UNIVERSITÄT BERN

Master Biomedical Engineering

Annual Report 2011

Master of Science in Biomedical Engineering

Contents

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Introduction

2011 in Retrospect

For our specialized master study course "Master of Science in Biomedical Engineering", 2011 was a year of continuous consolidation. The program originally started in March 2006 with a class of 23 students coming from various fields of studies. To date, a unique initiative between the University of Bern and the Bern University of Applied Sciences as collaborating partner has opened up the exciting interdisciplinary field at the interface between medicine and engineering to about 300 students from more than 20 countries.

Since the start of the specialized master course the constant effort to improve the quality of our curriculum has resulted in substantial changes of the course structure and its content over the past six years. The four semester program is now grouped into well-defined modules, where the major modules represent the focus areas, available to the students for their final specialization. Detailed information can be gathered from our website at www.bme.master.unibe.ch.

Currently the biomedical engineering program draws on the expertise of over 80 lecturers, offering almost 50 courses. They are faculty members of the University of Bern, the Bern University of Applied Sciences, the University of Basel, and since recently the Robert Mathys and the AO Foundation bring their expertise from the medical technology industry. This unique team covers a wide variety of aspects of biomedical engineering and promotes a high level of interaction between disciplines to assure a constantly evolving study program.

In 2011, three new courses, namely Applied Biomaterials, Materials and Technologies in Dentistry, and Reliabilities of MEMS for Medical Applications were introduced. By this, our curriculum comprises a wide variety of highly specialized courses, which are also of particular interest for the medical technology industry as part of their continuing education activities and programs.

In 2011, 32 students graduated as biomedical engineers of the University of Bern. 81% of the corresponding master theses were advised at the University of Bern and Bern University of Applied Sciences, 13% at collaborating Swiss Schools, namely the University of Basel, the Swiss Paraplegic Research, and the ZHAW, while 6% of the advisors came directly from the medical technology industry. With the help of our alumni organization, the BME Club (www.bmeclub.ch), our career event, the Biomedical Engineering Day, was successfully organized for the third time gathering many Medtech companies and more than 300 participants. It offers Swiss and international companies from the medical technological field an excellent opportunity to meet our highly qualified and motivated students face to face and to present themselves as attractive employers. Most importantly our post-studies analyses indicate that our graduates are very successful on the labour market.

After more than six years as the program director of the BME course program it is time for a change. Philippe Zysset, who joined the University of Bern as a member of the Medical Faculty last year, has taken over effective January 1, 2012. I am convinced that he will give new impulses to the program, but also stands for the necessary continuity. Let me take this opportunity to thank all lecturers and the study coordination office for their tremendous support during the past years.

Lutz-P. Nolte
Program Director

Organization

Master of Science in Biomedical Engineering

L. P. Nolte
Program Director

U. Jakob-Burger
Study Coordinator

S. J. Ferguson
Master Thesis Coordinator

V. M. Koch
Deputy Director

A. Neuenschwander
Study Coordinator

M. Reyes
Master Thesis Coordinator

J. Spyra
Study Coordinator

BME First Year Students 2011, Alter Hörsaal der Anatomie, University of Bern

Course Structure of the Master Program

Since the start of the Master Course Biomedical Engineering in March 2006, the constant effort to improve the quality of our curriculum has resulted in substantial changes of the course structure over the past years. The first curriculum consisted of a number of individual courses which were either mandatory or elective, but their coherence with regards to contents was in most cases not expressed by a defined structure. However, two major modules (formerly called "focus areas") already existed.
As of Fall Semester 2009, all courses were grouped in a strictly modular way in order to enhance both the clarity and the complexity of the curricular structure. A main idea was to guide the students through their studies in a better way by adding an elective part to the major modules, which formerly had consisted exclusively of mandatory courses. Besides, the curriculum was expanded by a number of new specialized courses as well as an additional major module called "Image-Guided Therapy".

The Curriculum

Duration of Studies and Part-Time Professional Occupation
The full-time study course takes 4 semesters which corresponds to 120 ECTS points, one ECTS point being defined as 25-30 hours of student workload. It can be extended to a maximum of 6 semesters. When a student decides to complete the studies parallel to a part-time professional occupation, further extension is possible on request. To support regular part-time work, mandatory courses take place (with rare exceptions) on only 3 days per week.

Basic Modules
The basic modules provide the students with the necessary background to be able to fully understand the highly complex subject matter in the specialized courses. All students with an engineering background (for all other students, individual study plans are set up which may contain certain variations) have to complete all courses in the Basic Modules Biomedical Engineering, Human Medicine, Engineering Mechanics, and Applied Mathematics. In the first semester, all courses belong to this group, whereas in the second and third semester, the courses from the basic modules make up for 25-30%.

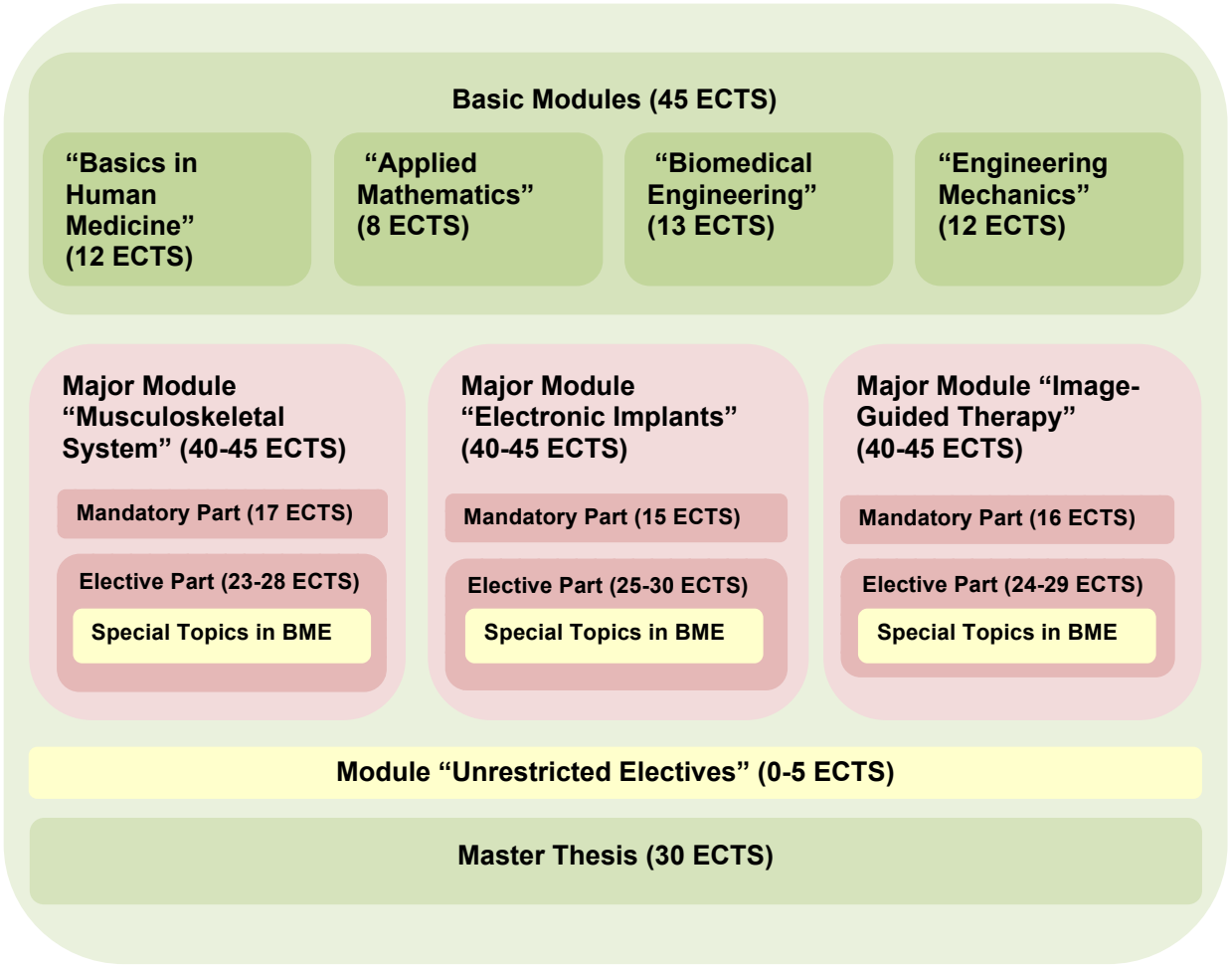
Major Modules
The choice of one of three major modules Musculoskeletal System, Electronic Implants, or Image-Guided Therapy after the first semester constitutes the first opportunity for specialization. Approximately one third of the major modules consist of mandatory courses. In the elective part of the major module, the student is allowed to select any course from the list of courses in the master program, giving rise to a high degree of diversity and flexibility and allowing for an almost infinite number of course combinations. However, this freedom makes it somewhat difficult for the student to make reasonable choices regarding professional prospects.

This is why the responsible lecturers developed a recommended study plan to guide the students through the course selection process and to avoid organizational problems such as overlapping courses. If a student follows the recommended path, he or she can be sure to establish a sound professional profile.

Module "Special Topics in Biomedical Engineering"
In order to meet an increasing demand for continuing education in the medical technology industry, the Special Topics in Biomedical Engineering have been developed. Scientists from institutions affiliated to the Medical Faculty of the University of Bern - the Artificial Organ (ARTORG) Center for Biomedical Engineering Research as well as the Institute of Surgical Technology & Biomechanics (ISTB) – established the course curricula in close collaboration with representatives from the leading medical technology companies in Switzerland. Courses have been designed to convey state-of-the-art knowledge in many future-oriented areas at the interface between applied scientific research and industrial research and development on a high level. Apart from contributing a hands-on aspect to the studies, thus complementing the theoretical foundation which is laid in the basic modules, these courses provide an excellent opportunity for industry professionals to deepen and enlarge their knowledge in selected areas of Biomedical Engineering. In 2011, the course list was augmented by the courses "Applied Biomaterials", Materials and Technologies in Dentistry" and "Reliability of MEMS for Medical Applications". Formally, this module has been integrated into the elective parts of the major modules.

Module "Unrestricted Electives"
Unrestricted electives can be freely chosen by the student from the entire curriculum of the University of Bern and the Bern University of Applied Sciences, Department of Engineering and Information Technology. Of these courses, a maximum of 5 ECTS points are credited. It is advisable to select courses which fit into the context of the student's study plan, either to make up for missing knowledge or to add new and interesting aspects to the individual study program.

Master Thesis
The last semester is dedicated to a master thesis project on an individually suited topic in an academic research group or, for particular cases, in an industrial research and development environment. As a rule, all 90 ECTS points from the course program have to be completed, thus ensuring that the student is able to fully concentrate on the challenges imposed by exciting research activities. The master thesis includes the thesis paper, a thesis defense as well as a one-page abstract for publication in the Annual Report of the master course.



Major Modules

Electronic Implants

V. M. Koch

Electronic implants are devices like cardiac pacemakers and cochlear implants. Due to miniaturization and other developments, many new applications become feasible and this exciting area is growing rapidly. For example, cochlear implants provide already approximately 200'000 people a sense of sound. These people were previously profoundly deaf or severely hard of hearing. Recently, researchers demonstrated that electronic retinal implants allow the blind to read large words.

There are many more applications for electronic implants beyond treating heart problems, hearing loss or blindness. For example, there are electronic implants that treat obesity, depression, incontinence, hydrocephalus, pain, paraplegia, and joint diseases.

In this module, students will learn about the basics of electronic implants. This includes: sensor and measurement technology, signal processing and analysis, microcontroller programming, actuator technology, and miniaturization of micro-electro-mechanical systems. Application-oriented topics are also taught, e.g., cardiovascular technology and biomedical acoustics.

Since the development and manufacturing of electronic implants is highly complex and since it involves many different disciplines, it is not the goal of this major that students are able to develop an electronic implant on their own but rather to be able to work successfully in a project team that develops electronic implants.

Students may already apply their knowledge as a part-time assistant in a laboratory and/or during their master's projects. After finishing the degree program, a wide variety of career paths are available, ranging from research and development to project and product management. Many well-known companies in Switzerland work in this field, e.g., Codman and Phonak Acoustic Implants. This list is, of course, not complete. For example, many „traditional" implants manufacturers have recently become interested in electronic implants, e.g., to measure forces in knee implants.

To detect arrhythmia, cardiologists need a long-term capturing device for ECG signals. Research teams at the ARTORG Center (Prof. Dr. Dr. Rolf Vogel) and the Institute for Human-Centered Engineering of BFH-TI (Prof. Dr. Marcel Jacomet and Prof. Dr. Josef Götte) develop a recorder that measures ECG signals from inside of the esophagus close to the heart. The data is processed and recorded in a behind-the-ear electronics platform.
Picture: courtesy by ARTORG Center

Image-Guided Therapy

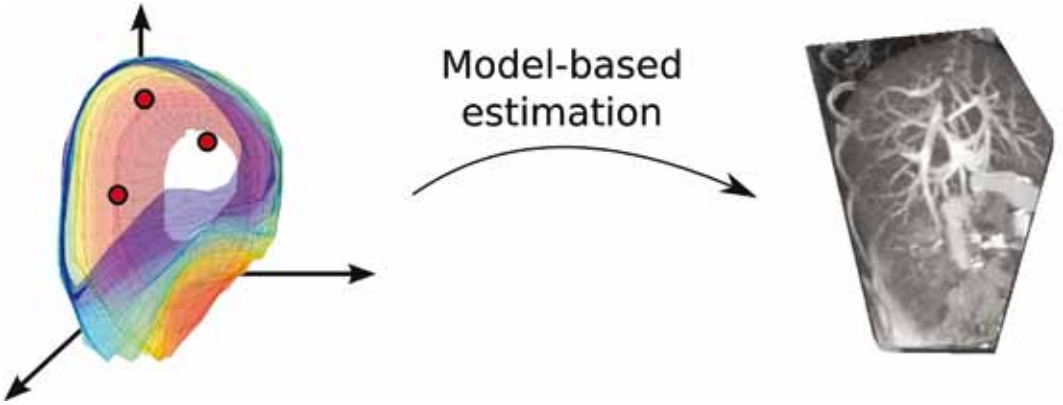
Ph. Cattin

Originally medical imaging was only applied during diagnosis. Later, X-ray systems were introduced in operating rooms to help localising anatomical structures, pathologic lesions, as well as surgical instruments in order to find the optimal access path to the target site.

Recently, fluoroscopes and the more cost-effective and non-ionising ultrasound devices became the predominant imaging modalities used in Image-Guided Therapy. Today's developments furthermore try to integrate computed tomography and magnetic resonance imaging systems in the operating room to support intraoperative navigation. All these developments aim at improving the surgical outcome in various aspects.

In particular complications, mobidity and surgical time should be minimised whilst improving the predictability of the surgical outcome through the use of advanced intraoperative navigation techniques.

In the Image-Guided Therapy module, the students will gain a comprehensive understanding of all technical fundamentals required to understand, improve and develop Image-Guided Therapy systems. In the mandatory courses of this module the fundamentals of Image-Guided Therapy systems are taught. In particular an introduction to signal- and image-processing, medical image analysis and the basics of computer assisted surgeries are given.



Based on the measurement of surrogate marker positions, the entire position of the organ can be estimated.

Major Modules

Musculoskeletal System


S. J. Ferguson, Ph. Zysset

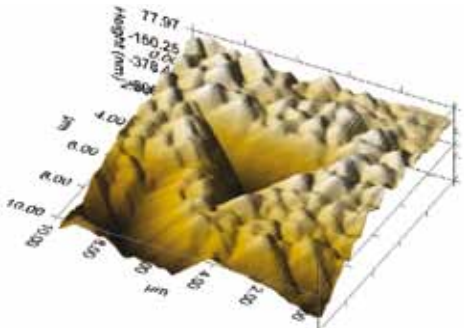
The Orthopaedic Biomechanics Group experienced a time of transition with the departure of Stephen Ferguson for the ETH Zurich and the arrival of Philippe Zysset from the Technical University in Vienna. Professor Zysset has been heading the Module "Musculoskeletal System" since the fall semester 2011.

