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Voxel-based density registration of trabecular bone: a longitudinal HR-pQCT study of postmenopausal women

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Bone mineral density (BMD) is one of the important indicators used to characterise bone diseases, such as osteoporosis [1]. Two-dimensional areal BMD can be analysed through dual X-ray absorptiometry (DXA) which is the recommended method to diagnose osteoporosis by WHO [2]. However, an in-vivo method to detect three-dimensional localised BMD of trabecular bone is still absent. HR-pQCT enables the in-vivo assessments of 3D microstructure down to trabecular bone (TB). Therefore, in this study, a voxel-based density registration (VDR) method is proposed to analyse the longitudinal changes of trabecular-bone density distribution.

Five healthy women aged between 55-70 years-old with more than one-year post menopause from a cohort of local dwelling were recruited into this 6-month longitudinal study. HR-pQCT scans were performed at the beginning and end of the study. Baseline and follow-up HR-pQCT (XtremeCT, Scanco Medical AG, Switzerland) scans were performed for all the recruited participant using the manufacturer's standard protocol (60 kVp, 1000 mA, 100-ms integration time). Four anatomical regions were defined (anterior, lateral, posterior, and medial) to observe the region-specific data, according to the previously published study [2]. The VDR method was programmed in-house using MATLAB 2020b to visualise and analyse the localised variation of TB density change at distal tibia after 6-month. The VDR programme contained 5-main steps, involving a pre-processing with a Laplace-Hamming filter; three-dimensional (3D) mutual information rigid registration; BMD calibration using manufacturer provided phantom; voxel-base BMD calculation between baseline and follow-up images; colour contour was mapped and presented. To evaluate the statistically significant differences ($p < 0.05$) of tBMD for the four anatomical regions before and after 6 months, repeated measures ANOVA (RM-ANOVA) were performed using SPSS 20.0 software (IBM Corp., NY, USA).

The time effect on localised changes of trabecular-bone mineral density was visualized and variations between different anatomical regions were quantified for the first time. Different distributions between anatomical regions were found in bone mineral density of trabecular bone (vBMDtrab), with a change of vBMDtrab at medial region (-0.56%) significantly higher than anterior (-1.58%) ($p = 0.032$). This study indicates that localised density changes might be used as a prior indicator for the effect of aging or other interventions.

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