Skeletal Tissue Mechanics

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R. Bruce Martin David B. Burr Neil A. Sharkey
David P. Fyhrie

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Second Edition

With 194 Illustrations

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R. Bruce Martin, retired
Orthopaedic Surgery
UC Davis Medical Center
Olga, WA, USA

Neil A. Sharkey
Kinesiology, Orthopedics
and Rehabilitation
Pennsylvania State University
University Park, PA, USA

David B. Burr
Department of Anatomy
and Cell Biology
Indiana University School of Medicine
Indianapolis, IN, USA

David P. Fyhrie
Orthopaedic Surgery, Biomedical
Engineering
UC Davis Medical Center
Sacramento, CA, USA

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Dedication

This book is dedicated to R. Bruce Martin, one of the smartest and most thoughtful scientists any of us has known. It is unusual for a book to be dedicated to its first author. However, in this case, it is entirely appropriate. This book was Bruce's brainchild, based on many years of lecturing and thinking about the skeleton and how it works both from an engineering perspective and from a biological one. Many of the ideas expressed in this second edition of *Skeletal Tissue Mechanics*, as in the first, were original with Bruce, and they still retain a freshness and originality of thought that continue to make them valuable insights into the workings of our musculoskeletal system. He thought of them; he developed them; he applied them. He, more than most, understood both the mechanical and the biological aspects of the skeleton; he could integrate them effectively, and he could explain them even to the novice; and with humility and objectivity, he rigorously critiqued them. We know, because he did this for us. Bruce's skill in integration and his interest in education make this book not just useful for teaching. It provides a foundation for further experimental and theoretical research in the skeletal tissues.

Bruce was not able to participate in the revision for this edition, although he wanted to. Several years before we began this revision, he tried to push us to bring the sadly out-of-date text into compliance with modern theoretical constructs, and informed by the many new experimental discoveries in areas such as mechanical signaling, the importance of bone architecture, bone quality markers, and bone fatigue, among others. The reader will easily see, by comparison to the first edition, that the science surrounding skeletal biology and its mechanical implications has by no means stood still. More sophisticated experiments and greater biological depth to computational modeling have produced insights that were unknown just a few years ago. Significant progress has been made in a few short years. We hope that, in Bruce's spirit, we have captured some of these advances in this second edition of *Skeletal Tissue Mechanics*.

Preface

The first edition of *Skeletal Tissue Mechanics*, published in 1998, grew out of Bruce Martin's lecture notes for a course by the same name, which was part of the biomedical engineering curriculum at the University of California at Davis. Given this history, it is not surprising that the book is intended to be used as a textbook, not a reference book. But it also is intended to comprehensively review the biology of all the skeletal tissues and their mechanical properties and biomechanical functions. The integration of anatomy and physiology with structural and material behavior was one of the book's principal objectives, and this remains the goal of the second edition as well. The interdisciplinary nature of the book is strengthened by the complementary blend of perspectives brought by the authors, who have backgrounds in Functional Anatomy, Anthropology, Physiology, Biomedical and Mechanical Engineering, and Orthopedics.

The first edition was primarily written for graduate and advanced undergraduate students in biomedical engineering. It fit a niche between textbooks focused on the biomechanics of locomotion and sport, and those aimed more specifically at orthopedic biomechanics, which often do not concentrate on the mechanical behaviors of skeletal tissues or the biologic processes that underlie them. In practice, the book was used more broadly by residents in orthopedic surgery and students at various levels who were studying anthropology, kinesiology, veterinary medicine, and skeletal physiology.

An explosion of new information—both experimental and computational—has improved our understanding of the influences on, and adaptability of, skeletal tissues. Our approaches to understanding both the dynamic and the static properties of skeletal tissues have become more sophisticated as well. Because of this, the first edition of *Skeletal Tissue Mechanics* became woefully dated, and its continued use as a text mandated that we update it and expand upon certain topics.

Besides updating and refreshing the content, and correcting some errors present in the first edition, the second edition of this book differs from the first in a number of important ways. The Biology of all skeletal tissues (bone, cartilage, ligament, and tendon) is now incorporated into a single chapter

and described using a hierarchical approach, focusing on the mechanics of the different biological levels of organization in each. The Mechanical aspects of each tissue are moved to subsequent chapters, with mechanics related to bone now at the end of the book. Having used the book ourselves, we have attempted to reorganize the chapters into a sequence that makes more sense from a didactic standpoint.

