Non-Invasive Assessment of Trabecular Bone Structural Anisotropy – Relevance to Mechanical Anisotropy

A thesis submitted for the degree of

Doctor of Philosophy

by

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Abstract

Although there are now many theories describing empirical relationships between strength properties of bone and various explanatory variables, the need for improved non-invasive diagnostic techniques to assess bone fragility is of core importance in clinical problems such as osteoporosis. The aim of this thesis was to develop non-invasive radiological methods to assess trabecular bone architecture.

Measures of structural anisotropy and bone structure from X-ray or radiological projections have been developed. The first measure, the projected mean intercept length (PMIL), allows extraction of the total bone surface (BS/TV) and the mean intercept length (MIL) from projections of trabecular structure. The second measure, the line projection deviation (LPD), is a technique that quantifies the preferential alignment of trabecular bone from projections of the trabecular structure. Hence, in combination, the PMIL and LPD allow non-invasive extraction of BS/TV and more detailed preferential alignment from projections of the trabecular structure.

In this thesis the PMIL and LPD are introduced and their properties explored. The PMIL and LPD are used to examine the anisotropy and architectural properties of a number of human vertebral body trabecular bone samples. When used in combination with clinical densitometry, these measures improve explanation of the variance in strength, elastic modulus and toughness of vertebral body trabecular bone samples by up to 40% when compared to densitometric values alone.

While μCT can provide the information needed to access trabecular architecture, it cannot be used in clinical settings since its high radiation dose makes it only applicable to small objects *ex-vivo*. At present, clinically available CT does not provide sufficient resolution to resolve trabecular structures. Thus, the methods described in this thesis will allow estimates of structural parameters from plain X-rays, providing for the first time, the possibility of clinical use of such estimates.

Declaration

This work contains no material which has been accepted for the award of any degree or diploma in any university or other tertiary institution and, to the best of my knowledge, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying, subject to the provisions of the copyright act 1968.

Arash Badiei

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Abbreviations

BMC	Bone mineral content
BMD	Bone mineral density
BS/BV	Specific bone surface
BS/TV	Total bone surface
BV/TV	Bone volume fraction
CT	Computed tomography
DA	Degree of Anisotropy
DXA	Dual energy X-ray absorptiometry
g	Grams
MIL	Mean intercept length
mm	Millimetre (1×10^{-3} meters)
LFD	Line fraction deviation
LPD	Line projection deviation
PMIL	Projected mean intercept length
SLD	Star length distribution
SMI	Structure model index
SVD	Star volume distribution
Tb.N	Trabecular number
TBPf	Trabecular pattern factor
Tb.Th	Trabecular thickness
Tb.Sp	Trabecular separation
vBMD	Volumetric bone mineral density
µCT	Micro-computed tomography
µm	Micrometre (1×10^{-6} meters)