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The Bethel Musculoskeletal Research Center (BMRC) BioBank: Establishing a Standardized, Reproducible Platform for Basic, Translational, and Clinical Musculoskeletal Research

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1 | Introduction

Impactful orthopaedic translational research requires large, reliable datasets that integrate molecular, imaging, and clinical information to enable accurate diagnosis, prognosis, and treatment decisions. Currently, most academic orthopaedic programs lack large-scale musculoskeletal (MSK) databases and standardized infrastructure necessary to achieve this integration, limiting the scope and capacity to perform robust translational research. Lack of comprehensive and standardized MSK datasets often leads to study findings that are difficult to reproduce or compare across institutions. The true value of surgical biospecimens depends not only on rigorous collection and processing, but also on a governed infrastructure linking each specimen to the patient's full clinical, imaging, and molecular data record. A dedicated MSK tissue bank is essential to this vision, as banked surgical biospecimens are the source material from which molecular and multi-omics data, including genomic, transcriptomic, and proteomic profiling, are generated. Capturing these specimens within a governed platform that links each molecular readout to the patient's imaging and electronic health record (EHR)-derived clinical data elevates a tissue repository from passive storage into a vehicle for translational discovery. Standardized, integrated biobanking platforms designed around the operational realities of academic orthopaedic programs represent a critical unmet need.

Here, we introduce the Bethel Musculoskeletal Research Center (BMRC) BioBank created at the University of Pittsburgh Department of Orthopaedic Surgery. It is a musculoskeletal biobanking platform built for standardization, reproducibility, and scalability across orthopaedic subspecialties. This report introduces a forthcoming three-paper series in the *Journal of Orthopaedic Research* offering practical guidance for MSK BioBank development and deployment.

2 | Methods

The BMRC BioBank is structured around three integrated and independently replicable domains: governance, operations, and data. *Governance* establishes the institutional foundation through Institutional Review Board (IRB)-approved consent, material transfer and data use agreements, as well as Health Insurance Portability and Accountability Act (HIPAA)-compliant infrastructure. Governance defines the biospecimen science rationale by specifying the tissue types collected across subspecialties, the specific processing protocols used, and the pre-analytical variables captured to preserve downstream analytical validity. *Operations* execute biospecimen collection and processing through standard operating procedure (SOP)-driven workflows with defined quality control (QC) thresholds and a three-tier specimen grading system applied at the point of collection, ensuring consistent quality across surgical cases and collection sites. *Data* integrates biospecimen metadata, longitudinal EHR-derived clinical data, Digital Imaging and Communications in Medicine (DICOM) imaging, and prospective multi-omics and molecular datasets within a secure, cloud-based research enclave, with surgical encounters serving as the central anchor for cross-domain linkage (Figure 1).

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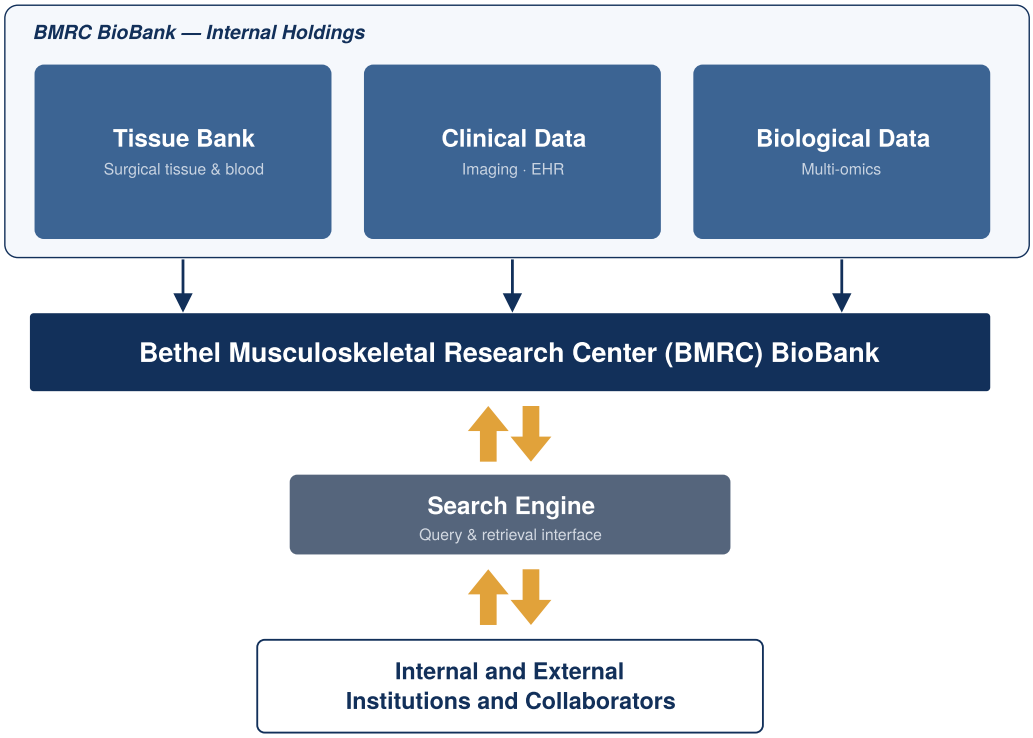


FIGURE 1 | Architecture of the BMRC BioBank. Three internal domains involving a tissue bank (surgical tissue and blood), clinical data (imaging and electronic health record [EHR] data), and biological data (multi-omics) feed into the unified BMRC BioBank. A search engine enables bidirectional query and retrieval, linking the repository to internal and external institutions and collaborators. BMRC, Bethel Musculoskeletal Research Center; EHR, electronic health record.

