Zurich University
of Applied Sciences

School of Engineering

IMES Institute of
Mechanical Systems

Service Catalogue

Version 3

Accredited Testing Laboratory STS 0526 (Swiss Testing Services) type C,
according to ISO/IEC 17025 by the Swiss Accreditation Service (SAS)

Measurement Equipment at a Glance

Part A: Component Testing and Analysis

Part B: Human Testing and Analysis

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Preface

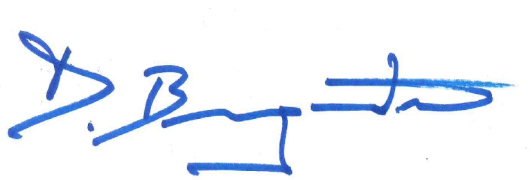
The Biomechanical Engineering of the Institute of Mechanical Systems has a long experience in product development and testing in arthroplasty, traumatology, spinal implants, and dental surgery. The knowledge is based on practical research and applied development in the field of anatomy and biomechanics as well as biocompatible materials. The expertise has been advanced over the last years to the development of sitting furniture, sport, training and rehabilitation devices, and includes not only material and functional device testing but also the investigation of the human body in interaction with the devices. Our group is composed of Mechanical and System Engineers as well as Human Movement Scientists. Our laboratory enables us to perform experimental tests according to up-to-date ISO standards.

Experimental and analytical methods are used to analyse and visualise the functionality of devices like implants or office chairs. We advise our customers regarding residual risk reduction of products by experimental tests of strength, functionality and connection security for endoprostheses, traumatology products, or surgical instruments. We further analyse the human-device-interaction using advanced motion capture systems, force sensors and electromyography systems to describe the human behaviour in applied situations.

The service catalogue provides an overview of our laboratory equipment including detailed product specifications and exemplary areas of application. To perform experimental tests, it is elementary to choose the appropriate devices specifically tailored to the relevant question, which we carry out together with our customers to provide a satisfactory solution.

Don’t hesitate to contact us to clarify how we may contribute to your project.

Yours Sincerely,



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Part A: Component Testing and Analysis

1. Mechanical Tests

Based on the Accreditation and Designation Ordinance and on the advice of the Federal Accreditation Commission, the Swiss Accreditation Service granted our laboratory according to ISO/IEC 17025 the accreditation as test laboratory type C for the development of test procedures and investigations on joint replacements, spinal products, traumatology products and instruments, as well as office, seating and object furniture and therapy, training and rehabilitation devices.

The definition of the scope of the accreditation type C is based on technology and measuring principles for which the competence has been demonstrated by our test laboratory. This empowers our laboratory to introduce, characterize and validate self-developed new test methods, as well as to offer test methods according to numerous national and international standards.

Static Tests

- Single-axis, quasi-static tensile and compression tests according to standards to determine material parameters such as yield, tensile or bending strength, breaking elongation, and modulus of elasticity.
- Point-Bending-Tests, using e.g. video-extensiometry to measure displacement.
- Quasi-static determination of implant properties using specially developed apparatuses (e.g. standard ASTM1717-11a: corpectomy model).
- Connection check, e.g. for CFRP components.
- Pull-out tests of complex mechanical components (e.g. clamping sleeves).

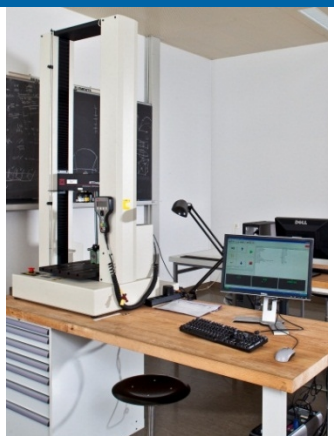
Dynamic Tests

- Dynamic, biomechanical tests according to ISO and ASTM standards.
- Test of implants, fixations and anchorages of preparations.
- Multi-axis superimposed load cases (e.g. extension / flexion and rotation).
- In vitro tests for spinal preparations.
- Functional tests of knee prostheses and intervertebral disc implants (superposition of two load cases compression and flexion / extension).
- Strength analysis of plastic connections.

1.1 Universal Test Machines

Uniaxial, static test machines for tensile, compression and bending tests on specimens and components made of metal, plastic, ceramics and composites.

