Orthopaedic robotics

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Regarding computer or robot assisted orthopaedic surgery, which of the following is correct:

a) All robots in orthopaedic surgery are fully automatic devices.

b) Use of a robot eliminates the need to be taught surgical skills.

c) The use of robotic has shown to improve accuracy of surgery.

Content

- Overview on Robotics
- Case study of the robot designed and manufactured in imperial college
- Current development in imperial in the field of orthopaedic robotics

Types of surgery

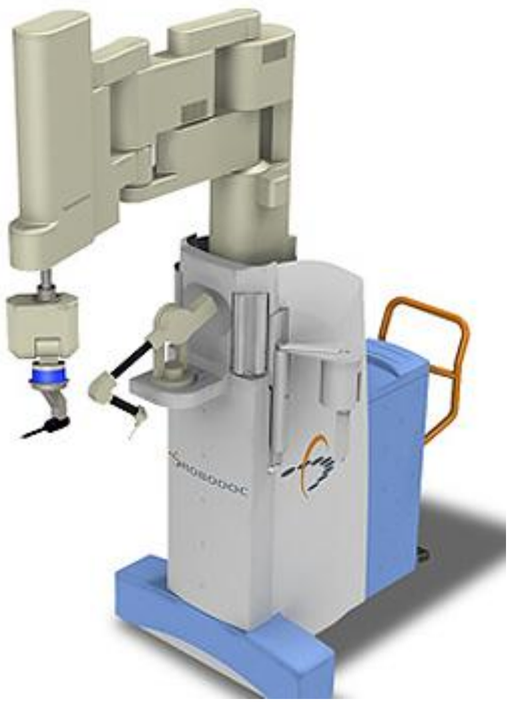
- Open Surgery
  - Using saw and guides to perform the surgery
- Minimally invasive Surgery (MIS)
  - Arthroscopic
- Robotic surgery (Expansion of MIS)

Advantage of using Robots

- Decrease surgeon fatigue during surgery
- Quicker
- Enhanced precision
- Deskilling surgeon
- Minimal access which reduces trauma and faster recovery, limited post-op pain
- Automation reduces personnel
- Cheaper

A view on Robotic Systems

- Supervisory-Controlled (Active)
  - Surgeon must provide extensive preparatory work, inputting data which initiate the full controlled surgical action
  - Challenge: No room for error, surgeons might feel redundant



- Example: Robodoc CUREXO Technology Company
  - The robot mills cavities for hip implant, removes bone cement for revision surgery and planes the femoral and tibia surfaces for knee implant.

A view on Robotic Systems

- Shared Control (Semi-Active)
  - Robot monitors surgeon performance and provides stability and support through active constraint. Example: Acrobot Sculptor, or MAKO-RIO, NavioPFS (BLUE BELT), used for uni-knee replacement
  - Challenge: Surgeons fatigue

A view on Robotic Systems

- Tele-Surgical (Passive)
  - Surgeon perform the operation from a console distant to operating table.
  - Challenge: Time delay between console and robot
- Example: Intuitive surgical –da Vinci
  - Laproscopic
  - Thoracoscopic
  - Prostatectomy
  - Cardiotomy
  - Cadriac Revascularization
  - Broad Urology
  - Gynecology
  - Periatric surgery
  - Has not yet been used in orthopaedics

Incentives and Barriers

By Whom?

- Surgeons (better outcome <-> don't want to be redundant)
- Patients (better outcome and faster recovery <-> fear of robot)
- Hospitals (attracting new patients, avoiding complications/surgical errors <-> Is it cost effective?)
- Regulatory (safety and efficacy)

Why use it?

- Does it solve real clinical problem?
- Does it save money?
- Is it more efficient?
- Better outcome?
- Avoid complications?

- Randomised clinical trials To check the above questions
  - Problem with control group
  - How long to follow
  - Who conducts them

Starting a robotic surgery

- Initial Planning
  - Determine financial viability
  - Involve other surgical specialities
  - Market analysis- expected surgical volume
  - OR preparation
    - Staff training (draping...)
    - Room modification
    - Hiring surgical assistant
  - Requires support of hospital, partners and OR staff

What is required

- Simpler, lower cost robotic systems. E.g., "Intelligent Tools" in the hands of the surgeon
- Minimally invasive, using smaller prostheses that cannot be implanted conventionally
- Procedures which are difficult to perform by conventional means
- Easy to setup and use
- Simple training
- An accurate CT based plan

Conclusions

- Robotic surgery is a movement that cannot be denied
- It will happen because the drivers are there
- When? Is now the time?

In development and future

- Improved instruments
- Preoperative planning automated
- Microsurgical robots (less invasive)
- Integrated ultrasound imaging
- Integrated image guidance
- Autonomy of OR support
- Long distance surgery?

Case study, Imperial College Technology base

Acrobot Company Limited, UK

The Acrobot Company Limited

- A SME for robotic orthopaedic surgery
- Spun off from Imperial College London in 1999
- 8 years of preliminary research at Imperial College
- Founder Directors: Professor Justin Cobb (Surgeon) & Professor Brian Davies (Engineer)
- Started as an R & D company in Imperial's laboratory

The Acrobot Current products are

- A modelling system (Software based)
  - Segmentation
- A planning system (Software based)
  - Optimal position and size of the implant
- A computer aided surgery navigation system (Hardware based)
  - Uni Knee, Hip resurfacing, total hip replacements
- A robotic surgery system (Hardware based)
  - Uni Knee replacement

Introduction

- Virtual surgery
    - For every high value arthroplasty

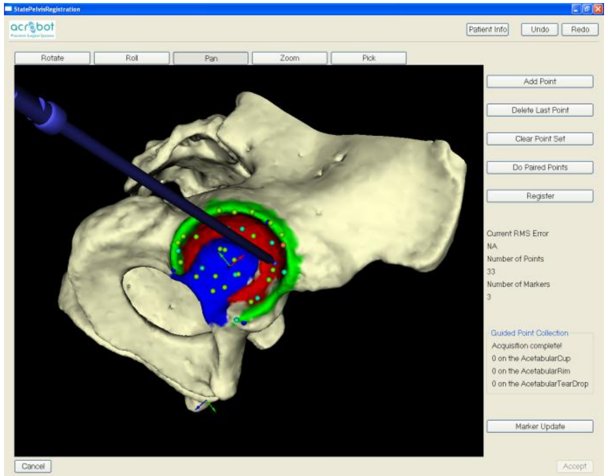
- Computerised assistants
  - active robots
    - For complex tasks
  - passive navigators
    - For simpler ones