The musculoskeletal system is the structural basis for our physical activities and its health has a profound influence on our quality of life. Musculoskeletal injuries and pathologies are the most costly ailments facing our health care systems, both in terms of direct medical costs and compensation payments related to loss-of-work. In this module, students will gain a comprehensive understanding of the multi-scale organisation of the musculoskeletal system, combining knowledge from the cell, tissue, organ to the body level. They will learn how to apply engineering, biological and medical theory and methods to resolve complex problems in biomechanics and mechanobiology. Students will learn to draw connections between musculoskeletal tissue morphology and mechanical response, and vice versa. Students will gain the required expertise to apply their knowledge in relevant, practice-oriented problem solving in the fields of orthopaedics, dentistry, rehabilitation and sports sciences.

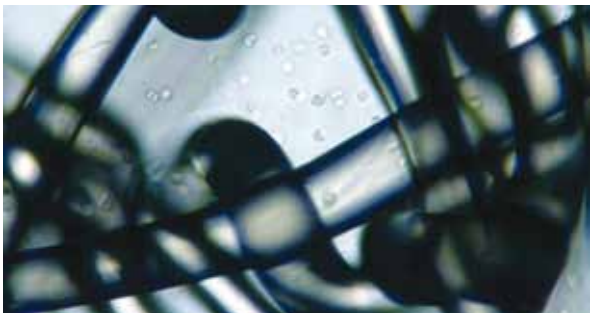
The mandatory courses in this module provide the student with fundamental knowledge of functional anatomy, finite element analysis, tissue biomechanics and tissue engineering. This provides an overview of the functional adaptation of the musculoskeletal system to the demands of daily living, and the potential for its repair and regeneration. This major module requires a prior knowledge of mechanics, numerical methods and related engineering sciences, as many of the mandatory and elective courses build upon these foundations. However, students with a background in medicine, natural sciences or computer science have also demonstrated their ability to acquire and consolidate such knowledge, which is complemented by their own unique profile. Elective courses allow the students to extend their competence in a chosen direction, gaining knowledge in analytical methodologies, medical device design, regenerative medicine, rehabilitation, orthopaedics or biological sciences.

Knowledge gained during the coursework highlights the multidisciplinary nature of this study focus area, encompassing the cell to body, the idea to application and the lab bench top to the hospital bedside. This knowledge is applied during the final thesis project, a project often with a direct link to a final diagnostic or therapeutic application. Examples of past thesis projects include the development of radiographic imaging methods for measuring three-dimensional bone kinematics, the evaluation of novel biomaterials for the reinforcement of fragile osteoporotic bone, the study of the link between mechanical loading and tissue metabolism and the application of porous scaffolds to guide stem cells towards the formation of de novo cartilage.

Career prospects are numerous. Many students proceed to further post-graduate education and research, pursuing doctoral research in the fields of biomechanics, tissue engineering, development of biomaterials, or in transversal disciplines such as systems biology. Most of the major companies in the fields of orthopaedics, rehabilitation engineering and pharmaceuticals are strongly represented within the Swiss Medical Technology industry and continue to experience growth, therefore driving a demand for graduates of this major module. At the interface between biomedical engineering and clinical applications, graduates may also pursue careers related to the evaluation and validation of modern health technology, a cornerstone for future policies on the adoption of these new methods in the highly competitive health care domain.



Indentation in bone tissue visualized by atomic force microscopy.



Three-dimensional textile scaffold for tissue-engineered repair of the intervertebral disc.

List of Courses

Applied Biomaterials
Biological Principles of Human Medicine
Biomedical Acoustics
Biomedical Instrumentation
Biomedical Laser Applications
Biomedical Signal Processing and Analysis
Cardiovascular Medicine and Engineering
Cardiovascular Signal Analysis and Modeling
Computer Assisted Surgery
Computer Graphics
Design of Biomechanical Systems
Engineering Design
Engineering Mechanics I
Engineering Mechanics II
Finite Element Analysis I
Finite Element Analysis II
Functional Anatomy and Histology
Functional Anatomy of the Locomotor Apparatus
Health Technology Assessment
Intelligent Implants and Surgical Instruments
Introduction to Medical Statistics
Introduction to Signal and Image Processing
Machine Learning for Vision Applications
Management
Materials and Technologies in Dentistry
Materials Science and Biomaterials
Medical Image Analysis
Medical Robotics
Medical Terminology
Microelectronics
Microsystems Engineering
Molecular Biology
Numerical Methods
Osteology
Physiology
Practical Course in Tissue Engineering
Principles of Medical Imaging
Programming of Microcontrollers
Regulatory Affairs and Patents
Rehabilitation Technology
Reliability of MEMS for Medical Applications
Technology and Diabetes Management
Tissue Biomechanics
Tissue Engineering

Special Topics in Biomedical Engineering – Continuing Education

- **Applied Biomaterials**
- **Biomedical Acoustics**
- **Cardiovascular Medicine and Engineering**
- **Cardiovascular Signal Analysis and Modeling**
- **Design of Biomechanical Systems**
- **Materials and Technologies in Dentistry**
- **Practical Course in Tissue Engineering**
- **Rehabilitation Technology**
- **Reliability of MEMS for Medical Applications**
- **Technology and Diabetes Management**

In order to meet an increasing demand for continuing education in the medical technology industry, the Special Topics in Biomedical Engineering have been developed. Scientists from institutions affiliated to the Medical Faculty of the University of Bern – the Artificial Organ (ARTORG) Center for Biomedical Engineering Research as well as the Institute for Surgical Technology and Biomechanics (ISTB) – established the course curricula in close collaboration with representatives from the leading medical technology companies in Switzerland. Courses have been designed to convey state-of-the-art knowledge in many future-oriented areas at the interface between applied scientific research and industrial research and development on a high level. Apart from contributing a hands-on aspect in the education of our students, thus complementing the theoretical foundation which is laid in the basic modules, these courses provide an excellent opportunity for industry professionals to deepen and enlarge their knowledge in selected areas of Biomedical Engineering. The course list is continuously augmented.

All our courses are not only open to our students but can also be attended by the interested public. If you want to participate in one of our Special Topics in Biomedical Engineering, please contact the Study Coordination Office for further details: bme@istb.unibe.ch.

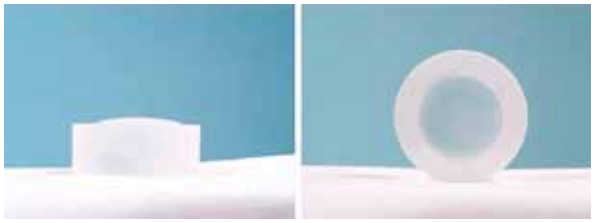
New Courses

Applied Biomaterials

R. Luginbühl (without picture), J. Sague, R. Heuberger, M. Bohner, L. Eschbach, R. Egli

All medical devices depend strongly on the performance of their base material, their design, and on the interaction between their material surface with proteins, cells and tissues. It is the aim of the course *Applied Biomaterials* to give an introduction to the world of biomaterials and discuss their application in medicine from a scientific and industrial perspective. Today, biomaterials are defined as materials that support optimally the functioning of devices with respect to their medical therapies without eliciting undesirable local or systemic effects in the recipients or beneficiaries of those therapies. In order to account for the complexity of second and third generation medical devices, it is important that biomedical engineers apply lateral thinking, consider and combine many different aspects such as material properties, surface engineering, material processing and device design since those aspects will all ultimately influence the performance of a device. Aside getting acquainted with physical, chemical and mechanical material properties of metals, ceramics, polymers and natural biomaterial, special attention is put on the materialographic assessment, the degradation and absorption behavior, and the understanding of different modes of device failure. This requires the application of appropriate analytical methods and test protocols. That knowledge will also help to rate cytotoxicity and advanced biocompatibility testing for the prediction of the device performance.

The course *applied biomaterials* is taught by materials engineers and chemists of the RMS Foundation – a research and service institute dedicated for the advancement of biomaterials and medical devices – who all have long standing experience in the field of biomaterials.



Example of an experimental spinal polymeric devices (HydroSpinal) which has to be comprehensively analyzed by chemical, physical and mechanical test methods before it is assessed in vitro and in vivo.

Orthopaedic implants are manufactured from many different materials including metals, polymers and ceramics. Furthermore, the device surfaces are refined by special coatings and structures.

Materials and Technologies in Dentistry




B. Müller, K. Jäger, B. Ilgenstein, M. Jungo

The course provides engineering and scientific knowledge from dental medicine to students, who potentially start working in MedTech industry in the field of dentistry.

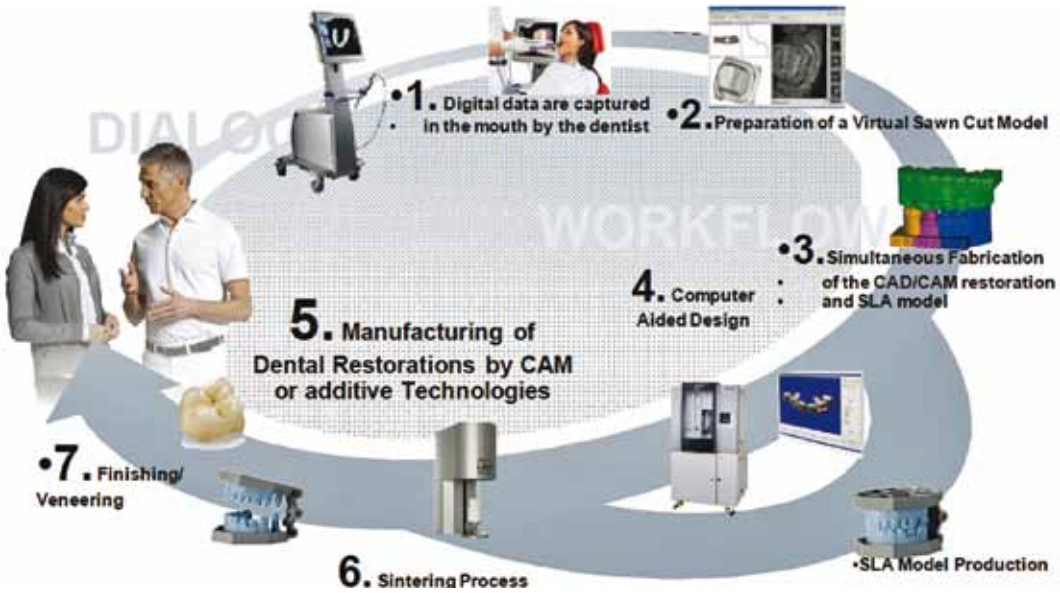
The lecture series give an idea how to interact with dentists and dental technicians to support their efforts in optimized patient treatment.

The wide variety of materials used in dentistry including metals, ceramics, polymers, and composites has been radically changed. Intolerance and incompatibility issues become more and more important, especially because of their patient-specific reactions. Based on the daily experience, three dentists explain materials-related problems, which comprise the determination of composition, periimplantitis and corrosion measurements within the oral cavity. Furthermore, the applications of advanced ceramics and composites for artificial teeth and bone augmentation before implant placement are discussed in detail.

The more or less sophisticated instruments for oral surgery and dental treatments are considered from the materials point of view. Finally, the application of lasers for bone cutting, pain treatment and reduction of bacteria in the root cannel will be presented as currently integrated into the well-equipped dental offices.

The graduates are face-to-face with advanced instrumentation, which includes:

- color measurements of teeth in the oral cavity
- preparation and recycling of dental materials
- articulator device for the measurements of forces and stresses in dentistry
- laser in dentistry: diode, carbon dioxide and Er:YAG laser
- bone augmentation materials to be compared using micro computed tomography
- ec-pen for in vivo corrosion measurements
- 3D scanner to generate patient-specific data for the fabrication of artificial denture
- identification of dental materials using energy-dispersive X-ray spectroscopy
- computer-aided oral treatments
- nanostructure of teeth for nature-analogue restoration (nanodentistry).



Digital workflow for the fabrication of a dental framework (steps 1-6). The veneering is handmade by the dental technician (step 7; image from 3M Espe, Seefeld, Germany).

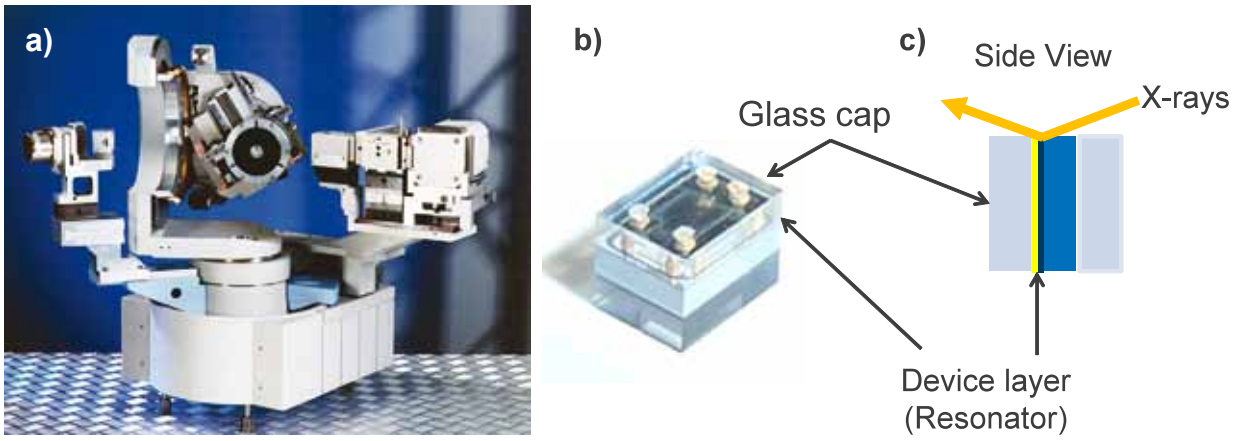
New Courses

Reliability of MEMS for Medical Applications


A. Dommann, A. Neels

MEMS (Micro-Electro-Mechanical Systems) or microsystems what they are often referred to, combine micron scale mechanical components with electronics. MEMS devices can operate based on a wide variety of physical principles for sensing and for actuation, the most common being electrostatic, thermal, magnetic, and piezo-electric. In a MEMS device, the mechanical and electrical effects are also tightly coupled. One can distinguish between purely mechanical failure modes where the mechanical properties of the materials are altered, and electrical failure modes, where electrical properties (such as conductivity) are changed, which then lead to either mechanical or electrical failures. MEMS aging, especially based on physical defect models, have the potential to reduce dramatically the test costs. The aging of MEMS is always connected with the occurrence of defects and their mobility. The wide variety of materials and physical principles used make it difficult to give general statements about MEMS reliability. The mobility of defects will be enhanced by greater stress gradients. Both, the stress gradient and the defects can be easily determined by means of High resolution X-ray techniques (HRXRD). Therefore using X-ray techniques enables us to connect mechanical stress, thermals load and even radiation damage with the structural properties which lead to signal drift of MEMS. HRXRD techniques are therefore very powerful tools to study aging through the determination of the stresses and defects in the devices.
For the determination of the strain state of the resonator and more importantly the change in its strain state related to the bonding procedure, different methods such as RAMAN but also HRXRD methods are available and are often combined with advanced modeling techniques. In the following, the strength of non-destructive HRXRD methods in bonding related issues is demonstrated.

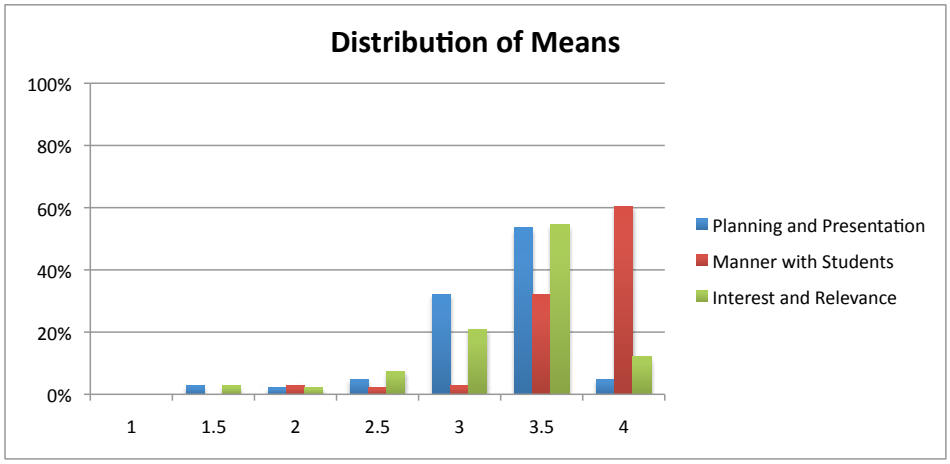
The strain in the silicon of the device layer at the bonding interface between the device layer and the cap wafer is investigated. HRXRD measurements (Fig. 1a) such as Reciprocal Space Mapping (RSM) are carried out focusing on the bonding interface between the resonator device layer close to the glass cap (Fig.1b,1c).
RSMs have been measured for several bonded and non-bonded devices on chip level. The strain has been monitored using HRXRD measured in the device layer before and after packaging.
The drift of a device function depends on the changes in device strain and defects and their mobility. Therefore we believe that the monitoring of those material related properties, which can be done using HRXRD methods, is essential for the production of reliable MEMS for space or medical applications where a high reliability is mandatory. We are convinces that these advanced state-of-the art X-ray methods will serve as a useful tool for setting up a fundamental understanding of aging problems of MEMS, especially for implantable MEMS.