MTS Insight, 30 kN - Electromechanical



Specifications

- Force max ± 30 kN
- Test speed max 500 mm/min
- Test speed min 0.001 mm/min
- Test area 405 x 1100 mm
- Position resolution 0.001 mm
- Position accuracy 0.01 mm
- Load Cells
  - 1.25 kN, 2.5 kN, 5 kN 15 kN and 30 kN

Zwick 1474, 100 kN - Electromechanical

Specifications

- Force max ±100 kN
- Test speed max 500 mm/min
- Test speed min 0.001 mm/min
- Test area 430 x 1200 mm
- Position resolution 0.001 mm
- Position accuracy 0.01 mm
- Load Cells
  - 1 kN and 100 kN

MTS 858 MiniBionix, 15 kN - Axial Servo Hydraulic

Description

Axial dynamic test machine for tension-compression fatigue load.

Specifications

- Force max ±15 kN
- Dynamic stroke ±50 mm
- Frequencies from 0.01Hz to 100Hz (depending on the stroke)
- Test area 460 x 789 mm
- Load Cells
  - 1 kN, 1.25 kN, 2.5 kN, 5 kN and 15 kN

MTS 370.02, 15 kN / 150 Nm - Axial/Torsional Servo Hydraulic

Description

Axial/Torsional, dynamic test machine for tension-compression fatigue load and torque tests, including rotation around the longitudinal axis.

Specifications

- Force max ±15 kN
- Torque max ±150 Nm
- Axial ±75 mm
- Rotation ±135°
- Frequencies from 0.01Hz to 100Hz (depending on the stroke)
- Test area 460 x 1412 mm
- Load Cell
  - 15 kN / 150 Nm
  - 4 kN / 56 Nm
  - 2 kN / 28 Nm

SELmaxi-025/SE1, 2.5 kN / 14 Nm - Biaxial Servo Electric

Description

Biaxial test machine with vertical and horizontal axes to analyse flexion movements.

Specifications

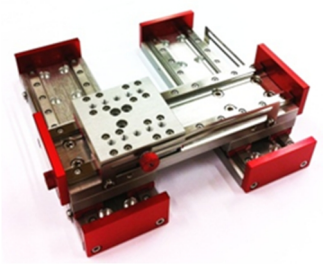
- Force max ±2.5 kN (axial)
- Torque max ±14 Nm (vertical)
- Dynamic stroke
- Axial ±75 mm
- Rotation ±60°
- Test area 500 x 500 mm
- Load Cell
  - 2.5 kN / 14 Nm

1.2 Additional Machine Equipment

XY-Table

Description

Table to eliminate reaction forces in the xy-plane.



Specifications

- Force max ±2.7 kN
- Position range ±50 mm (x/y direction)

MTS Horizontal Pivot Axis 608.30

Description

Hydraulic drive unit for flexion/extension simulations in spinal column tests.

Specifications

- Torque max ±50 Nm (vertical)
- Dynamic stroke
- Rotation ±60°

Kistler Torque Sensor 4501A12HA, 12Nm

Description

Operates on the strain gage principle and supplies an analogue output signal in mV/V, particularly suitable for screw drived assembly operations.

Specifications

- Nominal torque 12 Nm
- Connection hex
- Overload Capacity 1.5 x nominal torque
- Rotation angle measurement 2 x 360 pulse/revolution
- Nominal speed 3000 rpm
- Accuracy class 0.2%
- Output signal ± 2 mV / V

Potential Applications

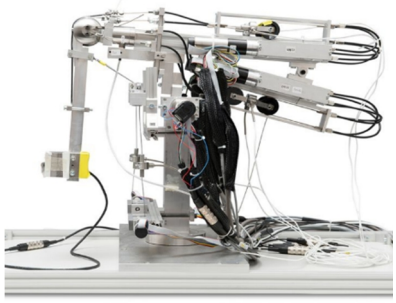
- To measure tightening and loosening torque of screws.
- Real time recording and visualization.

2. Simulator and Robot

Functional Shoulder Simulator, own development

Description

Muscle force controlled simulator to analyse bone kinematics, joint and muscle forces of e.g. shoulder implants or shoulder abnormalities.



