Development of synthetic 3D printed knee joint to assess mechanical and functional properties of degenerative cartilage

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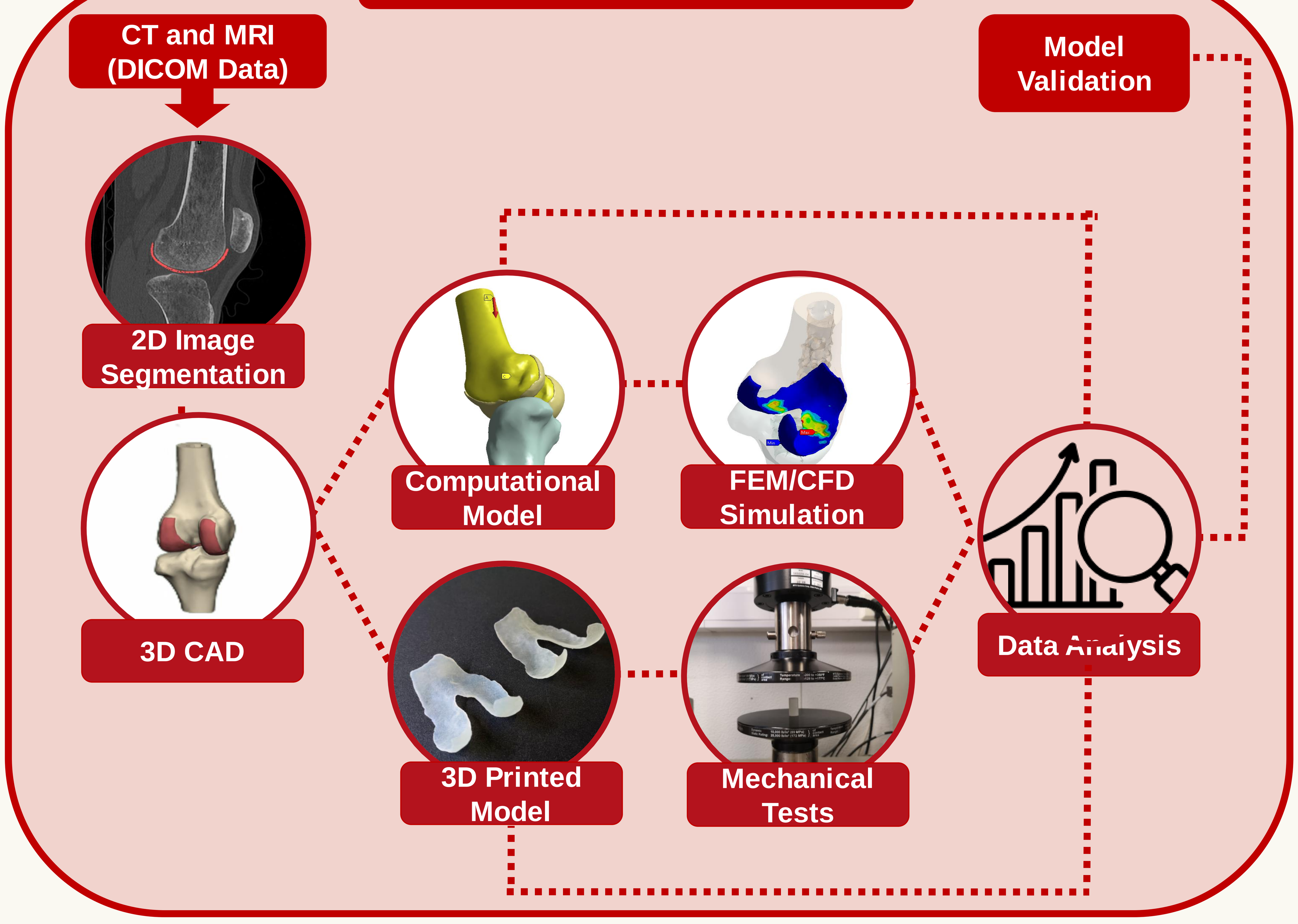
Aim of the Study

