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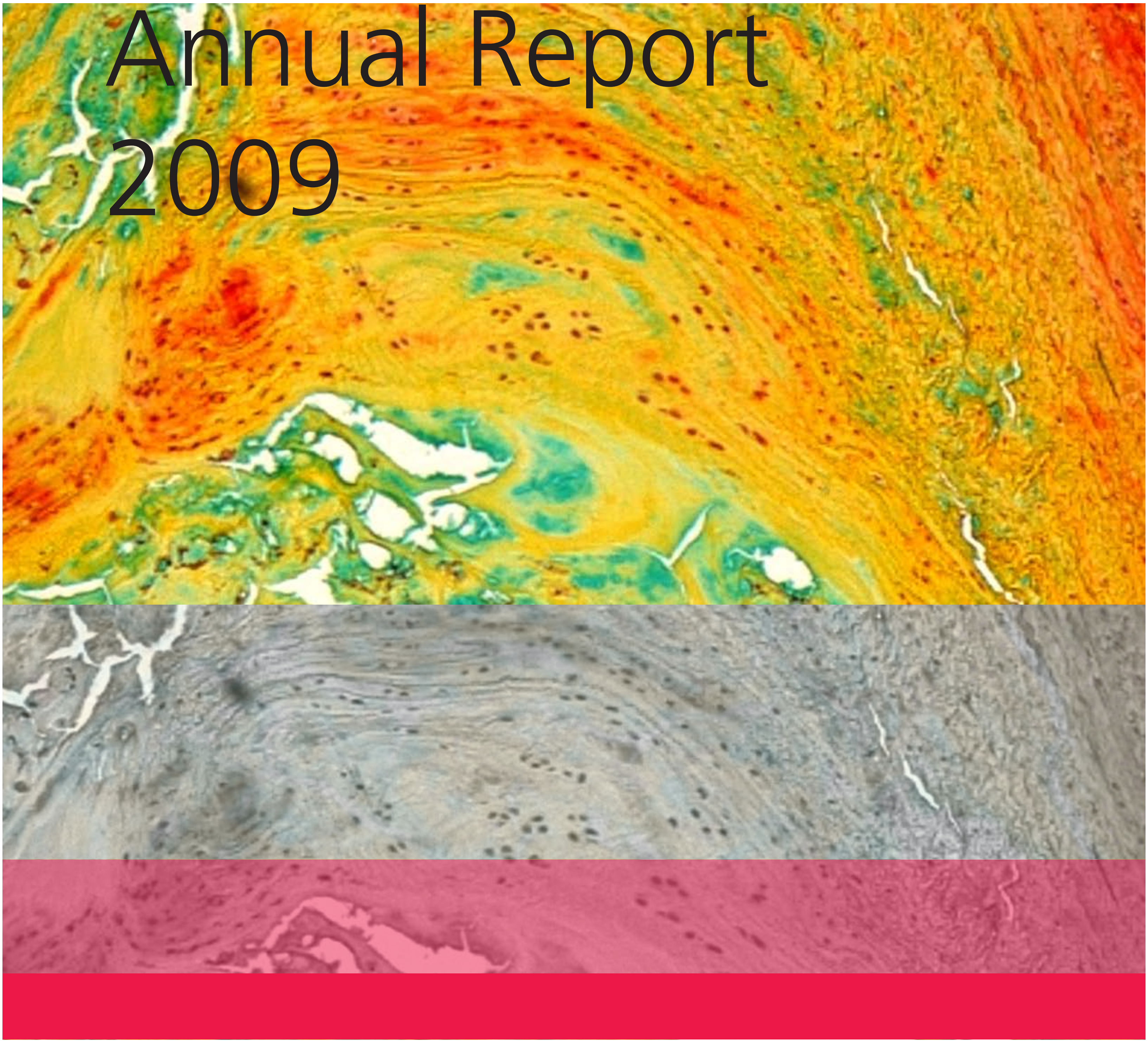
UNIVERSITÄT
BERN

Annual Report 2009



Institute for Surgical Technology & Biomechanics

Contents

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Introduction

2009 in Retrospect

For the research groups of the Institute for Surgical Technology and Biomechanics (ISTB), 2009 was a year of growth. Through our increased participation in national and international research network programs, we have been able to expand in all of our focus areas. Our institute comprises now a multidisciplinary team of over 60 co-workers. The institute is also closely integrated into the Artificial Organ (ARTORG) Center for Biomedical Engineering Research (www.artorg.unibe.ch), with two faculty members cross-appointed between the two institutions.

External funding was maintained at a high level through both governmental funding and with major contributions by non-governmental organizations and our industrial partners. The ISTB continues to co-direct the Swiss National Center of Competence in Research CO-ME (www.co-me.ch) and hosts various projects and subprojects that have a primary focus on computer aided medical interventions. This network of excellence has now moved into its third four-year phase, following the successful review of a competitive proposal for extension. We were proud to have our research efforts recognized by several prestigious awards in 2009, including the Grammer European Spine Journal award and the Ypsomed Innovation award. There have been significant achievements in the area of technology transfer, including the formation of two new start-up companies (CAScination and OrthoCompass) and the commercialization of a very successful orthopaedic planning software (Hip2Norm). Various patents were filed and granted during the year. Key collaborative projects with the Swiss MedTech industry continue to be developed through funding from KTI/CTI, which is the Innovation Promotion Agency of the Swiss Federal Office for Professional Education and Technology. International collaboration was strengthened with our participation in a new European Union initial training network and we have continued to expand our international activities with new partnerships in North and South America and Asia.

In the past year, the ISTB contributed to the organization of several international scientific meetings, most notably, the annual meeting of the International Society for Computer Assisted Orthopaedic Surgery (CAOS 2009), the Advanced Training High-Tech Course for Paranasal Sinus and Skull Base Surgery (PSSB 2009), the annual meeting of the Swiss Society for Biomedical Engineering (SSBE 2009), the 2009 Biomedical Engineering Day and the Swiss Spine Residents' Course.

In 2009 we continued our activities in training undergraduates, graduate students, and postdoctoral fellows for future leadership roles in teaching, research, and industry. Our Master of Science in Biomedical Engineering program (www.BIOENG.Master.unibe.ch) has now achieved a critical momentum, with the 4th class recently starting with 65 new students. Currently, over 100 students are enrolled in the program to become specialists in biomedical engineering. The program has now expanded to cover three main focus areas, in collaboration with the University of Basel and the Bern University of Applied Sciences. In addition, about 20 students from the ISTB are currently enrolled in the interdisciplinary biomedical science doctoral program (www.gcb.unibe.ch).

Lutz P. Nolte
Director

Organization

Institute for Surgical Technology & Biomechanics

Management


L. P. Nolte
Director

Central Services


A. Neuenschwander
Administration


H. Studer
IT-Support


B. Schmitter
Administration


H. Lu
IT-Support


K. Fahnemann
Administration

Division of Biomechanics


Orthopaedic Biomechanics
S. Ferguson
Division Head


Computational Bioengineering
P. Büchler


Tissue Mechanobiology
B. Gantenbein

Division of Surgical Technologies


Smart Device Technology
S. Weber
Division Head


Surgical Navigation
G. Zheng


Medical Image Analysis
M. Reyes

Master Biomedical Engineering


U. Jakob
Study Coordinator

Mechanical Design and Production


U. Rohrer

The Institute for Surgical Technology and Biomechanics conducts basic and applied research for the prevention and treatment of diseases of the locomotor apparatus. Currently, the institute focuses on two areas defined by its two primary divisions. The efforts of the Division of Surgical Technology are directed towards development of devices and technologies that provide improved surgical functionality, feedback, and integration, navigation and planning focused on less invasive procedures in various anatomical locations, and methods to process and optimally utilize data from a variety of medical imaging modalities. The Division of Biomechanics conducts basic and applied research focused on achieving a better understanding of the mechanisms of injury and degeneration of the human musculoskeletal system, with an aim of developing, evaluating and improving methods for effectively treating such disorders using in vivo and in vitro experimentation, linear and non-linear finite element methods, image analysis techniques, kinematic simulation, tissue culturing, histomorphometry and molecular biology methods.

Tissue Mechanobiology

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Group Members







Benjamin Gantenbein, Samantha Chan, Stefan Dudli, Ladina Ettinger, Michael Held, Thomas Steiner, Patricia Welz

Research Profile

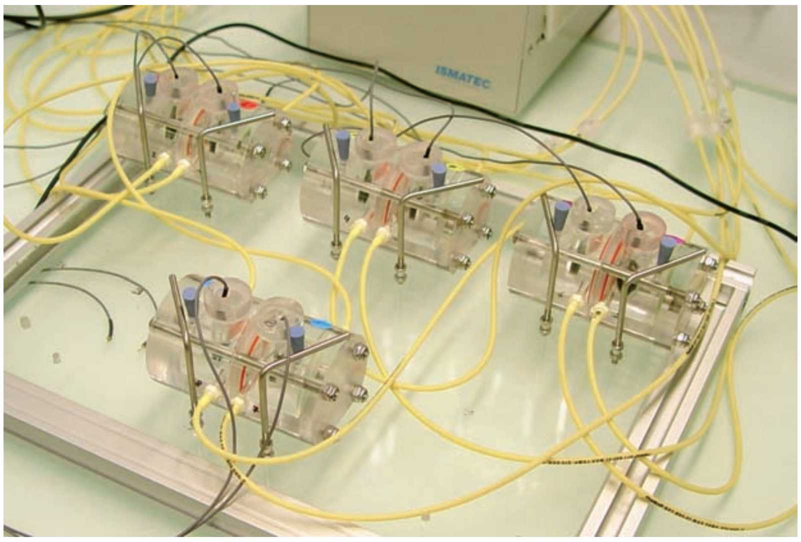
The Tissue Mechanobiology Group conducts research leading towards improving the current treatment methods for degenerative disorders and traumatic injuries of the spine. The group focuses its efforts on developing a better understanding of the interaction between living tissues and biomaterials, studying the influence of mechanical and physiological stimuli on tissue repair and development, and evaluating the potential for achieving a successful biological repair to an injury or to degeneration. We employ a variety of cell, tissue and organ level models in the study of normal and compromised intervertebral disc metabolism. A major initiative in our group is the development of appropriate three-dimensional scaffolds for the repair of intervertebral disc defects.

In 2009, we have expanded our efforts in the Spine Research Center (SRC). The SRC is a collaborative effort between the ISTB and the Department of Spinal Surgery at the Inselspital Bern, within the ARTORG Center for Biomedical Engineering Research. Prof. Benjamin Gantenbein-Ritter holds a cross-appointment between the ISTB and ARTORG and brings a complimentary biological research to our traditional biomechanics program. Details of related spinal research at the ARTORG Research Center can be found in the center's annual report (http://www.artorg.unibe.ch).

