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Real-time X-ray microradiographic imaging and image correlation for local strain mapping in single trabecula under mechanical load

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X-ray microradiography was employed to quantify the strains in loaded human trabecula. Samples of isolated trabeculae (n=6) from human proximal femur were extracted and glued in a loading machine specially designed and manufactured for the purpose. The samples were then tested in tension (n=3) and three-point bending test (n=3) until complete fracture of the specimen. To assess the deformation in the very small samples (thickness 0.1 mm, length 1-2mm) a real-time microradiography in conjunction with digital image correlation (DIC) has been employed. Loaded samples were illuminated continuously by X-rays (Hamamatsu L8601-01 with 5μm spot) during the test. Radiograms were acquired using 0.25s exposure time with hybrid single-photon counting silicon pixel detector Medipix2 (matrix 256×256 sq. pixels of 55 μm pitch). The distance between the source and detector was kept small to ensure radiograms of good quality in such a small time interval.

Design of the experimental loading device enables for precise control of the applied displacement which is important for the post-yield behaviour assessment of trabeculae. Unlimited dynamic range, high sensitivity and high contrast of the Medipix2 enables measuring even very small strains with DIC. Tested experimental setup enables to combine micromechanical testing of the basic building block of trabecular bone with time-lapse X-ray radiography to measure the strains and to assess the mechanical properties of single human trabecula and capture the softening curve with sufficient precision.

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