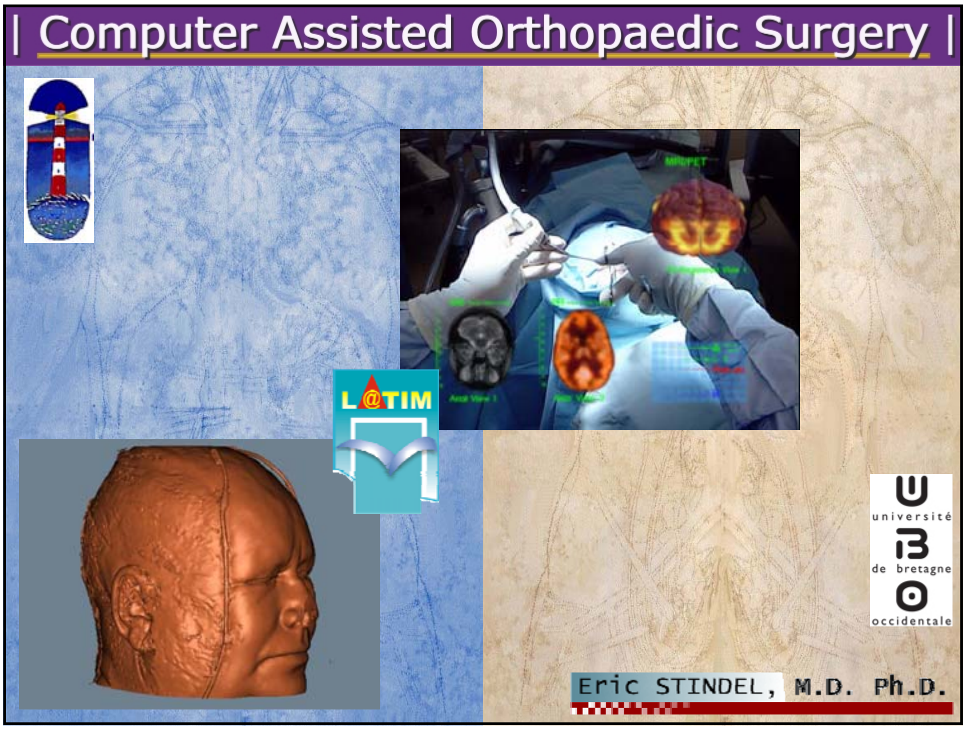

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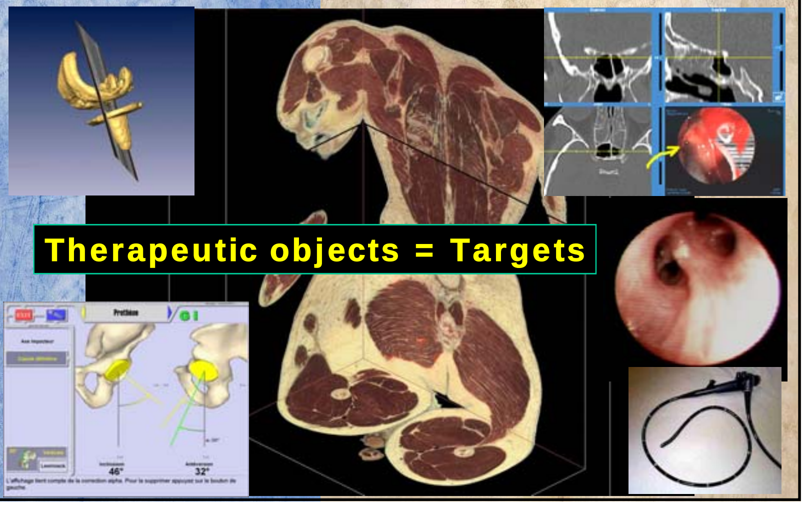
« Perform 3D actions in a 3D space on a 3D Object: a human being »



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History

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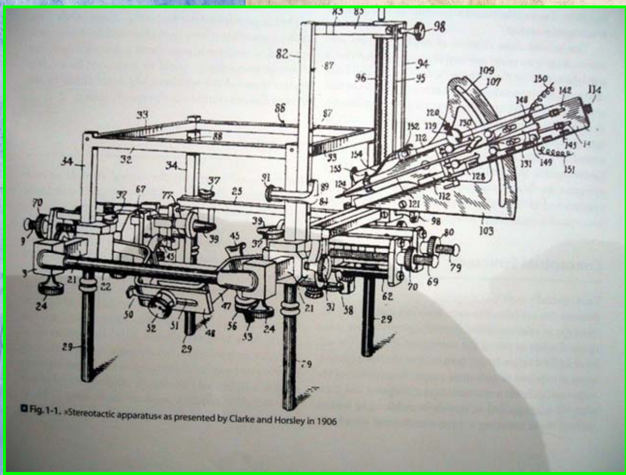
Neurosurgery

Frame based Stereotaxy : Clarke et Horsley - 1806



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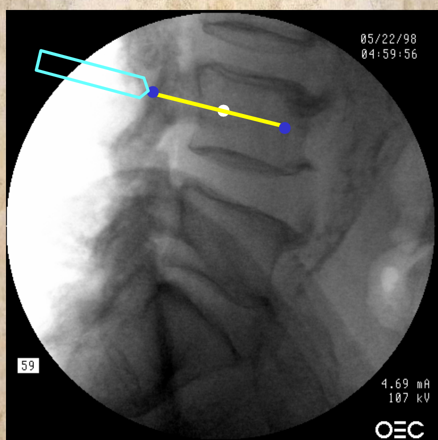
1990 1995 2000

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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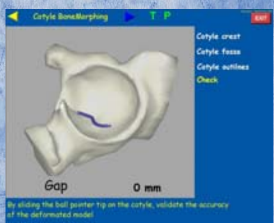
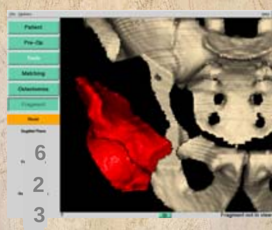
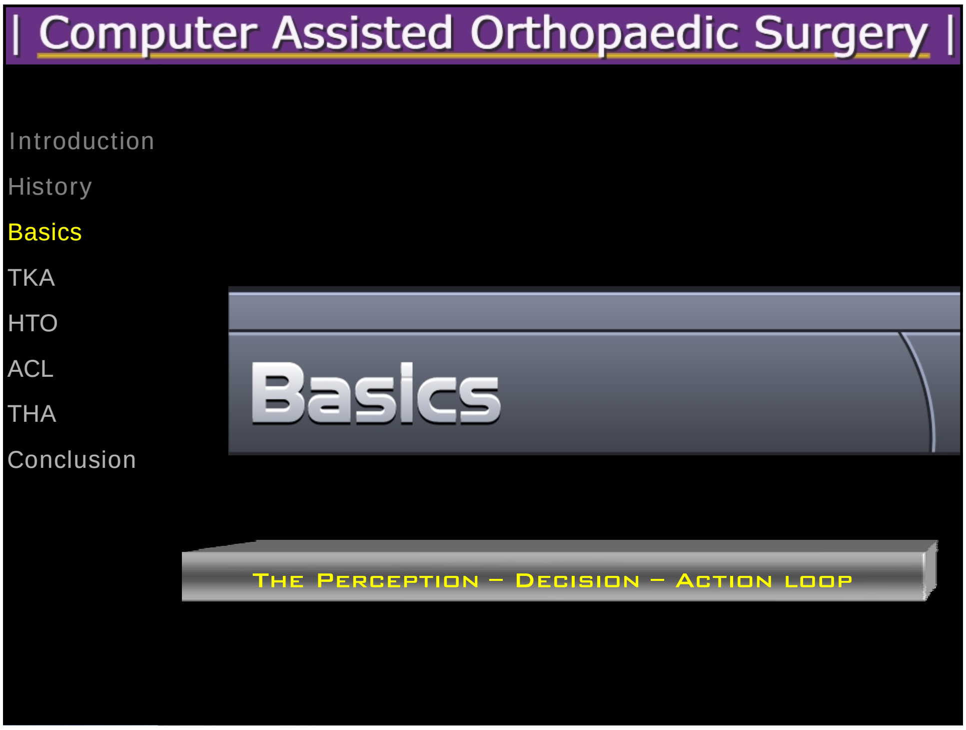
1990 1995 2000

Orthopaedic Surgery



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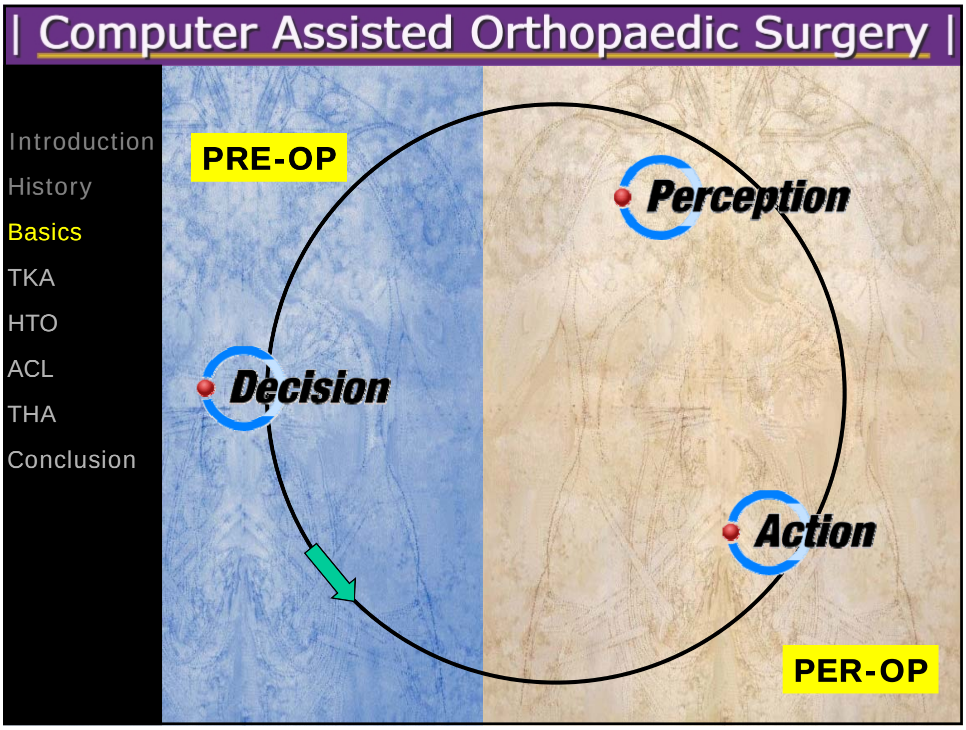
Basics
The Perception – Decision – Action loop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PER-OP

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Action

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Guiding systems

PASSIVE SYSTEMS
Navigation systems

3D localizers

Real-time feed back on the location of :

-Therapeutic objects

- Surgical instruments

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Guiding systems

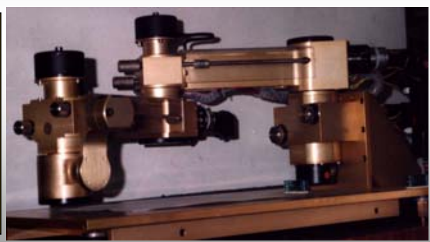
SEMI-ACTIVE SYSTEMS
The surgeon is guided in a restricted volume

Padyc

Synergistic robots

Collaborative robots

Impeachment robots



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

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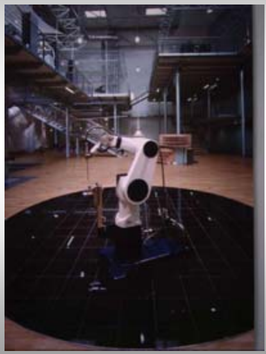
ACTIVE SYSTEMS
Active robots which performs
Part of the surgical procedure

Guiding systems

Active robots

Perform parts of the procedure

Based on per-op planning



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3D LOCALIZERS

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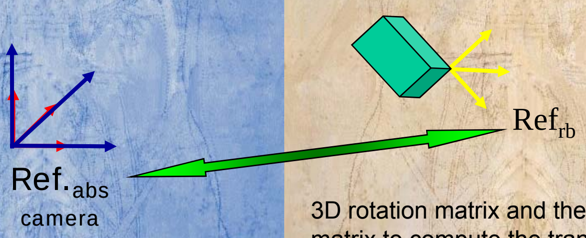
3D Localizers

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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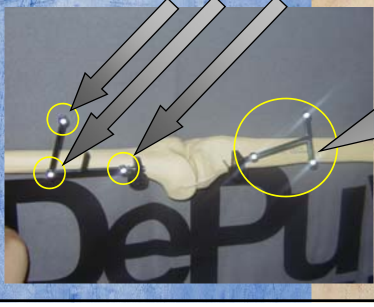
3D Localizers

Non deformable Objects

- Bony structures : therapeutic objects
- Surgical tools

- **Dynamic reference base** (DRB)



