Introduction of the Cooperation Research Center for Biomechanics of Budapest University of Technology and Economics

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Abstract
Our Institute established in 2002 became the local scientific center of biomechanical research programs in the Budapest University of Technology. Today this Center collects, organizes and strengthens the work of 17 Departments (of 5 Faculties) in these special inter- and multidisciplinary fields (under the control of the Dean of Faculty of Mechanical Engineering of BME from 2008). This introduction would like to show the most important research activities, results and future plans of our colleagues working at our Institute.

Keywords: research programs, biomechanics, cooperation, virtual center

Introduction

The Research Center for Biomechanics of Budapest University of Technology and Economics was established after a long preparation at the end of 2002. Different research programs were done already in the past at our Technical University in strong cooperation with other clinics, universities etc., but they were mostly highly individual and separated programs, often times the coworkers practically did not have any information about other similar efforts made by their colleagues at the neighboring departments. The main goal of the foundation of our Institute was to strengthen the cooperation, to eliminate the unnecessary parallel programs, to introduce new ideas in common interest. The Council of the University established the Center as a "virtual" Department, which could pursue independent scientific and economic activities, but hasn't own staff, only the staff of the Departments united in the Research Center make all the work, which is necessary to the continuous existence of an independent Center.

At the beginning of its work the Center had only nine members, but now already 17 Departments form the Institute. By the help of central university budget we began to build a new, independent laboratory in 2003, where first of all the dynamic experimental analysis of different bones and prosthetic systems are done. This is our most important development, and fortunately the Center has different successful grants to supply the measurements of this laboratory. Accreditation process of the laboratory was completed in 2008.

The Center now has activities in three classical fields of biomechanics: we **measure** different physiological properties under laboratory circumstances, we **compute** mechanical parameters of different biological phenomena using special – mostly finite elements – software and last, but not least we produce **new biomedical products** (prosthetic systems, special biomaterials, etc.). In this article we would like to interpret the most interesting efforts, research programs and future plans of the different groups of our Research Center.

Experimental biomechanics

One of our important laboratory activities is motion analysis (now this Laboratory is under redesign and reconstruction). In this research program an up-to-date on-line motion analysis laboratory was established. The basic equipment is the CMS-HS ultrasound-based active markers' system developed by Zebris GmbH *(Figure 1)*.

Figure 1. The view of the laboratory of motion analysis

The system works on the basis of the measurement of the delay of ultrasound signals and provides a lot of possibilities for motion analysis. As an example we mention the "ArmModel" or the special 19-point mechanical model which were developed here to measure in complex way the motion of professional athletes *(Figure 2)*.

We made important efforts in the laboratory analysis of different bones and prosthetic systems also. In *Figure 3* we can see a biomechanical test of a press-fit femoral fixation technique in ACL reconstruction. The purpose of this study was to evaluate the initial mechanical properties of this method by ultimate tensile load tests in different angles in human cadavers and to examine the ultimate load of this fixation during postoperative period using porcine knees. We also mention that simultaneously with this activity the same group measured the primary stability of osteochondral grafts used in mosaic plasticity and the bone mechanical competence in rat model of experimental osteoporosis.

Another experimental group developed an interesting laboratory method to measure the mechanical effects of 3D force transition in the case of different human prosthesis – *(Figure 4)*. – using photostress analysis to determine the surface stress distribution of cadavers.

Figure 2. The motion analysis of a professional cyclist

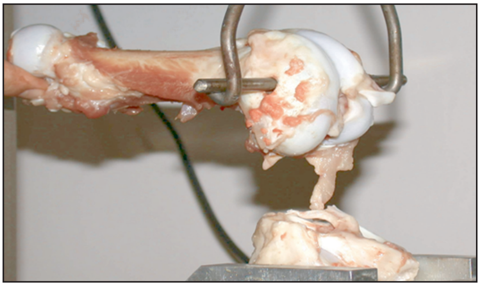


Figure 3. Test of press-fit femoral fixation

Figure 5 shows the investigation of a mandible, using photoelastic coating technique, to determine the surface strain and stress distribution in order to develop better fixation method for implants.

Also very interesting in vivo experimental analysis was made for the tensile deformability of human lumbar spine segments during traction bath therapy *(Figure 6)*. More thousand ultrasound pictures have been measured and evaluated to analyze the time-, aging-, sex-, body weight- and height dependent elastic and viscoelastic deformations of human lumbar segments.