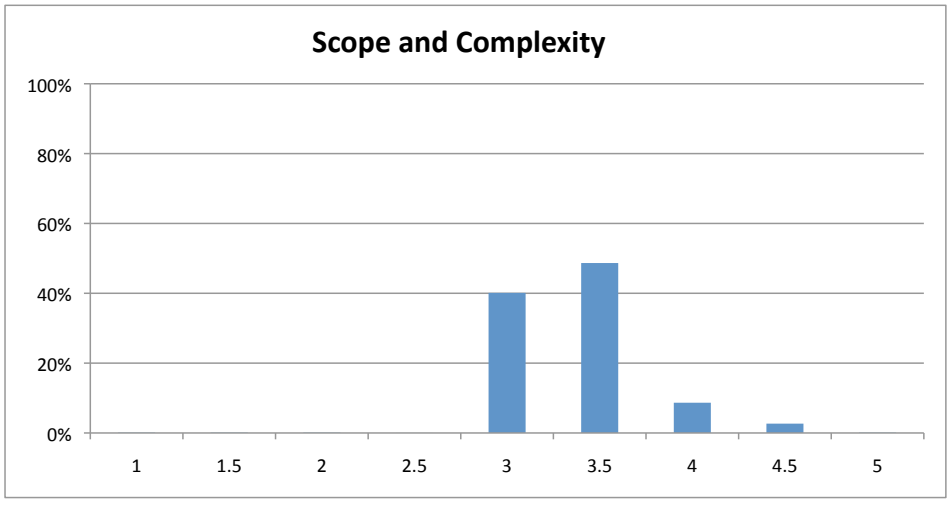
HRXRD equipment used for RSM investigations (a), encapsulated resonator MEMS (b), schematic view of the HRXRD experiment (c).

Evaluation 2011

For the first time a centralized evaluation was performed in the Master's program in 2011 according to the guidelines of the University of Bern. Both spring and fall semesters were considered leading to 43 course evaluations involving more than 1000 forms at total. The result regarding all forms (see below) reveals that the students are very satisfied with the course program and that the courses are interesting and demanding at the same time.



1: very poor
2: poor
3: good
4: excellent



1: far too narrow/narrow
3: just right
5: far too high/wide

Faculty

The BME Lecturers at Ziemer Ophthalmic Systems AG in Port, January 2011

To make this New Year's event for the lecturers of the Master in Biomedical Engineering Program truly amazing and different from last year, Professor Nolte proposed a visit to the company Ziemer Group in Port. Should you ever decide to get the feeling for what a bona fide Swiss high precision technology stands for: focused, well defined niche, state of the art technology and products of superb quality, yet outside the famous watch industry, Ziemer Group is your choice.

The lecturers were greeted by Mr. Ziemer himself, who took the time to explain the foundation and progress of his company, stating the main principles: right focus within the market, uncompromised high quality, with an entire chain of reproducible production under tight control. Ziemer was founded in 1999 and since then excels in ophthalmology products for both diagnostics and surgery. Their R&D evolves around patient needs, where medical approaches combine with cutting edge technological methodologies, and striving for competitiveness while not underestimating the costs. Mr Ziemer emphasized that the goal is not to produce unique perfect product, a sort of "Formula ONE" for ophthalmologists and optometrists, but to be able to ensure reproducible serial production of the perfect "Formula ONE". He explained that his high price politics allows and guarantees high quality products. Collaborations with other companies ensure highest quality components of their products, whose final assembly takes place under the roof of Ziemer Group.

After the fascinating introduction, we toured the company. We were shown a digital 3D model of the Femtolaser named FEMTO LDV (stands for Leonardo da Vinci), which incorporates 1000 pieces including many lenses for focusing, and weighs 250kg. FEMTO LDV replaces microkeratomes preceding the laser treatment of the cornea. Instead of cutting 100microns in the depth of the cornea, FEMTO LDV applies low energy beams to perforates the cornea, producing "cut" surface, which upon lifting allows subsequent application of the Excimer laser for precise cornea treatments. Amazing as it may sound, the whole procedure lasts only 5 minutes! We learnt that each laser is tested on 20 pig eyes, which have to be perfectly cut before the laser can be released to the market. We were next introduced to PASCAL, the new generation of dynamic contour tonometer, which essentially measures intraocular pressure, and is of utter importance for glaucoma patients. Easier to use and more precise compared with the classical device, based on a completely novel technological approach. Our next encounter was with GALILEI, which with extremely high precision measures corneal thickness and provides topographical measurements of the front and rear corneal surfaces. Finally, we had a demonstration of AMADEUS II, advanced automated microkeratome, a viable and dependable alternative to the FEMTO LDV. After refreshments, the respective specialist explained each product in more detail. We were truly impressed!

Still contemplating how a successful company built on well-defined values can prosper with such success, we travelled to the restaurant on Biel lake for yet another discovery – the famous "Treberwurst". This special sausage is cooked under the hood during distillation of special Schnapps. The distiller of the village cooks the sausages for the entire village. And they are seasonal – available only from mid January till the end of February. Thus, we were in luck to taste this speciality of the region, which attracts tourists from afar. Well, we understood why! Served with sauerkraut, new potatoes, and sprinkled with even more Schnapps, it tasted simply divine.

We had a chance to talk, to discuss, and to laugh – it was a perfect end of a wonderful afternoon – combination of science, entrepreneurship and excellent food! We are looking forward for the next event. And a big thank you to the organizers!

Frank Ziemer discussing with professors Niggli (UniBe) and Götte (BFH).

Faculty

Acikgöz Ersoy Dr., Bernur
Albrecht Prof. Dr., Christiane
Altmann Dr., Martin
Andres Prof. Dr., Anne-Catherine
Baum PD Dr., Oliver
Bernhard Dr., Hans
Bieri Dr., Oliver
Bohner Dr., Marc
Büchler Dr., Philippe
Burger PD Dr., Jürgen
Busato Prof. Dr., André
Cattin Prof. Dr., Philippe
Caversaccio Prof. Dr., Marco-Domenico
Czerwinska Prof. Dr.-Ing., Justyna
Debrunner Prof., Daniel
Dommann Prof. Dr., Alex
Egger PD Dr., Marcel
Eglin Dr., David
Eschbach Dr., Lukas
Firouzi Prof. Dr., Elham
Frenz Prof. Dr., Martin
Gantenbein Prof. Dr., Benjamin
Geiser Kamber Prof. Dr., Marianne
Götte Prof. Dr., Josef
Hänssgen, Kati
Hedbom Dr., Erik
Heuberger Dr., Roman
Hlushchuk Dr., Ruslan
Hofer Dr., Ulrich
Hofstetter Prof. Dr., Wilhelm
Hoppeler Prof. Dr., Hans-Heinrich
Hunt Prof. Dr., Kenneth
Hüsler Prof. Dr., Jürg
Ilgenstein Dr., Bernd
Jacomet Prof. Dr., Marcel
Jaeger Prof. Dr., Kurt
Jensen Prof. Dr., Björn
Jungo Dr., Markus
Keppner Prof. Dr., Herbert
Koch Prof. Dr., Volker
Kompis Prof. Dr., Martin
Kowal Prof. Dr., Jens
Kucera Prof. Dr., Jan
Lechmann, Beat
Lerf Dr., Reto
Luginbühl Dr., Reto
Lurman Dr., Glenn
Lüscher Prof. Dr., Hans-Rudolf
Mack Dr., Alexander
Moser Dr., Walter
Mougiakakou Prof. Dr., Stavroula
Müller Prof. Dr., Bert
Mussard Prof., Yves
Neels Dr., Antonia
Nef Prof. Dr., Tobias
Nesic PD Dr., Dobrila
Nevian Prof. Dr., Thomas
Niggli Prof. Dr., Ernst
Nolte Prof. Dr., Lutz-Peter
Reyes Dr., Mauricio
Sague Dr., Jorge
Schäfer PD Dr., Birgit
Schenk, Samuel
Schittny Prof. Dr., Johannes
Senn Dr., Pascal
Senn Prof. Dr., Walter Martin
Stahel Prof. Dr., Andreas
Sterchi Prof. Dr., Erwin
Stieger Prof. Dr., Christof
Stoyanov Dr., Jivko
Streit Prof. Dr., Jürg
Tschanz Dr., Stefan
Vandenberghe Prof. Dr., Stijn
Vetter Prof. Dr., Thomas
Vogel Prof. Dr., Rolf
Weber Prof. Dr.-Ing., Stefan
Wirz Dr., Dieter
Wolfram Dr., Uwe
Zeilhofer, Prof. Dr. Dr., Hans-Florian
Zheng PD Dr., Guoyan
Zwicker Prof. Dr., Matthias
Zysset Prof. Dr., Philippe

Master Theses 2011

In 2011, 32 students graduated as biomedical engineers of the University of Bern. 81% of the corresponding master theses were advised at the University of Bern and the Bern University of Applied Sciences, 13% at collaborating Swiss schools and research institutions, namely the University of Basel, the Swiss Paraplegic Research, and the ZHAW, while 6% of the advisors came directly from the medical technology industry.
For the first time, we are able to present the summaries of our master theses to a broad readership (pp. 17 – 37).
The following topics were worked on as well. However, for various reasons they did not allow for publication.

Asgari Siavash
Automated Pneumatic Driver for Ventricular Assist Device
Prof. Dr. Stijn Vandenberghe, University of Bern

Dellenbach Christian
Acquisition System for Multi-Mode Sensor Array II
Prof. Dr. Volker M. Koch, Biomedical Engineering Lab, Bern University of Applied Sciences

Kohler Lukas Christof
E2corder (Esophageal ECG recorder): Filter Design
Thomas Niederhauser, University of Bern
Prof. Dr. Rolf Vogel, Solothurner Spitäler AG

Martinec Michael
2D and 3D Interest Points in Medical Image Data
Dr. Beat Fasel, University of Basel
Prof. Dr. Philippe Cattin, University of Basel

Schneider Adrian
Augmented Reality for CMF Surgery
Prof. Dr. Jens Kowal, University of Bern
Prof. Dr. Philippe Cattin, University of Basel

Wüthrich Oliver
Trans-Catheter Mitral Valve Repair
Prof. Dr. Stijn Vandenberghe, University of Bern
Prof. Dr. Rolf Vogel, Solothurner Spitäler AG

Brun Dominik
Low Volume Flow Probe Calibrator
Prof. Dr. Stijn Vandenberghe, University of Bern

Hofmann Simon
Liver Surface Marker Tracking
Dr. Matthias Peterhans, University of Bern
Prof. Dr. Stefan Weber, University of Bern

Lovis Yannick
Trans-Catheter Mitral Valve Repair
Dr. Alberto Weber, University Hospital Bern
Prof. Dr. Stijn Vandenberghe, University of Bern

Schaffer Simon
Luft/Sauerstoff Gasmischer für die unabhängige Sauerstofftherapie
Dipl. Ing. Anton Rohrbach, Dräger Medical Schweiz AG
PD Dr. Jürgen Burger, Codman Neuro Sciences sarl

Thüring Martin
Optical Coherence Tomography Imaging of Crystalline Lens Posterior Surface
Prof. Christof Meier, Berner Fachhochschule – TI
Prof. Dr. Jens Kowal, University of Bern

Three Dimensional Mesenchymal Stem Cell Micro Cultures for Direct Expansion and Chondrogenic Differentiation

Giath Al-Dayri

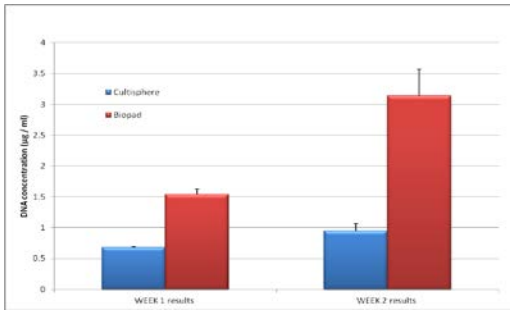
Supervisor: Dr. Jivko Stoyanov
Swiss Paraplegic Research, Spinal Injury Research

Background

An established method in the treatment of degenerative disc disease and induction of disc regeneration involves the expansion of mesenchymal stem cells (MSCs) on a flat surface, followed by using three dimensional cultures for chondrogenic differentiation and introduction to the degenerated intervertebral disc (IVD); however one of the problems with this approach is that it is time and resources consuming, and an alternative method involves the use of small three dimensional carriers which have large surface to volume ratio, offering an efficient environment for direct expansion and differentiation, and possess the ability to be directly injected to the IVD. The goal of this project was to develop such cultures.

Project Scope

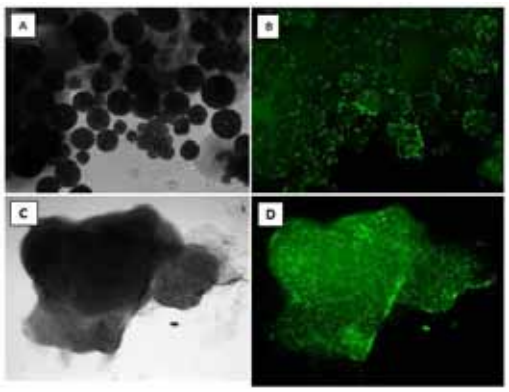
Different materials and processing methods were tested to develop potent carriers which were to be seeded with MSC and incubated in basic fibroblast growth factor (bFGF) based DMEM medium for 1-2 weeks for growth, followed by 2 weeks of incubation in control and chondrogenic differentiation media. Samples were compared in terms of their attachment, growth, chondrogenicity, and injectability potential. The experiments also evaluated the use of several dynamic versus static incubation settings for culture optimization.



DNA quantification of MSCs seeded on commercial micro carriers (Cultispher®) and lab-processed equine collagen type-1 sheets (Biopad®) at 1 and 2 weeks of seeding.

Results

Lab-processed wound dressing made of equine collagen type-1 demonstrated the highest growth potential, with DNA concentrations of 1.54 µg/ml ± 0.06 and 3.14 µg/ml ± 0.3 at one week and two weeks of MSCs seeding respectively; second to it were commercially available micro carriers (Cultispher®) which showed DNA concentration of 0.68 µg/ml ± 0.01 and 0.94 µg/ml ± 0.09 at one week and two weeks of MSCs seeding respectively in static conditions. PCR data showed that MSC seeded on the mentioned equine collagen type-1 carriers also demonstrated the highest expression of Aggrecan, Collagen type-2, and SOX9, suggesting the highest chondrogenic differentiation capacity when compared with other types of micro carriers in static conditions with consistent GAG assay results . Results also suggested a favorable outcome with static cultures over the tested dynamic cultures in terms of MSC proliferation and chondrogenic differentiation.



SYBR Green florescence and bright-field microscopy images at day 23 of MSC seeding on Cultispher® micro carriers (A,B) and the developed collagen type-1 carriers (Biopad®) (C,D).

Conclusion

Optimized equine collagen type-1 micro cultures have a significant potential for MSC direct expansion and chondrogenic differentiation. Further stages of evaluation and improvements on the developed carriers are consequently recommended.

