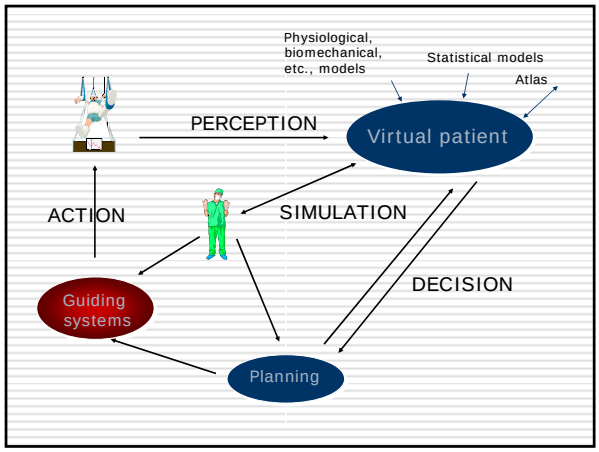
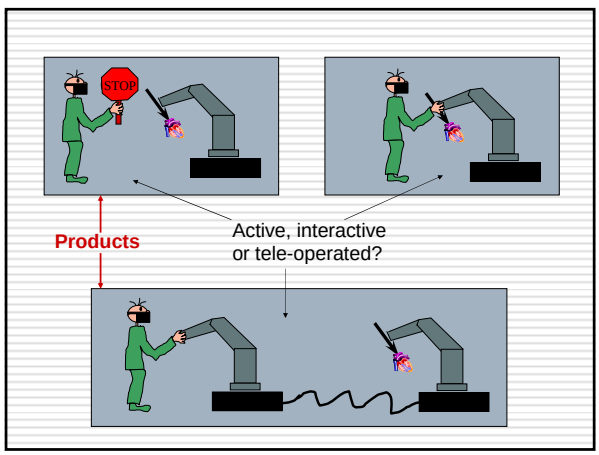
Guiding systems

Examples



A classification

- *Passive* systems
  - give information to the surgeon
- *Active* systems
  - realize the intervention with human supervision
- *Interactive* systems: mechanical guides
  - Semi-active devices
  - Synergistic devices
- *Teleoperated* devices



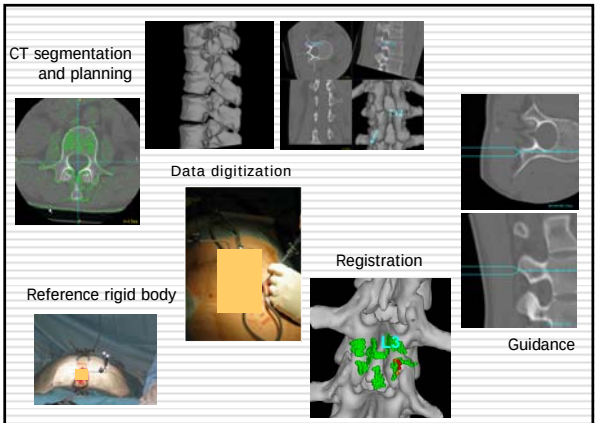
Passive systems

- Three components
  - a localization device
    - 3D localizer, surface sensor,
    - intra-operative imaging sensors (microscopy, endoscopy, interventional MR, etc.)
  - a registration component (optional)
  - a display (2D, 3D screen, 3D HMD, etc.)
- Well-suited to « simple » tasks
- Commercially available (neurosurgery, ortho [spine, knee, hip], ENT)

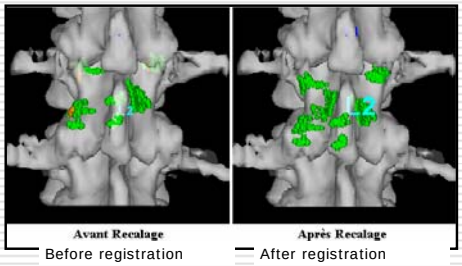
Navigation in the CT data

- Pre-operatively: CT data acquisition and surgical planning
- Intra-operatively: intra-operative data acquisition and registration, guidance
- Post-operatively: evaluation

