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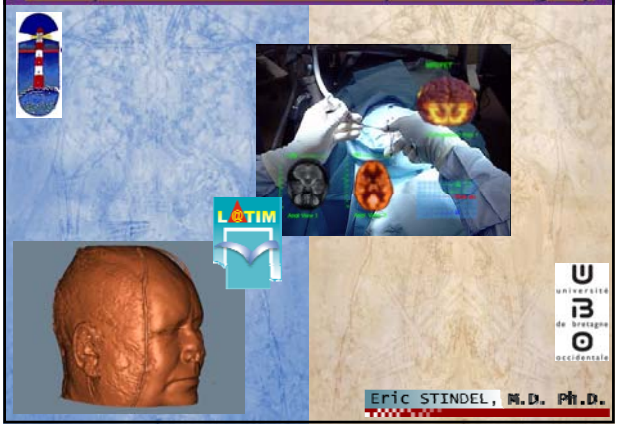

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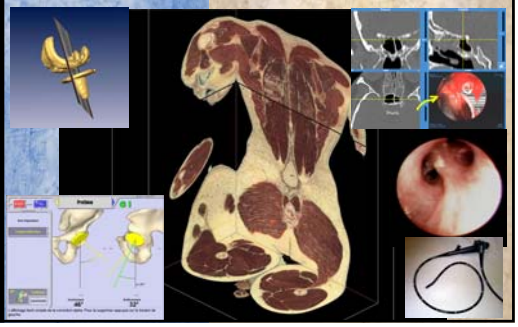
« Perform 3D actions in a 3D space on a 3D Object: a human being »



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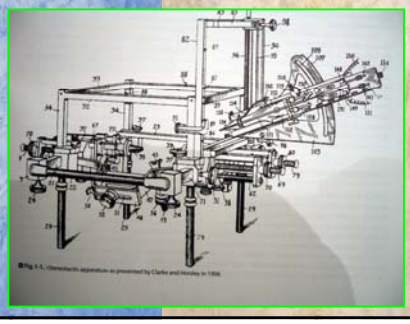
Neurosurgery

Frame based Stereotaxy : Clarke et Horsley - 1806



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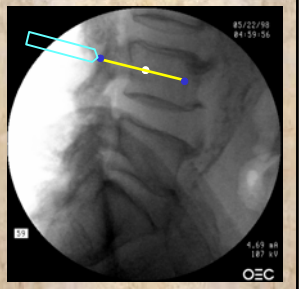
1990 1995 2000

Spine Surgery

Pedicular screwing



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1990 1995 2000

Robots for Hip

First generation : ROBODOC and CASPAR

Femoral drilling

Out of business

Cost

Invasiveness

No added value

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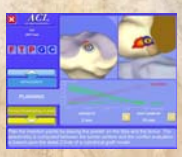
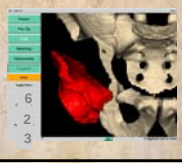
1990 1995 2000

Orthopaedic Surgery





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Basics

The Perception – Decision – Action loop

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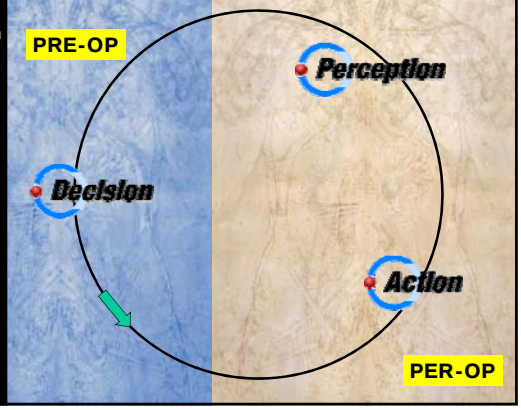

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Action

PASSIVE SYSTEMS
Navigation systems

Guiding systems

3D localizers

Real-time feed back on the location of :

-Therapeutic objects

- Surgical instruments

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Action

SEMI-ACTIVE SYSTEMS
The surgeon is guided in a restricted volume

Guiding systems

Padyc

Synergistic robots

Collaborative robots

Impeachment robots

http://www-timc.imag.fr/

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Action

ACTIVE SYSTEMS
Active robots which performs
Part of the surgical procedure

Guiding systems

Active robots

Perform parts of the procedure

Based on per-op planning

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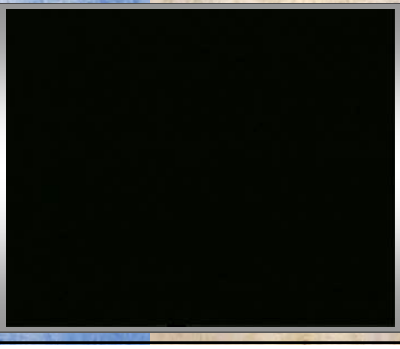