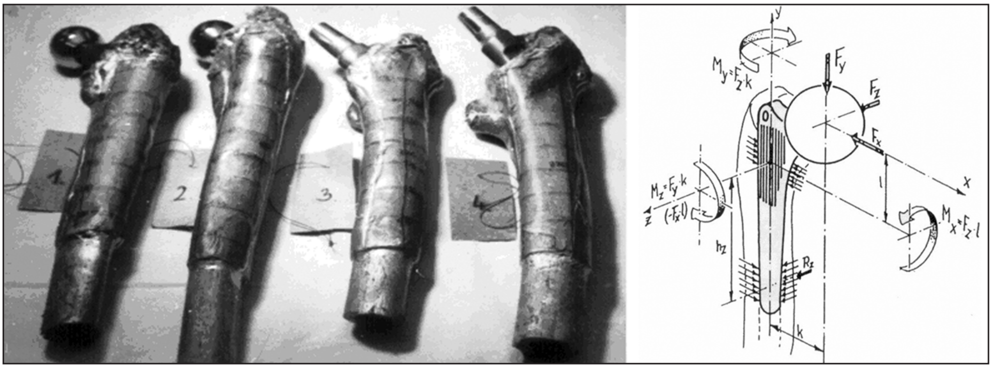


Figure 4. A group of specimens prepared by photoelastic coating

The test measurements were mainly carried out on the universal fatigue test machine of the Central Laboratory (in which the accreditation process now is in final stage, according to standard MSZ EN ISO/IEC 17025:2005), INSTRON 8872, with the load capacity of 2.5 kN. *(Figure 5.)*

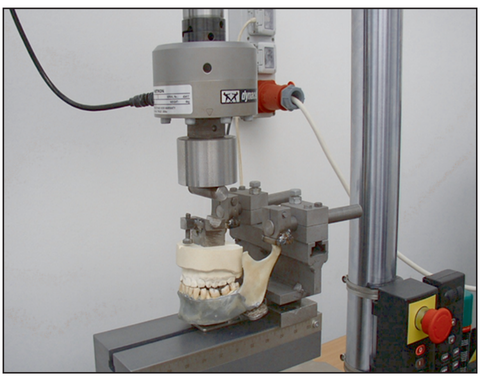


Figure 5. Investigation of a mandible with photoelastic coating technique

At last we should still mention here the different laboratory programs for the investigations of the properties of bone implant materials, artificial bones (chemical composition, microstructure, static-, dynamic- and fatigue properties, problems of biocompatibility, or the analysis of implant surface morphology [roughness, porosity, coating systems]), see for instance *Figure 7*.

One of our latest, most important developments is the realization of a new implant, based on bio-integration concept. This new implant has a core, upon it a special developed steel net, for the bio-integration of the

