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Exploration and Implementation of Medical-Engineering Interdiscipline Teaching Cases in the Biomechanics Curriculum

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Abstract

Biomechanics, a core component of biomedical engineering curricula, is an interdisciplinary field formed by the integration of mechanics, biology and medicine, and acts as a foundational discipline for cultivating interdisciplinary trained medical-engineering professionals. Traditional biomechanics instructional approaches mainly adopt theoretical lectures and classical mechanics case studies. To satisfy the complex, innovation-driven requirements of modern healthcare technology, interdisciplinary medical-engineering teaching cases must be incorporated into curriculum reform. Taking finite element analysis of knee joint biomechanics as a representative case, this paper proposes a systematic implementation framework for interdisciplinary medicine-engineering integrated case teaching in biomechanics courses. This paper analyzes the instructional design principles and implementation procedures, further integrates virtual simulation experiments, and summarizes feasible optimization strategies. This study provides a reference for the curriculum reform of biomechanics and the pedagogical practice of medical-engineering integration.

Keywords

Biomechanics, Medical-Engineering Integration, Case-Based Teaching, Curriculum Reform, Finite Element Analysis

1. Introduction

Driven by the implementation of the "Healthy China" strategy and the rapid

development of medical device and rehabilitation engineering industries, societal demand for high-level interdisciplinary professionals integrating medical and engineering knowledge has grown steadily. As a fundamental discipline that investigates the mechanical behaviors and underlying mechanisms of living systems (Li et al., 2024), biomechanics inherently acts as a bridge between medical science and engineering. Nonetheless, current biomechanics teaching in most universities is confronted with several challenges: the curriculum generally prioritizes engineering fundamentals (Ding et al., 2020), while often neglecting clinical relevance, and lacks an effective integration of medical and engineering perspectives. Engineering students generally do not possess a comprehensive understanding of clinical requirements, whereas medical students often encounter challenges when engaging with abstract mechanical models and engineering methodologies. In this context, transforming real clinical problems into intuitive teaching cases to reform traditional instructional modes (Bai et al., 2022) is essential for improving biomechanics teaching quality and cultivating high-caliber interdisciplinary medical-engineering professionals.

2. Design Interdisciplinary Teaching Cases for Medical-Engineering

The foundational principles for designing interdisciplinary medical-engineering teaching cases in biomechanics education was established in this study, as detailed below.

1) Authenticity and innovation. Each teaching case is derived from specific clinical and biomechanical problems, covering orthopedic implants, cardiovascular diagnosis, sports injury and rehabilitation, cellular mechanics and other related domains (Pottle, 2019). Emerging technologies, including 3D-printed bone prostheses, wearable sensing devices and surgical robots, are incorporated into case-based course design to guarantee the timeliness and advancement of the curriculum system. These practical cases guide students to carry out targeted analysis and independent inquiry.

2) Integration. Each case organically integrates fundamental medical theories including anatomy, physiology, and pathology with engineering techniques such as mechanical principles, numerical simulation, materials science, and electronic engineering. This integrated approach allows students to analyze clinical phenomena from an engineering perspective, and formulate engineering optimization strategies in accordance with actual clinical requirements.

3) Feasibility and difficulty. Case complexity and required analytical techniques should fall within students' capacity or be attainable via team-based collaboration. Furthermore, cases shall be arranged in multiple grades of difficulty to support both the consolidation of fundamental knowledge and the cultivation of advanced interdisciplinary competencies.

3. Implementation of Typical Teaching Cases

3.1. Clinical Background and Multidisciplinary Knowledge Preparation

Using knee joint biomechanics finite element analysis as a typical teaching case, this study explores a systematic implementation pathway including research background, teaching design principles, implementation procedures and feasible countermeasures.

1) Clinical Background: Osteoarthritis modifies the mechanical microenvironment of the knee joint (Zhu et al., 2024), giving rise to clinical demand for unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA) (Smith et al., 2017). Core research question: How can a personalized finite element model of the knee joint be constructed based on medical imaging data, and how can the stress distribution of the knee joint under different motion postures be analyzed to provide a theoretical foundation for prosthetic design and surgical planning?

2) Multidisciplinary knowledge preparation: From a clinical medical perspective, this encompasses the anatomy structure of the knee joint (including osseous tissue, articular cartilage and ligaments), pathological alterations of knee osteoarthritis and related clinical challenges. From an engineering perspective, this involves the reviewing of continuum mechanics and the fundamentals of the finite element method, as well as mastering basic operational skills for medical imaging (CT/MRI) processing software (e.g., Mimics) and finite element analysis software (e.g., Abaqus, Ansys) (Innocenti et al., 2014).