We have added new Historical Notes, set off from the main text in boxes, which we hope will increase student interest but also broaden their perspective. Additional boxes with Technical Notes will help students understand how to collect, analyze, and use information related to the textual material. We have updated the supplementary readings at the end of each chapter. We revised the exercise set we developed for students that we hope will help them to consolidate and use the information found in the chapters. Few of these exercises are simply practice at solving problems demonstrated in the book; rather, most are designed to stimulate the student to synthesize concepts based on material discussed in the text and to develop analytical problem-solving skills that will serve them in the future. Finally, figures have been updated and redrawn in some cases to improve content or make them more easily understandable, and color figures are included where we felt it would enhance learning.

We appreciate both our students and our colleagues who have contributed directly and indirectly to this book. Feedback and critical thought from students were particularly helpful in identifying gaps, or confusing presentations. Discussions with colleagues are always enlightening, and informed some of the changes. Beyond that, the coauthors themselves engaged in many entertaining discussions, some philosophical and others scientific, which expanded the boundaries of our own thinking. Finally, we would like to thank Drew Brown for his help in drawing (and redrawing, often several times) some of the new figures.

Olga, WA
Indianapolis, IN
University Park, PA
Sacramento, CA

R. Bruce Martin
David B. Burr
Neil A. Sharkey
David P. Fyhrie

Contents

Preface	vii
Chapter 1. Functional Musculoskeletal Anatomy	1
1.1 Introduction	1
1.2 An Illustrative Experimental Model	2
1.3 Static Analysis of Forces in Joints	4
1.3.1 Forces in the Elbow Joint	4
1.3.2 Forces in the Hip Joint	9
1.3.3 Clinical Significance of High Joint Forces	13
1.4 Hip Forces in Human Ancestors	13
1.5 Dynamic Joint Loading	17
1.6 Indeterminate Joint Problems	19
1.7 Equine Fetlock Forces	23
1.8 Summary and Further Reading	26
1.9 Exercises	27
References	32
Chapter 2. Skeletal Biology	35
2.1 Introduction to Bone	35
2.2 The Shapes of Bones	40
2.3 Types of Bone and Tissue	41
2.3.1 Cancellous Versus Compact Bones	43
2.3.2 Lamellar Versus Woven Bone	44
2.3.3 Primary and Secondary Bone	47
2.4 The Collagen-Mineral Composition of Bone	51
2.4.1 Quantitative Analyses of Bone Composition	56
2.4.2 Three Dimensional Imaging of Bone Using High Resolution Computed Tomography (microCT)	57
2.5 Bone Cells	60
2.6 Introduction to Cartilage	65
2.6.1 Mechanical Significance of Cartilage	70
2.6.2 Organization of Articular Cartilage	71

2.6.3 The Role of Cartilage in Growth	75
2.7 Longitudinal Growth of Bones	76
2.7.1 Development of Metaphyseal Trabeculae	79
2.7.2 Growth of the Physis	79
2.7.3 Closure of the Physes	80
2.8 Introduction to Ligament and Tendon	81
2.8.1 Structure and Composition	83
2.8.2 Injury and Repair	86
2.9 Summary for Further Reading	87
2.10 Exercises	87
References	89
 Chapter 3. Growth, Modeling and Remodeling of Bone	 95
3.1 Introduction	95
3.1.1 Growth	96
3.1.2 Modeling Versus Remodeling	96
3.1.3 The A-R-F Sequence and BMUs	99
3.1.4 The Six Phases of an Osteon's Lifetime	100
3.1.5 Remodeling Cycle Duration	102
3.1.6 Bone Structural Units Are Produced by Remodeling	104
3.1.7 Remodeling on the Different Bone Envelopes	105
3.2 Fracture Healing	108
3.2.1 Basic Concepts	109
3.2.2 Important Tissues in Fracture Healing	109
3.2.3 Three Biological Phases	111
3.2.4 Four Biomechanical Stages	114
3.2.5 Stability of Fixation	116
3.2.6 Primary Union	118
3.2.7 Posttraumatic Osteoporosis	118
3.2.8 Electrical Phenomena and Fracture Healing	119
3.3 Analysis of Bone Remodeling	119
3.4 Mathematical Notation for Bone Remodeling	121
3.5 Histomorphometric Measurement of Remodeling	122
3.5.1 Assumptions in Histomorphometry	123
3.5.2 Histomorphometric Measurements for Cortical Bone	125
3.5.3 Calculating BMU-Level Results	126
3.5.4 Histomorphometric Measurements for Cancellous Bone	131
3.5.5 True vs. Histologic BMU Activation Frequency in Cortical Bone	134
3.6 Remodeling Details	138
3.6.1 Activation Is Prime	138
3.6.2 Resorption: Out with the Old	139

3.6.3 Refilling: In with the New	142
3.6.4 Computation of FP	148
3.6.5 The Equal Lamellar Work Areas Principle	148
3.6.6 Why Does the Apposition Rate Slow Down?	150
3.7 Long-Term Effects of Osteonal Remodeling	154
3.7.1 Implications for the Aging Skeleton	154
3.7.2 Osteonal Overlapping	155
3.7.3 The Random Remodeling Assumption	155
3.7.4 Mathematical Theories	156
3.7.5 Another Theoretical Approach to Bone Remodeling	162
3.8 Summary and Further Reading	164
3.9 Exercises	165
References	168