3 | Results

The BMRC BioBank is fully operational across spine, joints, hand and upper extremity, foot and ankle, and pediatric orthopaedics. SOP-driven workflows have produced a growing repository of intraoperative tissue and blood biospecimens linked to longitudinal clinical records, perioperative imaging, and prospective molecular datasets. Since collection began in October 2024, and as of August 7, 2026, the BMRC BioBank has enrolled 502 patients (266 females, 236 males; mean age 60.9 years) and banked 17,929 aliquots (7540 tissue and 10,389 blood). This cohort includes a pediatric orthopaedic arm at the University of Pittsburgh Medical Center (UPMC) Children's Hospital of Pittsburgh, which has contributed 22 pediatric patients and 409 banked aliquots across spine, joints, hand, and foot and ankle cases. These biospecimens are linked to longitudinal EHR-derived clinical records and 1110 imaging studies, supporting cross-domain analyses without manual reconciliation. Over approximately 22 months since its inception, the BioBank has accrued biospecimens at a sustained pace of roughly 270 patients and nearly 10,000 aliquots per year. With current enrollment accelerating to approximately 7 patients per week, the repository is on track to reach a 1000-patient cohort by the end of 2027 or early 2028. This volume reflects a scale and velocity of collection that distinguishes the BMRC BioBank from most single-center musculoskeletal biobanks, which typically bank specimens on the order of dozens to hundreds per year.

Automated pipelines process and organize data within the BMRC BioBank, enabling investigators to build study cohorts reliably and reproducibly. Users can access integrated data through managed virtual environments that keep data within the secure enclave while using their preferred analysis tools and statistical software. Furthermore, investigators from academic and nonacademic institutions have already requested specimens and data across multiple orthopaedic subspecialties, from broad cohort to targeted inquiries. For example, one collaborator is analyzing the entire banked dataset for genomic and epigenomic characterization while another collaborator is interested in rare skeletal disorders in pediatric patients, showing that the linked tissue–data architecture supports both narrow and dataset-wide analyses.

4 | Discussion

This work introduces a forthcoming three-paper series in the *Journal of Orthopaedic Research*. Paper 1 (governance) presents the regulatory, legal, and biospecimen science framework underpinning the program. Paper 2 (operations) describes the two-phase collection and processing model, pairing a dedicated facilitator with a centralized biospecimen core. Paper 3 (data) details the secure, cloud-based infrastructure linking biospecimens to EHR, imaging, and molecular data for reproducible cohort construction.

The BMRC BioBank demonstrates that standardized, integrated musculoskeletal biobanking is achievable within an academic orthopaedic program. Its design integrates governance, operations, and data into one replicable system. Because each domain was built with replicability in mind, other academic orthopaedic

programs can adopt this platform directly using the relevant SOPs, a core metadata schema, and baseline infrastructure requirements, rather than building these frameworks from scratch. The structured, scalable data model also positions the BioBank for interoperability and multi-site collaboration, enabling biomarker discovery, imaging-pathology correlation, and precise orthopaedic research at scale.

Large integrated biobanks outside the musculoskeletal field, such as the UK Biobank and the National Institutes of Health All of Us Research Program, have shown how linking biospecimens to longitudinal clinical, imaging, and molecular data can aid in discovering associations and therapeutic targets that fragmented datasets cannot. The BMRC BioBank extends this model to orthopaedics. By coupling banked tissue and blood with imaging data and EHR-derived clinical trajectories, the platform enables studies such as our ongoing work to create a comprehensive surgical frailty score in collaboration with other research centers at the University of Pittsburgh. Analyses of this kind, which require specimens, imaging, and clinical outcomes to be pre-linked at scale, are impractical without governed, integrated infrastructure.

With regard to funding, the BMRC BioBank was established through a dedicated $18.5 million philanthropic gift from the Orland Bethel Family Foundation in 2024, within a center created by an earlier $25 million foundation gift matched by the University of Pittsburgh School of Medicine. In January 2026, an additional $53.5 million commitment, which brought the foundation's total giving to approximately $100 million, expanded the center's research, innovation, and training programs, including endowed professorships and leadership funds that help underwrite long-term operations. This combination of a dedicated launch gift, institutional co-investment, and endowed support constitutes a funding model intended to sustain collection and infrastructure well beyond inception.

Beyond the implementation details provided in this series, a subsequent study will evaluate replicability across additional academic orthopaedic centers through structured peer review and will additionally catalog the manuscripts that have cited or drawn on the BioBank, classify their principal findings, and report on the growth of the repository at that time. This series is intended to serve as a foundational, reproducible model for orthopaedic biobanking and to catalyze harmonized, multi-institutional research. We invite the orthopaedic research community to engage through external validation, data sharing, and collaborative implementation.

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