Borate bioactive glasses (BBGs) are emerging as a promising group of ceramic biomaterials with potential applications in bone tissue engineering and regenerative medicine. Unlike traditional, well-studied silicate bioactive glasses (SBGs), BBGs offer unique advantages such as a rapid but controlled biodegradability, enhanced bone-bonding ability, and superior tissue regeneration properties. **However, their full potential remains untapped due to limited understanding of their fundamental properties and advanced functionalities.** Firstly, unlike well-studied SBGs, borate glasses, especially those obtained via the sol-gel method, possess a much more complex and less explored structure. Secondly, the molecular mechanisms underlying the bone healing and regenerative activity of BBGs remain poorly understood. Finally, the processing of BBGs into forms suitable for biomedical applications (i.e., fully ceramic 3D structures - scaffolds) has not yet been investigated.

This research project aims to further advance the field of BBG research by:

1. **Unraveling the fundamentals:** investigating the relationship between the chemical composition, structure, and properties of BBGs, including their dissolution behavior and biological response.
2. **Developing innovative 3D structures:** employing advanced techniques like electrospinning and 3D printing to create novel three-dimensional glassy structures with tailored properties.
3. **Understanding biological mechanisms:** exploring the molecular mechanisms underlying the interaction between BBGs and cells, including bone regeneration (osteogenic response) and formation of new blood vessels (angiogenic response) as well as osteoimmunomodulatory properties.

The project will involve the following research activities: (i) Synthesizing a broad spectrum of borate bioactive glasses with varying compositions using a modified sol-gel technique previously developed by the project team. (ii) Comprehensively characterizing the glasses in terms of their structural, morpho-textural, and thermal properties. (iii) Evaluating the glasses in terms of the degree and the rate of ion release and transformation into crystalline phase upon incubation in simulated body fluid and cell culture media. (iv) Conducting *in vitro* biological studies of the glasses on human bone marrow stromal cells, human macrophage cell line, and primary human umbilical vein endothelial cell line to assess osteogenic, osteoimmunomodulatory, and angiogenic responses. (v) Developing electrospun fibers and 3D-printed glassy structures using electrospinning and 3D printing, respectively, in combination with the sol-gel method. (vi) Characterizing the glassy structures in terms of their structural, morpho-textural, thermal, and solubility-related properties, and evaluating their *in vitro* osteogenic, osteoimmunomodulatory, and angiogenic responses.

Through a multidisciplinary approach, combining materials science and advanced molecular biology techniques, we will elucidate the material determinants of borate bioactive glasses that govern immuno-osteo-angiogenic intracellular signaling, essential for creating a bone microenvironment conducive to complete bone healing and regeneration. This will allow the conscious design of bioactive borate glass compositions and morphologies tailored to specific biomedical applications. The findings from this research may have significant clinical implications, enabling the application of BBGs in orthopedics, maxillo-facial surgery, dentistry, and bone tissue engineering. Besides, we anticipate the significant advancements in the field of advanced processing techniques (electrospinning, additive manufacturing), including the development of personalized fully ceramic glassy biomaterials based on promising borate systems.