Effects of Implant Surfaces on the Peri-Implant Environment

Thomas De Bruyne

Supervisor: Prof. Dr. phil. nat. Willy Hofstetter
Department Clinical Research
University of Bern

Background

Stable implants in bone are designed to optimize the bone - implant connection. To improve the kinetics of osseointegration, the implant's surface has to be well designed by adapting the surface composition, surface chemistry and surface topography. These parameters will modulate the foreign body reaction that in term will determine the composition of the peri-implant micro-environment to become either osseogenic or osseoinductive. Based on earlier investigations by Boyan, *et al.* in 2003 and Refai, *et al.* in 2004 it is known that different titanium implant surfaces will affect the body's reaction to the foreign material, which in turn affects the repertoire of cytokines and growth factors released into the peri-implant environment. Earlier investigations suggest that certain implant surface structures will support the generation of osseogenic conditions in the vicinity of the implant. The tissue reaction follows the wound-healing pathway of haemostasis, namely inflammation, and proliferation without the regeneration of the wound. During this pathway different types of cells are involved and their function is affected by the various surface topographies.

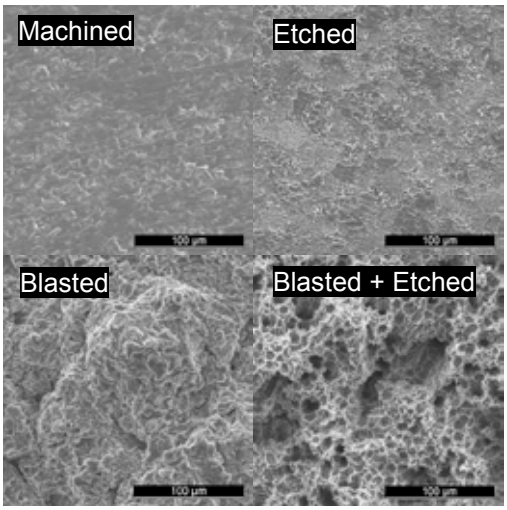


Fig. 1: SEM-Pictures of commercial pure Titanium (cpTi) discs with different surface topographies (scale: 100µm)

Project Scope

The aim of the thesis was to observe the effect of cpTi surface topographies on osteoblasts and cells from the monocyte/ macrophage lineages such as osteoclast progenitor cells (OPCs), bone marrow cell (BMC) and macrophage-like RAW264.7 cells.

The interactions of the cells and the implant surface were characterized by quantitating cell adherence (XTT-assay), diff-erentiation capacity (by evaluating Alkaline Phosphatases (ALP)) and morphology (Fluorescence staining). Furthermore, condi-tioned media (CM) were analyzed by enzyme-linked immune sorbent assays (ELISAs) for four cytokines, colony-stimulating factor 2 (CSF2), Osteoprotegerin (OPG), Tumor necrosis factor-α (TNF- α), Interleukin 1 beta (IL-1β). The CM were subsequently used to treat cultures of osteoblasts and OPCs, that were investigated for their proliferation (XTT-assay) and differentiation capacity (ALP & Tatrate-resistant acid phosphatase).

Results and Discussion

In this study cpTi surface topographies exert no reproducible effects on osteoblast adherence and differentiation. In the collected CM no levels of CSF2 were measured, significant levels of OPG could be measured depending on the surface topography. The observed dependency of OPG levels with the surface topographies concludes that the osteoblasts activity in secreting and using up OPG is influenced by the surface topography. Treatment of osteoblasts and OPCs with CM exerted no conclusive differences in cell adherence and differentiation between the treated cultures.

On cells of the macrophage lineages, the cpTi surface topographies exert reproducible effects on OPC adherence. However, the collected CM contained no levels of TNF-α or IL-1β. These results were in contrast and with investigations by Refai, *et al.* in 2004. Treatment of osteoblasts and OPCs with CM exerted no conclusive differences in cell adherence and differentiation between the treated cultures.

Diagnosis and Treatment of Bruxism with an Active Mouthguard

Raphael Deschler

Supervisor and first examiner: Prof. Dr. Volker M. Koch, *BFH*
Second examiner: Dr. med. Dr. med. dent. Michael Büttner, Inselspital
Financial support: INVENTUS BERN - Stiftung

Background

Bruxism is characterized by the subconscious and nonfunctional grinding or clenching of the teeth. Bruxism often results in abnormal wear patterns of the teeth and over time, dental damage will occur.

Bruxism is an uncontrolled habitual behavior and one of the most common sleep disorders. Studies have shown that about 5 % of the US population develop symptoms severe enough to have a mouthguard made by a dentist. A mouthguard out of hard acrylic is a standard treatment to reduce tooth wear.

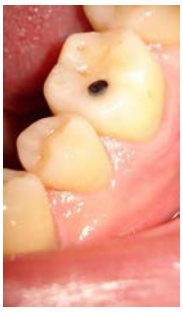
Another but seldom used treatment is the biofeedback method. In this method electrodes are placed on the masseter or temporal muscle and connected to a monitoring device which produces a sound whenever a muscle activity is detected. For short term use these devices seem to decrease bruxing time efficiently. Unfortunately the electrodes and their wires are uncomfortable and one can get used to the sound, and the effect decreases.

The aim of this project was to develop a mouthguard that incorporates an electronic device to measure and radio transmit the interocclusal distance and the sagittal and transversal mandibular displacement. Based on these real time data, an electrical stimulation could be produced and applied as feedback upon tooth-mouthguard contact.

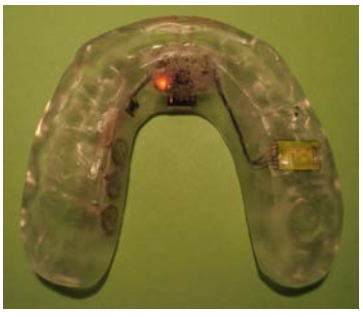
Project Scope

A tiny magnet was encapsulated in titanium and embedded in a tooth filling preexisting on the occlusal surface of a molar.

Two tiny electronic circuit boards have been developed to be encapsulated in the mouthguard, a transmitter board and a sensor board.



Encapsulated magnet in molar



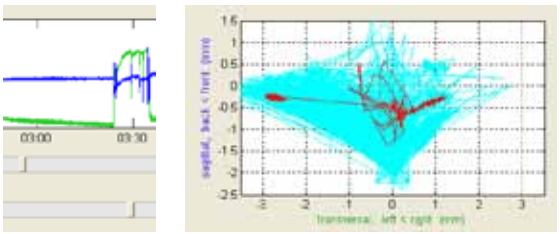
Active mouthguard with sensor and transmitter electronic and batteries

The sensors on the sensor board are read out four times a second by the transmitter board, which radio transmits the data to a receiver connected to a laptop. Depending on the sensor's measured field strengths, the magnet's position can be determined.

The electronic is powered by batteries that can be recharged via electromagnetic field (slit torus coil).

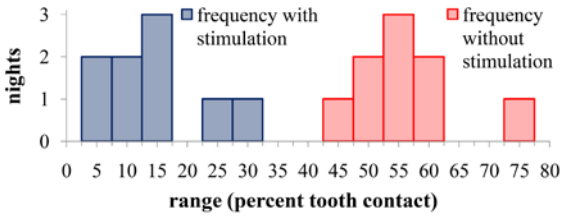
Results

With a Matlab program, data of a whole night with characteristic sleep phases can be analyzed.



A timeslot of interest and its sagittal versus transversal movement plot redrawn in red

First measurements of 8 nights with and without biofeedback resulted in a highly significant reduction of tooth-mouthguard contact.



Measurements of 8 nights with and without biofeedback

Discussion

Our measurements show grinding activities during short sleep phases as reported in several studies.

The new mouthguard offers additional variables like position and speed to define conditions upon which bruxing events are detected.

The hardest and still unsolved technical problem of the project is the fast degrading of the rechargeable batteries. They only lasted for 3 months.

Clinical research would have to prove the safe operation, long term effectiveness and further effects of a stimulation on the users sleep hygiene and mental health.

Determination of the Glenohumeral Joint Reaction Force at Archery

Christoph Farrér

Supervisor: PD Dr. Stephen Ferguson
Institute for Surgical Technology and Biomechanics
University of Bern

Introduction
The implantation of prosthesis in the area of knee- and hip joint nowadays is considered to be routine surgery. This is not the case in the area of the upper extremities. In order to achieve good clinical results, the resulting forces in the joints have to be examined more accurately. A combined abduction and elevation movement was analysed with the help of the activity archery. The goal of this study was to determine the glenohumeral joint reaction forces.

Method
Two different measuring methods were used to determine the glenohumeral joint reaction forces. On the one hand an indirect method based on inverse dynamics was applied; on the other hand a direct invivo measuring method was applied. With regard to the indirect method, the movement of three participants (FACH 83, STCH 68 and DIEV 59) during tensioning the bow string were measured in a motion capture laboratory. The characteristic elongation curve of the bow and the Thera-Bands were measured in a uniaxial tension test. The motion capture data and the characteristic curve were used to support a musculoskeletal model (AnyBody, Denmark) (Figure 1).

Figure 1: Musculoskeletal Model

With the help of inverse dynamics the reaction forces in the glenohumeral joint were determined. With regard to the direct method, the glenohumeral reaction forces of two subjects (S4R and S6R) with instrumented shoulder prosthesis were measured. Instead of a bow, two Thera-Bands (TB) were used, because the subjects were not able to pull the bow.

Results
Using the indirect measuring method, glenohumeral joint forces between 899N and 1418N were calculated (10 measurements per participant). Using the direct measure method, glenohumeral joint forces between 609N and 996N were measured (Figure 2).

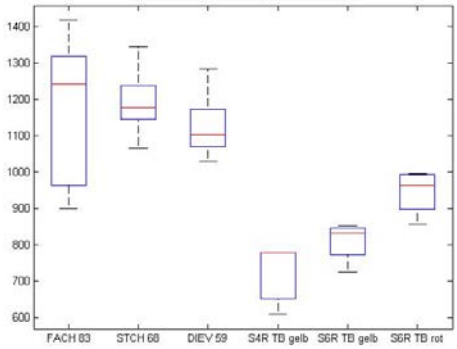


Figure 2: Glenohumeral joint reaction forces for different participants

Discussion
It is possible to use a musculoskeletal model to process the motion and the external force of the bow and to compute the glenohumeral joint reaction forces during the activity of archery.
The subject S4R was only able to pull the Thera-Band of the lowest force category (3 measurements). The subject S6R was able to pull the Thera-Band of the lowest and the second lowest force category (5 measurements per Thera-Band). The data sets of the direct and indirect measurement method were compared and normalised by three different criteria. The criterion “maximum pulling force” generated the best correlation. A statistical analysis of the measurement data was not possible due to insufficient subjects and too little measurement data sets per subject. The comparison of the direct and indirect method shows the same order of magnitude.

Multiview Autostereoscopic Displays and Rendering: A Prototype System and Potential Applications in Medical Technology

Mathias Griessen

Supervisor: Dr. Matthias Zwicker
Institute of Computer Science and Applied Mathematics
University of Bern

Background

3D image acquisition and stereo-view displaying is becoming a standard technology in medical systems. Yet, the next step are autostereoscopic displays. They provide a more natural 3D viewing experience than two-view stereo systems because they do not require special glasses. They further provide motion parallax, and they can show appropriate 3D images to several viewers simultaneously depending on their position.

Project Scope

In this project a working prototype of a multi-view autostereoscopic rendering and display system was build. This includes rasterized rendering of conventional polygon based objects and real-time volume rendering of medical dataset acquired by CT or MRI.

A light field mapping model makes it possible to change the native optimal viewing distances which is given by lenticular autostereoscopic displays. This mapping model is further extended with viewer tracking achieved by a stereo camera frame. This tracking system is limited to a single viewer but increases the image quality and the 3D perception.

Alioscopy 42" autostereoscopic display showing a real-time volume renderer CT dataset of a head (3D effect is obvious not printable)

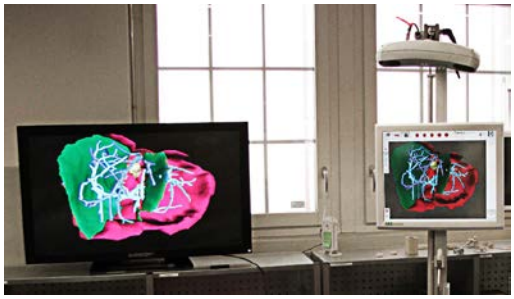
Results

Results

The light field mapping to different viewing positions and even more the mapping to a tracked viewer assume that the display parameters are very precisly known. The developed general usable calibration method for autostereoscopic lens systems, achieves this requirement.

The prototype system connects the different technologies and shows the possibilities with current hardware.

Autostereoscopic displays have some drawbacks which need to be solved for effective applications. To prove the technique in a more real environment, the prototype was integrated into the CAScination liver navigation software.



CAScination surgery navigation system extended with an autostereoscopic display

Discussion

Real-time volume rendering is already standard for visualization of 3D structures in the medical field. The extension to autostereoscopic viewing provides information about the depth which can be helpful. Specially for non invasive surgery where the intervention is completely driven by computer navigation on acquired images, the 3D view gives additional, more natural information about the tool position inside the subject.

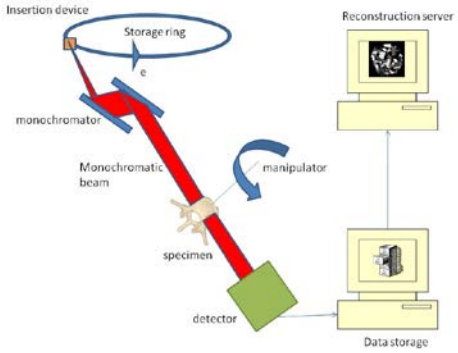
The Microstructure of Porous Scaffolds, Mandibular Bone Grafts and Three-Dimensional Cell Clusters

Sarper Gürel

Supervisor: Prof. Dr. Bert Müller
Biomaterials Science Center
University of Basel

Background

During the last decade, several tissues and biomaterials for medical applications in replacing bony tissues have been developed. Porous scaffolds, three-dimensional cell clusters and mandibular bone grafts are distinct examples of these developments. The characterization of the complex three-dimensional structures, however, is still mainly restricted on the two-dimensional analysis of histological slices. The present thesis examines the quantitative analysis of porous scaffolds, mandibular bone grafts and three-dimensional cell clusters on the basis of synchrotron radiation-based micro computed tomography (SRμCT) measurements.



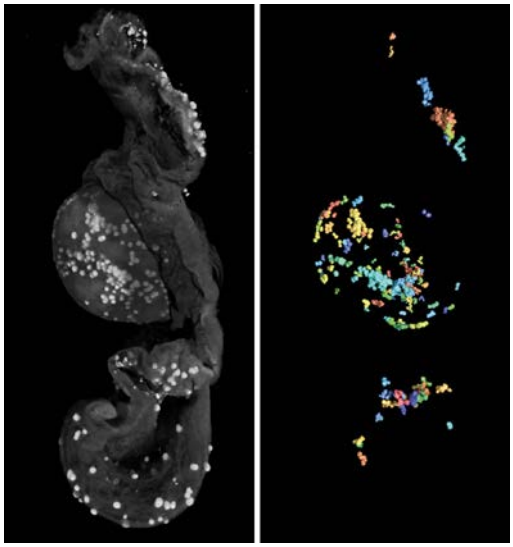
Schematic representation of a SRμCT experiment. Intensive x-ray radiation can be generated from a synchrotron radiation source. By using a monochromator, the wavelength of x-ray light is filtered so that the measured object becomes semi-transparent. Several hundreds to thousands of projections are recorded in order to reconstruct the microstructure of the sample in a non-destructive manner.

Project Scope

An automated search of pre-defined microstructures through component labeling is applied to the three-dimensional datasets in order to identify features that reside independently from other components.

Results

The examples demonstrate three levels of complexity: rather large pieces of bone augmentation material that touch each other, individual adipocytes difficult to automatically segment in a histoid and osmium-stained adipocyte exhibiting higher X-ray absorption than the surrounding tissue.



3D representations of the gray-scale data (left) emphasizing the spherically shaped adipocytes and the related color-coded components (right) are given. Note that the adipocytes form clusters.

Discussion

The present work illustrates that all 3 types of materials studied (HA scaffold, particulate bone graft, scaffold-free cell cluster) present a different micro-morphology and deliver complementary solutions for the design questions occurring during the implant preparation. Although the structures of interest such as the cells can be labeled, de-clustering of the components requires the incorporation of further tools including pre-defined masters or erosion and dilation algorithms.

