BIOMECHANICS AND MODELLING IN ORTHOPAEDICS; STATE OF THE ART

Lappalainen R
Department of Applied Physics, University of Kuopio, Kuopio, Finland

INTRODUCTION

Nowadays, total joint replacements for hip, knee and other joints are daily routine in orthopaedic hospitals. However, for the optimized solutions[1] basic knowledge of biomechanics is needed on the topics such as forces acting in the skeleton and extremities, the stress strain behavior of cartilage, bone, tendons, and ligaments, lubrication of joints, mechanics of bone fracture fixation and implant design. During the last decades, especially the development of numerical methods and computers has made it possible to develop more realistic biomechanical models and carry out extensive calculations. This paper will discuss some current topics related to biomechanical testing, modelling and calculations in orthopaedics based on the literature and Biomechanics and modelling symposium in Kuopio, February 18th, 2003.

METHODS

A starting point for many sophisticated biomechanical calculations is a selection of proper constitutive laws describing the mechanical behavior of the tissues and implants.[2] Models include some fundamental assumptions such as elasticity, viscosity, viscoelasticity, fluid flow or isotropy. Next step is to get a geometry, i.e. a realistic model of a section of a human body. This can be typically obtained using imaging techniques such as computed tomography (CT) or magnetic resonance imaging (MRI).[3,4] These techniques allow obtaining the dimensions in 3D of different tissues typically with a resolution in mm range or even with a resolution of a few microns with special equipment for micro imaging of small objects (μCT or μMRI). The 3D image data can be used to get solid or computer models. The solid models can be made, e.g. using rapid prototyping, to visualize an object in real size. The computer models can be converted to a calculation mesh using programs such as PATRAN (MSC Software Corp., Santa Ana, CA). When correct boundary conditions are obtained from literature or experimental measurements, mechanical equations are solved using a finite element software, such as ABAQUS (Hibbitt, Karlsson & Sorensen Inc., Pawtucket, RI).

Conventionally, biomedical testers are used to measure basic mechanical parameters such as strength, elasticity or creep in compression, tension or shear mode.[5] In addition to these tests, modern biomechanical tester allow several options for dynamic testing such as those simulating the loading during a gait cycle or forces acting in a collision. In principle, any dynamic load profile (e.g. measured from a patient) can be used as an input and can be repeated the required number of cycles. Complex simulators have been designed and are available to reproduce full anatomic joint movement in hip or knee. However, many relevant problems can be studied even using optimized and less expensive simulators such as a commercial hip joint simulator with six rotating stations and six soak-controls (ShoreWestern Manufacturing Inc., Monrovia, CA, USA) or an Instron 8874 dynamic tester available at the University of Kuopio.

Table 1. Fraction of papers in ORS 2003 containing some keywords related to biomechanics and modelling.

Keyword	Fraction of papers
biomechanics	22 %
finite element, FE model	6 %
Abaqus	2%
MTS, Instron	8 %

DISCUSSION

Table 1 shows the fractions of abstracts in ORS 2003, which contained some keywords related to biomechanics or modelling. This topic is very relevant both from theoretical and experimental point of view. Some of the current clinical problems in orthopaedics studied with these techniques include implant loosening, cartilage degeneration, bone substitutes and osteoporosis. All these problems lead to the lack of good biomechanical properties. Biomechanics can also give some relevant answers to these issues such as insights of body reaction to mechanical stimulation, description of clinical situations, improvements in implant design or more accurate drug targeting for bone remodelling.

The time scale of phenomena and calculations or biomechanical testing varies a lot.[5] The most straightforward task is a static situation, i.e. no movement and stabile parameters. However, quite often dynamic models are necessary, e.g. to simulate the movement of a joint where acting muscles and forces change continuously. In order to correctly model long-term behaviour in tissues, it is necessary to update the conditions and geometry of tissues during the simulations, e.g. to take into account bone remodelling, implant movements and structural changes. These topics offer a challenging work for any theoretical or experimental expert in this field.

REFERENCES

[1] Santavirta S, Böhler M, Haris WH, Konttinen YT, Lappalainen R, Muratoglu O, Rieker C, Salzer M, Acta Orthop Scand, in press.
[2] Mow V C, Hayes W C, *Basic Orthopaedic Biomechanics*, Raven Press, New York, 1991.
[3] Rawlinson J, Peters L, Campbell D, Wright T, Bartel D, 49th Annual Meeting of the Orthopaedic Res. Soc.,New Orleans, 2003, Poster #1347.
[4] Wei L, Sajda P, Laine A F, Guo X E, 49th Annual Meeting of the Orthopaedic Res. Soc., New Orleans, 2003, Poster #447.
[5] An Y H, Draughn R A (editors), Mechanical testing of bone and the bone-implant interface, CRC Press, New York, 1999.

The biomechanics of and biomaterials used in orthopedics have become increasingly important as the possibilities have increased to treat patients with foreign material introduced both as optimized osteosynthesis after trauma and as arthroplasties for joint diseases, sequelae of trauma or for tumor treatment. Furthermore, biomaterial substitutes are constantly being developed to replace missing tissue.Â This book covers both basic concepts concerning biomaterials and biomechanics as well as their clinical application and the experience from everyday practical use. This book will be of great value to specialists in orthopedics and traumatology, while also provide an important basis for graduate and postgraduate learning. Biomechanics Lab facilities - Haider.pdf. Orthopaedics Biomechanics Laboratory. Implant Testing Technology. 985360 Nebraska Medical Center - Scott Technology Center, Omaha, NE 68198-5360 Director: Hani Haider, PhD Tel: 402-5595607 E-mail: hhaider@unmc.edu.Â Produced state-of-the-art simulator to test Knee Replacement implants. Methodology now adopted as an International Standard Test Method (ISO 14243-1). We have 3 of these knee simulators in our lab and are fast becoming the top lab internationally in knee testing. Research evaluates new knee implant designs before clinical use, or produce reliable lab performance data for regulatory purposes and design improvement. 120 110 100. Biomechanics in Orthopaedics. Andreas F. Mavrogenis1*, Panayiotis D. Megaloikonomos1, Georgios N. Panagopoulos1, Nicola Maffulli2. 1. First Department of Orthopaedics, National and Kapodistrian University of Athens, School of Medicine, Athens, Greece; 2. Department of Musculoskeletal Disorders, Faculty of Medicine and Surgery, University of Salerno, Salerno, Italy.Â Â© Ivyspring International Publisher. This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY-NC) license (https://creativecommons.org/licenses/by-nc/4.0/). Provides a comprehensive overview of the state-of-the-art in biomechanics and biomaterials. Takes a bench to bedside approach, incorporating the basic science with detailed practical management issues. Written by the international authorities in biomaterials, orthopedics and traumatology. see more benefits. Buy this book.Â â€œThe purpose is to provide orthopedic surgeons with the available body of knowledge regarding biomechanics and the various implanted biomaterials to safely and successfully treat patients. â€¦ This second edition is justified in this very important area of orthopedic surgery. It is an essential addition to the academic orthopedic surgical library.â€