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3D Localizers

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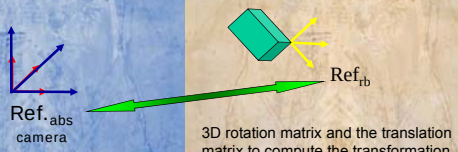
3D Localizers

Localization : non deformable Objects

- Bones or surgical tools
  - Location
  - Orientation



3D rotation matrix and the translation matrix to compute the transformation from Ref_{abs} to Ref_{rb}

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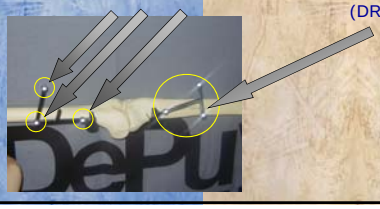
3D Localizers

Non deformable Objects

- Bony structures : therapeutic objects
- Surgical tools
- **Dynamic reference base** (DRB)



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3D Localizers

- **Dynamic reference base** (DRB)

Non deformable Objects

- DRB attached to :
  - Bony structures : therapeutic objects
  - Surgical tools

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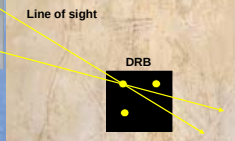
3D Localizers

Localizer = 1 Source + 1 Sensor

- Optical localizer with two 2 Dimensional sensors



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3D Localizers

Localizer = 1 Source + 1 Sensor

- Polaris :

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3D Localizers

Optical systems

- Infra-red sensors

Basics

Emitted by the DRB

Reflected by the DRB

Wave length **880 nm**

In the OR one can find
70 000 Lux
400 et 500 nm

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3D Localizers

Optical systems

- Active systems

Active emission of light
= source of energy

Drawbacks
- Cables on the operating field
- Batteries
- Weight
- Sterilization issues

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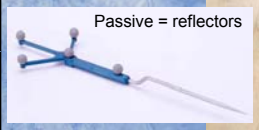
3D Localizers

Optical systems

- Passive system



Passive = reflectors

Drawbacks
- Single use
- Sensitive to surrounding light

Pros
- Cheap
- Light
- Can be set on any type of instrument

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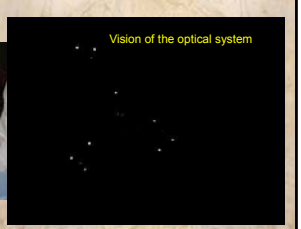
3D Localizers

Optical systems

- Vision of the camera

Surgical scene



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Application : TKA

40 000 TKA / Year / France

8 000 Uni / Year / France

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The challenges

- The challenges : two faces

•Geometric challenge
  •Align the implants with respect to mechanical axes

•Functional challenge
  •Perform a good ligament balance
  •Enough mobility
  •Enough stability

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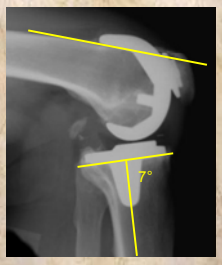
The challenges

- The challenges : two faces

•Mechanical axes :



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The challenges

- The challenges : two faces

•Geometric challenge
•Align the implants with respect to mechanical axes

•Functional challenge
•Perform a good ligament balance
•Enough mobility
•Enough stability

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The challenges

- Functional challenge

•Ligament balancing


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The challenges

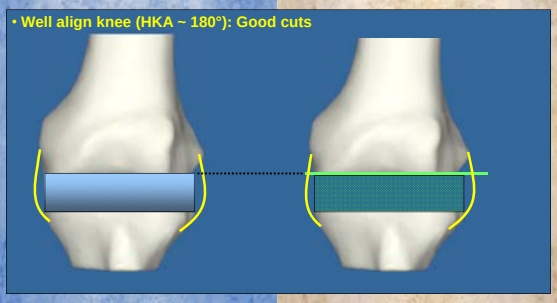
- Functional challenge

•Ligament balancing


•Lift-off = wear
•Instability

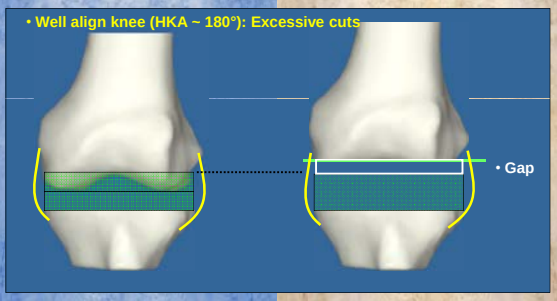
Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



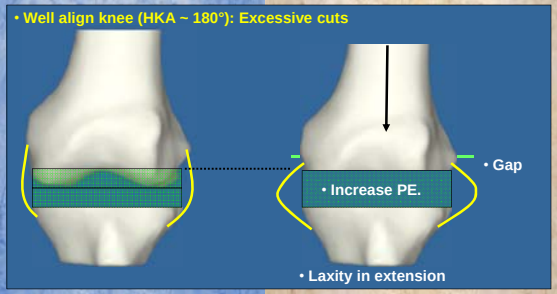
Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



