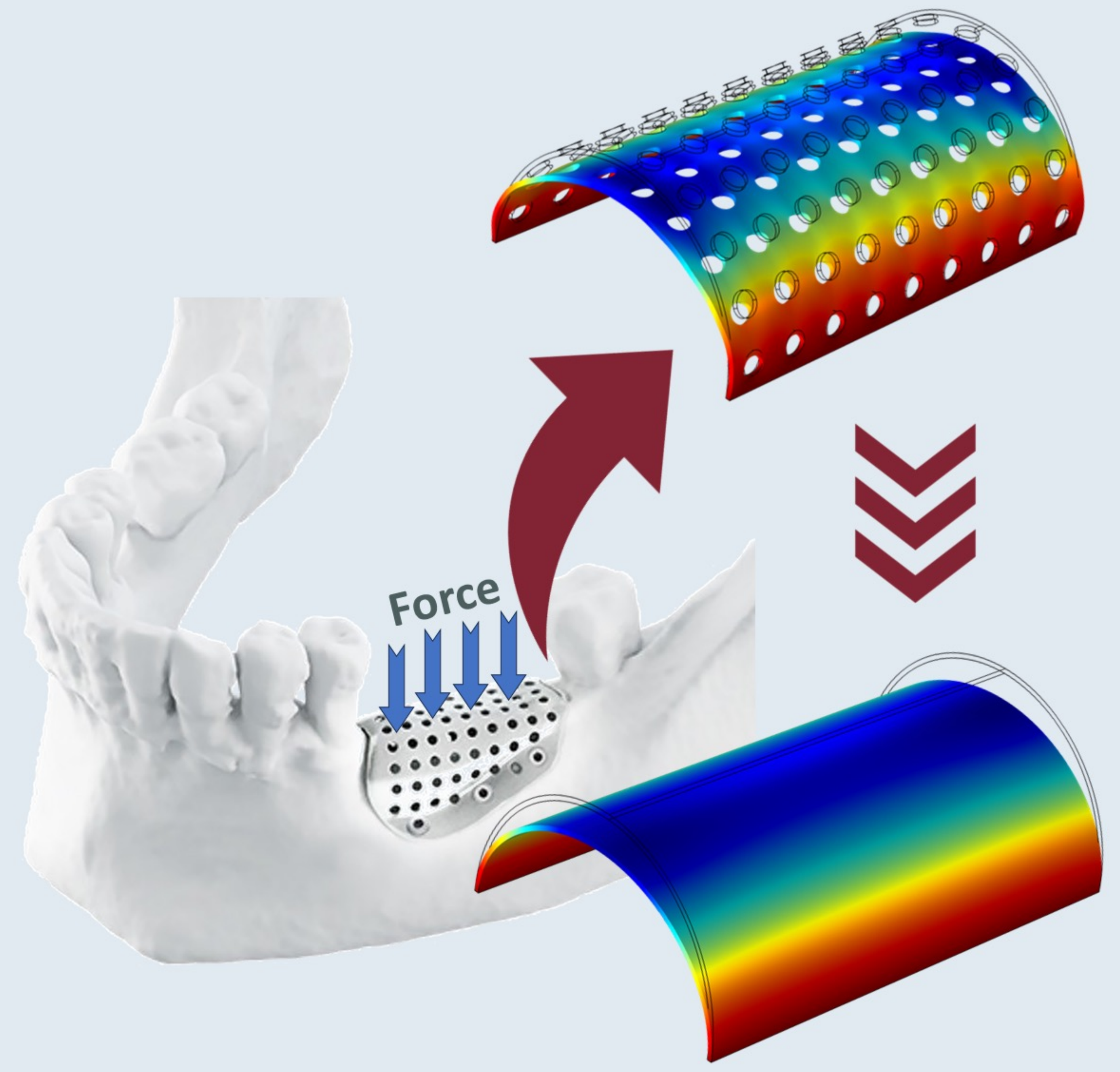

2D and 3D Micropolar FEM Models for Porous GBR Meshes in Dentistry Applications

- Finding effective properties of porous GBR meshes in 2D and 3D using COMSOL®
- 2D and 3D micropolar FEM models based on the found constitutive parameters using PDE weak form in COMSOL®

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Introduction

Guided Bone Regeneration (GBR) meshes are used in dentistry as mechanical barriers to isolate and protect the area of bone loss from the surrounding tissue while allowing new bone growth. The micropolar theory is adopted to provide a homogenized and efficient mechanical model for the heterogeneous porous model of the GBR mesh. The mechanical constants are derived based on the strain energy equivalence of a periodic porous plate with its equivalent micropolar model. The effects of various architectural features such as pore shapes, patterns and sizes on the material parameters are investigated. The results show that the micropolar theory can effectively predict the mechanical response of the GBR mesh with a more reliable performance compared to the classical Cauchy theory. The collected equivalent micropolar parameters are further used for GBR mesh design, considering both mechanical and biomedical requirements.