Integration of a Microcontroller based Beam Deflection Device into a Computer Assisted Retinal Laser Photocoagulation System

Tobias Imfeld

Supervisor: Prof J.H. Kowal, Ph.D.
ARTORG Center for Biomedical Engineering Research
University of Bern

Background

Retinal laser photocoagulation is an established treatment modality for a wide variety of eye diseases such as diabetic retinopathy or age-related macular degeneration, and is usually delivered in a manual procedure. The efficiency of the treatment procedure depends essentially on the experience of the doctor in handling the system and at the same time on the patient's behaviour. A computer assisted photocoagulation system could enhance the overall effectiveness of the treatment procedure as it is faster and more accurate than the ophthalmologist.

Project Scope

As part of the computer assisted retinal photocoagulation system project, a laser beam deflection unit has been developed, characterized and integrated in a scanning digital ophthalmoscope (SDO). In the frame of this master thesis the beam deflection unit was integrated into the existing online retina registration (ORR) software. The implementation requires closed-loop control of laser beam deflection in the x- and y-axis. Special consideration should be laid on latency control of the complete system because it is based on a video source.

Figure 1: SDO with mounted deflection unit pointing on an artificial eye

Additionally the thesis addresses the problem of planning the laser spot position using customized laser spot patterns on a fundus mosaic prior to the actual treatment.

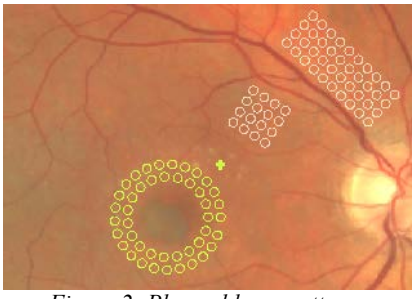


Figure 2: Planned laser patterns in the ORR software

Results

The deflection unit is successfully integrated in the ORR software. The laser beam is automatically deflected to each planned treatment point. As tests on the video hardware have shown, a latency of 3 frames appears in the current configuration. For the calculation of the automatic deflection, a scaling based algorithm was introduced which converts the difference between current laser location and planned treatment point to the angle format used by the deflection unit. Tests between a constant and an optimized scaling factor show significant improvements using the second value.

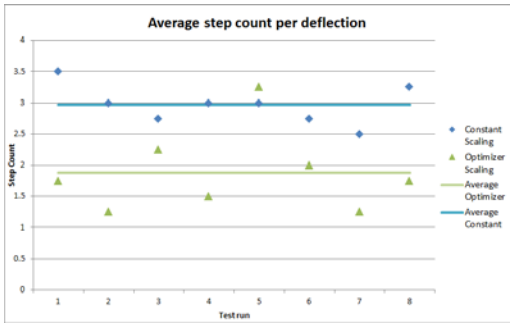


Figure 3: Diagram comparing scaling types

Discussion

The integrated automatic laser beam deflection allows speeding up the therapy session as it deflects the laser much faster and more accurate than an ophthalmologist could. In addition the system can react faster on movement of the patient which reduces unwanted injuries in the patient's eye. Therefore the current system is more effective and secure than the manual procedure.

Novel Delivery System for Trans-Catheter Aortic Valve Implants

Mark Keller

Supervisor: Prof. Rolf Vogel, MD, PhD
ARTORG CENTER, Cardiovascular Engineering Group
University of Bern

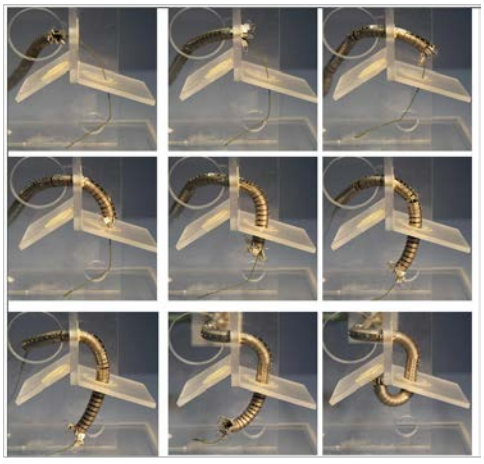
Background

Trans-catheter aortic valve implantation (TAVI) is a novel technique to treat severe aortic valve stenosis. Other than the standard surgical approach, TAVI is a keyhole procedure performed on the beating heart and does not require neither open-heart access nor heart-lung machine. Currently, the two clinically available devices are implanted via the transfemoral, transsubclavian or transapical approach. TAVI's current major limitations are related to the large device delivery systems, which makes implantation very difficult in patients with peripheral artery or may requires surgical access closure.

Project Scope

Goal of this project is to investigate a device delivery technique that overcomes the limitations of the present approaches.

Based on the implantation pathway, a delivery system for the retrograde approach was developed to get access to the aortic valve via vena cava inferior and septum passage.



The stiffenable Prototype access the aortic valve via the antegrade approach.

The concept of the built Prototype based on a stiffenable structure which consist of vertebrae like hollow Ti Elements which can be locked to each other. This stiffenable structure should be able to bear the occurring friction forces from the through passing artificial aortic valve.

Results

Functional tests of the Prototype had shown that the developed concept is capable to reach the site of the aortic valve where it could be positioned and stiffened with its distal end perpendicular to the natural aortic valve.

The magnitude of the occurred forces [60N] during the delivery of the artificial valve exceeded the strength of the material of the structure what had lead to failure of the prototype and the aortic implant.

The novel delivery catheter Prototype in its stiffened state

Discussion

The magnitude of the friction force in the distal ending of the delivery catheter shows clearly that the surface quality of the delivery channel must be improved and the transition from one locking element to its following has to be refined in such a way that it does not obstacle through passing aortic valve implant.

Joint Degeneration Pattern in Severe Pincer Impingement and its Implications for Surgical Therapy

Dr. med. Emanuel Liechti

Supervisors: Prof. Dr. Stephen Ferguson [a], Dr. med. Moritz Tannast [b]
[a] *Institute for Biomechanics, ETH Zürich*
[b] *Department of Orthopaedic Surgery, Inselspital University of Bern*

Background

Pincer impingement is an established cause of hip pain and osteoarthritis. The pain is due to an early pathological contact of the excessive acetabular rim with the femoral head-neck junction. According to previous radiographic descriptions, the joint degeneration in severe pincer impingement typically occurs in the superomedial aspect of the hip sourcil, which is not explained with the femoroacetabular impingement (FAI) concept.

Methods

3D finite element models of a dysplastic, normal and severe pincer joint were developed based on anatomical and radiological data (Fig. 1A-C). A fourth geometry was generated representing a severe pincer joint after acetabular rim trimming, which is the current surgical treatment for pincer FAI (Fig. 1D). In vivo force and motion data for walking and standing to sitting were applied to all joint morphologies.

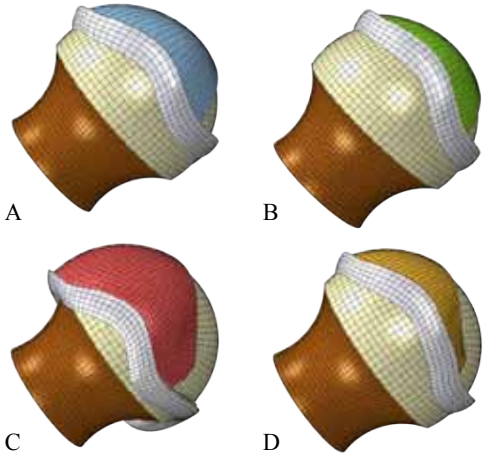


Figure 1. Frontal View of right hip joints; (A) Normal joint. (B) Dysplastic joint. (C) Severe Pincer FAI. (D) Rim Trimming.

Results

The calculated contact pressures and stresses of the severe pincer FAI were concentrated along the medial acetabular cartilage margin, whereby the peak stress during walking was about 1.6 times that of a normal joint (Fig. 2C). For the walking case, the dysplastic configuration, compared to the severe pincer FAI, showed an opposite stress and pressure pattern having its peak values located at the anterolateral acetabular rim (Fig. 2B). During all simulations no impingement occurred, hence the increased pressures and stresses were due to axial overloading.

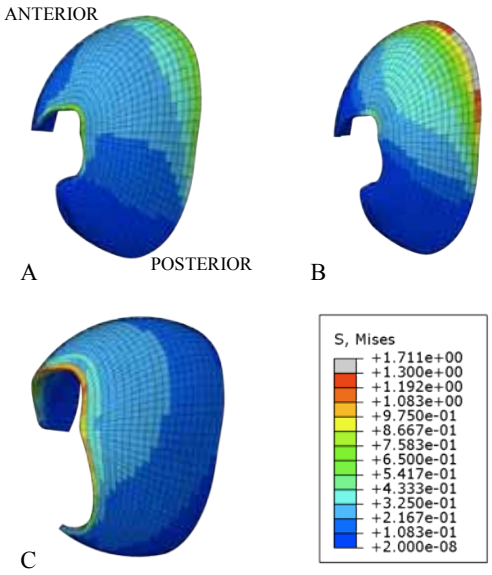


Figure 2. von Mises Stress distribution (in MPa) during the midstance phase of gait; (A) Normal acetabulum. (B) Dysplastic acetabulum. (C) Severe Pincer FAI.

Conclusion

These findings substantiated our hypothesis, that the acetabulum in severe pincer FAI is rotated to the lateral side, leading to an insufficient coverage of the femoral head in the medial aspect of the joint - similar to a 'medial dysplasia'. Zones with high von Mises stresses corresponded with clinically observed damage zones in the acetabular cartilage. Furthermore, this work provides useful information for joint-preserving surgical therapy of severe pincer impingement.

Simulation of the Effects of Different Pilot Helmets on the Neck During 'Air Combat'

Roger Mathys

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Institute for Surgical Technology and Biomechanics
University of Bern

Introduction

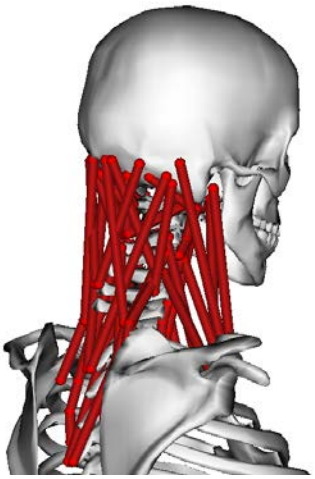
New generation pilot helmets with helmet mounted devices open up new areas of air combat and enhance the situational awareness of the pilots substantially. However the additional equipment increases the helmet mass and shifts its center of mass forward. Two pilot helmets with different mass properties are therefore modeled to simulate their effects on the muscle activations and joint reactions in the neck during air combat.

Methods

A musculoskeletal OpenSim-model is used which involves the kinematics of the head and neck, a variety of muscle units and all the different mass properties. The model consists of eight articulating rigid bodies (C0-C7) and their respective movements are given as a function of the total head-neck movement. The implemented muscles include physiological parameters like maximal isometric force, force-length and force-velocity behavior. An inverse dynamic approach is used to determine the required joint moments for given postures at various G-loads. The subsequent static optimization process reduces the cubed sum of muscle activations and estimates the required muscle forces. Finally the resulting joint reactions at the T1-C7 level are calculated. Basic quasi-static movements like flexion-extension, axial rotation and lateral bending are simulated in order to systematically analyze and compare the different helmet configurations.

Results

The systematic analysis of predefined movements allows the identification of head postures which induce much higher loads on the cervical spine than encountered in a neutral head position. The increased weight and the forwarded center of mass of a new generation helmet with mounted devices lead to higher muscle activations and higher joint reactions over a wide range of head and neck movements. High muscle activations occur especially in the lateral neck during extensive rotation, bending and extension. The muscle activations which are required to balance the head and neck in extreme postures increase the compressive force on the T1-C7 segment substantially. The mass of the helmet has a direct influence on the generated load in the neck.



An illustration of the musculoskeletal OpenSim-model used in this thesis.

Discussion

The calculated values have to be interpreted with care as the model has not been validated. However a comparison with data found in the literature showed that the results are reasonable. It is assumed that the physical mass properties of the head and helmets, together with the morphometric data of the implemented muscles have the largest influence on the outcome. A detailed motion analysis with the two helmets would help to refine the existing model.

New Approach to the Display of a Portable Visual Aid

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Bern University of Applied Sciences

Background

The sense of sight affects a large portion of our extrasensory perception. Various diseases of the retina and the nerve fibers, that significantly impair the sense of sight such as age-related macular degeneration (AMD), are currently not treatable. In these cases, one can attempt to compensate the visual impairment by technical means (e.g. by visual aids). The goal of magnifying visual aids is to compensate the vision loss by an appropriate enlargement to re-enable reading of texts.

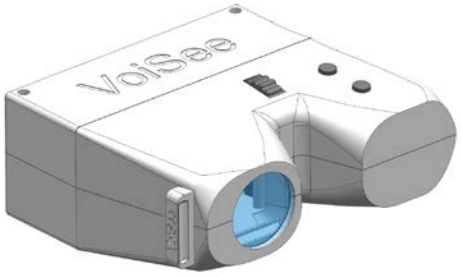
Within the scope of the VoiSee® project, research is conducted towards a novel, portable visual aid, which will considerably disburden the everyday life of AMD affected individuals by means of a large field of view to restore their ability to perform general tasks more independently as well as to read smaller writings outside their homes (as for example product inscriptions in supermarkets or departure boards in railway stations). In addition to the large field of view, a comfortable viewing must be achieved, while the dimensions of the device ought to remain acceptable. Both properties (optical and ergonomic) represent an important presupposition for the acceptance of the future VoiSee® vision aid, which thus distinguishes itself from already existing yet much more restricted portable visual aids.

Project Scope

During the present thesis a new approach for the display of a portable VoiSee® visual aid had been reviewed with regard to feasibility and was thereupon implemented. During a subsequent patient study, the newly developed display was compared to two already existing optical VoiSee® displays, which had also been optimized during this thesis. For the evaluation of the study, optical, ergonomic and economic criteria were considered for selecting the optimal display type.

Results

The newly developed display increases the maximum visual angle from 48.9° to 68° compared to the previous display types. Moreover, the new optics substantially improves the viewing comfort.



The newly developed display

The statistical significance of the benefits of the newly developed display was shown by a systematic study. 22 of 25 questioned AMD affected individuals preferred the newly developed display which was also the only one of the presented display types judged to be acceptable in everyday life.

Additionally, essential knowledge for further development of the VoiSee® vision aid could be gained during the study.

Discussion

The best possible display technology (display-hardware with appropriate optics) could be selected by study results. The chosen display type will be implemented into the first complete VoiSee® prototype in a future project. Therefore, a big leap could be taken towards an optimal portable electronic vision aid.

Analysis of High-speed Opto-biological Data from Excitable Tissues

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Bern University of Applied Sciences

Background

To elucidate and further understand electrical signalling in networks of excitable cells like cardiomyocytes and neurons, state of the art experimental techniques permitting to assess membrane potential fluctuations with high spatio-temporal resolution are indispensable. Generally, such experiments are based on the use of voltage sensitive dyes which report membrane potential variations by changing their fluorescence properties. The resulting light intensity changes are captured by photodiode arrays or high-speed cameras that are fast enough to follow electrical activation, i.e., the spread of action potentials with variable spatial resolution from single cells to entire tissues like the heart or the brain (fig. 1).

Project Scope

Whereas the acquisition of data works very well with these systems, available software solutions for data analysis are rudimentary and barely meet the specialized demands of researchers. In particular, they fail to calculate parameters describing the network behaviour of the excitable tissues under investigation. A solution to accomplish the task of processing cardiac mapping data is described in this thesis.

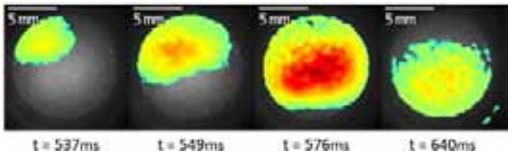

Fig.1, Propagating excitation wave on cardiac tissue, captured by the Micam Ultima high-speed camera and filtered by the developed software.

Results

The data analysis tool developed in this study provides basic data conditioning and processing functionalities as well as advanced feature extraction capabilities to statistically analyse the network behaviour of excitable cells. Recorded data is processed in both the spatial and the temporal domain. The software is based on a plug-in strategy that allows seamless integration of new data processing functionalities without the need of remodelling the whole architecture.

Raw mapping data from high-speed cameras and other sources like multi-electrode arrays can be processed using various approaches. Pre-implemented filters and analysis plug-ins allow the extraction of desired characteristics of recorded signals and the generation of different feature maps (e.g., activation-, speed- and upstroke velocity maps, fig.2). Moreover, the detection and tracking of phase singularities, the clustering of propagating wave fronts, the creation of velocity profiles or the tracking of activation paths are implemented in the software. For this, several new algorithms have been developed, like the tracing of activation waves based on the fast marching method.