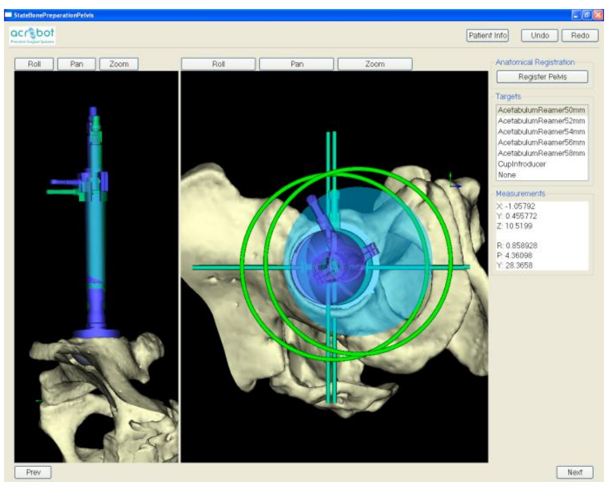
- Validation
    - Co-registered CT
    - Discriminant function scores
    - Metal ion levels

Acrobot navigation system

- Robot and Navigation systems are best used for tasks that Surgeons find difficult (e.g., Hip resurfacing -> mal-alignment)
- Hip Resurfacing (HR) Surgery is a MIS procedure that conserves bone stock
- Metal on metal components give a long life, but need to minimise ions in blood due to wear particles. I.e., optimise alignment of cup and femoral components

