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Evaluation of first metatarsal head declination through a modified distal osteotomy in hallux rigidus surgery. A cadaveric model

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ABSTRACT

Background: First metatarsal osteotomies have been described for treatment of hallux rigidus. Most of these techniques result in declination of the first metatarsal head through shortening of the metatarsal and transfer metatarsalgia may result.

Our objective was to evaluate the declination effect of a distal metatarsal osteotomy when different angulations and lateral translations are applied.

Materials and methods: A cadaveric study was conducted performing a modified distal oblique osteotomy, which produces head declination while limiting shortening. Several transverse inclination angles (0–10–20–30–40°) were used. Thereafter, plantar translation of the metatarsal head was registered at different lateral displacements (1, 3, 5 mm).

Results: Twenty-two specimens were included. Three feet were operated on with a 0° of angulation in the transverse plane, 6 with 10°, 5 with 20°, 5 with 30°, and 3 with 40°. Head declination significantly increased with higher angulation and with greater lateral translations ($p < 0.001$), but the interrelationship between these two variables did not achieve statistical significance ($p = 0.597$).

In regards to angulation, significant differences in head declination were found between 0° (0.1–0.7 mm), 10°–20° (0.5–1.2 mm) and 30°–40° (1.3–2.4 mm). The metatarsal sesamoid joint was compromised when the osteotomy was performed at a 40° inclination angle.

Conclusions: Metatarsal head declination is determined by the inclination angle of the oblique limb of the osteotomy and lateral displacement of the metatarsal head. Our results suggest that the effect of lateral displacement is an independent factor from angulation.

The latter may impact surgery planning and may improve clinical outcome by selecting a safer inclination angle when lateral displacement of the metatarsal head is being considered.

Level of evidence: Level II-A, systematic review with homogeneity of cohort studies.

1. Introduction

The hallux rigidus or limitus is the second most frequent forefoot pathology, overtaken only by hallux valgus [1]. Although etiology and biomechanics of this problem remain poorly understood, reports performing osteotomies on the first metatarsal that pursue declination of the metatarsal head have demonstrated satisfactory functional outcomes [2,3]. However, the precise declination produced by the osteotomy continues to be subjectively estimated, primarily due to the scant objective parameters to quantify it.

A myriad of first metatarsal osteotomies have been described to treat hallux rigidus [1,2,4–10]. All of these osteotomies attempt to relocate the head of the first metatarsal in the center of the proximal phalanx of the hallux. Relocation is obtained through declination of an abnormally elevated metatarsal head and thus improving dorsiflexion of the first metatarsophalangeal joint [7]. However, this biomechanical advantage is achieved through shortening of the metatarsal length and therefore,

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the consequent risk of central metatarsalgia needs to be considered. This risk is especially true in the index minus forefoot pattern.

To address the resultant metatarsal shortening, a modification of these distal metatarsal osteotomies has been proposed [11]. In order to efficiently decline the metatarsal head while controlling metatarsal length, an oblique osteotomy in both transverse and sagittal plane can be performed. This action yields lowering by means of a lateral translation of the metatarsal head. A dorsal vertical cut is associated to restrict shortening and prevent rotation. Therefore, a tridimensional correction of the deformity attempts to improve biomechanical conditions, range of motion and to decrease patient's symptoms.

The objective of this study is to evaluate, in a cadaveric model, the declination of the first metatarsal head when different osteotomy inclination angles and lateral translations of a modified distal oblique osteotomy are applied.

2. Materials and methods

Twenty-six fresh frozen specimens corresponding to the distal third of the tibia, ankle and foot were donated from the Human Anatomy Department. Donor's clinical information was not available for the investigators.

Exclusion criteria included: specimens with congenital or acquired deformities of the first ray or first metatarsophalangeal joint (one foot with evidence of Brandes–Keller–Lelièvre arthroplasty), inadequate bone quality preventing stable fixation of the osteotomy or precise measurement determination (2 ft); and intraoperative metatarsal fracture during osteotomy performance (one foot). Consequently, twenty-two specimens conformed the study group.

2.1. Surgical technique

A medial approach centered over the metatarsophalangeal joint was extended from 2 centimeters distal to the joint line to 3 cm proximal. After performing a longitudinal capsulotomy, the medial and central insertion of the plantar fascia as well as the flexor hallucis brevis insertion were then released.

Plantar vessels that irrigate the first metatarsal head were identified. A minimal bunionectomy was performed and 1.8 mm K-wire was driven into the center of the metatarsal head, parallel to plantar cortex of the first ray. This wire was used as a guide for all measurements. The perpendicular distance from this wire to the dorsal cortex of the first metatarsal head was measured with a Vernier's caliper (zero reading + 0.05 mm) and registered as X1 value (Figs. 1 and 2A).