Specifications

- Adjustable abduction and in-/external rotation angle
- Adjustable shoulder rhythm (scapula-thoracic-rotation)
- Adjustable bone anatomy (size and weight)
- Adjustable muscle forces and force action lines
- 3d joint reaction forces and moments
- Allows cadaver studies

Potential Applications

- To analyse primary stability of fracture plates under physiological load conditions.
- To study the influence of the Critical Shoulder Angle on humeral head migration in human cadavers.

KUKA KR150 R2700 Quantec

Description

Industrial robot to study structural-mechanical properties in complex kinematic motion patterns (6 degree-of-freedom) in the field of orthopaedics, including 3d force and torque measurements. Even real motion capture data to be used as input file (e.g. from Vicon or Optotrak).

Specifications

- Payload 150 kg
- Speed max 2,5 m/s
- Accuracy (absolute) 0,5 - 2 mm
- Repeatability ± 0,06 mm
- Force-Torque Sensors (Schunk FTN)
  - Gamma: Force/Torque max ±65 N / ±5 Nm
  - Delta: Force/Torque max ±330 N / ±30 Nm
  - Omega: Force/Torque max ±1500 N, ±240 Nm
- Control methods
  - Position mode
  - Force-Torque mode
  - Hybrid mode

Potential Applications

- Biomechanical investigation of cadavers.
- Design studies of implant systems.
- Validation of Finite Element Analysis.

3. Optical Measurement Systems

Leica M205A Stereomicroscope

Description

High-performance stereomicroscope with apochromatic corrected 20.5:1 zoom, DFC550 Digital microscope camera and TL5000 Ergo transmitted light base. The motorized zoom and focus allow reproducible and consistent experimental procedures and calibrated measurements over the entire magnification range.

Specifications

- Stereomicroscope
  - Zoom range 7.8x - 160x
  - Maximum resolution 525 lp/mm
  - Working distance 61.5 mm (Planapo 1x)
  - Object field Ø 29.5 mm - 1.44 mm
  - Magnification max 1280x
- Digital camera Leica DFC 550
  - 12.5 megapixels
  - Resolution max 4080x3072
  - Software Leica Application Suite LAS with assembly, measurement and live image builder Z

Potential Applications

- Visual analysis of surfaces in reflected and transmitted light applications (e.g. fracture surfaces, abrasion, cracks, and deposits).

Limess Video Extensometer and Hi-Speed Camera

Description

High-resolution video extensometer for quasi-static tensile tests and fast video extensometer (Hi-Speed Camera) for dynamic applications.

Specifications

- Video Extensometer
  - Sampling rate max 50Hz
  - Camera resolution 2 megapixels
  - Measurement accuracy for strain 20µstrains
- Hi-Speed Camera
  - Sampling rate max 1800Hz at 640x10 pixels
  - VGA Resolution 640 x 480 pixels
  - Measurement accuracy for strain 200µstrains
  - Zoom lens 24-85 mm
  - LIMShot image recording software

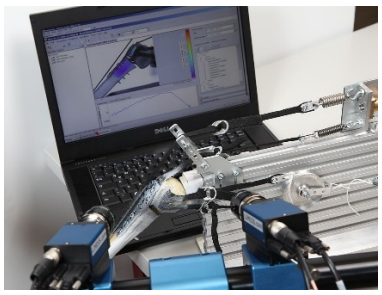
Potential Applications

- 2D strain measurement on test specimen (Video Extensometer).
- To analyse deformation of soft shoe soles (Hi-Speed Camera).

Limess 3D Image Correlation

Description

Optical 3D image correlation system to measure surface deformation, strain and contour. A “colour-speckle” pattern is required provided the natural surface structure is not sufficient.



Specifications

- Recording area up to 100 m^2
- Sampling rate up to 2’000’000 Hz
- Camera resolution 0.3 – 29 MPixel
- Accuracy 3d motion 0.01 Pixel
- Accuracy strain 200 µstrains (0.02%)
- Including real-time evaluation

Potential Applications

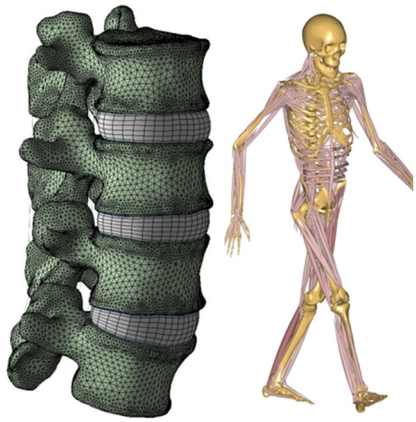
- To characterize 3d displacement of proximal humerus fracture fragments under load.
- Tensile test with high elongation.

