# Compression Staples for Transverse Metaphyseal First Metatarsal Base Wedge Osteotomy

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## INTRODUCTION

Hallux abducto valgus is a common lower extremity pathology that presents with symptoms of pain and discomfort. Without proper treatment, it can lead to more detrimental deformities such as overlapping digits, hallux dislocation, and ulceration. When pain persists after thoroughly exhausting conservative treatments, surgical intervention becomes a viable option that can lead to relief of both pain and physical deformity (1).

There are several surgical procedures that have been discussed in the literature that acknowledge the physical deformity and symptoms in a hallux valgus deformity. There are a myriad of options, ranging from soft tissue (2) to osseous procedures at different locations of the metatarsal. Mann et al observed that performing a distal soft-tissue procedure alone led to a persisting abnormally increased intermetatarsal angle (3). Despite narrowing it down to metatarsal osteotomies, the severity of the deformity often dictates the ideal location of the osteotomy site (1). While distal metatarsal osteotomies can successfully correct mild hallux valgus deformities, more progressive deformities with a moderate to severe intermetatarsal angle greater than 15 degrees may require a proximal metatarsal osteotomy or a first metatarsal cuneiform arthrodesis (4).

Deciding between an osteotomy and an arthrodesis is a process that requires patient education and understanding. A proximal first metatarsal osteotomy is the preferred option for patients who want to avoid the commitment of sacrificing a joint (5). Lack of osteoarthritis or hypermobility in the first metatarsal cuneiform joint proves difficult for some to justify destruction of the joint. However, in contrast, the first metatarsal cuneiform joint was described by Hansen as an “unnecessary joint” (6). As with fusion of any other joint, arthrodesis of the first metatarsal cuneiform joint can result in a transfer of motion to adjacent joints, which can lead to osteoarthritis of these adjacent joints over time. In 2008, Lagaay compared the success of these two procedures and determined that their revision rates were not statistically significant, with an 8.82% revision rate for the closing base wedge osteotomy and an 8.19% in the Lapidus procedure (7).

The closing base wedge osteotomy is an inherently stable osteotomy (8). It was first introduced in 1901 by Loison as a transverse metaphyseal osteotomy (9). The initial closing base wedge osteotomies were not internally fixated, but instead relied on the transverse orientation of the osteotomy and the medial hinge for stability. Christansen et al concluded that osteotomies of the proximal aspect of the first metatarsal base demonstrated superior stiffness when done with an intact hinge, as compared to osteotomies without a hinge (10). With the advance of internal fixation, Juvara modified the osteotomy in 1919 to an oblique osteotomy to allow for a single compression screw to be placed (11). In 1977, the Podiatry Institute introduced a long-arm oblique osteotomy to allow for 2 screws to be placed across the osteotomy site (12,13). However, with the transition from the transverse to an oblique osteotomy, the osteotomy was no longer within the metaphyseal portion of the first metatarsal.

The significance of the osteotomy occurring in the metaphyseal or diaphyseal bone is a result of the difference in the healing capacity of these types of bones. Diaphyseal bone marrow contains more fat, while metaphyseal bone consists of mesenchymal stem cells, allowing new bone formation (14). Fractures that occur in the diaphysis heal through a process that begins with inflammation and endochondral bone formation, also known as a bone callus (15). From there, soft bone forms and is transformed to hard bone over time. In contrast, metaphyseal bone fractures heal with stronger new bone formation (16). In addition, metaphyseal bone has the advantage of an extensive web of metaphyseal arteries to supply the new bone formation while diaphyseal bone often relies on a single nutrient artery (17). As a result, a transverse closing base wedge with the osteotomy exclusively in the metaphyseal aspect of the first metatarsal is expected to heal faster than the longer oblique osteotomy that is partially located in the diaphysis of the long bone (Figure 1).

As seen in the initial introduction of the closing base wedge osteotomy, a transverse osteotomy does not allow any room for ideal screw fixation. The use of staples in foot and ankle surgery is not uncommon, as it is used in procedures including epiphysiodesis, Akin procedures, and even tarsometatarsal joint fusions (18-20). However, discussion of its use in first metatarsal proximal base procedures is scarce. Numerous studies in the past have compared different fixation techniques for proximal bunionectomies

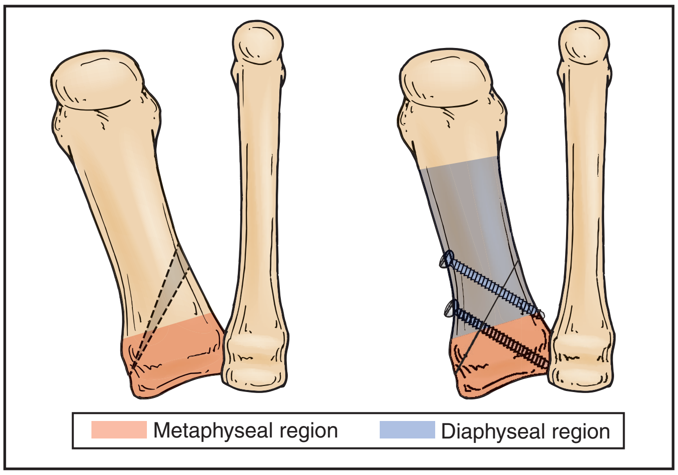


Figure 1.