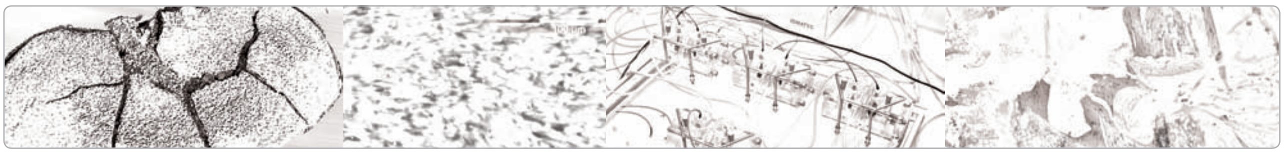
Current Research Areas

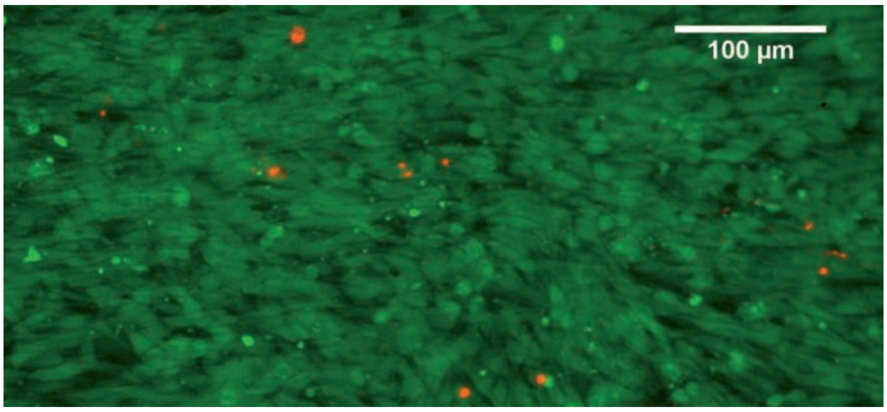
Direct Electrical Stimulation of Disc Cells

In the context of our program to investigate the mechanisms of solute transport in the disc, we have previously investigated the application of electrical fields to disc tissue, as a means to enhance solute transport via electro-osmosis or to enhance tissue permeability via electro-poration. However, the direct effect of electrical fields on cell metabolism is a relevant and little understood issue. The disruption of intradiscal streaming potentials has been proposed to contribute to extracellular matrix (ECM) degradation, e.g. in degenerative disc disease (DDD). It has previously been shown that coupled electrical fields have the potential to support chondrocyte proliferation and ECM gene expression. Knowledge concerning the effects of electrical field intensity (E) and current on intervertebral disc cells is still lacking. The aim of this study is therefore to examine whether the in vitro application of electrical currents to bovine nucleus pulposus (NP) cells alters cell morphology and viability. Bovine NP cells were seeded as monolayers and cultured for 5 days. At days 2, 3, and 4, currents of varying amplitudes and patterns were applied via carbon electrodes to the culture. Cells were exposed to either a constant DC current, monopolar pulses, or bipolar pulses. Cell morphology was accessed daily by inverted light microscopy and cell viability was qualitatively determined on day 5. Successive cellular detachment and contraction was observed for cells subjected to monopolar pulses, starting from day 3 Cells stimulated with bipolar pulses or DC current maintained their initial morphology and viability for the entire culture time. For bovine NP cells, viable ranges for electrical stimulation were identified, using DC current or bipolar pulses. These data provide a basis for future studies covering cellular response to electrical stimulation. The final goal is to explore the potential of local electrical field application to maintain or restore disc ECM integrity and thus provide an avenue for a minimally invasive therapeutic approach for the treatment of DDD.



In vitro cell stimulation chambers for the application of electrical fields to intervertebral disc tissue explants.

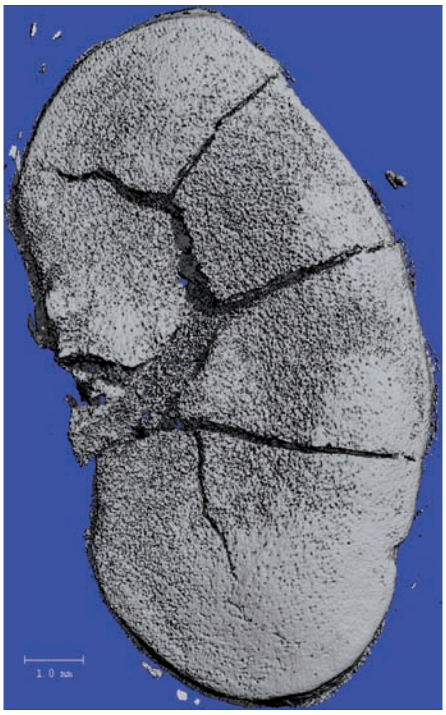




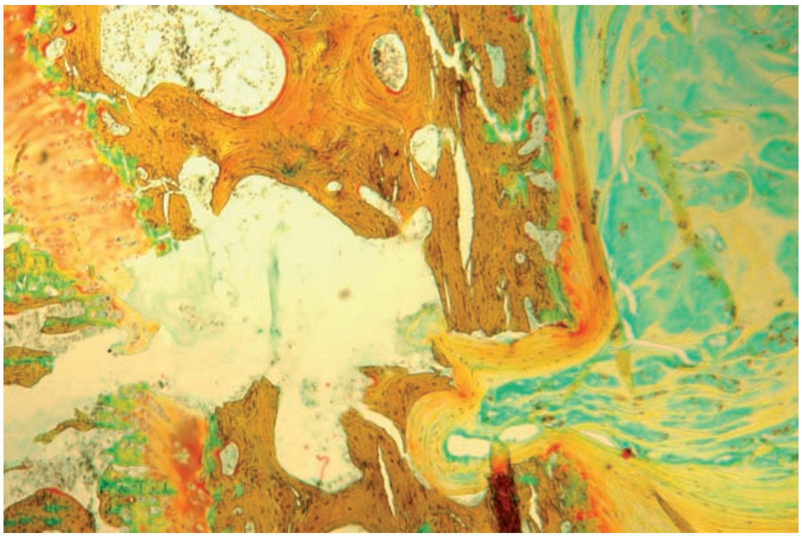
Nucleus pulpous cells stimulated with electric fields show high viability and proliferation.

Post-Traumatic Disc Degeneration

We have previously demonstrated that fractures of the vertebral endplate can trigger a severe cascade of degenerative processes within the intervertebral disc. We were proud to receive the 2009 Grammer European Spine Journal award for these first investigations into post-traumatic disc degeneration. In a continuation of this work, we have extended the in vitro experimental model to include a large portion of the adjacent vertebral bodies, to explore the potential influence of cell signaling with the marrow space of the vertebra after fracture, and to better replicate and understand the mechanical fracture process. With a refined testing protocol, we have reproducibly induced endplate fractures with vertebral compression and investigated concurrent disc changes in-vitro. Spinal segments were harvested en bloc from New Zealand White rabbits and specimens were kept in culture for a total of 5 weeks (4 weeks post-fracture). Cell damage was assessed for induced necrosis and apoptosis. Expression of genes involved in disc degeneration (matrix metalloproteinases, MMP-1, MMP-3, MMP-13) apoptosis (caspase 3, Fas-L) and inflammation (IL-6, IL-8, MCP-1, TNF-α) were monitored using qPCR. Preliminary results have demonstrated a strong dependence of vertebral and endplate fracture mechanics on segmental morphology. Furthermore, energy absorption by the disc seems heavily influenced by the momentum of the impact. These confounding mechanical factors lead to a highly variable biological response. In the more severe fractures, nucleus pulposus material is expressed through the endplate into the marrow space of the vertebral body. We have observed that it is not only the total impact energy applied to the spine that determines the degree of subsequent degeneration, but also the overall integrity of the disc compartment.



MicroCT image of experimentally induced burst fracture of the vertebral endplate.



High energy impact to the spine leads often to an expulsion of disc tissue through the fractured endplate into the marrow space of the adjoining vertebra, potentially a trigger for inflammation and degeneration.

Orthopaedic Biomechanics

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Research Profile

The Orthopaedic Biomechanics Group conducts basic and applied research focused on expanding the knowledge of the mechanisms of musculoskeletal disorders and developing improved strategies for their treatment. A main thematic area of study is the complex relationship between spinal loading, spinal motion, injury or degeneration and alterations to the biochemical and structural properties of the spine.

Work continues on the effective treatment of osteoporotic compression fractures of the spine. In 2009, we commenced our activities within the European Union consortium project VPHOP (Osteoporotic Virtual Physiological Human), using computer simulation methods to improve the diagnosis and treatment of fragility fractures.

Our group collaborates within the CO-ME Research Network of the Swiss National Science Foundation, starting this year a new project in the area of patient-specific tissue engineered constructs for cartilage repair. We have continued our participation in the AOSpine Research Network. In 2009 we welcomed Prof. Peter Cripton to our group, on a one-year academic sabbatical from the University of British Columbia, and also hosted one student from his group on an International Society of Biomechanics travel grant.

Current Research Areas

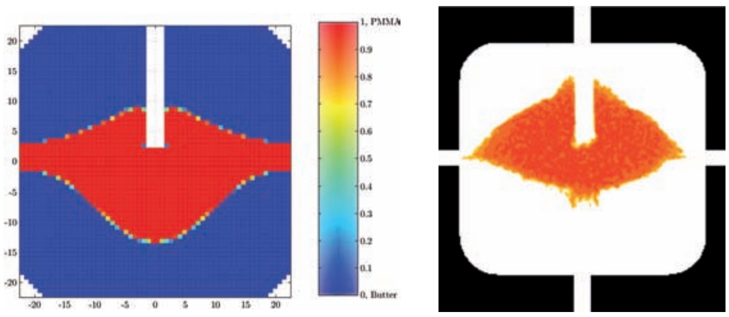
Applied Research

Last year we continued our collaboration with partners in the dental, biomaterials and orthopaedic industries on research activities ranging from simple material tests to complex multidisciplinary in vivo implant studies.

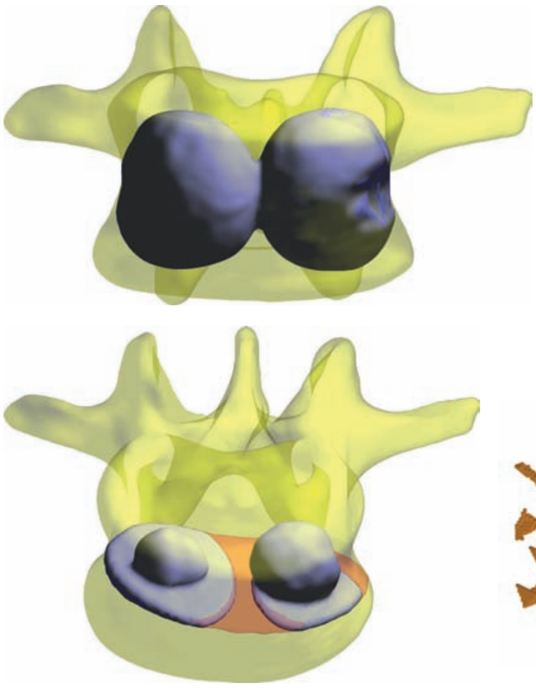
In collaboration with the MSRU of the VetSuisse Faculty of the University of Zürich, we contributed biomechanical testing to a new study investigating the healing performance of locking and unlocked compression plates for fracture fixation. In the field of implantology and osseointegration, we have completed the biomechanical evaluation of a variety of surface-treated metallic implants to improve our understanding of the potential benefits of bioactive coatings for dental and orthopaedic implants. With an industry partner, we have explored the potential for improving the anchorage of pedicle screws in poor-quality bone through the use of an intermediate polymer interface. Fracture fixation for small stature animals and alternative spinal stabilisation methods were the topics of two in vitro studies completed with the VetSuisse clinics in Bern and Zürich.

Bone Augmentation

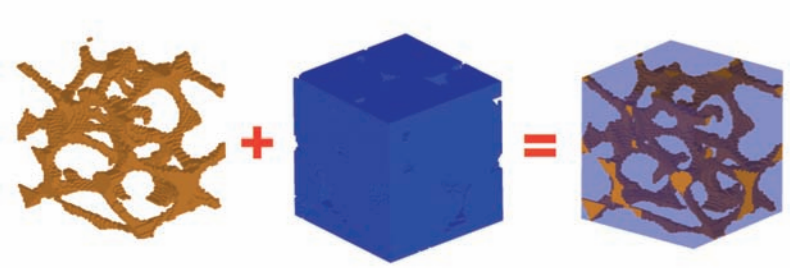
Percutaneous vertebroplasty is the injection of bone cement into the vertebral body in order to relieve pain and stabilize fractures and/or osteoporotic vertebrae. We have previously evaluated treatment risks and complications, which include cement extravazation into extraosseous tissues, including the epidural or paravertebral venous system, eventually ending in pulmonary embolism. The aim of this project is to develop a computational model to simulate the flow of two immiscible fluids through porous trabecular bone in order to predict the three- dimensional spreading patterns developing from the cement injection and minimize the risk of cement extravazation while maximizing the mechanical effect. The computational model estimates region specific bone porosity and anisotropic permeability from patient-specific clinical computer tomography data sets. The creeping flow through the porous matrix is governed by a modified version of Darcy's Law, an empirical relation of the pressure gradient to the flow velocity with consideration of the complex rheological properties of bone cement. To simulate the immiscible two phase fluid flow, i.e. the displacement of a biofluid by a biomaterial, a novel fluid interface tracking algorithm with mixed boundary representation was developed. Simulation trials showed close agreement with the findings from relevant literature and experimental results. The future model development will incorporate the morphology of the region specific trabecular bone structure for final incorporation into software for treatment planning and interventional guidance.