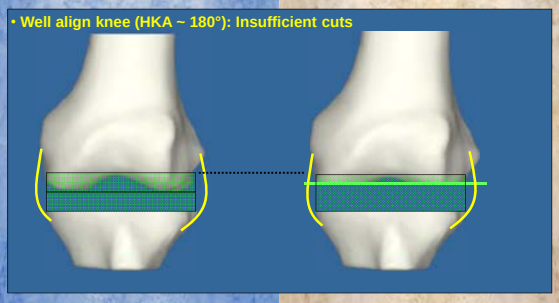
Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



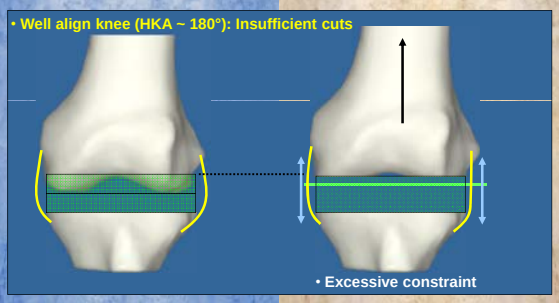
Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



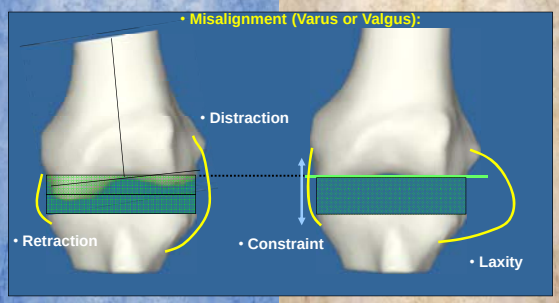
Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



Computer Assisted Orthopaedic Surgery

- Functional challenge
- Ligament balancing



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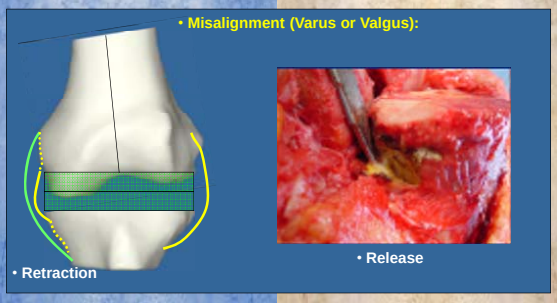
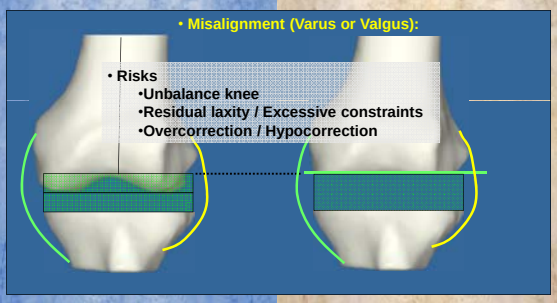
- Functional challenge
  - Ligament balancing



Computer Assisted Orthopaedic Surgery

- Functional challenge
  - Ligament balancing



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Application : TKA

The solutions

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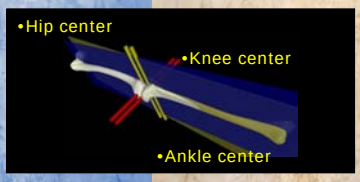
The solutions

Build a **SPECIFIC** model of the patient under surgery

- Build the specific GEOMETRY of this patient
  - Align the prosthesis with respect to the patient axes



- Localize **in 3D** the joint centers
- Build reference planes

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The solutions

Build a **SPECIFIC** model of the patient under surgery

- Build the specific MORPHOLOGY of this patient

Local adjustment to the bones
Ligament balance can only be made with local data

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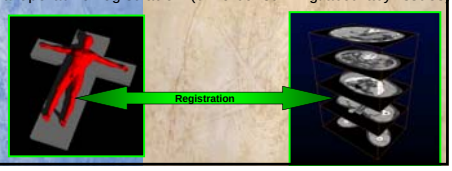
The solutions

Pros and Cons

- CT based approach
  - Pre-operative planning
  - Cost – Radio protection issues
  - Archiving and communication of images : PACS
  - No increasing time for acquisition and planning
- CT including Hip – Knee - Ankle
- Setup time
- Intra-operative registration (time consuming/accuracy issues)



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The solutions

Pros and Cons

- **Non image based system**
  - Simple
  - Low cost – No radiation
  - Integration of intra-operative data
  - No registration issue
- Increase the operative time

