

PRELIMINARY SYLLABUS – This is not the final syllabus and may change.



BME 404: Orthopaedic Biomechanics

Units: 4

Fall—MW—Two 80-minute lectures per week

Discussion: TBD (one 80-minute lecture per week)

Location: TBD

Instructor: Edward Ebramzadeh Abrams, PhD

Office: DRB 174

Office Hours: Two separate 1 hour sessions

Contact Info: Email: ebramzad@usc.edu, phone number: 213-742-1378, will reply to all emails within a 24-hour timeline

Teaching Assistant: TBD

Office: TBD

Office Hours: TBD

Contact Info: TBD

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Course Description

Mechanical properties of biological tissues, application of statics and dynamics to assess loads within the musculoskeletal structures, and fundamentals of orthopaedic implant performance.

Expanded Course Description

The goals of this course are to introduce the application of classical mechanics for the modelling and solution of an array of problems encountered in orthopaedic surgery and orthopaedic implant evaluation. Using an example-based approach, students will be involved in estimating and analyzing joint loads under different functional activities, while learning biomechanical functions of anatomical structures. Using stress and strain analysis, students will learn to identify and assess mechanisms and causes of fractures. Mechanical principles governing the application of implants for fracture fixation will be covered. Biomechanics of fracture healing and the underlying principles of tissue adaptation will be taught. Principles of joint replacement implant design and evaluation will be covered. The emphasis of the course throughout will be on practical applications in orthopaedic surgery for the evaluation and analysis of implant performance.

Learning Objectives

Upon successful completion of the course the student should be able to:

- Apply principles of mechanics to model loads and motion of biological structures.
- Describe physiological processes that intervene in bone healing and osseointegration of joint implants
- **Describe the market conditions and clinical environment that are taken into account when devising the design of an orthopedic implant**
- **Devise an approach for clinical testing and evaluation of a novel orthopedic device**
- **Analyze the clinical testing approach for an orthopedic implant considering regulatory processes from the FDA, ASTM and ISO**
- Research the orthopedic literature to explain and justify the physiological conditions of operation, design, clinical testing, and regulations of a new orthopedic implant

Pre-Requisite(s): MATH 245 and PHYS 151L

Co-Requisite(s): AME 201 or instructor permission

Recommended Preparation: Basic knowledge of anatomical structures, fundamentals of mechanics of materials including stress-strain relations, and mechanical properties of materials.

Course Notes

This course will be offered on-campus only. Lecture slides, homework, project and discussion-related assignments will be posted on Blackboard. Final grades will be given on a letter-grade basis.

Technological Proficiency and Hardware/Software Required

All students will have access to all materials posted on Blackboard, including course notes, slides, and reading material including literature from the peer-reviewed orthopaedic and biomechanics literature. A key objective of the course is for students to learn how to model physiological loads in natural joints as well as artificial joint prostheses. Students will be expected to review and analyze joint loads from websites and publicly available domains on joint load measurements, using both gait lab studies and instrumented implants. Extensive data to this effect is available from orthoload.com and similar websites. Discussion sections will be held to provide guidance and present clinical examples.

Required Readings and Supplementary Materials

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Notes and slides from the lectures, as well as supplementary readings including peer-reviewed journal articles and textbook chapters will be posted on Blackboard.

The required textbook is: Basic Orthopaedic Biomechanics and Mechano-Biology, 3rd Edition by Van C. Mow and Rik Huiskes, Published by Lippincott Williams and Wilkins. ISBN-13: 978-0781739337

Supplementary materials include: Biomechanics of Musculoskeletal Injury, 1st Edition by William Whiting. ASIN: B01A0CAEQW.

Description and Assessment of Assignments

Homework: Homework assignments will consist of both quantitative and qualitative problems related to topics covered in the lectures, and will be aimed to reinforce the students understanding of the material discussed in the lectures through problem sets and analytical thinking. Some of the homework assignments will be designed for individual assignment, whereas others will be designed for group projects in sets of 3-4 students.

Homework 1: Modeling of joint reaction loads, including set up of simplified assumptions and breakdown of biomechanical functions of each anatomical component.

Homework 2: Identification and analysis of fracture types in long bones using stress analysis.

Homework 3: Evaluation and comparison of different options for fracture fixation implants using stress analysis and knowledge of bone remodeling and fracture healing.

Homework 4: Analysis of variables affecting the performance of joint replacement prostheses including stress shielding, bone remodeling, and risk of dislocation.

Homework 5: Analysis of material selection based on resistance to wear, fundamentals of tribological behavior of prostheses materials, reaction of biological tissues to wear debris.

Students will be evaluated to measure how much they have absorbed from the lectures and the discussion sections by designing additional questions in each homework set. These additional questions will address practical issues related to the experimental work related to in vitro measurements and modeling used in preclinical testing of orthopaedic implants and devices and surgical procedures.

Quiz: Fifteen-minute quizzes will be given every three weeks based on the most recent week or two of lectures.

