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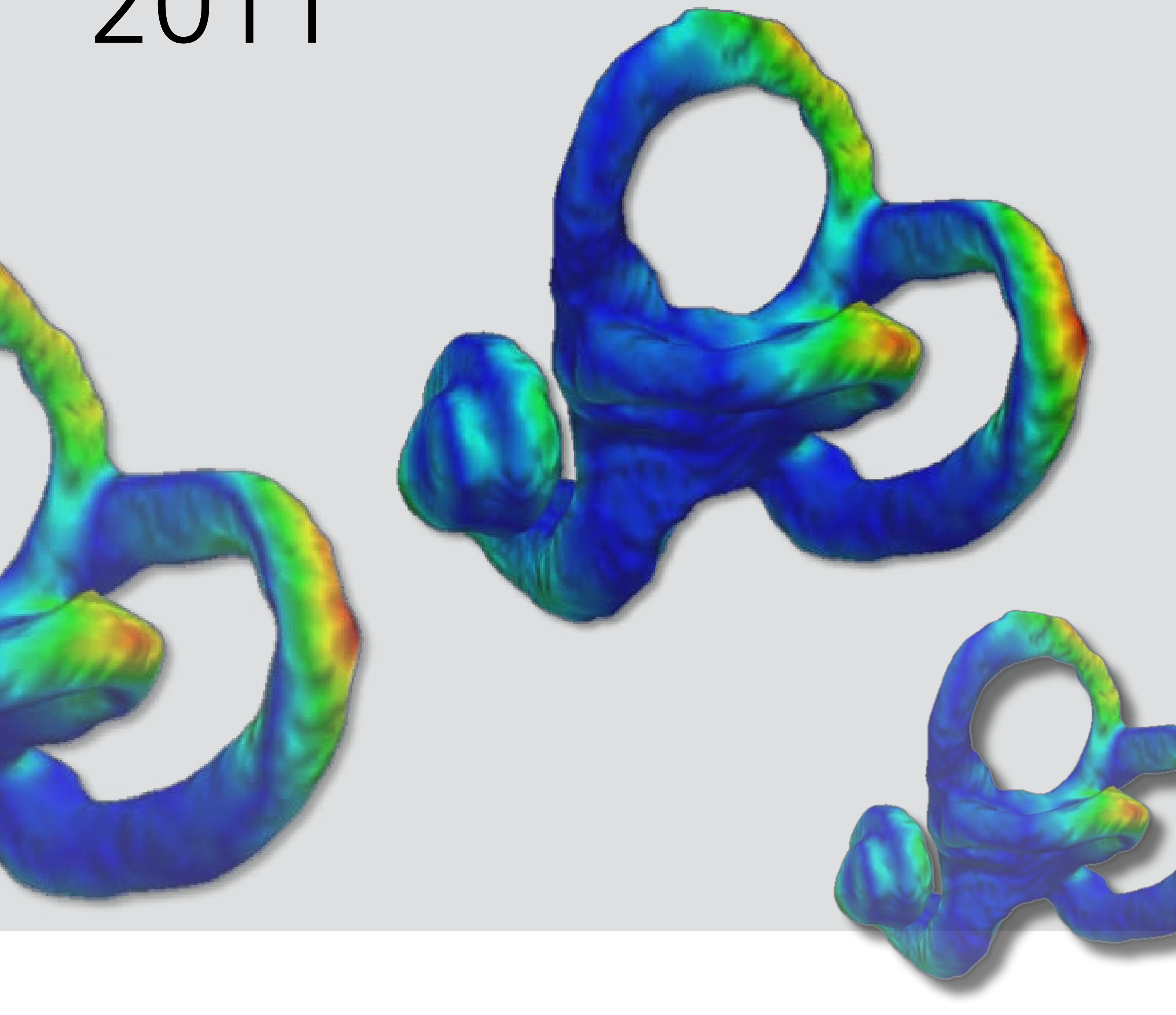
Annual Report 2011



Institute for Surgical Technology & Biomechanics

Contents

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Introduction

2011 in Retrospect

For the research groups of the Institute for Surgical Technology and Biomechanics (ISTB), 2011 was a year of continuous consolidation. Our institute comprises a multidisciplinary team of about 60 co-workers. It 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. Through participation in national and international research network programs, we have been able to continue research activities in all of our focus areas.

In July 2011 Stephen Ferguson, head of the Orthopaedic Biomechanics Division and deputy director of the ISTB was appointed full professor at the newly founded Health Science and Technology Department at the ETH in Zurich. Philippe Zysset, former university professor at the Technical University of Vienna was elected as a member of our Medical Faculty and assumed responsibility for our Biomechanics Division and as the deputy director in October 2011.

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 eleventh year since its inauguration in 2001. We were proud to have our research and development efforts recognized by several awards, including the nomination of our start-up company CAScination for the Swiss Technology Award. Close collaboration with both our recent start-ups, Crisalix and CAScination provides our laboratory direct access to highly advanced marked platforms for image guided therapy. Key collaborative projects with the Swiss MedTech industry continue to be developed through funding from KTI / CTI, which is the Confederation's innovation promotion agency.

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 2011), the Advanced Training High-Tech Course for Paranasal Sinus and Skull Base Surgery (PSSB 2011), the seventh Otological Microsurgery Course with Emphasis on Minimally Invasive Techniques (OMMIT 2011), the annual meeting of the Swiss Society for Biomedical Engineering (SSBE 2011) and the 2011 Biomedical Engineering Day.

In 2011 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) continues to attract students nationally and internationally, the 6th class recently starting with 43 new students. Currently, more than 150 students are enrolled in the program to become specialists in biomedical engineering. In addition, about 40 students from the ISTB and the ARTORG Center are currently enrolled in the interdisciplinary biomedical science doctoral program (www.gcb.unibe.ch).

Lutz P. Nolte
Director

Organisation

Institute for Surgical Technology & Biomechanics

Management

L. P. Nolte
Director

Central Services

K. Fahnemann-Nolte
Administration

H. Studer
IT-Support

A. Neuenschwander
Administration

H. Lu
IT-Support

B. Schmitter
Administration

Division of Biomechanics

Orthopaedic Biomechanics
S. Ferguson
Division Head (Jan - Sep)

Orthopaedic Biomechanics
Ph. Zysset
Division Head (Oct - Dec)

Computational Bioengineering
P. Büchler

Tissue Mechanobiology
B. Gantenbein

Division of Surgical Technologies

Smart Device Technology
S. Weber
Division Head

Computer Assisted Orthopaedic Surgery
G. Zheng

Medical Image Analysis
M. Reyes

Master Biomedical Engineering

U. Jakob
Study Coordinator

Mechanical Design and Production

U. Rohrer

The ISTB conducts basic and applied research for the prevention and treatment of disease, working from the cell level to the whole locomotor system. The focus is on developing solutions that address particular clinical problems or unmet clinical needs. Currently, the institute focuses on two areas defined by its two primary divisions. The efforts of the Division of Surgical Technology are directed towards the development of surgical 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 focus of the Biomechanics Division is the application of mechanical principles to biological systems, with an emphasis on the musculoskeletal system. In order to improve current diagnostic and treatment methods, a combination of experimental and computational studies is applied. The ISTB brings together scientists from different areas of biomedical research and actively collaborates with other research and development groups nationally and internationally. Through our Center for Competence in Medical Technology, knowledge and technology transfer is promoted by involving partners from the medical technology industry.

Tissue Mechanobiology

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Group Members

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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.

In 2011, we have further consolidated our efforts in the Spine Research Center (SRC). The SRC is a joint program of 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 complimentary biological research to our traditional biomechanics program. Details of related spinal research at the ARTORG Spine Research Center (SRC) can be found in the center's annual report (http://www.artorg.unibe.ch).

Current Research Areas

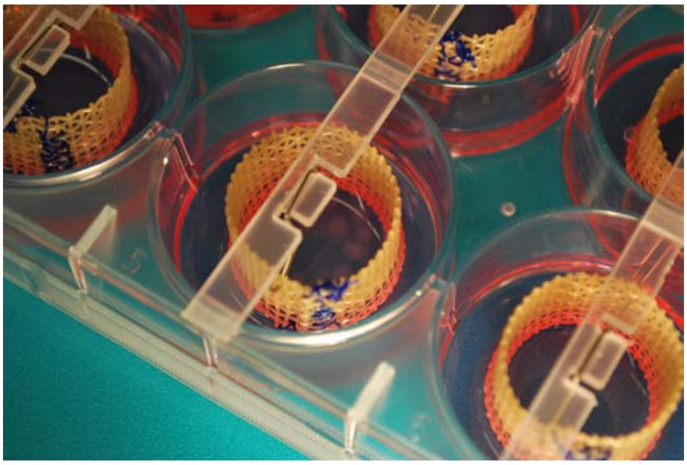
Understanding Complex Loading of Intervertebral Discs

In this project, which is supported by the Swiss National Science Foundation (SNF) for three years (2010-13) we test the influence of uniaxial compression and torsion on the intervertebral disc. It is a fact that low back pain caused from acute disc herniations affects mainly people between 25-60 years. These incidents are not only very painful but represent the highest potential cost for society. In this project, we try to address the importance of complex, so called "twisting" movements onto the disc tissue homeostasis. The concept and design of a two-degree of freedom bioreactor is unique and our group was the first to report about this technology. We also investigated culture technique using short-term, repetitive, biaxial loading, where we have shown both potentially beneficial and detrimental effects of complex loading, depending on magnitude. The tissue mechano-biology group is currently investigating complex loading patterns to highlight the mechanical causes of disc herniation and the challenging environment for treatment of this problem. Conclusions from this project will have implications for physiological and hyper-physiological mechanical loading parameters for the IVD and for future proof-testing of e.g. nucleus replacement or annulus repair implants.

Two-degree of freedom loading device to culture bovine intervertebral discs under uni-axial compression and torsion. The device has been designed to be removed easily from the incubator unit and the entire set-up can be either force or way-controlled. A real-time processor unit is located outside of the incubator which is recording data and controlling the device.

Direct Electrical Stimulation of Disc Cells

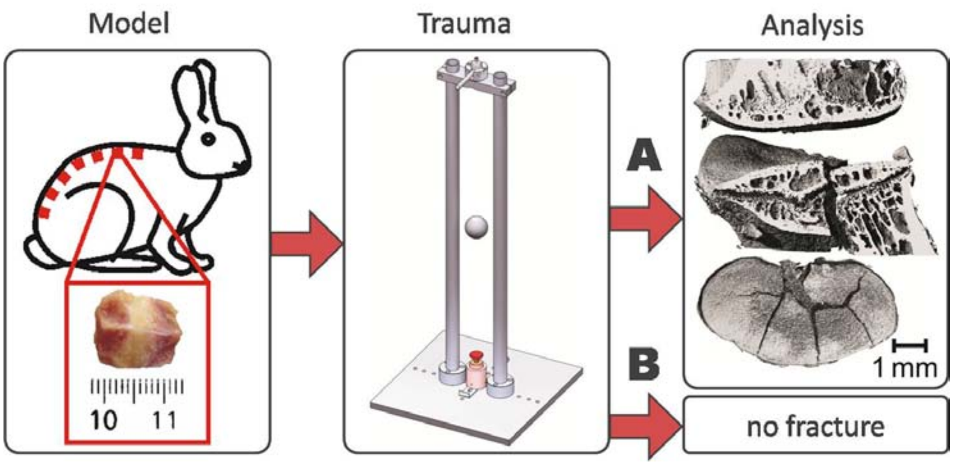
In the context of our program to investigate the mechanisms of solute transport in the disc, we have previously investigated the application of electrical fields to disc tissue, as a means to enhance solute transport via electro-osmosis or to enhance tissue permeability via electro-poration. However, 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). In our previous monolayer studies with nucleus pulposus cells, we have identified viable ranges for electrical stimulation, using DC current or bipolar pulses. In a follow-up study, we have investigated the response of nucleus pulposus cells embedded in a 3D culture system to electrical stimulation. The use of a 3D culture system approximates the native extracellular matrix. A comprehensive series of trials was completed evaluating a broad range of electrical field strengths, current densities, pulse characteristics and stimulation duration. Evaluation of cell response was conducted with biochemical and molecular biological assays. The final goal is to explore the potential of local in situ electrical field application to the whole disc organ, as a means to maintain or restore disc matrix integrity and thus provide an avenue for a minimally invasive therapeutic approach for the treatment of DDD.