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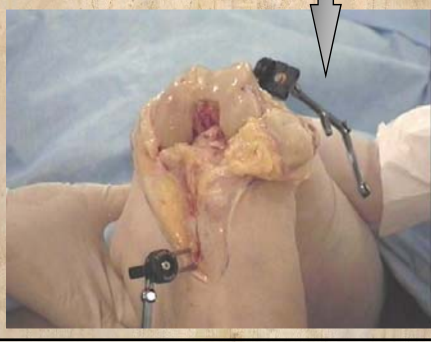
3D Localizers

- **Dynamic reference base** (DRB)

Non deformable Objects

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



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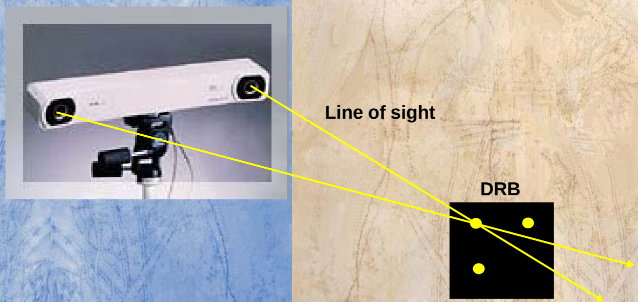
3D Localizers

Localizer = 1 Source + 1 Sensor

- Optical localizer with two 2 Dimensional sensors



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3D Localizers

Localizer = 1 Source + 1 Sensor

- Polaris :

POLARIS® - Technical Specifications

Accuracy	
0.35 mm 3D RMS(1)	
Workstation Interface	
Interface	RS-232/422
Max. Data Rate	115 kBaud
Position Sensor	
Weight	2 kg
Mounting	1/4" thread tripod mount
Dimensions	590 mm x 80 mm x 120 mm
enhanced Tool Interface Unit	
Weight	5 kg
Dimensions	320 mm x 130 mm x 300 mm
Power Requirements	
hybrid	100/120/220/240 V, 50/60 Hz, 2.5 A
passive	100-250 V, 50/60 Hz, 0.8 A

*Above weights and dimensions are approximate

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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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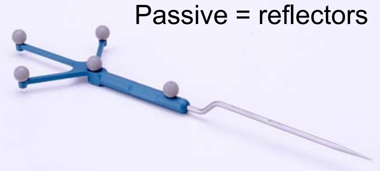
3D Localizers

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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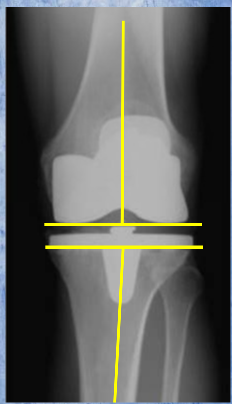
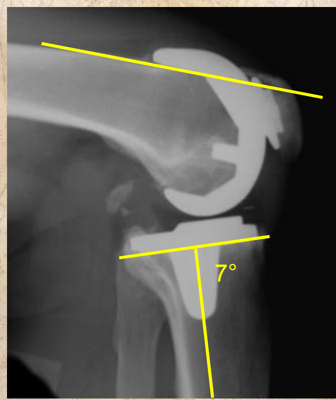
The challenges

- The challenges : two faces

•Mechanical axes :





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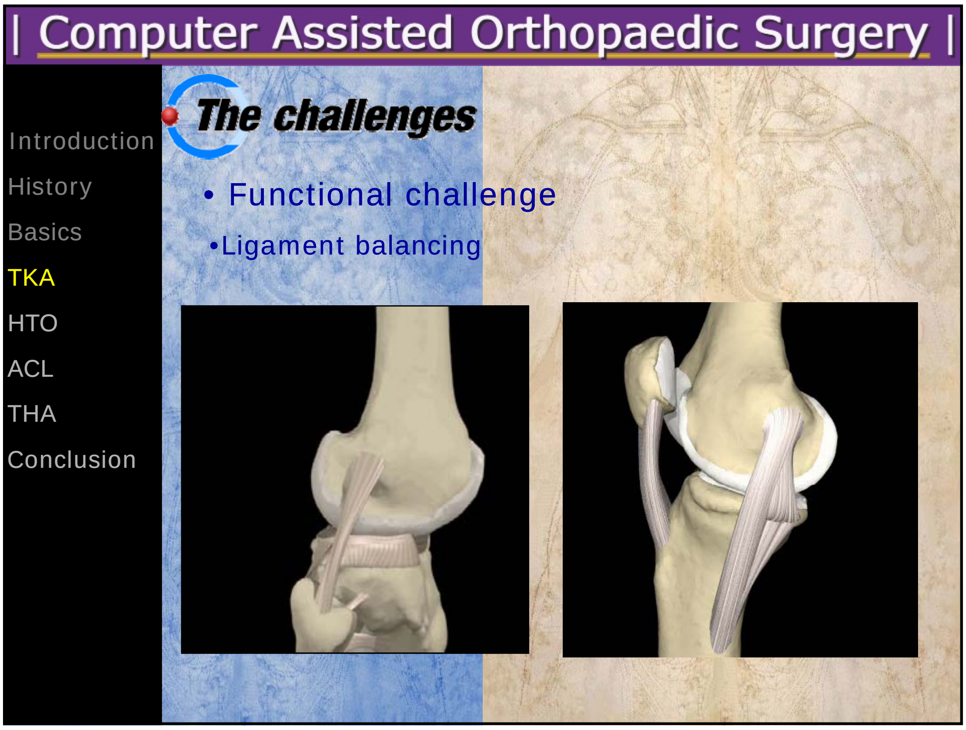
The challenges

- 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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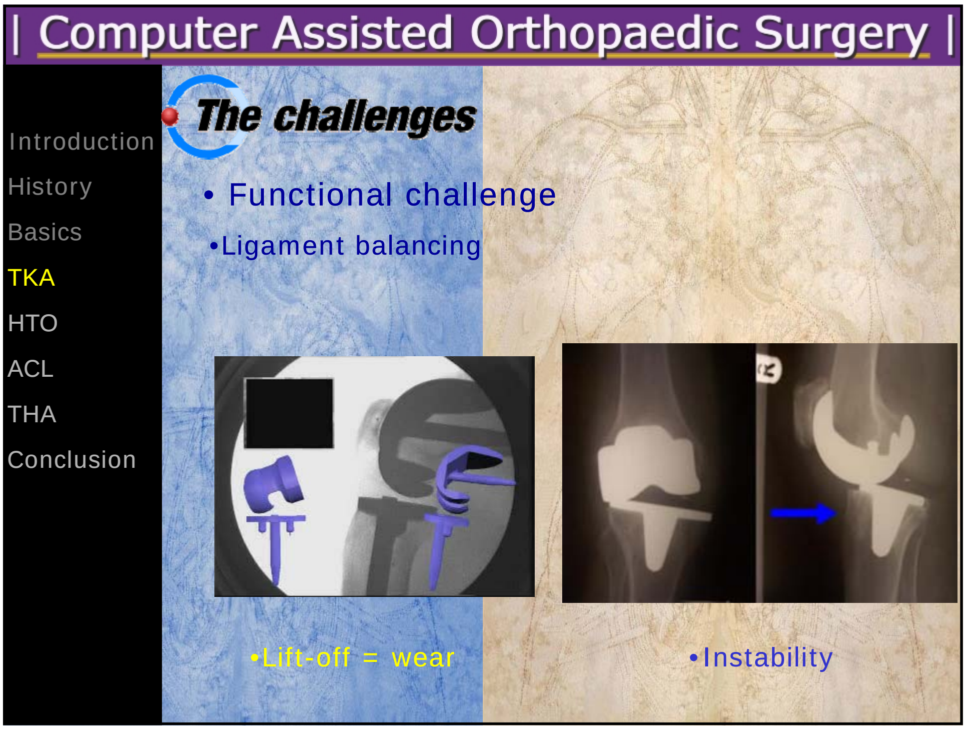
The challenges
• Functional challenge
•Ligament balancing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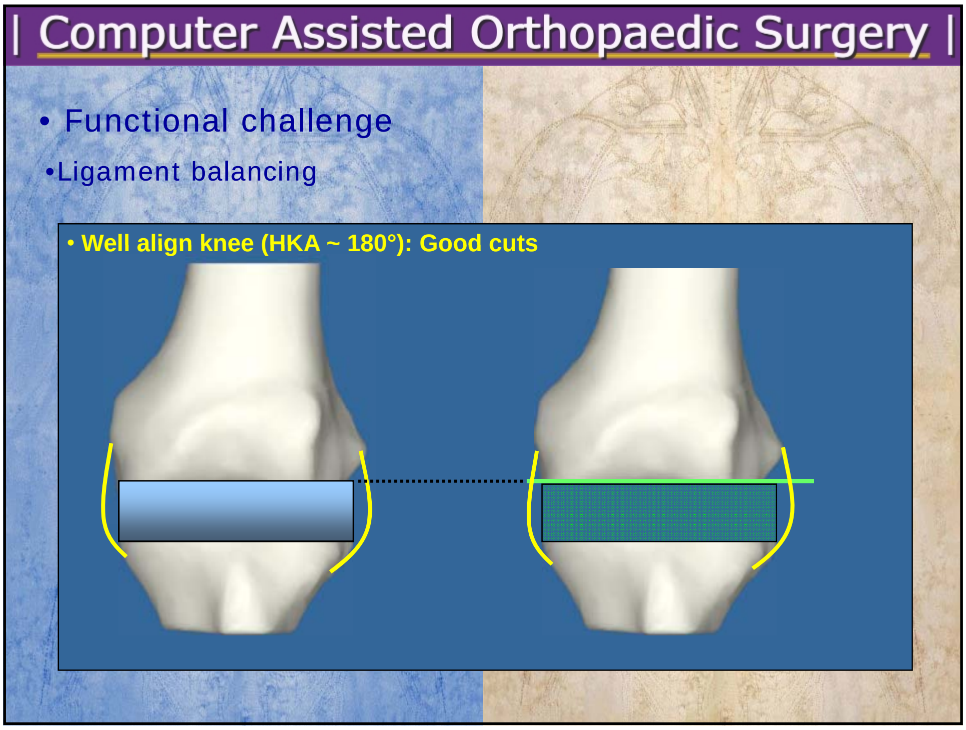
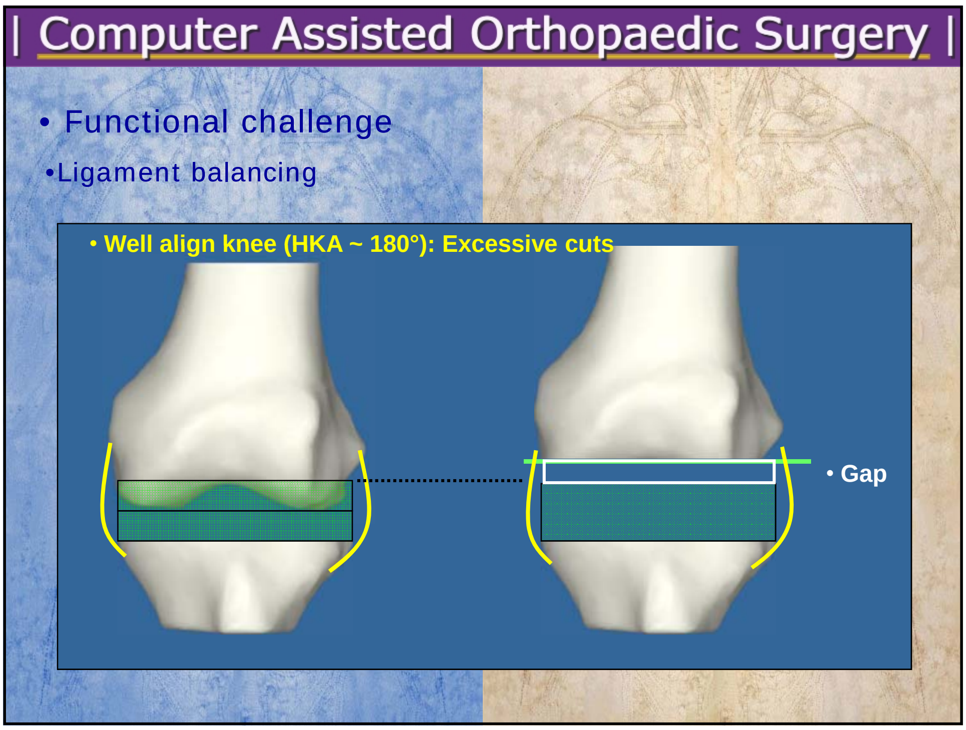
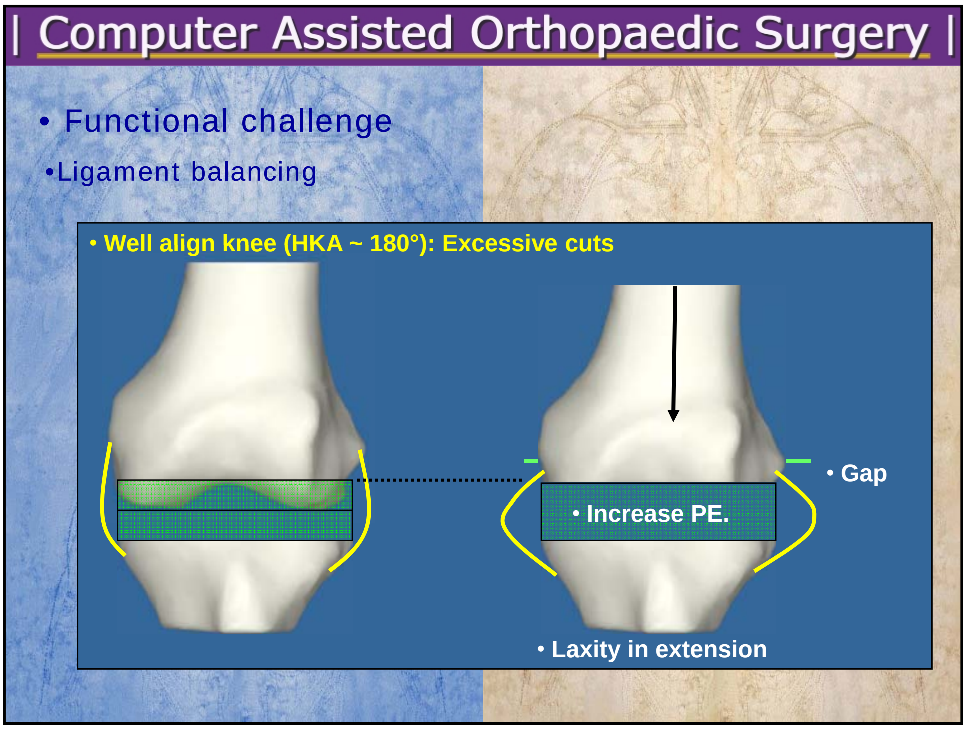
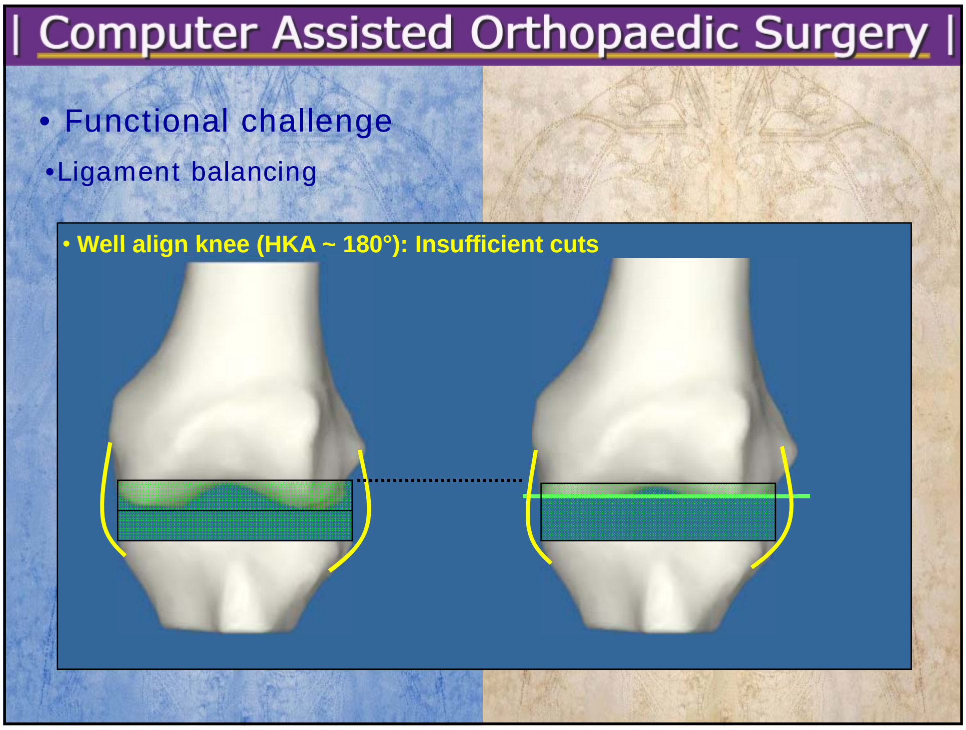
The challenges
• Functional challenge
•Ligament balancing
•Lift-off = wear
•Instability


| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Well align knee (HKA ~ 180°): Good cuts


| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Well align knee (HKA ~ 180°): Excessive cuts
• Gap


| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Well align knee (HKA ~ 180°): Excessive cuts
• Gap
• Increase PE.
• Laxity in extension


| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Well align knee (HKA ~ 180°): Insufficient cuts

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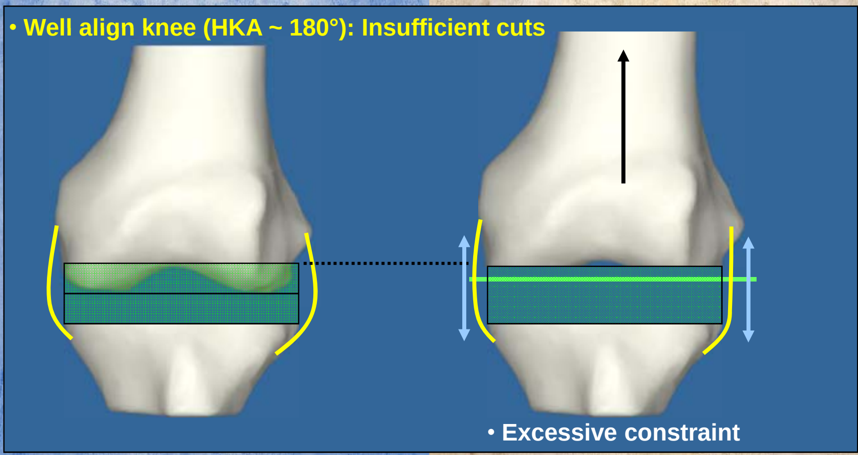
- Functional challenge
  - Ligament balancing



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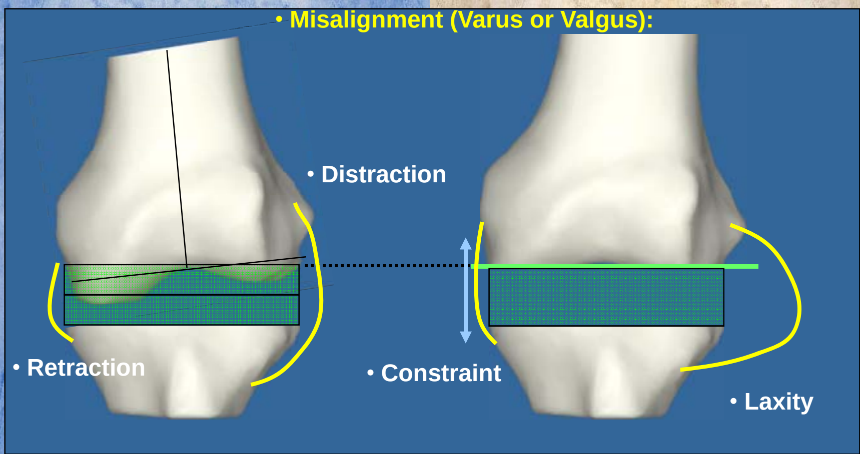
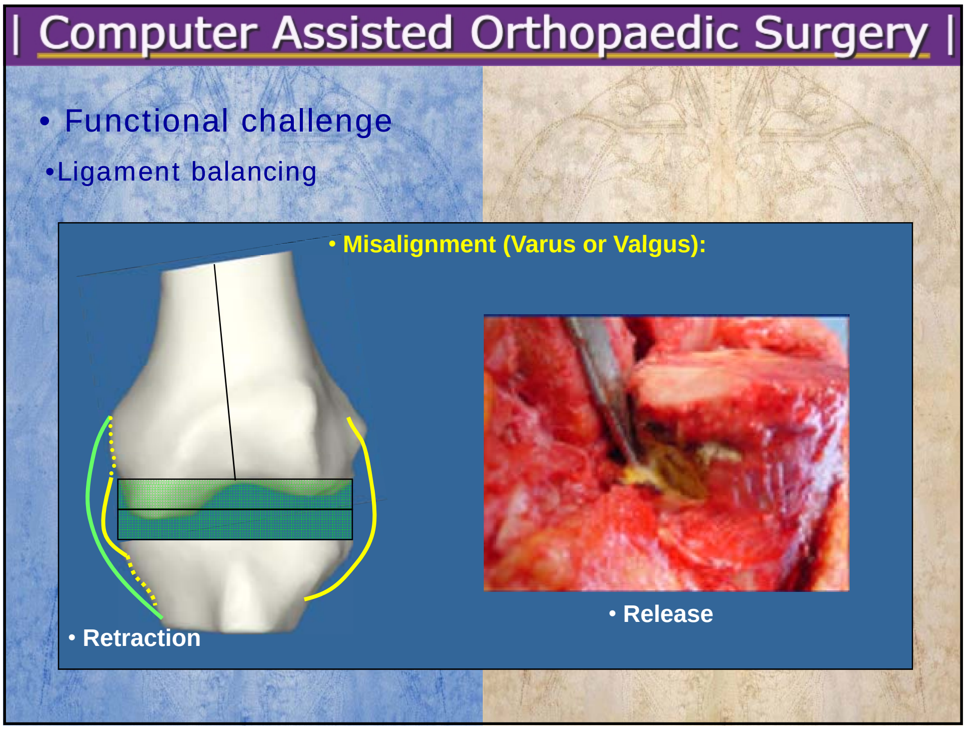
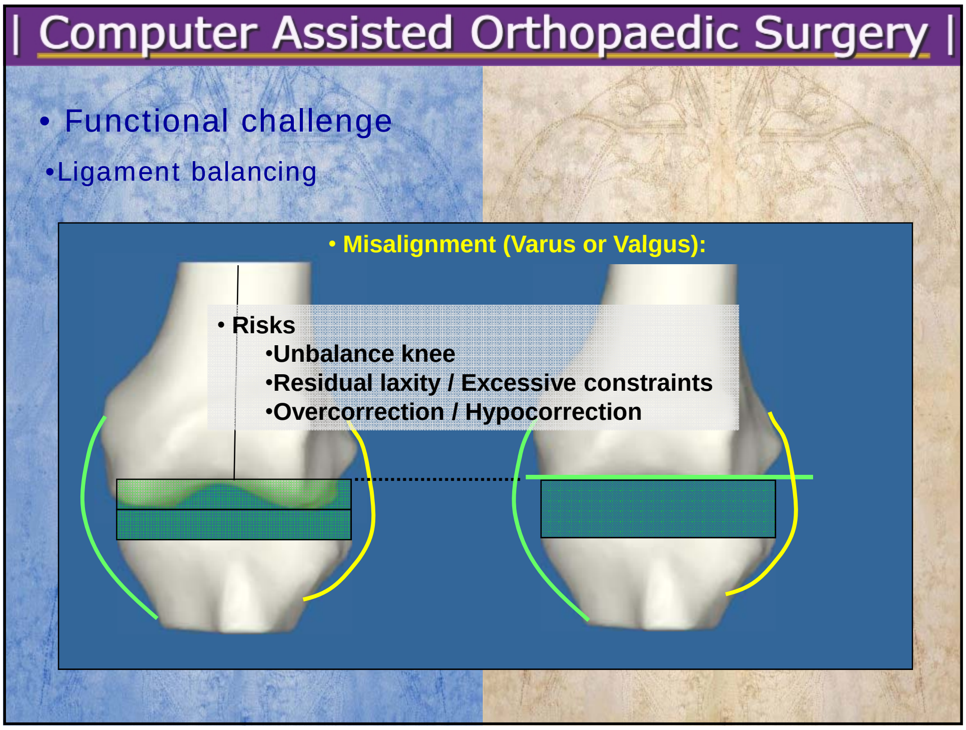
- Functional challenge
  - Ligament balancing




| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Misalignment (Varus or Valgus):
• Retraction
• Release


| Computer Assisted Orthopaedic Surgery |
• Functional challenge
•Ligament balancing
• Misalignment (Varus or Valgus):
• Risks
•Unbalance knee
•Residual laxity / Excessive constraints
•Overcorrection / Hypocorrection

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Application : TKA

The solutions

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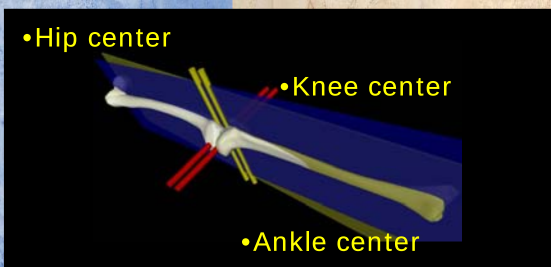
The solutions

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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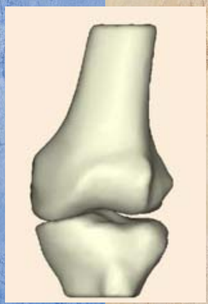
The solutions

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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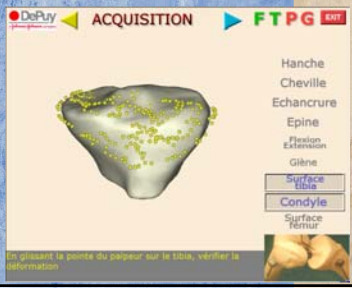
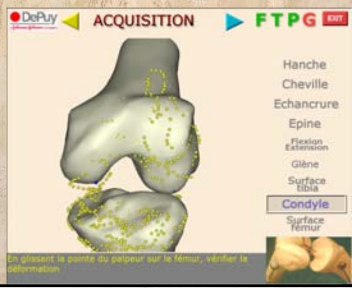
The solutions