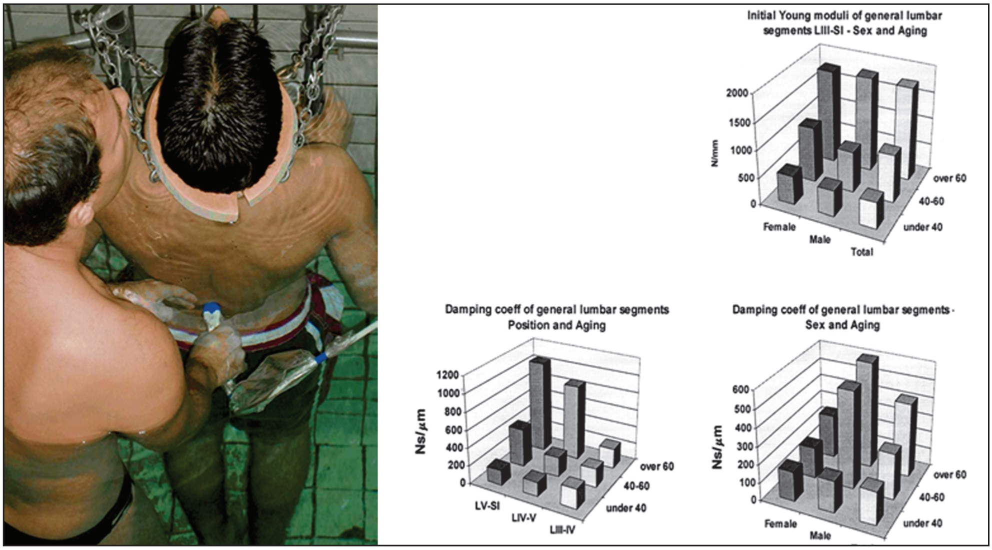


Figure 6. The subaqual ultrasound measuring method and the results

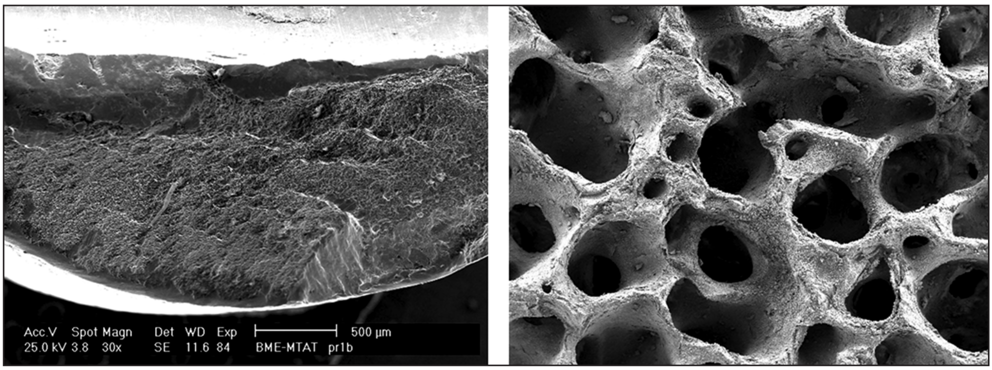
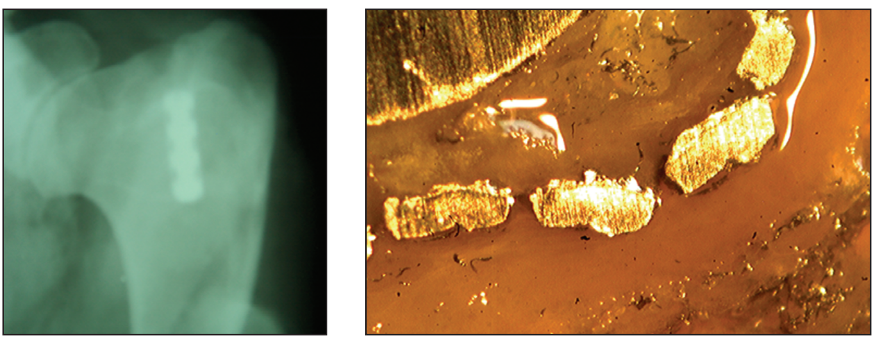


Figure 7. Microstructure analysis of implants and bones



a) fixation of the newly developed implant in a femur

b) the optical microscopic picture of the bone integration

Figure 8. Development of the bio-integration prosthesis

bone tissue. A successful 3 year-project was fulfilled in 2008 on this topic, with the result of animal experiments. See some pictures of the development phase in *Figure 8*.

Computational biomechanics

We would also like to mention the interesting thermodynamic analysis of our physicians, who have nice programs in thermodynamic bio-rheology, in the shape-change analysis of DNA in motion and in the thermodynamic theory of molecular motors, see an example for the cell division calculations in *Figure 9*.

Intensive work is going on in our Center for the blood circulation modeling in the artery. The periodic blood flow is to be modeled mathematically and so a simplified physical model of the artery system is to be built up. Using the physical model the unknown parameters of the mathematical model can be identified experimentally. Computations with this identified mathematical model can then be used to draw conclusions for diagnostics and treatment.

In the biomechanical analysis of the vascular systems there is a special, but very important area: the simulation of the rupture of the brain aneurysm. In strong cooperation with the Institute of Human Physiology and National Scientific Institute of Neurosurgery we created a complex finite element program for simulation of blood flow in the aneurysm and for measuring the load-bearing capacity of the wall of aneurysm, see some details from the original model and the numerical calculations in *Figure 10*.

