INTRODUCTION: Subchondral cortical and trabecular bone mineral density (BMD) may increase and/or decrease during different stages of osteoarthritis (OA) disease progression [1-3]. In vivo imaging studies examining direct associations between increased proximal tibial bone mineral density (BMD) and knee osteoarthritis (OA) offer conflicting results [4-9]. This may be due to the inherent limitations of current in vivo imaging tools used to assess BMD or to previous investigators’ choice of analysis regions containing cortical and/or trabecular bone. Dual energy x-ray absorptiometry (DXA), the most commonly used technique for assessing BMD, is poorly suited for analyzing both cortical and trabecular regions because: 1) DXA represents a complex 3D bony structure as a 2D projection image; 2) DXA is limited to imaging in the coronal and sagittal planes; and 3) DXA results are sensitive to patient positioning and physical size. Our objectives were to 1) assess the in vitro precision of current and novel 3D quantitative computed tomography (QCT) imaging techniques capable of assessing subchondral cortical and/or trabecular bone (CT-OAM & CT-TomasD), and 2) investigate the ability of 3D imaging techniques to distinguish subchondral bone properties in OA and normal cadaveric tibiae.

METHODS: Eight intact cadaver knees from five donors (4M:1F; age: 77±10) were repositioned and scanned three times using QCT (Toshiba 64 Aquilion; Mindways BMD Spine Phantom; 0.5mm isotropic resolution, 120kVP voltage, 300mA tube current, 0.15mSv dosage [10]). BMD was assessed using 1) computed tomography absorptiometry (CT-OAM) which uses maximum intensity projections to assess subchondral bone density within subchondral bone [11,12], and 2) our novel computed tomography topographic mapping of subchondral density (CT-TomasD) technique [13], which uses surface projections to assess both cortical and trabecular bone density at specific depths from the subchondral surface (Figure 1).

Average BMD at normalized depths of 0-2.5mm, 2.5-5.0mm, and 5.0-10mm from the surface were assessed using CT-TomasD. Regional analyses were performed consisting of: (1) medial/lateral (M/L) BMD ratio, and (2) BMD of a 10mm diameter core identified as having the maximum regional BMD. Precision was assessed using coefficients of variation (CV%) [14]. Each bone was assessed for OA (BAM) by examination of the CT images, and categorized using a modified-KL [15] scoring system: Normal (mKL=0); Early-OA (1-2); and Late-OA (3-4).

RESULTS: Precision errors of CT-OAM and CT-TomasD bone density measures were less than 4.2% (Table 1). OA was identified in four compartments of three tibiae (1 late OA+valgus, 1 late OA+varus, 1 early OA+neutral). Larger density differences between OA and normal knees were noted using CT-TomasD compared with CT-OAM (Tables 2 & 3, Figure 2). CT-TomasD demonstrated that the two knees with late OA demonstrated M/L BMD ratios differing by more than 3.4 SD compared with normals, with peak cores higher than normals across all depths. The knee with early OA and neutral alignment demonstrated M/L ratios less than normals while core differences were highest proximally, with density becoming lower than normals with increasing depth.

DISCUSSION: Both CT-OAM and CT-TomasD are capable of precise measures of subchondral cortical and/or trabecular bone density distribution in osteoarthritic and normal subjects. CT-TomasD demonstrated larger differences between OA and normal subjects when compared with CT-OAM differences. This may be due to CT-OAM primarily assessing peak density within the thin subchondral cortical endplate; a region demonstrating fairly uniform peak densities within a limited range (Figure 2). Additionally, CT-OAM largely overlooks density changes in nearby subchondral trabeculae, which are affected by OA. Differences between normal and OA subjects may be therefore difficult to detect using CT-OAM. Nevertheless, preliminary results demonstrate the potential of both CT-TomasD and CT-OAM analyses to quantify subchondral bone density differences which may be associated with OA progression.