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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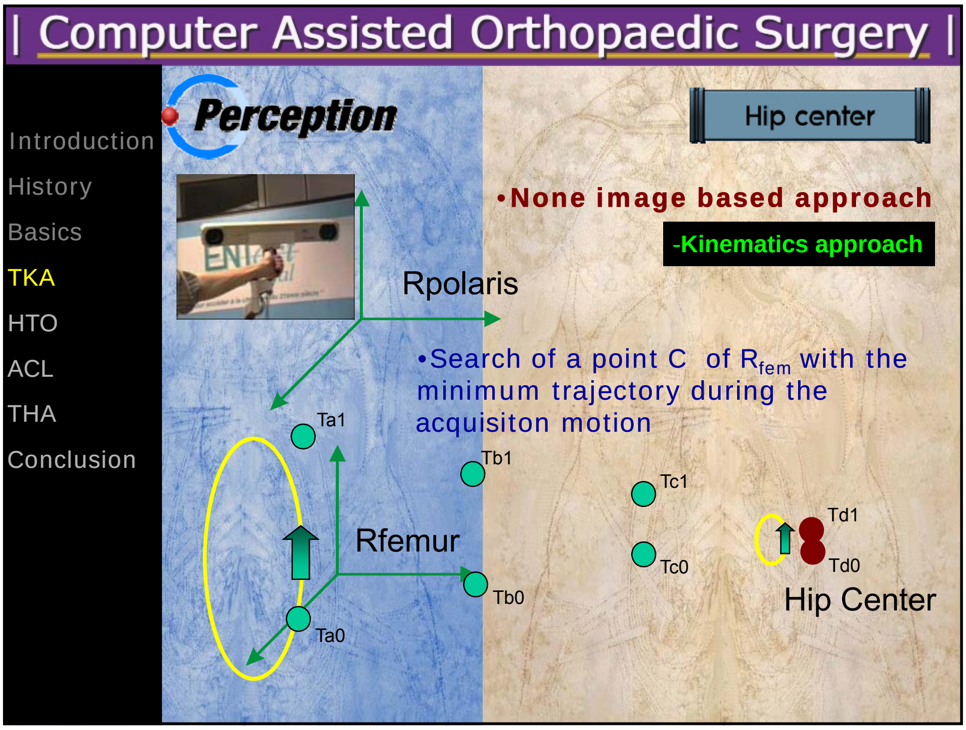
Hip center

•None image based approach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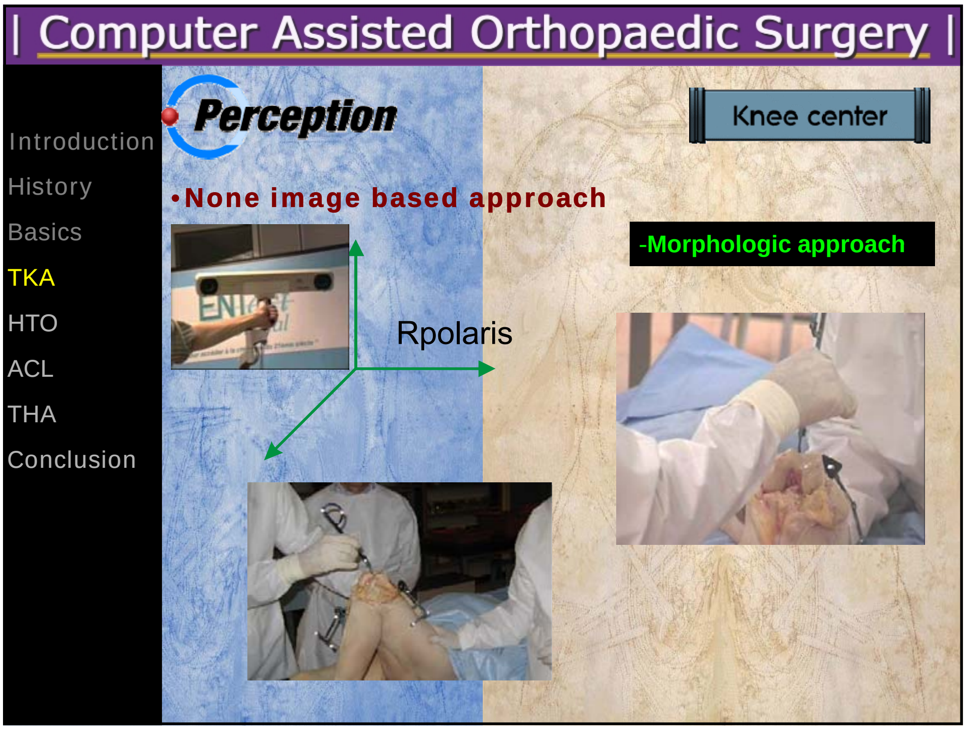
Hip center
•None image based approach
-Kinematics approach
Rpolaris
•Search of a point C of R_{fem} with the minimum trajectory during the acquisiton motion
Ta1
Tb1
Tc1
Td1
Rfemur
Tc0
Td0
Tb0
Hip Center
Ta0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•None image based approach
-Morphologic approach
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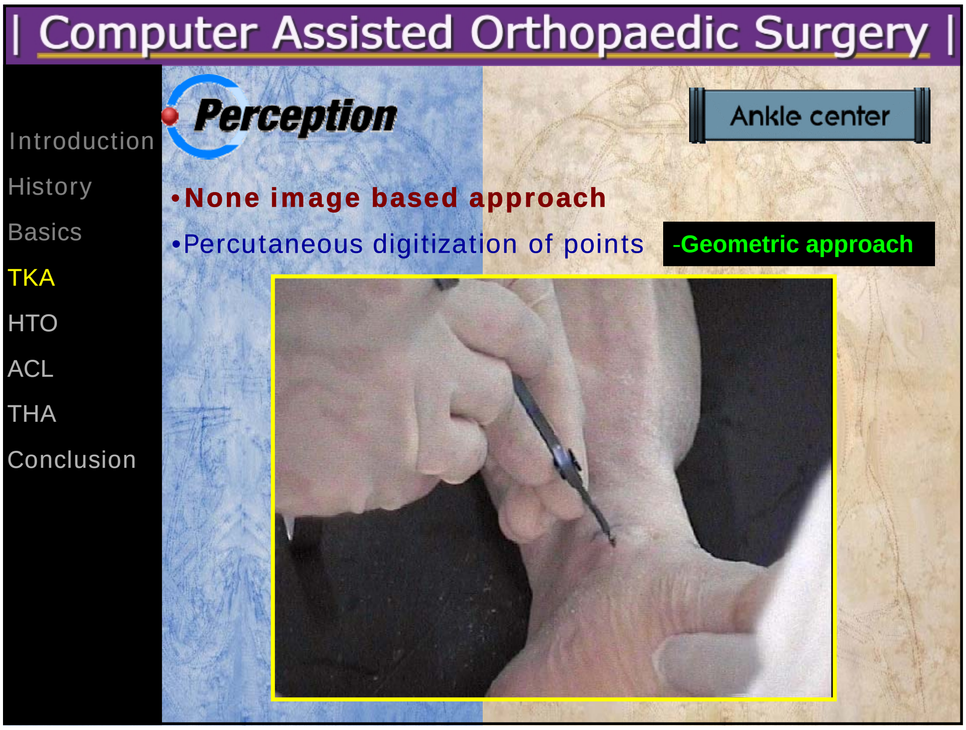
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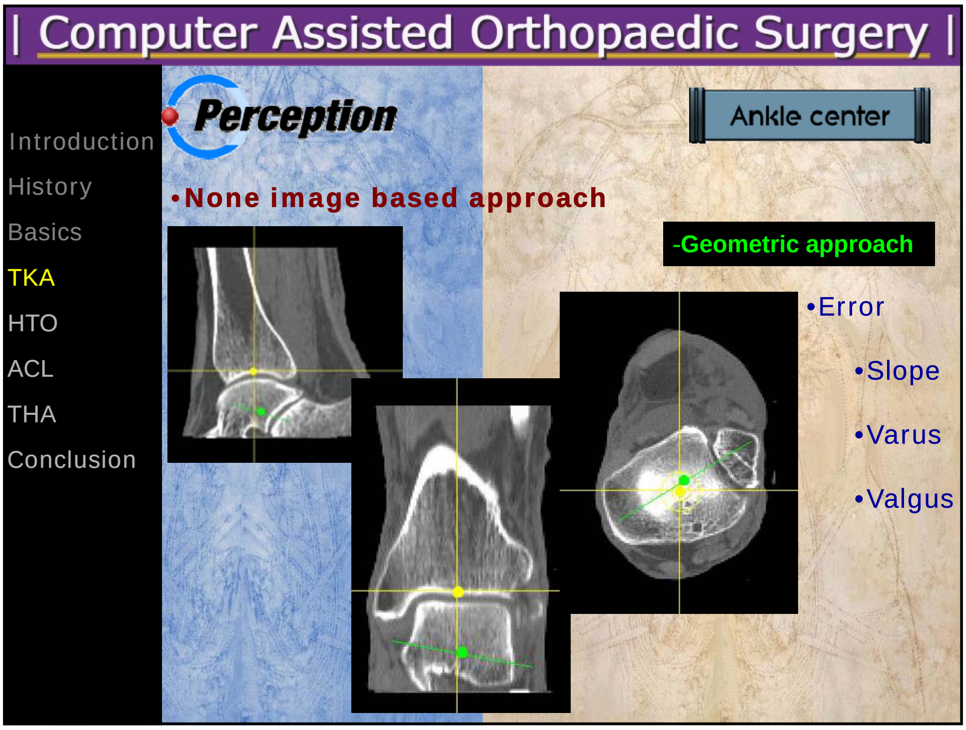
•None image based approach
•Percutaneous digitization of points
-Geometric approach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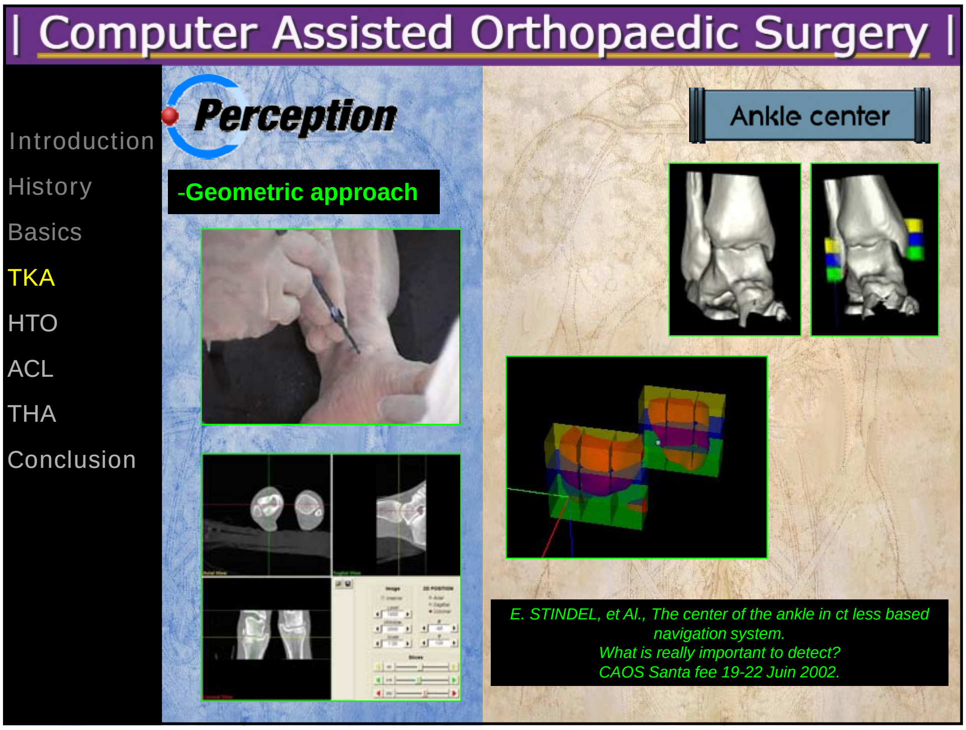
•None image based approach
-Geometric approach
•Error
•Slope
•Varus
•Valgus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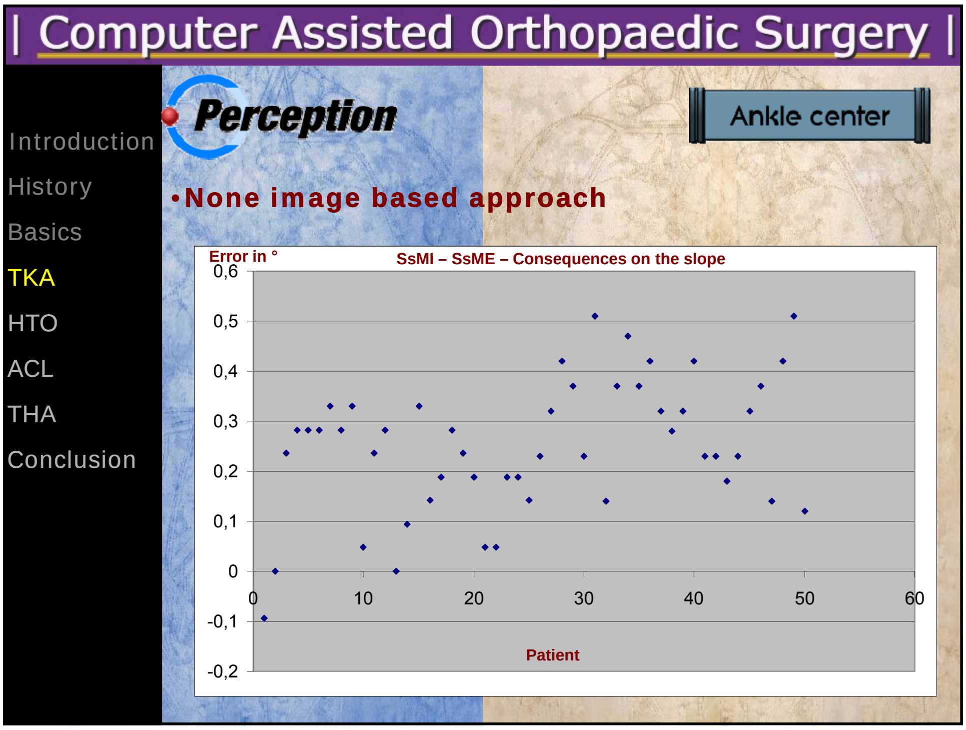
-Geometric approach
Ankle center
E. STINDEL, et Al., The center of the ankle in ct less based navigation system.
What is really important to detect?
CAOS Santa fee 19-22 Juin 2002.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Error in °
SsMI – SsME – Consequences on the slope
Patient