Setup for the electrical stimulation of bovine nucleus pulposus cells in 3D alginate cultures. Currents are delivered via carbon electrodes to the cultures. The alginate beads are kept in specially designed inserts polyetheretherketone (PEEK).

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 (Figure 3). The cellular response to intervertebral disc trauma is characterized by a strong up-regulation of pro-inflammatory cytokines (IL-6, TNF-α) and chemokines (MCP-1, IL-8). These agents are the hallmark of acute inflammation and stand at the beginning of a sequence of actions that lead to wound healing. Once putative polymorphonuclear cells (PMN) are attracted to the site of injury, they release their granules as a consequence of surface receptor activation. Upon trauma of the intervertebral disc, many PMN activators (fragments of collagen and hyaluronic acid, heparin sulfate, ATP, HMGB1, HSP, chromosomal DNA) are generated or released from disc cells. They are known as damage associated molecular patterns (DAMPs) and initiate a sterile inflammatory process. Endplate fractures facilitate the contact of disc material with PMNs and their activation. The implication of PMN in post-traumatic intervertebral disc degeneration was never investigated. Therefore, we hypothesized that trauma of the intervertebral disc and adjacent endplate trigger PMN recruitment and activation. Preliminary data from our organ culture model showed synthesis of pro-inflammatory cytokines (IL-1, TNF-α) and chemokines (IL-6) by NP cells when co-cultured with disc fragments. However, histological evaluation did not show PMN engraftment in central regions of the organ, although some enrichment of PMNs may be seen in the outer AF and easily accessible regions of the fractured endplate.



Experimental outline to induce and analyse energetic impact onto rabbit intervertebral discs in an organ culture model.

Orthopaedic Biomechanics

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Andrew Speirs (Visiting Scientist) | Andreas Treuholz | Jochen Walser | René Widmer | Uwe Wolfram

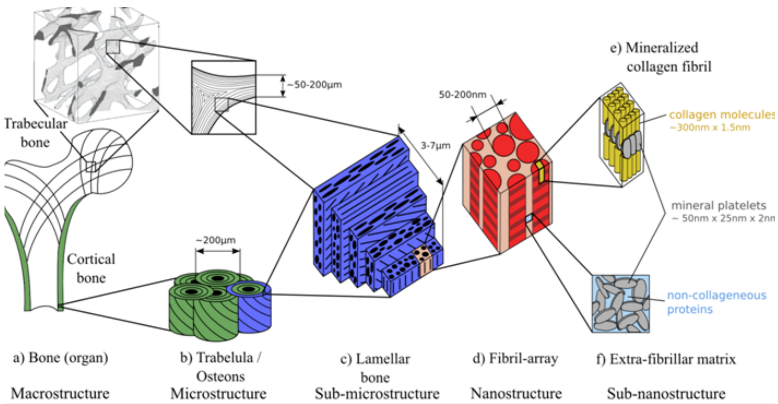
Research Profile

The Orthopaedic Biomechanics Group experienced a time of transition with the departure of Stephen Ferguson (SF) for the ETH in Zürich and the arrival of Philippe Zysset (PhZ) from the Technical University in Vienna. Nevertheless, the transition was smooth as applied research in the spine and the services for biomechanical testing are maintained.

The interdisciplinary research group of Stephen Ferguson focuses on the development of technologies that provide an insight into joint and tissue biomechanics, and movement and loading patterns, in order to understand musculoskeletal disease processes and to work towards new treatments. This knowledge is applied in the development of conventional and biological implants, passive and bioactive biomaterials, the improvement of implant anchorage, surgical techniques and rehabilitation programs for aged patients. The research program combines biology and engineering, with a strong translational component to transform research findings into clinical applications that can be tested in vitro and in vivo.

The research group of Philippe Zysset started in the fall and focuses on multi-scale structure-function relationships of bone tissue from the extracellular matrix to the organ level. A combined theoretical, experimental, and numerical approach is pursued to model, validate and simulate the mechanical behavior of human bone in the course of growth, aging, disease and treatment.The interests range from elucidation of lamellar bone theory up to failure mechanisms of the proximal femur. Clinical studies are pursued in collaboration with the pharmaceutical industry to evaluate the efficacy of anti-resorptive or anabolic treatment for osteoporosis using follow-up finite element analyses.

Both research groups are involved in the European Marie Curie Integrated Training Network "SpineFX", whose goal is to train highly skilled researchers capable of delivering effective solutions to spinal disease and trauma in public and private sectors.

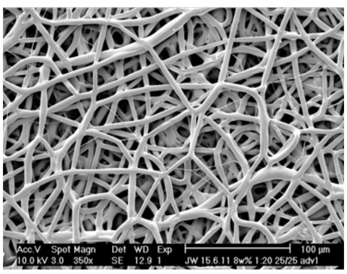


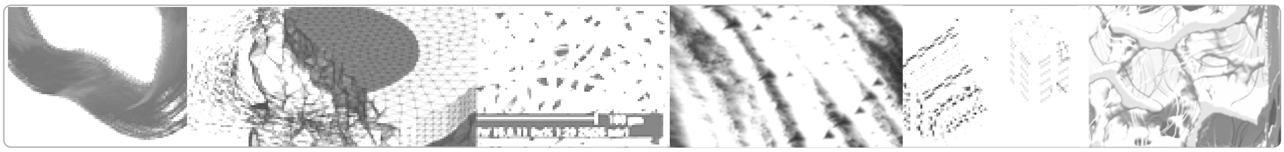
Hierarchical organization of bone tissue (from Reisinger, PhD thesis 2011).

Current Research Areas

Patient-Specific Scaffolds for Tissue-Engineered Cartilage in ORL Surgery (SF)

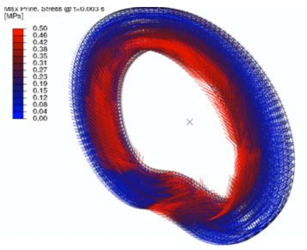
Cartilage reconstruction in the field of Oto-Rhino-Laryngology (ORL) represents an area of strong demand for viable tissue, which is not met by autologous transplantation. Tissue engineering for the creation of new grafts would appear a promising direction. Following our previous work on near-net-shape casting of tissue engineering scaffolds from cell-seedable gels, we turned out attention to the use of electrospinning technology for the production of micro-fibrous membranous and tubular scaffolds. Through careful optimization of the process parameters, we have shown that it is possible to produce porous scaffolds with a high degree of fibre orientation, mimicking the natural structure of the tissue. Furthermore, we have been able to produce scaffolds with a biphasic structure, exhibiting a high degree of orientation and porosity on one side, yet with a dense, mesh-like structure on the opposite. Through the use of heterogeneous structural cues, it is our goal to control the local cell response.





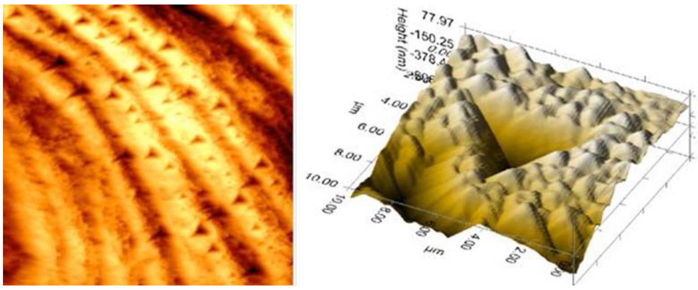
Intervertebral Disc Dynamic Response (SF)

Cartilage reconstruction in the field of Oto-Rhino-Laryngology (ORL) represents an area of strong demand for viable tissue in which our group has previously demonstrated a direct link between spinal trauma (impact) and disc degeneration. In this work, we focus on potential mechanisms of post-trauma disc degeneration by exploring the mechanisms of mechanical energy transfer through the disc structure. The dynamic behavior of the disc has been characterised through computational techniques with the development of an anisotropic, non-linear finite-element model of the fibre-reinforced structure. With this model, we were able to demonstrate the propagation and internal reflection of pressure waves through the disc, the influence of osmotic swelling on the impact response and also a unique structural damping response related to the fiber configuration.



Bone plasticity and damage (PhZ)

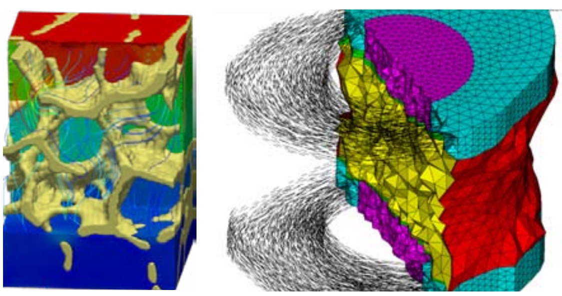
Motivated by the implications of metabolic bone diseases such as osteoporosis on bone fragility, this research investigates the material properties of bone extracellular matrix (ECM). The experimental method of indentation at the micrometer or nanometer scale represents a powerful method to quantify these material properties with a high spatial resolution and in various directions to account for lamellar organization. Nevertheless, the deformation of the tip in the material is very high and requires large strain continuum damage mechanics for proper interpretation. A phenomenological constitutive model for bone ECM including the viscous flow of plastic strain and the simultaneous degradation of elastic modulus is therefore, developed and tested with a virtual indentation analysis. Completed with adequate material and especially viscosity parameters, this model is likely to become the next standard for the numerical simulation of human bones using the finite element method.



Nano-indentation in bone extracellular matrix with multiple imprints in dark and bright sub-lamellae (left). Single imprint in mineralized turkey leg tendon visualized by atomic force microscopy (right).

Vertebral fractures (VPHOP & SpineFX, SF & PhZ)

Within the European Union VPHOP project, we have continued our work on the development of patient-specific computer planning tools for interventional treatment with biomaterial augmentation. Simulations have been developed for the complex flow of viscous biomaterials through porous bone and for the microscale interaction of biocements and bone. Work this year was concentrated on the full characterization of a micro-scale model of bone permeability, based on a subset of bone micro-architectural properties, which can be derived from clinical imaging methods. Our previously developed regression model of permeability was validated against microCT-based flow simulations and shown to account for over 90% of the subject-specific variability in permeability. This year we have also refined our microscale model of bone / cement interaction, validating our previous hypotheses about material-specific adhesion between the bone and biomaterial. Based on the solution of a high number of complex, microCT-based simulations of bone-cement composites, we have assembled a complete description of the pre- and post-failure mechanical response of augmented bone. Within the SpineFX project our aim was to improve our understanding of vertebral load transfer and quasi-static failure. For this purpose, state of the art continuum, anisotropic and non-linear constitutive models of the bone and the intervertebral disk were implemented in a commercial finite element code. On the bone side, the model was designed to undergo very large strains and was shown to predict quantitatively the post-yield stress and the energy dissipation of vertebral sections subjected to 80% compressive nominal strain. On the disc side, the model allowed the evaluation of the influence of boundary conditions on the ultimate load of human lumbar vertebrae. The developed tools will become available for clinical applications pursued by other researchers of the network.