4. Software

Key Software

Description

In addition to the device-specific software, our group uses the following key software applications.



Software list

- Ansys: Computer assisted calculation of component strength using finite element method (FEM).
- Anybody: To simulate the human musculoskeletal system, with already completed open source models.
- Catia: 3d CAD to construct components and deriving production drawings.
- Geo Magic Studio: To edit and process 3 d scans (reverse engineering).
- IBM SPSS: To perform advanced statistical data analysis.
- Key Shot: To render computer assisted designs.
- LabView: System design software to visualize, design and implement technical systems.
- Matlab: Tool to calculate complex computational problems (including statistics) and to visualise measurement data.
- Mimics: To reconstruct CT and MRI data.
- RecurDyn: Kinematic multibody simulation of non-deformable components (rigid body models).
- 3d Via Composer: To render computer assisted designs to generate assembly instructions.

Potential Applications

- Musculoskeletal modelling to calculate forces in joints, bones and muscles.
- To calculate stress, deformation and reaction force of test objects to provide information on strength and functionality.
- To create realistic simulation models based on anatomical structures gathered with CT or MRI.
- To process and analyse synchronously measured kinematic and kinetic data.

5. Laboratory facility

In vitro Laboratory

Description

Laboratory for experimental research using animal and human cadaver.

Equipment

- Operating table (Vet.)
- Standard surgical instruments
- Motor driven instruments
- Operating lights
- Cleaning and disinfecting unit
- Steam sterilizer
- Freezer -32 ° and -40° C

Potential Applications

- To implant endoprostheses and traumatology products in human cadaver.
- To test instruments and medical devices.
- To analyse surgical techniques.

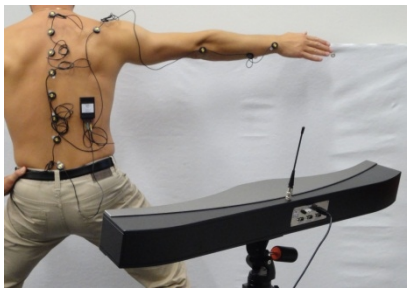
Part B: Human Testing and Analysis

1. Kinematic Measurement Systems

Steinbichler Lukotronic Motion Capture Unit 200

Description

Motion Capture System to track the coordinates of infrared-markers (diameter of 1 or 5 mm), including the software for data processing, evaluation and analysis (AS 202). The entire system is easy transportable in a suitcase.



Specifications

- Up to 48 active infrared-markers, 3 cameras
- Recording area up to 12 m (depth) to 6 m (width, height)
- Sampling rate 25 - 1200Hz
- Recording time unlimited (AC adapter), 30 minutes (batteries)
- Accuracy spatial coordinates ≤ 1 mm
- Full synchronisation capability with 3rd party devices

Potential Applications

- Measuring kinematics in cadaver experiments (e.g. in combination with shoulder simulator).
- To be used as reference standard to analyse the accuracy of new measurement systems and applications (e.g. Kinect, Smartphones).

Xsens Biomech Awinda

Description

Wireless Motion Capture System with advanced biomechanical model to calculate angle/orientation, acceleration and position of 22 joints and 23 body segments, including real-time visualisation and data export (latency 30ms). May be worn under clothing, and is particular suitable for prolonged kinematic analysis in field settings.

Specifications

- Up to 18 IMUs (3d Accel, Gyro, Magnetometer)
- Recording area up to 100 meters (diameter)
- Sampling rate 1000Hz, update rate up to 120Hz
- Recording time up to 6 hours (full body model)
- Static Accuracy: Roll/Pitch 0.2°, Yaw 0.5°
- Accuracy spatial coordinates <2%
- Full synchronisation capability with 3rd party devices

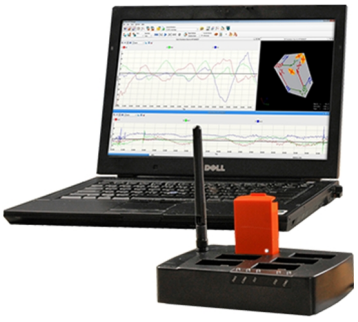
Potential Applications

- Physical activity measurements at the office workplace.
- Gait and sprint analysis in field settings.

