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Hajar Razi, Ph.D.
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Professional Profile

Dr. Razi is an expert in biomaterials, tissue engineering, regenerative medicine, and advanced bioinspired materials, with a versatile background spanning biomedical engineering, mechanical engineering, and materials science. Her published research encompasses computational modeling, medical implant development, and pre-clinical experimental studies. Among her key projects are the optimization of 3D-printed titanium scaffolds for large segmental bone regeneration, advanced numerical modeling for predicting fracture mechanisms, and the creation of sustainable, bioinspired materials with metal-like fracture resistance. She has partnered with clinicians, engineers, and industry leaders to transition complex products from prototype to market, leveraging her expertise in imaging, numerical modeling, and translational medicine.

Regenerative Medicine and Tissue Engineering

Dr. Razi's research in the regenerative medicine field centers on how physical stimulations influence bone adaptation throughout aging. Utilizing advanced imaging, including time-lapsed microCT and synchrotron CT together with computational modeling, she has revealed age-related disruptions in bone remodeling, uncovering that specific strain levels crucial for bone maintenance become ineffective as bones age. Her novel FEA models capture these effects in dynamic bone adaptation, offering insights for clinical interventions. In collaboration with surgeons and clinicians, she has developed patient-specific mechanobiologically-optimized, 3D-printed titanium scaffolds for large bone defects. These devices are now used in clinical settings and have shown to be successful in promoting bone regeneration.

Novel Material Design and Sustainable Bioinspired Material Development

Dr. Razi has also pioneered a computational framework for predicting fracture mechanisms in hierarchical materials inspired by naturally tough structures like bone and nacre. This framework, grounded in high-fidelity finite element analysis, provides a detailed understanding of crack propagation and fracture energy dissipation in complex material systems. This methodology serves as a powerful tool for material design, applicable across multiple industries that require enhanced mechanical robustness.

At ETH Zurich and Swiss Federal Laboratories for Materials and Technologies, Dr. Razi combined FEA, wet-lab techniques, and mechanical testing with advanced imaging to develop and characterize the fracture properties of densified cellulose laminates. Drawing inspiration from nature, her work has led to the development of sustainable bio-based composites with toughness rivaling that of metals, achieved through multiple concurrent toughening mechanisms. Her findings hold promise for environmentally friendly, high-performance alternatives that meet both durability and sustainability demands in industrial applications.

Dr. Razi is proficient in English and German.

Academic Credentials & Professional Honors

Ph.D., Engineering Science, Technical University of Berlin, 2015

M.Sc., Biomedical Engineering, Aachen University of Applied Sciences, 2010

B.Sc., Mechanical Engineering, University of Tehran, 2004

European Research Council, Marie Sklodowska-Curie Post-doc Fellowship, 2019 - 2023

Career Mentor, Technical University of Berlin, 2017-2018

Best PhD student award: European Society of Biomechanics 2013

Conference award: European Society of Biomechanics 2014

Young Scientist Prize: Traumatology/Orthopedics in 39 Berliner Chirurgentreffens 2014

Elsbeth Bohnhoff Foundation Research Grant 2013

Virtual Physiological Human Network of Excellence Grant 2012

ECTS PhD Studentship Grant 2010

Academic Appointments

Teaching and lectures:

> Mechanical Characterization of Biological Materials by means of Finite Element Modeling, Technical University of Berlin, WS and SS 2019
>
> Damage and its evolution in materials: Computational Science Investigation for Material Mechanics, ETH Zurich, WS and SS 2021-2022
>
> Bone: Mechano-adaptation, Healing, Tissue Material Behavior and A Means of Bio-inspiration, Terasaki Institute, 2023

Prior Experience

Principal Investigator, Swiss Federal Laboratories for Materials and Technology, ETH Zurich, Switzerland, 2021 – 2025

Group Leader, Technical University of Berlin, Germany, 2020 – 2021

Lead Scientist, Max Planck Institute of Colloids and Interfaces, Germany, 2016 – 2021

Research Scientist, Charite Medical School of Berlin, Germany, 2009 – 2016

Professional Affiliations

Materials Research Society

European Society of Biomechanics

German Society of Biomechanics

European Society for Calcified Tissue

American Society for Bone and Mineral Research

Orthopedic Research Society

Max Planck Society

German Society for Material Science

DKOU German Congress for Orthopedics and Traumatology

Virtual Physiological Human Network of Excellence

Publications

S Amini, T Zhu, H Razi, E Griesshaber, P Werner, P Fratzl. In operando 3D mapping of elastic deformation fields in crystalline solids. Matter 2024; 7 (7), 2591-2608