A mesh of a human lumbar vertebral body with cortical shell (red), homogenized trabecular bone (yellow) and idealized intervertebral disks including the hydrated nucleus pulposus (violet) and the annulus fibrosus (cyan) with its characteristic circumferential fibers.

Computational Bioengineering

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Group Members

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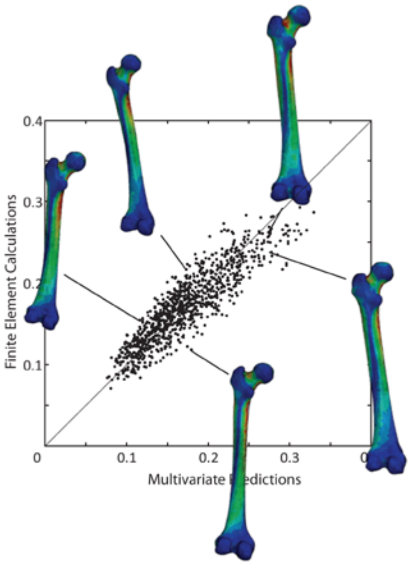
Research Profile

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 that are commonly used to evaluate the mechanical performance of the bone or the load transfer from the implant to the bone. However, most studies don't account for the large variability in bone shape and mechanical properties existing in the population. The objective of this project is to develop methods to integrate bone mechanical information in statistical shape models. Material properties are obtained from the image grey levels, which enables one to build a statistical stiffness model of the bone. Based on this information the mechanical performance of the bone can be predicted with numerical tools such as the finite element method. The goal is to use the generated models to gain a better understanding of the relationship between bone shape and mechanical properties, to propose population-based implant designs or to calculate the patient-specific mechanical response of the bone.

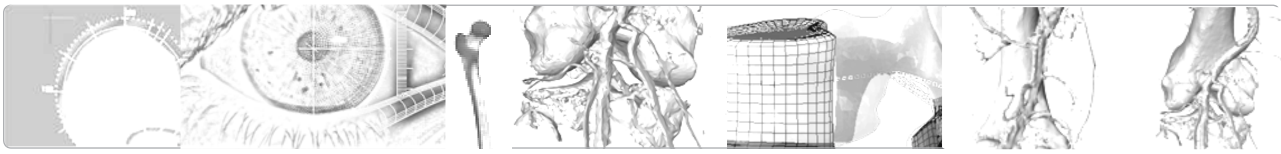


Statistcal shape models of bone shape and intensity are use to evaluate bone fracture risks and compare different populations.

Biomechanics of Refractive Surgery

The cornea provides over 60% of the refractive power of the human eye. An ideal refractive shape is an axis-symmetric surface with an elliptical profile, but real corneas show various degrees of optical aberrations. A wide range of ophthalmic surgical procedures alter corneal biomechanics to induce local or global curvature changes for the correction of visual acuity. However, the current surgical approach to define incision parameters rely on statistical information and is unable to accurately predict patient-specific surgical outcome.

A software tool called OptimEyes has been developed for the surgical planning of refractive surgeries based on patient-specific biomechanical simulations.



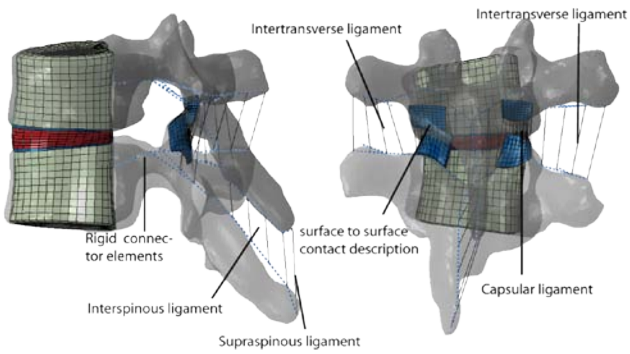
To improve the current clinical situation, realistic models of the biomechanics and optics of human corneas are needed. Our first challenge was to propose a constitutive model of the tissue able to take the stromal microstructure into consideration. Based on this mechanical model, we developed tools to generate patient-specific models of the cornea. A clinical study on cataract surgery has been performed to validate the numerical predictions. The geometries of the patient's corneas were assessed pre- and postoperatively with topography devices. Results showed a good agreement between the numerical prediction and clinical measurements, which indicates that the simulations are able to closely predict the specific corneas' biomechancial response.

Biomechanics of the Scoliotic Spine

Adolescent Idiopathic Scoliosis is defined as a lateral curvature of the spine, involving a rotation of the vertebral bodies towards the convexity. Surgical correction is required for severe deformities, which demands careful planning, excellent surgical technique and intra-operative monitoring. Selection of appropriate fusion levels, amongst other considerations, will greatly influence the final goal of establishing a mechanically well-balanced spine in both the coronal and sagittal planes. However, the biomechanics of scoliosis remain poorly understood.

Over the past years, we proposed a method for the intra-operative assessment of the mechanical properties of scoliotic motion segments. These in-vivo measurements were used to solve an inverse problem in order to identify material parameters of the connective tissues, using a finite element model with patient-specific geometry. Numerical simulation is the ideal tool to provide insight into scoliosis evolution and correction, since no valid animal model exists for scoliosis due to the large anatomical and physiological difference between animal and human. Based on the identified mechanical properties, simulation models will be developed and validated to predict scoliosis progression and postoperative outcome.

An accurate description of the biomechanical behavior of the spine is crucial for the understanding of degenerative spine disorders and spinal deformities as well as for the development of new treatment strategies. However, to be used clinically, this information should be available before the surgical intervention. Therefore, we develop a method to determine the mechanical properties of the spine based on pre-operative tests. The main challenge is to design an appropriate measurement technique, which is able to provide the surgeons with an observer independent and reproducible three-dimensional assessment of the spine flexibility, suitable for daily clinical use.

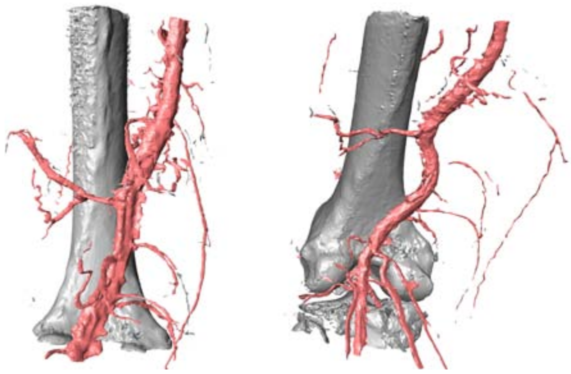


A finite element model of the scoliotic spine is used to identify material parameters of the connective tissues based on intra-operative experimental data.

Superficial Femoral Artery

Endovascular therapy has emerged rapidly as a minimal-invasive treatment option since its first application over three decades ago. Facilitated by technical innovations, endovascular therapy has evolved as the first-line treatment modality for most patients with claudication and critical limb ischemia. However, restenosis remains the major drawback of this method. While the introduction of modern Nitinol stents has lowered the risks, restenosis still occurs in every third patient undergoing stenting. Biomechanical properties of this challenging arterial segment remain poorly understood and are limited to anecdotal experiences.

In this project, the objective is to establish a finite element model capable of simulating different disease patterns and clinical scenarios for patients with peripheral arterial disease. A validated finite element model would allow for a better understanding of the unique biomechanical requirements of the femoropopliteal tract. Moreover, the behavior of the stented artery could be simulated and various technical concepts (different stent lengths, stent positions, stent designs) that can otherwise only be tested in patients could be tested ex vivo thereby hopefully providing precious pre-clinical information.



The deformation of the femoropopliteal artery is quantified based on patient's data acquired at different knee flexion angles.

The Center for Computer Assisted Surgery (ISTB)

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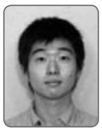
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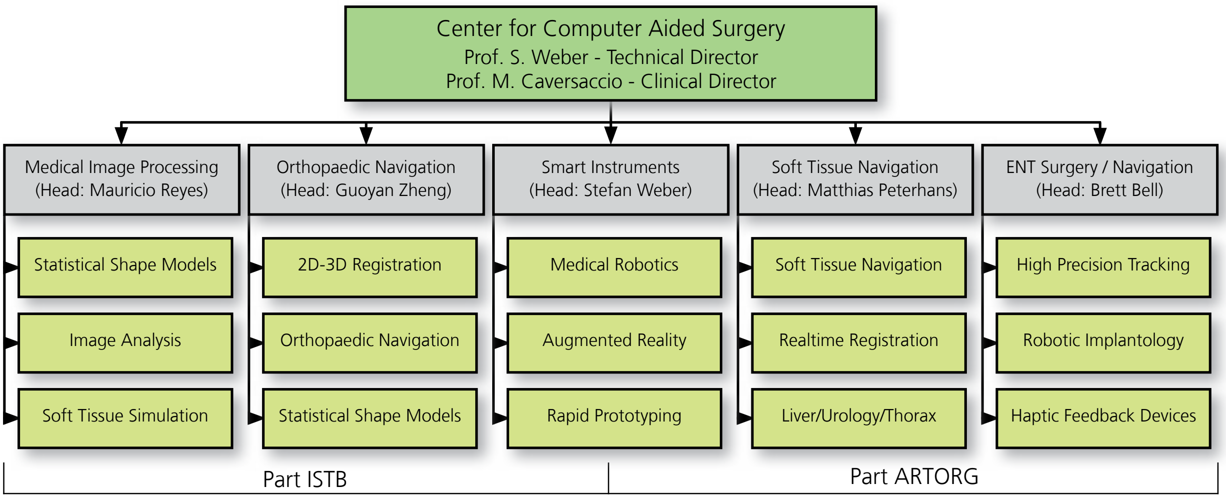
Daphne Wallach


Tom Williamson

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 and Biomechanics (ISTB) and the Inselspital Bern. Its network of engineers and clinicians conduct research and develop novel diagnosis and treatment solutions in the area of computer assisted and image guided interventions. It not only focuses on the technical research aspects but also aims at the advancement of novel technology towards clinical routine through the support and conduction of clinical investigations. CCAS ultimately envisions supporting society and its healthcare systems for the demographic, economic and socio-cultural challenges to come.
The center provides technological and clinical expertise in the areas of computer-assisted and image-guided surgery, diagnosis, medical image processing and smart instruments based on clinical experience and motivation. The bandwidth of its research ranges from fundamental investigation of technological aspects to clinically oriented research and clinical validation through our network of clinicians.
CCAS is composed of five different research groups focusing on different aspects of fundamental and translational research.