Chapter 4. Mechanical Properties of Ligament and Tendon 175

4.1 Quasi-static Tensile Properties	175
4.2 Viscoelastic Properties	178
4.3 Mathematical Modeling	181
4.4 Measuring Structural and Material Properties	184
4.4.1 Storage and Testing Environments	184
4.4.2 Measuring Cross-Sectional Area	186
4.4.3 Gripping Slippery Viscoelastic Tissues	187
4.4.4 Determining Resting Length	189
4.4.5 Measuring Specimen Elongation	190
4.5 Functions at Junctions	193
4.5.1 The Myotendinous Junction	193
4.5.2 Ligament and Tendon Insertions to Bone	194
4.6 Functional Adaptation and Specialization	198
4.6.1 Determinants of Tendon Architecture	200
4.6.2 Sites of Tendon Compression	201
4.6.3 Flexors and Extensors	204
4.7 Age and Mechanical Behavior	206
4.8 Exercise and Immobilization	209
4.9 Pathology and Healing	210
4.9.1 Ligament	210
4.9.2 Tendon	211
4.9.3 Surgical Repair	213
4.9.4 Anterior Cruciate Ligament	213
4.9.5 Supraspinatus Tendon (Rotator Cuff)	215
4.9.6 Flexor Tendons of the Hand	216
4.10 Summary and Further Reading	217
4.11 Exercises	218
References	220

Chapter 5. Synovial Joint Mechanics	227
5.1 Introduction	227
5.1.1 Functions of a Synovial Joint	228
5.1.2 Joint Diseases	229
5.2 Mechanical Properties of Cartilage	230
5.2.1 Initial Points	230
5.2.2 Structure of Articular Cartilage	233
5.2.3 Permeability	234
5.2.4 Indentation Testing	235
5.2.5 Tensile Tests	237
5.2.6 Poroelastic Theory of Articular Cartilage	239
5.2.7 Other Models for Cartilage Mechanics	244
5.2.8 Modeling Tissue Charge	244
5.2.9 Inhomogeneity of Modulus	245
5.2.10 Effect of Strain Rate on Tensile Tests	246
5.2.11 Effect of Strain Rate on Compression Tests	247
5.3 Lubrication of Joints	248
5.3.1 Friction	248
5.3.2 Wear	250
5.3.3 Types of Lubrication	250
5.3.4 Synovial Joint Lubrication	260
5.3.5 Diversity of Joint Architecture	263
5.4 Summary and Further Reading	265
5.5 Exercises	266
References	270
 Chapter 6. Mechanical Adaptability of the Skeleton	 275
6.1 Introduction	275
6.2 The Historical Context	276
6.3 Mechanical Adaptability and Evolutionary Adaptability	280
6.3.1 Somatic Versus Evolutionary Adaptation	280
6.3.2 Somatic Versus Evolutionary Effects	282
6.4 What Is the Design Goal: What Does Bone Adapt to?	284
6.4.1 Optimization, Mechanical Adaptability, and Structure-Sensitive or Insensitive Properties	285
6.5 How Does Bone Adapt: What Are the Signals and How Are They Transduced?	286
6.5.1 Measurement of Strain in Living Animals	287
6.5.2 Principal Stresses, Strains and Trabecular Orientations	288
6.5.3 Compressive Strains Are Larger than Tensile Strains	290
6.5.4 Canine Disuse Experiments	295

6.5.5	The Mechanostat and the Equilibrium Strain Range	295
6.5.6	Mechanical Compensation and the Roles of Bone Modeling and Remodeling	297
6.5.7	Optimization and the Mathematical Basis of Wolff's Law	302
6.5.8	Some Final Thoughts on Optimization, Adaptation and the Scientific Method	303
6.5.9	How Frequently Should Dynamic Loads Be Applied: The Role of Strain Rate	306
6.5.10	Effects of High Frequency Loading: Vibration	308
6.5.11	When Theory Meets Reality	309
6.5.12	Is Strain a Direct Stimulus to Bone Cells? Do Strain Gradients and Distributions Regulate Regional Bone Cell Activity?	310
6.5.13	Fluid Flow	313
6.5.14	Summary	315
6.6	Some Additional Theories	316
6.6.1	Pauwels' Stress Magnitude Theory: Control of Modeling Drifts	317
6.6.2	Adaptive Elasticity Theory: Control of Density or Modeling Drifts	319
6.6.3	What Controls Osteonal Tunneling Directions?	320
6.6.4	Adaptive Finite Element Models: Control of Density	323
6.6.5	Self-Trabeculating Models: Control of Density and Trabecular Alignment	327
6.6.6	Related Engineering Models	331
6.6.7	Synthesis	332
6.6.8	Experimental Consistency	332
6.6.9	Relationship of Mechanically Adaptive Responses to Other Control Factors	334
6.6.10	Mechanical Adaptability and Damage Repair	335
6.7	Mechanical Adaptability in Cartilage	336
6.7.1	The Carter–Wong Chondral Calcification Theory	336
6.7.2	Frost's Chondral Modeling Theory	338
6.8	Summary and Further Reading	339
6.9	Exercises	340
	References	343

