Non-Metallic Bio Polymer Composite Design and Selection for Replacement of Rigid Non-Degradable Orthopedic BioWare

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INTRODUCTION

This project aims to validate the properties of polymer-ceramic composites experimentally, utilizing designated ASTM standards. Building upon previous research that utilized GRANTA software to estimate mechanical properties, this work extends the analysis by incorporating finite element models. The rule of mixtures (ROM) was used for the previous research, which is a simple and approximate way of predicting the tensile strength of fiber-reinforced composites [2]. However, ROM is not effective to predict the accurate value of the composite [2]. Hence, modified ROM is used to get the more accurate prediction The ultimate objective is to utilize computational data to create a bio-composite design for bone fixation devices. By leveraging the mechanical property estimates obtained from computational analysis, non-metallic composite bone fixation devices will be developed for orthopedic applications.

METHODS

- Halpin Tsai equation [Eqn 1] is a micromechanical model used to estimate the effective mechanical properties of composite materials based on the properties of their individual constituents [3].
- This method is very popular in both micro and nano mechanics because of its simplicity. In this method, the longitudinal and transverse moduli (EL and ET) of composites were calculated [3].

$$E_L = E_m \frac{1 + 2\frac{l}{t}\eta_L V_f}{1 - \eta_L V_f}, E_T = E_m \frac{1 + 2\eta_T V_f}{1 - \eta_T V_f}$$

$$\eta_L = \frac{\frac{E_r}{E_m} - 1}{\frac{E_r}{E_m} + 2\frac{l}{t}}, \eta_T = \frac{\frac{E_r}{E_m} - 1}{\frac{E_r}{E_m} + 2}$$

[Eqn. 1]

E_m and E_r are the elastic moduli of the matrix and reinforcement, E_L and E_T are the longitudinal and transverse moduli respectively, l is length of reinforcement, r and t are the radius and thickness of the platelet reinforcement respectively, V is the volume fraction of the material.

RESULTS

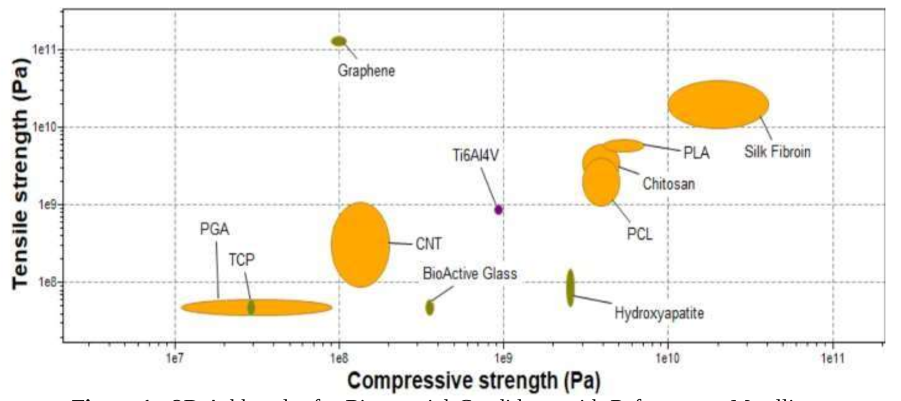

Figure 1: 2D Ashby plot for Biomaterial Candidates with Reference to Metallic Biomaterial (Ti6Al4V) Currently Used in Orthopedic Fixation Devices - Granta

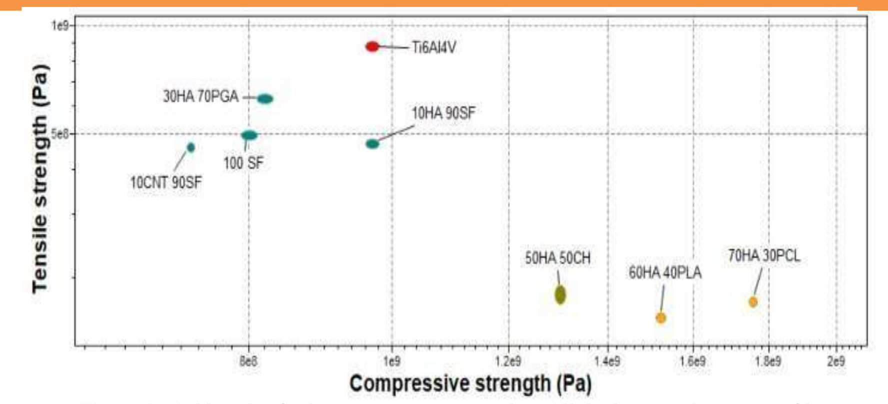

Figure 2: Ashby plot for bio-composite materials – All the best combinations of bio-composites

