

# Osteoarthritis:Regional and Subregional Quantitative Assessment of Trabecular Bone Micro-Architecture via 7T MRI

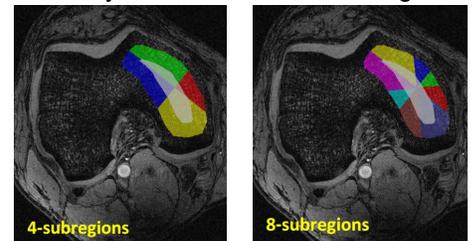
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**Introduction.** Osteoarthritis (OA) affects approximately 46 million Americans with annual healthcare costs of approximately \$127 billion. The pathogenesis of OA is multifactorial, but especially involves interactions between articular cartilage degeneration and alterations in subchondral bone. OA progression takes places in a spatially heterogeneous fashion, typically affecting the medial compartment to a greater degree than the lateral compartment. The goal of this study was to utilize high resolution 7T MRI to perform a regional and subregional quantitative assessment of trabecular bone micro-architectural changes in the knee for subjects with osteoarthritis and healthy controls.

**Methods.** Six human subjects (4 OA patients, age: 62 y +/- 4.3; 2 healthy controls (H), age: 36 y +/- 9.9) were recruited for this study. All subjects were scanned on a 7T whole body MR scanner (Siemens, Erlangen, Germany) using a quadrature knee coil (18 cm diameter, transmit-receive). We utilized a high-resolution 3D-FLASH sequence (TR/TE=20/4.5 ms; flip angle, 10°; 130 axial images (195µmX195µm X1000µm resolution); bandwidth 130 Hz/pixel; one signal acquired) . The study was approved by the institutional review board. Bone volume fraction (BVF) images were computed from MR images using local marrow intensity-derived linear mapping functions accounting for space varying RF coil signal and requiring no thresholding. Four anatomic compartments, namely, medial femoral condyle (MFC), lateral femoral condyle (LFC), medial tibial plateau (MT), lateral tibial plateau (LT), were manually drawn on each MR image.

Each compartment was further subdivided into four or eight angular subregions for analyses (see Figures 1a and 1b). Fuzzy algorithms were applied to determine total bone volume (TBV) and apparent bone density (ABD). Digital topological analysis (DTA) was applied to determine bone surface-curve ratio (S/C, marker of plate-to-rod ratio) and bone erosion-index (EI, marker of topological sparsity). DTA was also applied to marrow volume fraction images (MVF, an inverse of BVF image) to determine marrow S/C and marrow EI. Student's unpaired t-tests were utilized to determine the statistical differences between two groups.



**Results.** At the compartment level, OA subjects demonstrated decreased TBV compared to healthy subjects for MFC, LFC, MT, and LT ( $p < 0.05$ ). At the 4-subregion (R) level, OA subjects demonstrated decreased TBV within R2 and R4 of MFC, LFC, MT, and LT ( $p < 0.05$ ). In addition, within LT, OA subjects demonstrated decreased marrow EI within R1 and decreased ABD within R2 ( $p < 0.05$ ). Within MT, OA subjects demonstrated decreased TBV of R1 ( $p < 0.05$ ). At the 8-subregion level, OA subjects demonstrated: decreased TBV within R3, R4, R7, R8 of LFC; decreased TBV, ABD, and bone S/C within R3 of the LT; decreased TBV within R4 and R8 of LT; decreased marrow EI within R2, R6, R7 of LT; decreased TBV within R1, R2, R6 of MT, decreased TBV and ABD of R 7 of MT, decreased marrow EI of R3, R6 of MT ( $p < 0.05$  for all). Selected results are shown below.

Compartment Level	LFC – TBV	MFC – TBV	LT – TBV	MT – TBV
OA Mean	125320.21	113614.39	78053.24	93197.87
Std Dev	26066.60	26932.46	12879.14	21353.88
H Mean	189169.99	168305.20	110835.33	152538.99
Std Dev	26333.01	17721.88	7251.37	718.82
P value	0.047	0.054	0.019	0.011

4 Subregion Level	LT – R1 Marrow EI	MT – R1 TBV	LFC – R2 TBV	MFC – R2 TBV	LT – R2 TBV	LT – R2 ABD	MT – R2 TBV
OA Mean	0.2803	16055.76	20875.03	41689.29	14511.48	0.2622	28422.62
Std Dev	0.05422	2534.06	9314.33	17489.70	4183.99	0.02138	11702.95
H Mean	0.3671	23341.84	43670.09	68838.30	22931.33	0.3015	56605.43
Std Dev	0.0001025	9.48	3445.23	2335.73	1585.44	0.00862	677.93
P value	0.049	0.010	0.033	0.050	0.024	0.032	0.016

8 Subregion Level	LFC – R3 TBV	LFC – R4 TBV	LFC – R7 TBV	LFC – R8 TBV	LT – R3 TBV	LT – R3 ABD	LT – R3 Bone S/C	LT – R2 Marrow EI	LT – R6 Marrow EI	MT – R7 ABD	MT – R3 Marrow EI	MT – R6 Marrow EI
OA Mean	6385.59	14476.9	5235.59	10547	5726.49	0.2557	4.62382	0.26788	0.32237	0.26406	0.2797	0.26361
Std Dev	1844.77	7467.58	1470.1	4312.97	1837.41	0.0265	0.87794	0.05225	0.06974	0.02651	0.06553	0.05728
H Mean	11736	31916.4	11722.7	23958.1	8945.8	0.3051	7.4987	0.35447	0.45731	0.30398	0.37657	0.36625
Std Dev	1867.53	1579.08	1784.26	2864.68	468.874	0.0082	1.21775	0.00652	0.01776	0.00616	0.02171	0.01251
P value	0.028	0.036	0.0085	0.017	0.034	0.028	0.02708	0.04321	0.02575	0.05272	0.0569	0.03282

**Conclusion.** 7 Tesla MRI can detect changes in trabecular bone micro-architecture in subjects with OA compared to healthy controls. While compartmental analysis identified differences only in TBV, subregional analysis allowed detection of topological differences in trabecular bone micro-architecture between groups. This technique could potentially provide more accurate characterization of the spatial distribution of pathologic bone changes within the osteoarthritic knee joint.