Biodamage: Image Based Diagnostic Medicine

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Introduction

Many older people suffer from a variety of bone and joint related injuries. Often these injuries result in severe pain, loss of function and need for surgery or artificial replacement. Additionally, athletes subject themselves to extreme loads, making them more likely to experience similar injuries. In engineering, fracture mechanics and fatigue have been used for years to develop damage tolerance systems that ensure safe use of parts, even parts sustaining previous damage. These systems use an understanding of the way that damage propagates in materials to set inspection intervals for parts that ensure safe use, but allow for maximum part life.

With the increasing availability of imaging centers it seems that a similar system using imaging to accomplish *in vivo* inspections of body parts such as bones and soft tissue could be used to increase the precision of diagnosis and treatment of body parts that have incurred damage or are at high risk to incur damage.

The goal of my work is to develop a better understanding of the structure and properties of biological systems to determine the feasibility of this goal and some of the challenges that must be overcome in order to develop such a system for the human body. A particular emphasis was placed on understanding hard tissues.

Procedure

General background research was carried out to create a presentation overviewing the project and outlining some of the challenges. This presentation was given to other students in the NPRL research group, the head of sports medicine at Georgia Tech, the team's orthopedic surgeon, and the Dean of the College of Engineering, Dr. Francois Sainfort to get their feedback on the project and advice for the future.

Results and Discussion

Initial background research revealed that there are many challenges presented by the complexity of a system such as the human body. There is a great deal of work being done to understand and model the mechanical behavior of tissues, but because of its complex hierarchical structure this still presents challenges.

Bones, for example, are made up of two general types of tissue: Cortical bone, which is the layered, outer shell of most bones and Cancellous bone, which is a matrix of interconnecting branches of bone tissue that form the inside of most bones. While cortical bone is significantly harder on a whole than cancellous bone, it is not known if these types of tissue have distinctly different constituent mechanical properties or if their overall properties vary simply because of their structure. Efforts to characterize the mechanical properties of these tissues have yielded varying results. Values for the elastic modulus of cortical bone has been found to vary from 5.7 to 18.7 Gpa[1]. Factors affecting measured mechanical properties include the type of test used (tensile, 3 point bending, etc.), the size scale the test was performed on, the location the bone was obtained from, and the individual it was taken from. Bone also undergoes a fairly complicated healing process unlike any engineered material. In this process, known as the bone remodeling cycle, cells called osteoclasts break down damaged bone tissue and cells called ostoblasts fill the area and form new bone tissue. Still, the mechanism by which these cells are summoned is not well understood. As a result the rate and factors affecting rate of healing within bone are not well understood. In fact, it is this same process that leads to the disease osteoporosis, which results in a decreased bone mass in the elderly. In just the case of bone, the mechanical properties and the mechanisms for healing must be well understood before the imaging based systems outlined above would become feasible. Other challenges include understanding how these properties and mechanisms vary from individual to individual.

Further feedback from more knowledgeable professionals verified interest in a more systematic approach to diagnosis and treatment of injury, but revealed several other challenges that there is a great demand for work in many of these areas. In particular, they reemphasized the need for further knowledge about healing in the body, how it occurs, the rates it occur at, and factors affecting it would be one of the most important challenges to overcome. Possible future work could include creating a large clinical database tracking the repair of injuries and noting other factors that might affect healing to try to understand more precisely how each of these factors affect the repair of different types of injuries.

Conclusions

A system similar to damage tolerance systems used in the aerospace industry could be extremely beneficial for the diagnosis and treatment of injuries. However, many challenges in understanding the mechanical properties of biological tissues and how they vary from person to person still exist before such a system could be created. Additionally it would be necessary to better understand the nature of healing within the body.

References

1. H.H. Bayraktar et al., 2004. Comparison of the elastic and yield properties of human femoral trabecular and cortical bone tissue. Journal of Biomechanics 34, 27-35.

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