The Relative and Absolute Bone Density at the TMT Joint in Hallux Valgus

INTRODUCTION
The aetiology of hallux valgus is thought to be mechanical in nature with a laterally directed force at the great toe moving the metatarsophalangeal joint medially. This change in joint alignment could alter the forces carried across the joints in the midfoot and cause bone remodeling. Our objective was to measure the density of bone at the tarsometatarsal joint in hallux valgus feet to determine if remodeling of bone occurs due to changes in joint angulation.

METHODS
Five cadaveric specimens were tested (two were male donors; average specimen age was 75.4 years, range of 65 to 84 years). One Kirschner wire was placed parallel to the plantar surface of the foot through the proximal intercuneiform joint and another through the mid-shaft of both the first and second metatarsals. The feet were placed on an x-ray plate and an AP radiograph was taken with the weight of the foot holding the specimen to the plate. Following a CT scan, the first and second TMT joints were dissected and embedded in two-part epoxy resin. The intermetatarsal Kirschner wire was removed and bone slices sectioned from the embedded joint. The CT slices and bone slices were aligned perpendicular to the first tarsometatarsal (TMT) joint and parallel to the intercuneiform K-wire. The average slice thickness was determined from caliper measurements at three points on each slice. X-ray radiographs of the bone slices placed on an x-ray plate together with an aluminum penetrometer were obtained. The penetrometer allowed consistent and uniform correction of radiographic images for brightness and contrast or direct computation of bone mineral density [1-4].

Four circular regions of interest (ROI) were defined by a musculoskeletal radiologist in the medial and lateral sections of the TMT joint, two in the distal cuneiform and two in the proximal metatarsal. These ROI, of approximately 10mm², were placed on successive CT slices and the average Hounsfield number in each ROI recorded. A digital image of the CT slice and ROI’s was recorded. The radiologist also took angular measurements of the TMT joint from the CT and x-ray images. The ray angle, on CT and plain film, was defined as the angle between a line down the long axis of the first metatarsal and the first phalanx. The intermetatarsal angle was defined as the angle between the long axes of the first metatarsal and the first phalanx. The proximal metatarsal had a significantly higher Hounsfield number than the distal cuneiform (p=0.27). On the lateral side, the ROI in the distal cuneiform had a significantly higher Hounsfield number than the proximal metatarsal (1.1 times higher, p=0.0001). There was no significant difference in the Hounsfield numbers for the medial side of the distal cuneiform and proximal metatarsal (p=0.14). We also found a trend towards reduced Hounsfield number (and reduced bone density) from dorsal to plantar.

In all four ROI’s in the TMT joint, there was a trend towards reduced Hounsfield number from the dorsal to plantar surface. Weighted Pearson’s correlations for linear fits to the data were poor (R² = 0.233) to good (R² = 0.534). In three regions of the TMT joint, there was also a trend towards reduced apparent density as position changed from dorsal to plantar. Weighted Pearson’s correlation coefficients for linear fits to the data were poor (R² ≤ 0.299).

RESULTS
The proximal medial metatarsal had significantly higher Hounsfield numbers than the proximal lateral metatarsal (approximately 1.1 times higher, p=0.0001). There was no significant difference in the density of the medial and lateral portions of the distal cuneiform as measured by Hounsfield number (p=0.27). On the lateral side, the ROI in the distal cuneiform had a significantly higher Hounsfield number than the proximal metatarsal (1.1 times higher, p=0.0001). There was no significant difference in the Hounsfield numbers for the medial side of the distal cuneiform and proximal metatarsal (p=0.14). We also found a trend towards reduced Hounsfield number (and reduced bone density) from dorsal to plantar.

DISCUSSION
A dorsal to plantar difference in density was also observed in an analysis of bone density in the normal human first TMT joint by Coskun et al. and in the first MT by Muehleman et al [2, 6]. Using DEXA, Muehleman et al. also found that lateral first MT bone was denser than medial first MT bone in normal feet [6]. In contrast, our analysis of hallux valgus feet showed that for regions of interest in the proximal metatarsal, medial bone was denser than the lateral bone. This suggests that the change in TMT joint angulation causes remodeling of bone in the medial metatarsal of the TMT joint.

SIGNIFICANCE
To our knowledge, the data presented in the abstract is the first evidence of remodeling of bone in hallux valgus feet. The data supports the argument that there is a change in the load transmission across the joints of the midfoot in hallux valgus feet. Clinically, knowledge of the changes in bone density of joints in the midfoot can help guide surgical decisions.

REFERENCES