Overcoming barriers to interdisciplinary research in engineering and orthopaedic surgery

Cite this article:
Bone Joint Res 2025;14(9):
791–794.

DOI: 10.1302/2046-3758.
149.BJR-2024-0444.R1

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Engineering is at the heart of trauma and orthopaedic practice. By leveraging the knowledge, skills, and expertise from orthopaedic surgery and engineering, innovative solutions can improve the efficacy and risk profile of orthopaedic treatments, and improve patient care by reducing intraoperative trauma, improving surgical ergonomics, or enhancing the precision and accuracy of procedures through improving surgical planning, instrumentation, or implant design.[1]

This article discusses the common challenges to effective research collaboration and suggests solutions, including effective team design, research infrastructure, resources, and practical considerations to facilitate improved collaboration, research dissemination, and translation. While some barriers to successful interdisciplinary research and innovation are situation-specific,[2] this article focuses on universal challenges applicable to all research teams.

Strategies for effective collaboration: communication

A successful and sustainable collaboration between engineers and orthopaedic surgeons relies on a shared goal and common vocabulary. Effective communication enables researchers to share responsibilities, with clinicians guiding problem identification and engineers leading solution development. Together, they can design studies to evaluate solutions ready for clinical application.[3]

Identifying, defining, and communicating the research problem

Clinical orthopaedic problems are complex and require a systematic approach to identify root causes. Key factors can include: complex clinical pathologies (e.g. patient anatomy, disease aetiology), clinical team dynamics (e.g. communication, staff mix, training), device limitations (e.g. design, capabilities, or technique), the clinical care environment, or often a combination of these variables. An engineering perspective can help to analyze or to resolve the problem.

To optimize research resources, clinically important and solvable problems must be clearly defined as tangible research questions. An evidence-based medicine (EBM) approach can enhance interdisciplinary communication and help conceptualize complex clinical issues. A well-formed research question should include a clear problem statement, a defined population, and a measurable outcome. The Stanford Biodesign Program "Needs Statement" may be useful: "A way to address a **problem** for a specific **population** to achieve a desired **outcome**", e.g. "A way to increase total hip replacement stability for adult osteoarthritis patients, to reduce the incidence of dislocation" (Problem statement 1).[4] Investigators should avoid prematurely proposing

a solution, as this can limit the range of possible solutions and hinder effective communication.

Stakeholder engagement strategies

To maximize efficiency and research relevance, Boaz et al[5] outlined strategies for engaging stakeholders in research. Key stakeholders should ideally include the 7Ps: 1) patients and public, 2) providers, 3) purchasers, 4) payers, 5) policymakers (including non-governmental advocates), 6) product makers, and 7) principal investigators.[6] Effective stakeholder engagement should begin early and be actively maintained throughout the research process. While many examples of stakeholder engagement in research exist, Beneciuk et al[7] successfully engaged a diverse stakeholder group in musculoskeletal (MSK) pain research using the Patient-Centered Outcomes Research Institute (PCORI) engagement rubric to develop research infrastructure and capacity.[8]

Identifying a suitable solution

Awareness among orthopaedic surgeons of engineering approaches can help to identify suitable solutions to clinical problems. Engineering spans various disciplines and sub-specialisms, of which mechanical, materials, electrical, chemical, mechatronics, software, robotics, and biomedical offer relevant expertise to orthopaedic surgery. Orthopaedic engineering laboratories have an engineering focus and specialize in a subset of technical skillsets, including but not limited to, mechanical testing, computer-aided design (CAD), finite element analysis (FEA), motion capture, 3D musculoskeletal simulation, programming, image segmentation, 3D printing, and AI and machine learning (ML) applications.[9] Solving clinical problems may require a combination of technical skillsets.

Research questions can be approached clinically or through engineering. For example, for problem statement 1: patients with greater postoperative hip motion have a higher dislocation risk.[10] A clinical study may test different cup sizes,[11] while an engineering study could offer an explanation for the clinical observation, e.g. study the influence of altering cup size on bone-implant micromotion, or offer a solution to the problem, e.g. to design an optimized implant to improve implant stability.[12]

Disseminating interdisciplinary research

Effective research dissemination is crucial for scientific progress and impact, ensuring that bioengineering studies reach the appropriate audience and that research findings are clear and understandable for clinicians to facilitate translation into clinical practice. Dissemination can include academic journal publications and presentations at academic meetings. Journals that encourage interdisciplinary research, such as *Bone & Joint Research*, are essential for reaching both clinical and engineering audiences, supported by cross-disciplinary co-authorship. To ensure that bioengineering research is accessible to both clinicians and scientists, articles should provide a clear summary of clinically relevant findings, avoid complex engineering terminology without compromising scientific rigour, and include commentaries on the quality of the research.[13-15] If the engineering methodologies are novel, methodological details can be concurrently published in specialized engineering journals. In addition to academic journal publications, infographics, podcasts, and videos are becoming increasingly important to engage a wider audience.

Intellectual property, including patents for novel methods, techniques, or products (or a combination thereof), plays a key role in advancing bioengineering research. As publishing novel research precludes patenting, securing intellectual property should be considered before publishing research to prevent patenting issues.

