BIOMIMETIC 3D PRINTED INTERFACES

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Introduction

The design of interfaces between extremely soft and hard materials with dissimilar mechanical properties is challenging due to differences in load capacity, adhesive damage, and stress concentrations [1]. Natural architected structures, such as the tendon enthesis, offer high performance due to features such as morphological interdigitations and functional gradients [2]. Multi-material 3D printing techniques have made it possible to mimic these natural designs [3]. Here, we implemented some of these microarchitectural features (*e.g.,* collagen-like helices, randomly distributed particles) using experiments and computational models to understand their impact on the mechanical performance of biomimetic soft-hard interfaces [4,5]. This study provides design guidelines for improving the mechanical performance of bioinspired soft-hard interfaces with potential applications in tissue engineering, soft robotics, and architected materials.

Materials and Methods

Here, a 3D printer (ObjetJ735 Connex3) with voxel-level control was used to fabricate biomimetic soft-hard interfaces using two photopolymers (Agilus30^{TM} Clear for the soft phase and VeroCyan^{TM} for the hard phase). We considered the narrow section of a standard tensile test specimen and varied two interface parameters (*i.e.,* width and geometrical design) using different values of width and different geometries (*e.g.,* collagen-like helices and random particles). The specimens were 3D printed and tested for mechanical properties through quasi-static uniaxial tensile tests and digital image correlation (DIC). Stress-strain curves, elastic modulus, ultimate tensile strength, and strain energy density were obtained. The designs were modeled using finite element (FE) analysis in Abaqus 2017.

Results and discussion

We investigated the mechanical performance of soft-hard interfaces with different architectures, resulting in different patterns of contact surface area and total values. The best-performing designs had similar strengths and failure modes (failure within the soft region), while the control group (*i.e.*, non-graded) underperformed. The cause of failure in the control group was due to shear strains at the interface edges. The results of the experiments were validated by numerical simulations, which showed strain concentrations at the edges of the interface in most of the specimens. The absence of sharp edges in the design and a smooth transition of material density can alleviate these strain concentrations and improve their mechanical performance. Maintaining connectivity of the hard material also ensured the integrity of the interfaces.

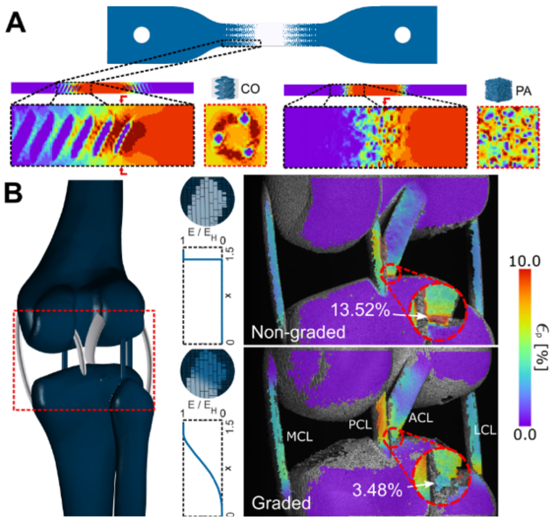

Figure 1: A) FE analysis of the soft-hard interfaces. B) DIC analysis of a knee-ligament system incorporating functional gradients.

Conclusion

Our study investigated the impact of design on the mechanical performance of soft-hard interfaces. Our findings highlight the significance of increased contact area, elastic modulus functions, and strain concentration mitigation in achieving high-performing interfaces. The application of these design features resulted in improved strength and toughness of the interfaces. Future research should use computational methods to optimize these interfaces, leading to the development of advanced materials with potential applications in medical devices, tissue engineering, and soft robotics.

References

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