Simulations of biomaterial flow from an injection site (left) show good qualitative and quantitative correspondence to experimental results (right).



To improve our predictions of the mechanical effect of bone augmentation, we have been studying the complex interaction between a variety of reinforcing biomaterials and trabecular bone at the micro-scale. Using a combination of computational simulations and experimental methods, we have shown that the mixture of a biomaterial and bone is not adequately described by a mechanical model based on the theory of constituent mixtures; interaction at the bone-biomaterial interface greatly influence the integrity of the composite material. Results of this study are being incorporated into improved biomechanical simulations of osteoporosis treatment and into the development of new cement formulations.

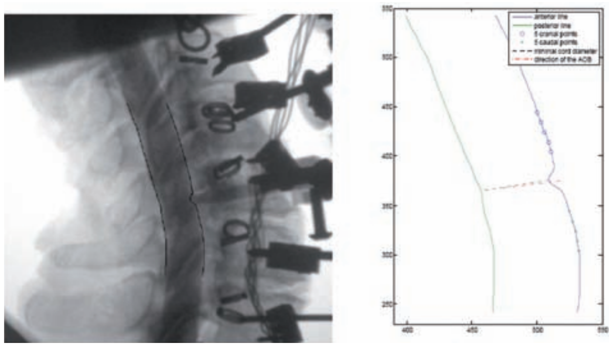


Biomaterial flow simulations are being used to predict cement filling patterns during bone augmentation and to reduce the risk of cement leakage along fracture planes.

Micro-scale constituent simulations and experiments have been developed to better understand the mechanical interaction of biomaterials and bone.

Geriatric Spinal Cord Injury

The average age of people suffering spinal cord injuries in many countries is shifting toward an older population, with a disproportionate number occurring in the spondylotic cervical spine. These injuries are typically due to low energy impacts, such as a fall from standing height. It has been hypothesized that excessive flexion or extension can cause cord injury, despite the low energy impact, as degenerative bony features occlude the canal. However, this injury mechanism has not been observed experimentally. In a continued collaboration on a study with the Orthopaedic and Injury Biomechanics Group of the University of British Columbia, we have improved our in vitro measurements to better replicate degenerative features in the elderly spine. We have shown that the range of motion of degenerated cervical spines is considerably smaller in all cardinal directions than the reported average range of motion of normal subjects and corresponds with earlier findings of clinical studies. Changes in cord compression were observed for different test conditions and physiological head positions. These changes could be correlated to spinal motion.



An in vitro model of cervical spine stenosis and spinal cord compression shows direct compression of a radio-opague surrogate spinal cord during spinal motion (collaboration with UBC).

Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis (SCFE) is a hip pathology which occurs in adolescents. The slip occurs along the growth plane of femoral head, where the femoral epiphysis translates posteriorly or inferiorly relative to the metaphysis. The initiator of such a slip could be high shear forces due to obesity or extreme shock loads. The existence of SCFE creates an abnormal condition for the hip joint. The impingement of the metaphysis against the acetabular rim is reported as one of the serious consequences of this pathology. Using three-dimensional computer modelling techniques, we have visualized and analyzed the effectiveness of the „Southwick's osteotomy", as well as the effects of the translational slip on impingement. The results of the simulation showed that, although all the SCFE joints have the same angular slip, the severity of the impingement increases with increasing translation of the head and often a complex realignment is required to prevent impingement. We have shown that a three-dimensional evaluation of an SCFE joint is necessary to define the severity of pathology as well as for surgical planning, rather than using only a conventional anterior-posterior Southwick's angle.

Computational Bioengineering

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Group Members

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Research Profile

The Computational Bioengineering Group tackles challenges in basic and applied medical research with modern computational simulation tools. Rather than focusing on the computational methods themselves, we are concerned with their appropriate application to resolve practical and fundamental clinical questions. Numerical methods are combined with experimental and clinical research in order to improve the quality and extend the validity of our models.

Together with our collaborators we constitute a strong team covering a wide spectrum of research topics ranging from direct support of surgical patient treatment to basic cell research. Besides our core expertise in applying finite element analysis to study skeletal biomechanics, we are seeking to improve planning of various computer aided interventions by developing and applying refined numerical techniques into the field of computer aided surgery. Another important research focus of the group is the development of novel statistical finite element methods to incorporate uncertainty in bone shape and mechanical properties in the evaluation of bone biomechanics.

Current Research Areas

Statistical Modeling for Biomechanical Simulations

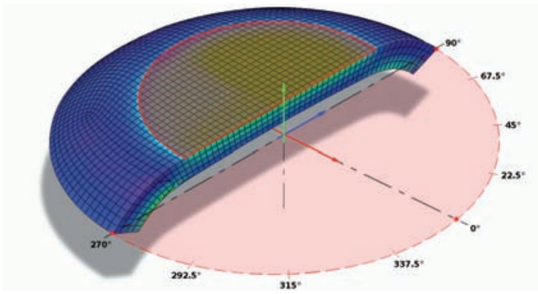
Finite element models built from CT data are commonly used to evaluate the mechanical performance of the bone or the load transfer from the implant to the bone. However, most analyses overlook the wide variation in material properties and geometry that may occur in natural tissues or the manufacturing imperfections in synthetic materials. Some authors recognized this limitation and included uncertainties in finite element biomechanical simulations, but failed to capture bone anatomical variability. The objective of this project is to propose a method to include bone anatomical variations for the evaluation of bone performance. Our technology allows a compact model that represents the variation of bone shape and mineral density encountered in a set of bones to be automatically built. The model is based on a large collection of CT scans. Statistical analysis techniques are employed to determine the average bone shape and density in a given population, as well as the distribution around this average. Once the model is built, it allows generating as many bone instances as required to accurately represent the population. Finite element calculations are used to evaluate the biomechanical properties of these bone instances. The initial evaluations are focusing on the prediction of bone strength.

Statistical shape models are used to study the variation of bone shape and mechanical properties in different populations - biomechanical information are included using finite element calculations. This statistical modeling platform is expected to have a substantial potential to evaluate implant fixation and function.

Biomechanics of Refractive Surgery

The optical characteristics of the human cornea depend on the mechanical balance between the intra-ocular pressure and intrinsic tissue stiffness. A wide range of ophthalmic surgical procedures alter corneal biomechanics to induce local or global curvature changes for the correction of visual acuity. Due to the large number of surgical interventions performed every day, a deeper understanding of corneal biomechanics is needed to improve the safety of these procedures and medical devices.

The first aim of this project is to propose a biomechanical model of the human cornea, based on its stromal microstructure. We developed a constitutive mechanical law that includes collagen fiber distribution based on X-ray scattering analysis and collagen cross-linking. Our results showed that the proposed model is able to

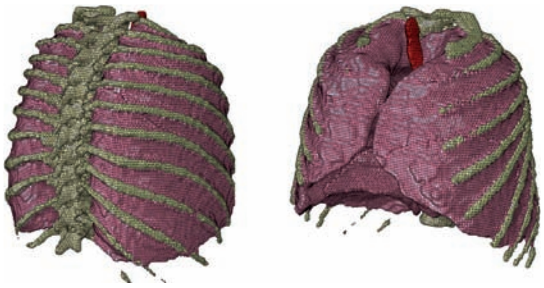


A numerical model of the human corneal has been developed. Since the material model is based on both isotropic and anisotropic experimental data, it has the potential to simulate mechanical interference, including non-symmetric surgical interventions, such as laser-assisted in situ keratomileusis (LASIK) or limbal relaxing incisions (LRI).

reproduce inflation and extensiometry testing data. The mechanical properties obtained for different age groups demonstrated an increase in collagen cross-linking for older specimens. In future work such a model could enable the surgeon to define the parameters used for the surgery in order to get the best clinical results, i.e., to enable a patient specific planning of geometric parameters such as the location and depth of the laser incisions.

ContraCancrum

The ContraCancrum (Clinically Oriented Translational Cancer Multilevel Modelling) is an European Project within the Virtual Physiological Human Initiative. It aims at developing a clinical platform for simulating, at both the macro and microscopic levels, the tumor development and tumor response to therapeutic treatments. The project focuses on glioblastomas and lung cancers. The contribution of the computational bioengineering group concerns the biomechanics of tumor growth. The shape and development of the tumor depends on the mechanical environment in the tissues. Therefore, the oncosimulator requires a fully automatic calculation of the stresses and strains in and around the tumor. This information is then transmitted to a cellular simulator. An automatic meshing algorithm and finite element code have been implemented in the framework of the oncosimulator. Results of the simulations will be compared to clinical observations.

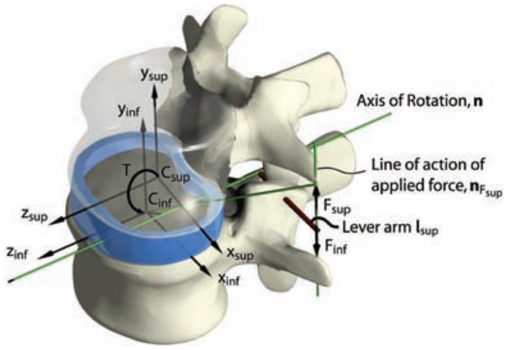


Automatic generation of a finite element mesh of the lung. Smoothing is used to improve accuracy of the rough surfaces generated with "voxel mesh" method. The outer surface of the mesh is extracted and smoothed according to the geometric signal processing approach of Taubin, which ensures volume preservation.

Biomechanics of the Scoliotic Spine

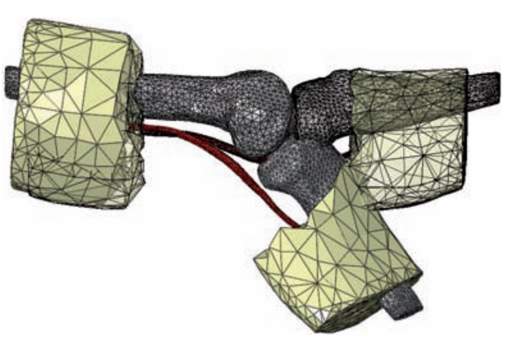
Adolescent Idiopathic Scoliosis is defined as a lateral curvature of the spine, involving a rotation of the vertebrae towards the concavity. Although the trigger causing the evolution of the deformity remains unknown, it is generally believed that the progression is linked to mechanical parameters. The only treatment that prevents further progression and can reduce the deformity is an invasive surgery in which vertebra are fused. However, this halts the natural growth and can have negative long-term effects. Many basic questions remain in this area. In order to better understand the progression of the curve and to develop non-fusion strategies, the knowledge of the biomechanical properties of scoliotic motion segments is essential. We developed an intra-operative measurement apparatus to determine stiffness properties of the spine. The apparatus includes a distraction forceps to measure force and displacement and an optoelectronic camera to track motion. This protocol enables in vivo stiffness measurements of the spine functional units. The feasibility and accuracy of the approach have been evaluated on lumbar ovine spines. The lateral bending stiffness was determined with the proposed concept and compared well with the stiffness acquired on a spinal loading simulator (considered as gold standard). The mean values of the stiffness computed were within a range of ±15% as compared to data from the spinal loading simulator.

The kinematic behavior of the motion segments recorded intra-operatively is analyzed to determine the applied moment as well as the position and orientation of the axis of rotation. This allows to compute pure decoupled standard motions such as pure flexion/extension, lateral bending or axial rotation.



Superficial Femoral Artery

Endovascular treatment of femoropopliteal obstructions has gained widespread acceptance as the primary revascularization approach in patients with claudication. The use of nitinol stents was recently shown to be superior to balloon angioplasty as a stand-alone procedure in patients with femoropopliteal arterial obstructions. However, stent fractures were reported to occur in up to one quarter of the cases, supposedly because of deformations in the arteria during limb movement. In this project, finite element models of the lower limbs were developed in order to assess the effect of mechanical loading on stent design and risks of fractures. Initial validation of the model was performed based on contrast enhanced-MRI images of healthy volunteers during knee bending. Motion of the artery measured on the MRI was similar to the displacements predicted with patient-specific numerical models. Stent fractures can now be investigated based on this validated model.