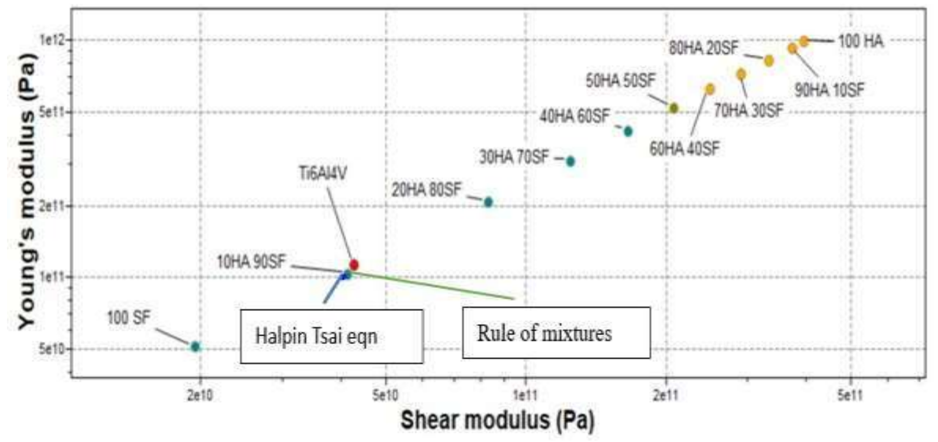

Figure 3: Ashby plot for bio-composite materials – Young's modulus vs Shear modulus

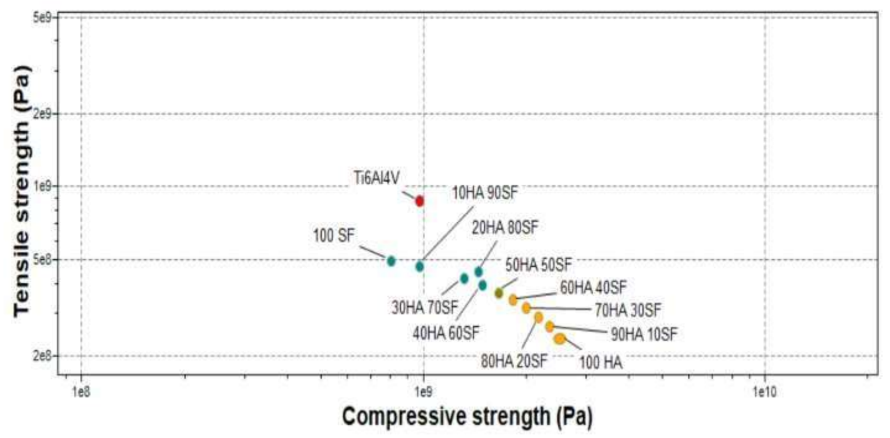

Figure 4: Ashby plot for bio-composite materials – Tensile strength vs compressive strength

