AUTOMATED MODELLING OF CORTICAL BONE FROM CLINICAL CT

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SUMMARY OF THESIS

Osteoporosis is an age-related skeletal disease characterised by an increased incidence of fragility fractures. In this thesis I develop a new technique capable of measuring the thickness of the previously unmeasured endocortical region, and providing an improved measure of the cortical bone mineral density (cBMD) from in-vivo clinical CT scans. These features are of interest as both have been linked to fracture risk.

The new technique is developed within the cortical bone mapping (CBM) framework so that it provides localised architectural measurements over a bone's surface. Its performance is assessed using simulated QCT data from three simulated phantoms with differing bone architecture, and two paired datasets of ex-vivo QCT and HR-pQCT scans across the proximal femur and the lumbar spine. The simulated data allows for inaccuracies in CBM measurements caused by beam hardening effects to be considered for the first time: I show that beam hardening leads to an underestimation in cortical thickness and an overestimation in trabecular BMD and that these inaccuracies can be reduced through adjustments to the CBM optimisation process.

A new technique of analysing HR-pQCT scans is also developed, for the validation of the new CBM method. It was used in place of other established HR-pQCT techniques for its ability to provide localised measurements of the endocortical region. A comparison with the well known full-width half-maximum (FWHM) method shows that it is less susceptible to errors caused by beam hardening. It also measures the mean cBMD, which has a greater clinical relevance than the peak cBMD measured by the FWHM method as it includes the impact of porosity. I demonstrate that the endocortical thickness can be measured to an accuracy of $-0.15 \pm 0.71\,\mathrm{mm}$, and that local cBMD measurements are possible down to $300\,\mathrm{mg/cm^3}$ from QCT scans over the proximal femur. I also validate CBM methods over the vertebrae for the first time and demonstrate that the cortical thickness and endocortical thickness can be measured with accuracies of $0.10 \pm 0.30\,\mathrm{mm}$ and $-0.20 \pm 0.53\,\mathrm{mm}$.

Two clinical trials involving Teriparatide are used to demonstrate that the new CBM method is able to detect significant regional changes in the dense cortical and endocortical bone over the proximal femur and lumbar spine, which can be attributed to changes in intracortical remodelling and endosteal apposition. The analysis of a cross-sectional fracture discrimination trial shows that fracture incidence is associated with significant decreases in endocortical thickness over specific regions.