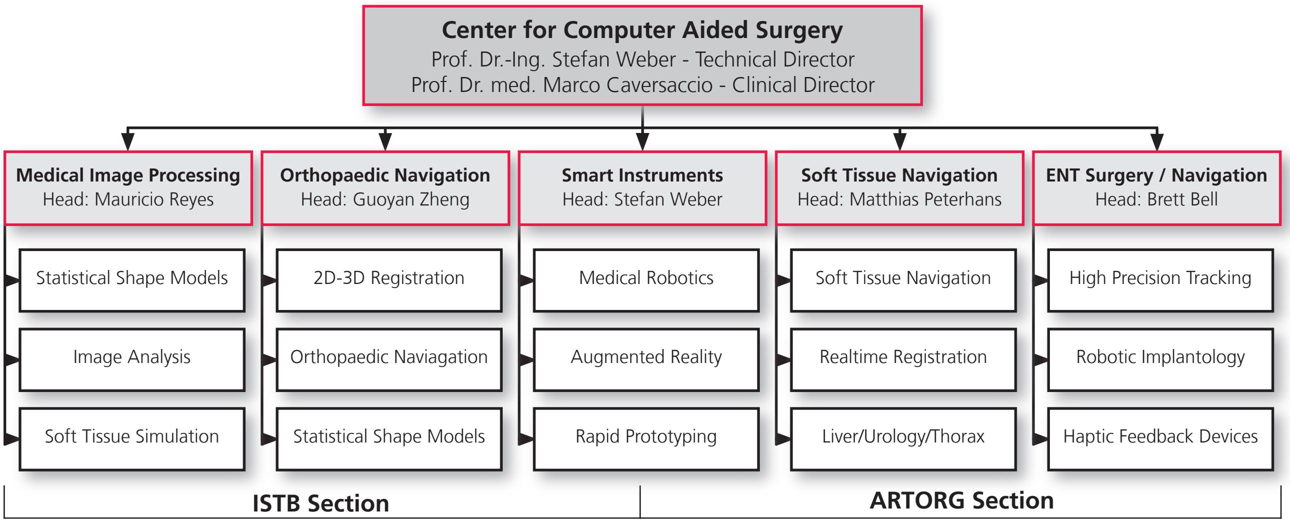


The motion of the superficial femoral artery while bending the knee was calculated using patient-specific model. These models will be used to study stent designs.

The Center for Computer Aided Surgery (ISTB Section)

Research Profile

The Center for Computer Aided Surgery (CCAS) is a collaborative effort between the ARTORG Center for Biomedical Engineering Research, the Institute of Surgical Technologies (ISTB) and the Inselspital Bern. It specifically focuses on clinically related research and development activities in the broad area of computer aided surgery. It aims at providing novel technologies for diagnostics, therapy and implantation to the interested clinical communities and enabling their evaluation in clinical routine. Our activities are primarily focused on supporting medical image analysis and diagnosis as well as surgical and interventional treatments by improving accuracy and reproducibility. At present, the centre is composed of five different research groups ranging in their focus from fundamental research all the way to clinically related topics.



The centre provides technological expertise in the areas of computer aided surgery, diagnosis, medical image processing and smart instruments based on clinical problems and motivations. The bandwidth of our research activities ranges from answering novel clinical challenges to improving existing approaches and medical technology with competencies ranging from pure algorithm development across component and systems development all the way to clinical validation (through our clinical network).

CCAS envisions to support society and its healthcare system for the challenges to come (demographic, economic, socio-cultural) by the enhancement and integration of novel technology, improving its availability for patients and indications and demonstrating its clinical benefit respectively. A powerful network of scientists with engineering and medical backgrounds as well as clinicians with understanding of technological approaches and possibilities will enable the creation of novel diagnosis and therapy solutions with real clinical impact.

CCAS is co-directed by two experts from the scientific and clinical disciplines, respectively.

Smart Instruments Group

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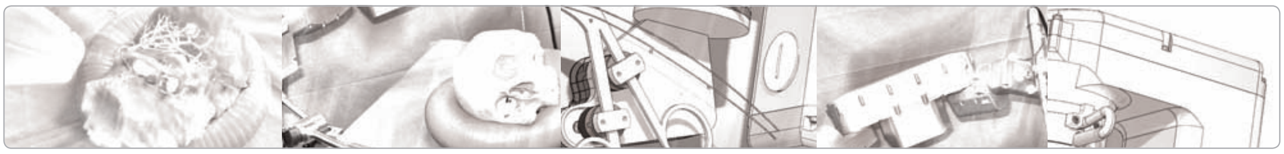
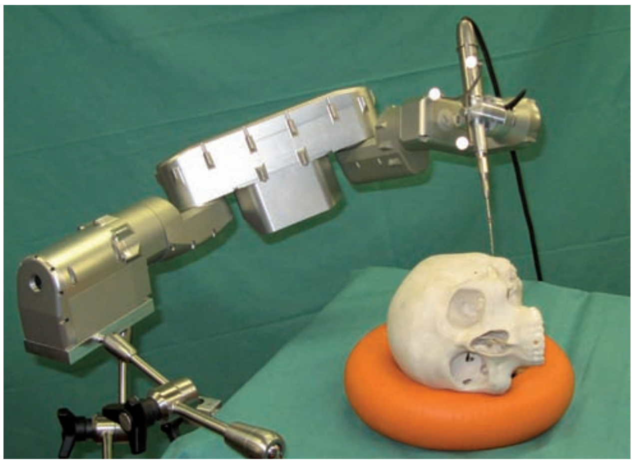
Current Research Areas

High precision Medical Robotics for ENT surgery

The surgical procedure for the placement of implantable hearing aids is performed on a very small scale and in proximity to critical structures such as the facial nerve. In order to improve the accuracy of the milling for the implant cavity, we developed a novel miniature robotic instrument manipulator. Embedded in the workflow of computer aided planning and navigation, the drilling trajectory is carried out exactly as planned by the clinical experts. The optical tracking of the robot by the navigation



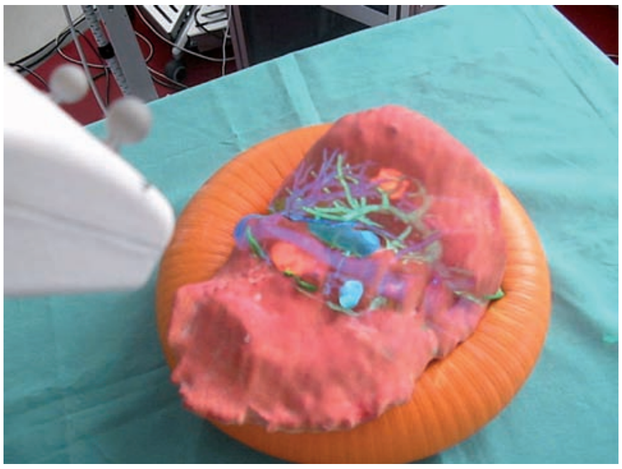


system enables the registration of the drill position with respect to the pre-operative CT data and can automatically follow the planned trajectory. The robot system is equipped with a 6 degree of freedom force-torque-sensor to provide the surgeon with tactile information relative to milling resistance.

The surgical robot system with an attached surgical milling device for application in ENT surgery.

Portable Image Overlay Navigation Projector

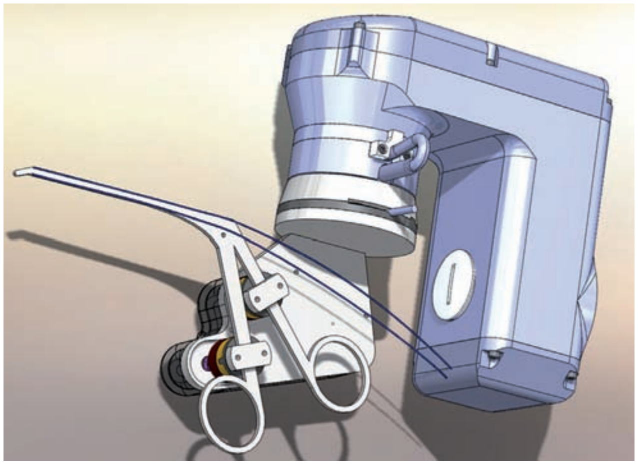
As minimally invasive surgical techniques become more common, a need for alternative visual guidance methods becomes increasingly apparent. A portable image overlay navigation projector was designed and developed to aid surgeons in visualizing the location of surgical targets and surrounding anatomical structures. It is predicted that the projector tool will assist in the planning of surgical entry points and paths by highlighting the position of high risk anatomical structures such as nerves and vessels. Through the implementation of navigation and registration techniques, patient specific data reconstructed from CT images can be superimposed directly on the patient's body surface during surgical procedures. Fundamentaly, this technology projects a view of anatomical features of interest onto the skin or surface of an organ, which allows surgeons to view the position of these structures within the body. The passively tracked handheld tool can be used with existing surgical navigation systems and is therefore an economically viable alternative to expensive, fixed image overlay systems currently in trial.



Projecting of a three dimensional vessel model onto a liver phantom.

Force Sensing in Micro Instruments

In an attempt to better equip ENT surgeons, novel smart instruments are under development. These new instruments will provide force feedback to surgeons for procedures requiring very fine clamping forces. One such instrument currently being developed is a ENT micro forceps fitted with a fiber-optic Bragg grating, which is capable of measuring strains on the order of 0.5με. This instrument is being developed specifically for stapedectomy and the following prosthesis implantation. Crimping of the prosthesis wire hook is a delicate process and it is believed that excessive clamping force could lead to necrosis of the incus. With this device, we can begin to understand the magnitude of forces involved in middle ear surgery, and provide future guidance to surgeons performing these types of procedures. Specifically, we hope to correlate clamping force with prosthesis integration and durability studies in a clinical setting. The overarching goal of this research is to augment currently available surgical instruments with force measurement capabilities. Finally, these tools are also integrated into the robotic assisted surgery scheme.



Development of optical fibre based force sensor equipped forceps for robotic integration.

Medical Image Analysis

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Group Members

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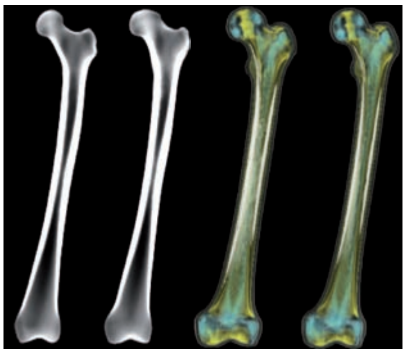
Research Profile

The Medical Image Analysis group conducts theoretical and applied research in image processing, computer vision, and artificial intelligence for the analysis of medical image datasets. Although particular focus is given to orthopaedic research and applications, the spectrum of topics and research interests is broad and open to other fields where medical image analysis techniques can provide solutions to biomedical-related problems.
All our projects are done in collaboration with internationally outstanding academic, clinical and industrial partners.

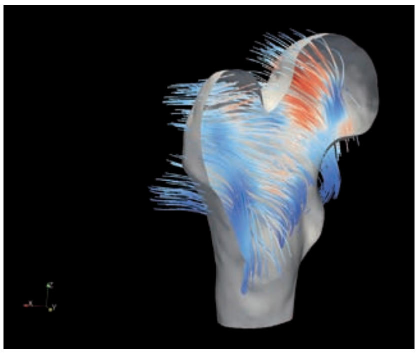
Current Research Areas

Bone Shape Analysis and Statistical Finite Element Modelling using Computational Anatomy Techniques

Computational Anatomy enables analysis of biological variability on a population. Using statistically inspired mathematical techniques, models can be built to represent the typical shape of an anatomical structure and the predominant patterns of variability in shape across a given population. These techniques can be used to generate new statistically conforming shapes and to predict, from sparse information, the shape of unknown ones. These methods have been extended to perform automatic morphometry and bone mineral density studies, which are of great relevance in orthopaedic research. Our group also use these models to perform patient-specific bone shape prediction from clinically relevant measurements. To extend this further, we are developing methodologies to combine several univariate parametric regression models into the problem of multivariate and high-dimensional regression of medical images. The final of this is to improve prediction capabilities without assuming any specific data distribution while avoiding the problem of curse of dimensionality. In collaboration with the Computational Bioengineering group, patient-specific information and biomechanical constraints have been incorporated into the model. In this direction, we have developed automatic methods for finite element mesh generation, and statistical assessment of biomechanical properties under certain load conditions.