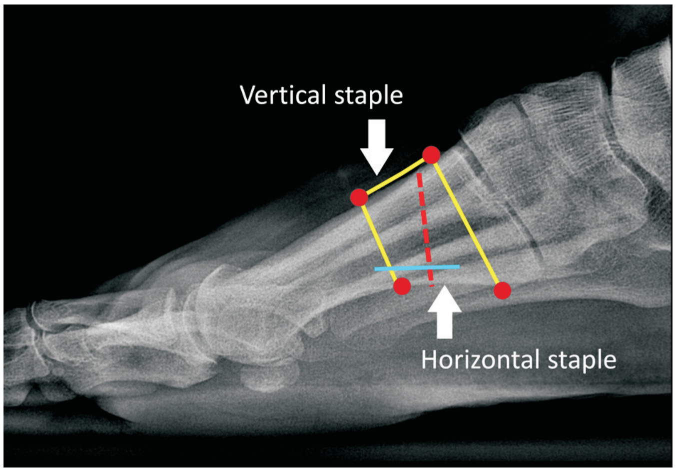


Figure 2.

(21). These include fixation options such as plates, single and double screws, and Kirschner wires (K-wires) (21). Staples are a dynamic source of internal fixation that can function in several ways, by altering its application (22). When placed on the tension side of an osteotomy, it can prevent any gapping or distraction and instead convert that force into compression.

In this study, we investigated the dimensions of the first metatarsal to be able to determine ideal staple lengths for fixating first metatarsal osteotomies. We propose that by applying staples to a closing base wedge osteotomy with a transverse cut, placing one dorsal-lateral to plantar-lateral and one plantar-medial to plantar-lateral, we can employ the tension band effect to prevent the distractive forces on the plantar aspect of the metatarsal and provide compression throughout. By doing this, we would be able to correct severe hallux abducto valgus deformities with high intermetatarsal angles (IMAs) with a proximal metatarsal base wedge osteotomy, a stable surgical option that allows for early weight-bearing.


Figure 3.

## METHODS

We retrospectively reviewed 504 weight-bearing plain film radiographs of the lower extremity obtained from 2014-2016 from a private practice group. Radiographs were excluded if there was a history of any soft tissue or osseous surgeries to the foot or ankle, trauma, or if the patient was younger than 18 years old. The following dimensions were recorded from the lateral view: dorsal to plantar depth of metatarsal 1 cm from the joint at the proposed location of the proximal staple arm, and dorsal to plantar depth of the joint at the level of the distal staple arm. On the dorsal-plantar view we measured the medial to lateral length of the metatarsal approximately 1 cm from the first metatarsocuneiform (MC) joint and the medial to lateral length of the metatarsal 2.5 cm from the first MC joint (Figures 2, 3).

From the results of the initial phase of the study described above, we worked with a medical device company to create staples that fit the dimensions of base of the first metatarsal where we propose the staples to be placed. We simulated a transverse base wedge osteotomy on cadaver limbs to investigate the strength of the staples when used in this type of osteotomy. The construct's load to failure was measured and compared to the same osteotomy, which was fixated with alternative forms of fixation, such as screws and plates.

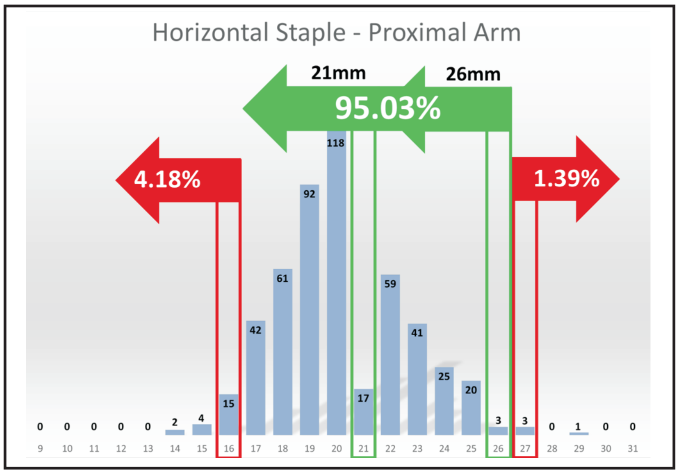


Figure 4.

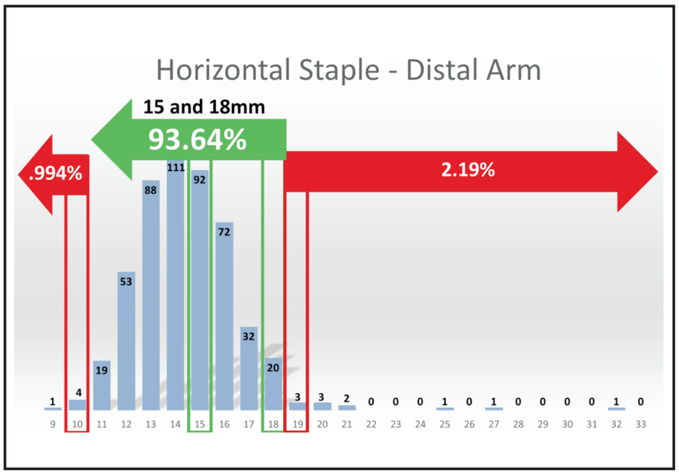


Figure 5.