In connection with the formerly mentioned experimental analysis of human lumbar spine, we shall also mention the numerical simulations of traction therapies which are used to clear the mechanical behavior and

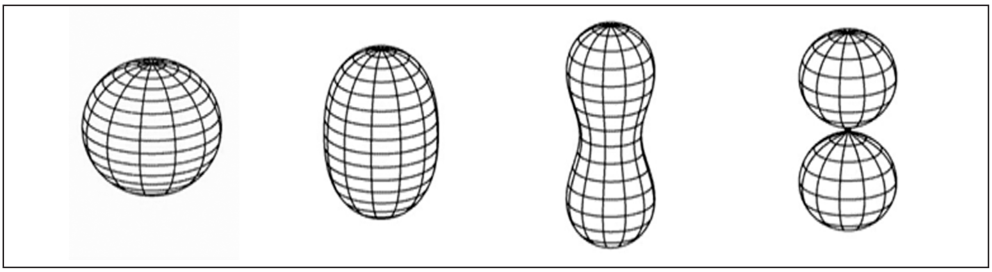


Figure 9. Calculation results of cell divisions

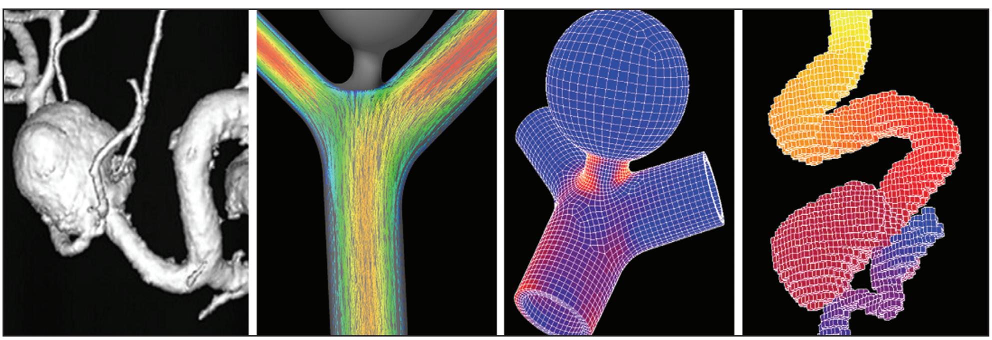


Figure 10. Some details from the brain aneurysm

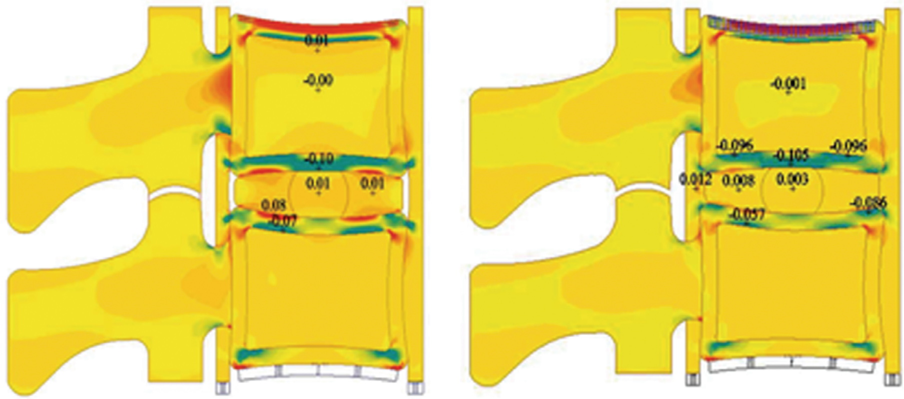


Figure 11. FEM analysis of lumbar spine segments

role of different organs (vertebrae, discs, ligaments, etc.), which constitute the very complicated biomechanical structure of spinal motion segments *(Figure 11)* about the FEM analysis of a single lumbar motion segment. We note that an effective 3D FEM-model already exists in this program.

Very nice numerical simulations were made at one of our groups for different bone mechanical problems and prosthetic systems. In *Figure 12.* details of operative treatment of pelvic ring fractures and a 3D FEM analysis of femur prostheses can be seen.

We should mention a little bit different, but also very important other research efforts in other areas. For instance, the biomechanical analysis of biodegradable land-filled waste will be extremely important in Hungary: the decomposition of organic matter, the detailed analysis of the different aerobic and anaerobic processes will be a basic design parameter at the design of similar objects *(Figure 13)*.