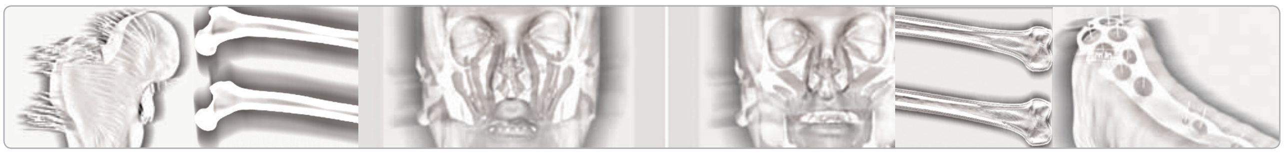
Computational anatomy for the analysis of shape and bone mineral density. Left: Example of two distinct pattern of shape and intensity variations across a given population. Right: Simulation of aging bone from 50 to 84 years of age, left and right respectively. Decrease in cortical bone thickness at the Diaphysis (middle part in white color) and Epiphysis (femoral head) indicate a reduction of the bone mechanical strength.



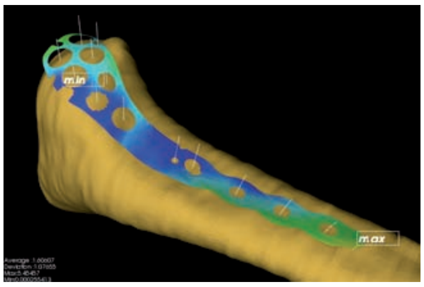
Computational anatomy for the analysis of bone shape and bone mineral density changes over time. Simulation of bone aging from 50 to 84 years of age and visualization of typical changes of bone shape over time using 3D streamlines. Streamlines colors represent typical amount of deformation. The analysis highlighted a decrease of the neck-shaft angle (NSA) as well as an inclination in the cranio-caudal direction of the major trochanter.

Evidence Based Implant Design

The methods highlighted above have been applied to the problem of optimisation of orthopaedic implants. In collaboration with our industrial partners we have collected the largest research CT data bone database in the world, which allows us to provide significant statistical statements about the appropriateness of proposed implant designs. During 2009, this methodology was utilized for the first time to perform computer-assisted orthopaedic implant design based on analysis of a given population. The outcome of this project is of great benefit to the orthopaedic implant manufacturing industry. In addition, in collaboration with the Computational Bioengineering group, the study has been extended to analyse the biomechanical stability of an implant under certain loads, across the whole range of the target population.



Automatic orthopedic implant bone fitting. Result example of implant fitting on proximal tibia. Colors represent the quality of the fitting, "min" and "max" labels indicate best and worst fitting points. Based on this technique and statistical analysis of an entire selected population, modifications to the implant design can be proposed.



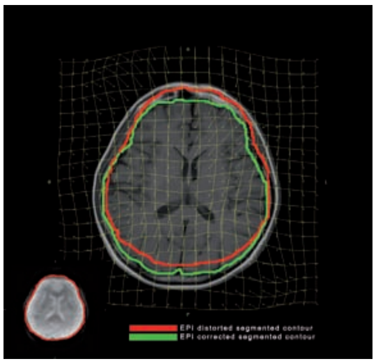
Soft Tissue Simulation for Cranio-Maxillofacial (CMF) Surgery

The system developed in the previous years for computer-aided CMF surgery has been developed and introduced into routine clinical practice. It offers a 3D surgical planning environment, which is currently being extended to consider soft tissue deformations to realistically predict realistic facial appearance after surgery. Methodologies have been developed to perform patient-specific facial muscle prediction from CT images, maintaining current clinical workflow, as well as avoiding the difficult and time consuming task of muscle tissue segmentation. In addition, during 2009, special emphasis was given to study the effects of non-homogeneous and anisotropic tissue properties on CMF surgery prediction. Experiments in clinical data have shown good agreement between the simulations and post-operative outcome, highlighting the plausibility and promising integration of the proposed method into clinical practice.

Soft tissue simulations for Computer-Assisted Cranio Maxillo Facial (CMF) Surgery. Example case of the system used to predict soft tissue deformations after CMF surgery. Middle and Right-most image show different muscle templates used to compute the deformations. Right-most muscle model developed by Giuseppe Giovanni and Prof. Edoardo Mazza, ETHZ.

Brain Image and Brain Image Tumour Analysis and Simulations using Highly Efficient Cuda-Enabled Technologies

Magnetic Resonance Imaging (MRI) is a powerful image modality that encompasses rich anatomical and physiological information at a high resolution. This project aims at developing methods to analyze MRI images with focus on image registration, interpretation and pattern recognition. Novel methodologies are being developed to improve existing rigid and non-rigid image registration techniques. During 2009, special emphasis was given to the problem of non-rigid registration of multimodal brain images. In this sense, a novel multimodal non-rigid registration method was developed, featuring fast and accurate non-rigid registration. Research efforts have been made to employ these methodologies for the task of brain image segmentation in the presence of tumours. In this direction, an atlas-based patient-specific tumour-induced brain image segmentation method is being developed.



Correction of distortion in echo-planar (EPI) images (useful modality for functional neuroimaging. See bottom left corner) through combination of a synthetic deformation model and a novel multimodal diffeomorphic non-rigid image registration method. A T1 image (in the center) is used as a reference image to correct for the distortions in the EPI image. The red and green contours show the segmented EPI image before and after correction, respectively. A deformed grid has been overlaid to describe the local deformations applied to the EPI image.

Multimodality Image Based Computer Assisted Biopsy

A computer navigated solution for Positron Emission Tomography/Computer Tomography (PET/CT) image based biopsy has been developed. The system aims at assisting radiologists to precisely locate, reach and remove tumours as part of the biopsy procedure with minimal radiation exposure to the radiologist and patient. The project is conducted in collaboration with the Computer-Assisted Surgery Center (CCAS). The support of the Medical Image Analysis group is based on providing expertise in medical image segmentation and registration, as well as simulation of soft tissue deformations for surgical procedures.

Computer Assisted Liver Surgery

The aim of this project is to perform navigation and guidance of liver surgery procedures. Special focus has given to the integration of the system into clinical practice, as well as to validate the developed system through clinical trials. This project is conducted in collaboration with the Computer-Assisted Surgery Center (CCAS), where the support from the Medical Image Analysis group is based on providing expertise in medical image segmentation and registration, as well as simulation of soft tissue deformations for surgical procedures.

Computer Assisted Orthopaedic Surgery

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Group Members





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Research Profile

The Computer Assisted Orthopaedic group aims at developing state-of-the-art medical image computing technologies to enhance the autonomy and improve the usability of computer assisted interventional systems.

In the past year we have continued our pursuit of novel medical image computing methodologies/systems for various clinical applications. These include a novel algorithm for statistically deformable 2D/3D reconstruction of a patient-specific 3D model from a single un-calibrated x-ray image, a novel cost-effective system for high-precision placement of acetabular cup in total hip arthroplasty, a system for computer assisted diagnosis and treatment of femoroacetabular impingement, a novel technique for determination of pelvic orientation based on calibrated ultrasound images, and a method for automated vertebral segmentation from MRI data.

Current Research Areas

Statistically Deformable Reconstruction of a Patient-specific 3D Model from a 2D Un-calibrated X-ray Image

Knowing the patient-specific morphology information of an anatomical structure is important for various computer assisted diagnosis, planning, navigation, and treatment follow-up applications. Such information can be easily obtained from a CT or MR scan. However, these have the disadvantages that they are expensive, time-consuming and/or induce high-radiation doses to the patient. We have developed a statistically deformable reconstruction method for derive a patient-specific 3D model from a 2D un-calibrated x-ray image. The computational engine behind our method is the combination of the statistical shape models of the targeted structures and a novel 2D/3D correspondence building algorithm. We validated our method on two different x-ray imaging means (fluoroscopic image and x-ray radiograph) and on two different anatomical structures (pelvis and lumbar vertebra), as shown in Figure 1.

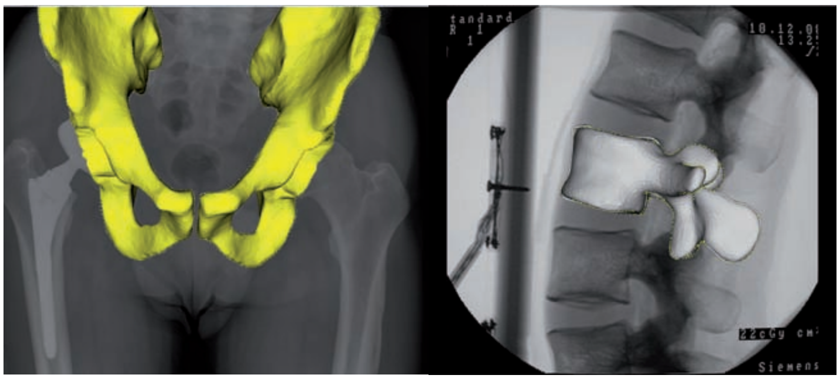

Figure 1: Reconstructing a patient-specific 3D model from a single standard 2D AP pelvic x-ray radiograph.

A novel cost-effective system for high-precision placement of acetabular cup in total hip arthroplasty

To address the limitations of existing works for Total Hip Arthroplasty (THA) operated in lateral approach, we have developed a novel cost-effective system for high-precision placement of acetabular cup, which has following features: (1) it is cost-effective. Our system uses a mechanical alignment unit with Bull'-eye bubble level indicators, taking advantage of the constant direction of the natural gravity force as a globally available reference for acetabular cup placement; (2) it is patient-specific. Our system allows for a calibration with respect to the patient's individualized morphology; (3) it does not need CT/MR scan. The patient-specific morphology information is derived from a 3D model that is reconstructed from a standard AP pelvic x-ray radiograph; and (4) it is completely integrated with the standard treatment protocol (Figure 2).

Figure 2: A novel cost-effective system for high-precision placement of acetabular cup in total hip arthroplasty.

Computer Assisted Diagnosis and Treatment of Femoroacetabular Impingement

Femoroacetabular impingement (FAI) is defined by the bony conflict between the proximal femur and the acetabulum at the end range of motion. This repetitively abutment is caused by morphological alterations at either femoral head-neck junction and/or the acetabular rim. FAI leads to lesions at the labrum and damages the adjacent cartilage, which finally causes early osteoarthritis to a young a very active patient population. Today's surgical treatment is hampered by the inability to accurately determine the impingement location. The purpose of this project is to evaluate whether computer-assisted treatment is able to improve and to facilitate the surgical treatment. A diagnosis application have been developed, which virtually computes impingement areas while simulating hip motions based on 3D models. A navigation application, which have been developed and validated, guides the surgeon intraoperatively according to the planned situation (Figure 3).

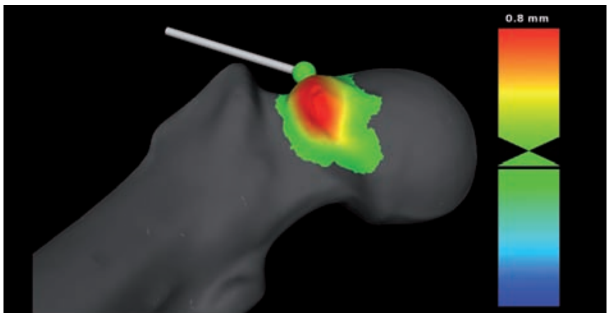

Figure 3: Screenshots of the computer assisted diagnosis and navigation system for treatment of femoroacetabular impingement.

Determination of Pelvic Orientation Based on Calibrated Ultrasound Images

In the field of computer-assisted orthopaedic surgery, the Anterior Pelvic Plane (APP) is commonly used to determine the pelvic orientation. This reference plane is used to precisely place the acetabular cup. An accurate cup insertion and therefore a precise detection of this plane are very important for the clinical outcome. B-mode ultrasound potentially provides a precise means to support the surgeon during this step. In order to derive 3D information, the ultrasound probe is tracked by a navigation system. We have developed a novel hierarchical reconstruction method, which uses statistical shape models of the pelvis to accurately reconstruct the pelvic orientation based on sparse point data, derived from tracked ultrasound images. Experimental trials based on a soft-tissue simulation phantom proved the validity of our method (Figure 4).