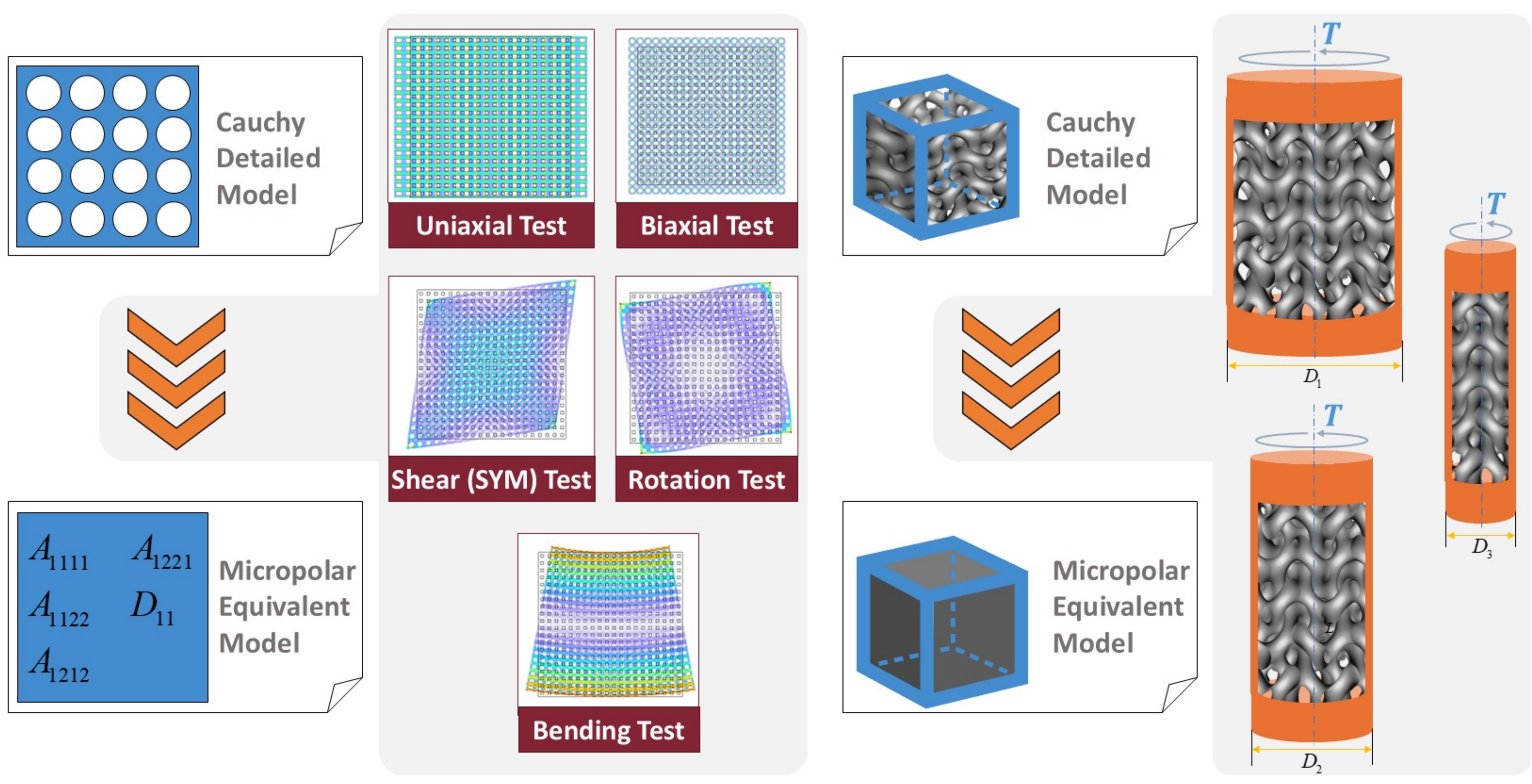

FIGURE 1. Homogenization Procedure for 2D (left) and 3D (right) porous structures to find equivalent micropolar model.

Methodology

Homogenization: For 2D porous structure by equating the strain energy stored in the detailed structure to the equivalent micropolar continuum the corresponding micropolar material parameters are found. In 3D, the size dependency observed in the torsional stiffness of the metamaterial structures, predicted by micropolar theory, is utilized.

FEM Micropolar Model: Governing equations of micropolar theory are implemented using the PDE Weak form in COMSOL® to conduct FE simulations. The developed implementation can account for complex geometry, loading and boundary conditions within a user-friendly interface.