D Weimann, C Fleck, H Razi. Marginal integrity in minimally invasive molar resin composite restorations: Impact of polymerization shrinkage. Journal of the mechanical behavior of biomedical materials 2024; 155, 106554

M Razi, AS Cherati, H Dadgostar, K Ahadi, H Razi, S Razi, M Soleimani. Arthroscopic-Assisted Posterolateral Corner Reconstruction of the Knee: Novel Technique, Classification, Surgical Algorithm, and Midterm Results. Arch Bone Jt Surg. 2024;12(11): 746-753

T Volders, L Zorzetto, H Razi, R Weinkamer, D Ruffoni. Designing Architectured Materials with Tunable Damage Behavior Inspired by Osteonal Bone. Imparting Intelligence in and Through Self-Learning Materials and Structures 2022

Q Chen, H Razi, CM Schlepütz, C Fang, X Ma, B Fei, I Burgert. Bamboo's tissue structure facilitates large bending deflections. Bioinspiration & Biomimetics 2021; 16 (6), 065005

M Frey, L Schneider, H Razi, E Trachsel, E Faude, SM Koch, K Masania, ...High-performance all-bio-based laminates derived from delignified wood. ACS Sustainable Chemistry & Engineering 2021; 9 (29), 9638-9646.

D Weimann, A Morgenthal, F Schwendicke, C Fleck, H Razi. Substantial regional differences in the biomechanical behavior of molar treated with selective caries tissue removal technique: A finite element study. Dental Materials 2021; 37 (3), e162-e175

AF Van Tol, V Schemenz, W Wagermaier, A Roschger, H Razi, I Vitienes, ...The mechanoresponse of bone is closely related to the osteocyte lacunocanalicular network architecture. Proceedings of the National Academy of Sciences 2020; 117 (51), 32251-32259

S Amini, H Razi, R Seidel, D Werner, WT White, JC Weaver, MN Dean, ...Shape-preserving erosion controlled by the graded microarchitecture of shark tooth enameloid. Nature Communications 2020. 11 (1), 5971

B Javaheri, H Razi, S Gohin, S Wylie, YM Chang, P Salmon, PD Lee, ...Lasting organ-level bone mechanoadaptation is unrelated to local strain. Science Advances 2020; 6 (10), eaax8301

H Razi, J Predan, FD Fischer, O Kolednik, P Fratzl. Damage tolerance of lamellar bone. Bone 2020; 130, 115102

A van Tol, V Schemenz, W Wagermaier, H Razi, P Fratzl, R Weinkamer. Journal of Bone and Mineral Research 2019; 34, 81-82

A van Tol, V Schemenz, W Wagermaier, A Roschger, H Razi, I Vitienes, ...Relationship between the fluid flow pattern through the lacunocanalicular network and adaptive mechano-response in mouse tibia. Springer-Verlag 2019

B Javaheri, H Razi, M Piles, R de Souza, YM Chang, I Maric-Mur, ...Sexually dimorphic tibia shape is linked to natural osteoarthritis in STR/Ort mice. Osteoarthritis and Cartilage 2018; 26 (6), 807-817

J Nunez, A Goring, B Javaheri, H Razi, D Gomez-Nicola, E Hesse, ...Regional diversity in the murine cortical vascular network is revealed by synchrotron X-ray tomography and is amplified with age. European cells & materials 2018; 35, 281-299

AM Pobloth, S Checa, H Razi, A Petersen, JC Weaver, K Schmidt-Bleek, ...Mechanobiologically optimized 3D titanium-mesh scaffolds enhance bone regeneration in critical segmental defects in sheep. Science translational medicine 2018; 10 (423), eaam8828

M Paris, A Götz, I Hettrich, CM Bidan, JWC Dunlop, H Razi, I Zizak, ...Scaffold curvature-mediated novel biomineralization process originates a continuous soft tissue-to-bone interface. Acta biomaterialia 2017; 60, 64-80

FD Fischer, O Kolednik, J Predan, H Razi, P Fratzl. Crack driving force in twisted plywood structures. Acta biomaterialia 2017; 55, 349-359

AI Birkhold, H Razi, GN Duda, S Checa, BM Willie. Tomography-based quantification of regional differences in cortical bone surface remodeling and mechano-response. Calcified tissue international 2017;100, 255-270

M Razi, AS Cherati, H Dadgostar, K Ahadi, H Razi. Arthroscopic-assisted posterolateral corner reconstruction of the knee: Our technique, classification, surgical algorithm, and midterm results. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation 2016.

