

Contents

1	Introduction and Questions	1
2	Basis for the Design of the Computer Models	7
2.1	Qualitative and Quantitative Description of Joint Incongruity	7
2.1.1	Hip Joint	7
2.1.2	Ankle Joint	8
2.1.3	Humeroulnar Joint	9
2.1.4	Humeroradial Joint	9
2.1.5	Shoulder Joint	9
2.1.6	Our Own Investigations	10
2.2	Finite Element Method	13
2.2.1	Preprocessing	14
2.2.2	Processing	15
2.2.3	Postprocessing	15
2.3	Theory of Mechanoadaptive Bone Remodeling	16
2.3.1	Roots, Mathematical Formulation, and Implementation with the Finite Element Method	16
2.3.2	Cellular Basis and Concept of Modern Bone Remodeling Algorithms	18
2.3.3	Homeostatic and Time-Dependent Formulations, Experimental Validation, and Numerical Instability	23
3	Materials and Methods	33
3.1	Idealized Model of Concave Joint Incongruity	33
3.2	Idealized Comparative Geometric Models	35
3.3	Anatomically Based Model of the Humeroalnar Joint	36
3.4	Experimental Validation	41
3.5	Morphological Investigations on the Elbow Joint	41
3.5.1	Determination of the Subchondral Mineralization by Means of CT-OAM	41

3.5.2	Assessment of the Trabecular Architecture	43
3.5.3	Analysis of the Subchondral Split Lines	43
4	Results	45
4.1	Idealized Model of Concave Joint Incongruity	45
4.2	Idealized Comparative Geometric Models	55
4.3	Anatomically Based Model of the Humeroulnar Joint . .	61
4.4	Experimental Validation	68
4.5	Morphological Findings at the Elbow Joint	70
4.5.1	Distribution of the Subchondral Mineralization .	70
4.5.2	Trabecular Bone Architecture	72
4.5.3	Subchondral Split Lines	74
5	Discussion	75
5.1	Methodological Discussion	75
5.1.1	Design of the Computer Models	75
5.1.2	Biomechanical Experiment	83
5.1.3	Morphological Investigations on the Elbow Joint	83
5.2	Effect of the Incongruity on the Pressure in the Joint . .	85
5.2.1	General Observations	85
5.2.2	Humeroulnar Joint	87
5.2.3	Conclusions About Other Joints	88
5.3	The Relationship Between Joint Incongruity, Mechanoadaptive Bone Remodeling and the Morphology of the Subchondral Bone	89
5.3.1	General Observations	89
5.3.2	Humeroulnar Joint	91
5.3.3	Conclusions About Other Joints	93
5.4	Phylogenetic and Ontogenetic Origin of Joint Incongruity	94
5.5	Perspectives and Further Investigations	97
5.5.1	Noninvasive, Quantitative Determination of Joint Incongruity and Cartilage Thickness by MRI	97
5.5.2	Biphasic Modeling of the Articular Cartilage . . .	98
5.5.3	Anisotropic Simulation of Bone Remodeling . .	101
5.5.4	Computer-Aided Determination of the Long-Term Loading From the Subchondral Density	102
5.5.5	Computer Simulation of Growth and Differentiation of the Connective Tissues . .	103

6	Conclusions	107
	References	111
	Acknowledgements	129