3.2. Phased Task-Driven Implementation

1) 3D Reconstruction: Using knee CT and MRI images of obtained from volunteer (see **Figure 1**), we performed image segmentation and intensity thresholding in specialized software such as Mimics to reconstruct three-dimensional geometric models of anatomical structures such as the femur, tibia, meniscus, ligament, cartilage.

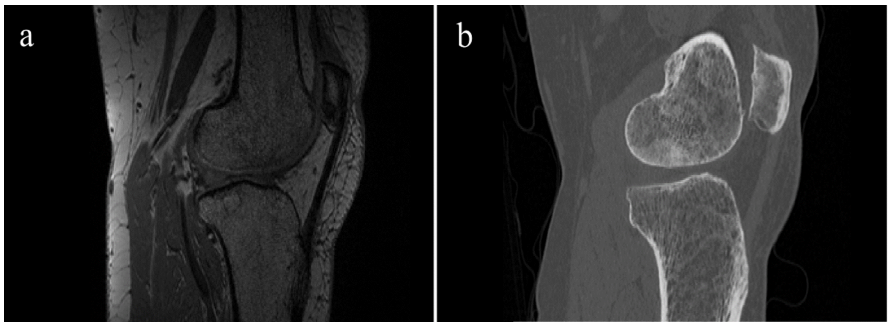

Figure 1. MRI image and CT image of the knee joint.

2) Model preprocessing: The geometric model is imported into 3D modeling

software for surface smoothing, and subsequently exported to finite element analysis software for mesh generation. To balance the trade-off between finite element calculation accuracy and solution time, different mesh sizes were used for various tissues and anatomical regions. Set the grid size to 1mm and 0.8 mm. The tetrahedral mesh is divided into a total of 248,345 elements. In this teaching session, predefined material parameters (see **Table 1**) for biological tissues including bone, meniscus, ligament and cartilage (Bendjaballah et al., 1995; Donahue et al. 2002) are provided to students.

Table 1. Material properties of various tissues in the knee joint finite element model (Ma, 2025; Liang, 2021).

Tissue	Material property	Parameters
Cortical bone	Linear isotropic elastic	Young's modulus (E) = 17 GPa; Poisson ratio (ν) = 0.33
Cancellous bone	Linear isotropic elastic	Young's modulus (E) = 0.4 GPa; Poisson ratio (ν) = 0.33
Cartilage	Linear isotropic elastic	Young's modulus (E) = 5 MPa; Poisson ratio (ν) = 0.46
Meniscus	Linear elastic, transversely isotropic	Circumferential modulus (E_θ) = 125 MPa, radio modulus (E_R) = axial modulus (E_Z) = 27.5 MPa, shear modulus ($G_{\theta R}$, $G_{\theta Z}$) = 2 MPa, G_{RZ} = 10.34 MPa Poisson ratios: $\nu_{\theta R}$, $\nu_{\theta Z}$ and ν_{RZ} are 0.1, 0.1 and 0.33
Ligaments	Isotropic hyperelastic	ACL C_{10} = 5.83 MPa, D = 0.00683 MPa^{-1} PCL C_{10} = 6.06 MPa, D = 0.0041 MPa^{-1} MCL C_{10} = 6.43 MPa, D = 0.00126 MPa^{-1} $LCLC_{10}$ = 6.06 MPa, D = 0.00126 MPa^{-1}

3) Setup of loads and boundary conditions. Students are required to review the relevant literature and utilize real clinical data to determine the joint loads (axial compressive load of 1000 N and anterior tibial load of 134 N are applied) and boundary conditions (the distal tibia was fixed at its inferior surface) for typical human movement scenarios, including mid-stance during standing and walking. Contact pairs are defined between soft tissues and soft tissues, and between soft tissues and bony structures: 6 pairs of contact pairs are constructed between the femoral/tibial cartilage and the meniscus.

4) Solution and post-processing: The finite element simulation was performed, followed by extraction and visualization of von Mises stress and equivalent strain distribution contours on both the joint contact surfaces and the solid components (Peña et al., 2006).

5) Data analysis and reporting. Each group analyzed the stress concentration regions and displacement distribution characteristics of the knee joint, then investigated their correlations with common clinical complications (such as cartilage abrasion and ligament tears) (Kedgley et al., 2019), and finally compiled the complete experimental reports. **Figure 2** presents a schematic illustration of the finite element analysis workflow for the knee joint.