- Most used type of system

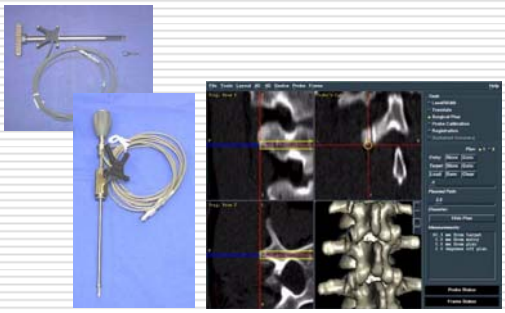


Data registration



Before registration — After registration

Navigation system



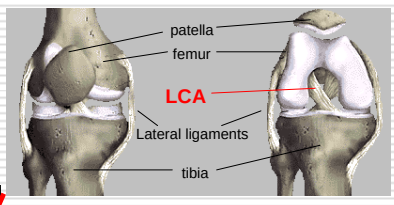
Purely intra-operative data navigation

Examples:

- Ligamentoplasty of the knee
- Total Knee Arthroplasty
- Virtual Fluoroscopy

Ligamentoplasty of the knee

Knee anatomy



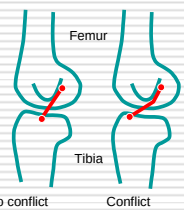
The cruciate ligament is the most broken in knee pathology

Its reconstruction targets obtaining a normal kinematics

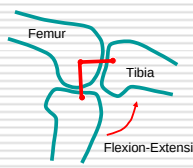
Dr. R. Julliard, S. Lavallée, V. Dessene, M. Fleute, et al.

Criteria for clinical results

- Choice of the insertion points of the graft
- Avoid conflicts with anatomical structures



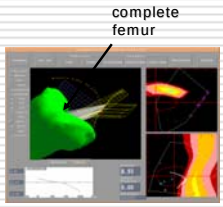
- Orientation of the tibial and femoral tunnels, length of these tunnels
- Fixation of the graft
- Nature of the graft

