-knee cadaveric specimen are described in (Table 1). Mean pre-osteotomy tarsal tunnel pressure in the Saw Group were 25.8 mm Hg ± 5.1 mm Hg versus 26.4 mm Hg ± 4.3 mm Hg in the Burr Group. There was no statistical difference in the pre-osteotomy tarsal tunnel pressure between groups ($p=0.85$). The mean post-osteotomy tarsal tunnel pressure was 63.4 mm Hg ± 9.5 mm Hg in the Saw Group versus 47.8 mm Hg ± 4.3 mm Hg in the Burr Group. This difference was statistically significant ($p=0.01$). Additionally, the increase in tarsal tunnel pressure after lateralizing calcaneal osteotomy was significantly lower in the Burr Group (21.4 ± 4.5) compared to the Saw Group (37.6 ± 9.5) ($p=0.03$) (Table 2). In the Saw Group, there was a 146% increase in tarsal tunnel pressure after calcaneal osteotomy versus an 81% increase in the Burr group. The mean percent increase in tarsal tunnel pressure was 43% lower in the Burr Group compared to the Saw Group.

Table 1. Tarsal tunnel pressures in cadaveric specimens

Group	Pre-Osteotomy Tarsal Tunnel Pressure (mmHg)	Post-Osteotomy Tarsal Tunnel Pressure (mm Hg)	Change in Tarsal Tunnel Pressure (mm Hg)
Saw group	20	56	36
	33	54	21
	27	63	36
	22	78	56
	27	66	39
Burr	27	46	19

Group	22	50	28
	33	54	21
	23	46	23
	27	43	16

Table 2. Mean tarsal tunnel pressure before and after Lateralizing Calcaneal Osteotomy

	Saw Group	Burr Group	p-value
Mean Pressure Pre-Osteotomy (mm Hg)	25.8 ± 9.5	26.4 ± 4.3	0.85
Mean Pressure Post-Osteotomy (mm Hg)	63.4 ± 5.1	47.8 ± 4.3	0.01
Mean Change In Pressure (mm Hg)	37.6 ± 12.5	21.4 ± 4.5	0.03

DISCUSSION

In this study, the effect on tarsal tunnel pressure differences following lateralizing calcaneal osteotomy using either an oscillating saw or a minimally invasive burr were investigated. While lateralizing calcaneal osteotomies have routinely been performed with an oscillating saw, the use of a minimally invasive approach with a burr has been reported to be effective for hindfoot correction and was associated with fewer wound and nerve complications [9]. No prior study has evaluated tarsal tunnel pressure differences with respect to the use of an oscillating saw versus a MIS burr. Our study showed that both the absolute and percent increases in tarsal tunnel pressure were significantly lower when the calcaneal osteotomy was performed with a burr compared to an oscillating saw (Table 2).

Lateral, but not medial, calcaneal osteotomies may result in significant reduction of tarsal tunnel volume and an increase in tarsal tunnel pressure [10]. Furthermore, it is well documented that a lateralizing calcaneal osteotomy may result in a tibial nerve palsy [11-14]. Van Valkenburg *et al*. performed a retrospective review on 80 feet in 72 patients who underwent a lateralizing calcaneal osteotomy using a saw and found a 34% incidence in neurologic deficit [11]. Walls *et al*. presented a case report of acute tarsal tunnel syndrome following a lateralizing calcaneal osteotomy with use of a sagittal saw, which they attributed to scarring of soft tissues causing tethering of the tibial nerve within the tarsal tunnel despite accounting for a reduction in the tarsal tunnel volume [13]. However, the association between tibial nerve palsy and the use of a minimally invasive burr when performing lateralizing calcaneal osteotomies has not been evaluated in the literature. There is also a lack of knowledge as to how tarsal tunnel pressure is affected by the use of a MIS Shannon burr. To our knowledge, this is the first study to compare the tarsal tunnel pressures following calcaneal osteotomy performed using an oscillating saw versus a MIS burr.