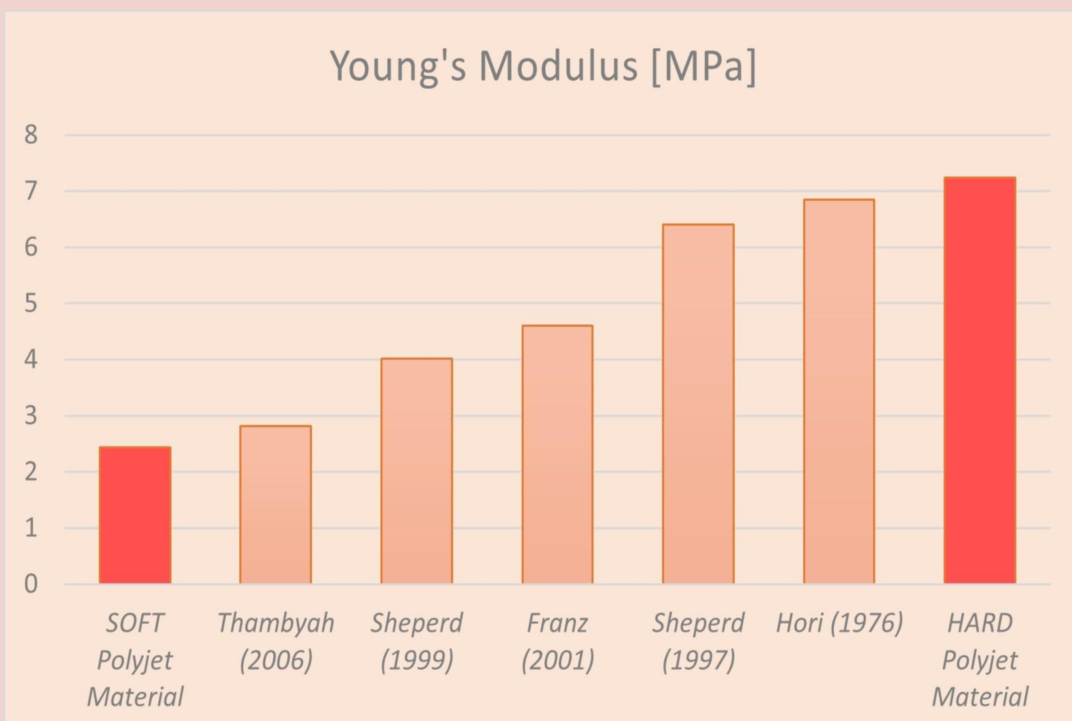
Knee osteoarthritis (OA) is a prevalent condition characterized by the gradual breakdown of cartilage in the knee joint.
In this study, we aimed to develop synthetic 3D-printed knee joint models, starting from real patient data [1], to evaluate the mechanical and functional properties of degenerative cartilage.
The feasibility of using synthetic knee models to represent the mechanical properties of knee cartilage was evaluated. The Finite Element Analysis served as a validation of the empirical tests conducted on the 3D printed models from healthy and degenerate morphology.
The study provides insights into the mechanical and functional properties of degenerative cartilage and demonstrates the potential of using synthetic 3D printed knee joint models for assessment and research purposes.