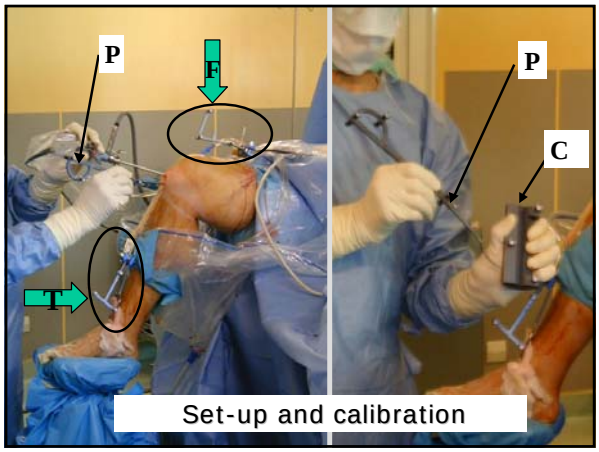


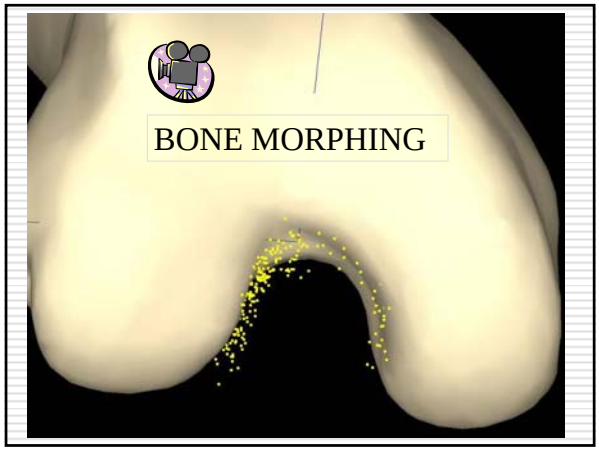
Computer Assisted Ligamentoplasty

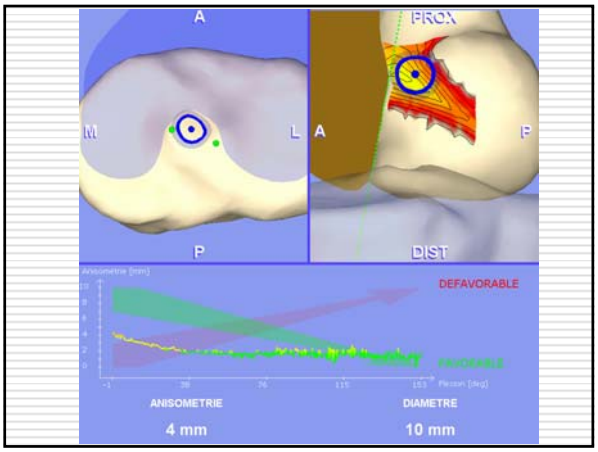
1992

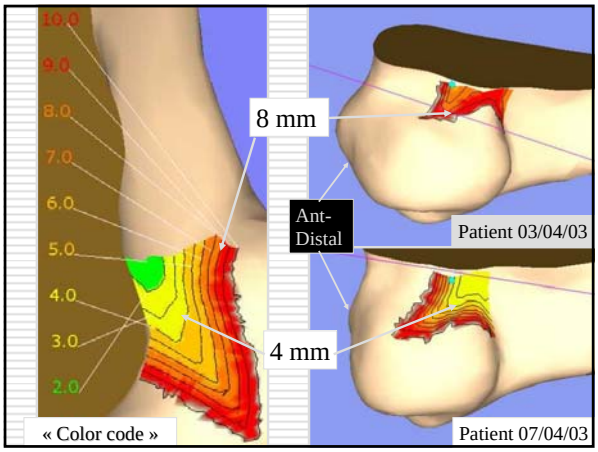
- Acquisition of the points under arthroscopic control











Status

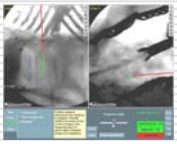
- EC marked product
- Developed in Grenoble (R.Julliard Clinique Mutualiste, S. Plaweski CHU Grenoble) – TIMC – PRAXIM
- Learning curve: about 20 knees for a surgeon to feel comfortable with the system
- Extra time: about 10mn

Virtual Fluoroscopy

- Context: screw fixation (spine), nail locking (femur fractures) under fluoroscopic control
- Objectives: to reduce X-Ray dose to the surgeon and to the patient
- Mean: to superimpose screw position on pre-recorded calibrated X-Ray images via a localizer

Virtual fluoroscopy

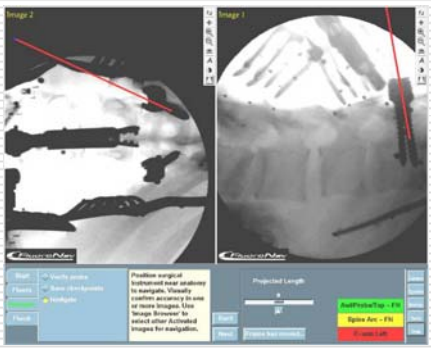
Image acquisition
(calibrated XRays)



Navigation

Virtual Fluoroscopy

Pr. P. Merloz, C. Huberson, SDG-Medtronics



Pedicle screw placement

CT-based Navigation

Fluoroscopy-based Navigation

Stealth Station
(Medtronic/Sofamor-Danek)

FluoroNav
(Medtronic/Sofamor-Danek)