Our study found that tarsal tunnel pressure following lateralizing calcaneal osteotomy was 47.8 mm Hg ± 4.3 mm Hg in the Burr group versus 63.4 mm Hg ± 5.1 mm Hg in the Saw group (p=0.01). This significant difference is promising and suggests that performing a lateralizing calcaneal osteotomy with a MIS burr may be associated with a lower incidence of tarsal tunnel syndrome in vivo. However, the minimum pressure threshold at which tarsal tunnel syndrome will develop is not currently known. There is no known “clinically important difference” value for tarsal tunnel pressure. Patients may be predisposed to developing tarsal tunnel syndrome with the associated potential sequelae of tibial nerve branch palsy with either osteotomy technique, and the clinician must use their judgment regarding the benefits and risks of performing a tarsal tunnel release at the time of lateral sliding calcaneal osteotomy. Future prospective in vivo studies should be performed to confirm the potential benefits of performing hindfoot correction using a MIS burr[15].

The pressures within the tarsal tunnel have been studied and documented previously both inside and outside the context of lateralizing calcaneal osteotomies. Pressures have been reported at 3.5 mm Hg in neutral position (NP) of the ankle, 8.8 mm Hg in Dorsiflexion (DF), and 17 mmHg in Plantarflexion (PF) in cadaveric models.15 Additionally, in intra-operative assessment,
measurements have been reported at 4 mm Hg for NP, 4 mm Hg in DF, and 13 mm Hg in PF [16]. However, despite multiple studies examining these variable pressures, the pressure threshold for symptoms of tarsal

tunnel syndrome has not been reliably reproduced. Similarly, there is a paucity of literature on the incidence of tarsal tunnel syndrome following lateralizing osteotomies of the calcaneal tuberosity. A retrospective review by Van Valkenburg *et al*. reported a 34% incidence of tibial nerve neurological deficits, with over half of these resolving within 3 months [11]. In contrast, there have been also reports of no neurological deficits following the procedure [12]. Ultimately, Halm *et al*. concluded in their biomechanical cadaveric study that the risk of tarsal tunnel syndrome should be strongly considered if lateralization exceeds 8 mm [6].

The use of an MIS Shannon Burr is gaining popularity as an alternative for performing calcaneal osteotomies. Durston *et al*. performed a cadaveric study with 13 specimens to evaluate if the use of a MIS Burr poses a risk to the medial and lateral neurovascular structures [17]. It was demonstrated that, in two specimens, two small proximal branches of the sural nerve were transected but otherwise there was no significant neurovascularly injury. Similarly, Kendal *et al*. performed calcaneal osteotomies on 81 patients, with 50 being through an open approach with a saw and 31 through a minimally invasive approach with a burr. They found that three patients experienced sural nerve neuropathy in the open group compared to zero in the minimally invasive group [9]. There is some concern that the MIS Burr technique may result in delayed union or nonunion; Coleman *et al*. examined outcomes of medializing calcaneal osteotomies using an MIS burr technique, and reported that during the study period there was a 1 year timeframe in which the incidence of nonunion after MIS burr calcaneal osteotomy was 28%. In contrast, during the initial 3 year period of that study, the incidence of nonunion after MIS burr calcaneal osteotomy was 0.5%.18 This disparity in outcomes during different time periods of the Coleman *et al*. study, coupled with the dearth of further published data in the literature, demonstrates that there is not yet a comprehensive consensus on the safety of MIS burr technique for calcaneal osteotomy; this is an area under active investigation by other authors [18].

Several limitations exist in this study. The cadaveric nature of the study could have resulted in measurement biases compared to measurements in live patients. Additionally, cadaveric specimens were randomly assigned to either the Saw Group or the Burr Group, but there may have been anatomic variations and pathologies within the individual specimens that were not accounted for; this may have skewed our results. The method to which tarsal tunnel pressure measurements has been performed is variable throughout the literature. We selected ultrasound guided needle-pressure measurements because of the familiarity of our study group with this procedure and reproducibility of the results. However, ultrasound guided procedures are technique and user-dependent, and thus this is a limitation of our study. The location of specific tarsal tunnel pressure measurement was selected because it was easy to identify within the tarsal tunnel with ultrasonography, and it provided a reproducible target for intramuscular fluid infusion. Procedural technique was thus as close as possible to what is performed with exertional compartment pressure measurement acquisition. The similarity of pre-osteotomy pressures between the two groups, and similarity in expected results makes this less likely, however. Lastly, the small sample size of 10 specimens may influence the generalizability of these findings.