Acrobot Navigation system for hip resurfacing





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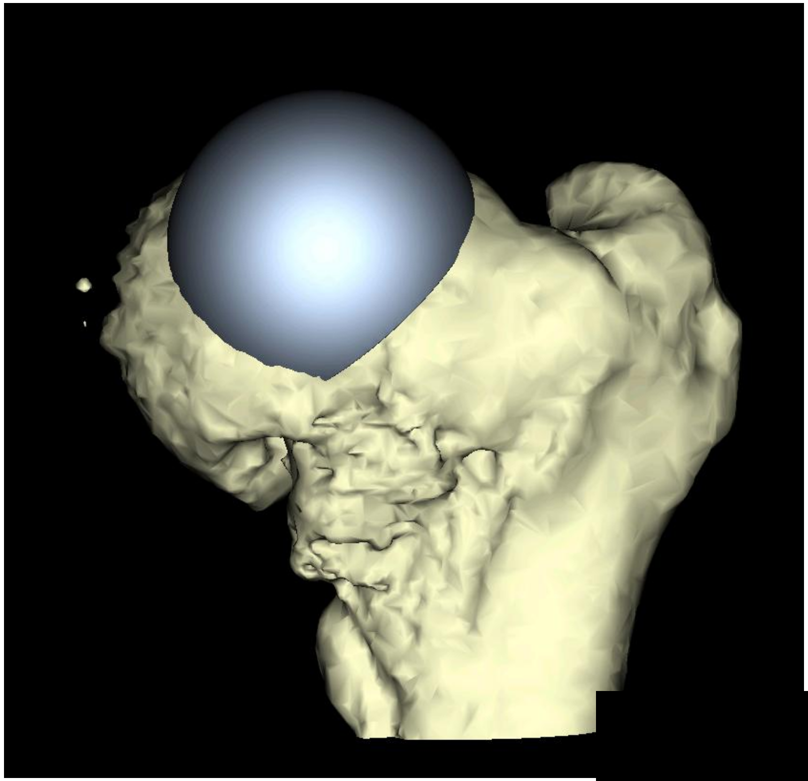