Xsens MTw Development Kit

Description

Wireless motion tracker set with sensor fusion algorithms to ensure a highly accurate, drift-free output of 3d inertial data with precise inter-tracker synchronization. Including intuitive software for real-time visualization, easy logging and export function (MT Manager and Software Development Kit).



Specifications

- 7 IMUs (3d Accel, Gyro, Magneto- and Barometer)
- Recording area up to 100 meters (diameter)
- Sampling rate 1800Hz, update rate up to 120Hz
- Recording time up to 6 hours
- Static Accuracy: Roll/Pitch < 0.5°, Yaw < 1°
- Angular Resolution 0.05°
- Full synchronisation capability with 3rd party devices

Potential Applications

- Kinematic analysis of a particular kinematic chain in applied settings (e.g. hand, lower and upper arm during writing).
- To use kinematic data as input to control external devices (e.g. exoskeletons)

2. Electromyography Systems

Myon 320 EMG System

Description

Wireless Electromyography System for muscular signal capturing and processing in a broad sphere of applications with real-time function and very low latency (16ms). The signal is amplified and digitized before transmission to reduce motion artefacts. The software (proEMG, prophysics AG) makes processing EMG data simple and flexible, and allows to define processing routines.

Specifications

- 12 bipolar EMG electrodes
- Recording area up to 60 meters (diameter)
- Sampling rate max 4000Hz
- Recording time up to 10 hours
- Resolution 12-bit
- Full synchronisation capability with 3rd party devices

Potential Applications

- To perform muscle activity measurements with real-time biofeedback.
- To measure muscular activity synchronously with a motion capture system during activities of daily living.

Delsys Trigno EMG System

Description

Wireless Electromyography System to analyse muscular activity using surface electrodes with real-time processing and visualisation including real-time data export (latency: 48ms). Each sensor has a built-in tri-axial accelerometer. The additional processing software (EMGworks) allows for quick and easy signal processing including automatization function.

Specifications

- 16 four-pole EMG electrodes with 3d accelerometer
- Recording area up to 80 meters (diameter)
- Sampling rate 1926Hz
- Recording time up to 8 hours
- Resolution 16-bit
- Baseline Noise <0.5mV RMS
- Full synchronisation capability with 3rd party devices

Potential Applications

- To measure muscular activity (amount and timing) and acceleration while performing a one-leg balance test.
- Suitable for test measurements with complex sensor placement.

EMG-LommeLab: Pocket Lab for Biomechanics

Description

Wireless surface EMG sensors with Inertial Measurement Unit, HD video and real-time biofeedback. The system is via Bluetooth connected to a tablet running an Android App to record and analyse muscular activity, segment orientation (3d) and video. The application directly calculates typical EMG parameters (e.g. RMS, FFT, average value) and 3d orientation and allows exporting data to CSV.

Specifications

- Two bipolar EMG electrodes
- 9 degree-of-freedom Inertial Measurement Unit
- Video (full HD: 1080p, 30Hz)
- Recording area 20 meters (sensor-tablet distance)
- Sampling rate 1000Hz (10-480Hz passband)
- Recording time up to 6 hours (without power supply)

Potential Applications

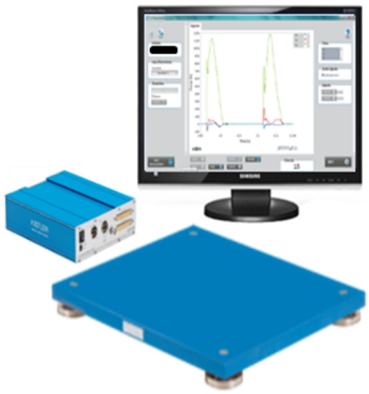
- Instant muscular measurements in explorative trials (pilot testing).
- To compare muscular timing with synchronized video in outdoor occasions.
- To estimate the proportion of type I and II muscle fibres from frequency spectrum during strength exercises.

