

## Computer Assisted Orthopaedic Surgery with Individual Templates

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**INTRODUCTION:** The recent developments in the area of computer assisted surgery offer different technological solutions to translate the high geometric accuracy of the preoperative imaging and planning into a precise intraoperative execution /Taylor96/. But the analysis of tasksequences of the surgical team in the course of typical conventional orthopedic interventions shows, that the overall time spent in activities with some relevance of exact spatial orientation, only take about 10-15% of the total operating time. Additional time needed for the interaction with complex technical systems and for additional registration of bone structures can be tolerated only to a very limited amount. Problems also arise due to the overall costs of the sensor- or robot-based systems, the spatial arrangement of displays, sensors and robot systems within the operating room and mismatches regarding aspects of cognition and manual control.

**GOAL:** Development of a low-cost and easy-to-use technical solution for CT-image based 3D-planning and execution of work on bone structures.

**METHOD:** In orthopedic surgery standard templates are very familiar technical means for the guidance of tools. However, in general the spatial position of these toolguides in relation to the bone structure cannot be exactly defined and reproduced according to the individual preoperative planning (Fig. 1). Individual templates are customized on the base of 3D-reconstructions of the bone structures extracted from CT-image data and depending on the individual preoperative surgical planning. For the preoperative customization of these mechanical toolguides, a desktop computer controlled milling device is used

as a „3D-printer“ to automatically mould the shape of small reference areas of the bone surface into the body of the template. Thus the planned position and orientation of the toolguide in spatial relation to bone is stored physically and can be reproduced intraoperatively by simply putting this individual template with its customized contactface formclosed on bone without the need of any additional intraoperative computerized equipment or waste of time. Mechanical tool-guides for drills, saws, chisels or milling tools are adaptable or integrated into these individual templates for different types of interventions.

This approach has been demonstrated for different applications:

- pedicle screw fixation
- puncture of a cystic cavity in femoral bone
- intertrochanteric repositioning osteotomy
- reference osteotomies for TKR
- triple-osteotomy of pelvic bone (TÖNNIS)
- open-door decompression (HIRABAYASHI) in cervical spine
- transcorporal decompression in cervical spine
- decompression in lumbal spine (SENEGAS)
- shaft preparation for THR.

**CLINICAL APPLICATION:** We proposed the periacetabular repositioning osteotomy for the therapy of hip dysplasia as an exemplary clinical application for image guided orthopedic surgery using individual templates. In acetabular dysplasia the task is to enlarge the weight-bearing part of the acetabulum covering the femoral head in order to reduce the pressure in this area to physiological limits. We use the technique according to TÖNNIS (/Tönnis 84, 94/). Therefore the acetabulum has to be mobilized by three osteotomies, which have to be performed in defined position and orientation in relation to the acetabulum. A short distance from the acetabulum bears a higher risk of avascular necrosis. On the other hand if the acetabular fragment becomes too large the free rotation may be impeded. For the exact manipulation and repositioning of the acetabulum two Schanz' screws are fixed on bone.

In the framework of the EU-project IGOS (EC, DGXIII, TAP Project No. HC1026 HC) we build up a demonstrator for clinical routine. It consists in an integrated low-cost PC-based 3D-planning and NC-manufacturing system. The task sequences of a computer based planning session are subdivided into sections for diagnosis, planning of osteotomies and bores, simulation and biomechanical analysis and the definition of a contactface. At the beginning of a planning session, the surgeon selects the type of intervention and the specific surgical technique. After this selection he is guided along the subsequent steps of surgical planning according to established surgical guidelines and handbooks. After the definition of adequate contact faces, the relating individual templates are customized automatically.

The clinical evaluation of this new integrated system (since August 1997) showed very promising results concerning both, the enhanced possibilities of the 3D-planning system (optimisation of the cutplanes for an optimal rotation and preoperative analysis of the possibilities to manipulate and fix the acetabular fragment; 3D-analysis of the coverage of the femoral head) as well as the accurate intraoperative reproduction of planned geometries and very intuitive intraoperative handling of the individual template device.