A quite different topic is the biomechanical application of stereo-photogrammetry. A lot of different problems – studying the changes in live organs, the determination of the internal surface points of the antrum of highmore, developing the surface model of human gums, comparative accuracy investigation of dental procedures, analysis of ultrasound pictures, etc. – were analyzed.

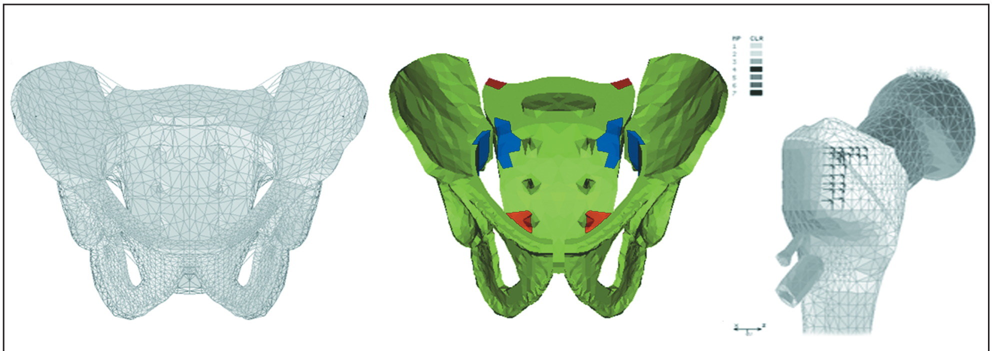


Figure 12. FEM simulations for bones and prostheses

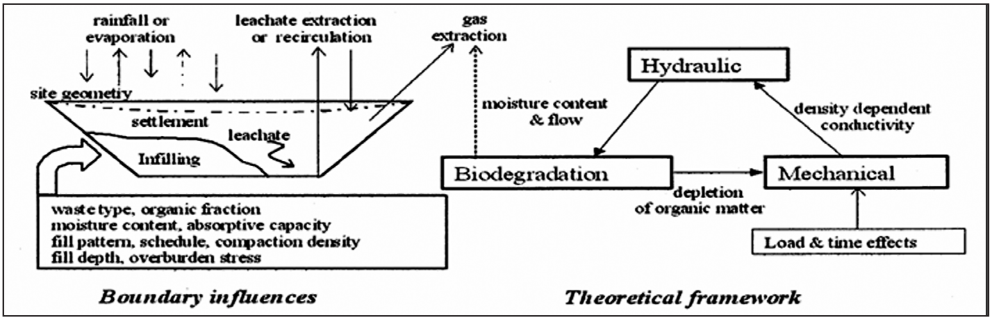


Figure 13. The coupled analysis of bio-degradation landfill

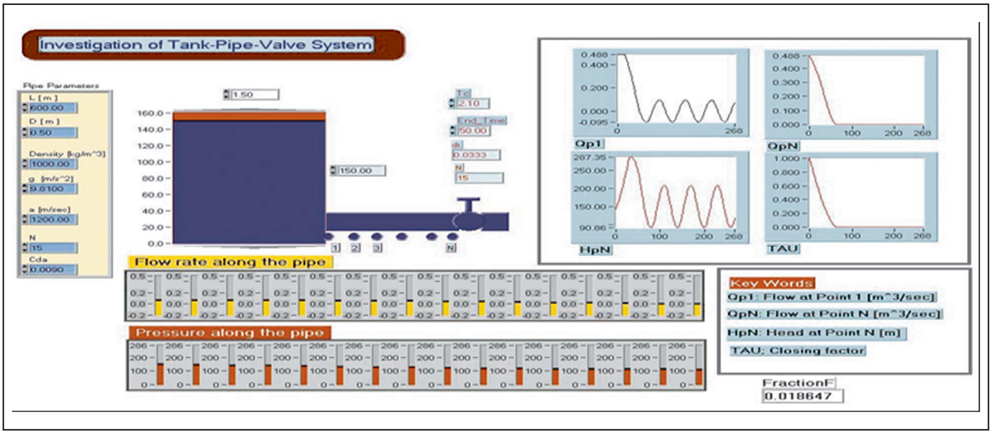


Figure 14. Fluid flow model in LabVIEW environment

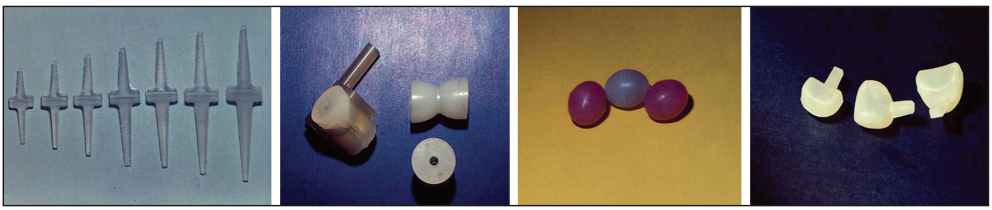


Figure 15. Silicon materials for implants

Last but not least we must mention the work of a small, but very active group, which made efforts to develop different compartment models of biological systems in LabVIEW programming language environment. For instance