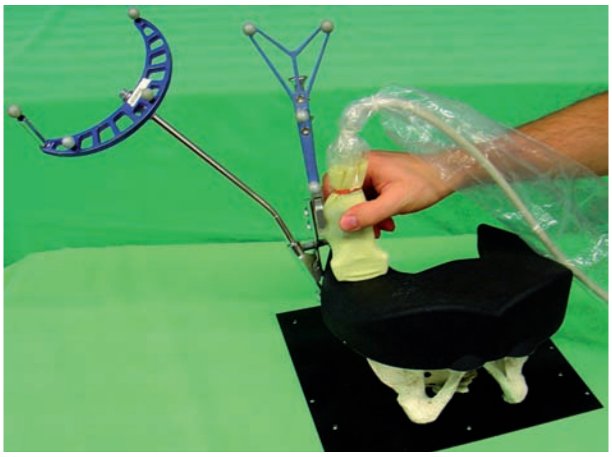

Figure 4: Statistical shape model based reconstruction from calibrated ultrasound data.

Automated Vertebral Segmentation from MRI Data

MR imaging of vertebrae has several advantages. It can show soft-tissue details well and it does not induce radiations to the patient. Its segmentation, in comparison to the CT segmentation, is much challenging due to heterogeneous signal intensities in tissues and poor signal to noise ratio. In this project, we are aiming to develop a template-based level-set solution, which can integrate the information from the template, the information from the intensity distribution, and the information from the image edges. Figure 5 shows a preliminary validation result of segmenting a 3D MRI data.

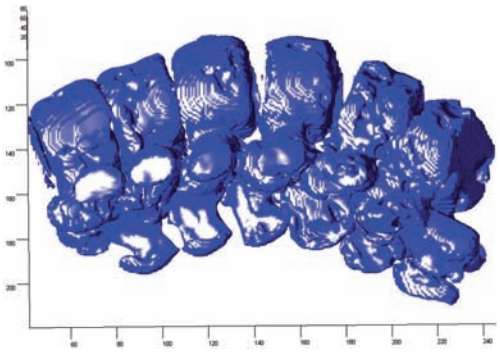

Figure 5: A MR image segmentation example.

Master of Science in Biomedical Engineering

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Group Members

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Overview

In March 2006, 23 students of different nationalities, coming from various fields of study, gathered in the lecture hall of the Institute for Surgical Technology and Biomechanics to commence the new specialized master study course "Master of Science in Biomedical Engineering". Despite the fact that medical technology is a particularly well established industry sector in Switzerland that has reached very high standards, only a limited number of corresponding education programs had existed before 2006. Taking into account the high need for well-trained medical engineering professionals in the Swiss MedTech industry, the unique study course was created through a combined effort on the part of the University of Bern and the Bern University of Applied Sciences. To date, the program has opened up the exciting interdisciplinary field at the interface between medicine and engineering to 180 students from 22 countries. Most of them are still continuing their studies, while 47 graduates have taken up a professional career. Many of these are employed in the industry, others are pursuing their education towards a Ph.D. degree in an academic environment. In the ISTB alone, 6 former master students currently hold a position as Ph.D. students, while others went to Zurich, Basel, or abroad to enroll in a Ph.D. program.

Characteristics

The course of studies is assigned to the Faculty of Medicine of the University of Bern, and is offered in cooperation with the Bern University of Applied Sciences. The Master Course in Biomedical Engineering was one of the first (and is among the few) university level master courses in Switzerland to open its doors to graduates from a University of Applied Sciences without additional prerequisites. Due to the high demand for continuing education in medical engineering, the courses have been also opened to industry professionals.

The Biomedical Engineering program is a specialized master course. It has no bachelor course of studies as a precursor. Admission is granted to applicants coming from various fields of study. Students are intended to apply their previously acquired knowledge and abilities to fully integrate the highly interdisciplinary subject matter. The fact that students with different backgrounds, such as Medicine, Engineering, Physics, or Computer Science, are in the same classroom gives the chance to both students and lecturers to enlarge their views in a stimulating environment.

It is possible to complete the studies in parallel to a part-time professional occupation. Recommended courses take place - with rare exceptions - on only 3 days per week. Students who take the master course while working part-time may also apply for an extension of the maximum study duration.

Currently, 54 lecturers convey their knowledge in over 45 courses, 85% of which are taught in English, 15% in German. Most exams can be taken in both languages, some even in French. For the future, we are preparing a 100 percent English course program. The curriculum is subject to constant improvement and development.

The Course Structure

The study course takes 4 semesters, which corresponds to 120 ECTS points, one ECTS point being defined as 25-30 hours of study. The study program can be extended to a maximum of 6 semesters. The modular structure of the course comprises Basic Modules in Biomedical Engineering, Human Medicine, Engineering Mechanics, and Applied Mathematics. After the first semester, the students select one of three Focus Areas (Major Modules Musculoskeletal System, Electronic Implants, or Image-Guided Therapy) and pursue their interests further in a number of specialized courses (Modules "Advanced" and "Unrestricted Electives"). The last semester is dedicated to a master thesis project in a research group or, in many cases, in an industrial environment.

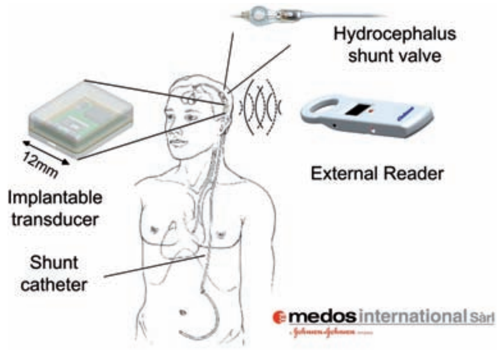
1st Semester	2nd Semester	3rd Semester	4th Semester
Basic Modules 28 ECTS	Major Modules 16 ECTS	Major Modules 8 ECTS	Master Thesis 30 ECTS
		Unrestricted Electives 5 ECTS	
	Advanced Modules 6 ECTS	Advanced Modules 10 ECTS	
	Basic Modules 9 ECTS	Basic Modules 8 ECTS	

The Focus Areas (Major Modules)

The choice of one of three Focus Areas (Major Modules) after the first semester constitutes the first opportunity for specialization. Each Major Module in itself consists of several mandatory courses as well as a number of elective courses. The elective parts of the Major Modules as well as the elective Modules „Advanced" and „Unrestricted Electives" give rise to even more diversity and flexibility, allowing for an almost infinite number of course combinations. To guide the students through the course selection process, and to avoid organizational problems such as overlapping courses, the responsible lecturers have developed a recommended study plan for each Major Module which fits into a timetable of three days per week.

Electronic Implants

This focus area comprises two main topics: Electronic implants (e.g., cardiac pacemakers, cochlear implants, retinal implants, implantable flow sensors) as well as aids to improve surgery (e.g., medical robotics and smart surgical instruments). The mandatory courses provide fundamental knowledge in the areas of intelligent implant technology, medical robotics, micro-systems engineering, biomedical signal processing and analysis, and engineering design, thus ensuring a comprehensive technical understanding. Elective courses allow the students to extend their competence in various directions.



Flow sensor for the treatment of Hydrocephalus.

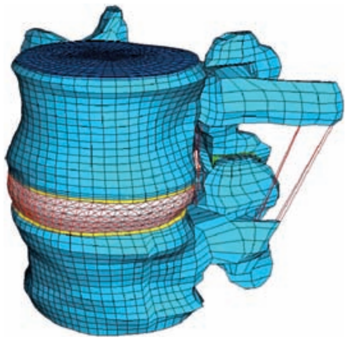
Image-Guided Therapy

Originally, medical imaging was only applied during diagnosis. Later, X-ray systems were introduced in operating rooms (OR) to help localize 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-ionizing ultrasound devices became the predominant imaging modalities used in Image-Guided Therapy (IGT). Today's developments try to integrate computed tomography (CT) and magnetic resonance imaging (MRI) systems in the OR to support intra-operative navigation. All these developments in IGT aim at improving the surgical outcome in various aspects. A comprehensive understanding of all technical fundamentals required to understand, improve and develop Image-Guided Therapy systems is provided in the courses of this module.

The four-dimensional lung motion model is used for cancelling organ motion in tumor therapy.

Musculoskeletal System

Musculoskeletal disorders are the most frequent cause for long-lasting or chronic pain and, therefore, for restrictions on physical performance. Musculoskeletal disorders affect hundreds of millions of people worldwide and a strong increase in this number can be expected in the next decades due to the predicted growth of the elderly portion of our population. In this module, students will gain a comprehensive understanding of the multi-scale characteristics and response of the musculoskeletal system, combining knowledge at the body, organ, tissue and cell level. Students will gain the required expertise to apply their knowledge in relevant, practice-oriented problem solving in the fields of rehabilitation, sports science and orthopaedics.



Computer simulation of a spinal segment provides insight into disease and injury processes and allows the pre-clinical evaluation of many possible treatments

Information event for first semester students in November 2009

Mechanical Design & Production

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Group Members

					
Urs Rohrer	Pascal Aebersold	Sara Corinti	Sebastian Marti	Erland Mühlheim	Ronald Ramseier

Profile

The primary function of the Mechanical Design and Production (MDP) group is the co-development and manufacturing of mechanical and electro-mechanical components related to the research pursuits of the ISTB. The MDP group supports all levels of the design and manufacturing process from concept to production. This includes computer assisted design (CAD) modelling with SolidWorks®, prototyping and production with technical drawings, standard tooling, computer assisted manufacturing (CAM) with MasterCam® software, and CNC-machines. We also support industrial and academic external research collaborators with their mechanical design and production needs.
The MDP group has a secondary role in training. This training encompasses the skills required to safely and proficiently operate machine shop tooling and equipment, the knowledge required to achieve the best results with a variety of materials and the skills needed to efficiently manage the design and production workflow.
Trial apprenticeships are used as a means to evaluate candidates for a full apprenticeship in the MDP group. This year, we performed three such courses and finally we selected Patrick Moser as our next apprentice and he will begin his training in August of 2010 as a Polytechnician.
After his Apprenticeship at our Institute we employed Sebastian Marti in August 2008 until end of February 2009 as a Polytechnician in the MDP. We thank him for his solid workmanship and we wish him all the best in his future.
After 17 years of service as a mechanic and foreman, Erland Mühlheim has chosen to seek a new professional challenge thereby leaving the Institute at the end of August. We appreciate him as an independent and responsible worker, and wish him all the best in his future endeavors. As a replacement for Erland Mühlheim, Pascal Aebersold joined our workshop on June 1. We wish him much success in his new occupation, and look forward to a fruitful cooperative effort.

Projects

Retrofitting of the Schaublin 102 CNC-Lathe

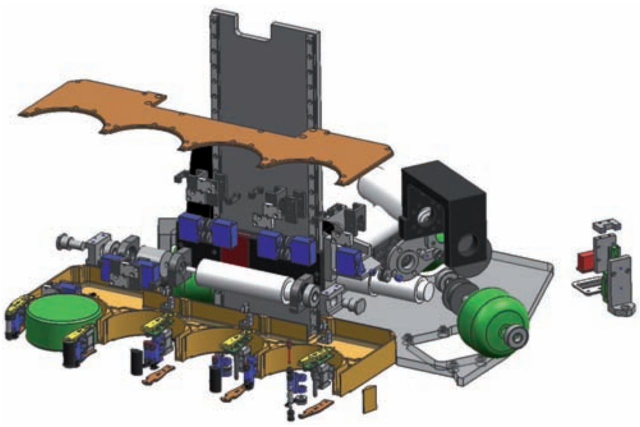
This year, the old OSAI® controller of the Schaublin 102 CNC-Lathe was replaced with a new HEIDENHAIN Manualplus 620® controller The simplicity of this controller has greatly reduced the effort of using this machine. The new control system makes it possible to directly program and create parts in the simplest fashion. This process eliminates the conventional CAD-post-proccessing techniques previously employed.