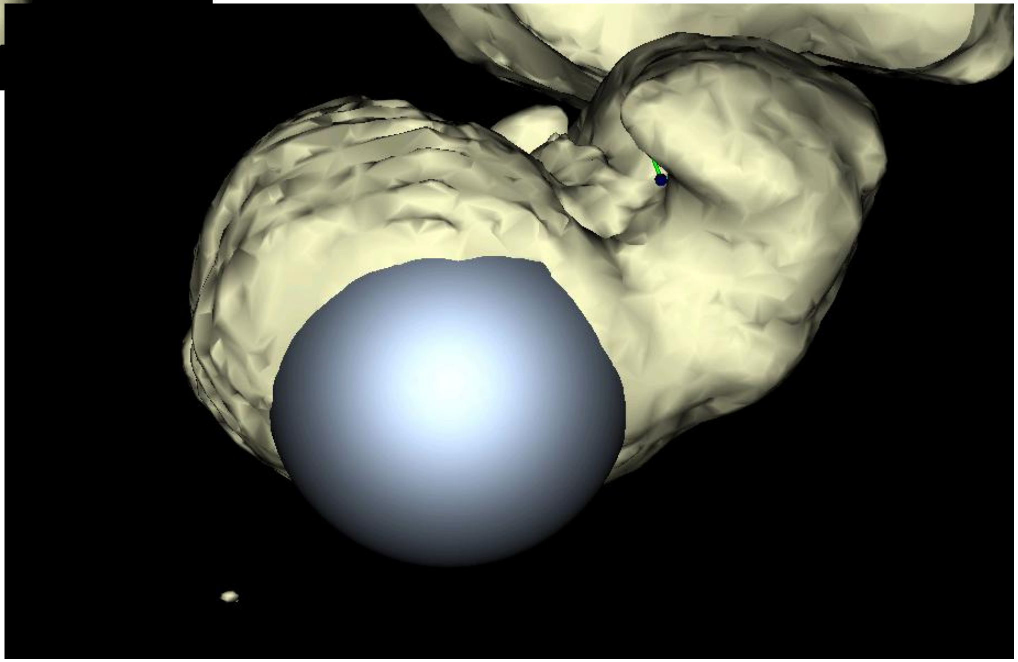
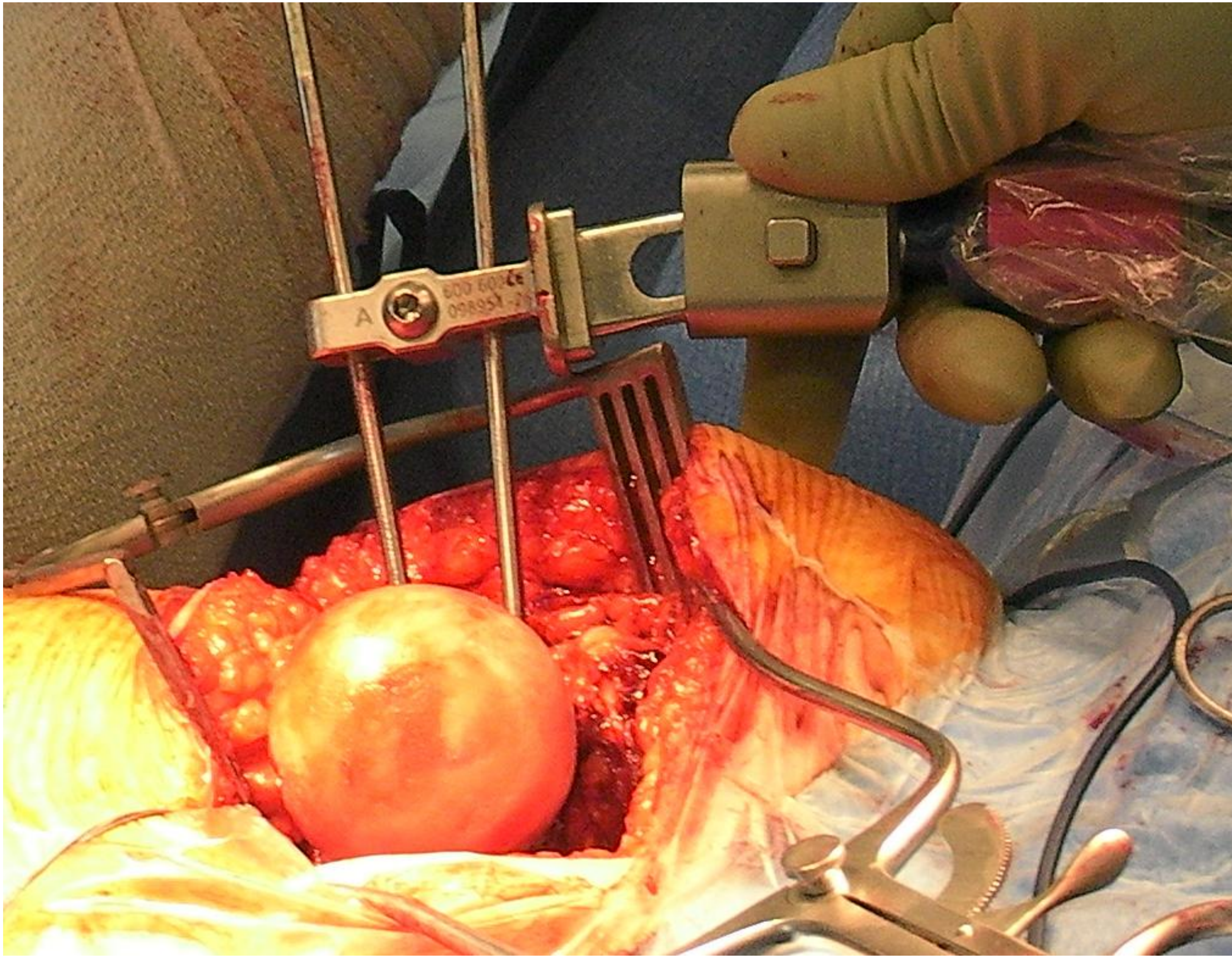
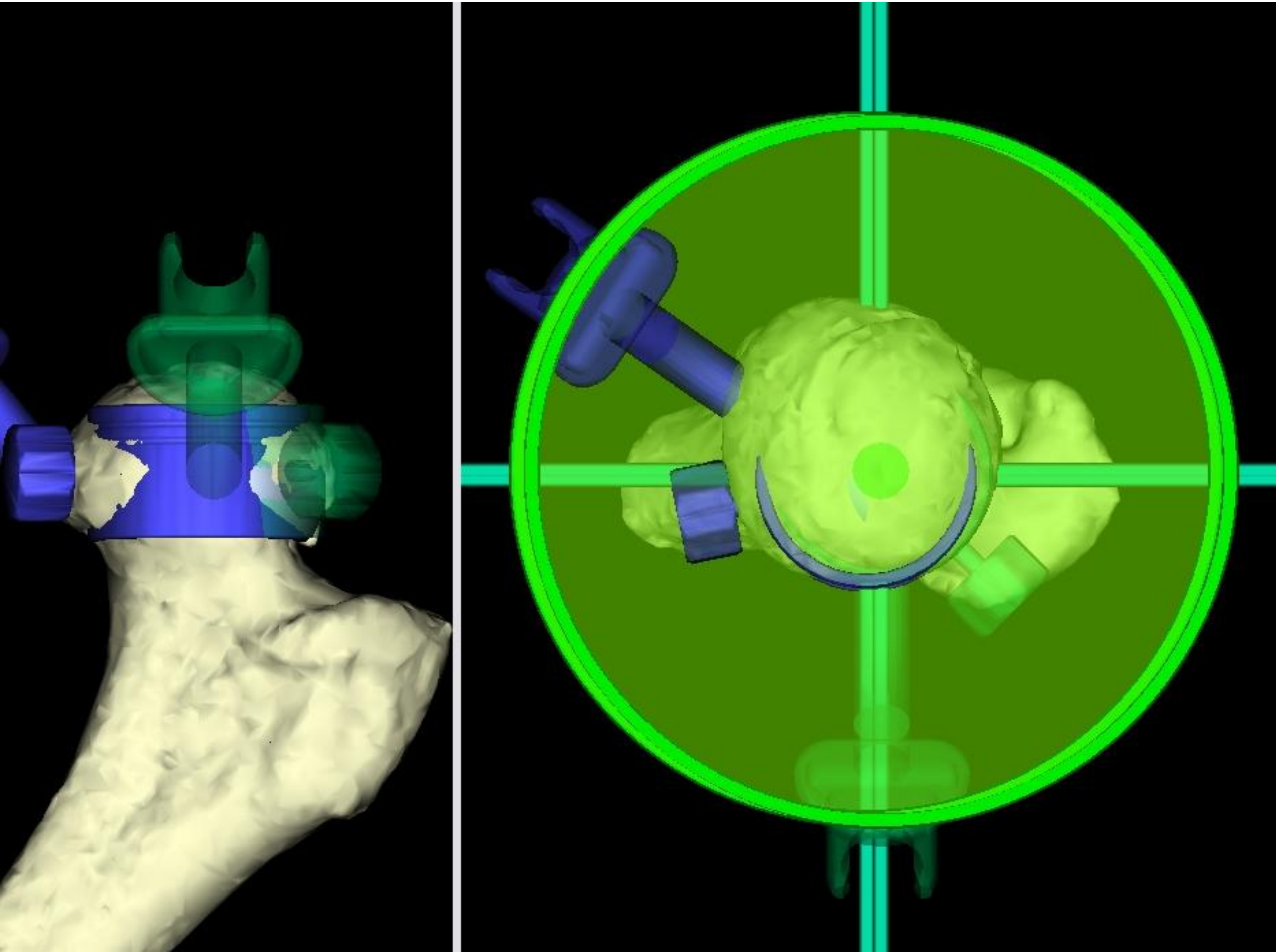
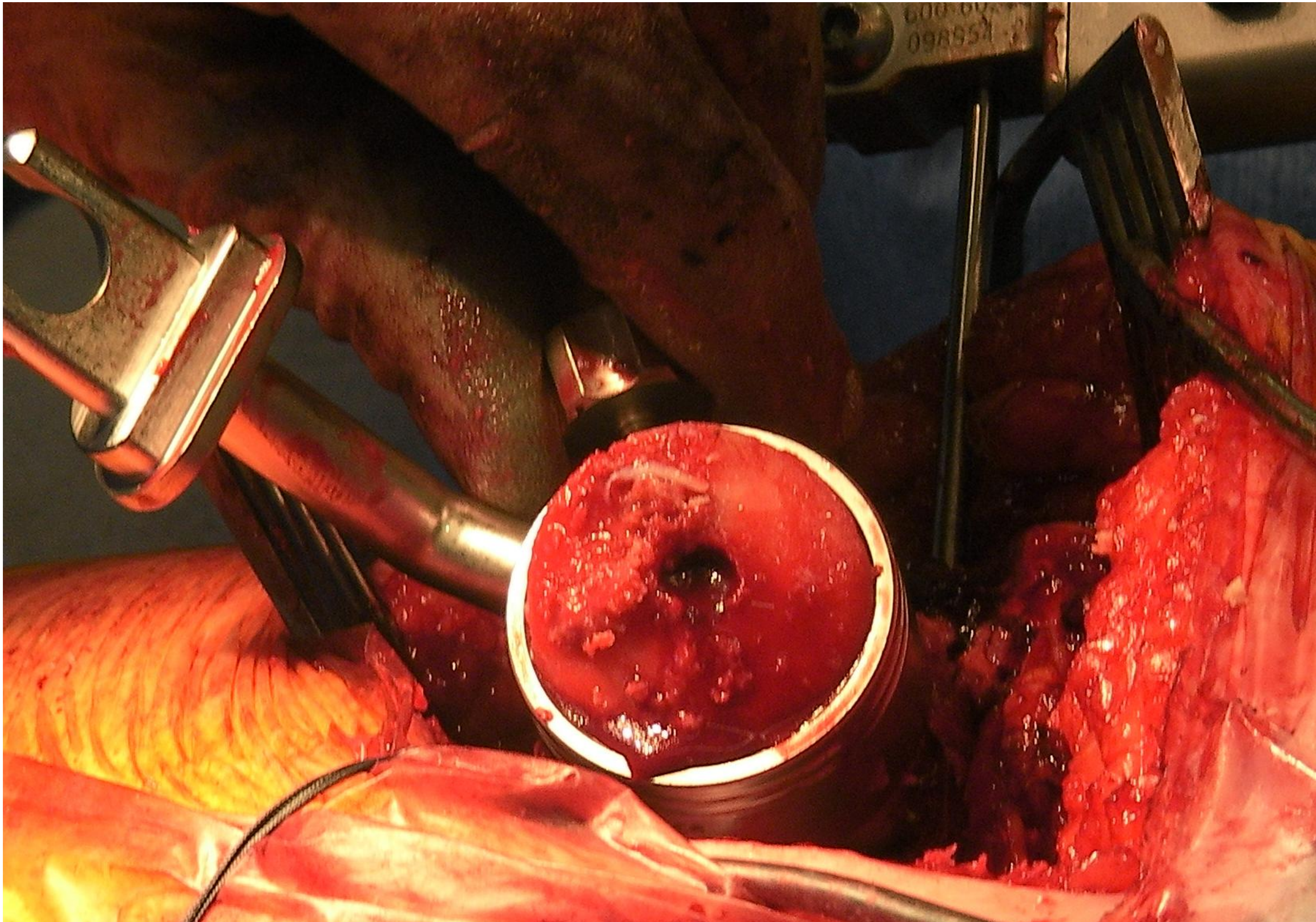
Planning