they made complex systems for different pharmacodynamical, pharmacokinetic and physiological systems. An illustrative example could be seen in *Figure 14.*

Development of new materials and instruments

The third and also very interesting scientific area of our Center is the development of different new biocompatible materials and new machines for human medical treatment respectively.

We have extremely good results in the creation of new silicon materials, which are

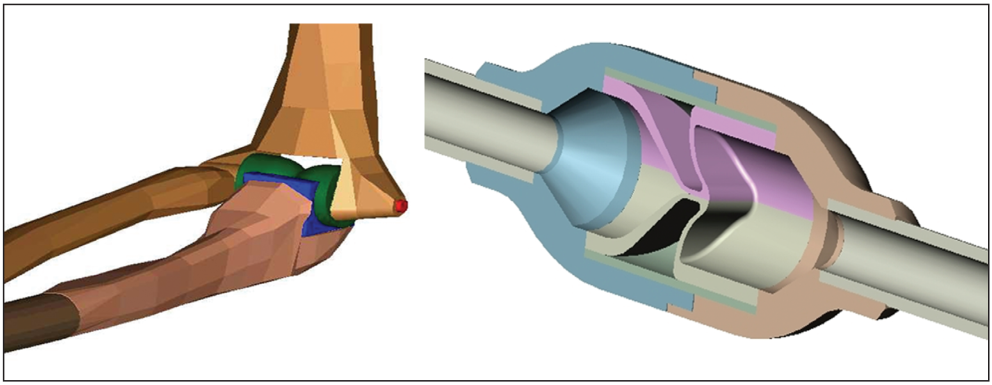


Figure 16. Medical instruments from silicon

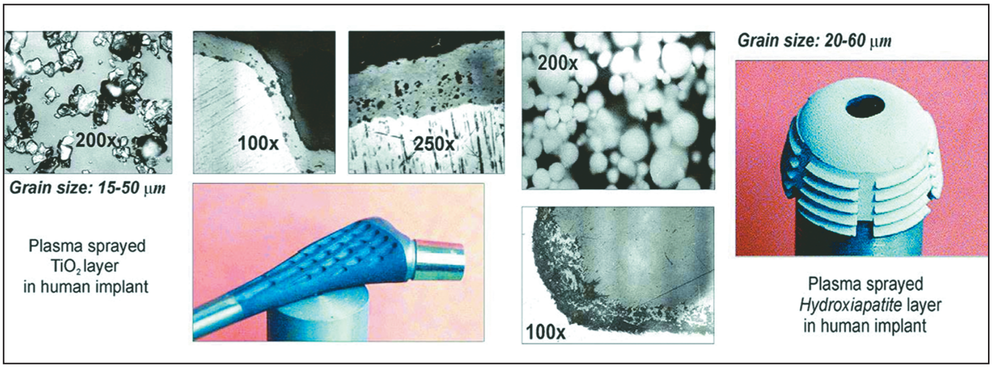


Figure 17. Plasma sprayed human implants and surface analysis

excellent for different medical applications. In *Figure 15.* different applications (implants, eyes, etc.) can be seen.

More complex implants could also be made from silicone-rubber. In *Figure 16.* we interpret a joint prosthesis and a special rectifying instrument both of them developed in our Institute.