Exam: There will be two midterm exams and a final exam. Each exam will consist of approximately 50% quantitative problem solving and 50% essay type answers involving reasoning and critical analysis. For the quantitative problems, students will be required to construct models by making simplifying assumptions and defining free body diagrams and use principles of mechanics and stress-strain equations. The essay type questions will challenge the students to reason through analysis of clinical problems and solutions such as proper design or selection of implant material properties, or explain behavior of biological materials. Students who are not able to attend an exam due to medical or emergency reasons must notify the instructor before the exam via email at ebrazad@usc.edu. Makeup exams may be administered if a valid excuse is provided with documentation.

Course Project: Students will be divided into groups of three or four. Each group will be assigned a different topic representing the state of the art in a current topic in orthopaedic biomechanics research. As an initial step each group will be instructed to conduct a literature search to find 5-10 relevant articles from the peer-reviewed literature. Students will be evaluated on the quality of the search strategy and the results. The instructor will designate between 5-10 articles as a basis for their project (which may or may not include those found by the students). The final set of articles will be selected and assigned at Week 8, so that students will be familiar with the technical aspects of the articles, yet still have ample time to complete the project within the semester.

In general, the articles will cover biomechanical modeling and evaluation of implant performance and prosthesis design. For their projects, students will be expected to compare assumptions

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and methodology used in different studies using objective criteria and ideally tabulated and quantitative information extracted from each article. Similarly, students will be expected to compare and combine results from the different studies whenever possible using their own statistical methods and graphical or tabulated information. The purpose of this phase is to encourage students to think critically about the results presented in each study, and to be able to explain differences, if possible, as a function of simplifying assumptions, type and design of each approach, and sources of possible error.

The students will be required to write a 10- to 15-page analysis of the articles following the basic structure of a peer-reviewed journal article. Students will be encouraged to use as much as possible their own graphs, diagrams, tables, and analysis in the document. In addition to the written manuscript, the students will present the project using a PowerPoint presentation to the class. The length of the presentation will be 10 minutes, followed by 5 minutes of discussion with the instructor and the class. Whenever possible, arrangements will be made to invite outside academic scholars for input and stimulation.

Examples of previously completed successful projects topics include:

- Biomechanics of deformity correction in scoliosis surgeries
- Simulation of fretting wear between modular components of total joint replacements
- Simulation of whiplash injuries in cadaver models.

Expected time commitment outside of class: The estimated total time that each student is expected to spend on reviewing course lecture notes and slides and reading additional material, including visitation for office hours and working on homework problems and the project and preparing for midterm exams and presentations, is an average of 8 hours per week.

Grading Breakdown

Grades will be based on: the homework assignments, project, quizzes, midterm exams, and final exam.

Assessment Tool (assignments)	% of Grade
Homework	15
Project	20
Quizzes	20
Midterm Exam I	10
Midterm Exam II	10
Final Exam	20
Participation*	5
TOTAL	

*Participation will be based on interaction during lectures, discussions, and office hours as well as email.

Assignment Submission Policy

Hardcopy results of homework assignments will be due by the indicated due date. PDF versions of project material will be uploaded through Blackboard. In addition, the final project manuscript and the PowerPoint presentation will be uploaded through Blackboard, prior to the presentation date for review and approval by the instructor.

Grading Timeline

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Graded homework assignments will be returned one week and no later than two weeks after the due date. Graded exams will be returned within one or two weeks of each exam. The project report will be graded within two weeks of submission.

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Additional Policies

Email: Students are encouraged to email the professor at any time. All emails will be answered within a maximum of 24 hours.

Late Policy: Homework solutions and final project report should be submitted on time by the due date. Late submissions will be penalized. In cases where homework assignment is solved and answered in class, an appropriate substitute assignment may be assigned if a valid reason for missing the original assignment is provided.

Electronic Devices: Electronic communication devices (i.e., cell phones and iPads) must be turned off or placed away during lectures. Students are prohibited from using messaging apps/programs during class. In addition, no audio or video recording of classroom lectures by the students will be allowed at any time.

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Course Schedule: A Weekly Breakdown