3. Kinetic Measurement Systems

Kistler Force Platform 9260AA

Description

Mobile multicomponent force plate to record 3d ground reaction force and automated calculation of moments and centre of pressure. The platform has a built-in charge amplifier and is compatible with common motion capture and EMG systems, including scientific and rehabilitation/training software (BioWare and MARS).



Specifications

- 4 piezoelectric sensors
- Sensor range +5 kN (vertical), ±2.5 kN (horizontal)
- Recording area 600 x 500 mm
- Sampling rate max 10’000Hz
- Recording time unlimited (AC adapter)
- Response threshold <250 mN (vertical)
- Centre of pressure error ≤ 2 mm
- Full synchronisation capability with 3rd party devices

Potential Applications

- To measure 3d peak force at heel strike while jogging.
- To track the centre of pressure in a one-leg balance test.

Tekscan Pressure Mat DualCONFORMat #5330

Description

Mat for pressure measurements on complex, deformable surfaces. Due to the high spatial resolution suitable for recording pressure profiles with small contact areas. Research software for real-time data visualisation and analysis, as well as export function to Matlab file. Including additional calibration and equilibration device. Including additional pressure mats for in-shoe gait analysis.

Specifications

- 2 times 1024 electronic sensors (resistive)
- Recording area 2 times 470 x 470mm
- Sensor thickness < 0.8mm
- Measuring range 1-34 kPa (0.1-3.4 N/cm2)
- Sampling rate max 100Hz
- Recording time unlimited (AC adapter)
- Full synchronisation capability with 3rd party devices

Potential Applications

- To record pressure profiles while sitting on different office chairs.
- To analyse pressure distribution of rehabilitation devices.
- To compare different running shoes regarding in-shoe pressure distribution and centre of pressure trajectory.

4. Indirect Calorimetry

Cosmed K5

Description

Wireless spiroergometer to analyse oxygen consumption and carbon dioxide production including airflow measurement with total energy expenditure calculation. The Omnia software allows conducting standardized performance tests. Device equipped with GPS transmitter and an inertial measurement unit.

Specifications

- Oxygen and Carbon dioxide sensor, airflow turbine
- Recording area unlimited (body worn, <800g)
- Mixing chamber or „breath-by-breath“ technology
- Recording time up to 4 hours without power supply
- IP 54 certified (weather-/sweat resistant)
- Typical accuracy 20 ml/min

Potential Applications

- To determine VO_{2max} (maximum oxygen uptake rate).
- To determine the resting energy expenditure (REE).
- To compare energy consumption in different office work tasks.

Key References

1. Baumgartner D, Tomas D, Gossweiler L, Siegl W, Osterhoff G, and Heinlein B (2014). Towards the development of a novel experimental shoulder simulator with rotating scapula and individually controlled muscle forces simulating the rotator cuff. *Med Biol Eng Comput. 52*(3):293-299.

2. Hoppe S, Loosli Y, Baumgartner D, Heini P, and Benneker L (2014). Influence of screw augmentation in posterior dynamic and rigid stabilization systems in osteoporotic lumbar vertebrae: a biomechanical cadaveric study. *Spine (Phila Pa 1976). 39*(6):E384-389.

3. Kuster R P, Scheuner E, Ameti S, Denzler D, Textor D, Rast F and Heinlein B (2015). Assistive System to regain functional motivity of the shoulder. Article in German. *VDE Verlag GmbH Berlin-Offenbach*, ISBN 978-3-8007-3901-1, 83-88.

4. Moor B, Kuster R P, Osterhoff G, Baumgartner D, Clement W M, Zumstein M A, and Bouaicha S (2016). Inclination-dependent changes of the Critical Shoulder Angle significantly influence superior glenohumeral joint stability. *Clinical Biomechanics (Bristol, Avon). 32*:268-273.

5. Kuster R P, Heinlein B, Bauer C M, and Graf E S (2016). Accuracy of KinectOne to quantify kinematics of the upper body. *Gait&Posture. 47*:80-85.

6. Kuster R P, Bauer C M, Oetiker S, and Kool J (2016). Physiological motion axis for the seat of a dynamic office chair. *Human Factors. 58*(6):886-898.

7. Koller T and Baumgartner D (2017). Automated two-point discrimination (TPD) for phantom pain: Effect of a 3-week automated therapy based on TPD for a transtibial amputee with phantom pain. Article in German. *Schmerz. 31*(1):69-73.

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