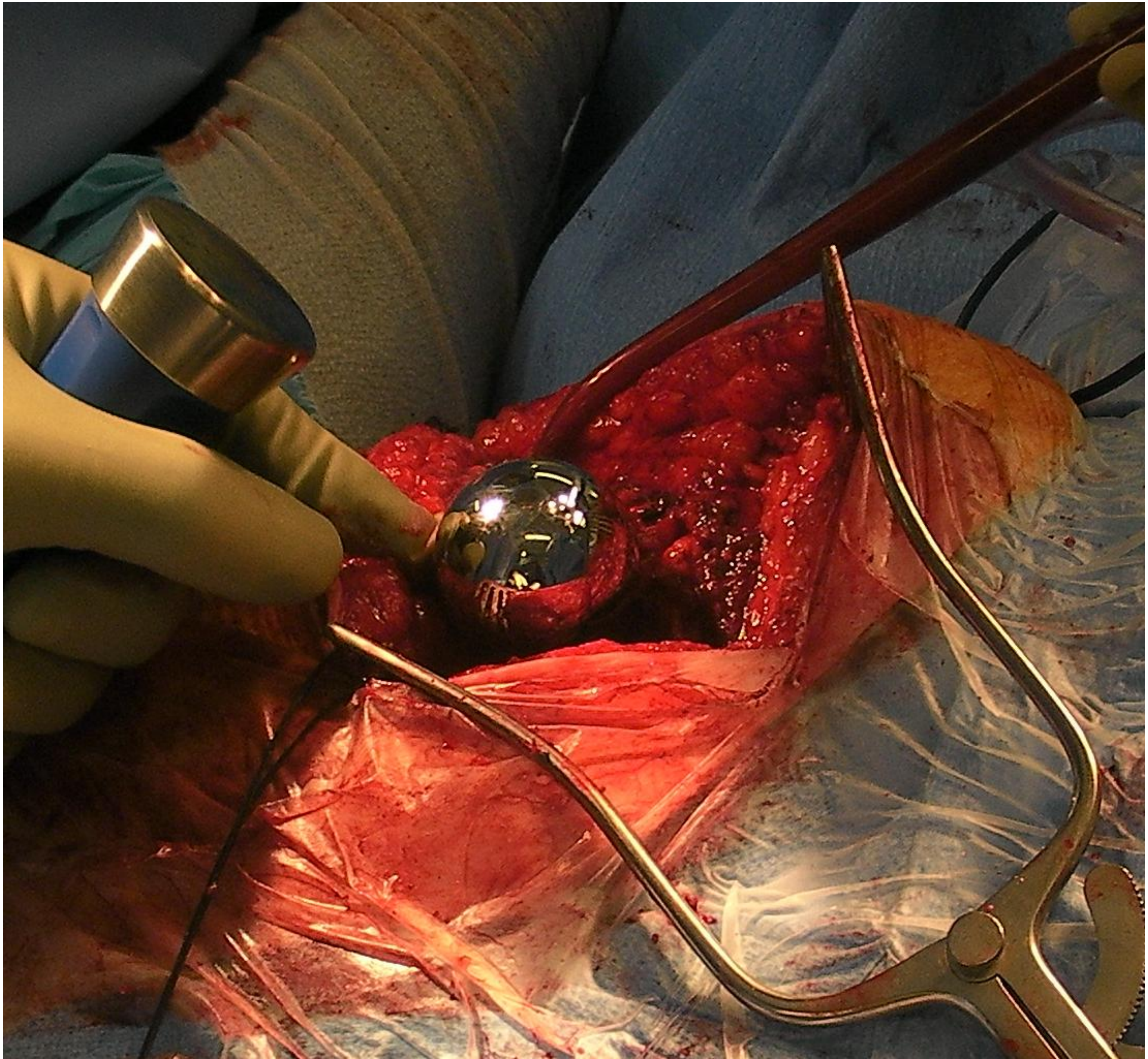




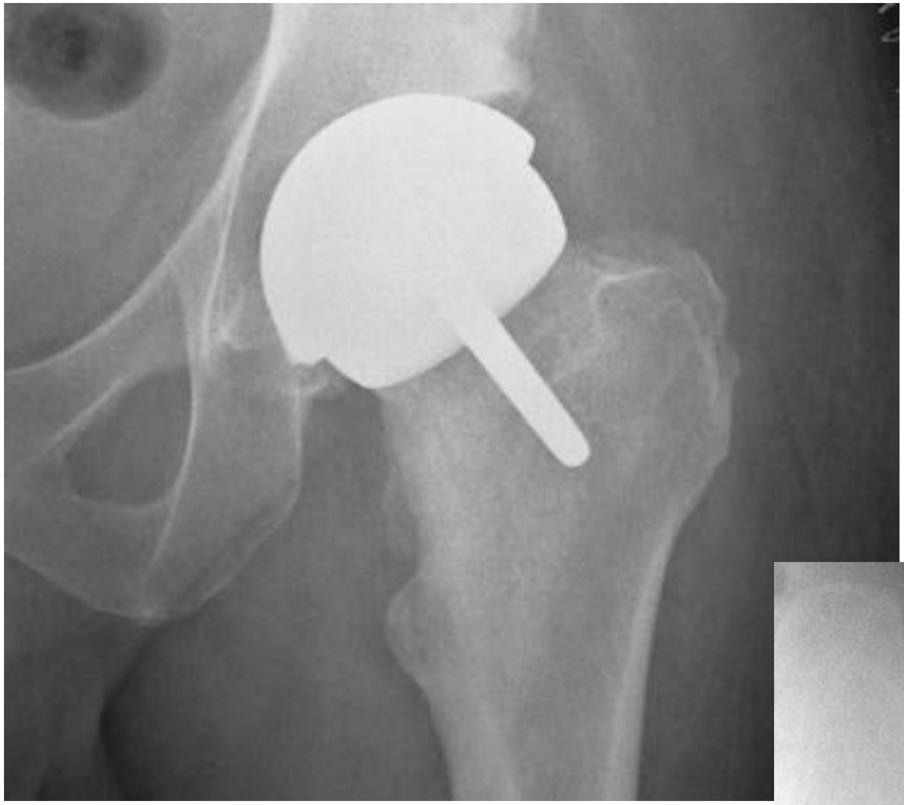


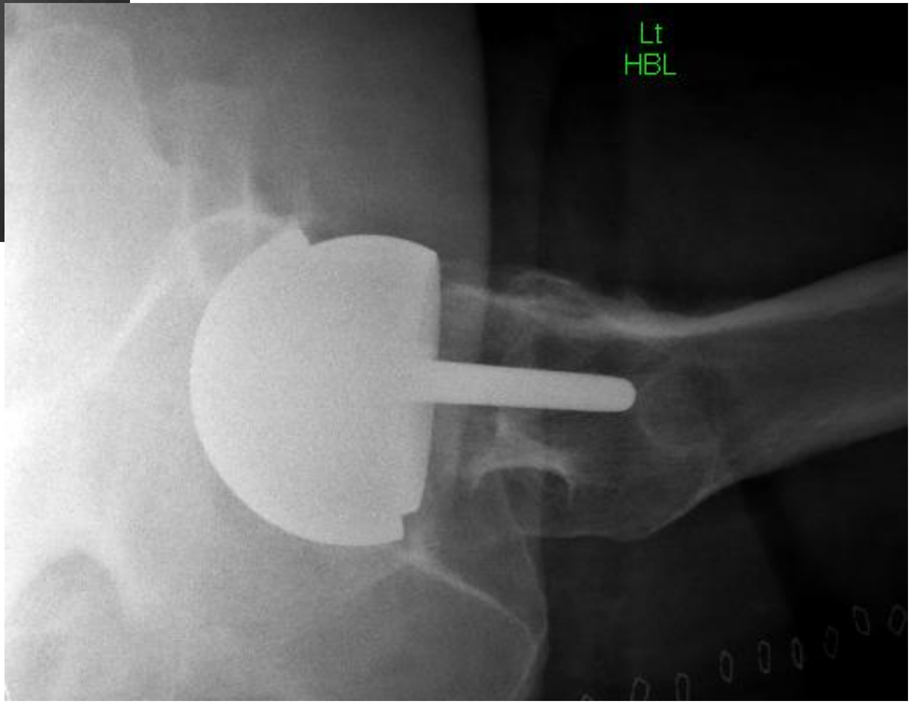






Post surgery



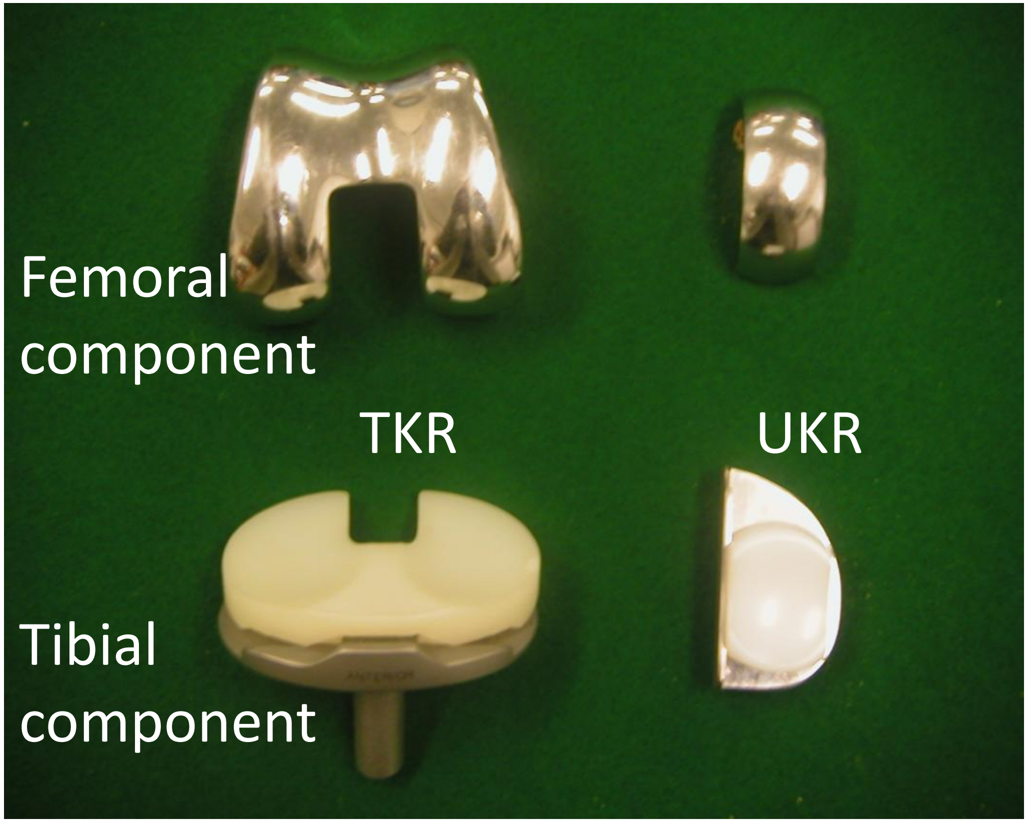


Acrobot Navigation system

- It has also been used for:
  - Uni Knee replacement