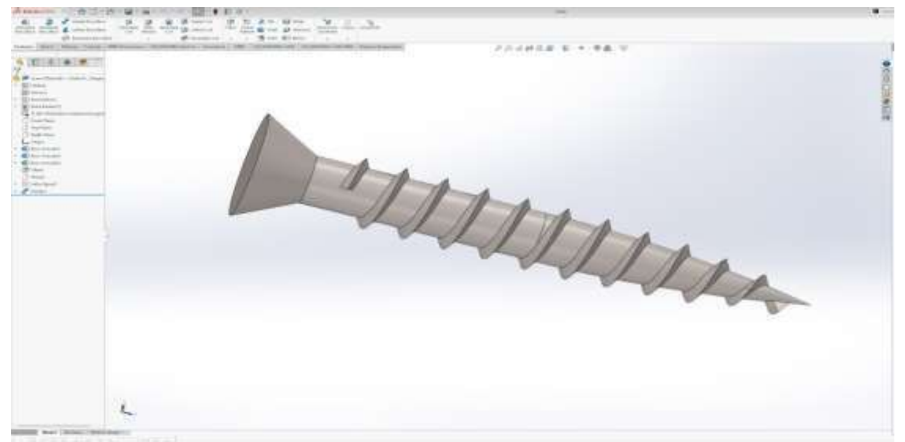

Figure 5: 3D model of bone compression screw created in SolidWorks

3D simulations for bone compression screw with load at the tip

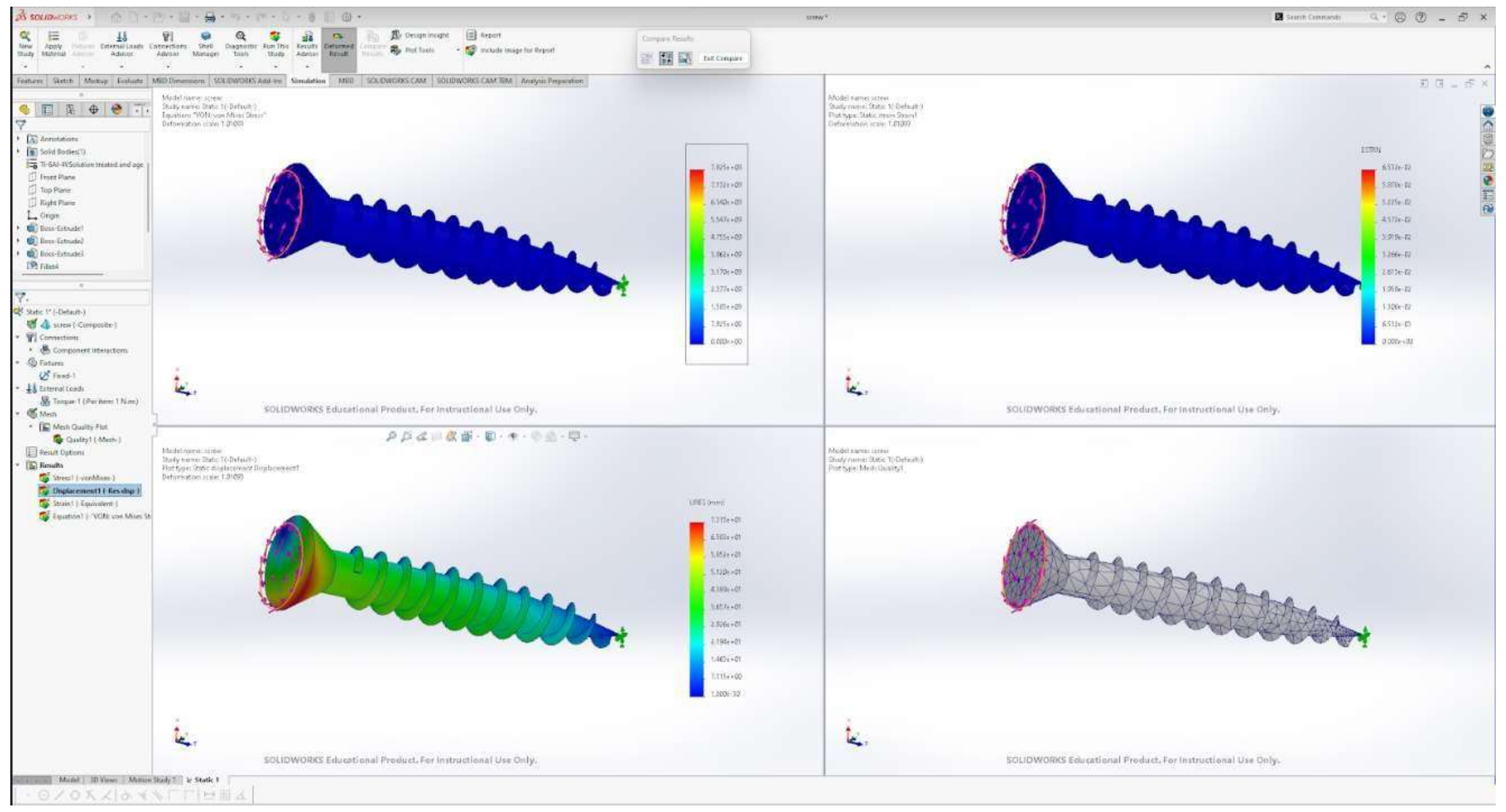

Figure 6: Simulation for bone compression screw in SolidWorks

SUMMARY AND CONCLUSIONS

- This study demonstrates the utility of computational models to provide early estimates of composite material systems.
- This study will help to minimize the number of experimental trials to verify optimal composite material contributions.
- This will also serve as a basis for developing more detailed computational finite element analysis (FEA) models (Ansys).
- 3D model made with the help of SolidWorks of bone compression screw (Fig 5) which is the basis for the experimental model.
- This study shows the simulation to the 3D model of bio-composite bone compression screw by incorporating Elastic modulus values to the composite where Halpin Tsai equation is the firm basis that helps to develop further with the non-metallic composite bone fixation device.

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