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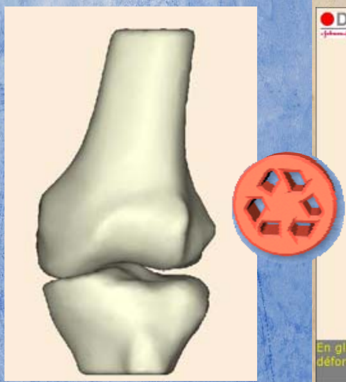
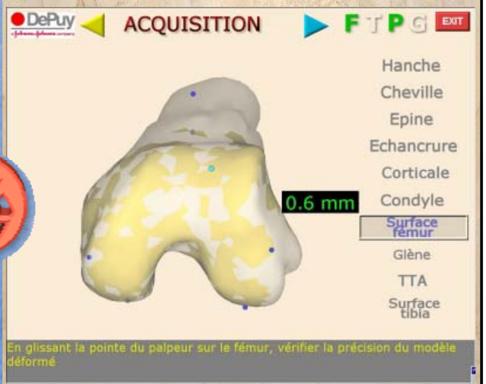
Perception

Morphology

•**Femoral and tibial shape : Bone morphing**

•Use of statistical deformable models





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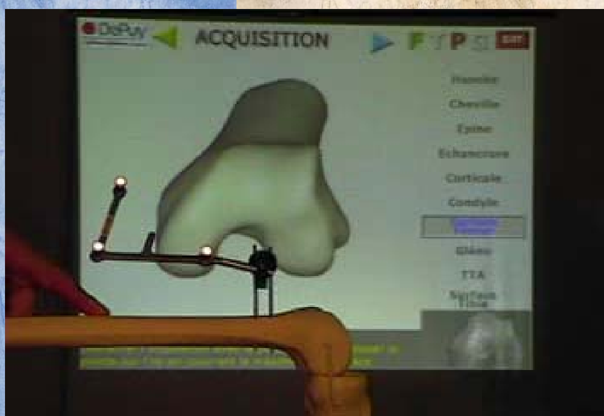
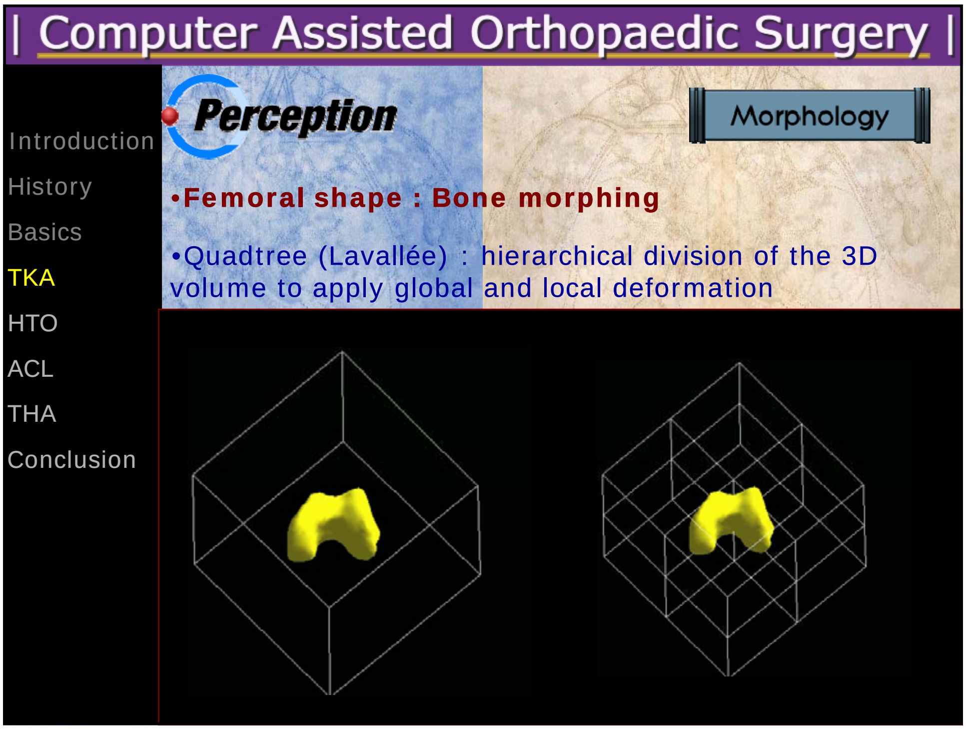
Morphology

•**Femoral shape : Bone morphing**

•Acquisition – Deformation – Quality control

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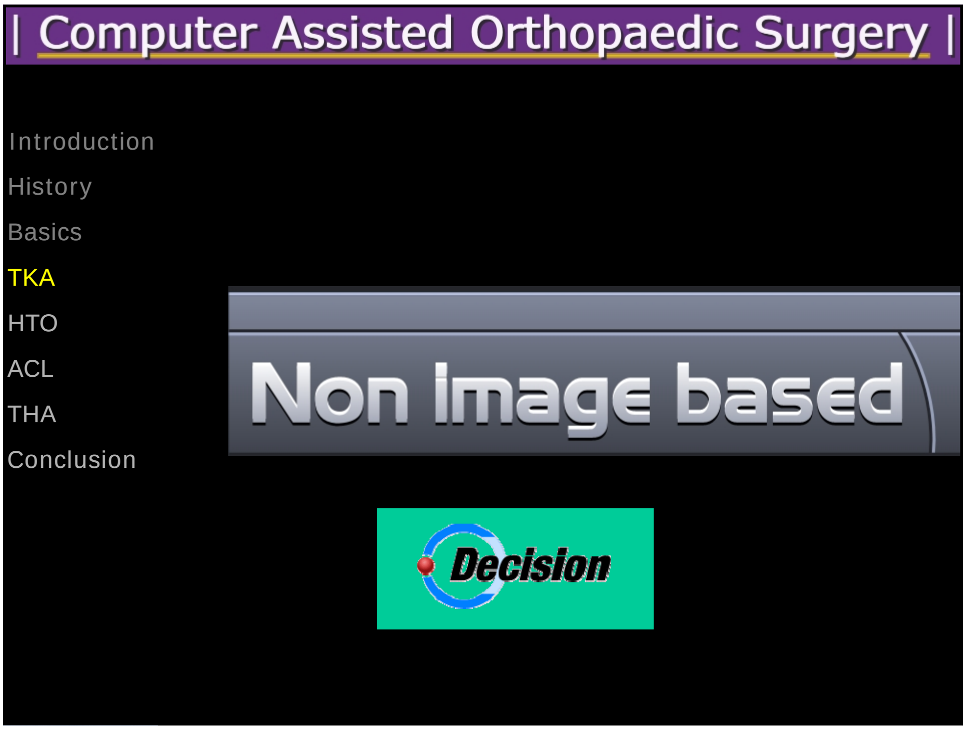
Morphology
•Femoral shape : Bone morphing
•Quadtree (Lavallée) : hierarchical division of the 3D volume to apply global and local deformation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Non image based
Decision

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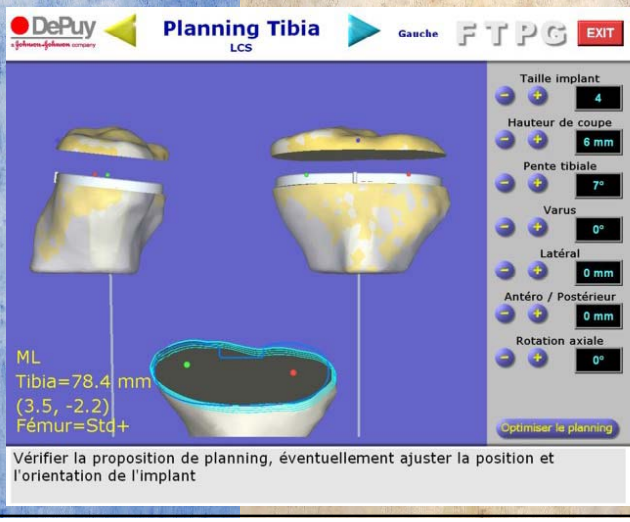
•Level 1 : based on morphologic data



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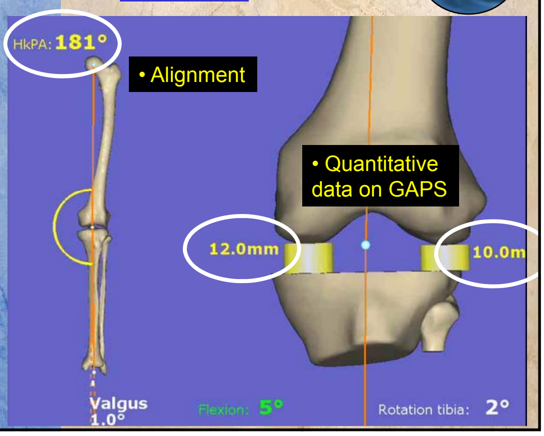
•Level 2 : based on dynamic per-operative data

Sensor

Software

Spacer

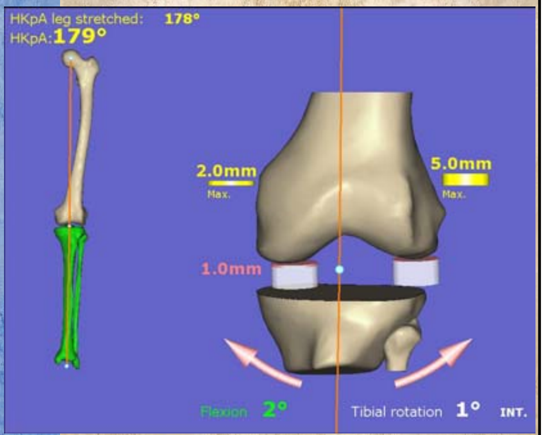


| Computer Assisted Orthopaedic Surgery |

Decision

- Level 2 : based on dynamic per-operative data

- Test residual laxity
  - Varus Max.
  - Valgus Max.
- If the residual laxity is over a threshold



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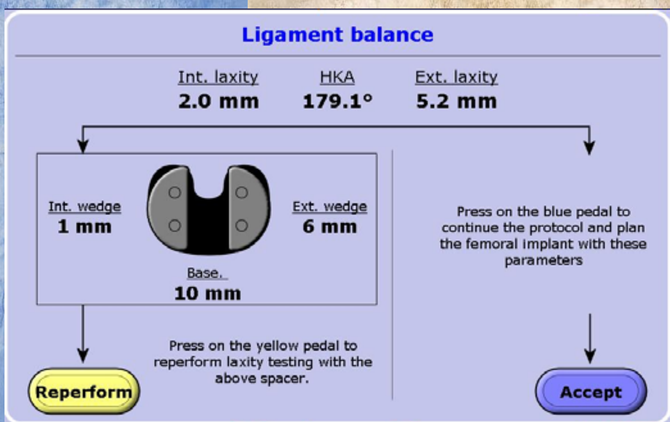
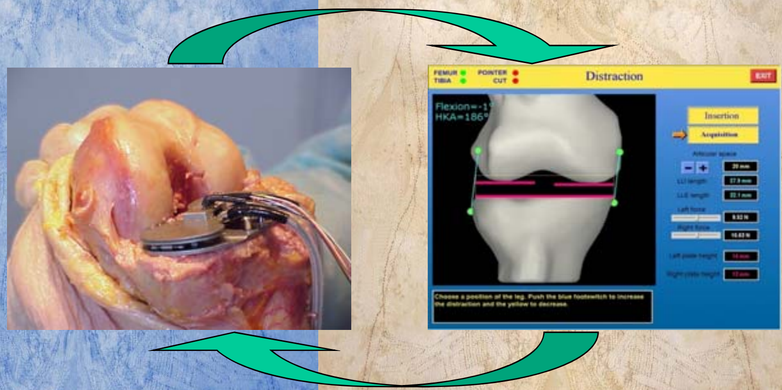
- Level 2 : based on dynamic per-operative data
  - Loop until the threshold is reached



| Computer Assisted Orthopaedic Surgery |

Decision

- **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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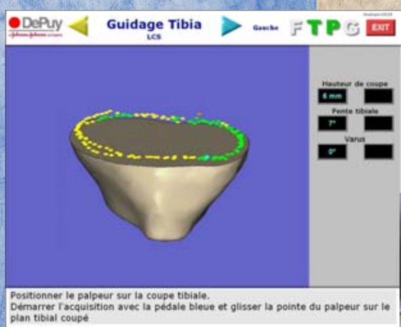
Decision