We also have results int he analysis of metallic materials. In another group different versions of the plasma sprayed human femur implants were analyzed *(Figure 17).*

Among our new instruments we must emphasize our special rehabilitation robot, which can help a lot in the physiotherapy of spastic hemiparetic – stroke – patients. This robotic therapy system minimizes the time spent by physiotherapists in performing repetitive physiotherapy exercises. Its introduction in human treatment will allow more patients to be seen, assessed and rehabilitated. Some details could be seen in *Figure 18.*

Conclusion

In this small summary we wanted to show the most interesting results and efforts of the Cooperation Research Center for Biomechanics of BME. We deeply suggest every interested people they should not hesitate to contact us for any kind of scientific cooperation.

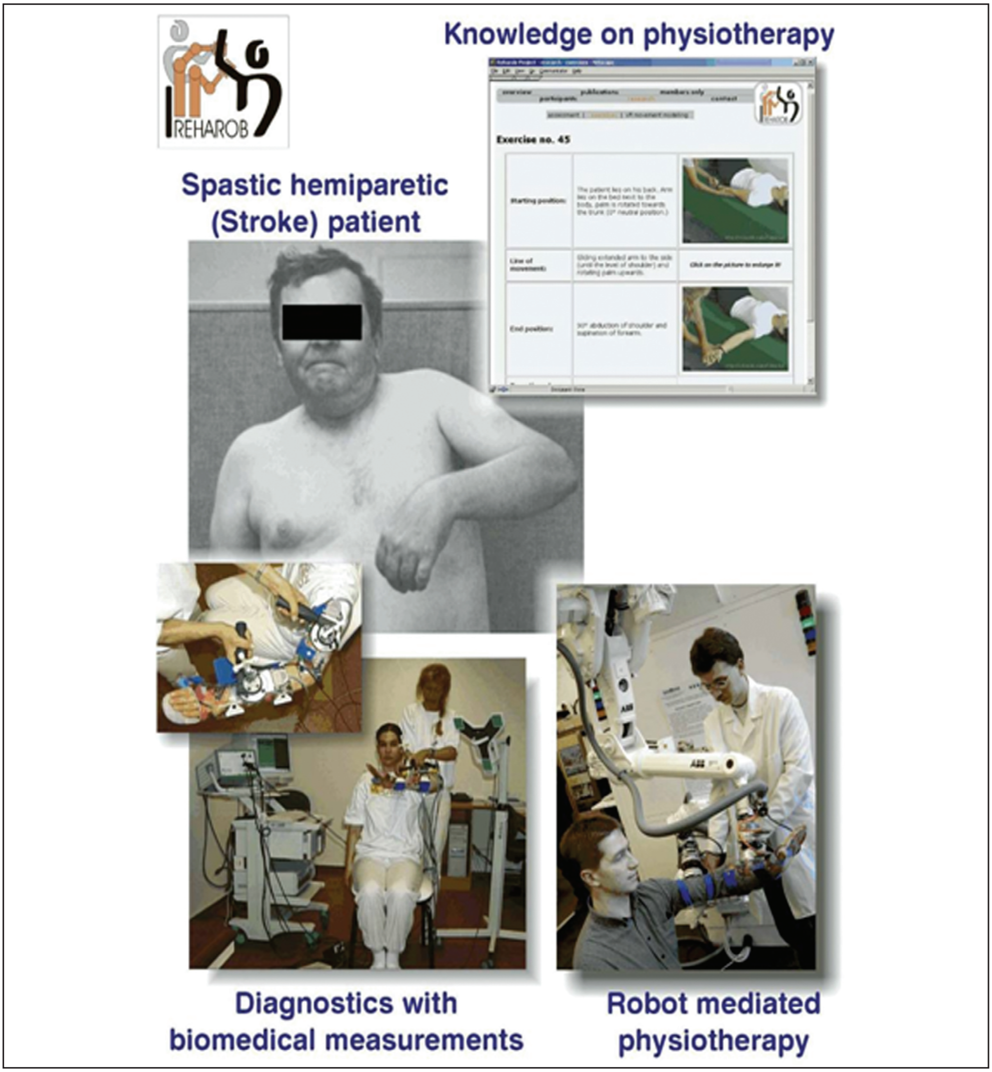


Figure 18. Rehabilitation with robot mediated physiotherapy

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