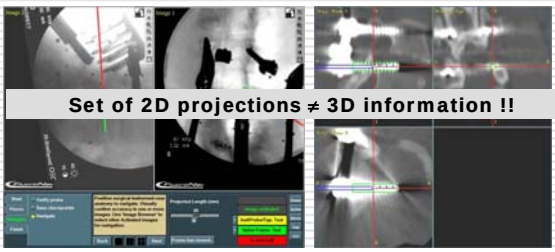
Clinical results (overall)

With *FluoroNav*	With *CT-based*
- **13** patients; **40** pedicle screws	- **56** patients; **130** pedicle screws
→ **15** % (6/40) of misplaced screws (cortex penetration >2 mm)	→ **10** % (**13**/130) of misplaced screws (cortex penetration >2 mm)

Clinical results (pathology)

With *FluoroNav*	With *CT-based*
Scoliosis:	Scoliosis:
- **5** patients; **10** pedicle screws	- **24** patients; **62** pedicle screws
→ **30** % (3/10) of misplaced screws	→ **13** % (8/62) of misplaced screws
Fractures, spondylolisthesis, …	Fractures, spondylolisthesis, …
- **8** patients; **30** pedicle screws	- **32** patients; **68** pedicle screws
→ **10** % (3/30) of misplaced screws	→ **7.5** % (5/68) of misplaced screws

FluoroNav : 15 year old female patient with scoliosis



Set of 2D projections ≠ 3D information !!

Intraoperative trajectory = OK !

Postoperative result = misplaced screw!

FluoroNav vs CT-based

FluoroNav :

+ No preoperative Imaging required

+ Less radiation for patient and staff

+ No intraoperative registration required

- Pseudo-axial view is missing (no real 3D information)

CT-based :

+ No intraoperative irradiation

+ Real 3D image information

- Time-consuming Registration (2 to 10 min with *Stealth Station*)

- Preoperative CT scan necessary

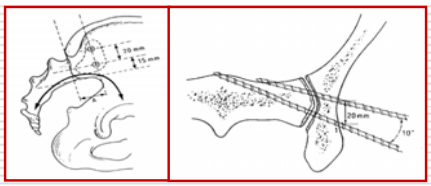
- Possible anatomical modification between preoperative CT scan and surgery not taken into account by system.

Lesson n° 1

- No ideal system
- Depends on the application
- Requires:
  - Careful specifications
  - Careful evaluation

Pelvis surgery

- Percutaneous osteosynthesis for sacro-iliac disjunction



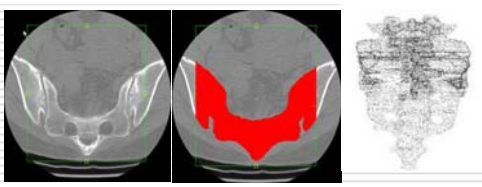
- Avoid extra-osseous trajectories and related morbidity

The approach

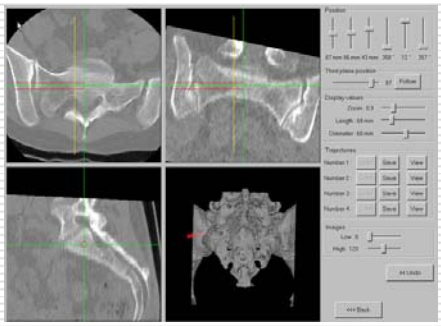
- CT pre-operative acquisition
- Image segmentation (3D model) and planning
- Intra-operative US acquisition (US images localized in space)
- Automatic registration
- Guidance using passive navigation

- Description of laboratory prototype and validation

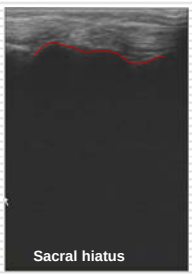
CT acquisition and segmentation

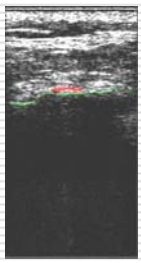


Planning



Echographic image segmentation





Version 1: manual segmentation
Version 2: automatic segmentation using a priori knowledge

US to CT registration

Guidance: ancillaries

Clinical evaluation (Dr Tonetti)