Osteotomy's starting site was marked at 10 mm from the first metatarsophalangeal (MTP) articular line in the dorsal aspect of the metatarsal head (Fig. 3A). A second K wire was placed perpendicular to the second metatarsal, 1 mm inferior to the dorsal cortex and at 10 mm from the articular line. This wire guided angulation for the oblique osteotomy cut (Fig. 3B) and was placed with 0°, 10°, 20°, 30° or 40° of angulation with respect to the first K wire, in the coronal plane (Fig. 4). The exit site was marked 30 mm proximal to the articular site and the plantar vessels, in the plantar cortex of the first metatarsal shaft (Fig. 3C).

The osteotomy was then performed following the planned traces. The first cut was made in the transverse plane in an oblique manner from the medial aspect of the metatarsal head in a dorsal-distal to plantar-proximal direction. This cut was initiated 1 mm inferior to the dorsal cortex and at 10 mm from the joint line and accomplished at 30 mm from the joint line in the plantar cortex (Fig. 1). This part of the osteotomy was performed at different angulations (0°, 10°, 20°, 30° and 40°).

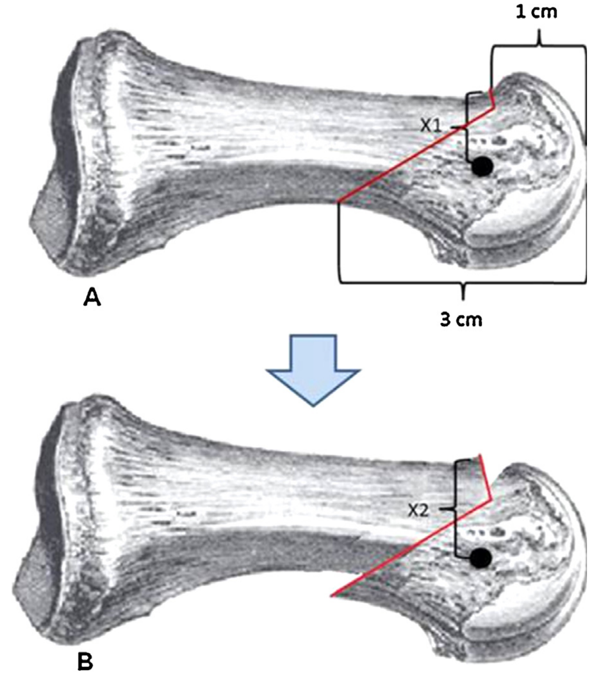

Fig. 1. Osteotomy design, lateral view: (A) Reference marks for osteotomy performance and measurement of X1 distance prior to osteotomize. (B) Final position of the osteotomy and measurement of head declination (X2).

Next, the second limb was made in the dorsal cortex of the first metatarsal at 10 mm from the MTP joint line. Direction of these cut was perpendicular to the second metatarsal (Figs. 1 and 5). Following the osteotomy, bone fragments were freed using chisels. The objective of this part of the osteotomy is to control metatarsal shortening and corresponds to a modification to the original

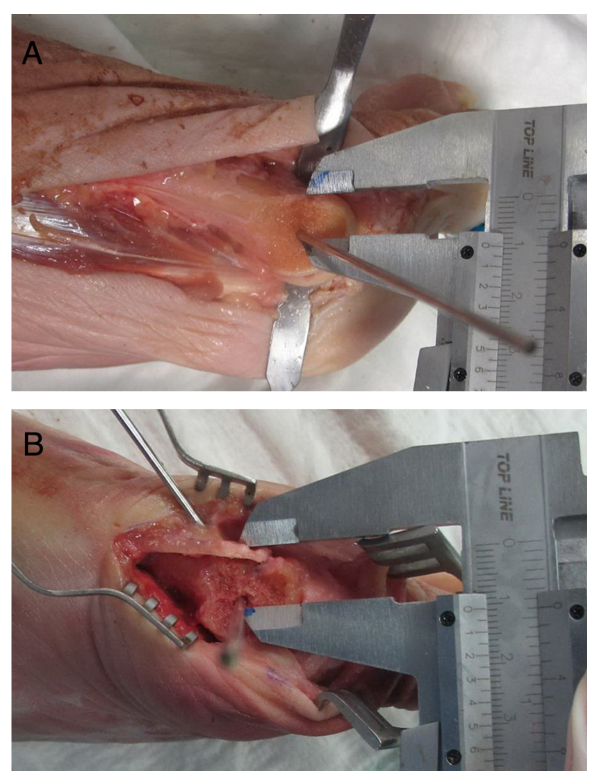

Fig. 2. A Intraoperative measurement of head declination before osteotomy (X1). Fig. 2 B Intraoperative measurement of head declination after osteotomy (X2).