  - Total hip replacement

The Acrobot Company Limited

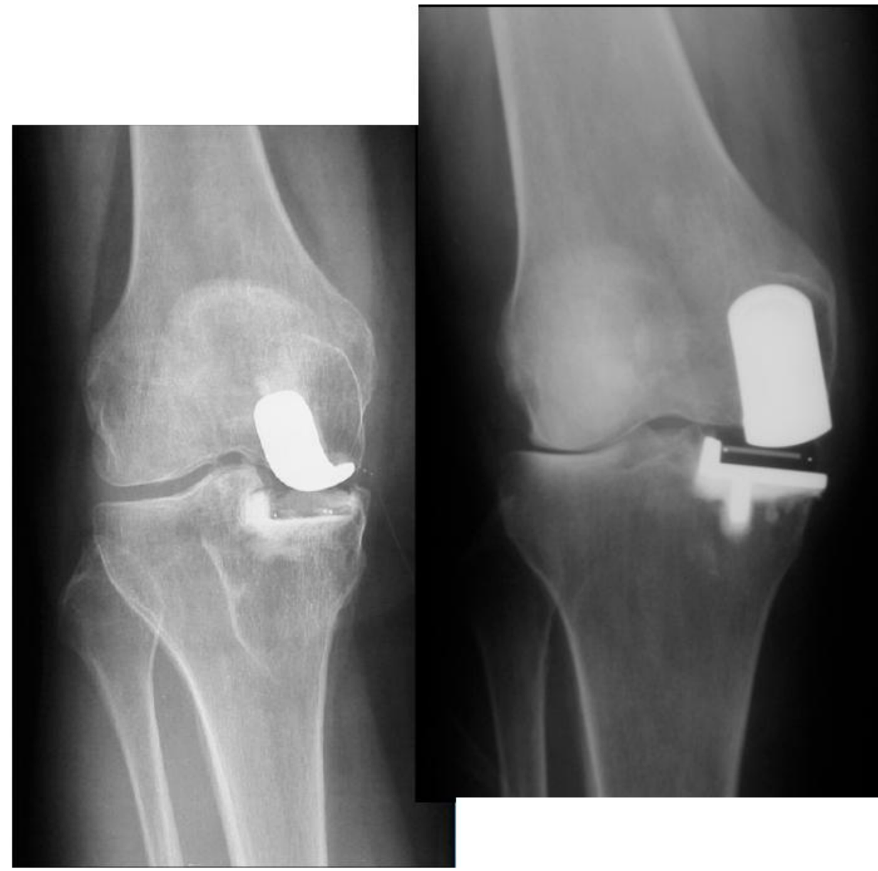
- ACROBOT Sculptor:
  - a “Hands-on” Robot Used for Uni-Condylar Knee Arthroplasty



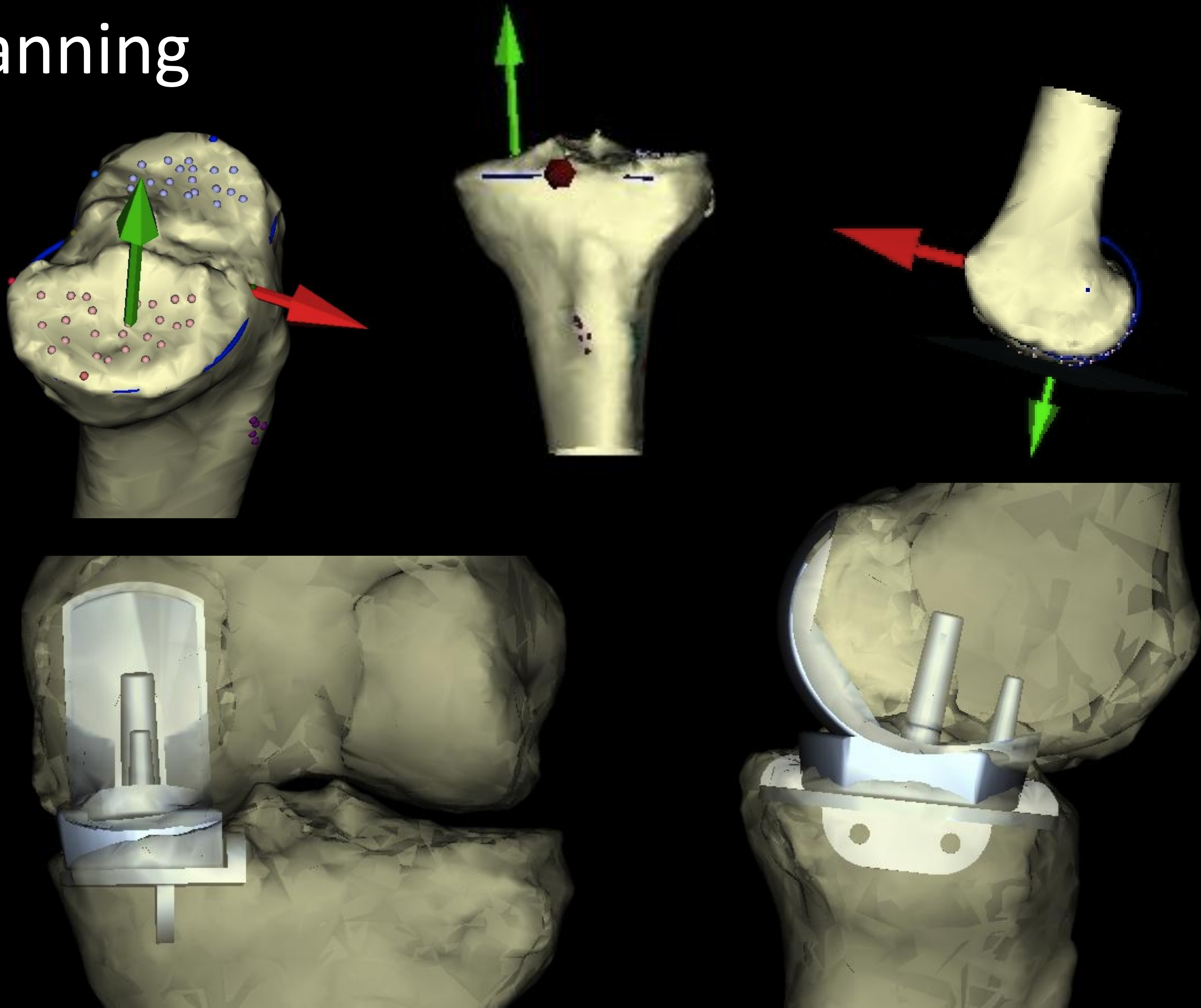
Results are not always satisfactory with conventional methods