- 4 patients
  - 1 pseudarthrosis sacrum
  - 2 recent lesions sacrum
  - 1 bilateral arthrodesis (sacro-iliac)
- 3 women, 1 man
- Average age: 48,5 (37-71)
- 10 screws
- No pre-op neurological signs

Clinical trial



Non reflecting draping

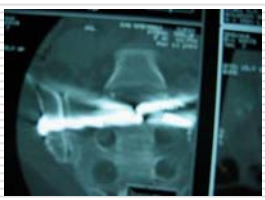
Passive guidance on a screen

Fluoroscopic control

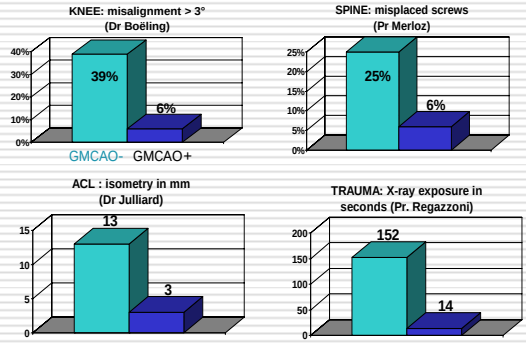
Results

Patients	n°1	n°2	n°3	n°4	Total	Mean
Age (years)	34	47	71	42		**48,5**
Screw number	2	2	2	4	**10**	
Operating time (mn)	120	105	120	240		**146**
Other gesture	yes	no	yes	yes	**3**	
Time for US acqui. + seg. (minutes)	20	26	30	20		**24**
Time for patient irradiation (minutes)	0,1	0,5	0,4	0,4		**0.35**
Voltage per patient (Kvolt)	68	75	89	80		**78**
Intensity per patient (mA)	3,1	3,2	3,1	3,1		**3,1**
Iatrogenic neurological lesion	0	0	0	0	**0**	
EVA 3 months	6	4	6	1		**4.25**
OMS 3 months	2	0	0	0		**0.5**
Majeed score 6 months	62	93	71	100		**81,5**

Four screws inserted

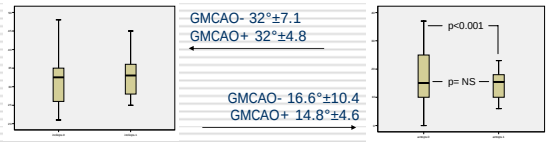



Results (more)



Clinical benefits (more)

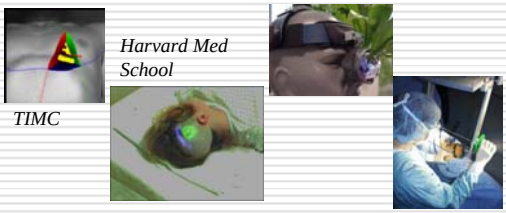
- Reducing the variability of results
- Example:
  - position of the acetabulum implant in THA
  - Objective: inclination=40°, anteversion=15°



[Parratte,Argenson07]

Augmented reality

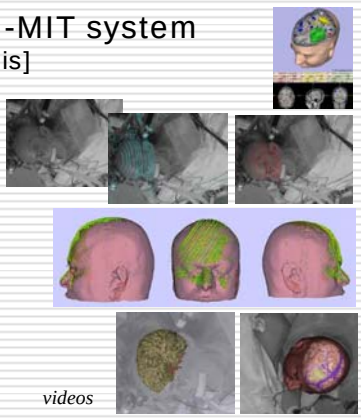
- For a better ergonomy and a more direct data interpretation
- Video overlay or see-through systems



Harvard Med School

TIMC

The Harvard-MIT system
[Grimson, Kikinis]



- Pre-operative MR imaging and 3D modelling
- Intra-operative surface acquisition (laser scanning) and registration
- Video overlay

videos

Fuchs' system (UNC)

- Ultrasound-guided punctures

2.5D echography acquisition and planning

Image overlay in the HMD