CONCLUSION

Overall, we demonstrated that there is a significantly lower increase in the tarsal tunnel pressure after lateralizing calcaneal osteotomy using an MIS burr versus using an oscillating saw. The risk of tarsal tunnel syndrome and permanent neurological deficit following lateralizing calcaneal osteotomy is established, and the results of this study suggest that use of an MIS burr may decrease the incidence of these complications. However, further in vivo studies are necessary to establish this definitively. Future investigations in vivo are critical because the results could significantly impact practice management and prevent patients from inadvertently developing postoperative tarsal tunnel syndrome.

REFERENCES

1. Lau JT, Daniels TR. Tarsal tunnel syndrome: a review of the literature. Foot Ankle Int. 1999;20(3):201-9.
2. Bracilovic A, Nihal A, Houston VL, et al. Effect of foot and ankle position on tarsal tunnel compartment volume. Foot Ankle Int. 2006;27(6):431-37.
3. Taguchi Y, Nosaka K, Yasuda K, et al.The tarsal tunnel syndrome: report of two cases of unusual cause. Clin. Orthop. Relat. Res.1987;217:247 -52.
4. Kopell HP, Thompson WA. Peripheral entrapment neuropathies of the lower extremity. N Engl J Med. 1960 14;262(2):56-60.
5. Lam SJ. A tarsal-tunnel syndrome. The Lancet. 1962 29;280(7270):1354-5.
6. Halm S, Fairhurst PG, Tschanz S, et al. Effect of lateral sliding calcaneus osteotomy on tarsal tunnel pressure. Foot Ankle Orthop. 2020;5(3).
7. Guyton GP. Minimally invasive osteotomies of the calcaneus. Foot Ankle Clin. 2016;21(3):551-66.
8. Novak M, Penhaker M, Raska P, et al. Extremity compartment syndrome: A review with a focus on non-invasive methods of diagnosis. Front Bioeng Biotechnol. 2022;10:801586.
9. Kendal AR, Khalid A, Ball T, et al. Complications of minimally invasive calcaneal osteotomy versus open osteotomy. Foot Ankle Int. 2015;36(6):685-90.
10. Bruce BG, Bariteau JT, Evangelista PE, et al. The effect of medial and lateral calcaneal osteotomies on the tarsal tunnel. Foot Ankle Int. 2014;35(4):383-88.
11. VanValkenburg S, Hsu RY, Palmer DS, et al. Neurologic deficit associated with lateralizing calcaneal osteotomy for cavovarus foot correction. Foot Ankle Int. 2016;37(10):1106-12.
12. Jaffe D, Vier D, Kane J, et al. Rate of neurologic injury following lateralizing calcaneal osteotomy performed through a medial approach. Foot Ankle Int. 2017;38(12):1367-73.
13. Walls RJ, Chan JY, Ellis SJ. A case of acute tarsal tunnel syndrome following lateralizing calcaneal osteotomy. Foot Ankle Surg. 2015;21(1):1-5.
14. González-Martín D, Herrera-Pérez M, Ojeda-Jiménez J, et al. Neurological injuries after calcaneal osteotomies are underdiagnosed. J Clin Med. 2021;10(14):3139.
15. Barker AR, Rosson GD, Dellon AL. Pressure changes in the medial and lateral plantar and tarsal tunnels related to ankle position: a cadaver study. Foot Ankle Int. 2007;28(2):250-54.
16. Rosson GD, Larson AR, Williams EH, et al. Tibial nerve decompression in patients with tarsal tunnel syndrome: pressures in the tarsal, medial plantar, and lateral plantar tunnels. Plast Reconstr Surg. 2009;124(4):1202-10.
17. Durston A, Bahoo R, Kadambande S, et al. Minimally invasive calcaneal osteotomy: does the Shannon burr endanger the neurovascular structures? A cadaveric study. J Foot Ankle Surg. 2015;54(6):1062-66.
18. Coleman MM, Abousayed MM, Thompson JM, et al. Risk factors for complications associated with minimally invasive medial displacement calcaneal osteotomy. Foot Ankle Int. 2021;42(2):121-31.