Good

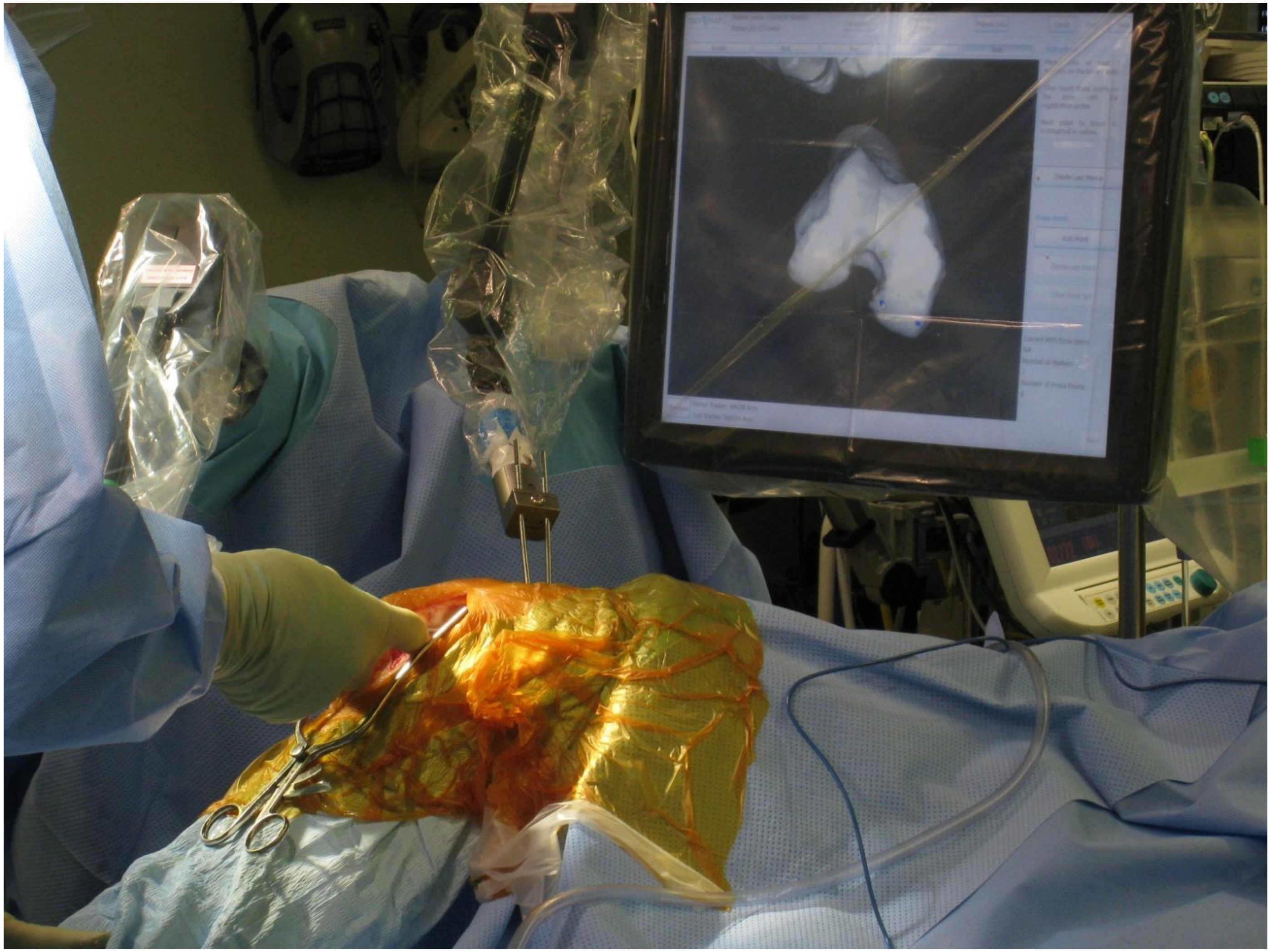
Not so good



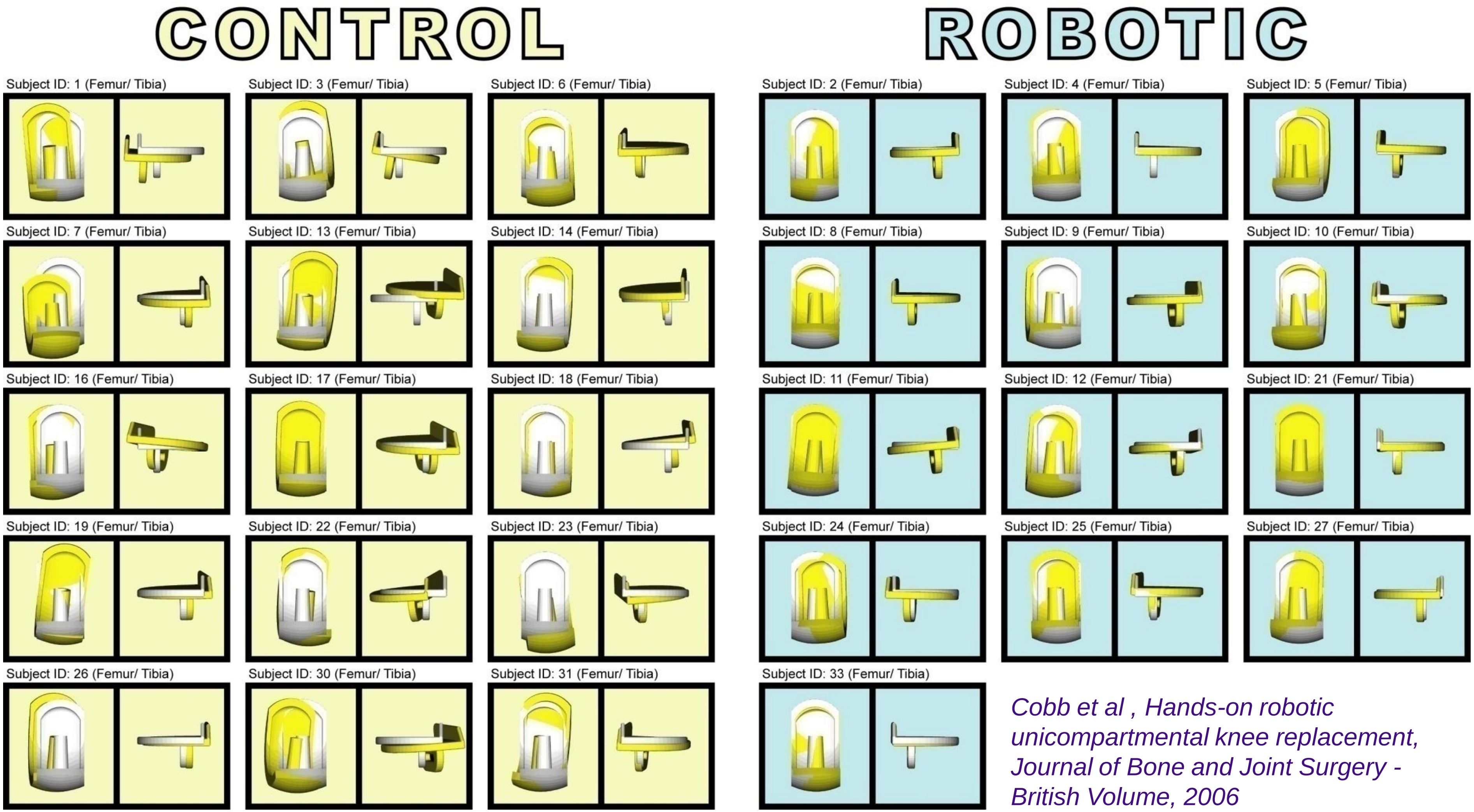
Planning



Register the bone to your plan



Clinical Evidence



Cobb et al , Hands-on robotic unicompartmental knee replacement, Journal of Bone and Joint Surgery - British Volume, 2006

Acrobot much more accurate than conventional

Tibio-Femoral angle	Type of surgery		All knees
	Acrobot System	*Conventional*	
$\leq \pm 2°$	13 (100%)	6 (40%)	19
$> \pm 2°$		9 (60%)	9
Total	13	15	28