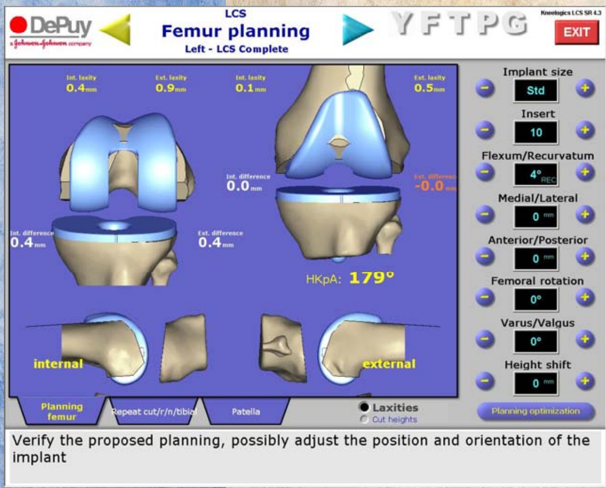
- **Level 3 : Integration of quality control in the decision loop**



| Computer Assisted Orthopaedic Surgery |

Decision

- Femoral planning



| Computer Assisted Orthopaedic Surgery |

Non image based

Action

| Computer Assisted Orthopaedic Surgery |

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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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•Robotized cutting guides

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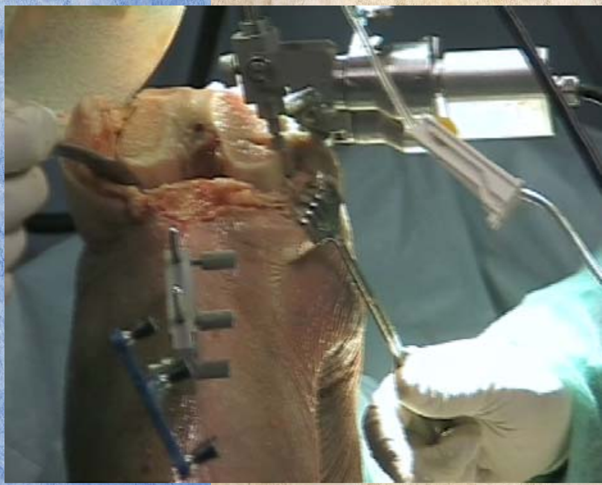
- Robotized milling guides



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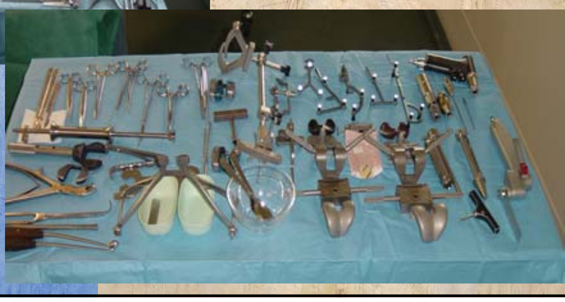

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Navigation of cutting guides

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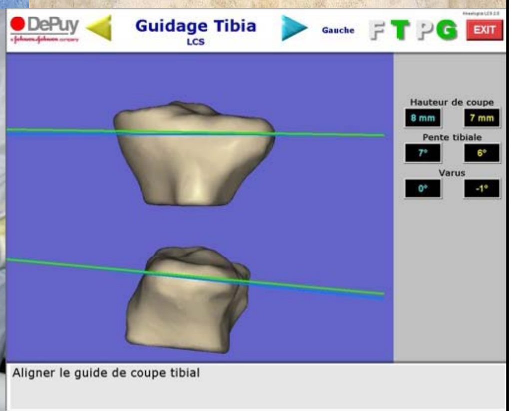
Navigation of cutting guides



| Computer Assisted Orthopaedic Surgery |

Application : HTO

7 000 cases / Year / France

| Computer Assisted Orthopaedic Surgery |

- **Integration of bricks**

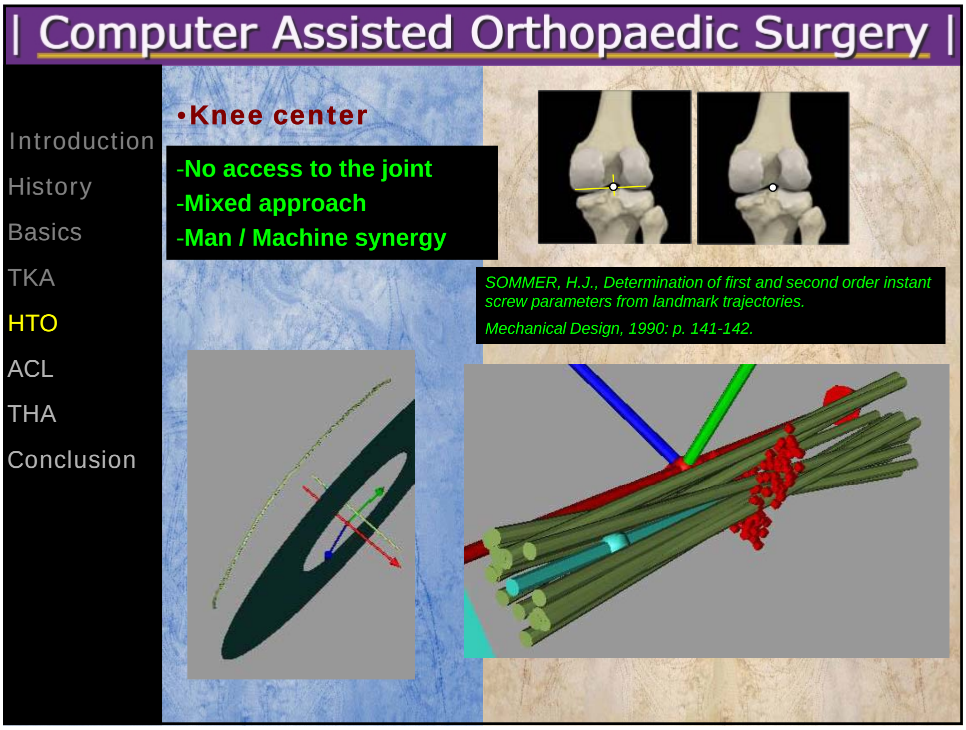
-Hip center : Same brick

-Knee center : Specific solution

-Ankle center : Same brick

-3D Planning

Computer Assisted Surgical Protocol - CASP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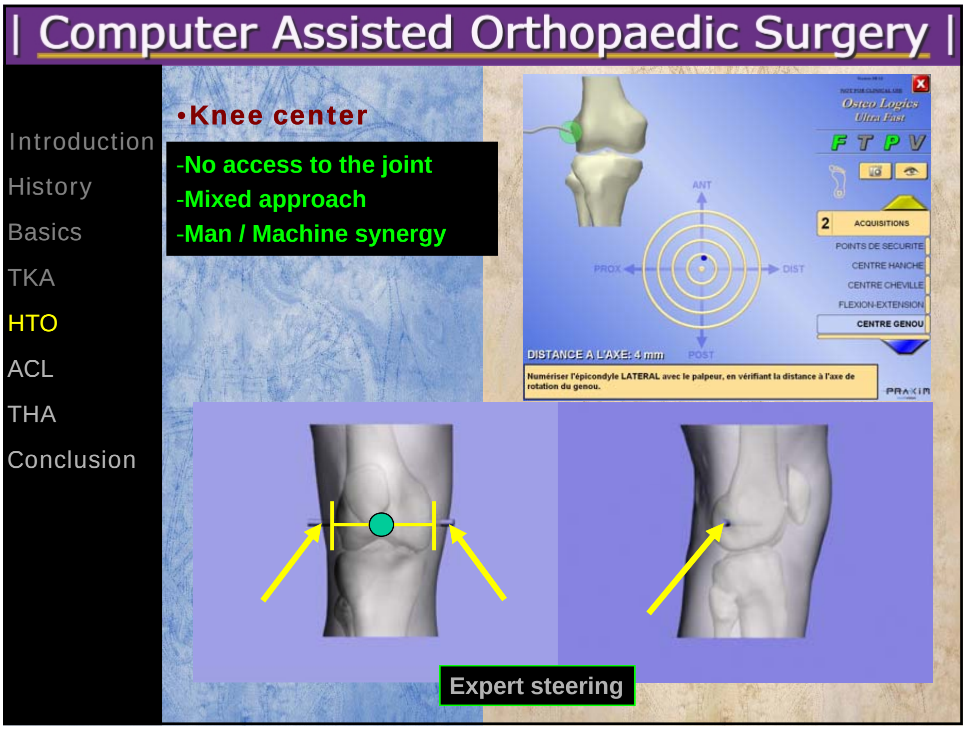
•Knee center
-No access to the joint
-Mixed approach
-Man / Machine synergy
SOMMER, H.J., Determination of first and second order instant screw parameters from landmark trajectories.
Mechanical Design, 1990: p. 141-142.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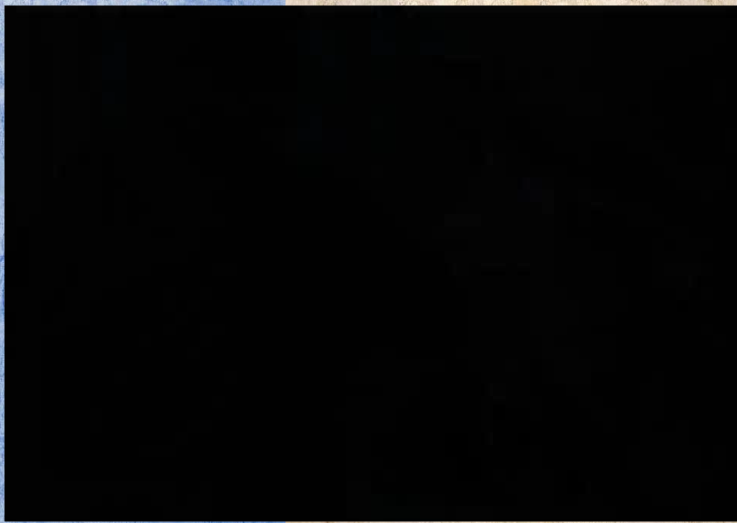
•Knee center
-No access to the joint
-Mixed approach
-Man / Machine synergy
Osteo Logics
Ultra Fast
F T P V
2 ACQUISITIONS
POINTS DE SECURITE
CENTRE HANCHE
CENTRE CHEVILLE
FLEXION-EXTENSION
CENTRE GENOU
ANT
PROX
DIST
POST
DISTANCE A L'AXE: 4 mm
Numériser l'épicondyle LATERAL avec le palpeur, en vérifiant la distance à l'axe de rotation du genou.
PRAXIM
Expert steering

| Computer Assisted Orthopaedic Surgery |

- In the OR



| Computer Assisted Orthopaedic Surgery |

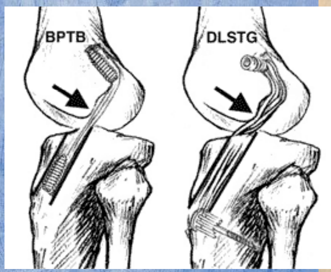
Application : ACL

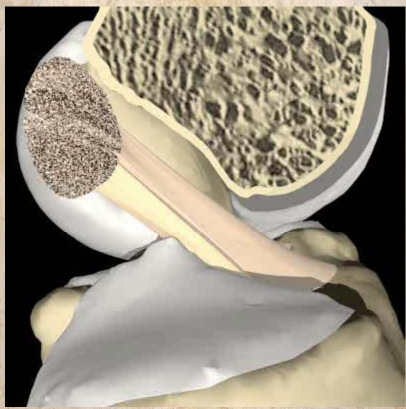
Computer Assisted Orthopaedic Surgery

•Anterior Cruciate Ligament Replacement

•The challenges

- Isometry
- Avoid impingement





Computer Assisted Orthopaedic Surgery

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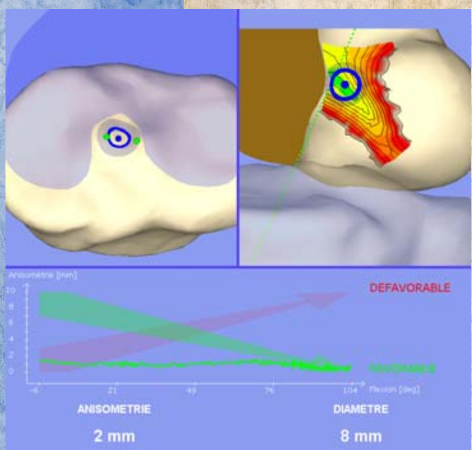
•Anterior Cruciate Ligament Replacement