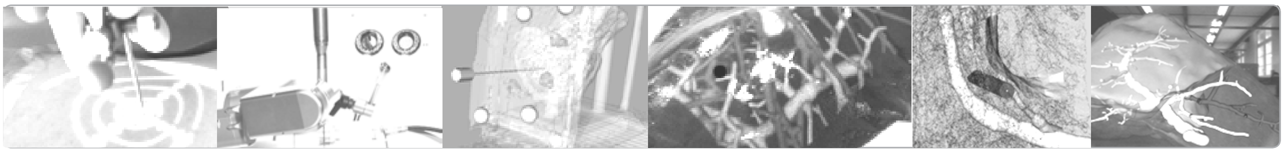


Current Research Areas

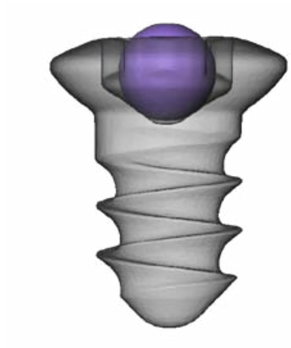
Computer Assisted Microsurgery for ENT applications

Minimally Invasive Surgery In The Ear

Direct cochlear access (DCA) is a minimally invasive implantation technique which allows the surgeon to introduce an electrode into the cochlea through a small tunnel less than 2 mm in diameter. If successful, this procedure may dramatically revolutionize the field by enabling drastically lower comorbidity, shorter hospital stays, and ultimately reduced intervention costs. However,



the DCA is not without its difficulties. Small and narrow passages bordered by risk structures must be safely traversed before the middle ear can be reached; a feat otherwise impossible without the assistance of high accuracy computer aided planning and tool guidance.



Autonomous force controlled registration: ball-in-cone model with 3 mm cranial surgical screw (left) and registration tool over implanted screw fiducial (right).

Robotic Tool Guidance

During the last year, the focus of the robotics project has been the improvement of the overall system accuracy aiming at maximum errors below the 0.5 mm mark. Focus has been placed on three areas which, at present, account for the largest portion of the final error: model based fiducial localization in 3D image data sets, patient-image registration using force based localization, and high accuracy optical tracking/visual servoing.

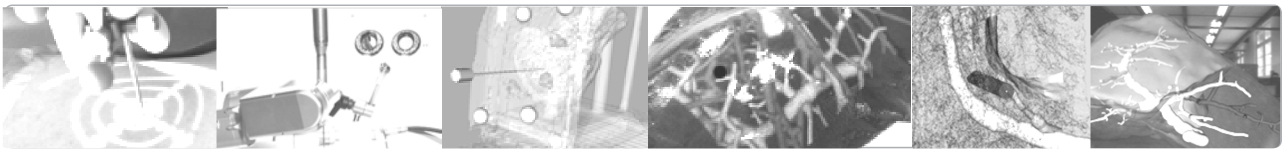
Accurate surgical outcome naturally begins with an accurate surgical plan. An integral component of which is the later spatial referencing of the plan with the actual anatomy. To date, the highest accuracy available is afforded through the use of bone anchored fiducials. The accurate identification of such fiducials in the image data can be a challenge as smaller screws (utilized to reduce the invasiveness) introduce more uncertainty in consequence of the reduced number of image pixels occupied by the screw. Thus, various model based matching algorithms have been investigated to achieve sufficient localization accuracy. Similarly, we have improved the accuracy of fiducial localization by the robot system by abandoning the manual visual alignment method used previously in favor of a force minimization scheme in which the robot automatically finds the fiducial center using a ball in cone principle. This method has allowed the uncertainty of fiducial positions to be reduced to 5-10 µm.

Increased tracking accuracy and robustness motivated the development of LED based trackers. This active approach reduces computation time due to stray reflections and offers a clinically valid solution. This tracking technique has been combined with the robot system and can be used to correct the tool position through a multi-sensor fusion technique. A visual servoing controller has now been implemented to compensate for kinematic errors, deflections of the robotic arm, and patient movement.

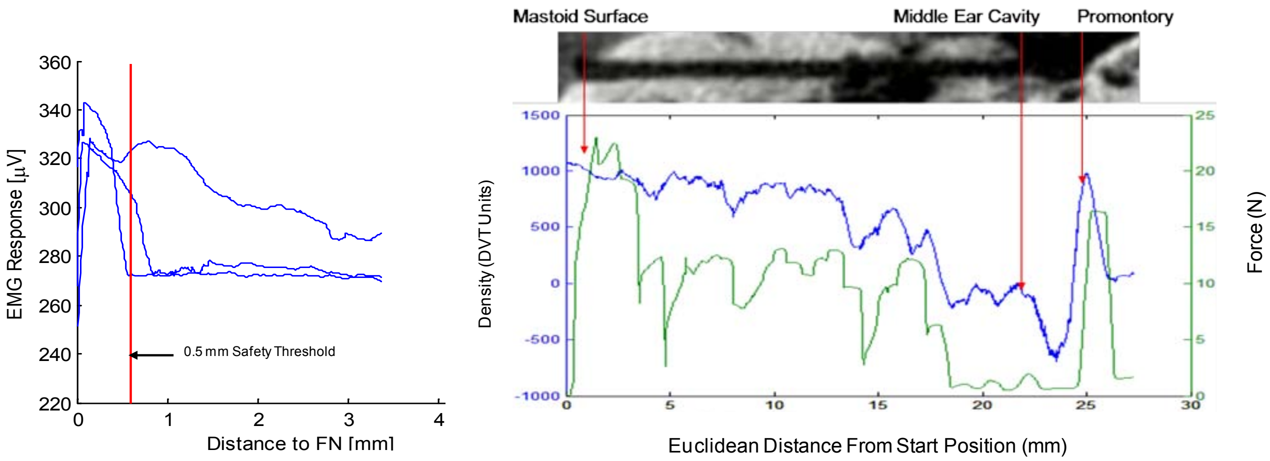
The robot system with high accuracy tracking camera (right) and drill and patient active tracking markers for high accuracy robotic tool guidance (left).

Sensor Fusion Enhancement of Procedure Safety

Although robotic tool guidance can achieve very high accuracies, the procedure still lacks an independent objective measure which can ensure avoidance of the facial nerve. Thus, we are investigating the fusion of measurements from multiple sensors which may ultimately increase the certainty of the drill position measurement relative to the patient anatomy. One such sensor is the facial nerve monitor, which has recently been integrated with surgical drills for real time monitoring of electromyography signals in response to nerve stimulation. Initial tests on phantom nerve models have shown that it may be possible to abort drilling procedures based on this functional parameter.



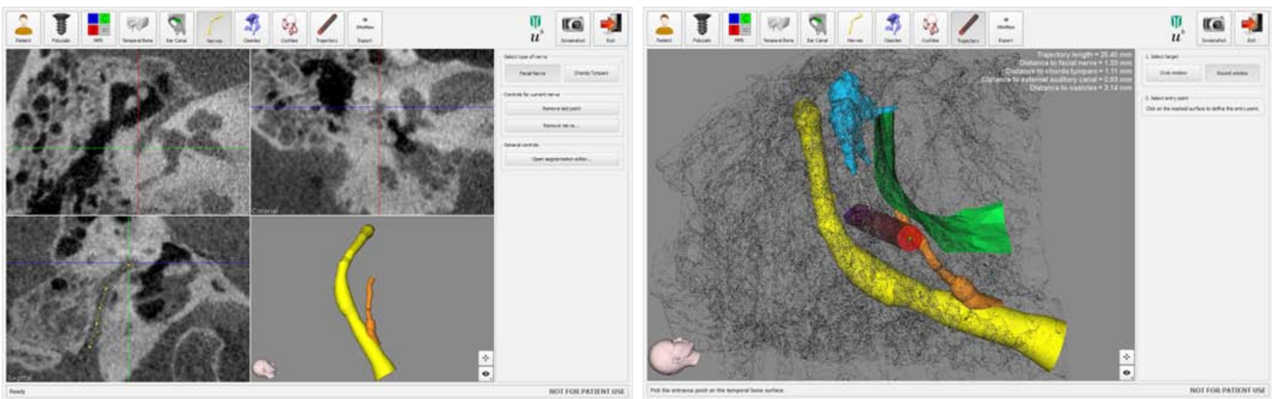
A second source of additional information is derived from the co-registration of image intensity gradients and force-torque data. Here, the objective is to co-register the force profile along the drill trajectory with the corresponding path in the image data.



Methods for ensuring the safety of the system, through the consideration of alternative sensor sources such as physiological nerve response (left) and drilling forces (right), are under consideration.

Planning

Progress on the otological-surgery planning tool OtoPlan has continued with the addition of new functionalities. A surgical plan can be efficiently created by systematically performing procedure optimised tasks. Compared to a fully automatic planning procedure, this methodology allows the user to complete the surgical plan and check the validity against image data simultaneously. Thus, the user can achieve the highest degree of accuracy in an efficient and effective manner.

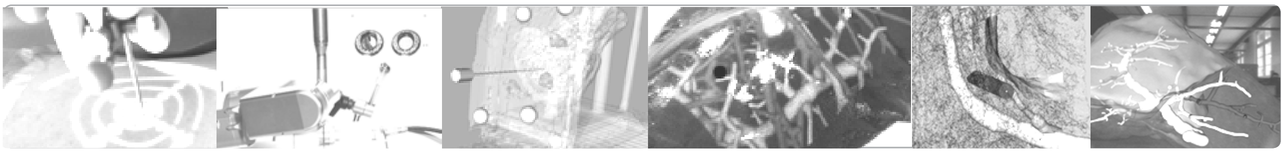


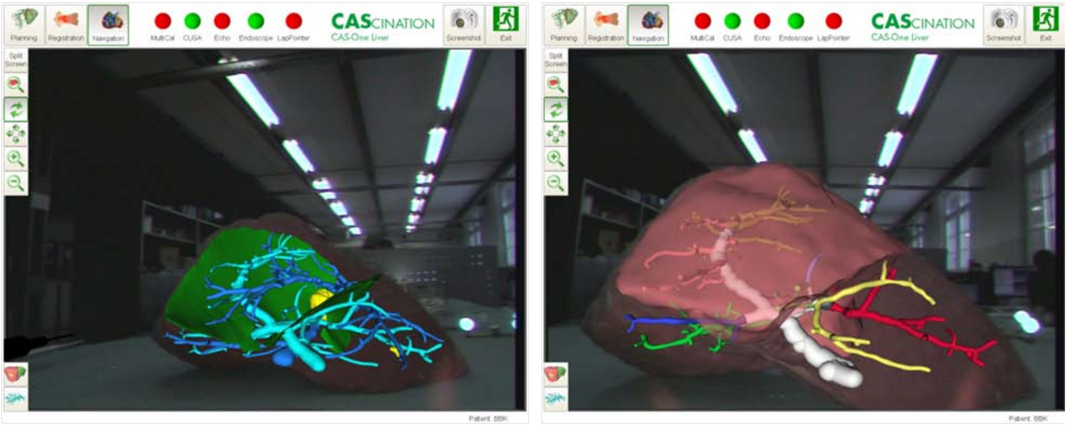
OtoPlan: Preoperative planning software for image guided robotic cochlear access for hearing aid implantation. Facial nerve segmentation (left) and the final plan with drilling trajectory (right).

Soft Tissue Navigation

Computer-Assisted Laparoscopic Surgery

Laparoscopic surgery is performed using miniaturized cameras and instruments which are inserted into the abdomen through small incisions instead of performing open surgery. This minimally invasive treatment technique results in reduced trauma and shorter recovery times but leads to challenges in anatomical orientation as surgeons have to rely solely on video images. We develop an image guidance system for supporting complex operations on the liver with an overlay of surgical planning data from pre-operative scans onto laparoscopic camera images. The existing surgical navigation system for liver surgery was extended for laparoscopic instruments and a camera calibration approach was developed to achieve an overlay of the virtual guidance scenario with the laparoscopic images. Current research addresses tracking of flexible instruments and patient registration in a minimally invasive scenario.