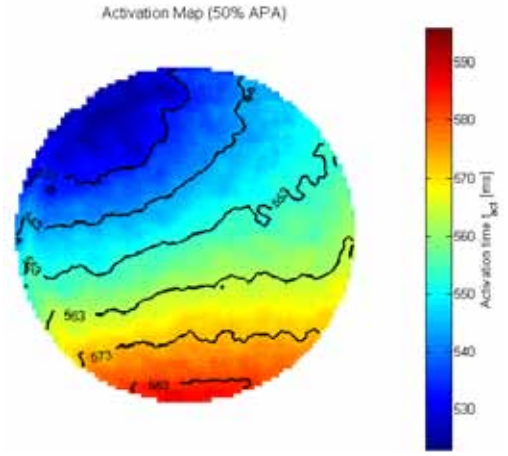

Fig.2, Example activation map displaying the color-coded action potential activation times (APA=Action potential amplitude).

Discussion

The new software drastically reduces the evaluation time of cardiac mapping data and also improves the general handling during this phase of analysis. It is now possible to process data in an intuitive way by the graphical user interface that offers direct feedback, rather than manually writing code for data analysis. The software enables scientists to obtain a comprehensive analysis of the experiments in short time which allows them to focus on the understanding and treatment of the causes of heart diseases.

Finite-Element-Model of the Lumbar Spine to Analyse the Effects of Posterior Dynamic Stabilisation Systems on the Range of Motion

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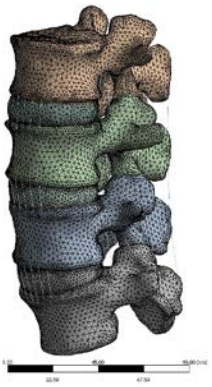
ZHAW Zürcher Hochschule für Angewandte Wissenschaften
IMES - Biomechanical Engineering

Background

To find and analyse the origin of back pain, there are different established possibilities like in-vitro and in-vivo tests or the simulation with Finite-Elements (FE). These FE-Simulations offer the chance to calculate deformations and stresses, if mechanical forces act on a geometrical defined model with appropriate material properties.
The goal of the present study was to build an analytically correct model of the human lumbar spine from L2 – L5 to simulate and analyse the biomechanical behaviour of dynamic spinal implants.

Materials and Methods

The spinal model was built with the commercial available FE-Tool Ansys Workbench. The 3-dimensional anatomical geometries of the vertebra were gathered by CT-Data reconstruction. As there were no MRT-Data available, the intervertebral discs (IVD) were constructed manually with CAD. The ligament structures are based on non-linear springs and internal FE-constraints.
During an evolution process several FE-Models based on these geometries were built. A simple, pure linear FE-Model served as base model. This model was then successive extended with the missing structures and complex non-linear material laws.

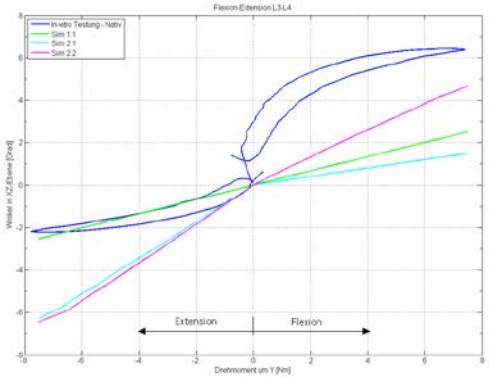


Extended Spine FE-Model from L2-L5

To simulate the flexion/extension, lateral bending and axial rotation motions, a torsional moment of 7.5Nm was applied in the three principal anatomical planes. The models were further numerically verified and underwent a ligament specific sensitivity analysis.

Results

The results of the base model showed good quantitative correlation in three load cases compared to the in-vitro test data (Sim 1.1). In the other load cases the IVDs limited the spinal movement excessively.
The extended FE-models (Sim 2.1, 2.2) showed a hypermobile kinesic behaviour compared to the basic model.



RoM at L2-L3 of Sim 1.1, 2.1, 2.2 and the in-vitro test data during flexion / extension

Discussion

Compared to the in-vitro test data, the FE-models show a mainly linear curve progression. On the one hand, this originates from the used material data, and on the other hand from the parameterization of the IVDs. Nevertheless, good correlation of the in-vitro data and the simulation at the maximal RoM point could be achieved. This offers the possibility to use the FE-models to analyse specific physical properties like stresses, strains, etc. not just of the spinal implant but also of the surrounding bony tissue at maximal deflection.

Influence Of Kyphosis On Spinal Loading

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Background

Osteoporosis affects an estimated 75 million people in Europe, USA and Japan. The biggest risk of fracture is in the spine. A 50 year old white woman has a 16% lifetime risk of experiencing a vertebral fracture (Melton LJ 3rd et al. 1992). Osteoporosis takes a huge personal and economic toll. The spine has different curves in the sagittal plan to absorb impacts. When the curvature is beyond physiological norms it causes serious problems. An excessive curvature in the thoracic spine, also called hyperkyphosis, results from wedge-shaped compression of individual vertebral bodies after a fall or even in daily activities in the case of osteoporosis.
Literature shows also that an excessive thoracic curvature is an important risk factor for future fractures, even independent of low bone mineral density or prior fracture.

Project Scope

The influence of posture and muscle aging (sarcopenia) on spinal loading during box lifting is to investigate. For the most severe cases is the effect of taping to demonstrate.
The software is a three-dimensional multi-body dynamic simulation package called AnyBody Modeling System (AnyBody technology A/S, Aalborg, Denmark). It defines the model in a text-based, declarative, object-oriented language.

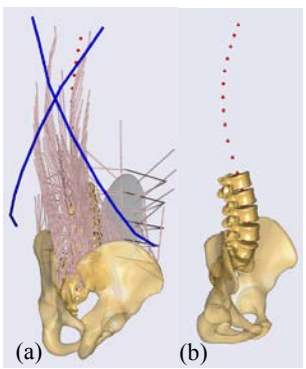

Figure 1: Modified model with tape elements in blue (a) and without muscles (b). Image source: AnyBody Modeling System

Results and Discussion

Kyphosis and sarcopenia do not influence the compression and shear load in the spine in a clear trend. The moments in contrast are increasing when the erector spinae gets weaker or when the kyphosis degree increases (Fig. 2).

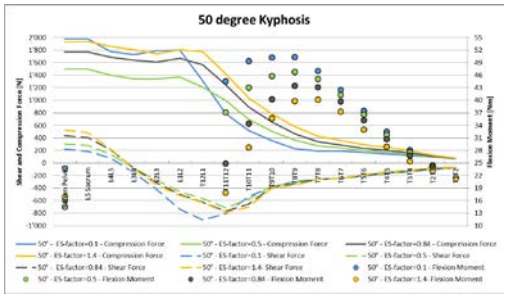

Figure 2: Influence of sarcopenia in the case of a 50 degree kyphosis. ES-factor represents the scaling factor of the erectus spinae muscle.

The hypothesis was that the spinal load increases when the erector spinae gets weaker or when the kyphosis degree increases. So the compression and the shear forces do not behave like expected.
The actual model has a stiff thoracic spine because there are not enough muscles to balance the degrees of freedom of each vertebra. So the moments in the thoracic spine are carried only from the joints. In reality these moments are carried from muscles which contract and so produce additional compression and shearing load in the vertebral bodies. Some of these muscles span from the thorax to the pelvis or sacrum, thus creating compression and shearing forces in the entire spine.
It is to expect that the bigger moments in the thoracic spine of the actual model are increasing the load in the whole spine when additional muscles were implemented and so the thorax is no longer stiff.
Taping showed a decrease of these moments in the upper thoracic spine.

Endoscopic Measurement Head for Optical Coherence Tomography

Peter Stalder

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Institute for Human Centered Engineering, OptoLab
Bern University of Applied Science

Background

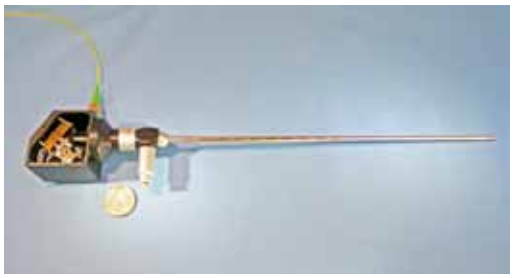
Osteoarthritis of the knee joint is a painful mechanical degradation and abrasion of the articular cartilage and the subchondral bone. It can be induced by cartilage structure irregularities and micro lesions. About one in ten individual is affected with early osteoarthritis in western countries which leads to considerable limitations of daily living. Today's arthroscopic treatment of osteoarthritis implies debridement (removal of damaged or infected tissue), lavage, analgesics (pain killers) or total knee joint arthroplasty (replacement) for severe degradations. But the usefulness and achievements of these procedures are questionable. Therefore, cartilage reconstruction or grafting is a demanded and an ongoing research topic. Virtual biopsy *in situ* by Optical Coherence Tomography OCT would be a valuable tool to assess cartilage thickness and abrasion degree and to detect micro lesions.

Project Scope

However, due to the restricted penetration depth of OCT, which is generally less than 3mm, it requires some type of endoscope probe for direct access to articular cartilage. The OCT laser beam has to be deflected at the proximal end of the endoscope in order to acquire cross-sectional images. The OCT scanning unit should be insertable into working channels intended for surgery tools. They are commonly no larger than 2mm in diameter. This limiting factor makes the mechanical scan probe design very challenging but also limits physically the maximal possible scan range.

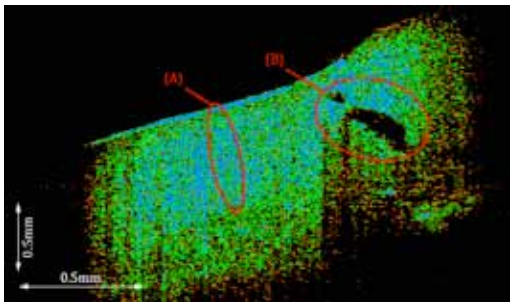
Results

In this thesis, an optomechanical setup was designed by using a GRIN (gradient refractive index) relay rod lens to displace the scanning unit towards the distal end of the endoscope and therefore outside the human body.



OCT scanner integrated in dummy endoscope.

Thereby cross-section size and biocompatibility were considerably improved. A 2d MEMS mirror chip was implemented to provide 3d OCT volume assessment.



OCT cross-section with OCT endoscope of porcine knee joint with (A) the articular cartilage layer and (B) small cartilage fractures which cannot be seen superficially.

Discussion

An endoscopic OCT scanner prototype was produced and assembled, tested and characterized. The endoscopic OCT system has high signal sensitivity of 100dB and first OCT images of porcine cartilage gathered by the newly designed endoscope probe were exceedingly promising in the area of osteoarthritis and chondral irregularities. Cartilage thickness and structure abnormalities as small as 50µm could be illustrated.

S100 as a Potential Marker of Human Articular Chondrocytes Redifferentiation

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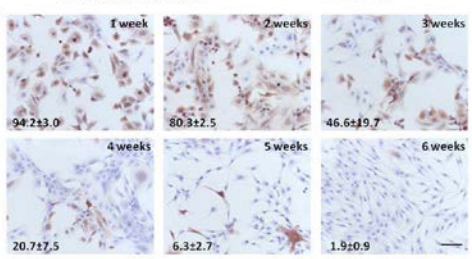
Institute of Pathology
Medicine Faculty of the University of Bern

Background
Autologous chondrocyte implantation (ACI) is currently considered as one of the most promising cell-based treatments of defined cartilage lesions. During the ACI procedure a small number of human articular chondrocytes (HAC) is taken via biopsy and expanded in vitro to gain sufficient amount of HAC for re-implantation. During this necessary expansion step in monolayer culture, chondrocytes undergo the process of dedifferentiation and lose their potential to form stable cartilage tissue. Recently the calcium binding protein S100 was identified as a potential intracellular marker correlating with the level of chondrocytes differentiation status in monolayer culture, allowing surveillance of chondrocyte dedifferentiation during the expansion step mimicking the ACI procedure.

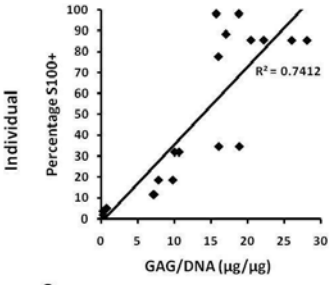
Project Scope
The aim of this study was to establish the existence of a direct correlation between the percentage of S100 positive (S100+) chondrocytes in monolayer with their ability to produce neocartilagenous tissue in pellets, i.e. their intrinsic chondrogenic potential.

Methods
A predetermined number of S100+ chondrocytes was mixed with a predetermined number of S100 negative (S100-) chondrocytes in a co-culture experiment. Furthermore, in a dedifferentiation experiment, ACI conditions for cell expansion were mimicked where the number of cumulative population doublings (PD), percentage of S100+ cells and neochondrogenesis in pellet cultures were evaluated in the same cells. The analysis comprised macroscopic evaluation (change in pellet shape), histology (proteoglycan and collagen deposition), immunohistochemistry (synthesis of collagen type I and II and S100) and biochemistry (GAG/DNA).



Expression of S100 in monolayer during 6 weeks. The number of weeks in culture and the mean ± SEM of percentage of S100+ cells (n = 3) are indicated, magnification 20x, bar = 500µm.

Results and Discussion
The number of S100+ cells incubated in the co-cultured pellets, correlated positively with the neochondrogenic properties of chondrocytes. The dedifferentiation experiment revealed a correlation between the percentage of S100+ cells in monolayer with the number of cumulative PD, the number of PD correlating with the loss of intrinsic chondrogenic potential (GAG/DNA), and a direct correlation between the number of S100+ cells and neochondrogenesis was established. Therefore, S100 can be considered as a marker of chondrocytes intrinsic chondrogenic potential in vitro. However, more donors need to be analyzed in future studies for final validation.



Correlation between the percentage of S100+ cells and GAG/DNA values as indicators of chondrocytes intrinsic chondrogenic potential.

Development and Characterization of a Linear Hydraulic Resistor for Baroreflex Simulation

Fatih Toy

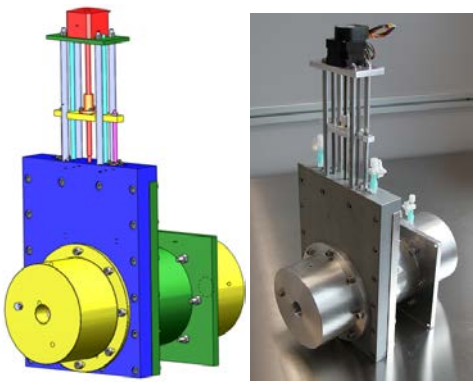
Supervisor: Prof. Dr. Stijn Vandenberghe
ARTORG Center Bern, Cardiovascular Engineering
University of Bern

Background

The purpose of this project is to develop and characterize a linear hydraulic resistor for a hemodynamic simulator. This simulator is intended to mimic patient's hemodynamics for evaluation of therapeutic devices, such as blood pumps. It is based on the Three-Element-Windkessel model, consisting of three distinct elements that each represents a specific hydraulic function of the arterial vasculature. The peripheral resistance of the arterial system is one of the functions and is generated by contraction of small arteries (called arterioles) and capillaries, thereby having a body pressure regulating mechanism which is known as baroreflex. The linear hydraulic resistor as part of the Three-Element-Windkessel model should therefore be able to regulate the blood pressure in the simulator within a range observable in the human body (0.53 – 1.2 [mmHg·s/ml]).

Project Scope

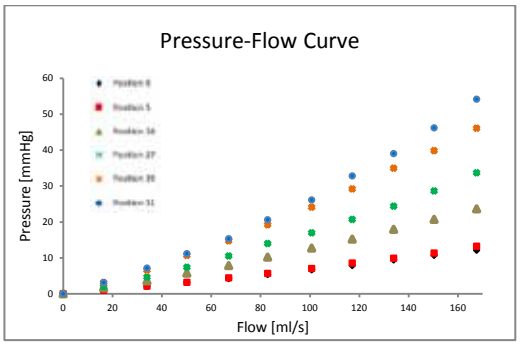
In order to improve the controllability of the hydraulic resistor, its pressure-flow characteristic should be linear. Since most commercially available resistors show highly nonlinear characteristics, we developed our own laminar flow element (LFE) which guarantees a high linearity. The simple principle follows the division of the flow into many small parallel streams.