•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

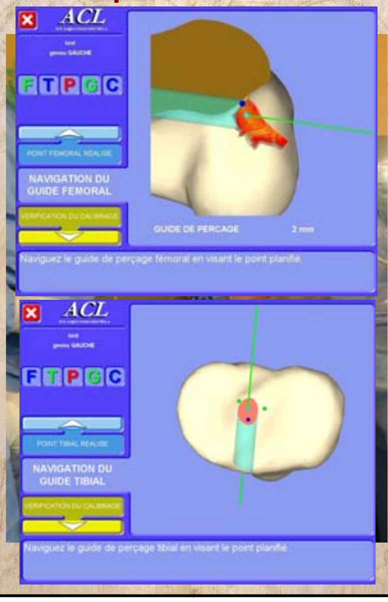
•**Action**

• Take the usual guide

• Attache a rigid body

•Perform the calibration

• Drill the tunnels with the help of the GUI



| Computer Assisted Orthopaedic Surgery |

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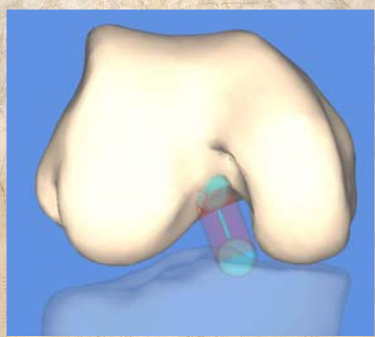
•Anterior Cruciate Ligament Replacement

•**Impingement**



• Digitized the anterior fiber of the graft

| Computer Assisted Orthopaedic Surgery |

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Application : THA

100 000 cases / Year / France

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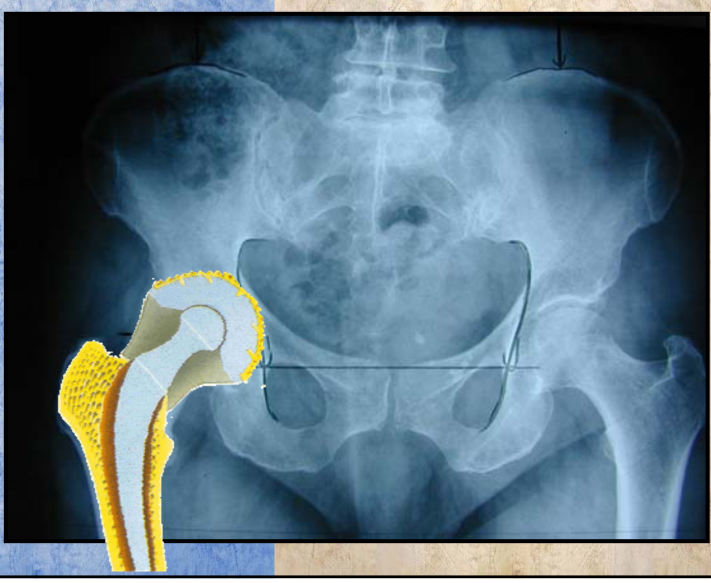
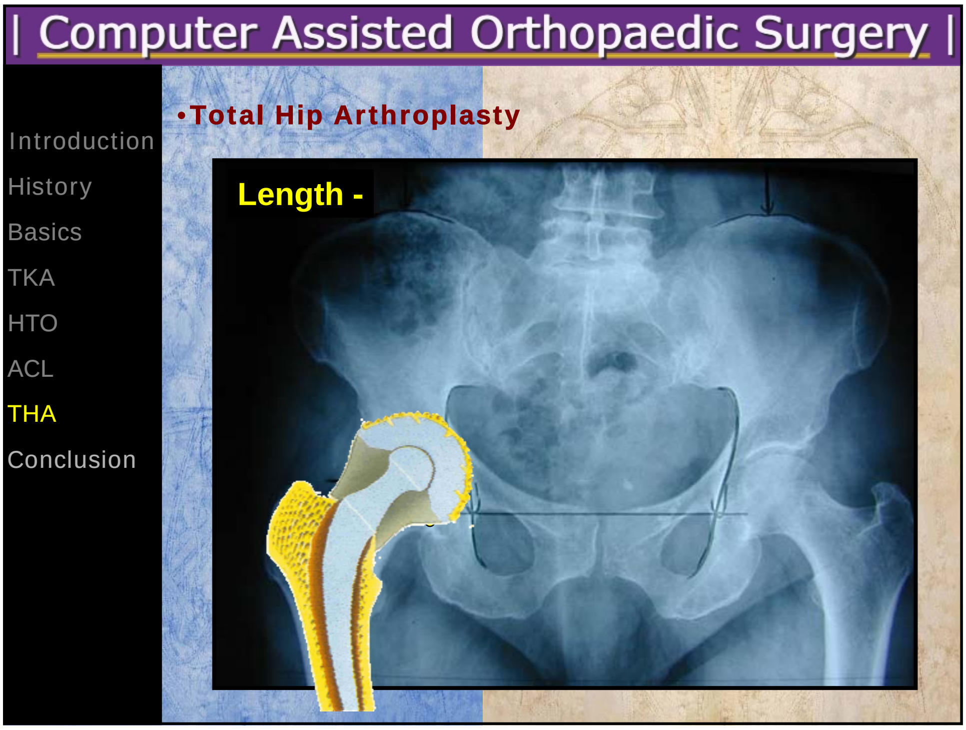
- **Total Hip Arthroplasty**




| Computer Assisted Orthopaedic Surgery |
•Total Hip Arthroplasty
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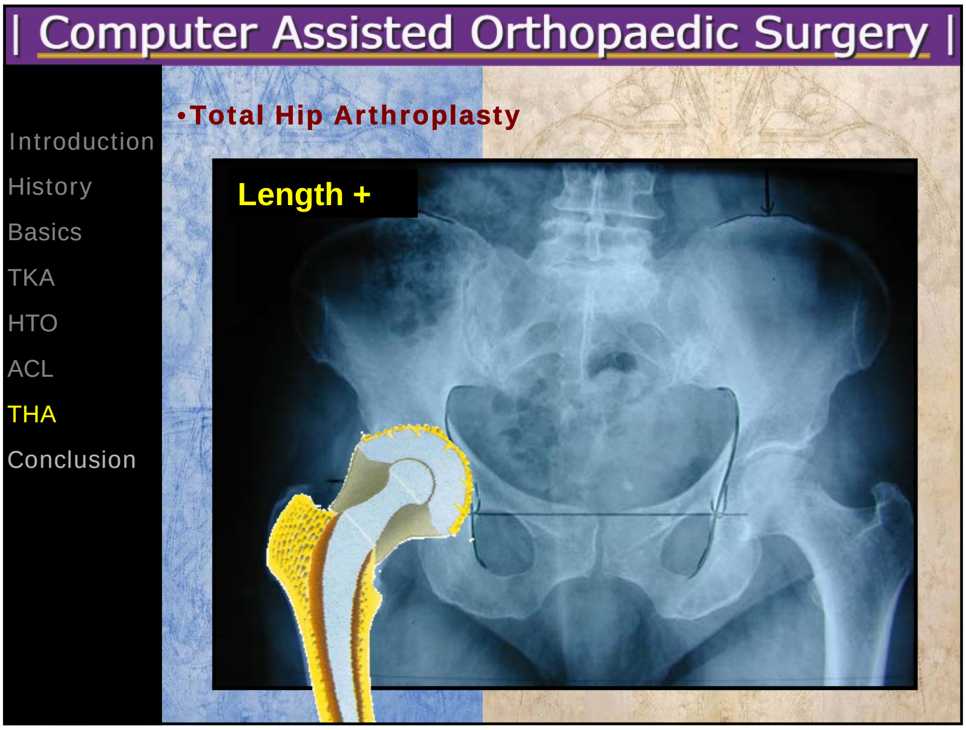
Length -


| Computer Assisted Orthopaedic Surgery |
•Total Hip Arthroplasty
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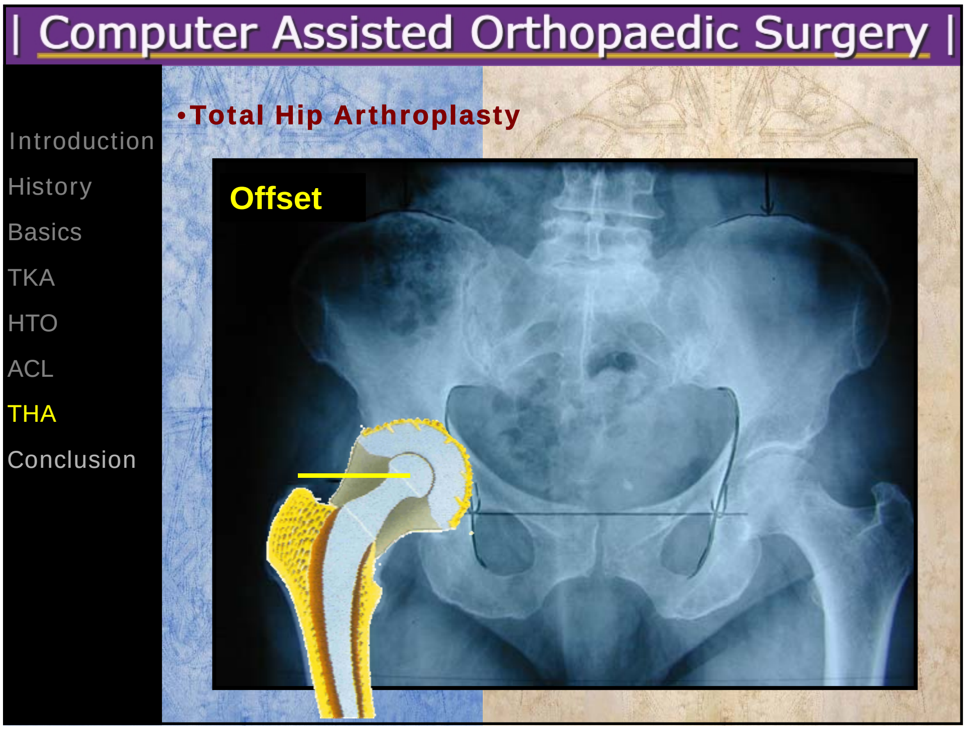
Length +


| Computer Assisted Orthopaedic Surgery |
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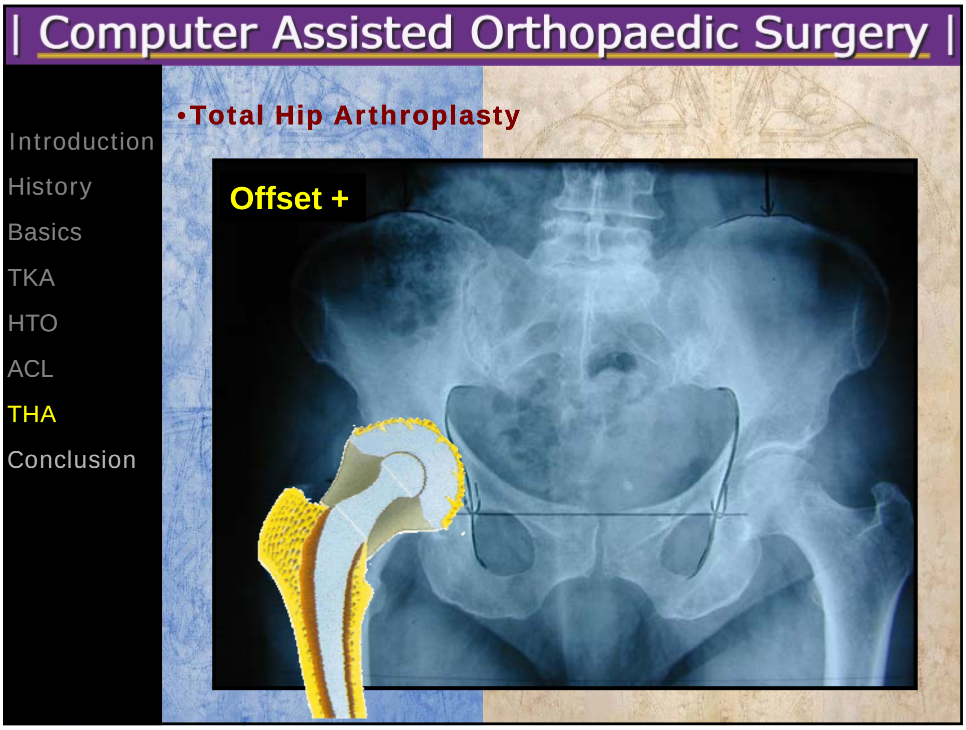
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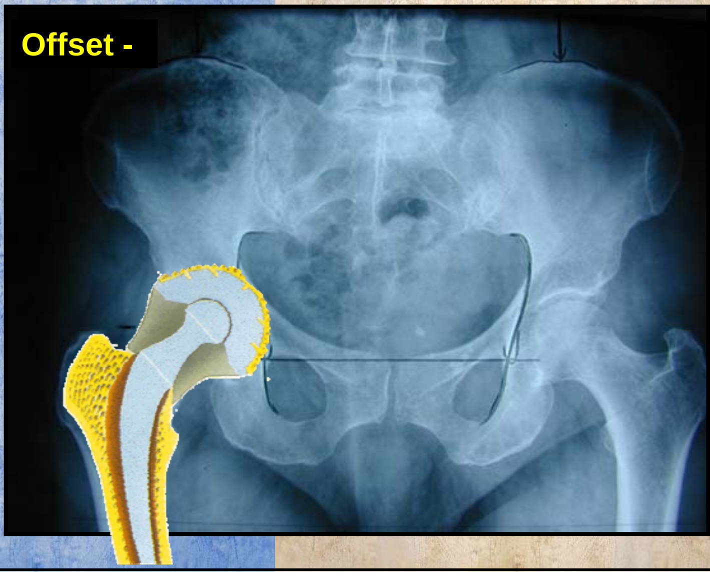
| Computer Assisted Orthopaedic Surgery |