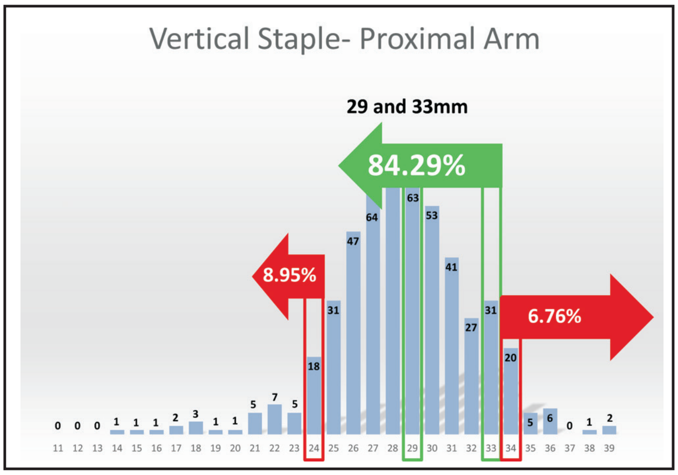


Figure 6.

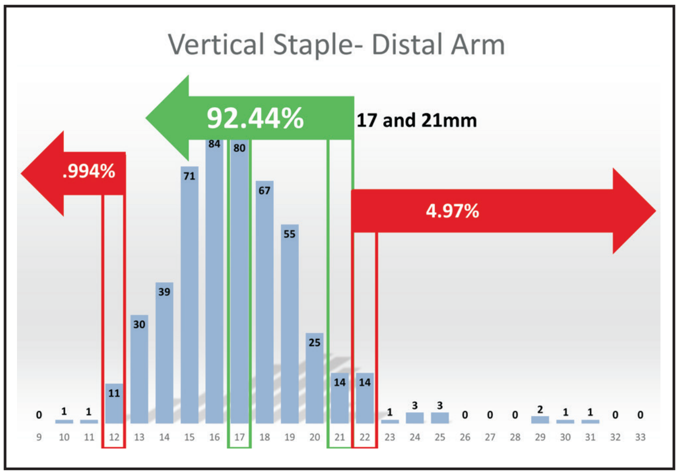


Figure 7.

## RESULTS

The resulting lengths of the 4 staple legs varied immensely between the measurements recorded. This indicated the need for a staple with varying lengths of the proximal and distal legs. For the values taken from the dorsal-plantar view of measurements intended for the proximal arm of the horizontal staple directed plantar medial to plantar laterally, 95.03% of all subjects were within 4 mm less than the measurements 21 mm and 26 mm. As for the distal arm of same horizontal, 93.64% of the subjects were within 4 mm less than of 15 mm and 18 mm (Figures 4-7).

When looking at the lateral view, the lengths of the vertical staple oriented dorsal-lateral to plantar-lateral can be determined. In the measured population, 84.29% of all subjects fall within 4 mm less than the measurements of 29 mm and 33 mm. As for the distal arm, 92.45% of the subjects fall within 4 mm of 17 mm and 21 mm. A small sample of the reviewed population was taken to determine the average angle required, which was found to be 10 degrees from the perpendicular. As a result, we have determined that by using 2 staple sizes for the vertical staples with proximal and distal legs measuring 21 and 33 mm, and 17 and 29 mm, respectively, we are able to provide compression for a significant amount of the population. As for the horizontal staple, the two staple sizes with proximal and distal legs measuring 26 and 18 mm, and 21 and 15 mm, adequate compression will be provided to a significant amount of the population

## DISCUSSION

There are several stable surgical options to choose from when attempting to correct hallux abducto valgus. There are even more options to choose the fixation when doing these procedures. When correcting a severe hallux abducto valgus deformity with a high IMA, often, the proposed procedures require a prolonged period of time prior to weight-bearing. In addition to serving as a deterrent to many patients, it is also a concern for those who may not be able to perform their activities of daily living without being able to bear weight. With the procedure discussed, (the closing base wedge osteotomy with a transverse osteotomy fixated with 2 staples, one dorsal and one medially), hallux abducto valgus deformities with severe IMAs may be a stable method of fixation and allow the convenience of early weight-bearing. When looking at the staples available today, they are not optimized to fit the measurement requirements of this proposed osteotomy. Further research can be done to look at the load to failure of this proposed method of fixation.

The closing base wedge osteotomy was initially described in 1901 as a transverse osteotomy and has evolved into an oblique osteotomy to allow for 2-screw fixation. By reverting back to a transverse osteotomy and preoperatively measuring the first metatarsal base to use staples with a bridge angulated at 99 degrees, early weight-bearing is an option after correction of severe or rigid bunion deformities. Further studies should investigate the load-to-failure, plantar gapping and stiffness of 2 staples compared to 2-screw fixation.

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