Load-bearing Potential of Carbonised Plant-derived Scaffolds for Bone Grafts

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Abstract:

Modern bone tissue engineering requires scaffolds that replicate the hierarchical and anisotropic microstructure of native bone while ensuring sufficient mechanical strength. This study investigates carbonised scaffolds derived from hardwood (hornbeam, oak) and selected softwood species as biomimetic graft substitutes. Controlled pyrolysis (400–1000°C) preserved the internal plant architecture while converting the organic matrix into a load-bearing carbon structure. Experimental validation using Digital Image Correlation (DIC) and SEM analysis identified hornbeam carbonised at 800–1000°C as the optimal material. These scaffolds achieved a Young's modulus of 5.69 ± 0.76 GPa and flexural strength of 18.97 ± 2.11 MPa, corresponding to human cancellous bone and the lower range of cortical mandibular bone. Current research focuses on developing carbon–polymer composite scaffolds inspired by natural hierarchical structures. 3D models are being designed for additive manufacturing using FDM and SLA technologies, supported by parallel numerical modelling for validation and optimisation. Engineered interconnected channels are incorporated to promote cell

attachment and tissue integration. This integrated approach combines biomorphic characterisation, computational modelling, and composite fabrication to develop advanced, nature-inspired bone graft substitutes for clinical applications.

Keywords:
Biomorphic biochars, DIC analysis, FEM modeling, bone scaffolds, pyrolysis.