Research Equipment Design & Manufacturing

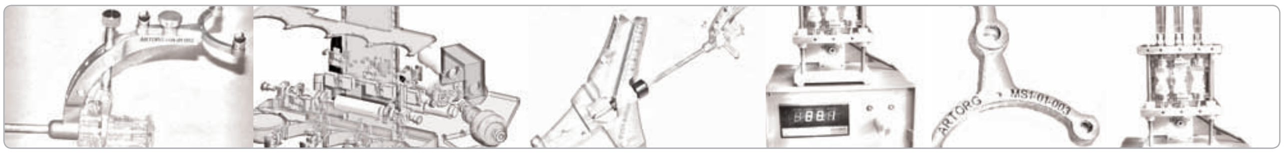
As expected, the requirements of a machine shop supporting research in the biomedical engineering field are as diverse as the research field itself. The variety of subjects researched in the ISTB yield a number of diverse design and production requests from prototype clinical and surgical tooling to fixtures for mechanical, biological and kinematic testing, as well as imaging system accessories and calibration equipment. The following illustrations highlight a few of this year's projects.

Kleito Eurobot

In conjunction with the technical college of Biel, the Kleito Team constructed the Eurobot. Our workshop was asked to build all of the mechanical pieces for the robot. This project was a real challenge in view of the precision and time requirements dictated by the robot design requirements. The Kleito team took part in the Swiss finalist competition, which was held on the 8th of May in Yverdon les Bains. Unfortunately, the Kleito team did not qualify for the European championship.



Kleito AssemblyRobot



Navigation Platform 3rd Generation

The navigation platform series was continued this year with a new model. The new navigation platform incorporates larger casters to improve ease of rolling safety. Furthermore, the height adjustment mechanism was redesigned to improve ease of use by reducing the number of adjusting elements from 3 to 2. Finally, fitting the platform with a touch screen monitor with an accompanying computer eliminated the need of laptop support brackets.

Navigation Platform

BoneNeedle Multicaltool and shields

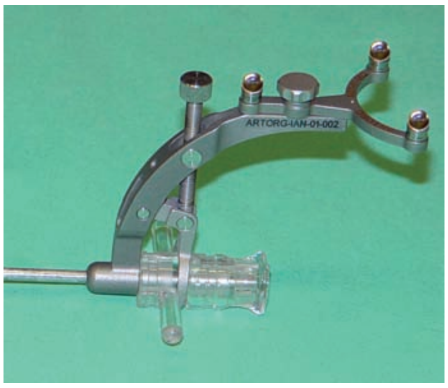
Multicaltool & Markershields

The old aluminum navigation marker shields are being replaced by a new light weight titanium design. By including multiple mounting-hole sizes, a variety of marker spheres and mounting posts can be used from previous and newer designs. The accompanying Multicalibration Unit is also made of titanium and facilitates the calibration of many types of tools. Special tool forms can also be calibrated through the creation and attachment of appropriate adapter blocks.

Bone needle DRB-Support

Two special clamp base prototypes have been created for biopsy needle navigation. The first model was made of aluminum, and the second of titanium.

BoneNeedleclamp



Cardiovascular Tissue Pumpdevice

A pump drive has been developed and built in collaboration with the tissue engineering group of the cardiovascular surgery division of Inselspital. In contrast to the earlier pumping unit, this drive can deliver unique stroke volumes to three concurrent experiments. Furthermore, the pump is fitted with a small powerful motor making it easy to handle.

Old Cardio Tissue Device (left) and new Cardio Tissue Device (right)

Acknowledgments

A research institution such as ours depends significantly on support from a number of bodies including government, industry and other private sponsors. We are indebted to the AO-Foundation for its generous contributions to our budget. We graciously thank the Swiss National Science Foundation for its support within the Swiss National Center for Competence in Research CO-ME and individual Division III project grants, and the Federal KTI/CTI Innovation Promotion Agency for providing R&D matching funds. Furthermore we are grateful to the European Commission for its support within the Seventh Framework Programme. In addition, support in the form of equipment, donations, or finances for a large number of specific research projects by various foundations and companies is gratefully acknowledged.

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Innovation Promotion Agency CTI

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CO-ME
COMPUTER AIDED AND IMAGE GUIDED MEDICAL INTERVENTIONS

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MSc & PhD Degrees at the ISTB

MSc in Biomedical Engineering

In a continuing effort to support Swiss innovation and ensure a critical mass of skilled labor in the field of Bioengineering, the University of Bern's Medical Faculty in collaboration with the University of Applied Sciences Bern are offering a masters degree by coursework. The program is composed of advanced classes in fields ranging from orthopaedic mechanics and tissue engineering, to computer aided surgery, smart surgical instrumentation and outcome based research and is open for engineering and computer science graduates from the Universities of Applied Science (Fachhochschulen). For further information visit the program's web site at www.bioeng.master.unibe.ch.

PhD in Biomedical Engineering

The doctorate degree in biomedical engineering at the ARTORG Center is undertaken within the Graduate School for Cellular and Biomedical Sciences at the University of Bern, which is jointly administered by the Faculties of Medicine, Science and Veterinary Medicine (Vetsuisse). The programme usually lasts three years and offers structured post-graduate training in experimental research. For further information please visit the graduate schools web site at www.gcb.unibe.ch.

Master Theses

Aghayev, E.
Generation of a mean 3D model of mandible; Mandible morphometry; Calculation of distances and angles for the path of a reconstructive mandible plate

Bürki, A.
Development and design of a test stand to investigate orthopaedic saw blades

Christen, P.
Contact mechanics of a discrete fiber-reinforced cartilage model

Held, M.
In vitro evalution of the influence of pulsed electromagnetic fields on bovone nucleus pulposus

Steiner, F.
Biomechanics of Geriatric SCI

Stucki, R.
Sensor for elderly people

Tekari, A.
In-vitro strain measurement in a loaded tibia: Experimental validation of a finite element model

Wenger, A.
Development and design of a new pedicle anchoring system in combination with BoneWelding™

Widmer, R.
Simulation of biomaterial flow through porous trabecular bone

Dissertations

Ambrosetti, S.
Wireless smart surgical instrumentation for spinal interventions

Bardyn, T.
Patient-specific preoperative assessment of primary stability in implant dentistry

Chegini, S.
Constituent-based tissue models for the simulation of hip joint pathologies

Kozic, N.
Statistical shape space analysis based on level sets for optimization of orthopaedic implant design

Editorial & Review Contributions

Annals of Biomedical Engineering
Annals of BMVA
ASME Journal of Biomechanical Engineering
Biomedical Engineering Online
Clinical Biomechanics
Clinical Orthopaedics and Related Research
European Cells & Materials
European Spine Journal
IEEE Transactions on Biomedical Engineering
IEEE Transactions on Medical Image Analysis
International Journal of Computer Assisted Radiology and Surgery
Journal of Anatomy
Journal of Biomechanics
Journal of Biomedical Materials Research
Journal of Healthcare Engineering
Journal of Oral and Maxillofacial Pain
Medical Engineering and Physics
Medical Image Analysis

Editorial & Review Contributions

Medical Physics
Proceedings of the Institution of Mechanical Engineers, Part H, Journal of Engineering in Medicine
Recent Patents on Biomedical Engineering

Editorial Board Member

Clinical Biomechanics
European Spine Journal

Funding Reviewer for Following Agencies

AO Foundation and AO Spine, Switzerland
Austrian Science Fund, Austria
Engineering and Physical Sciences Research Council, United Kingdom
Natural Sciences and Engineering Research Council, Canada
Swiss National Science Foundation, Switzerland

Awards

GRAMMER European Spine Journal Award
Haschtmann, D., Stoyanov, J.V., Gédet, P., Ferguson, S.J.
Vertebral endplate trauma induces disc cell apoptosis and promotes organ degeneration in vitro
European Spine Society, Warsaw, Poland

Ypsomed Innovation Award for Research and Development
Peterhans, M., Weber, S.
Development and clinical application of a navigation system for computer aided liver surgery
Ypsomed Innovationsfonds, Burgdorf, Switzerland

Ypsomed Innovation Award for Research and Development
Zheng, G., Nolte, L.-P., Echeverri, S.
A novel cost-effective system for high-precision placement of acetabular cup in total hip arthroplasty
Ypsomed Innovationsfonds, Burgdorf, Switzerland

Research Award Alumni MedBern
Salzmann, J., Stieger, C., Caversaccio, M., Arnold, A., Zheng, G., Gerber, N., Nolte, L.-P., Weber, S.
Concept of a miniature robot for hearing aid implantation
Alumi MedBern, Tag der Klinischen Forschung, Bern, Switzerland

1st Poster Prize Session 5
Andereggen, L.
Stereolithographic models for advanced treatment planning in complex intracranial aneurysms
neuroRAD, Jahrestagung der DGNR 2009, Gürzenich Köln, Germany

2nd Poster Prize
Steppacher, S., Tannast, M., Zheng, G., Zhang, X., Kowal, J.H., Siebenrock, K.A., Murphy, S.B.
Accuracy of CT-based computer-navigated total hip arthroplasty
Schweizerische Gesellschaft für Orthopädie und Traumatologie SGO, Geneva, Switzerland

Medical Cluster Award
Schumann, S.
X-ray machine calibration and its feasible application for 2D/3D reconstruction of a patient-specific surface model of the proximal femur
Biomedical Engineering Day 2009, Bern, Switzerland

Invited Lectures

Büchler, P.
Integration of statistical shape modeling in biomechanical simulation
International Society for Computer Assisted Orthopaedic Surgery, Statistical Shape Modeling, pre-congress Educational Workshop, Boston, USA

Ferguson, S.J.
The biomechanics of bone augmentation
22nd European Conference on Biomaterials, European Society for Biomaterials, Lausanne, Switzerland

Ferguson, S.J.
Spinal trauma from impact loading induces intervertebral disc degeneration
Third Switzerland-Japan Workshop on Biomechanics (SJB 2009), Engelberg, Switzerland

Ferguson, S.J.
The science of nuclear replacement and annular repairs; do they work?
Global Spine Congress, San Francisco, California, USA

Ferguson, S.J.
Biomechanics of disc degeneration
Annual Meeting: Swiss Society of Neurosurgery, Lucerne, Switzerland

Ferguson, S.J.
Biomechanics of spine fractures
Swiss Spine Residents Course on Spinal Trauma, Bern, Switzerland

Ferguson, S.J.
From dysplasia to impingement: Finite element analysis
AO North America Symposium on Surgical Preservation of the Hip, Lake Tahoe, California, USA

Ferguson, S.J.
Role and biomechanical function of the labrum
AO North America Symposium on Surgical Preservation of the Hip, Lake Tahoe, California, USA

Nolte, L.-P.
Introduction to smart devices for orthopaedic surgery
Swiss IEEE EMBS Chapter, Bern University of Applied Sciences, Biel, Switzerland

Nolte, L.-P.
Advancements of smart devices for orthopaedic surgery
6th International Practical MIS Knee Navigation & MIS Hip Training Course, Hospital Oberengadin, Samedan, Switzerland

Nolte, L.-P.
Development of computer assisted navigation surgery in Bern
Farewell Symposium in honour of Prof. Dr. Dr. h.c. Rudolf Häusler, Impact of New Technologies on Clinical Otorhinolaryngology, Bern, Switzerland

Nolte, L.-P.
Laudation for Mr. Beat Haldimann - Winner in the craftsmanship-creation category
Prix Gaïa 2009, La Chaux-de-Fonds, Switzerland

Nolte, L.-P., Puls, M.
Computer assistance for the diagnosis of FAI
4th Annual Conference of The British Society for Computer Aided Orthopaedic Surgery, Royal Society of Medicine, London, United Kingdom

Nolte, L.-P., Zheng, G.
3-D reconstruction of a surface model of the proximal femur from calibrated radiographs
4th Annual Conference of The British Society for Computer Aided Orthopaedic Surgery, Royal Society of Medicine, London, United Kingdom

Nolte, L.-P.
Swiss medical technology – overview and innovation promotion
Collegium Helveticum, Zurich, Switzerland

Invited Lectures

Reyes, M.
Computational anatomy for bone morphometry orthopaedic implant design
CAOS 2009 Workshop - Statistical Shape Modelling, Boston, USA

Zheng, G.
Statistical shape model-based 2D/3D and 3D/3D reconstruction for computer navigation
Statistical Shape Modeling workshop during CAOS 2009, Boston, USA

Zheng, G.
Guidance in orthopaedic surgery
Tutorial on Image-guided Interventions: Technology and Applications during MICCAI 2009, London, United Kingdom