	Lecture Topics	Readings	Deliverables
Week 1	Overview and history of Orthopaedic Biomechanics	Chap 1	
Week 2	Mechanical modeling/ Loads and motions in anatomical structures	Chap 2	Homework 1 Assigned
Week 3	Mechanical consequences of differences in anatomical structures	Chap 3	Homework 1 Due
Week 4	Bone Remodeling: Introduction	Chap 4	
Week 5	Bone Remodeling in Fracture Fixation and Total Joint Replacement	Chap 4 Cont.	Homework 2 Assigned
Week 6	Fracture Fixation and Fracture Healing	Chap 13	Homework 2 Due
Week 7	From concept to market: Design/Development of an Orthopaedic implant <u>Mid-Term Exam #1</u>	Lecture Notes	
Week 8	Orthopaedic Product Evaluation/pre-clinical tests and considerations	Handouts, EA Articles	Homework 3 Assignment
Week 9	Understanding and Interpreting Clinical Outcome	Handouts, EA Articles	Project Assigned; Homework 3 Due
Week 10	Total joint replacement – Historical perspective: Hip/Knee/Shoulder	Chap 14	Homework 4 Assigned
Week 11	Total joint replacement – Advanced topics: Disc Replacements for Spine <u>Mid-Term Exam #2</u>	Chap 12	Homework 4 Due
Week 12	Lubrication, friction and wear – An introduction to tribology of implants	Chap 11, Handouts, EA Articles	
Week 13	Laboratory testing of Orthopaedic devices: ASTM/ISO/FDA Regulatory	Handouts, ASTM/ISO/FDA	Homework 5 Assigned
Week 14	Principles of Experimental Design	Handouts, EA Articles	Homework 5 Due
Week 15	Project Presentations**	Articles	Project Reports Due, Project Presentations
FINAL			Refer to the final exam

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	<u>Final Exam</u>		schedule in the USC Schedule of Classes at classes.usc.edu .
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**** There are typically 30-35 students in the class placed in 8-10 groups, so with each presentation taking a maximum of 15 minutes including questions and discussion, we can fit all presentations in two 80-minute lecture periods.**

Discussion Sections

All of the Discussion sessions will be led by the course instructor (Dr. Abrams). The Discussion Sections will be interactive with participation of the students, but Dr. Abrams will lead every session to guide the students.

In general, the Discussion Sections are aimed at accomplishing the following goals:

- (1) Enhancing course lectures: The lectures for this class are multi-disciplinary drawing from anatomy, physiology, statics, strength of materials, stress analysis, materials and biomaterials, and mechanical design. Therefore, with a mix of students with different backgrounds and strengths in different areas, there are always an array of questions and issues that present themselves. In the past these have been partially addressed during office hours; however, this has obvious limitations, particularly with regard to length of time and accessibility for students (not all students can make office hours regularly). Therefore, an extended dedicated discussion section that is formally committed and accessible to all students on a regular basis will enhance the course tremendously.
- (2) Providing and exposing students to hands on experience and dealing with practical problems: While the field of orthopaedic biomechanics draws from basic mechanics and clinical sciences, the nature of the field is highly practical and to a large extent, experimentally based. For the majority of undergraduate students, this is uncharted territory and requires training and guidance to provide the best educational experience.
- (3) Providing an interactive environment for students: The material will include state of the art results of research and development in orthopaedic implants and orthopaedic surgeries. Therefore, it is educationally valuable for students to assess the levels of evidence provided for recent technologies and learn to critically evaluate its design.

The instructor will lead the entire discussion section, with the TA present to provide additional in-class support. It is estimated that students will spend two out-of-class hours a week to complete additional designated study materials that relate to the topics covered in the discussion sections.

	Lecture Topics	Discussion Topics
Week 1	Overview and history of Orthopaedic Biomechanics	Musculoskeletal anatomy review

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Week 2	Mechanical modeling/ Loads and motions in anatomical structures	Free body diagrams and equilibrium review
Week 3	Mechanical consequences of differences in anatomical structures	Load distributions in biomechanical structures
Week 4	Bone Remodeling: Introduction	Review of Wolfe’s Law
Week 5	Bone Remodeling in Fracture Fixation and Total Joint Replacement	Review of research in bone remodeling
Week 6	Fracture Fixation and Fracture Healing	Demonstration and discussion of fracture fixation methods
Week 7	From concept to market: Design/Development of an Orthopaedic implant Mid-Term Exam #1	Midterm Review
Week 8	Orthopaedic Product Evaluation/pre-clinical tests and considerations	Demonstration and hands on presentation of preclinical experiments
Week 9	Understanding and Interpreting Clinical Outcome	Discussion of clinical examples
Week 10	Total joint replacement – Historical perspective: Hip/Knee/Shoulder	Demonstration and hands on presentation of implant designs
Week 11	Total joint replacement – Advanced topics: Disc Replacements for Spine Mid-Term Exam #2	Midterm Review
Week 12	Lubrication, friction and wear – An introduction to tribology of implants	Discussion of biomaterials and implant material selection
Week 13	Laboratory testing of Orthopaedic devices: ASTM/ISO/FDA Regulatory	Examples of ASTM, ISO, and FDA documentation and requirements
Week 14	Principles of Experimental Design	Discussion of sample size estimation, choice of relevant variables
Week 15	Project Presentations	Final Exam Review
FINAL		

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards”

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policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press “0” after hours – 24/7 on call

studenthealth.usc.edu/sexual-assault

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity | Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
uscsa.usc.edu

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101

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diversity.usc.edu

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

dps.usc.edu, emergency.usc.edu

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call

dps.usc.edu

Non-emergency assistance or information.