AI Birkhold, H Razi, GN Duda, R Weinkamer, S Checa, BM Willie. The periosteal bone surface is less mechano-responsive than the endocortical. Scientific reports 2016; 6 (1), 23480

H Razi, AI Birkhold, R Weinkamer, GN Duda, BM Willie, S Checa. Aging leads to a dysregulation in mechanically driven bone formation and resorption. Journal of Bone and Mineral Research 2016; 30 (10), 1864-1873

H Razi. An in silicio study of age-related changes in the mechanical regulation of bone adaption, 2015

AI Birkhold, H Razi, R Weinkamer, GN Duda, S Checa, BM Willie. Monitoring in vivo (re) modeling: a computational approach using 4D microCT data to quantify bone surface movements. Bone 2015; 75, 210-221

H Razi, AI Birkhold, P Zaslansky, R Weinkamer, GN Duda, BM Willie, S Checa. Skeletal maturity leads to a reduction in the strain magnitudes induced within the bone: a murine tibia study. Acta biomaterialia 2015; 13, 301-310

H Razi, AI Birkhold, M Zehn, GN Duda, BM Willie, S Checa. A finite element model of in vivo mouse tibial compression loading: influence of boundary conditions. Facta Universitatis, Series: Mechanical Engineering 2014; 12 (3), 195-207

AI Birkhold, H Razi, GN Duda, R Weinkamer, S Checa, BM Willie. The influence of age on adaptive bone formation and bone resorption. Biomaterials 2014; 35 (34), 9290-9301

AI Birkhold, H Razi, GN Duda, R Weinkamer, S Checa, BM Willie. Mineralizing surface is the main target of mechanical stimulation independent of age: 3D dynamic in vivo morphometry. Bone 2014; 66, 15-25

BM Willie, AI Birkhold, H Razi, T Thiele, M Aido, B Kruck, A Schill, ...Diminished response to in vivo mechanical loading in trabecular and not cortical bone in adulthood of female C57Bl/6 mice coincides with a reduction in deformation to load. Bone 2013; 55 (2), 335-346

A Birkhold, H Razi, R Weinkamer, S Checa, G Duda, B Willie. Trabecular bone Adaptation declined Asymmetrically with Aging: a 3D Dynamic in vivo Morphometry Study. Journal of Bone and Mineral Research 2012; 28

A Birkhold, H Razi, G Duda, S Checa, B Willie. Cortical bone Adaptation is greater at the Metaphysis than Diaphysis. Journal of Bone and Mineral Research 2012; 28

H Razi, S Checa, KD Schaser, GN Duda. Shaping scaffold structures in rapid manufacturing implants: a modeling approach toward mechano-biologically optimized configurations for large bone defect. Journal of Biomedical Materials Research Part B: Applied Biomaterials 2012; 100.

H Razi, S Checa, A Birkhold, B Willie, G Duda. The reduced Response of Bone to In vivo Loading in Adulthood is concurrent with a Shift in Strains. Journal of Biomechanics 2012, S103.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Global and site-specific adaptation of cancellous bone to in vivo loading. Journal of Biomechanics 2012, S97.

H Razi, A Birkhold, GN Duda, BM Willie, S Checa. Cortical bone in adult mice exhibits lower strain levels at remodeling sites compared to young mice. European Society of Biomechanics 2012.

Presentations

Razi H, J Predan, O Kolednik, P Fratzl. Modulating Intrinsic Brittleness Impacts Damage Mechanisms in Bioinspired Lamellar Materials. MRS Fall Meeting, Boston, 2024

Razi H, Fratzl P, Ding Y, Ciabattoni B, Masani K, Beciri V, Peterlik H, Burgert I. Bio-inspired toughening mechanisms in densified delignified wood laminates. MRS Fall Meeting, Boston, 2024.

Razi H, Fratzl P, Ding Y, Ciabattoni B, Masani K, Beciri V, Peterlik H, Burgert I. Bio-inspired toughening mechanisms in architectured densified wood laminates. International Conference on Mechanics of Biomaterials and Tissues, Hawaii, 2023

Razi H, J Predan, O Kolednik, P Fratzl. Intrinsic constituent brittleness determines crack and damage mechanisms in bioinspired lamellar architectured materials. International Conference on Mechanics of Biomaterials and Tissues, Hawaii, 2023

Razi H, J Predan, O Kolednik, P Fratzl. Crack and Damage Propagation in Lamellar Bone, Congress of the European Society of Biomechanics, Vienna, July 2019.

H Razi, S Checa, A Birkhold, B Willie, G Duda. Strain Levels Initiating the Targeted Adaptive Response of Bone to Load are Similar Between Ages, World Congress for Biomechanics, Boston, July 2014.

