

Contents

Abstract	1
Resumen	3
Resum	5
Motivation	7
Objectives and structure	10
Chapter 1. Introduction	12
1.1 Clinical scenario: Bone and Osteoporosis	12
1.1.1 The bone tissue	12
1.1.2 Bone development and remodeling	15
1.1.3 Osteoporosis	17
1.2 Magnetic resonance imaging	21
1.2.1 Physical principles	22
1.2.2 System architecture	25
1.2.3 Pulse sequences	29
1.2.4 MR in the study of bone	32
1.2.5 Acquisition requirements for trabecular bone characterization	34
1.3 Image processing and quantification of trabecular bone	35
1.3.1 Image processing in digital radiology. Applications to the study of trabecular bone	35
1.3.2 State of the art in trabecular bone characterization. Quantification of trabecular bone from MR images	36
Chapter 2. Methodology	42
2.1 Image acquisition	42
2.1.1 Region of acquisition	42
2.1.2 MR Hardware	42
2.1.3 MR pulse sequence	44
2.2 Image processing	46
2.2.1 Segmentation	47
2.2.2 Coil heterogeneities correction	53
2.2.3 Sub-voxel processing	54
2.2.4 Binarization	55
2.3 3D reconstructions of the trabeculae	56
2.4 Morphometry analysis	59
2.4.1 Morphology	59
2.4.2 Complexity	63

2.4.3 Topology	67
2.4.4 Anisotropy	75
2.5 Mechanical analysis using the FE method	82
2.5.1 Generation of a voxel-based FE model	82
2.5.2 Mechanical simulation of compressive conditions	88
2.5.3 Processing of the results	91
2.6 Reproducibility and validation of the measurements	92
2.7 Study groups	95
2.8 Statistical analysis	96
Chapter 3. Results and discussion	98
3.1 Evaluation in a healthy population. Normality values	98
3.1.1 Morphometry results in healthy subjects	98
3.1.2 Mechanical results in healthy subjects	107
3.2 Assessment of morphometry and mechanical alterations under pathological conditions in osteoporosis disease	114
3.2.1 Morphometry results in osteoporotic patients	115
3.2.2 Mechanical results in osteoporotic patients	127
3.2.3 Morphometry and mechanical relationships with bone mineral density	130
3.3 Reproducibility analysis	132
3.4 Validation of the measurements	134
Chapter 4. Conclusions	139
Chapter 5. Future work	142
5.1 Evaluation of patients with different etiopathogenesis	142
5.2 Longitudinal analysis of the morphometry and mechanical parameters in a group of patients under treatment	143
5.3 Use of MDCT for the trabecular bone characterization	143
5.4 Mechanical simulations of trabecular bone in the non-linear regime	144
5.5 Study of cortical bone water using ultra-short echo times	145
5.6 Imaging based evaluation of bone deposition on polymer scaffolds in tissue engineering	147
5.7 Development of an integrated image post-processing platform	147
References	149
Publications	161
Abbreviated terms	165
Appendix	168