The Integrity of the First Metatarsal Head Vascularization and Soft-Tissue Envelope following Minimally Invasive Chevron Osteotomy for Hallux Valgus (HV) Deformity. A Micro-CT and Anatomical Assessment

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INTRODUCTION:

Minimally invasive surgery (MIS) Chevron osteotomy for Hallux Valgus (HV) treatment offers a surgical alternative to open surgery with minimal surgical dissection and a hypothetical decreased risk for soft-tissue complications. During this procedure, there is a concern regarding the injury to the blood supply of the first metatarsal head. The objective of this study was to assess the incidence of injuries: 1) to the soft-tissue envelope around the first metatarsal head complex and, 2) to the blood supply of the first metatarsal head and also by using Micro-CT, 3) looking for safe zones close to the first metatarsal head to perform MIS Chevron osteotomy. We hypothesized that the MIS Chevron osteotomy procedure would preserve the soft-tissue envelope of the first metatarsal head complex and the blood supply of the first metatarsal head.

METHODS:

Twenty HV deformity cadaveric specimens were used to perform MIS Chevron osteotomy of the first metatarsal head.

Specimen Preparation for Anatomic Study

The specimens were frozen at –20 °C, then thawed at room temperature for 24 hours. After completing the MIS Chevron osteotomy surgical procedure, all specimens were dissected by the same surgeon.

Anatomical dissection of all specimens was then performed to assess macroscopic injury to the first metatarsal head complex soft-tissue structures, including Extensor Hallucis Longus (EHL) tendon, Extensor Hallucis Brevis (EHB) tendon, Flexor Hallucis Longus (FHL) tendon, Flexor Hallucis Brevis (FHB) tendon, Abductor Hallucis tendon, Adductor Hallucis tendon, Sesamoid complex, Dorsomedial and Dorsolateral nerves of the first toe, the Dorsomedial nerve of the second toe, and Medial branch of the dorsomedial nerve of the first toe. The blood supply of the First Metatarsal Head was assessed macroscopically by the First Dorsal Metatarsal Artery (FDMA), Lateral Dorsal Branch of FDMA, and Plantar Metatarsal Artery.

Macroscopic injuries were classified using a calibrated digital caliper. Any chondral damage to the first metatarsal head was quantified in mm^2.

Specimen Preparation for Imaging

For the imaging study, seven fresh frozen specimens were used. The anterior and posterior tibial arteries were identified and cannulated with a 16-gauge catheter. The arteries were perfused under a physiologic firm manual pressure with 50 ml of heparinized saline and then 50 ml of formalin, followed by another 50 ml of heparinized saline, until the effluence from the saphenous vein and intramedullary canals of the cut bone was clear.

To assess the amount of first metatarsal head blood supply, specimens were preoperatively perfused with 200 ml of a low viscosity radiopaque polymer preoperatively. All leaks were sealed with 3-0 suture or clamps, and the polymer was allowed to be set for 24 hours in a 4°C refrigerator.

After that, we performed a transverse osteotomy of the foot at the level of the medial cuneiform bone and a longitudinal osteotomy between the second and the third metatarsal bone to fit the specimen in the Micro-CT machine.

Micro Computed Tomographic Image Analysis

Specimens containing the first metatarsal head were scanned at a 24 µm/voxel resolution using a benchtop scanner. An X-ray microscope was used in the study to assess the blood supply to the first metatarsal head.

Three-dimensional and two-dimensional CT images of the first metatarsal were used for volume analysis of the vasculature along the first metatarsal head using sophisticated software.

Extraosseous and intraosseous vascularity was assessed and incorporated into a three-dimensional rendering. Descriptive statistics and percentages were utilized for categorical data.

RESULTS:

We did not find injuries in the EHL, EHB, FHL, Abductor Hallucis, or Adductor Hallucis tendons. We found a 2mm injury in the FHB tendon in one specimen.

No injuries were found in the Dorsomedial and Dorsolateral nerves of the first toe, the Dorsomedial nerve of the second toe, and the Medial branch of the dorsomedial nerve of the first toe. In 3 cases, we found an injury on the first metatarsal head (1mm) due to the passage of the K-wire and, in 1 case, due to the inadvertent passage of the drill (4.41mm).

Macroscopically and using Micro-CT, we did not observe injuries in the First Dorsal Metatarsal Artery (FDMA), Lateral Dorsal Branch of FDMA, and Plantar Metatarsal Artery.

Micro-CT helped estimate a safe distance to finish the proximal exit of Chevron osteotomy (25mm from the most distal point of the first metatarsal head).

DISCUSSION AND CONCLUSION:

In this study, the minimally invasive Chevron osteotomy for treating HV seems to be a technically safe procedure, presenting a low rate of iatrogenic injuries with a low degree of severity.

In addition, using Micro-CT promoted a better visualization of the microvasculature that nourishes the first metatarsal head.

A proximal distance of 25 mm from the most distal part of the first metatarsal head could be a safe place to finalize the Chevron osteotomy, minimizing the risk of injury to the blood supply of the first metatarsal head.

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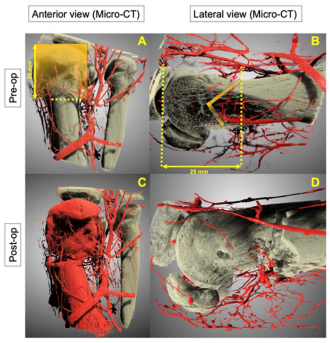

Figure 1. Blood Supply Micro-CT assessment. Pre-op (A) Vascular dorsal plexus of first metatarsal head (yellow square), **(B)** Estimate a safe distance to finish the proximal exit of Chevron osteotomy (25mm from the most distal point of the first metatarsal head), **Post-op:** Chevron osteotomy performed in a safe position, **(A) Anterior view:** Preserving vascular dorsal plexus of first metatarsal head, **(B) Lateral view:** Preserving vascular dorsal and plantar plexus of first metatarsal head.

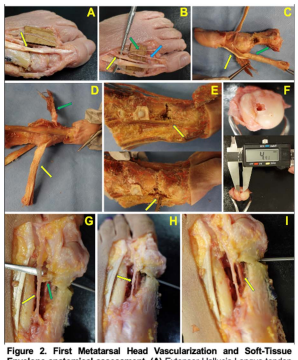

Figure 2. First Metatarsal Head Vascularization and Soft-Tissue Envelope anatomical assessment. (A) Extensor Hallucis Longus tendon (yellow arrow), **(B)** Extensor Hallucis Brevis tendon (yellow arrow), Dorsolateral nerve of the first toe (blue arrow), Dorsomedial nerve of the second toe (green arrow), **(C)** Flexor Hallucis Longus tendon (yellow arrow), Flexor Hallucis Brevis tendon (green arrow), **(D) Plantar view:** Abductor Hallucis tendon (yellow arrow), Adductor Hallucis tendon (green arrow), **(E)** Injured Flexor Hallucis Brevis tendon (yellow arrow), **(F)** Injured First Metatarsal Head cartilage, **(G)** First Dorsal Metatarsal Artery (FDMA) (yellow arrow), Lateral Dorsal-Branch of FDMA (green arrow), **(H)** FDMA (yellow arrow), **(I)** Plantar-Metatarsal Artery (yellow arrow).