The 3D CAD Model (left) and constructed linear resistor (right).

Results

The differential pressure over the resistor was measured for 1 to 10 [l/min] flow rates for different positions of the slider. Linearity was demonstrated by least squares fitting to a linear line, yielding correlation coefficients between 0.97 [-] and 0.99 [-]. Moreover, two valves (gate valve and inclined seat valve) were characterized as comparator to the resistor. In the experiments with the resistor, a minimal error of 8.1% and maximal error of 56% between measured and predicted values were observed. The measured range of resistance for a fluid viscosity of 0.008 [Pa·s] amounted from 0.06 – 0.32 [mmHg·s/ml] while expected range was 0.08 – 0.44 [mmHg·s/ml].



Pressure-flow curves of the designed linear resistor.

Discussion

In conclusion, the plotted pressure-flow curve presented the expected behavior in linearity. The measured range of resistance showed close values to predetermined ones. In spite of some larger errors, the total error is in an acceptable range.

This thesis is the basis and guideline for future research. In the next phase, the pressure-flow curve with a blood-like fluid has to be determined, before the tests with pulsatile flow can be performed to integrate the linear resistor in the hemodynamic simulator.

Diurnal Variation of Internal Pore Pressures in the Intervertebral Disc

Andreas Treuholz

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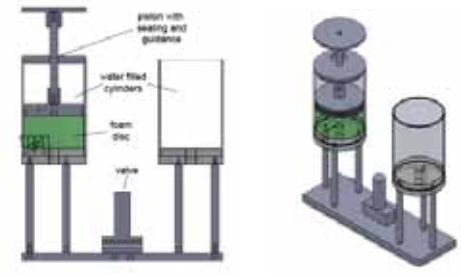
Institute for Surgical Technology and Biomechanics
University of Bern

Background

Diurnal water exchange in the intervertebral disc is of great importance for disc viability and metabolism since the disc can only pick up its nutrients through diffusion. A loss in disc nutrition or a reduction of water content can lead to degenerative disc diseases that will lead to pain and disabilities for the patient. The poroelastic theory has often been used to simulate the response of the intervertebral disc to loading and to illustrate the load sharing between solid stresses and fluid pressures. Recently it has been postulated that it is non-physiological to generate negative pore pressures inside an intervertebral disc, despite the fact that negative pore pressures are a well known phenomena in geomechanics. The aim of this thesis was to investigate the pore pressure response of an intervertebral disc model using both experimental and simulation methods during diurnal variations and with varying parameters.

Project Scope

For the experimental part, different foam discs have been used as a physical model for the intervertebral disc. This foam discs have been swollen in water and have been placed in a testing device called consolidometer, designed similiarly to those implemented in geomechanics. In this consolidometer the pore pressures at different locations of the foam discs have been measured under different loading conditons.

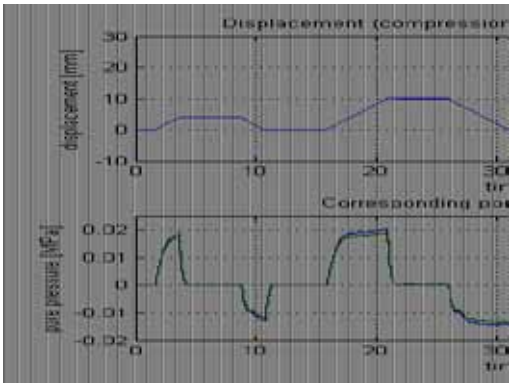


CAD Model of the designed consolidometer for experimental testing

In the simulation part, a finite element model has been designed which should coincide with the experimental test setup in order to validate the use of the poroelastic code implemented in Abaqus. The axissymmetric model was subjected to the same loading patterns as the foam discs in the consolidometer.

Results

First measurements revealed positive and negative pore pressures inside the foam discs upon loading and unloading. The results out of parameter variation studies were also satisfying and met the expectations. Nevertheless, the finite element code could not have been completely validated against the results.



Pore pressures measured inside the foam disc during different loading cycles on the MTS

Discussion

The outcome of this master thesis clearly shows that positive and negative pore pressures are present in a poroelastic material. Consequentially they have to be present in the intervertebral disc and therefore they play a certain role in disc water exchange and hence in disc metabolism. For a future project, the focus is going to be the design of a more sophisticated experimental setup and the implementation of a more accurate finite element code for modelling disc response.

Finite Element Prediction of Screw Stability in the Human Temporal Bone

Daniel Widmer

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University of Bern

Background

Nowadays bone screws are routinely used to achieve primary implant stability of reconstruction plates, dental implants or other implants such as the bone anchored port (BAP) which is under development at the ARTORG Center. This novel port provides a save and durable access for dialysis patient when the standard treatment is not longer possible. Due to its functionality, the implanted BAP undergoes traction and shear forces short after implantation. The finite element method provides a tool to predict screw stability in human temporal bone (HTB). But due to prohibitive calculation time for microscopic models, a homogenization approach for large micro computed tomography (µCT) scans was introduced. Microscopic architectural information were derived from the µCT scans and transferred to simplified macroscopic model (Fig. 1).

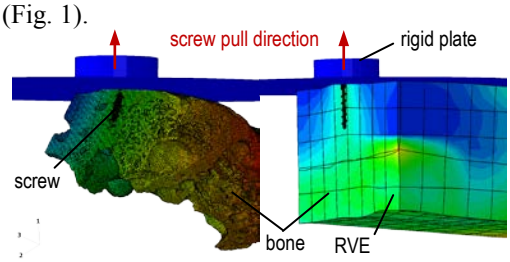


Fig. 1 Simulation of a micro- (left) and macroscopic model (right) in the experimental setup.

Project Scope

To read the microscopic architectural information from the µCT scan of HTB a Matlab algorithm has been developed. To calculate the anisotropy of the bone structure the Mean Intercept Length (MIL) method was implemented. For every representative volume element (RVE) in the homogenized macroscopic model, the anisotropy information and additional density estimation were calculated. The micro- and macroscopic models were tested with load cases correspondent to traction and shear. First, the mechanical parameters published for distal radius and vertebral bone were used. In a second step the homogenized parameters for HTB were estimated from the acquired µCT data sets.

Results

The simple loading cases showed a mean error with the homogenized models between 4%-11% under traction and 17%-30% for shear deformations (Fig. 2). It could also be shown that the minimal RVE size had to be at least 4mm^3 for the homogenization approach. The experimental tensile simulations indicated that the current approach is able to provide qualitative conclusions on the implant stability but is not accurate enough to precisely predict the mechanical reaction of bone screws.

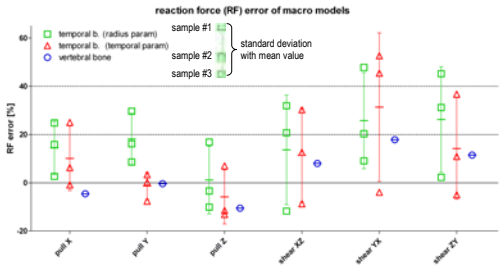
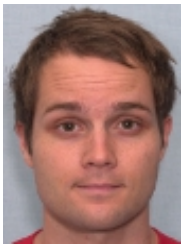


Fig. 2 Error of the simulated reaction forces with the homogenized models compared to the microscopic models (error = 0%) with different loading cases.

Discussion

With homogenized models it was possible to simulate temporal bone behavior. Results obtained in the present work indicated that the homogenized parameters are varying for different anatomical regions. The parameters identified for the temporal bone were different from the published data on the vertebra and radius. The overall simulation time was drastically reduced with the homogenized models. A qualitative screw behavior prediction is possible with the introduced approach. Further work has to be done to evaluate the correct mechanical parameters for human temporal bone such as the redesign of the homogenized model for more accurate screw predictions.

A Visual Servoing Scheme for a High Precision Surgical Robot



Tom Williamson

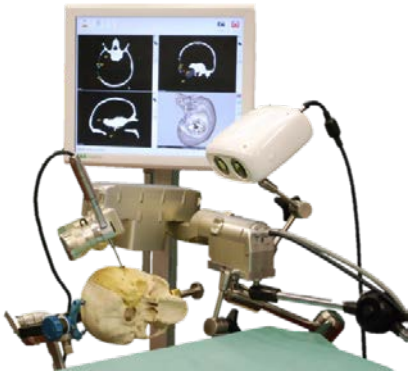
Supervisor: Prof. Dr. Ing. Stefan Weber
Institute for Surgical Technology and Biomechanics
University of Bern

Background

A robotic manipulator designed specifically for interventions in the temporal bone region has been produced at the Centre for Computer Assisted Surgery (CCAS). The target application for the robotic system is the minimally invasive implantation of hearing devices in the cochlea, this process requires extremely accurate placement of a drill trajectory in order to avoid damaging vital structures.

Project Scope

Previous work has focused on the development of a robotic manipulator designed specifically for Direct Cochlear Access. The 5-degree-of–freedom robot was optimized for use in a clinical setting by minimizing weight and complexity, thereby minimizing the impact of the system on existing operating room layouts. Initial system evaluation and experimentation revealed an absolute positioning accuracy of 0.171mm, while a study completed on the accuracy of the overall system workflow through cadaver experiments revealed an accuracy of 0.56±0.41 mm at the

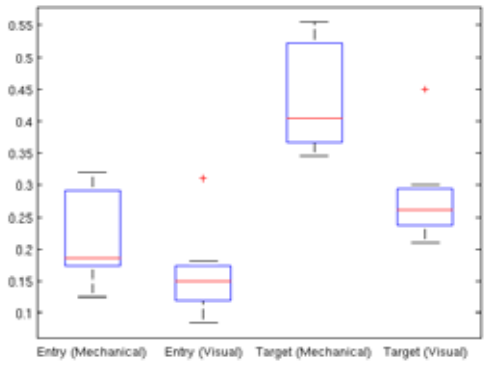


The high accuracy cochlear implantation system

target. These results fail to satisfy the 0.5mm criteria commonly cited as the threshold for clinical application; as such, efforts have been made to improve the workflow to an acceptable level. The work completed in this Master's thesis represents one such effort. The aim of the project was to develop a visual servoing system which enabled the robot to achieve a target drilling accuracy below the 0.5mm threshold.

Through the combination of high accuracy optical tracking, Kalman filtering and optimized positioning control, and in combination with the efforts of other ISTB coworkers, this aim was successfully achieved.

Results



Results of phantom drilling: Mechanical vs. Visual Tracking

In order to assess the final accuracy of the control scheme a phantom was constructed using a 37mmx37mmx22mm aluminium block in which a 5mm radius circular recess had been milled at the center. Four registration screws were placed at known positions in the surface and a path planned through the center of the recess. This removed errors introduced through the imaging and planning components of the surgical process. In total, fourteen holes were drilled; seven using mechanical tracking and seven using the final visual servoing algorithm. The mechanical tracking showed a mean target error of 0.43±0.087 mm. The results with visual servoing were determined to be significantly improved; a mean target error of 0.283±0.079 mm was achieved.

Calcium Signaling in Atrial Cells

Marcel Wullschleger

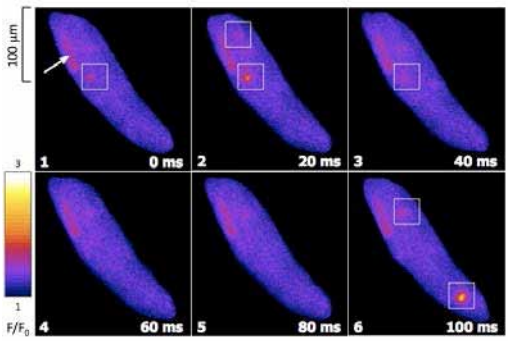
Supervisor: Prof. Dr. Marcel Egger
Department of Physiology
University of Bern

Background

The main compartments of the heart are the atria and the ventricles existing in pairs. The atria play an important role in assisting ventricular filling during exercise and stress. On a cellular level, contraction and relaxation of the heart during systole and diastole are regulated through intracellular calcium. The temporal and spatial regulation (homeostasis) of Ca^{2+} signaling in atrial cells (atrial myocytes) is not completely understood. Especially its role under pathophysiological situations (i.e. arrhythmia) is unclear. In ventricular and atrial myocytes the central mechanism of intracellular Ca^{2+} release is "Ca^{2+}-induced Ca^{2+} release" (CICR). Ca^{2+} is released from intracellular Ca^{2+} stores (sarcoplasmic reticulum, SR) into the cytosol via SR-Ca^{2+} release channels (ryanodine receptors, RyRs). Predominantly in atrial myocytes a second mechanism, Ca^{2+} release through channels sensitive to the intracellular second messenger inositol-1,4,5-triphosphate ($InsP_3$), has been described. The contribution and significance of $InsP_3$-mediated Ca^{2+} release in cardiac excitation-contraction-coupling (ECC) is a matter of debate. The aim of this project was to examine the intracellular Ca^{2+} signaling link between RyRs and $InsP_3$Rs in atrial muscle cells.

Project Scope

Mouse atrial cells were isolated via excision and retrograde perfusion of the heart. The atrial cells were kept in a physiologic salt solution. In order to get "access" to the SR and its channels a particular experimental technique was established and adapted to atrial cells called "skinned cell preparation". Within this technique the cell membrane (sarcolemma) is partially dissolved which allows for keeping the permeabilized cell in an "intracellular" medium with direct pharmacological access to intracellular receptors on the SR. Upon these preparative steps the protocol for the measurement of Ca^{2+} signaling events in atrial cells was performed using laser confocal microscopy in combination with high-speed 2D image recording. A Ca^{2+} indicator (fluo-3, a specific fluorescence dye) was used in order to visualize Ca^{2+} release events from the SR. Pharmacological interventions were performed to specifically block either RyRs or $InsP_3$Rs. The outcome was measured both by manual screening of image data and by a software based method. This included Ca^{2+} release event number, -characteristics and -duration.



The time series of a permeabilized atrial cell shows Ca^{2+} release events, which are indicated by local changes in the fluorescence intensity (F/F_0). Ca^{2+} release events are marked with a square. The arrow locates the nucleus.

Results and Discussion

The exposition of permeabilized atrial cells to $InsP_3$ ($InsP_3$R agonist), 2-APB ($InsP_3$R antagonist), Ca^{2+} (RyR agonist) and tetracaine (RyR antagonist) indicated the presence of RyR- and $InsP_3$R Ca^{2+} release events in the preparation examined. Upon $InsP_3$ application a shift of 32% towards $InsP_3$R Ca^{2+} release events was observed. On average a pharmacological exposition provoked a decrease in Ca^{2+} release event number about 26%. The applied 2D imaging technique allowed for a systematic analysis of the relatively rare long-lasting Ca^{2+} release events (>180 ms). $InsP_3$ triggered these events in a dose dependent manner. More sophisticated software tools, transgenic models and a specific pharmacology will further help to understand the dynamics of Ca^{2+} release events from the SR in atrial myocytes.

Biomedical Engineering Day 2011

On May 13, the Biomedical Engineering Day took place in the auditorium Ettore Rossi at the Inselspital in Bern. This event was organized for the third time by the Master in Biomedical Engineering program of the University of Bern and its alumni association, the Biomedical Engineering Club.

The event is an efficient platform in Switzerland for networking of Master and PhD graduates and Swiss and international medical technology companies. This year's companies introduced themselves through oral presentations and gave insight into their commercial activities and their company philosophies as well as showed their demands on junior employees. Students thus had the opportunity to get to know potential future employers and contact them directly. This was made possible between the sessions in personal conversations and at the exhibitors' booths. This year a broad spectrum was covered as presenters came from young start-ups from the University of Bern up to large companies operating globally.

The BME Day offered great opportunities for the Bernese biomedical researchers, too. The ARTORG Center for Biomedical Engineering Research and the Institute for Surgical Technologies and Biomechanics as well as the Bern University of Applied Sciences, a partner within the Master program, used the possibility of presenting current research projects to over 300 participants. Interestingly, Master and PhD students play an important role in many of these projects. Thereby, this event was a demonstration of scientific achievements, too.

BME Day participants applaud a speaker.

Auditorium Ettore Rossi with BME Day participants.

Besides company representatives, scientists, researchers, and young academics, many medical doctors participated in this year's event as they had the chance for intensive communication with the biomedical engineers.

