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BONE QUALITY

Forward: A Fresh Look at Measuring and Altering Bone Quality

Matthew R. Allen[1,2,3]

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Abstract This special issue of Clinical Reviews in Bone and Mineral Metabolism presents a series of review articles on how bone quality is measured and how it is altered by intervention. These articles highlight the great progress that has been made over the past three decades to define and study bone quality. The stage is now set to harness these concepts of bone quality for development of new approaches to strengthen the skeleton and reduce fracture risk.

Keywords Imaging · Finite element modeling · Reviews · Bone mechanics · Mechanical properties

The phrase 'bone quality' has been used for over 30 years to describe properties that contribute to a bones' fracture resistance. In 1993, a group organized by the National Institutes of Health developed the working definition of bone quality as 'the material, architectural, and mechanical characteristics which, in addition to bone mass, contribute to bone strength'. A simpler definition that captures this same idea is that bone quality and bone mineral density (BMD) together dictate the mechanical properties of a bone. Yet to this day, there remains ambiguity/confusion around the phrase. 'Bone quality everything you can't measure that relates to fracture risk' is a fairly common statement made by those not intimately working in the area. While this may have been true 30 years ago, it could not be further from the truth today as we move from an era of defining bone quality to an era of modifying bone quality as an approach to reducing musculoskeletal burden. In this special issue of Clinical Reviews in Bone and Mineral Metabolism, we present a series of review articles on how bone quality is measured and how it is altered by intervention.

Bone quality encompasses numerous aspects of the tissue and organ. The most straightforward property is architecture/geometry, measures of how the bone material is organized. At a micro-/nanoscale, properties of the mineralized phase (level and degree of heterogeneity as well as crystal size/shape), the organic phase (collagen organization, cross-linking, and proteoglycan levels), tissue damage, and hydration all fall under the umbrella of bone quality. While we have a solid understanding and capacity to measure some of these variables, others prove more challenging. In the opening article of this special issue, Dr. Eve Donnelly and co-authors provide a clear and concise overview of methods used to measure bone quality—highlighting those that are well established as well as those that necessitate further exploration.

The advancement of various imaging modalities has allowed both clinical and preclinical studies to move beyond BMD as an outcome measure and has been a major factor in advancing an understanding of bone quality. These have yielded a wealth of data showing that trabecular architecture and cortical geometry provide additional information with respect to bone mechanical properties that are not captured by BMD. An important application of these architecture/geometry data is that they can be used to produce finite element analyses (FEA) for studying bone

✉ Matthew R. Allen
matallen@iupui.edu

[1] Department of Anatomy and Cell Biology, Indiana University School of Medicine, 635 Barnhill Dr., MS 5035, Indianapolis, IN 46202, USA

[2] Department of Biomedical Engineering (Adjunct), Indiana University Purdue University of Indianapolis, Indianapolis, IN, USA

[3] Roudebush Veterans Administration Medical Center, Indianapolis, IN, USA

mechanical properties. This has brought forth the concept of patient-specific assessments of estimated mechanical properties—an exciting aspect of work that has high potential as the field moves toward personalized medicine. In this issue, Dr. Richard Abel and co-authors review some of the key aspects of 3D imaging, specifically focused on synchrotron, and how they have advanced the field of bone quality, while Dr. Chris Hernandez and co-authors review work related to FEA and how it incorporates and offers insight into bone quality.

Much of our knowledge about bone quality has come from studying how it is changed with treatment. A number of studies using bone-targeting drugs have used specific aspects of bone quality as outcome measures. An overview of how drugs affect properties of mineral and collagen is provided by Dr. Adele Boskey and her co-authors. Other pharmacological intervention studies have more indirectly assessed on bone quality by measuring bone mechanical properties. By using traditional mechanical approaches to test bones, and then adjusting for differences in bone mass and organization, estimates of material properties, which can be thought of as bone quality, can be derived. These studies are reviewed in the article by Dr. David Burr. Finally, a review by Dr. Joey Wallace and his co-author summarizes how non-pharmacological intervention, specifically exercise, alters bone quality as assessed by both specific measures and mechanical assessment of material properties.

The editorial team would like to thank the authors for their contribution to this special issue. As evident by these articles, great progress has been made over the past three decades to define and study bone quality. The stage is now set to harness these concepts of bone quality for development of new approaches to strengthen the skeleton and reduce fracture risk.

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Compliance with ethical standards

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