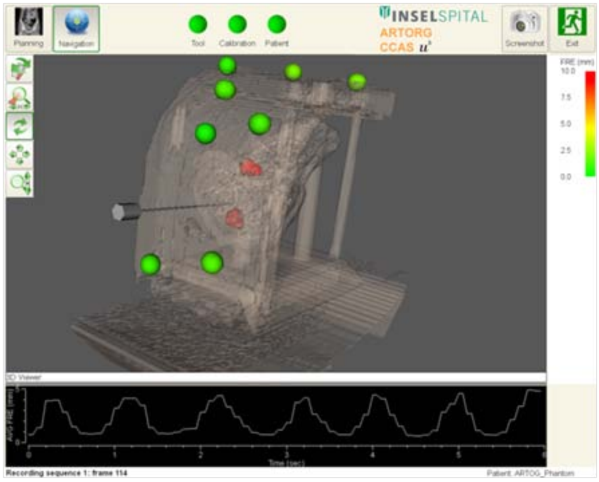




Navigated laparoscopic surgery: Virtual planning data is merged with the laparoscopic camera image.

Image-Guided Percutaneous Ablation Treatments

Percutaneous ablation procedures enable locally confined destruction of tumors. The key factor for successful ablation is accurate placement of the ablation needles in the tumor center. We have developed a surgical navigation solution for ablation treatments performed under computer tomography (CT) guidance. The solution incorporates an ablation planning software and a needle guidance module which accounts for respiratory motion during needle insertion. Besides improving accuracy, image-guided ablation aims to reduce radiation exposure to the patient and the radiologist and enables a larger choice of access paths to tumors which are difficult to reach with conventional ultrasound or CT guided approaches. The proposed system has been tested on animal models and first clinical test are planned for 2012.

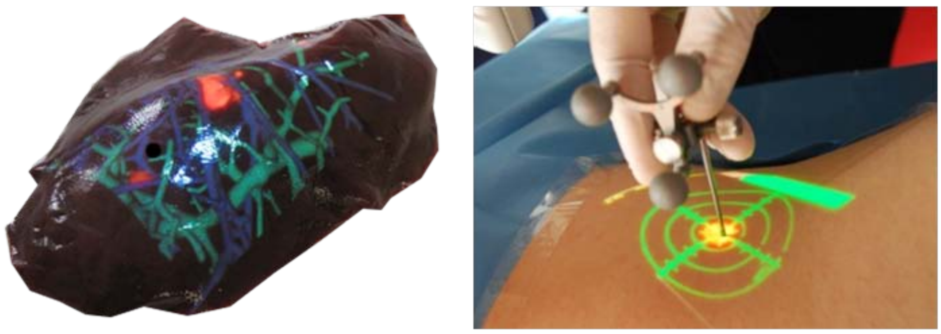


Screenshot of the percutaneous ablation software: Guidance of an ablation needle in the top window, respiratory motion tracking in the bottom window.

Image Overlay for Surgical Guidance

The users of surgical navigation systems face the challenge that the operation situs as well as the navigation screen need to be observed continuously in order to achieve optimal treatments. It is therefore desirable to display relevant navigation information as close as possible to the treatment location.

For this purpose, an image overlay device providing visualization directly on the patient was developed. A miniaturized video beamer is integrated into a navigated and handheld device which can be moved freely around the patient and displays anatomical data as well as tool guidance information directly on the surgical situs. An explorative study on possible application areas indicates usability in a variety of surgical procedures where structures below the organ surface need to be localized precisely.



Exploration of possible application areas for an image overlay device. Projection of internal vascular anatomy and tumors onto the surface for the liver (left) and projection of needle guidance information onto the skin (right).

Medical Image Analysis

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Group Members

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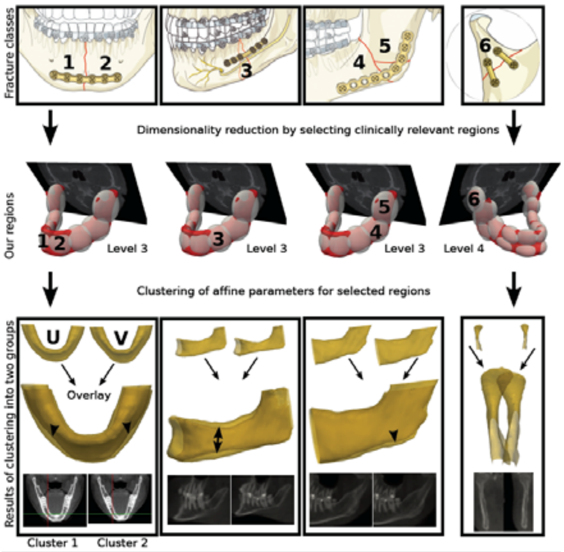
Research Profile

The Medical Image Analysis group conducts basic and applied research in medical image analysis, computer vision for medical applications, and analysis of medical image datasets. The spectrum of topics and research interests are linked to the medical fields of orthopaedics, neuroimaging, and oral and maxillofacial surgery.
All our projects are done in collaboration with internationally outstanding academic, clinical and industrial partners.

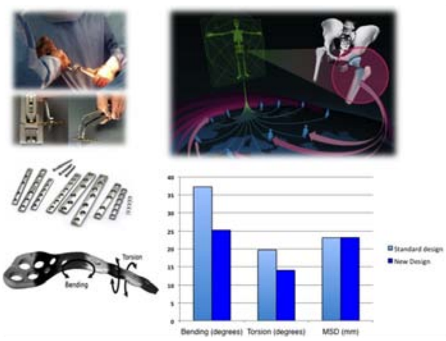
Current Research Areas

Computational Anatomy Techniques For Orthopaedic Research

Computational anatomy enables analysis of biological variability on a population. Using statistical mathematical techniques, models can be built to represent the typical shape of an anatomical structure and the predominant patterns of variability across a given population.
In orthopaedic research we have used these techniques for automated patient-specific and model-based bone segmentation. During 2011, we have developed algorithms to augment the information included in these models in order to assist radiologists in the task of region identification and generation of scanning plan in bone MRI imaging.Computational anatomy techniques have also been developed to study the variability of bone shapes in a population using shape descriptors directly related to the clinical application and the existing knowledge of the clinicians about the anatomy. In this sense our goal during 2011 was to drive the development of these models using clinically known shape descriptors. This has established a new methodology that is anatomy-aware and driven by clinical information.
Last but not least, we continue developing algorithms to perform population-based orthopaedic implant design.
During 2011 our efforts concentrated on taking into account both the quality of bone-implant fitting as well as the minimization of intra-operative implant reshaping. As result, we have been able to propose algorithms for population-based implant design, and patient-specific implant reshaping considering current devices used in clinical practice.



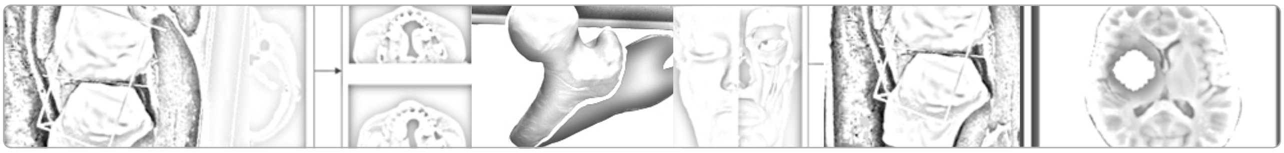
Anatomy-aware bone shape modellling. Computational anatomy based techniques are being used to model the shape variability within a population while considering clinically-relevant shape descriptors. In this example, the anatomy of the mandible is described following the AO fracture classification. The technique can be then used, for instance, for improved design of implants.



Population-based implant design. Computational anatomy techniques are used to improve the design of orthopaedic implants. The vast anatomical variability and the type of deformations (bending, torsions) available by the clinical tools used to reshape an implant have been considered. The lower-right plot describes the population-wide reduction of torsion, bending, while keeping the same quality of implant fitting for a newly designed implant for tibia fractures.

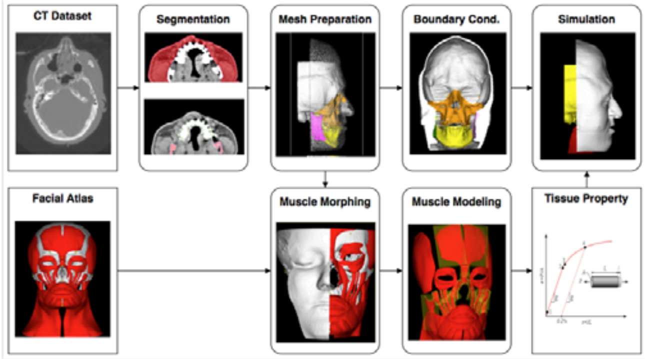
Oral And Cranio-Maxillofacial (CMF) Surgery

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

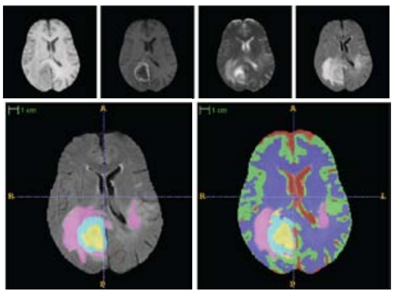


tissue deformations to realistically predict facial appearance after surgery. Methodologies have been developed and evaluated on real clinical cases to perform prediction of facial soft tissue deformations for CMF surgery. Special emphasis has been given to maintain the current clinical workflow, as well as avoiding the difficult and time consuming task of muscle tissue segmentation. The method includes the incorporation of non-homogeneous and anisotropic tissue properties as well as sliding contact considerations, and has been clinically evaluated during the last years. During 2011 we have concentrated our efforts on further improving the clinical usability of the system by establishing collaboration within the Swiss National Foundation (SNSF) project CoMe to automate the image segmentation task and the model building process.

In the area of facial soft tissue surgery, in collaboration with the spin-off company Crisalix, a web-enabled image-based face reconstruction and surgical simulation system is being developed under the auspice of the KTI technology transfer promotion agency. During 2011 a first beta version of the system was produced, featuring fast 3D face reconstruction and rhinoplasty simulation from frontal and lateral photographs.



Soft tissue simulations for Computer-Assisted Cranio Maxillo Facial (CMF) Surgery. Workflow of the system used to predict soft tissue deformations after CMF surgery. The system features incorporation of non-homogeneous and anisotropic muscle behavior, slide contact considerations and fully conforms to the clinical workflow.



Automatic segmentation of tumor-bearing brain image. The developed method features the combined utilization of all image modalities used in clinical practice. The algorithm combines Support Vector Machine classification using multispectral intensities and textures with subsequent hierarchical regularization based on Conditional Random Fields (CRF). The CRF regularization introduces spatial constraints to the powerful SVM classification. The figure shows the image modalities (top) used for the classification (bottom) of healthy (gray matter, white matter, and CSF), and non-healthy tissues (active tumor component, necrotic, edema).