One highlight of the day was the live cardiac intervention by Professor Dr. Bernhard Meier, Director Department of Cardiology, Inselspital Bern. Illustrative explanations in the auditorium were given by Professor Dr. Rolf Vogel, ARTORG Center for Biomedical Engineering Research.

The presentation "An Inside Track to Entrepreneurship" by Ulf Claesson, serial entrepreneur was perceived very well. Eloquently and humorously he talked about the challenges when founding a company and gave insight into entrepreneurship from unexpected angles. Founding their own company might be an attractive professional perspective for many participants.

In connection with translational medical technology research, strategic and direct innovation promotion is very important from a political point of view. The Minister of Economic Affairs of the Canton of Bern, Andreas Rickenbacher, introduced the manifold activities of the Cantonal innovation promotion to the audience.

At the end of the day, three awards for excellent academic achievements in the field of Biomedical Engineering at the University of Bern were presented.

Patrik Stirnimann received the Medical Cluster Award 2011 for the best Master thesis. His work "Determinants of the mechanical response of trabecular bone-cement composite" has been accepted for publication in a journal and the results of his thesis have already been incorporated into a new diagnostic simulation software.

The Medical Cluster Award 2011 for the best PhD thesis was given to Matthias Peterhans for his work "Ultrasound-based non-invasive referencing of anatomical structures for computer-assisted soft tissue surgery". His thesis is another example of successful translation of biomedical research into a commercially useful product.

The NCCR Co-Me Poster Award 2011 was given to Khadija M'Rabet Bensalah. Her poster "Multiscale hemodynamic modeling of the intrarenal circulation using the COMSOL multiphysics software" convinced the jury.

Nina Ruef, BME Master student in her first year, was the lucky draw winner of an iPad sponsored by Ypsomed.

Stephen Ferguson, University of Bern, Patrik Stirnimann, winner Medical Cluster Award 2011 (Master), and Rubino Mordasini, president Medical Cluster (from left to right).

Khadija M'Rabet Bensalah, winner of the NCCR Co-Me Poster Award 2011, with Stephen Ferguson, University of Bern.

Stephen Ferguson, University of Bern, Matthias Peterhans, winner Medical Cluster Award 2011 (PhD), and Rubino Mordasini, president Medical Cluster (from left to right).

Prabitha Urwyler, BME Club president (left), and Rudolf Siedler, Ypsomed (right), hand Master student Nina Ruef her new iPad.

The Biomedical Engineering Club

The BME Club and Its Mission
The BME Club is an alumni club whose mandate is to promote networking among the biomedical engineers.
The BME Club of the University of Bern connects you to a growing network of biomedical engineers, scientists, past and present students and medical technology corporate with a desire to bring together the principles of engineering, biology, and clinical medicine. This goal is accomplished by hosting events such as information sessions on the latest cutting-edge research in the fields of biomedical engineering; attending international conferences in related areas; and touring various industrial plants, hospitals, and laboratories. The club is run by an executive committee following the dictates of our constitution, and it is recognized as an official alumni association of the University of Bern under the umbrella organization – Alumni UniBe.

We are an enthusiastic and versatile group with diverse activities:

- bi-monthly meetings in a local restaurant to network, brainstorm or simply socialize ("Stammtisch")
- visits to medical and engineering companies
- providing information on career opportunities
- annual welcome event for "New Students"
- annual BME day (co-organized with Master Study Coordination Office)
- annual lecturers' event (collaboration with Master Study Coordination Office)
- bi-annual BME Newsletter
- access to the Medical Cluster events
- joint membership with SSBE (Swiss Society for Biomedical Engineering)
- providing updated list of MedTech events and BME Master thesis defenses

In short, the BME club represents a unique platform for professional lifelong communication and networking.

Executive Committee for 2011-2012
President: Prabitha Urwyler
Vice President: Tom De Bruyne
Secretary: Julia Spyra
Treasurer: Christian Güder
Webmaster: Tobias Imfeld
Faculty Representative: Dobrila Nesic
Student Representative: Lilibeth Salas Tellez
Alumni Representative: Lukas Bosch
Industry & Job Market Manager: Rudolf Sidler
Auditor: Lutz Nolte
Auditor: Patrick Roth

History Behind the Motivation and Vision for the BME Club
The idea for the BME Club arose in Spring 2009 during the discussion on how to keep in tuned with the whereabouts of the former students. Research had started on tracking the previous master students, PhD students, postdocs. We realized that only an organization could muscle enough persuasion - and so the BME Club was born and quickly took off. The official inaugural meeting of the BME Club took place on 12th August 2009 at the Restaurant Beaulieu in Bern. An interim executive board represented the club until the first general assembly in 2010. During the first year, there were quite a few activities and membership was less than 100 people. We initiated the concept of the Stammtisch in order to network with the broad spectrum of members. Having the backbone of an organization, we were able to bring in great events. For further details look up our website containing our acitivity reports of the past years at http://www.bmeclub.ch.
The size of the club allowed us to join hands with the Master Study Coordination for annual events such as the Biomedical Engineering Day (BME Day), and the lecturers' event. The momentum ball just kept on rolling. We formed alliances with the Swiss Society of Biomedical Engineering (SSBE) offering joint memberships to our regular members. Another feather in our cap is our friendly tie-up with the Medical Cluster Bern which opened up opportunities for our members to the Medical cluster events like the "Morning talk". Thus we were able to extend our events and activities in addition to our membership base. Currently, we have approximately 180 members.

How to Join
Becoming a member is easy! Simply sign up at any BME Club event or visit us at http://www.bmeclub.ch. When signing up you will be regularly informed of BME events happening across Switzerland also held by organizations other than the BME Club as well. When signing up, you can also indicate your wish to have a joint membership with the SSBE. BME alumni who join us will automatically become a member of Alumni UniBe, the alumni association of the University of Bern. Among other benefits this includes receiving a lifelong UniBe email address.

Alumni Barbecue 2011

For the first time in the history of the Biomedical Engineering Master study course there was an alumni only meeting: time for sharing memories.

On the first Friday in September, the Club invited all alumni - Master and PhD - for an Alumni Grill Event to the new ARTORG building at Murtenstrasse 50 in Bern. For the 25 alumni that accepted the invitation, the evening started with Professor Lutz Nolte providing an overview of the ARTORG center, and outlining the changes regarding the Master course.

In the last few years, a lot has changed: to date, the Master course has three focus areas: Electronic Implants, Image-Guided Therapy, and Musculoskeletal System. It also has an impressive number of students. At the beginning of the fall semester 2011, there were approximately 140 students in our program. The introductory talk was followed by a tour through some of the ARTORG laboratories for those interested.

The ARTORG Center does not only host innovative scientists, however. The building itself is outstanding, too. That evening, we all benefitted especially from the breath taking view over Bern. An apero was offered on the roof

deck of the building. This gave all participants the opportunity for catching up and talking about their careers. Later, the grill was switched on for the barbecue. Due to the warm evening, it was possible to sit outside even after sunset. With good discussions and one more glass of red wine, the evening slowly drew to a close. Rumor has it that BME alumni were seen in the bars downtown till dawn.

Bern Grand-Prix 2011

Bern, May 14th 2011, 1.30 p.m.: cloudy, dry. Team for the 4.7 km Altstadt-GP gets a perfect warm-up from Patrick Roth. 2.20 p.m. waiting for the start at 2.30 p.m.: dark clouds, rain, thunderstorm. 2.30 p.m: yippeeh, starting signal, too many people trying to start running at the same time, walking, running, clothes soaking wet. Crazy rain loving spectators on the sidewalk cheering untiringly. Finally around 3 p.m the finish line, finisher medal, isostar bottle, banana and a happy but soaking wet BME Club Team. Some time later the almost same procedure for the 10 miles GP Team.

Dream team 10 miles:
Lukas Kohler, Christian Gloor, Patrick Roth, Daniel Lachner, Matthias Peterhans (from left to right)

Dream team 4.7 km:
Tom De Bruyne, Jorge Sague, Constanze Hofmann, Christian Güder (from left to right)

Graduate Profile

Prabitha Urwyler, PhD

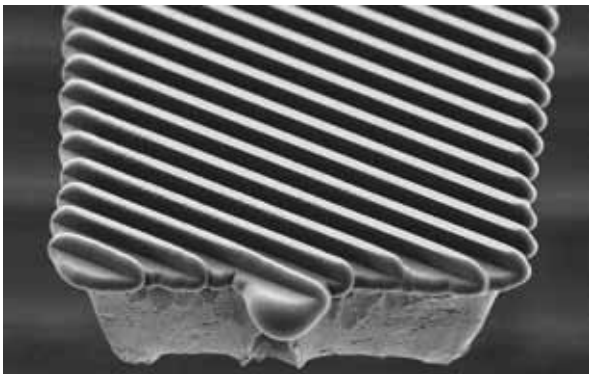
The Biomedical Engineering program at the University of Bern is growing from year to year. We take the opportunity in this year's Annual Report to catch up with a graduate of the first class of our program, Prabitha Urwyler, to gain some insight into her motivation to pursue the BME program, and where her studies have taken her since.

BME: What was your academic and professional background prior to your BME studies?

PU: I studied computer Science and Engineering for four years (8 semesters) leading to a Bachelor in Technology, back home close to my hometown in India. My bachelor degree fetched me a job in Mumbai, way back in September 1995. My first job gave me an opportunity to work on an offshore software project for the Swiss News Agency (SDA). The successful execution of the newsroom software project opened doors for my travel to Switzerland. The short term visit very soon changed to long term visa as an internal employee of the Swiss News Agency allowing me to settle in Bern.

BME: Why did you choose to pursue your Master's studies at the University of Bern?

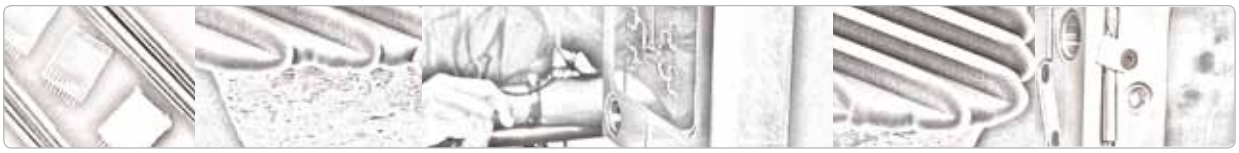
PU: Medicine and biology interested me since childhood. The software job was not challenging enough after 10 long years in the field. I started looking out for options for higher studies with my Engineering Bachelor from India. Either the Indian degree was unknown or the qualifications did not match leading to great disappointment. And then came the saviour for me: the Bologna system! During the breaks of my second maternity leave, I browsed around for new options and stumbled upon the new Masters in Biomedical Engineering on the homepage of the University of Bern. There was no hesitation after that. My dream of coming closer to medical technology seemed possible. With a zeal to learn more about human anatomy and physiology, I decided to select the focus area 'Musculoskeletal System'



Scanning electron micrograph of a surface patterned polypropylene micro-cantilever. The line pattern (period 10 µm, depth 5 µm, and width 5 µm) is transferred during the injection molding process from a foil-like mold to the surface of the micro-cantilever.

BME: You continued to work during your studies. How was this experience?

PU: Maintaining a good balance between family, work and studies was challenging, especially with two small kids. Being a mother, I was already working part-time, so continued working with my same pace, but the additional three days of classes made it challenging. The second semester with a maximum number of exams seemed like



a great uphill task. I worked 50% during the first three semesters and reduced to 40% during my master thesis. The additional working hours were compensated during the semester holidays. Cooperation from my co-workers, employer and family was a driving factor for me to complete the courses and the master thesis as early as possible.

Inspection of the new mold installed in the injection molding machine (Arburg 320 Allrounder).

BME: What was your PhD project and how is it related to biomedical engineering?

PU: After earning a Master of Science in Biomedical Engineering in 2008, I was at the crossroads between industry and academia. With great encouragement and advice from my well-wishers I decided to take up a PhD under the supervision of Professor Bert Müller at the Biomaterials Science Center (BMC) at the University of Basel. My PhD project was funded by the Swiss Nanoscience Institut (SNI) under the framework of the applied research project "DICANS". Due to the collaborative nature of the project, I was mainly working at the Paul Scherrer Institut (PSI) in Villigen and the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in Windisch. The goal of my PhD project was to fabricate disposable polymeric micro-cantilevers for biomedical applications. This involved the fabrication, characterization, functionalization and application of polymeric micro-cantilevers. The project being multidisciplinary in nature, had collaborators with expertise in polymer engineering to cell culture techniques. Courses from the Master studies such as Biomaterials, Engineering Mechanics, Tissue Biomechanics, and Finite Element Analysis were of great use in the PhD project. We were acquainted with various aspects of the academia world like scientific writing, literature review both at the courses and the thesis work. This gave a great foundation for starting the PhD work.

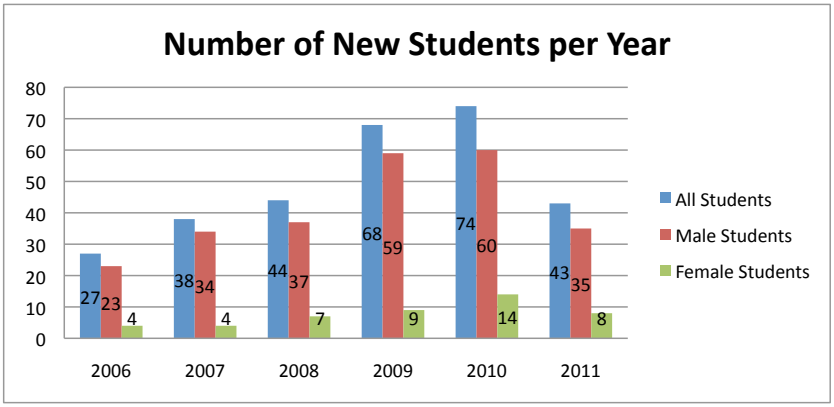
BME: What is your career plan after PhD?

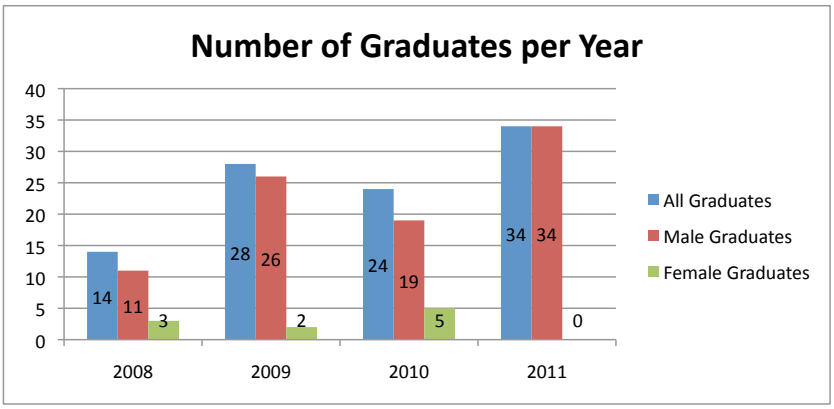
PU: Currently, I am working as a PostDoc at the Biomaterials Science Center at the University of Basel. Both academia and industry have their pros and cons. I would like to stay in the academia field for a short time and then make a decision of switching to the industry.

Injection-molded polymeric micro-cantilever arrays compared to a paper clip.

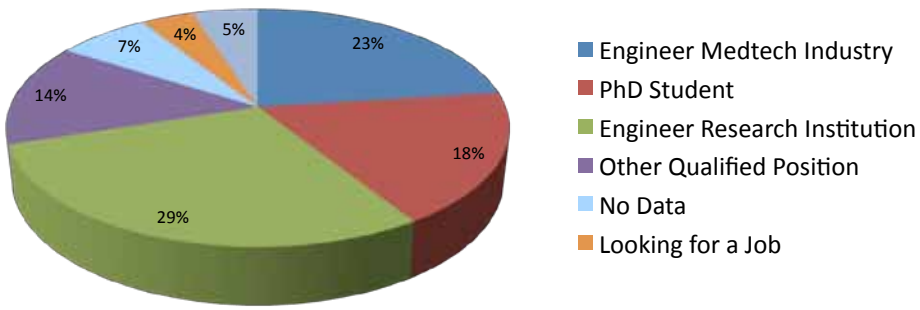
Statistics

Number of Students and Graduates per Year





BME Alumni: Career Directions
Profession after Graduation



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