Publications - Journal Papers

Bardyn, T., Gédet, P., Hallermann, W., Büchler, P.
Quantifying the influence of bone density and thickness on resonance frequency analysis: An in vitro study in biomechanical test materials
The International Journal of Oral & Maxillofacial Implants, 24 (6), pp. 1006–1014

Chegini, S., Beck, M., Ferguson, S.J.
The effects of impingement and dysplasia on stress distributions in the hip joint during sitting and walking: A finite element analysis
Journal of Orthopaedic Research, 27:195-201

Dong, X., Zheng, G.
Automatic extraction of proximal femur contours from calibrated x-ray images: A Bayesian inference approach
International Journal of Functional Informatics and Personalised Medicine, 2(2):231 – 240

Dong, X., Zheng, G.
Matching parameterized shapes by nonparameteric belief propagation
International Journal of Pattern Recognition and Artificial Intelligence, 23(2):209 – 246

Dong, X., Zheng, G.
Automatic extraction of proximal femur contours from calibrated X-ray images using 3D statistical models: An in vitro study
International Journal of Medical Robotics and Computer Assisted Surgery, 5(2): 213 – 222

Gédet, P., Haschtmann, D., Thistlethwaite, P.A., Ferguson, S.J.
Comparative biomechanical investigation of a modular dynamic lumbar stabilization system and the Dynesys system
European Spine Journal, 18:1504-11

Hediger, K.U., Ferguson, S.J., Gédet, P., Busato, A., Forterre, F., Isler, S., Barmettler, R. Lang, J.
Biomechanical analysis of torsion and shear forces in lumbar and lumbosacral spine segments of nonchondro-dystrophic dogs
Veterinary Surgery, 38:874-80

Hofstetter, M., Gédet, P., Dhoerr, M., Ferguson, S.J., Forterre, F.
Biomechanical analysis of the three-dimensional motion pattern of the canine cervical spine segment C4-C5
Veterinary Surgery, 38:49–58

Hulme, P.A., Boyd, S.K., Heini, P.F., Ferguson, S.J.
Differences in endplate deformation of the adjacent and augmented vertebra following cement augmentation
European Spine Journal, 18:614-23

Jünger, S., Gantenbein, B., Lezuo, P., Ferguson, S.J., Ito, K.
Effect of limited nutrition on in situ intervertebral disc cells under simulated physiological loading
Spine, 34:1264-71

Kozic, N., Weber, S., González -Ballester, M.A., Abdo, G., Rüfenacht, D.A., Ferguson, S.J., Reyes, M.
Automated cement segmentation in vertebroplasty using level sets
Journal of Computer Aided Surgery

Larrea, X., Büchler, P.
A transient diffusion model of the cornea for the assessment of oxygen diffusivity and consumption
Investigative Ophthalmology & Visual Science, 50(3), pp. 1076-1080

Steppacher, S.D., Tannast, M., Zheng, G., Zheng, X., Kowal, J., Anderson, S.E., Siebenrock, K.A., Murphy, S.B.
Validation of a new method for determination of cup orientation in THA
Journal of Orthopaedic Research, 12:1583-1588

Thoranaghatte, R.U., Garcia, J., Caversaccio, M., Widmer, D., González-Ballester, M.A., Nolte, L.-P., Zheng, G.
Landmark-based augmented reality system for paranasal and transnasal endoscopic surgeries
International Journal of Medical Robotics and Computer Assisted Surgery, 5:415-422, 2009

Zheng, G., Gollmer, S., Schumann, S., Dong, X., Feikas, T., González-Ballester, M.A.
A 2D/3D correspondence building method for reconstruction of a patient-specific 3D bone surface model using point distribution models and calibrated X-ray images
Medical Image Analysis, 13:883 - 899

Zheng, G., Zhang, X., Steppacher, S.D., Murphy, S.B., Siebenrock, K.A., Tannast, M.
HipMatch: An object-oriented cross-platform program for accurate determination of cup orientation using 2D-3D registration of single standard X-ray radiograph and a CT volume
Computer Methods and Programs in Biomedicine, 95(3), 236 – 248

Zheng, G., Zhang, X.
Robust automatic detection and removal of fiducial projections in fluoroscopy images: An integral solution
Medical Engineering & Physics, 31(5): 571 – 580

Zheng, G., Schumann, S.
3D reconstruction of a patient-specific surface model of the proximal femur from calibrated X-ray radiographs: A validation study
Medical Physics, 36(4): 1155 – 1166

Zheng, G., Zhang, X.
A novel parameter decomposition based optimization approach for automatic pose estimation of distal locking holes from single calibrated fluoroscopic image
Pattern Recognition Letters, 30(9), 838 – 847

Publications - Conference Papers

Bardyn, T., Reyes, M., Boyd, S., Büchler, P.
Influence of smoothing on voxel-based mesh accuracy in micro finite-element
MICCAI Workshop - Computational Biomechanics for Medicine IV. London, UK, p. 78-86, Sept. 20-24

Blanc, R., Reyes, M., Seiler, C., Székely, G.
Conditional variability of statistical shape models based on surrogate variables In Medical Image Computing and Computer-Assisted Intervention
MICCAI 2009, London, U.K, in press. 2009

Ecker, T.M., Puls, M., Tannast, M., Steppacher, S.D., Weber, S., Siebenrock, K.A., Kowal, J.H.
Diagnosis of femoroacetabular impingement based on the equidistant hip joint simulation strategy
Davies BL, Joskowicz L, Murphy SB (eds): Computer Assisted Orthopaedic Surgery. Berlin, Deutschland, ProBusiness: 2009, pp. 439-443

Ecker, T.M., Puls, M., Steppacher, S.D., Weber, S., Tannast, M., Siebenrock, K.A., Kowal, J.H.
Automated detection of the acetabular rim - a novel and accurate method
Davies BL, Joskowicz L, Murphy SB (eds): Computer Assisted Orthopaedic Surgery. Berlin, Deutschland, ProBusiness: 2009, pp. 335-338

Juenger, S., Gantenbein-Ritter, B., Lezuo, P., Ferguson, S.J., Alini, M., Ito, K.
The combined effects of high frequency loading and limited nutrition on intervertebral discs
Proceedings of the 55th Annual Meeting of the Orthopaedic Research Society, Las Vegas, NV, USA

Kozic, N., Buechler, P., González-Ballester, M.A., Reimers, N., Nolte, L.-P., Reyes, M.
Population-specific evaluation of implant bone fitting using PCA shape space and level sets
6th International IEEE ISBI Conference, Boston, Massachusetts, USA

Publications - Conference Papers

Puls, M., Ecker, T.M., Steppacher, S.D., Weber, S., Siebenrock, K.A., Kowal, J.H., Tannast, M.
Accuracy and reliability of computer-assisted osteochondroplasty of the femoral head-neck junction
Davies BL, Joskowicz L, Murphy SB (eds): Computer Assisted Orthopaedic Surgery. Berlin, Deutschland, ProBusiness: 2009, pp. 199-202

Puls, M., Ecker, T.M., Steppacher, S.D., Murphy, S.B., Kowal, J.H., Siebenrock, K.A., Tannast, M.
Prediction of impingement-free range of motion in Legg-Calve-Perthes disease – an experimental pilot study
Davies BL, Joskowicz L, Murphy SB (eds): Computer Assisted Orthopaedic Surgery. Berlin, Deutschland, ProBusiness: 2009, pp. 323-325

Reyes, M., González-Ballester, M.A., Li, Z., Kozic, N., Chin, S., Summers, R.M., Linguraru, M.G.
Anatomical variability of organs via principal factor analysis from the construction of an abdominal probabilistic atlas
6th International IEEE ISBI Conference, Boston, Massachusetts, USA

Salzmann, J., Zheng, G., Gerber, N., Stieger, C., Arnold, A., Rohrer, U., Nolte, L.-P., Caversaccio, M., Weber, S.
Development of a miniature robot for hearing aid implantation
Proceedings of 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2009)

Schmidt, W., Reyes, M., Fischer, F., Geesink, R., Nolte, L.-P., Racanelli, J., Reimers, N.
Quantifying human knee anthropometric differences between ethnic groups and gender using shape analysis
Annual Meeting of the American Society of Biomechanics, Penn State University, USA

Schumann, S., Weber, S., Nolte, L.-P., Zheng, G.
Statistical shape model based anterior pelvic plane determination: A feasibility study
Proceedings of the 9th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery (CAOS 2009), Boston, MA, USA

Steppacher, S.D., Tannast, M., Zheng, G., Zhang, X., Kowal, J., Anderson, S.E., Siebenrock, K.A., Murphy, S.B.
Validation of a new method for determination of cup orientation in total hip arthroplasty
Proceedings of The Annual Meeting of the Swiss Society of Orthopedy and Traumatology, Geneva, Switzerland, June 24 – 26, 2009, Swiss Medical Weekly, 139(23-24):34S, 2009

Steppacher, S.D., Tannast, M., Zheng, G., Zhang, X., Kowal, J., Siebenrock, K.A., Murphy, S.B.
Accuracy of CT-based computer navigated total hip arthroplasty
Proceedings of The Annual Meeting of the Swiss Society of Orthopedy and Traumatology, Geneva, Switzerland, June 24 – 26, 2009, Swiss Medical Weekly, 139(23-24):44S

Steppacher, S.D., Tannast, M., Zheng, G., Zhang, X., Kowal, J., Murphy, S.B.
Accuracy and reliability of measuring acetabular component orientation using 2D-3D matching technique
Proceedings of the 55th Annual Meeting of the Orthopaedic Research Society (ORS), Las Vegas, Nevada, USA

Tannast, M., Kakaty, D.K., Steppacher, S.D., Zheng, G., Siebenrock, K.A.
What is a normal acetabulum?
Proceedings of the 55th Annual Meeting of the Orthopaedic Research Society (ORS), Las Vegas, Nevada, USA

Steppacher, S.D., Tannast, M., Zheng, G., Zhang, X., Kowal, J., Anderson, S.E., Siebenrock, K.A., Murphy, S.B.
Validation of a new method for determination of cup orientation using 2D/3D matching
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Steppacher, S.D., Tannast, M., Kowal, J., Zheng, G., Siebenrock, K.A., Murphy, S.B.
Accuracy of CT-based computer navigated total hip arthroplasty
Proceedings of the 9th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery (CAOS 2009), Boston, MA, USA

Tannast, M., Kakaty, D.K., Steppacher, S.D., Werlen, S., Zheng, G., Siebenrock, K.A.
Gender-dependent discrepancies in femoroacetabular impingement
Proceedings of the 55th Annual Meeting of the Orthopaedic Research Society (ORS), Las Vegas, Nevada, USA

Tannast, M., Kakaty, D.K, Zheng, G., Siebenrock, K.A.
What is a normal acetabulum? A computer-assisted radiographic study
Proceedings of the 9th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery (CAOS 2009), Boston, MA, USA

Welz, P., Ito, K., Ferguson, S.J.
Solute transport characteristics in intervertebral disc tissue with and without the application of an electrical field
Proceedings of the 55th Annual Meeting of the Orthopaedic Research Society, Las Vegas, NV, USA

Zheng, G.
Statistically deformable 2D/3D registration for accurate determination of post-operative cup orientation from single standard x-ray radiograph
Proceedings of the 12th International Conference on Medical Image Computing and Computer Assisted Interventions (MICCAI 2009), Part I, LNCS 5761, Springer, pp. 820 – 827

Zheng, G.
Statistical deformable model-based reconstruction of a patient-specific surface model from single standard x-ray radiograph
Proceedings of the 13th International Conference on Computer Analysis of Images and Patterns (CAIP 2009), LNCS 5720, Springer, pp. 672 – 679

Zheng, G., Schumann, S.
A system for 3-D reconstruction of a patient-specific surface model from calibrated X-ray images
Proceedings of Medicine Meets Virtual Reality 17 (MMVR 2009): NextMed: Design for the Well Being, Long Beach, CA, USA

Zheng, G., Echeverri, S., Dong, X., Vallotton, J., Nolte, L.-P., Weber, S.
A novel patient-specific, gravity-assisted navigation sytem for acetabular cup placement
Proceedings of the 9th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery (CAOS 2009), Boston, MA, USA

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