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Non image based

Perception

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Perception

- **No pre-operative images**
- Build a specific model of the patient : Acquisition

- Geometric data
  - Axes
    - Hip center
    - Knee center
    - Ankle center

- Morphologic data
  - Bone surfaces

- **Digitization of points with a 3D probe**


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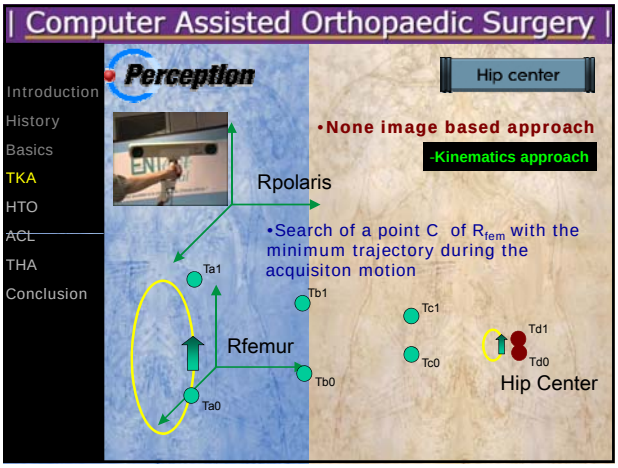
Hip center
•None image based approach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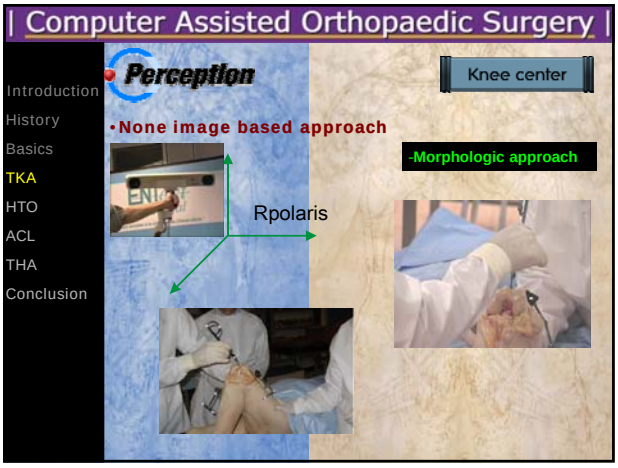
Hip center
•None image based approach
-Kinematics approach
Rpolaris
•Search of a point C of R_{fem} with the minimum trajectory during the acquisiton motion
Ta1
Tb1
Tc1
Td1
Rfemur
Tc0
Td0
Tb0
Ta0
Hip Center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•None image based approach
-Morphologic approach
Rpolaris

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Ankle center

•None image based approach

•Percutaneous digitization of points

-Geometric approach

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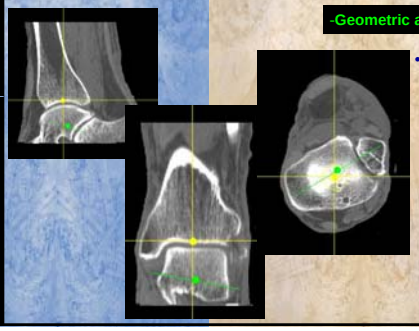
Ankle center

•None image based approach

-Geometric approach



•Error

•Slope

•Varus

•Valgus

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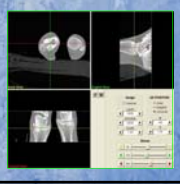
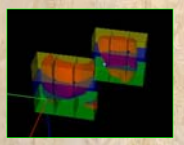
Ankle center

-Geometric approach





E. STINDEL, et Al., The center of the ankle in ct less based navigation system.
What is really important to detect?
CAOS Santa fee 19-22 Juin 2002.

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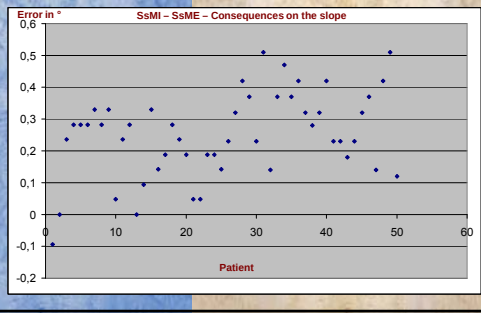
Ankle center

- **None image based approach**



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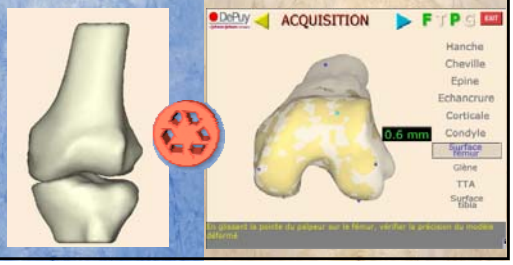
Morphology

- **Femoral and tibial shape : Bone morphing**
- Use of statistical deformable models