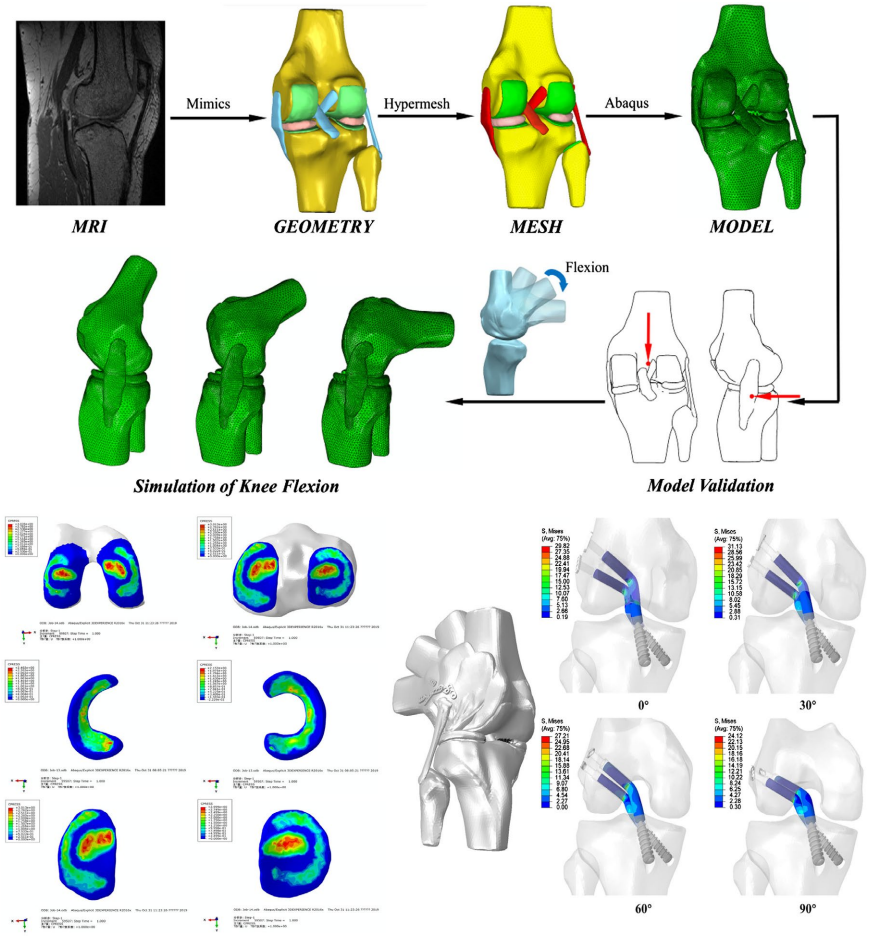

Figure 2. Schematic illustration of finite element analysis process for the knee joint.

6) Clinical application case analysis: The application of unicompartmental knee joint replacement and the finite element analysis of artificial ligaments (see Figure 3) can both extend the above-mentioned finite element analysis process to enable further calculations.

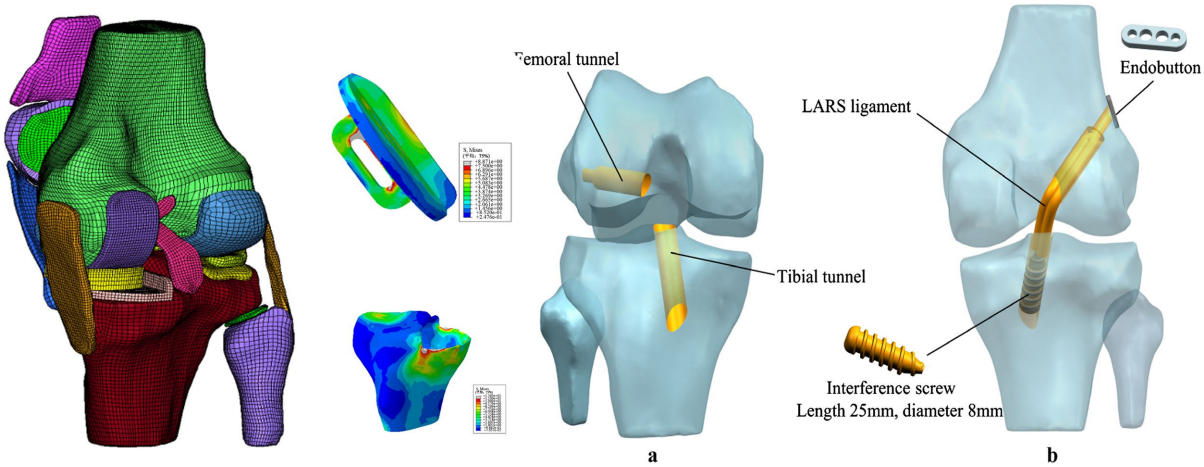

Figure 3. Schematic representation of the finite element analysis procedure for UKA and artificial ligament reconstruction.