H Razi, S Checa, A Birkhold, B Willie, G Duda. Cortical bone in adult mice exhibits lower strain levels at remodelling sites compared to young mice, 19th Congress of the European Society of Biomechanics, Podium presentation, Patras, Greece, August 2013. ESB student award winner

AM Pobloth, H Razi, A Petersen, JC Weaver, K Schmidt-Bleek, Duda G. Rekonstruktion segmentaler Knochendefekte durch mechanobiologisch modulierte, Laser-gesinterte Titan-Mesh-Scaffolds. 39 Berliner Chirurgentreffens.

H Razi, S Checa, A Birkhold, B Willie, G Duda. Adaptive response of diaphyseal bone to mechanical loading spatially relates to local strains with higher threshold in periosteum than endosteum, Proceedings of the 11th International Symposium, Computer Methods in Biomechanics and Biomedical Engineering, Podium presentation, 2013, Salt Lake City, Utah, USA.

H Razi, S Checa, A Birkhold, B Willie, G Duda. Endosteal bone is more mechanoresponsive than periosteal bone at the tibial diaphysis, Deutschen Kongress fuer Orthopaeadie und Unfallchirurgie, Podium presentation, Berlin, Germany, October 2013.

H Razi, S Checa, A Birkhold, B Willie, G Duda. The reduced response of bone to in vivo loading in adulthood is concurrent with a shift in strains. Podium. European Society of Biomechanics Conference 2012, Lisbon, Portugal. Journal of Biomechanics, Volume 45, Supplement 1, July 2012, Page S10.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Global and site-specific adaptation of cancellous bone to in vivo loading. European Society of Biomechanics 2012, Lisbon, Portugal. Journal of Biomechanics, Volume 45, Supplement 1, July 2012, Page S97.

Razi H. Age-related changes in the mechanical regulation of bone adaptation. European Calcified Tissue Society PhD Training Course 2012, Oxford, UK

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Mechanoregulation of Cortical and Cancellous Bone Adaptation Measured by Correlating Dynamic Bone Morphometry to the Global and Local Mechanical Environment. ASBMR 2012, Minneapolis, United States.

Razi H and Birkhold A et. al. Quantifying the mechanoregulation of bone adaptation by correlating dynamic changes in bone morphology to the local mechanical environment. Computer Methods in Biomechanics and Biomedical Engineering 2012, Berlin, Germany.

Razi M., S. Cherati A., Dadgostar H., Razi H., Ahadi K. Arthroscopic popliteus tendon reconstruction: introduction a novel technique and primary results, Transactions of the 15th ESSKA Congress, Geneva, 2012.

Razi H et. al. Investigation of Different Mesh Configurations in Femoral Laser Sintered Implants, Transactions of the 57th Annual Meeting of the Orthopedic Research Society, Long Beach, CA, 2011.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Aging impairs trabecular bone adaptation to loading: a 3D dynamic in vivo morphometry study, 19th Congress of the European Society of Biomechanics, Podium presentation, Patras, Greece, August 2013.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Cortical Bone adaptation is greater at Metaphysis than diaphysis: a 3D dynamic in vivo morphometry study, ASBMR, Poster, Baltimore, MD, USA, Oct. 2013.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Trabecular bone adaptation declined asymmetrically with aging: a 3D dynamic in vivo morphometry study, ASBMR, Poster, Baltimore, MD, USA, Oct. 2013.

A Birkhold, H Razi, T Thiele, S Checa, G Duda, B Willie. Cortical bone at the metaphysic has greater adaptive response to loading than diaphysis: a 3D dynaic in vivo morphometry study, Proceedings of the 11th International Symposium, Computer Methods in Biomechanics and Biomedical Engineering, Podium, 2013, Salt Lake City, Utah, USA.

Project Experience

- Age-related changes in bone tissue mechano-adaptation: pre-clinical in vivo, in silico study
- Class III patient-specific mechanobiologically-optimized 3D titanium-mesh scaffolds to enhance bone regeneration in large segmental defects: clinical research, development, prototyping, pre-clinical and surgical evaluation.
- Theory of fracture in natural Bouligand (e.g. twisted plywood) structures like bone and nacre
- Stress-shielding in human hip implants implementing gait analysis data and validated lower limb internal forces from hip arthroplasty patients with embedded in vivo biosensors.
- Numerical analysis of Internal Forces of the Lower Limb at High Flexion Angles
- Bio-based bio-inspired cellulose nanomaterials with enhanced mechanical failure properties.
- Failure in rigid vs. plastic adhesives in densified delignified wood.
- Failure in minimal invasive dental restorations especially after resin composite polymerization shrinkage.

Peer Reviews

ACS Nano

MRS Advances

Journal of Biomechanics

Journal of Computer Methods in Biomechanics and Biomedical Engineering

Journal of Computers in Medicine and Biology

Journal of Royal Society Interface

Materials Today

Polymer Testing

Annals of Biomedical Engineering