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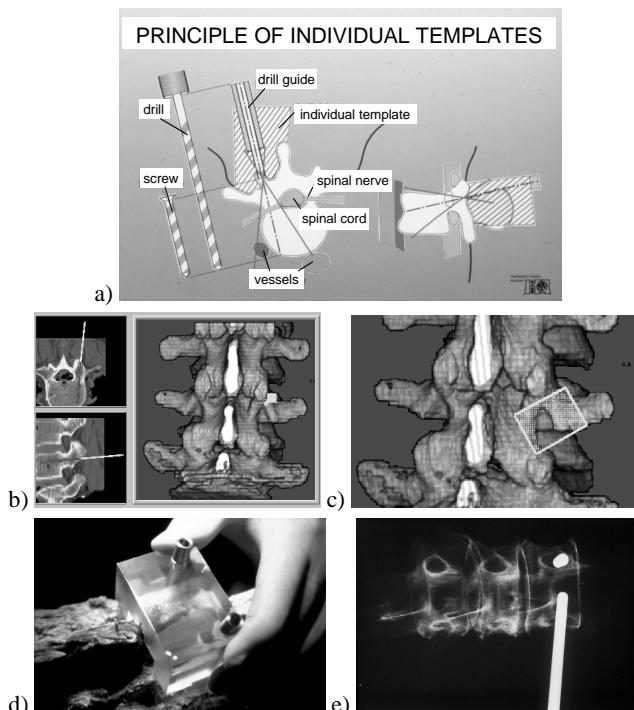
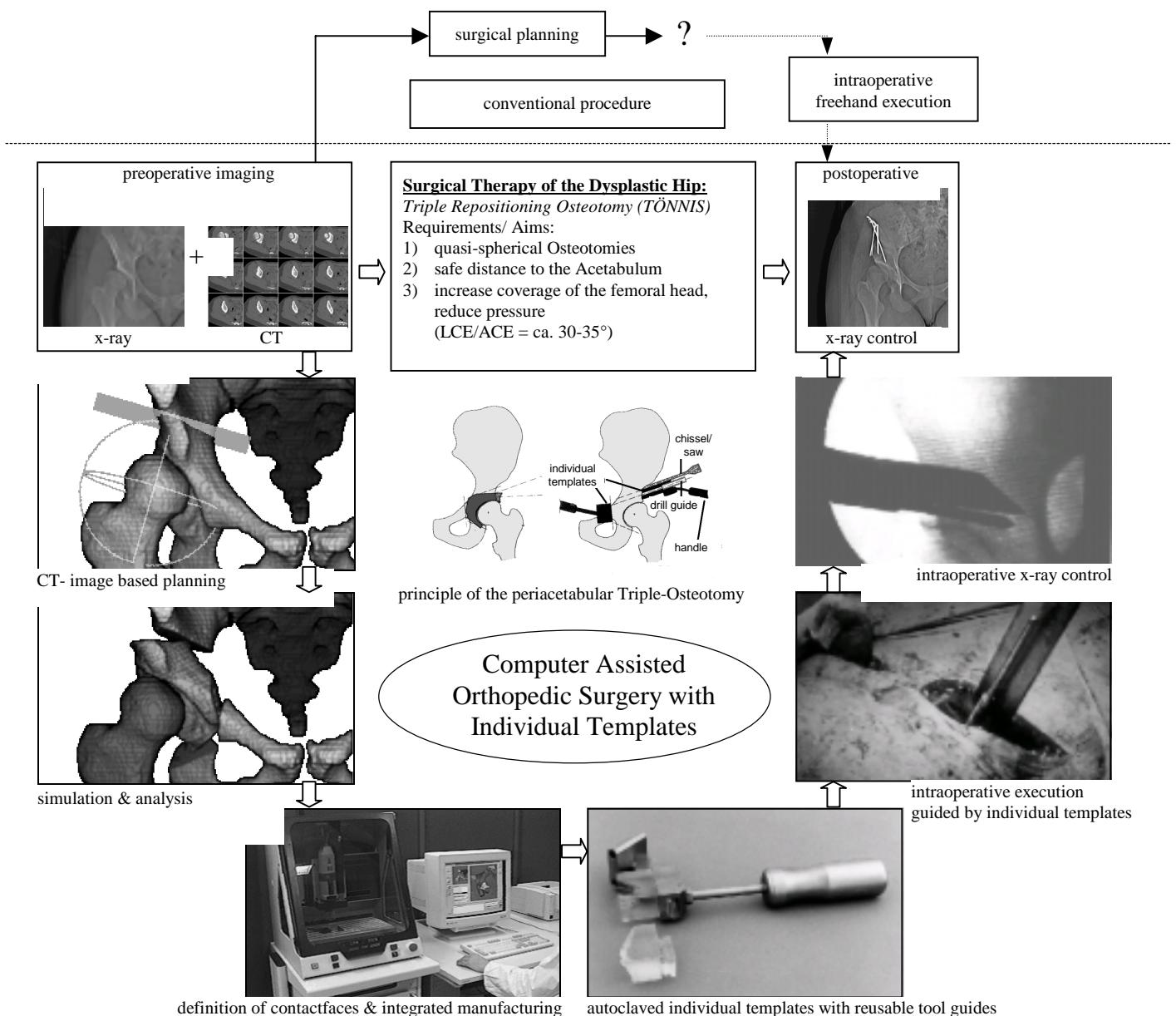