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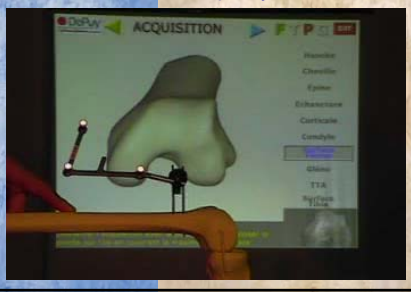
Morphology

- **Femoral shape : Bone morphing**
- Acquisition – Deformation – Quality control



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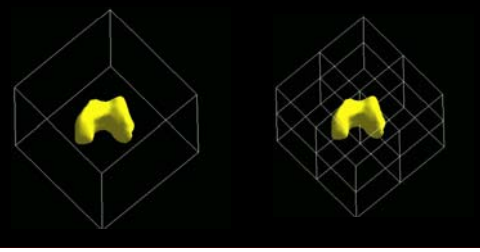
Morphology

- **Femoral shape : Bone morphing**
- Quadtree (Lavallée) : hierarchical division of the 3D volume to apply global and local deformation



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Non image based

Decision

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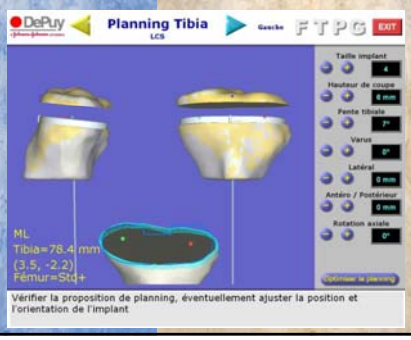
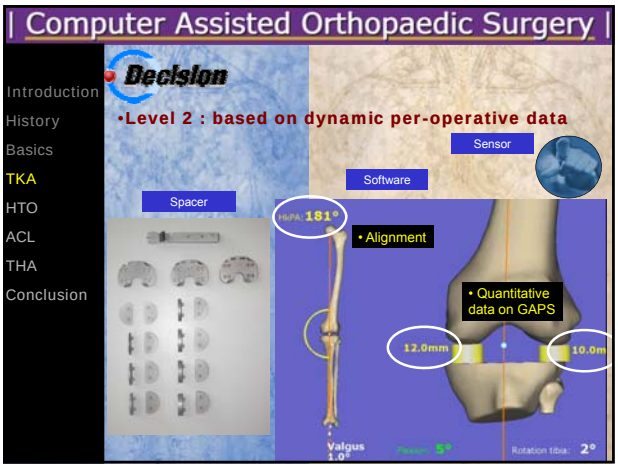
Decision

- **Level 1 : based on morphologic data**

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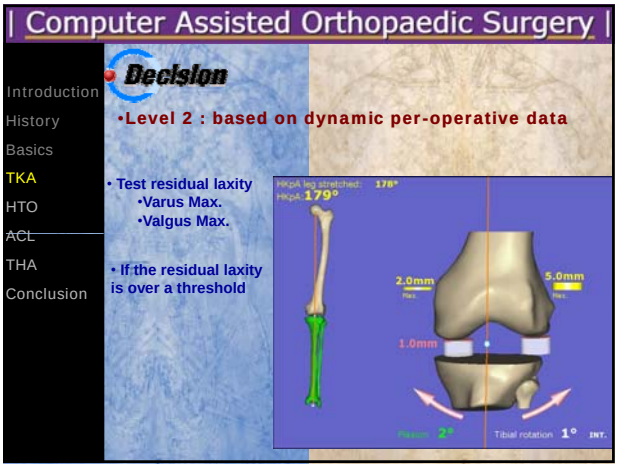
•Level 2 : based on dynamic per-operative data
Sensor
Software
Spacer
• Alignment
• Quantitative data on GAPS
12.0mm
10.0m
Valgus
Rotation tibia: 2°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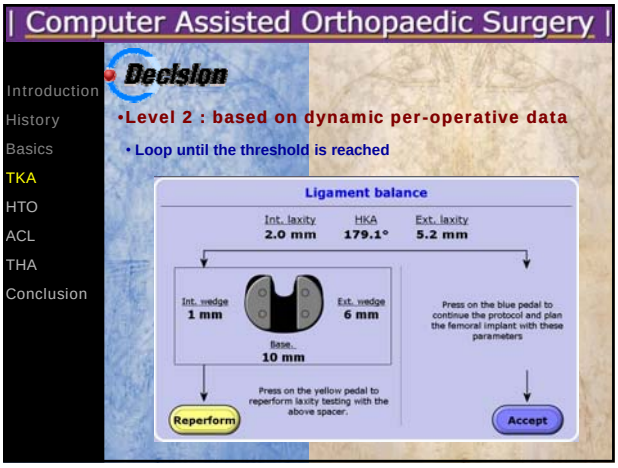
•Level 2 : based on dynamic per-operative data
• Test residual laxity
•Varus Max.
•Valgus Max.
• If the residual laxity is over a threshold
HKpA leg stretched: 178°
HKpA 179°
2.0mm
5.0mm
1.0mm
Flexion 2°
Tibial rotation 1° INT.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•Level 2 : based on dynamic per-operative data
• Loop until the threshold is reached
Ligament balance
Int. laxity 2.0 mm
HKA 179.1°
Ext. laxity 5.2 mm
Int. wedge 1 mm
Ext. wedge 6 mm
Base. 10 mm
Press on the blue pedal to continue the protocol and plan the femoral implant with these parameters
Press on the yellow pedal to reperform laxity testing with the above spacer.
Reperform
Accept