The course is currently in a pilot phase and is open to undergraduate students majoring in biomedical engineering in 2026. The class has 20 students, divided into four groups, each consisting of two students with a medical background and two students with an engineering background.

3.3. Assessment and Evaluation

Shift the assessment paradigm from a single-examination approach to an integrating formative and summative evaluation. Formative assessment focuses on students' task completion, teamwork competency, and software operation proficiency across multiple learning stages, accounting for 40% of the total score. Summative assessment is graded based on students' final complete experimental reports, model quality and presentation performance, and accounts for 60% of the total course score. Figure 4 presents a schematic illustration of the experimental test report and the scoring criteria for knee joint assessment. The scoring criteria for each step of the operation are all available. There are a total of 15 scoring points.

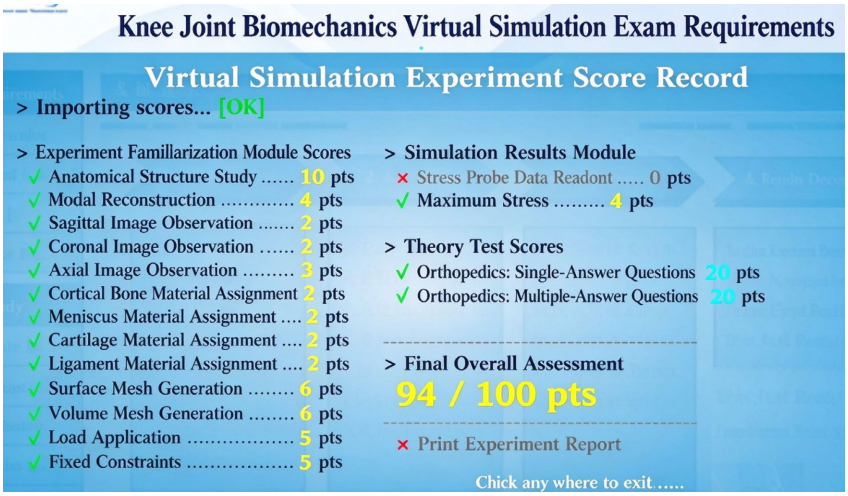

Figure 4. Schematic illustration of the experimental test report and scoring criteria for knee joint assessment.

4. Challenges and Countermeasures in Case-Based Teaching

1) Heterogeneity of student knowledge levels. Strategy: implement interdisciplinary collaboration by grouping students from biomedical engineering and medical disciplines to enable knowledge complementarity and promote academic exchange. Simultaneously, a modular image processing, basic knowledge of mechanics, modular knowledge base of anatomical structure repository was established to support self-paced learning that adapts to students' personalized requirements.

2) Limited by available teaching resources and class hours. Strategy: the software and numerical simulation platform are fully utilized. The teaching module based on the finite element analysis case of the knee joint serves as supplementary resources for the course. Most of the practical activities are completed outside of class time, while class time is mainly devoted to learning the composition, structure and bio-

mechanical properties of bones, cartilage, menisci, and ligaments, in-depth study of stress relaxation, creep and other issues, and conducting group discussions and question-and-answer sessions.

3) Challenges facing the teaching faculty. Strategy: the teaching team invited clinical physicians and engineers to serve as part-time instructors and participate in case design and teaching activities. The teacher participated in academic exchange programs at medical institutions and industry enterprises.

4) Development of the teaching case database. Strategy: regular updates of case resources shall be implemented based on technological advancements, student feedback and clinical findings, and corresponding research outputs shall be converted into teaching cases.

5. Conclusion

Integrating interdisciplinary teaching cases into biomechanics curricula acts as an effective facilitator for transforming theoretical knowledge into practical professional competencies. This pedagogical approach enables students to acquire hands-on practice with the entire workflow, ranging from identifying clinical demands to developing engineering solutions, within a numerically simulated research and engineering environment. Through specifically designed cases, rigorously implemented frameworks, and diversified evaluation forms, students' practical abilities are expected to be enhanced, with anticipated benefits. The integration of high-quality teaching cases into classrooms will be continuously promoted to steadily improve the quality of biomechanics curriculum development and interdisciplinary talent cultivation.