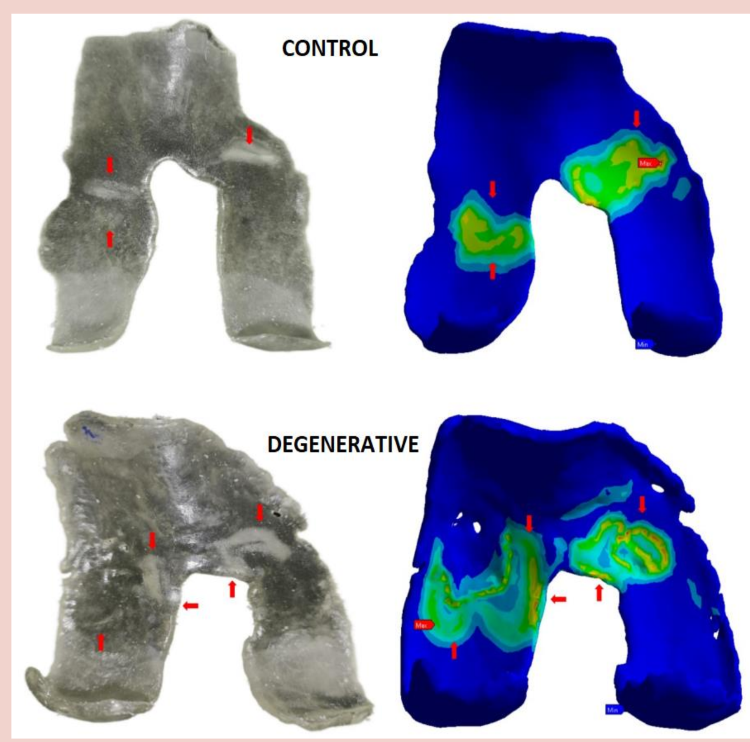
Materials and Methods

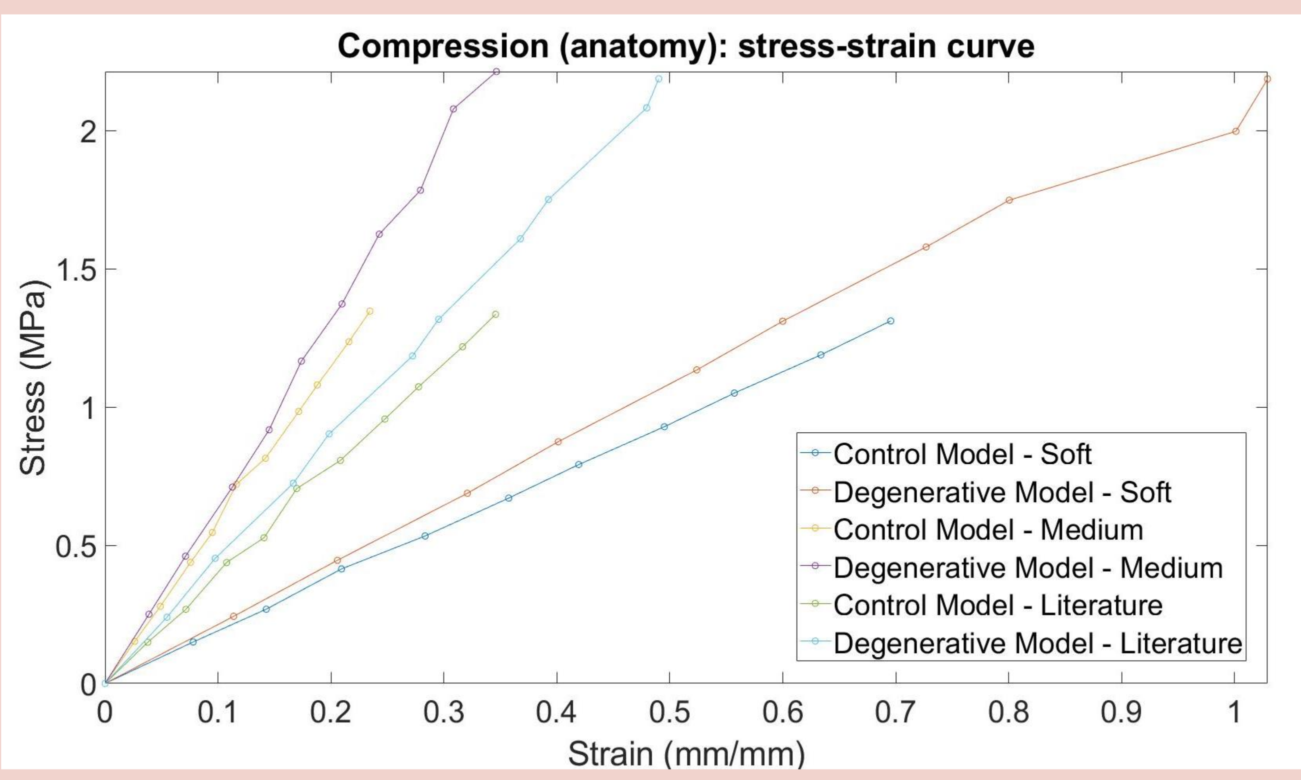


Results and Discussion

The mechanical performance of biological cartilage tissue is affected by a lot of factors (i.e. age, OA, physical activity), thus reference values found in literature tend to differ a lot [2]. However, considering reference values from multiple studies, on average, the results from our printed materials can be considered the extreme points of this range of values. These findings demonstrate the feasibility of creating a synthetic representation of cartilage's elastic properties.







The OA condition brings the major difference: even using the same material properties, the stress-strain curves obtained in the simulation depends on the morphology (thickness and presence of holes), emphasizing the significant influence of OA degenerative mechanism on the mechanical behavior.
The result demonstrates the feasibility of a 3D physical simulator for full extension stride. We can assess that the empirical experiments with the synthetic knee joint for control and degenerative subjects validate the FEA simulation [3].

Conclusions and Outlook

The typical testing methods focus on mechanical characterization only, not taking into account the morphology and geometrical structure of the tissue. In this context, the development of patient-specific knee joint models and the use of a physical synthetic knee joint allowed for the evaluation of mechanical properties and the simulation of joint behaviour. Consequently, this approach provided valuable inshights into potential failure mechanisms related to femoral cartilage. The developed synthetic knee joint simulator has the potential to contribute to future research and clinical advancements in knee OA management.

Main References

[1] F. K. Ciliberti et al., "CT- and MRI-based 3D reconstruction of knee joint to assess cartilage and bone," Diagnostics (Basel), vol. 12, no. 2, p. 279, 2022.
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