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A Mechanobiology-based Algorithm to Optimize the Microstructure Geometry of Bone Tissue Scaffolds

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Abstarc :

Complexity of scaffold geometries and biological mechanisms involved in the bone generation process make the design of scaffolds a quite challenging task. The most common approaches utilized in bone tissue engineering require costly protocols and time-consuming experiments. In this study we present an algorithm that, combining parametric finite element models of scaffolds with numerical optimization methods and a computational mechano-regulation model, is able to predict the optimal scaffold microstructure. The scaffold geometrical parameters are perturbed until the best geometry that allows the largest amounts of bone to be generated, is reached. We study the effects of the following factors: (1) the shape of the pores; (2) their spatial distribution; (3) the number of pores per unit area. The optimal dimensions of the pores have been determined for different values of scaffold Young's modulus and compression loading acting on the scaffold upper surface. Pores with rectangular section were predicted to lead to the formation of larger amounts of bone compared to square section pores; similarly, elliptic pores were predicted to allow the generation of greater amounts of bone compared to circular pores. The number of pores per unit area appears to have rather negligible effects on the bone regeneration process. Finally, the algorithm predicts that for increasing loads, increasing values of the scaffold Young's modulus are preferable. The results shown in the article represent a proof-of-principle demonstration of the possibility to optimize the scaffold microstructure geometry based on mechanobiological criteria.

Key Word :
Numerical Optimization; Mechanobiology; Scaffold Microstructure; Mechano-regulation Algorithm.

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