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Author Contributions

Gaiping Zhao: Writing original draft, Software, Methodology, Formal Analysis, Conceptualization, Data curation. Eryun Chen: Writing original draft, Software, Investigation, Validation. Wentao Yan: Writing review and editing. Jie Wu: Writ-

[1] https://vlab.usst.edu.cn/xnfz/cms/c_87.html?id=17

ing review and editing, Supervision. Weiqi Li: Conceptualization, Supervision. Zhan Zhao: Writing review and editing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Bai, T., Jiang, W., Chen, Y., & Li, Y. (2022). "Biomechanics Innovation and Practice" Course Construction and Practice-Exploration of Science-Education Integrated Teaching. *Education and Teaching Forum, No. 24,* 108-111. (In Chinese)

Bendjaballah, M., Shirazi-Adl, A., & Zukor, D. (1995). Biomechanics of the Human Knee Joint in Compression: Reconstruction, Mesh Generation and Finite Element Analysis. *The Knee, 2,* 69-79. https://doi.org/10.1016/0968-0160(95)00018-k

Ding, H., Yang, G., & Lu, J. (2020). Teaching Problems and Teaching Methods Reform of Biomechanics Course. *Education Teaching Forum, No. 16,* 212-213. (In Chinese)

Donahue, T., Hull, M. L., Rashid, M. M., & Jacobs, C. R. (2002). A Finite Element Model of the Human Knee Joint for the Study of Tibio-Femoral Contact. *Journal of Biomechanical Engineering, 124,* 273-280. https://doi.org/10.1115/1.1470171

Innocenti, B., Bilgen, Ö. F., Labey, L., van Lenthe, G. H., Sloten, J. V., & Catani, F. (2014). Load Sharing and Ligament Strains in Balanced, Overstuffed and Understuffed UKA. A Validated Finite Element Analysis. *The Journal of Arthroplasty, 29,* 1491-1498. https://doi.org/10.1016/j.arth.2014.01.020

Kedgley, A. E., Saw, T., Segal, N. A., Hansen, U. N., Bull, A. M. J., & Masouros, S. D. (2019). Predicting Meniscal Tear Stability across Knee-Joint Flexion Using Finite-Element Analysis. *Knee Surgery, Sports Traumatology, Arthroscopy, 27,* 206-214. https://doi.org/10.1007/s00167-018-5090-4

Li, W., Zhao, G., & Zhang, P. (2024). Exploration on the Reform of Hybrid Experimental Teaching Methods in Biomechanics. *Open Journal of Social Sciences, 12,* 123-131. https://doi.org/10.4236/jss.2024.122008

Liang, P. (2021). *Finite Element Study on the Biomechanical Properties of the Anterior Cruciate Ligament after Reconstruction of the Knee Joint*. Master's Thesis, University of Shanghai for Science and Technology.

Ma, J. (2025). *Biomechanical Characteristics Study of Unicompartmental Knee Arthroplasty under Gait Cycle*. Master's Thesis, University of Shanghai for Science and Technology.

Peña, E., Calvo, B., Martínez, M. A., & Doblaré, M. (2006). A Three-Dimensional Finite Element Analysis of the Combined Behavior of Ligaments and Menisci in the Healthy Human Knee Joint. *Journal of Biomechanics, 39,* 1686-1701. https://doi.org/10.1016/j.jbiomech.2005.04.030

Pottle, J. (2019). Virtual Reality and the Transformation of Medical Education. *Future Healthcare Journal, 6,* 181-185. https://doi.org/10.7861/fhj.2019-0036

Smith, W. B., Steinberg, J., Scholtes, S., & Mcnamara, I. R. (2017). Medial Compartment Knee Osteoarthritis: Age-Stratified Cost-Effectiveness of Total Knee Arthroplasty, Unicompartmental Knee Arthroplasty, and High Tibial Osteotomy. *Knee Surgery, Sports Traumatology, Arthroscopy, 25,* 924-933. https://doi.org/10.1007/s00167-015-3821-3

Zhu, S., Qu, W., & He, C. (2024). Evaluation and Management of Knee Osteoarthritis. *Journal of Evidence-Based Medicine, 17,* 675-687. https://doi.org/10.1111/jebm.12627