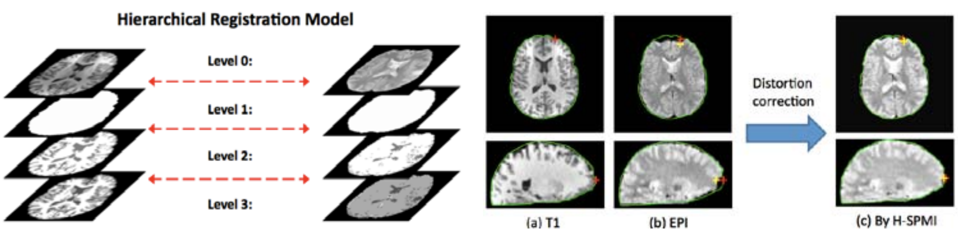
Brain Image And Brain Image Tumor Analysis And Simulations

Magnetic Resonance Imaging (MRI) and its variants are a powerful imaging modality that encompasses rich anatomical and physiological information at a high resolution. In neurosciences these modalities have become a standard in clinical practice. However, the interpretation of the images requires the combined use of different modalities, which leads to the need of computer-assisted technologies.

During the last years our group has developed several methodologies to analyze MRI images with focus on fast multimodal non-rigid image registration and multimodal image segmentation for brain image tumor analysis studies. The developments are driven by clinical requirements such as computation speed, robustness, use of standard clinical imaging protocols, and task-specific accuracy.

During 2011, the accuracy of the previously developed fast multimodal non-rigid registration algorithm has been further improved for the registration of fMRI/MRI images. The improvement in accuracy has been achieved by considering clinically-relevant landmarks and estimated tissue-type information. During 2011, application of our developments for the treatment of epileptic patients using image fusion of fMRI/MRI/CT imaging has been conducted in collaboration with our clinical partners at the Inselspital, Univ. Bern.

The problem of tissue classification in brain tumor studies has been also focus of research and developments in our group during the last years. Previously we have presented an algorithm for multimodal brain tissue segmentation in grade III and IV glioblastoma cases. The algorithm considers the standard clinical imaging protocol as well as the classification of healthy brain tissues (i.e. gray matter, white matter, csf) and tumor layers (necrotic, active and edema regions). In collaboration with the computational engineering group of our institute, a multiscale model of brain tumor growth and brain tissue classification has been developed into a unified framework for atlas-based brain tumor bearing segmentation.



Diffusion weighted image (DWI) distortion is corrected by using a novel hierarchical segmentation-assisted multimodal registration (termed H-SPMI). The figure illustrates the correction of an EPI image (b) using as reference the structural T1 image (a). A software implementation is available.

Computer Assisted Orthopaedic Surgery (CAOS)

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Group Members

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Research Profile

The Computer Assisted Orthopaedic Surgery (CAOS) 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 robust and flexible method for C-arm/X-ray image calibration, 2D/3D acetabulum reconstruction for diagnosis and planning of femoroacetabular impingement (FAI), single X-ray image based 2D/3D reconstruction for automated cup planning, a method for 2D/3D reconstruction of patient-specific models of the complete lower extremity from clinically available X-rays, a method for estimation of both shape and intensity from calibrated C-arm/X-ray images, and a robust statistical method for shape instantiation.

Current Research Areas

Robust and flexible C-arm/X-ray image calibration

Although C-arm/X-ray imaging has an inferior accuracy in comparison to 3D imaging such as CT or MRI, it remains the standard imaging modality for the diagnosis and planning of various orthopaedic problems, largely because of its simplicity, availability, and minimal expense associated with its acquisition. While C-arm/X-ray images are easily obtained, quantitative measurements on these images cannot be performed, as scaling information is normally not available. In order to extract quantitative information from 2D X-ray images, a calibration step is required. For this purpose, we have developed a robust and flexible calibration method, which can be easily integrated into the standard treatment loop. The proposed method was successfully applied to calibrate both fluoroscopic c-arm images and X-ray radiographs.

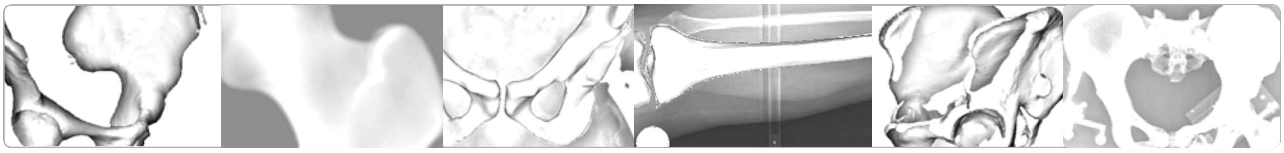
2D/3D Acetabulum reconstruction for diagnosis and planning of femoroacetabular impingement (FAI)

3D surface models of the hip joint could essentially support the diagnosis and planning of FAI. The common approach to derive 3D models is by direct segmentation of CT or MRI datasets. However, these have the disadvantages that they are expensive, time-consuming and/or induce high-radiation doses to the patient. The alternative is to reconstruct patient-specific 3D models from 2D calibrated X-ray images. The 2D/3D reconstruction scheme developed in our group depends on establishing correspondences between the contours extracted from the X-ray images and the apparent contours extracted from a statistical shape model. Accurate overall reconstruction results for various anatomical structures have been reported with this scheme. However, for diagnosis and planning of FAI, the surgeon is interested not only in an accurate reconstruction of overall shape of the anatomical structures but also in an accurate reconstruction of the specific acetabular joint. We have developed a hierarchical 2D/3D reconstruction scheme to specifically improve the accuracy of the acetabulum surface reconstruction. Validation study conducted on 12 hip joints demonstrated on average an accuracy of 1.0 mm.

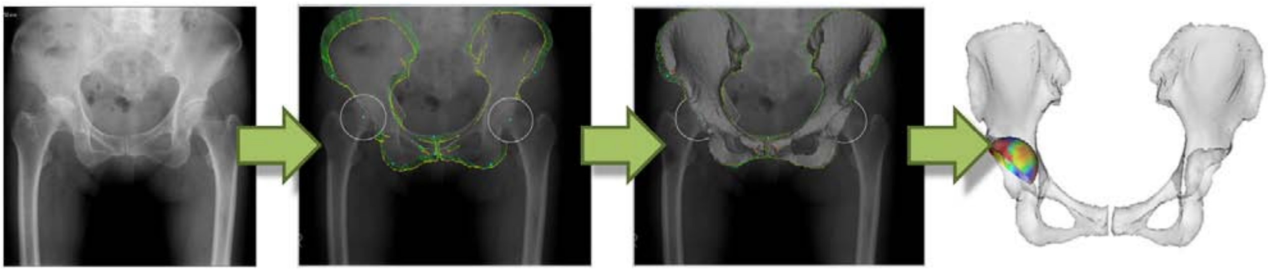
A hierarchical 2D/3D reconstruction scheme for 3D model derivation for FAI application.

xPlan: single X-ray based 2D/3D reconstruction for automated cup planning

Together with Professor Yoshinobu Sato's team in Osaka University, Japan, we have explored the feasibility of using a 3D patient-specific model reconstructed from a single anteroposterior (AP) X-ray radiograph and a statistical shape model of the



pelvis for automated cup planning. Preliminary study conducted on 6 cases demonstrated that when the estimation of the relative scale error was smaller than 5%, the performance of the automated planning based on the 2D/3D reconstruction results was about the same as the situation when 3D CT-images were used.



A single image-based 2D/3D reconstruction pipeline for automated cup planning.

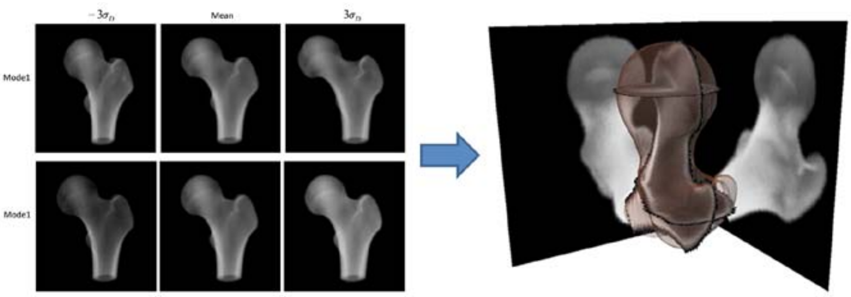
iLeg: 2D/3D reconstruction of patient-specific models of the complete lower extremity from clinically available X-rays

Knee osteoarthritis (OA) is a degenerative disease of the knee joint, affecting more than 40% of the population over the age of 60, imposing significant socioeconomic consequences. Knee arthroplasty (KA) and lower extremity osteotomies (LEO) are two common surgical treatments for knee OA at different stages of the disease. In clinical routine surgeons depend largely on 2D x-ray radiographs and their experience to plan and evaluate surgical interventions at the knee. Numerous studies have shown that pure 2D x-ray radiography based measurements are not accurate due to the error in determining accurate radiography magnification and the projection characteristics of 2D radiographs. In this project, with statistical shape models of both the femur and the tibia, we proposed to develop a system called iLeg that will allow reconstructing patient-specific 3D models of the complete lower extremity from clinically available X-rays for true 3D planning and evaluation of surgical interventions at the knee. Our preliminary validation experiment demonstrated encouraging results.

A single image-based 2D/3D reconstruction pipeline for automated cup planning.

Personalized reconstruction of both shape and intensity of the proximal femur

We developed an approach for reconstructing a patient-specific shape model and internal relative intensity distribution of the proximal femur from a limited number (eg., 2) of calibrated C-arm images or x-ray radiographs. Unlike existing works, our approach used independent statistical shape and appearance models that are learned from a set of training data to encode the a priori information about the proximal femur. An intensity-based non-rigid 2D/3D registration algorithm is then proposed to deformably fit the learned models to the input images. Comprehensive experiments conducted on images of cadaveric femurs demonstrated the efficacy of the present approach.



Independent statistical shape (top-left) and appearance (bottom-left) models, and a reconstruction example (right).

Robust Surface Model Reconstruction from Sparse Point Data

Finding a deformable shape by matching a parameterized model to the observation data is a frequently encountered problem in image registration, object tracking, image segmentation and image recognition. This work aims to match a point distribution model, where a shape is represented as a linear combination of a set of orthogonal vectors, to the observed points. The problem is formulated by directly finding the optimal correspondence assignment and the shape parameter, while the transformation between the shape model and the observation data is then solved in a closed form. Expectation Conditional Maximization algorithm is exploited to fully automatically find an optimal solution for the matching problem.

Mechanical Design & Production

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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) modeling with SolidWorks®, prototyping and production with technical drawings, standard tooling, computer assisted manufacturing (CAM) with MasterCam®, and CNC-machining. 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 two such courses and finally selected Lukas Rufener as our next apprentice. He will begin his training in August of 2012 as a Polymechanic.
After his apprenticeship at our Institute, we employed Ronald Ramseier in August 2010 until the end of February 2011 as a Polytechnician in the MDP. After basic military training, he decided to pursue an extra-occupational bachelor's degree in micro-medical technology. Thus, we were able to continue his employment at a 50% rate since the September 1, 2011 for one year.
After 1 1/2 years of service as a mechanic and foreman, Pascal Aebersold has chosen to seek a new professional challenge and left the Institute at the end of May. We greatly appreciated Pascal as an independent and responsible worker, and wish him all the best in his future endeavors.

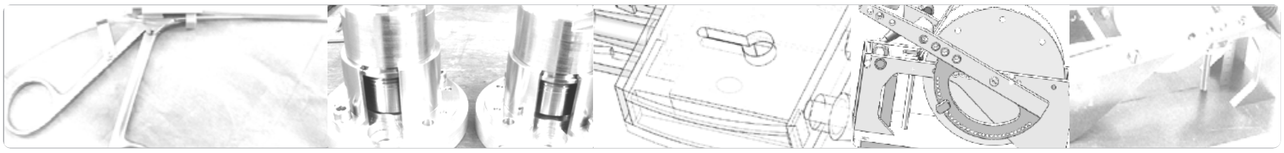
Projects

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 prototypes of clinical and surgical tooling to fixtures for mechanical, biological and kinematic testing, as well as imaging system accessories and calibration equipment. The following sections highlight a few of this year's projects.