•**Total Hip Arthroplasty**



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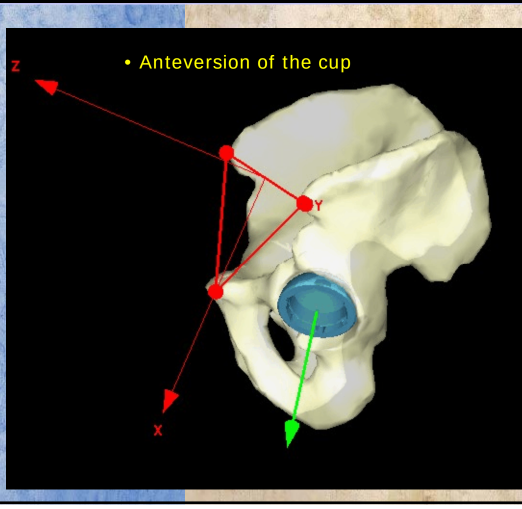
•**Total Hip Arthroplasty**

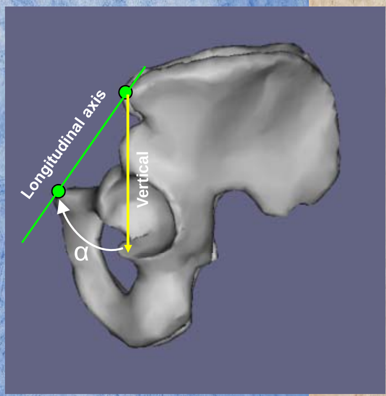
-Length -Centre of rotation
-Offset -Stability



Computer Assisted Orthopaedic Surgery

•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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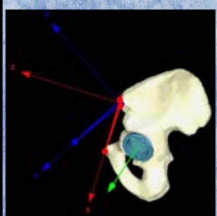
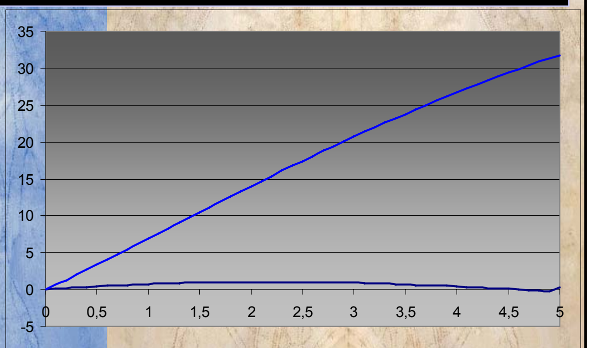
•Total Hip Arthroplasty

-Reference plane





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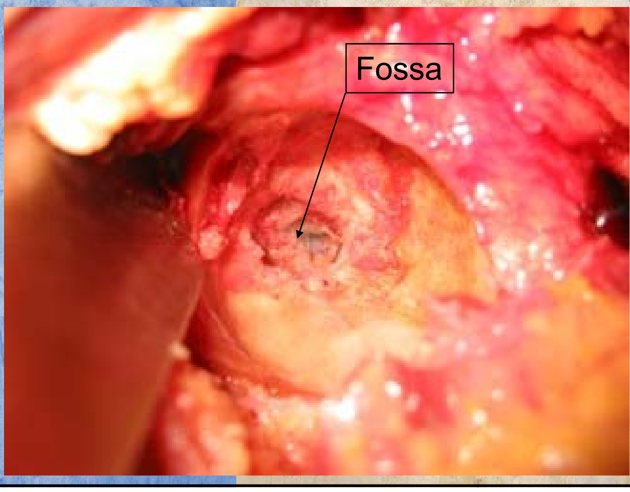
•**Total Hip Arthroplasty**

-Local bone morphing instead of global

•View of the acetabulum fossa before reaming



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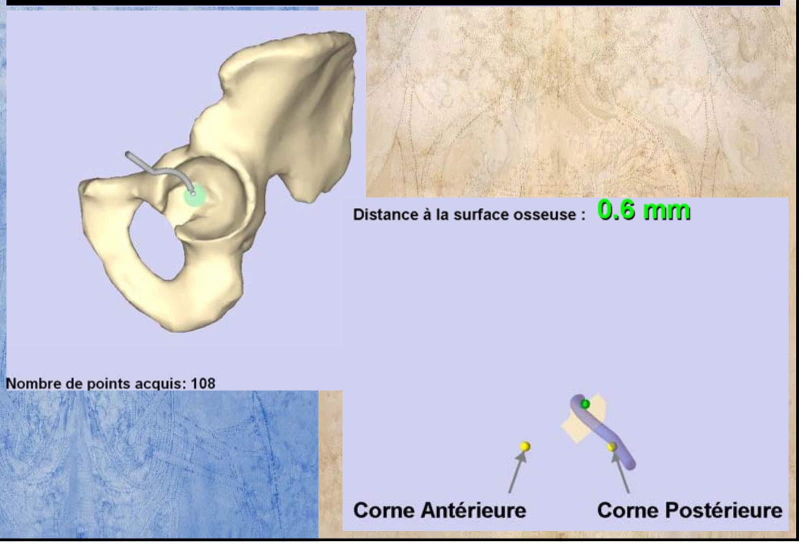
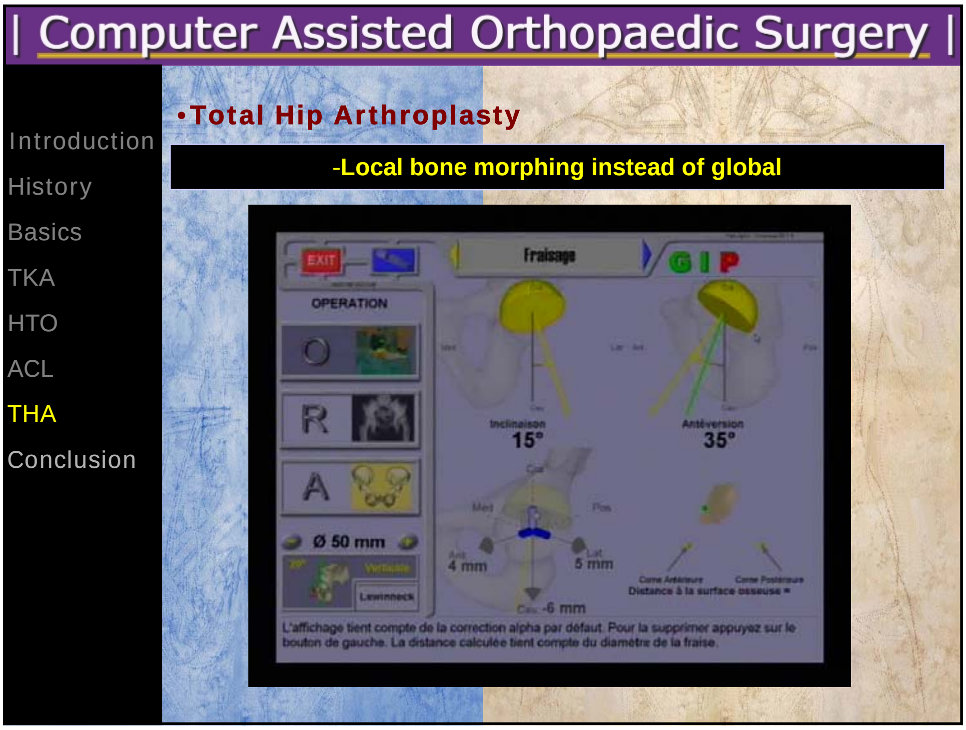
•**Total Hip Arthroplasty**

-Local bone morphing instead of global

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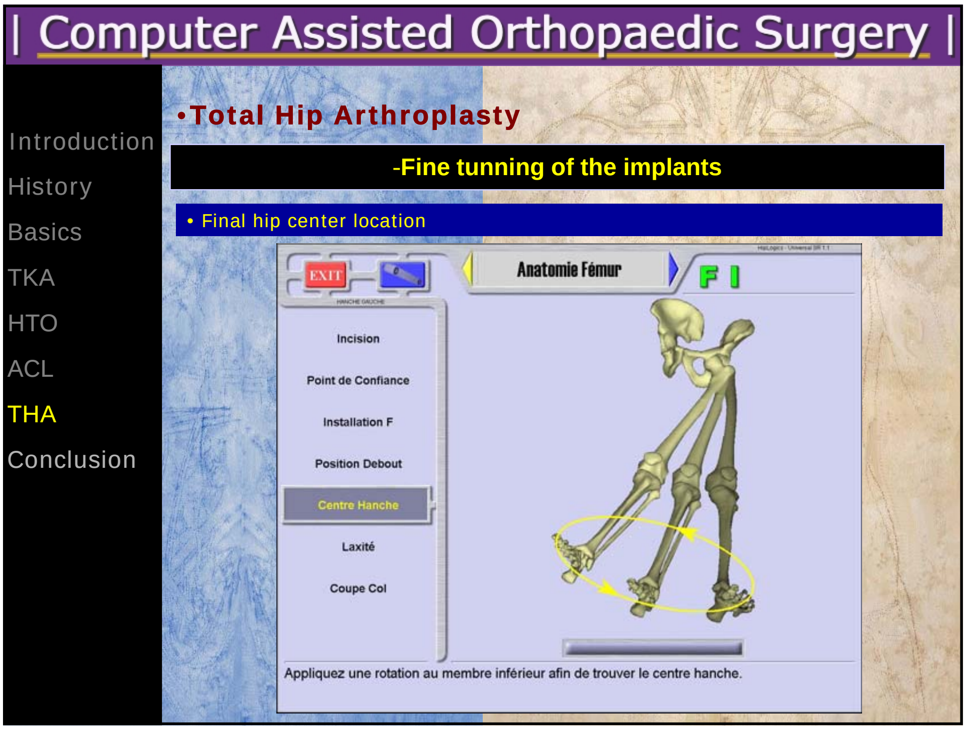
-Local bone morphing instead of global
EXIT
Fraisage
G I P
OPERATION
O
R
A
Ø 50 mm
Inclinaison
15°
Antéversion
35°
4 mm
5 mm
-6 mm
L'affichage tient compte de la correction alpha par défaut. Pour la supprimer appuyez sur le bouton de gauche. La distance calculée tient compte du diamètre de la fraise.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•Total Hip Arthroplasty
-Fine tunning of the implants
• Final hip center location
EXIT
Anatomie Fémur
F I
Incision
Point de Confiance
Installation F
Position Debout
Centre Hanche
Laxité
Coupe Col
Appliquez une rotation au membre inférieur afin de trouver le centre hanche.

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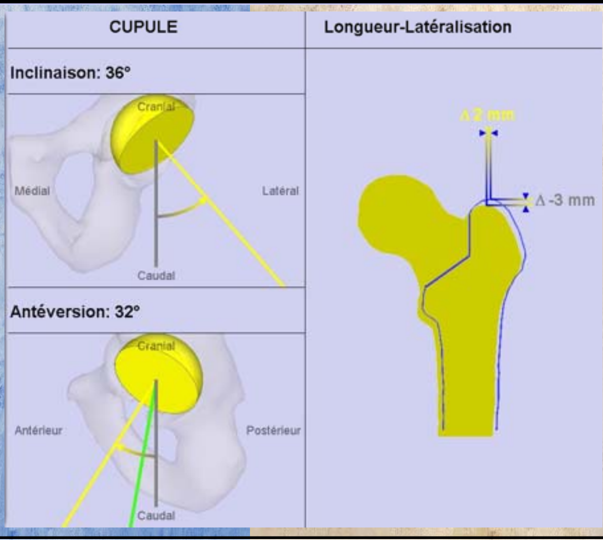
•Total Hip Arthroplasty

-Fine tunning of the implants



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