EXPLORATION OF HYDROGEL TISSUE SCAFFOLDS TO IMPROVE THE BIOMECHANICS OF OSTEOPOROTIC BONE

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Introduction

Osteoporosis is a skeletal disease characterised by low bone mineral density, loss in bone architecture, and reduced stiffness which results in high fracture risk [1]. Reports show that 8.9 million fractures occur annually due to fragility [2]. Risk of death is increased by 10% - 20% due hip fractures in women [3], therefore, total hip replacement (THR) is often used but it has some problems regarding aseptic loosening, periprosthetic fractures, and inflammations [4]. Figure 1 shows conventional and novel treatments highlighted in a recent review which shows that hydrogel tissue scaffolds impregnated with stem cells, drugs, and growth factors show promising biological impact on the osteoporotic bones [4]. However, the effect of hydrogels on the mechanical function of osteoporotic (OP) bone has not yet been investigated. This study aims to investigate feasibility of improving mechanical properties and biological regeneration using hydrogel tissue scaffolds.

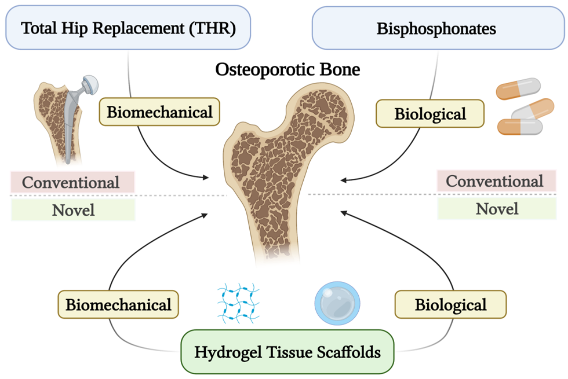

Figure 1: Conventional and novel treatment approaches for osteoporotic bones, created with BioRender.com.

Methods

A 2D finite element model (FEM) is developed to represent the structure of the trabecular bone using commercial software (Abaqus 2022, Dassault Systèmes®). The geometry of a unit cell of trabecular bone was taken from da Silva *et. al.* [5] using boundary conditions of 1% strain in a uniaxial direction [6], shown in Figure 2(A). Four cases were simulated, trabecular bone with no fill, and bone filled with hydrogels with stiffnesses of 22, 550 and 1100 MPa. The mesh was designed using triangular elements (S3) which demonstrated convergence after a sensitivity analysis, Figure 2 (B). The resultant reaction forces were used to calculate the stiffness of the structure, shown in Figure 3, and von Mises stress plots were calculated from the FEM, see Figure 2(C,D). The results showed good correlation with the stiffness in He *et al.*[6].

Results

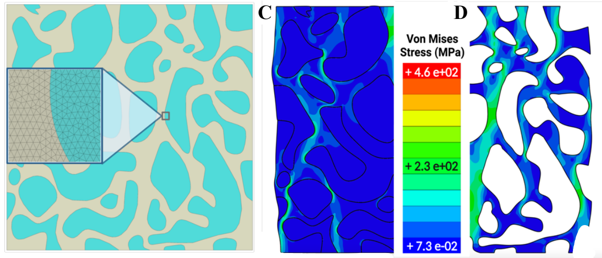

Figure 2: (A) The trabecular bone with hydrogel filling all the voids, (B) S3 mesh on structure, (C) von Mises stress plot of the hydrogel filled structure, and (D) the von Mises plot of the unfilled trabecular bone structure.

There is a significant increase in the structure's stiffness when filled with hydrogel as illustrated by Figure 3. The increase in the stiffness is found to be dependent on the modulus of elasticity of the hydrogel. However, the failure loads are found to be comparable in all cases tested.

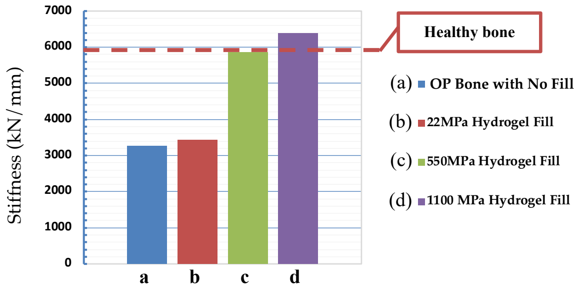

Figure 3: Stiffness of hydrogel filled and unfilled bone.

Discussion

This preliminarily work showed that hydrogels can immediately restore bone stiffness. It is likely that the use of hydrogels would also improve biological function as reported in the literature [4]. This study uses a 2D structure, which has some limitations regarding fill, and contact assumptions but further work will be conducted to obtain results that are more robust by implementing 3D simulations and *ex vivo* experiments to understand the bone-hydrogel composite behaviour and validate the findings.

References

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