Results

The parametric study of GBR sheets allow us to find a configuration with the material parameters close to the bone. For rectangular pore, by selecting pore size as 0.13 L ~ 0.15 L and porosity about 0.7, a good agreement can be achieved.

Being inspired by the natural functionally graded (FG) porous structure of the bone, a new design is that the central part possesses mechanical properties close to cancellous bone while providing a proper porosity and the part near fixing areas as near as possible to compact bone to provide required load-bearing.

Suggesting an innovative 3D design for GBR scaffolds, where the microstructure evolves from the highly porous structure inside the scaffold to the compact structure at the load bearing surfaces.

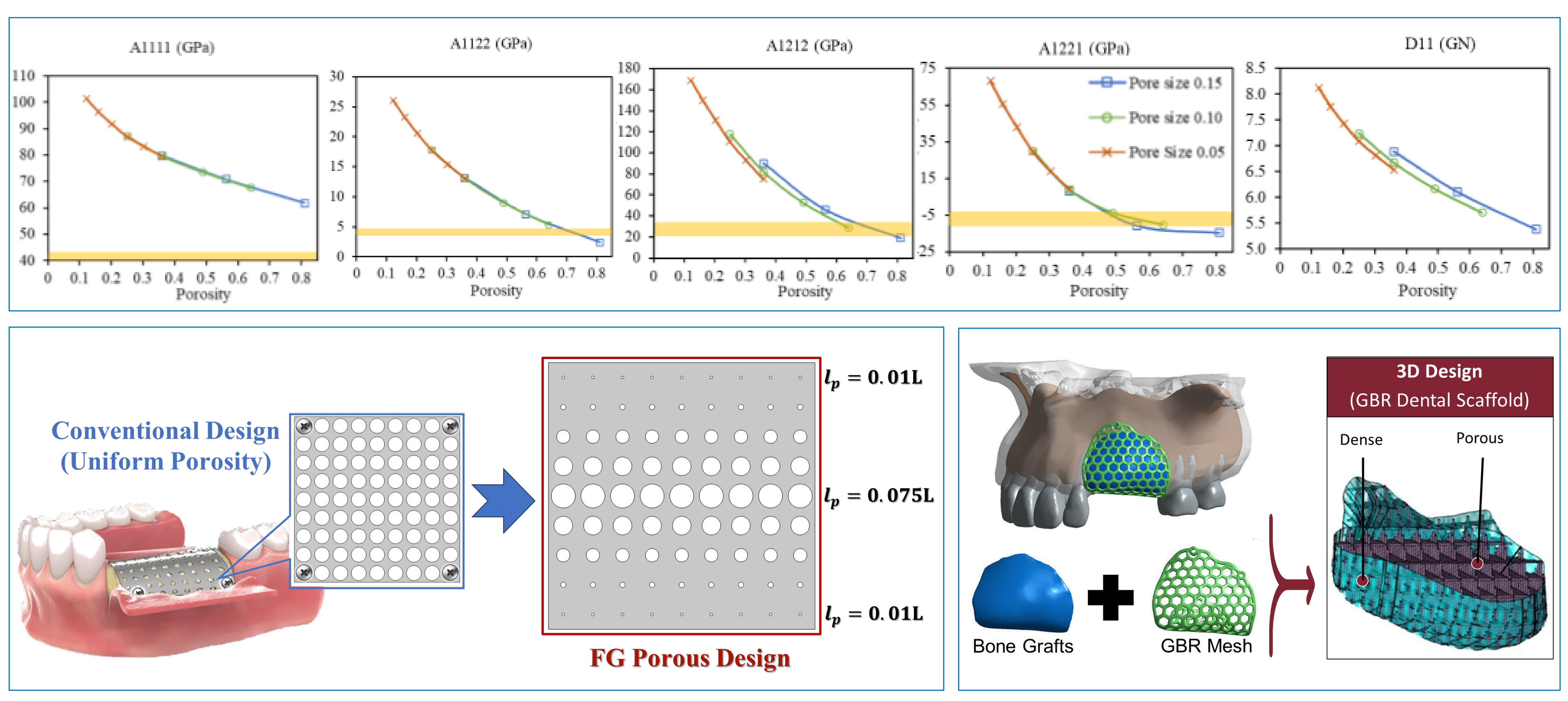

FIGURE 2. Equivalent micropolar parameters for square pores, each dataset for a specific pore size and various number of pores and indicated compact bone's equivalent parameter range (top). Suggested FG porous (Type O) design for GBR mesh (bottom-left). 3D functionally graded design for GBR Meshes (bottom-right).

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