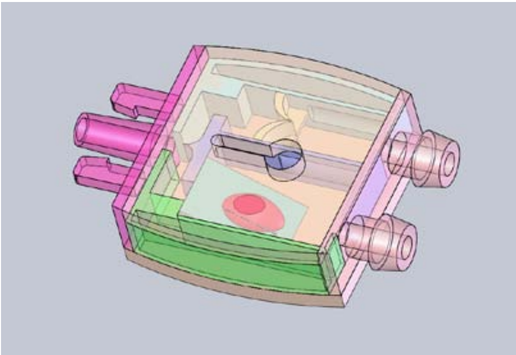
Biomechanics Division: Electro-Spinning

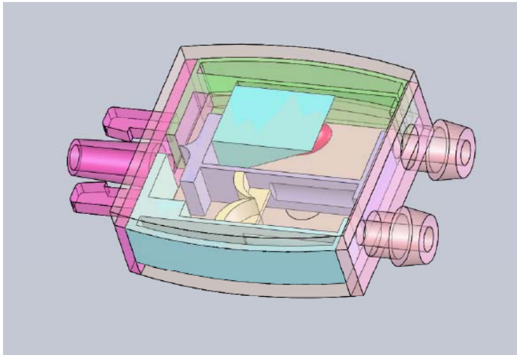
Together with Jochen Walser, we were able to produce some challenging and interesting components for the electro-spinning project. An expanding collector enables the system to produce tubes of varying diameter with a simple adjustment of the collector. Two special grippers with plastic inserts were also produced for mechanical testing of the electro-spun material.



Combined Rinse / Suction Device

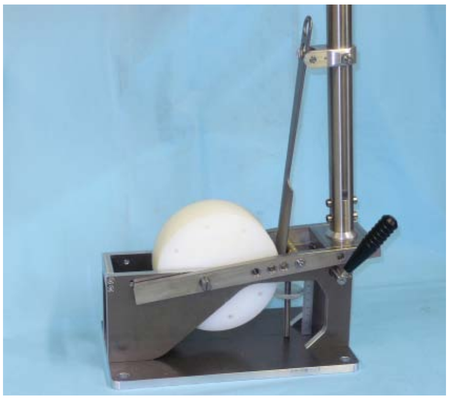
Neurosurgical procedures often require rinsing where upon the liquid must then be extracted with a suction device. A CAD model for a study prototype was created together with Dr. Lennart Stieglitz from the neurosurgical department at Inselspital in Bern, which performs both functions in a single component.





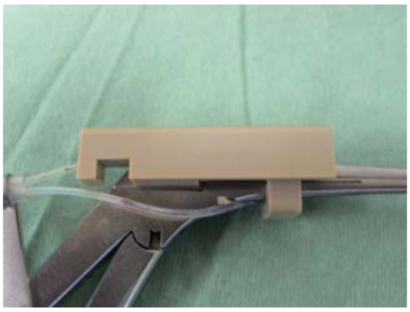
Bone - Retractor Bending Jig

Together with an industrial partner specialized in surgical technology, we were able to design and construct a jig used to bend bone retractors to a specified shape. This jig enables the bending process to be performed repeatably so that quality assurance requirements may be fulfilled.



CAS Division Project: Instrumented micro forceps

The goal of this project was to instrument miniature forceps with sensors which enable the device to measure force and displacements as a stapes prosthesis is crimped to the incus (a small bone in the middle ear). The small channels for the fiber optic Bragg grating sensors had to be milled with an endmill smaller than 0.5 mm in diameter. Though very challenging, we were able to successfully complete this project.



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 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.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Innovation Promotion Agency CTI

FNSNF
FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

EUROPEAN COMMISSION

CO-ME
COMPUTER AIDED AND IMAGE GUIDED MEDICAL INTERVENTIONS

AOSPINE

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 covering a wide variety of topics within our current focus areas, which are electronic implants, image-guided therapy, and musculoskeletal system. Students who hold at least a bachelor degree from a regular university or a university of applied sciences (Fachhochschule) in biomedical, mechanical, electrical, systems or civil engineering or in micro technology, mechatronics, computer science, physics, medicine or closely related fields are eligible for the master study course biomedical engineering. For further information visit the program's web site at www.bme.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

Griessen M.
Autostereoskopische Visualisierung für die Medizin

Guggisberg S.
Interaction of Synthetic PEG Scaffold, Growth Factors and Mechanical Loading on Mesenchymal Stemcells

Hofstetter A.
Differentiation of Human Mesenchymal Stem Cells towards the "Intervertebral Disc-like

Liechti E.
Joint degeneration pattern in severe pincer impingement and its implications for surgical therapy

Mathys R.
Simulation of the effects of different pilot helmets on the neck during air combat

Spreiter G.
Influence of kyphosis on spinal loading

Steiner T.
Comparing a stochastic loading pattern to cyclic loading in an in vitro testing of rabbit flexor digitorum profundus tendon

Treuholz A.
Diurnal Variation of Internal Pore Pressures in the Intervertebral Disc

Widmer D.
Finite Element Prediction of Screw Stability in the Human Temporal Bone

Williamson T.
Visual Servoing of a surgical manipulator

Dissertations

Kim H.
Computer-assistance in Cranio-Maxillofacial surgery: A Clinically-Driven Approach

Oliveira dos Santos T.
Multimodality-based Navigation System for Biopsy Procedures and Intra-operative Tumour Localization

Reutlinger C.
Patient Specific Properties of Scoliotic Spinal Motion Segments: Experiments and Parameter Identification

Welz P.
Direct electrical stimulation of intervertebral disc tissue to support solute transport and cell metabolism

Editorial & Review Contributions

African Invertebrates
Annals of Biomedical Engineering
Apoptosis
Automatisierungstechnik
ASME Journal of Biomechanical Engineering
Clinical Biomechanics
Computer Aided Surgery
Current Eye Research
European Cells & Materials
European Spine Journal
HNO
IEEE Transactions on Biomedical Engineering
IEEE Transactions on Medical Imaging
IEEE Transactions on Pattern Analysis and Machine Intelligence
International Journal of Computer Assisted Radiology and Surgery
International Journal on Medical Robotics and Computer Aided Surgery

Editorial & Review Contributions

Journal of Anatomy
Journal of Biomechanics
Journal of Biomedical Materials Research
Journal of Negative Results in Biomedicine
Journal of Orthopeadic Research
Journal of the Mechanical Behavior of Biomedical Materials
Journal on Medical Devices
Medical & Biological Engineering & Computing
Medical Engineering and Physics
Medical Image Analysis
Medical Physics
Minimally Invasive Therapy
Molecular Phylogenetics and Evolution
Ostheoarthritis and Cartilage
Spine
Surgical Innovation
Tissue Engineering part A and part C
Tissue Engineering and Regenerative Medicine
World Journal of Orthopeadic Research

Editorial Board Member

Clinical Biomechanics
European Spine Journal
Journal on Medical Devices
World Journal of Orthopedics

Review Activities for Funding Agencies

AO Foundation and AO Spine, Switzerland
Austrian Research Promotion Agency (FFG)
Bundesministerium für Bildung und Forschung, Germany
Department of Health, Great Britain
Deutsche Forschungsgemeinschaft, Germany
Natural Sciences and Engineering Research Council, Canada
Royal National Institute of Deaf People, Great Britain

Review Activities for Academic Institutions

Swiss Federal Institute of Technology, Zurich, Switzerland
Berne University of Applied Sciences, Biel, Switzerland
The University of Tokyo, Tokyo, Japan
University of Leeds, Leeds, UK
University of Hong Kong, Hong Kong
University of Zürich, Zürich, Switzerland
Zurich University of Applied Sciences, Winterthur, Switzerland

Review Activities for Conferences

American Society of Orthopedic Research
CAOS Computer Assisted Orthopaedic Surgery
CARS Computer Assisted Radiology and Surgery
CURAC Annual Conference of the German Society for Computer and Robot Assisted Surgery
ICIAR International Conference on Image Analysis and Recognition
IEEE Annual Conference of the Engineering in Medicine and Biology Society, EMBS
IEEE International Conference Intelligent Robots and Systems, IROS
IEEE International Symposium on Biomedical Imaging, ISBI
IPCAI International Conference on Information Processing in Computer-Assisted Interventions
IPMI International Conference on Information Processing in Medical Imaging
MICCAI Medical Image Computing and Computer Assisted Interventions
Orthopaedic Research Society

Awards

CTI Swiss Best Poster Award
Bell B., Gavaghan K., Gerber N., Stieger C., Caversaccio M., Weber S., "High-Precision Robot for Implantable Hearing Systems"

Hanjörg Wyss Start-up Award from AO Spine International
Gantenbein-Ritter B., Eglin D., Benneker L.M., "Biological Response of Mesenchymal Stem Cells seeded in Thermo-Reversible HA-Hydrogel implanted in Intervertebral Disc Organ Culture under Twisting Motion", AO World Spine Conference 2011, Barcelona, Spain

Medical Cluster Award
Stirnimann P., M.Sc. thesis, "Determinants of the mechanical response of trabecular bone-cement composite"

MICCAI Young Scientist Award
Seiler C., "Geometry-Aware Multiscale Image Registration Via OBB Tree-Based Polyaffine Log-Demons", MICCAI 2011, Torronto, Canada

Nomination, best Ph.D. thesis work in Biomedical Engineering, Swiss Society of Biomedical Engineering
Kim H., "Computer-assistance in Cranio-Maxillofacial surgery: A Clinically-Driven Approach"

Nomination, Swiss Technology Award
Peterhans M., CAScination

Invited Lectures

Büchler P.
Computational Biomechanics for Surgical Planning
School of Engineering of the University of Liverpool, UK, May 11, 2011

Ferguson S. J.
Orthopaedic Technologies for an Ageing Population
Schulthess Klinik Research Symposium, Zürich, Switzerland, April, 2011

Gantenbein-Ritter B.
Bioreactors in Mechano Biology - The Missing Link
Masters in Biomedical Engineering, ETH Zürich, Switzerland, May 12, 2011

Gantenbein-Ritter B.
Regeneration of the Intervertebral Disc - Lessons from Mechano-Biology
Artificial Organs: Fact or Fiction? - Swiss MD-PhD Association (SMPA), Inselspital, Switzerland, October 14, 2011

Gantenbein-Ritter B.
The Intervertebral Disc - Can we regenerate or repair it?
Seminar Series at Institute of Pharmacology, University of Bern, Switzerland, November 02, 2011

Gantenbein-Ritter B.
Mechano-Biologie der Bandscheibe
Do-Mo Fortbildung, Orthopeadic Department, Inselspital, Switzerland, November 10, 2011

Gantenbein-Ritter B.
Intervertebral disc Regeneration – Fact or Fiction?
Center for Applied Biotechnology and Molecular Medicine (CABMM), Switzerland, November 17, 2011

Nolte L.-P.
Statistical shape model-based 2D/3D reconstruction for orthopaedic interventions
Waldemar Link, Hamburg, Germany, January 28, 2011

Nolte L.-P.
GPS for orthopaedic surgery
SimTech Colloquium 2011, University of Stuttgart, Germany, May 2, 2011