Strategies for effective collaboration: infrastructure and funding

Successful interdisciplinary research collaboration requires effective communication, and institutional and government support to foster collaborations between orthopaedic surgeons and engineers. Shared spaces should be established to facilitate collaboration, by enabling frequent interactions with open and ongoing feedback between orthopaedic clinical and engineering teams; this approach has been shown to improve collaborations.[16] Institutionally, not-for-profit organizations (e.g. AO Foundation), engineering research labs within clinical settings (e.g. the Hospital for Special Surgery (HSS) research institute), or universities should establish cross-appointed faculty to lead hospital-based labs.

To address the major challenge of high clinical workload,[17] government level funding support from research councils, such as the Medical Research Council (MRC) (UK) and National Institutes of Health (NIH) (USA), and industry is essential to enable orthopaedic surgeons to engage in research. Strong leadership is also crucial in cultivating a research culture that is based on mutual respect and an understanding of each field's unique challenges.

Strategies for effective collaboration: national/international opportunities

Orthopaedic research groups can facilitate orthopaedic surgeon and engineer collaborations through annual meetings/conferences, fellowships, and targeted meetings that include both orthopaedic surgeons and engineers. These organizations may also support research through funding, research dissemination through associated journals, and courses. Most organizations are region-specific, for example the British Orthopaedic Research Society (UK), European Orthopaedic Research Society (Europe), Orthopedic Research Society (USA), Canadian Orthopedic Research Society (CORS), Australian Orthopaedic Association (AOA), New Zealand Orthopaedic Association (NZOA), and South African Orthopaedic Association (SAOA).

Knowledge translation

The goal of clinical research is to translate research findings into routine clinical practice. Relevant expertise, either directly or through translational teams within universities and certain healthcare organizations, can provide crucial guidance to ensure compliance with complex regulatory frameworks. Medical device regulatory bodies and requirements vary geographically and according to the device class.[18] We will discuss three medical device markets: the USA, the European Union (EU), and the UK. In the USA, the Food and Drug Administration (FDA), through its Quality System Regulations, oversees the development and surveillance of medical devices.[19] In the EU, obtaining a Conformité Européenne (CE)

mark from the European Medicine Agency (EMA) permits use of a medical device. Previously, in the UK, conformity with Medicines and Healthcare products Regulatory Authority (MHRA) regulations used to result in CE marking of a medical device. However, following the withdrawal of the UK from the EU and the latest reforms of the EU Medical Device Regulation,[20] there is no longer harmony between these regulatory standards.[21] Therefore, medical devices in the UK are regulated by the MHRA,[22] with implant manufacturers encouraged to engage with the 'Beyond Compliance' framework where applicable.[23] This adds a layer of 'red tape' and delays the availability of new technologies to the UK market. Finally, it has been suggested that the IDEAL framework (Idea, Development, Exploration, Assessment, and Long-term study) based on MRC recommendations,[24] should be adopted for the development and surveillance of surgical innovations.[25,26] New devices, processes, or technologies can be licensed or co-developed with industry partners, who can provide regulatory expertise and scalability for rapid clinical translation.

Successful examples: interdisciplinary collaboration

Two successful examples of collaboration between orthopaedic surgeons and engineers, which have led to innovative solutions that have advanced clinical practice, include the Oxford Knee and the Exeter Hip. The Oxford Knee is a partial knee replacement device originally designed by orthopaedic surgeon Professor John Goodfellow and engineer Professor John O'Connor, to minimize wear of the polyethylene mobile bearing and to reduce stresses through the implant bone interfaces.[27,28] Today, the Oxford Knee is the most widely used partial knee replacement in the world. Another notable example is the Exeter Hip, which was designed by orthopaedic surgeon Professor Robin Ling and engineer Professor Clive Lee.[29] Today, the Exeter Hip continues to provide reproducible improvements in clinical outcomes for total hip arthroplasty patients.[30]

In conclusion, interdisciplinary research collaborations between orthopaedic surgeons and engineers can drive innovative solutions that advance orthopaedic practice. To ensure a successful collaboration, effective communication, infrastructure, and adequate funding are required to create opportunities to foster national and international partnerships. Engineers and orthopaedic surgeons must understand each other's fields to develop a shared vocabulary for effective communication. While many challenges remain, this article highlights key strategies and solutions to overcome these barriers, to promote productive and sustainable collaborations and effective knowledge translation to advance orthopaedic care.

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A. H. R. W. Simpson: Supervision, Writing – review & editing, Conceptualization.

Funding statement

The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement

C. E. H. Scott is PI on an institutional grant from Stryker, and reports consulting fees from Stryker, Smith & Nephew, and Osstec, and payment for teaching on courses from Stryker, all of which are unrelated to this work. C. E. H. Scott is also Editor-in-Chief of *Bone & Joint Research*, a member of the editorial board for *The Bone & Joint Journal*, a member of the Data Safety Monitoring Board for the PASHION study, and a member of the advisory boards for Osstec and Smith & Nephew. A. H. R. W. Simpson holds a leadership or fiduciary role in the International Society of Fracture Repair and International Orthopaedic Research Societies, and participates on the Data Safety Monitoring Board or Advisory Board of the PART Trial. S-T. J. Tsang reports payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events from Bonesupport, unrelated to this work, and is a member of the editorial board of *Bone & Joint Research*, the executive committee of the Bone and Joint Infection Registry, and the research committee of the Bone and Joint Infection Society. I. Yang reports a discovery grant from NSERC, royalties or licences from Sydney Children's Hospital Network, and a patent for an orthopaedic device for correction of deformities in a bone, all of which are unrelated to this work. I. Yang is also a Specialty Editor for *Bone & Joint Research* and a committee member of the International Section for Fracture Repair.