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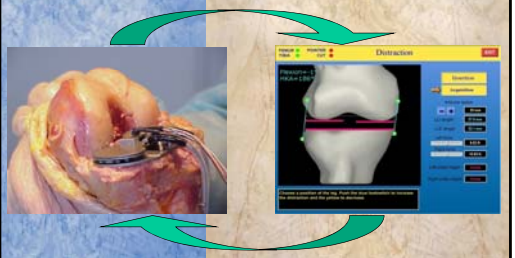
- **Level 2 : based on dynamic per-operative data**
  - Loop until the threshold is reached



- Courtesy of Christophe Marmignon and Philippe Cinquin – TIMC - Grenoble

Computer Assisted Orthopaedic Surgery

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- **Level 3 : Integration of quality control in the decision loop**

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- **Femoral planning**

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Non Image based

Action

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Action

Active system : robots

Passive system : navigation

- Freehand
- Tools are localized in the 3D space in real time with respect to the bones

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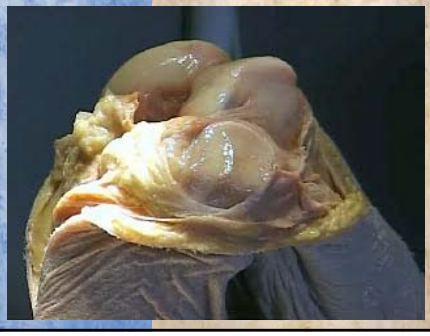
Action

- **Robotized cutting guides**



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•Robotized milling guides

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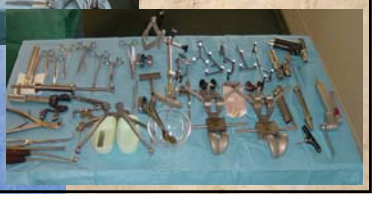

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Navigation of cutting guides

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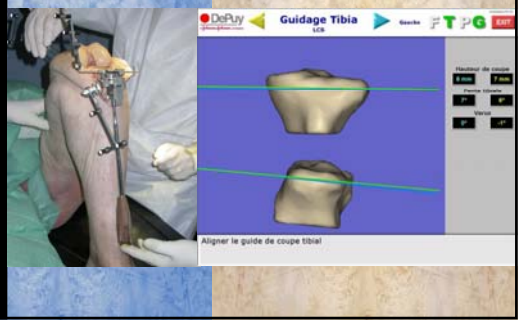
Navigation of cutting guides



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Application : HTO

7 000 cases / Year / France

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- Integration of bricks

-Hip center : Same brick

-Knee center : Specific solution

-Ankle center : Same brick

-3D Planning

Computer Assisted Surgical Protocol - CASP

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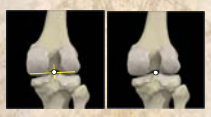
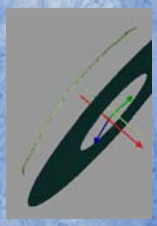
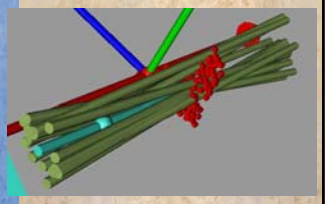
- **Knee center**
  - -No access to the joint
  - -Mixed approach
  - -Man / Machine synergy



SOMMER, H.J., Determination of first and second order instant screw parameters from landmark trajectories. Mechanical Design, 1990: p. 141-142.