Fig1: Principle of Individual Templates -Example: Spine Surgery - Guidance of a pedicle screw placement: a) the principle, b) computer assisted planing with the DISOS planning system c) interactive definition of the reference contact face, d) formclosed intraoperative fitting of the template (preservation of the periost), e) x-ray control of the placement of 5 mm rods in the pedicles without any perforation in situ

# - Clinical Application to Periacetabular Repositioning Osteotomies -



## Steps of the Procedure:

- A) preoperatively:**
- CT-scan and data transfer
  - I. 3D-reconstruction & -analysis
  - II. surgical planning & -simulation
  - III. definition of the contactfaces
  - IV. automatic NC-toolpath programming
  - V. autom. computer controlled milling (I.-III. ca. 5-15 Min.; IV.-V. ca. 10-20 Min.)
  - autoclavation (e.g. 135°C; 5-20 Min.)
- B) intraoperatively:**
- conventional surgical entrance
  - VI. formclosed Fitting of the Individual template on the bone (optional: x-ray control)
  - VII. work on bone structure guided by the individual template according to the preoperative planning

## Characteristics:

- + precise preoperative 3D-planning & analysis
- + precise intraoperative execution
- + accuracy better than 1 mm or 1°
- + conventional intraoperative procedure
- + easy and intuitive handling
- + conventional toolguide systems (e.g.TKA) can be adapted
- + no additional intraoperative equipment
- + no additional intraoperative registration
- + no additional space needed in the OR
- + reduction of the time for intervention
- + no iterative adjustment work under intraoperative x-ray control
- preoperative CT-imaging required
- preoperative planning necessary
- in general no percutaneous application possible (except e.g. dental surgery)

## Actual Research:

- specific tools for planning and simulation for different interventions
- advanced 3D-based analysing tools
- ergonomic user-guidance, interface design and evaluation
- models for efficient biomechanical analysis
- context dependent segmentation techniques
- MR-image processing
- a-priori analysis of contact faces
- development of tool guides and adapter systems for different interventions
- evaluation of positioning accuracy
- clinical evaluation
- development of new surgical strategies based on the individual template technique
- Integration of new types of interventions (THA, TKA, spine,...)

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