Chapter 7. Mechanical Properties of Bone	355
7.1 Introduction	355
7.2 Fundamentals of Solid Mechanics	356
7.2.1 Strength and Stiffness of a Structure	356
7.2.2 Stress and Strain	358
7.2.3 Principal Directions	360
7.2.4 Strength and Modulus of a Material	360
7.2.5 Generalized Hooke's Law: Anisotropy	362
7.3 Determinants of the Strength of a Whole Bone	365
7.3.1 Mechanics	365
7.3.2 Examples	367
7.3.3 Mechanical Failure of Whole Bones	371
7.4 Material Properties of Cortical Bone	374
7.4.1 Properties of Individual Secondary Osteons	374
7.4.2 Combined Loading Effects	377
7.5 Summary	378
7.5.1 Effects of Osteons on Cortical Bone Mechanical Properties	380
7.5.2 Anisotropy of Cortical Bone Mechanical Properties	385
7.5.3 Anisotropy Effects Determined by Load-Deformation Testing	385
7.5.4 Anisotropy Effects Determined by Ultrasonic Measurements	387
7.5.5 Determinants of Osteonal Bone Mechanical Properties	389
7.6 Material Properties of Cancellous Bone	399
7.6.1 Stress-Strain Curves for Cancellous Bone	399
7.6.2 Strength in Tension Versus Compression	400
7.6.3 Modeling Cancellous Bone as a Cellular System of Plates or Struts	407
7.6.4 Invariance of Yield Strain Hypothesis	408
7.7 Predicting Material Properties: Bone as a Composite Material	409
7.8 Summary and Additional Reading	410
7.9 Exercises	411
References	414
 Chapter 8. Fatigue and Fracture Resistance of Bone	 423
8.1 Introduction	423
8.2 Basic Fracture Mechanics	425
8.2.1 Linear Elastic Fracture Mechanics	425
8.2.2 Kinds of Cracks	427
8.2.3 Modes of Cracking	428
8.2.4 Maximum Tolerable Flaw Size	431
8.2.5 It Takes Energy to Propagate a Crack	431

8.2.6 Beyond the Linear Theory: Real Cracks Have Ears	432
8.2.7 Beyond the Linear Theory: Real Cracks Are Complicated	434
8.2.8 Crack Growth and Fatigue	437
8.3 Fatigue Behavior of Bone	438
8.3.1 The S-N Curve	438
8.3.2 Fatigue Damage in Bone	439
8.4 Creep Behavior of Bone and Its Relationship to Fatigue	442
8.5 Fatigue Behavior of Fiber-Reinforced Composite Laminates	445
8.5.1 The Birth and Growth of Cracks	445
8.5.2 Material Strength and Fiber Diameter	446
8.5.3 The Road to Failure	447
8.6 Osteonal Bone as a Fibrous Lamellar Composite Material	448
8.6.1 Osteonal Bone's Road to Failure	448
8.6.2 Bone Toughness	451
8.6.3 The Conflict between Strength and Toughness in Bone	452
8.6.4 Controlled Crack Propagation Studies	452
8.6.5 Mathematical Analysis of Osteonal Pullout	453
8.6.6 Comparing Theory with Data	454
8.6.7 Crack Initiation	456
8.6.8 Crack Stopping	457
8.6.9 Strain Rate	457
8.6.10 Effect of Remodeling	458
8.7 Modeling Fatigue Damage Effects in Osteonal Bone	459
8.7.1 Why Would Cracks Be Stopped in Tension But Not in Compression?	461
8.7.2 If Cracks Are Self-Limiting in Tensile Fatigue But Not in Compressive Fatigue, Why Is Fatigue Life Longer in Compression Than in Tension?	462
8.8 The Role of Fatigue in Activating Bone Remodeling	463
8.8.1 Random or Directed Repair	463
8.8.2 The Physiological Basis for Targeted Remodeling	464
8.8.3 Microdamage and Bone Fragility in the Elderly	466
8.9 Modeling Stress Fractures	468
8.10 Summary and Additional Reading	474
8.11 Exercises	475
References	477
Index	483