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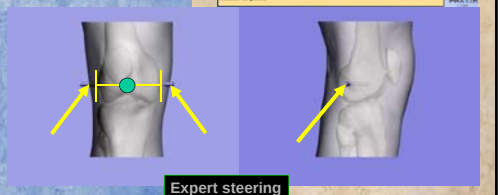
- **Knee center**
  - -No access to the joint
  - -Mixed approach
  - -Man / Machine synergy



Expert steering

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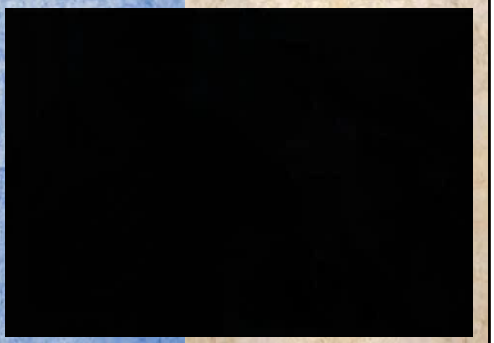
- **In the OR**



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Application : ACL

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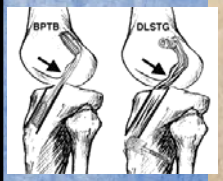
- **Anterior Cruciate Ligament Replacement**
  - **The challenges**
    - Isometry
    - Avoid impingement



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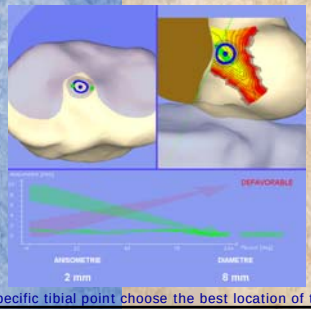
- **Anterior Cruciate Ligament Replacement**
  - **Planning**
    - Projection of the tibial point / Femoral notch projection
    - Compute the anisometry map



- For a specific tibial point choose the best location of the femoral point

Computer Assisted Orthopaedic Surgery

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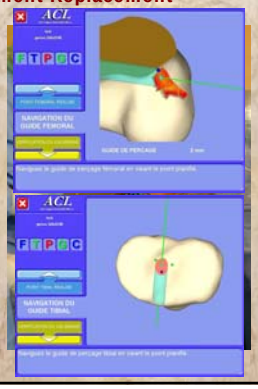
- **Anterior Cruciate Ligament Replacement**
  - **Action**
- Take the usual guide
- Attache a rigid body
- Perform the calibration
- Drill the tunnels with the help of the GUI



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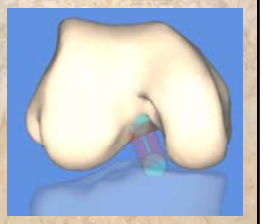
- **Anterior Cruciate Ligament Replacement**
  - **Impingement**



- Digitized the anterior fiber of the graft

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Application : THA

100 000 cases / Year / France

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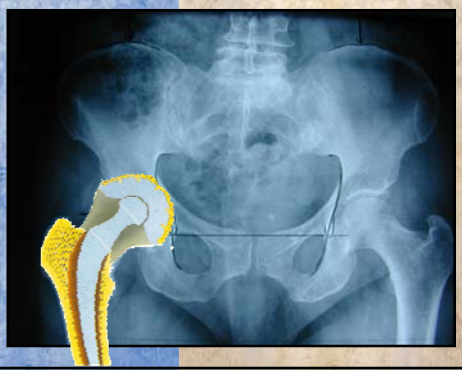
- Total Hip Arthroplasty



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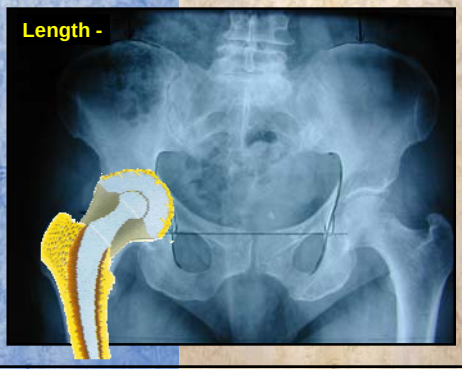
- Total Hip Arthroplasty



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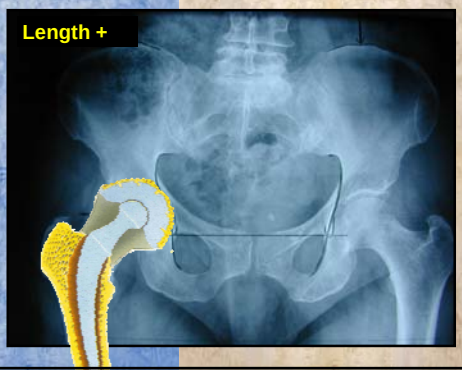
- Total Hip Arthroplasty



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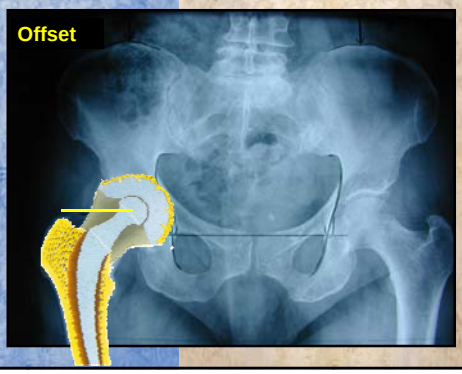
- Total Hip Arthroplasty