Nolte L.-P.
Computer aided orthopaedic surgery – State of the art
42nd Annual Meeting of the Italian Orthopaedic and Traumatology Society, Milano, Italy, May 20, 2011

Invited Lectures

Nolte L.-P.
GPS for Surgery (in German)
Forum University Society, Bern, June 8, 2011

Nolte L.-P.
How to innovate with CTI Medtech
First Medtech Process Day – Medtech-lab, Delemont, Switzerland, October 20, 2011

Nolte L.-P.
CTI Medtech Innovation Promotion
Forum for Life Sciences, Taiwan – Canton Vaud, November 10-11, 2011

Reyes M.
Brain Image analysis at the ISTB
Invited Lecturer at the Center for Biomedical Imaging EPFL, Lausanne, Switzerland, June 2011

Reyes M.
Principles of Brain Registration and Applications to Computational Oncology
Lecturer at the First Summer School on Computational Oncology, Crete, Greece, June 2011

Schumann S., Zheng G.
Statistical shape model based methods for determination of pelvis orientation from sparse B-mode ultrasound images
Workshop on Statistical Shape Modeling and its Application is CAOS, CAOS 2011, London, UK,

Weber S.
The challenge of instrument navigation in moving organs
Swiss Society for Experimental Surgery, Fribourg, Switzerland, January 20, 2011

Weber S.
Image Guided Liver Surgery – Clinical Applications and Scientific Trends
University of Leeds, Leeds, Great Britain, June 01, 2011

Weber S.
Computer assisted micro surgery – Experiences from ORL surgery
CAOS Conference, Workshop on Smart Instrumentation, London Great Britain, June 15, 2011

Weber S.
Image Guided Liver Surgery Clinical Applications and Technological Trends
Swiss Society for Biomedical Engineering, Bern Switzerland, August 23, 2011

Weber S.
Image guided microsurgery on the ear
OMMIT Workshop, Bern, Switzerland, August 30, 2011

Weber S.
Robot and Image guided micro surgery on the ear
Swiss Society for Computer Aided Surgery, Delemont, Switzerland, October 20, 2011

Weber S.
Robot and Image guided micro surgery on the ear
Vanderbilt University, Nashville, USA, December 1, 2011

Zheng G.
Medical image computing for computer assisted orthopaedic applications: statistical atlas-based solutions
Workshop on Statistical Shape Modeling and its Application in CAOS, CAOS 2011, London, UK

Publications - Journal Papers

Abouhossein A., Weisse B., Ferguson S. J.
A multibody modelling approach to determine load sharing between passive elements of the lumbar spine
Computer Methods in Biomechanics and Biomedical Engineering, vol 14, pp 527-537, June 2011

Bauer S., May C., Dionysiou D., Stamatakos G., Buechler P., Reyes M.
Multi-scale modeling for image analysis of brain tumor studies
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Bertolo A., Ettinger L., Aebli N., Haschtmann D., Baur M., Berlemann U., Ferguson S. J., Stoyanov J. V.
The in vitro effects of dexamethasone, insulin and triiodothyronine on degenerative human intervertebral disc cells under normoxic and hypoxic conditions
European Cells & Materials Journal, vol 21, pp 221-229, 2011

Bertolo A., Thiede T., Aebli N., Baur M., Ferguson S. J., Stoyanov J. V.
Human mesenchymal stem cell co-culture modulates the immunological properties of human intervertebral disc tissue fragments in vitro
European Spine Journal, vol 20, pp 592-603, April 2011

Bonaretti S., Seiler C., Boichon C., Buechler P., Reyes M.
Mesh-based vs. Image-based Statistical Appearance Model of the Human Femur: a Preliminary Comparison Study for the Creation of Finite Element Meshes
Mesh Processing in Medical Image Analysis, Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 2011

Bou-Sleiman H., Ritacco L.E., Aponte-Tinao L., Muscolo D.L., Nolte L.P., Reyes M.
Allograft selection for transepiphyseal tumor resection around the knee using three-dimensional surface registration
Annals of Biomedical Engineering, pp 1-8, 2011

Bell B., Stieger C., Gerber N., Arnold A., Nauer C., Hamacher V., Kompis M., Nolte L., Caversaccio M., Weber S.
A Self-Developed and Constructed Robot for Minimally Invasive Cochlear Implantation
Acta Oto-Laryngologica, Accepted for publication 2011

Bell B., Roder S., Gerber N., Gavaghan K., Stieger S., Caversaccio M., Weber S.
Computerassistierte Präzisionschirurgie am Ohr
AT-Automatisierungstechnik, vol. 59(10), pp 638-648, 2011

Chan S.C.W., Ferguson S.J., Gantenbein-Ritter B.
The effects of cyclic uni-axial compression onto the Intervertebral Disc - A Review
European Spine Journal, vol. 20, pp 1796-1812, 2011

Dudli S., Haschtmann D., Ferguson S.J.
Fracture of the vertebral endplates, but not equienergetic impact load, promotes disc degeneration in vitro
Journal of Orthopaedic Research, epub ahead of print

Dudli S., Haschtmann D., Ferguson S.J.
Prior storage conditions and loading rate affect the in vitro fracture response of spinal segments under impact loading
Journal of Biomechanics, vol. 44(13), pp 2351-2355, 2011

Gantenbein-Ritter B., Chan S.C.W.
The evolutionary importance of cell ratio between notochordal and nucleus pulposus cells - An experimental 3D co-culture study
European Spine Journal, epub ahead of print

Gavaghan K., Oliveira-Santos T., Peterhans M., Reyes M., Kim H., Anderegg S., Weber S.
Evaluation of a portable image overlay projector for the visualisation of surgical navigation data: phantom studies
International Journal for Computer Assisted Radiology and Surgery, online Oct 21, 2011

Gavaghan K., Peterhans M., Oliveira-Santos T., Weber S.
A Portable Image Overlay Projection Device for Computer Aided Open Liver Surgery
IEEE Transactions on Biomedical Engineering, Vol. 58, No. 6, pp 1855-1864, 2011

Helgason B., Stirnimann P., Widmer R., Ferguson S. J.
Experimental and computational models to investigate the effect of adhesion on the mechanical properties of bone-cement composites
Journal of Biomedical Materials Research Part B: Applied Biomaterials, vol 99 pp 91-198, October 2011

Jürgens P., Klug C., Krol Z., Beinemann J., Kim H., Reyes M., Guevara-Rojas G., Zeilhofer H. F, Ewers R.,
Schicho K Navigation-guided harvesting of autologous iliac crest graft for mandibular reconstruction
Journal of Oral and Maxillofacial Surgery, May, 2011

Knell S.C., Burki A., Hurter K., Ferguson S.J. , Montavon P.M.
Biomechanical comparison after in vitro laminar vertebral stabilization and vertebral body plating of the first and second lumbar vertebrae in specimens obtained from canine cadavers
American Journal of Veterinary Research, vol 72, pp1681-1686, December 2011

Publications - Journal Papers

Oliveira-Santos T., Klaeser B., Weitzel T., Krause T., Nolte L.P., and Weber S.
A navigation system for percutaneous needle interventions based on PET/CT images: Design, workflow and error analysis of soft tissue and bone punctures
Computer Aided Surgery, September, vol 16(5), pp 203–219, 2011

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Description of an ancient social bee trapped in amber using diagnostic radioentomology
Insectes Sociaux, vol 58, pp 487-494, 2011

Schumann S., Nolte L.-P., Zheng G.
Compensation of sound speed deviation in 3-D B-mode ultrasound for intraoperative determination of the anterior pelvic plane
IEEE Transaction on Information Technology in Biomedicine, Epub, pp 1-12, 2011

Schumann S., Nolte L.-P.,Zheng G.
Determination of pelvic orientation from sparse ultrasound data for THA operated in the lateral position
International Journal of Medical Robotics and Computer Assisted Surgery, Epub, pp 1-7, 2011

Stieger C., Caversaccio M., Arnold A., Zheng G., Salzmann J., Widmer D., Gerber N., Thurner M., Nauer C., Mussard Y., Kompis M., Nolte L.-P., Häusler R., Weber S.
Development of an auditory implant manipulator for minimally invasive surgical insertion of implantable hearing devices
The Journal of Laryngology & Otology, vol 125, pp 262-270, 2011

Stoyanov J., Gantenbein-Ritter B., Aebli N., Baur M., Alini M., Grad S.
Role of hypoxia, GDF5 and TGF-beta on differentiation of human mesenchymal stem cells towards intervertebral nucleus pulposus-like cells
European Cells and Materials. vol 21, pp 537-544, 2011

Tasci A., Ferguson S.J., Buchler P.
Numerical assessment on the effective mechanical stimuli for matrix-associated metabolism in chondrocyte-seeded constructs
Journal of Tissue Engineering and Regenerative Medicine, vol 5 pp 210-219, March 2011

Widmer R.P., Ferguson S.J.
A mixed boundary representation to simulate the displacement of a biofluid by a biomaterial in porous media
Journal of Biomechanical Engineering, 133:051007, May 2011

Zheng G., Nolte L.-P., Ferguson S. J.
Scaled, patient-specific 3D vertebral model reconstruction based on 2D lateral fluoroscopy
International Journal of Computer Assisted Radiology and Surgery, vol 6, pp 51-366, 2011

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Bauer S., Nolte L.P., Reyes M.
Segmentation of brain tumor images based on atlas-registration combined with a markov-random field lesion growth model
In ISBI'11: Proceedings of the 2011 IEEE international conference on Biomedical imaging, pp 2018 - 2021, Chicago, IL, USA, March 2011

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Fully automatic segmentation of brain tumor images using support vector machine classification in combination with hierarchical conditional random field regularization
In Medical Image Computing and Computer-Assisted Intervention - MICCAI 2011, pp 354-361 September 2011

Bou-Sleiman H., Ritacco L.E., Nolte L.P., Reyes M.
Minimization of intra-operative shaping of orthopaedic fixation plates: A population-based design
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3D model-based reconstruction of the proximal femur from low-dose biplanar x-ray images,
In Proceedings of the British Machine Vision Conference (BMVC) 2011, pp 35.1-35.10, 2011

Gavaghan K., Anderegg S., Peterhans M., Oliveira-Santos T., Weber S.
Augmented Reality Image Overlay Projection for Image Guided Open Liver Ablation of Metastatic Liver Cancer,
In Proceedings of MICCAI 2011 Workshop on Augmented Environments in Computer-Assisted Interventions (AE-CAI), September 2011, Lecture Notes in Computer Science

Hofstetter A., Barbe L., Guenat O., Gantenbein-Ritter B.
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Geometry-aware multiscale image registration via obbtree-based polyaffine log-demons,
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Book Chapters

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Patient-Specific Modeling in Tomorrow's Medicine, chapter Soft-Tissue Simulation for Cranio-Maxillofacial Surgery: Clinical Needs and Technical Aspects. Studies in Mechanobiology
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Patents

A method and a system for manufacturing a container for an organ
European Patent No. EP11162738.6
Peterhans M., Candinas D., Weber S.Universität Bern, Switzerland, 2011

Shape reconstruction using X-ray images
US Patent No. US8055046
Thomas F., Zheng G.
November 2011

Device for computer assisted distal locking of intramedullary nails
European Patent No. EP1968468
Zheng G., Zhang X.
January 2011

Method and Device for computer assisted distal locking of intramedullary nails
European Patent No. EP2051647
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January 2011

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