



PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 39th cycle

**PNRR 118 PA Research Field: PATIENT-ORIENTED SUSTAINABLE ENGINEERED
SOLUTIONS FOR TACKLING BONE FRAGILITY**

Monthly net income of PhDscholarship (max 36 months)

€ 1400.0

In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity

Motivation and objectives of the research in this field

Age-related bone fractures are a major health concern, resulting worldwide in high economic and psycho-social burden, morbidity and increasing mortality. With aging and in presence of bone pathologies, human bone becomes more brittle and prone to damage.

At the macro-scale, the identification of fragility is assured by the clinical practice: common clinical tools, however, are able to predict only 70% of fractures. For this reason, a deep investigation of the bone micro-architecture would be a fundamental hint for the comprehension of damage mechanisms, improving the reliability of fracture risk indicators and performing more accurate diagnosis of bone pathologies.

This knowledge level goes beyond the current state of the art and this is where this doctoral path comes into play, providing multi-disciplinary and transversal strategies for multi-scale comprehension, detection and patient-specific treatments of bone fractures.

The aim of the research is to design novel tailored sustainable solutions for preventing and tackling bone fragility. The adopted multi-disciplinary strategy, combining high-level experimental and numerical approaches, will lead to:

1) the definition of **innovative clinician- and patient-oriented solutions for preventing and mini-invasively treating bone fragility**;

2) the **digital transition** of bone preventive strategies towards the definition of a micro-scale index to be applied



	<p>in clinics;</p> <p>3) the research result valorization in accordance to FAIR principles, via the implementation of an Open Data Repository of anonymized multi-scale bone fragility data;</p> <p>4) a sustainable perspective in tackling bone fragility through the adoption of biodegradable solutions.</p> <p>The research activities will result in a net innovation of public administrations, an improvement of our life quality and will contribute to advances in various scientific and engineering fields.</p>
Methods and techniques that will be developed and used to carry out the research	<p>This research requires a multi-faceted range of methods and techniques to investigate multi-scale fracture phenomena and to translate this understanding to the design of targeted and patient-oriented constructs for bone repair:</p> <ol style="list-style-type: none"> 1. Imaging techniques: micro-computed tomography, synchrotron analyses, scanning electron microscopy are especially useful for identifying multi-scale bone architectural features; 2. Multi-scale mechanical testing to assess bone physio-pathological mechanical properties and construct mechanical response and ability to sustain loads; 3. 3D bio-printing for construct realization, developed in collaboration with TU Eindhoven, where the Doctoral Candidate will spend 6 months; 4. Computational modeling, to simulate bone remodeling within designed constructs, to evaluate damage evolution, weakening and toughening phenomena at the multi-scale, including extended finite element (XFEM) strategies to model fracture progression; 5. Neural network-based strategies for the prediction of bone regeneration and for the translation to the clinics of engineered constructs, in collaboration with Fondazione I.R.C.C.S. Policlinico San Matteo, where the Doctoral Candidate will spend 6 months.
Educational objectives	<p>This cutting-edge research perspective on tailored green solutions for bone repair is a unique opportunity for PhD students to:</p> <ol style="list-style-type: none"> 1. Elucidate the complexity of the multi-scale structure and characteristics of biological materials, as well as the



	<p>fundamental principles governing their response to damage towards sustainable engineered solutions.</p> <p>2. Employ a diverse array of methodologies and approaches, encompassing advanced imaging techniques, mechanical testing, and computational modeling, to investigate and analyze these materials.</p> <p>3. Cultivate critical thinking and problem-solving abilities while nurturing innovation and creativity by providing guidance to doctoral students in the creation of novel bio-inspired structures that exhibit improved mechanical properties.</p> <p>4. Establish interdisciplinary collaboration among students and faculty from various disciplines, including biology, physics, mechanical engineering, and material engineering, to foster cross-pollination of ideas and expertise.</p>
Job opportunities	<p>Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.</p> <p>Cooperating to this research are:</p> <ol style="list-style-type: none"> 1. MIT, Boston - Laboratory for Atomistic and Molecular Mechanics, development of artificial intelligence-based solutions; 2. TU, Delft, bio-inspired material design; 3. Elettra synchrotron, high-resolution real-time imaging of damage.
Composition of the research group	<p>1 Full Professors 0 Associated Professors 1 Assistant Professors 3 PhD Students</p>
Name of the research directors	Laura Maria Vergani

Contacts

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For questions about scholarship/support please contact phd-dmec@polimi.it

Additional support - Financial aid per PhD student per year (gross amount)



Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Fondazione I.R.C.C.S. Policlinico San Matteo
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	TU Eindhoven
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707,13.</p> <p>Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.</p>