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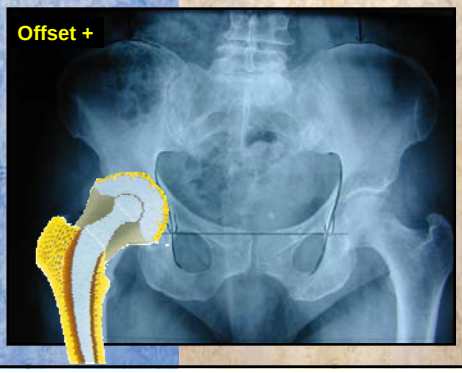
- Total Hip Arthroplasty



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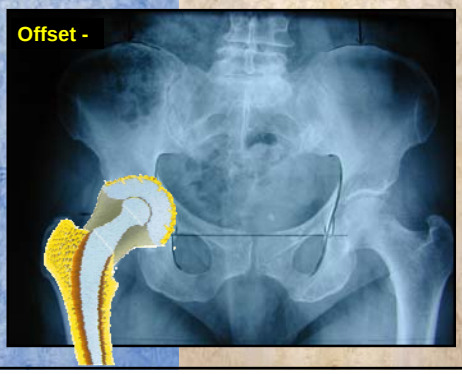
- Total Hip Arthroplasty



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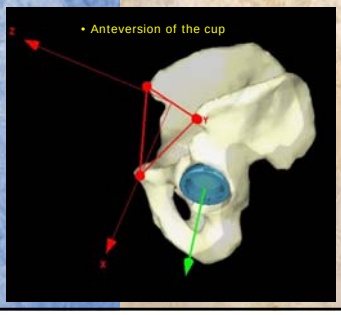
•Total Hip Arthroplasty

-Length	-Centre of rotation
-Offset	-Stability



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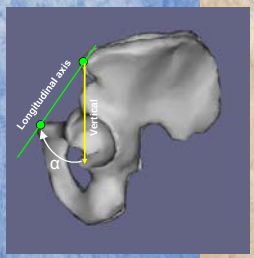
•Total Hip Arthroplasty

-Reference plane



- **Not an absolute reference**
- **Can be define on an X-Ray**
- **Change in supine position**
- **Influence anteversion values**

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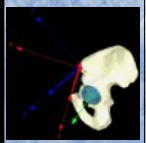
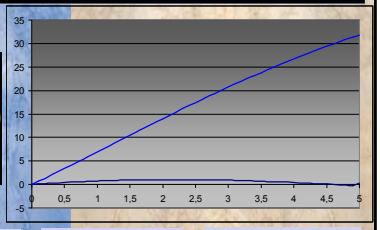
•Total Hip Arthroplasty

-Reference plane





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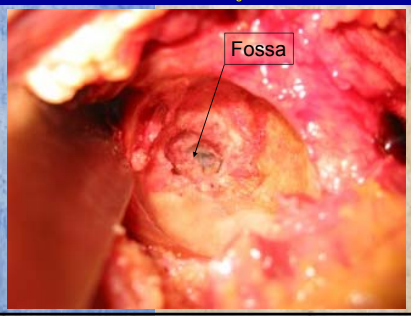
- **Total Hip Arthroplasty**

-Local bone morphing instead of global

- View of the acetabulum fossa before reaming



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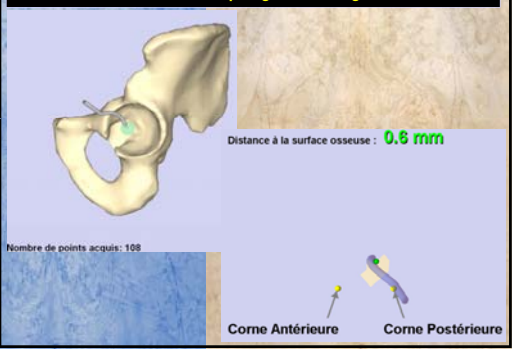
- **Total Hip Arthroplasty**

-Local bone morphing instead of global



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- **Total Hip Arthroplasty**

-Local bone morphing instead of global

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- Total Hip Arthroplasty

-Fine tunning of the implants

- Final hip center location

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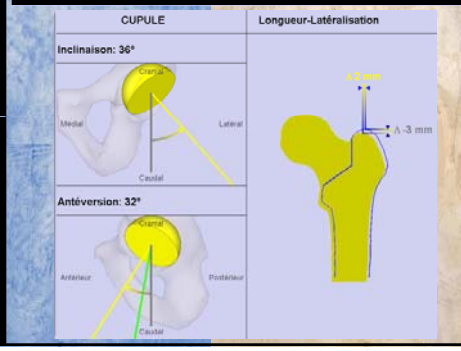
- Total Hip Arthroplasty

-Fine tunning of the implants



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