P<0.001 (Fischer's exact t test)

And they work better after 18 month

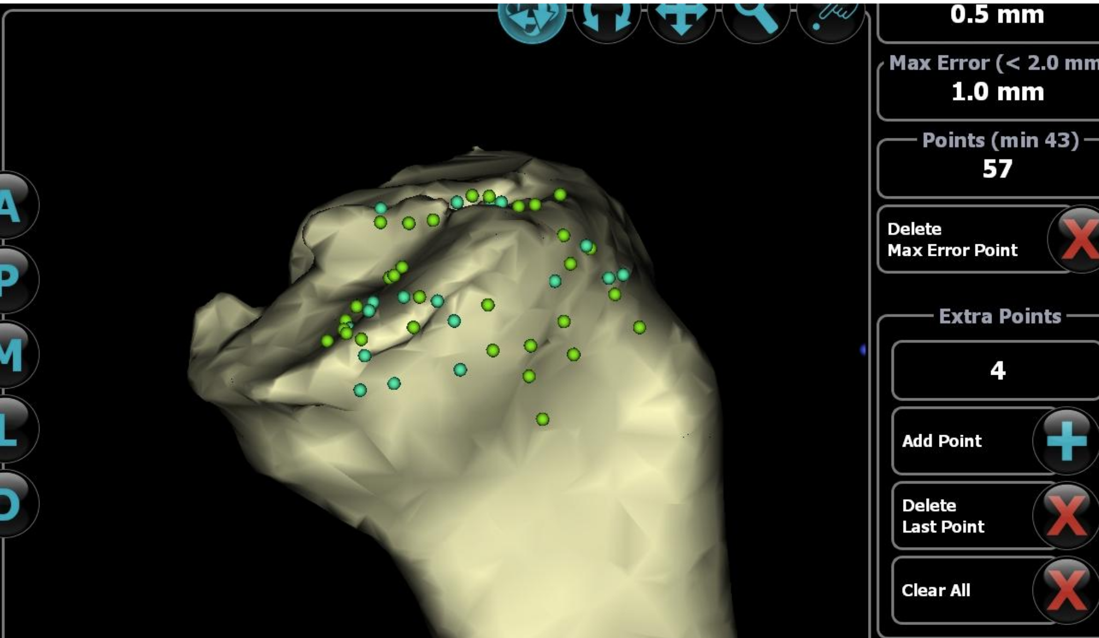
Acrobot's Sculptor™ System

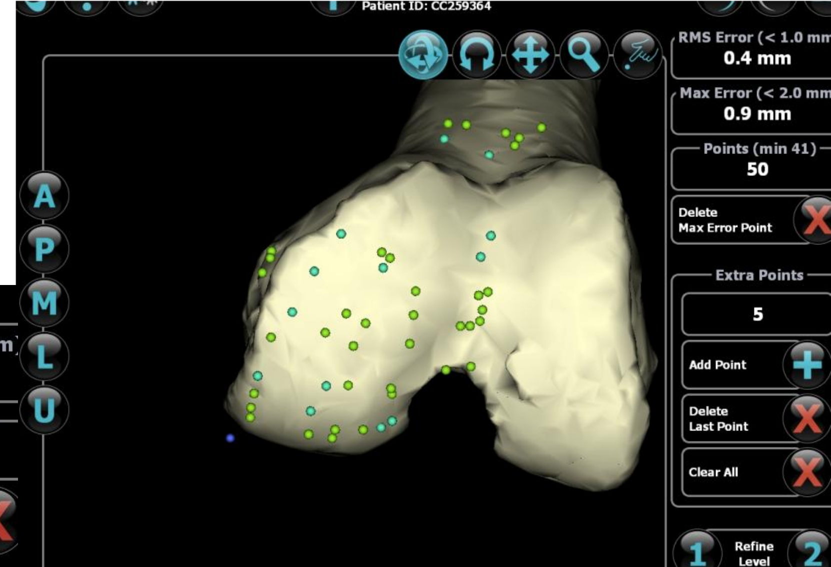
- 3D hands-free sculpting
- Dynamic constraint control
- Low encumbrance
- Potential for:
  - *Reduced operating time*
  - *True minimal access surgery*

Acrobot Sculptor Hand on robot for Uni Knee arthroplasty

- CT based
- Active constrained robot
- 3 DoF sculpting arm
- 6 DoF tracking arm

Co-Registration

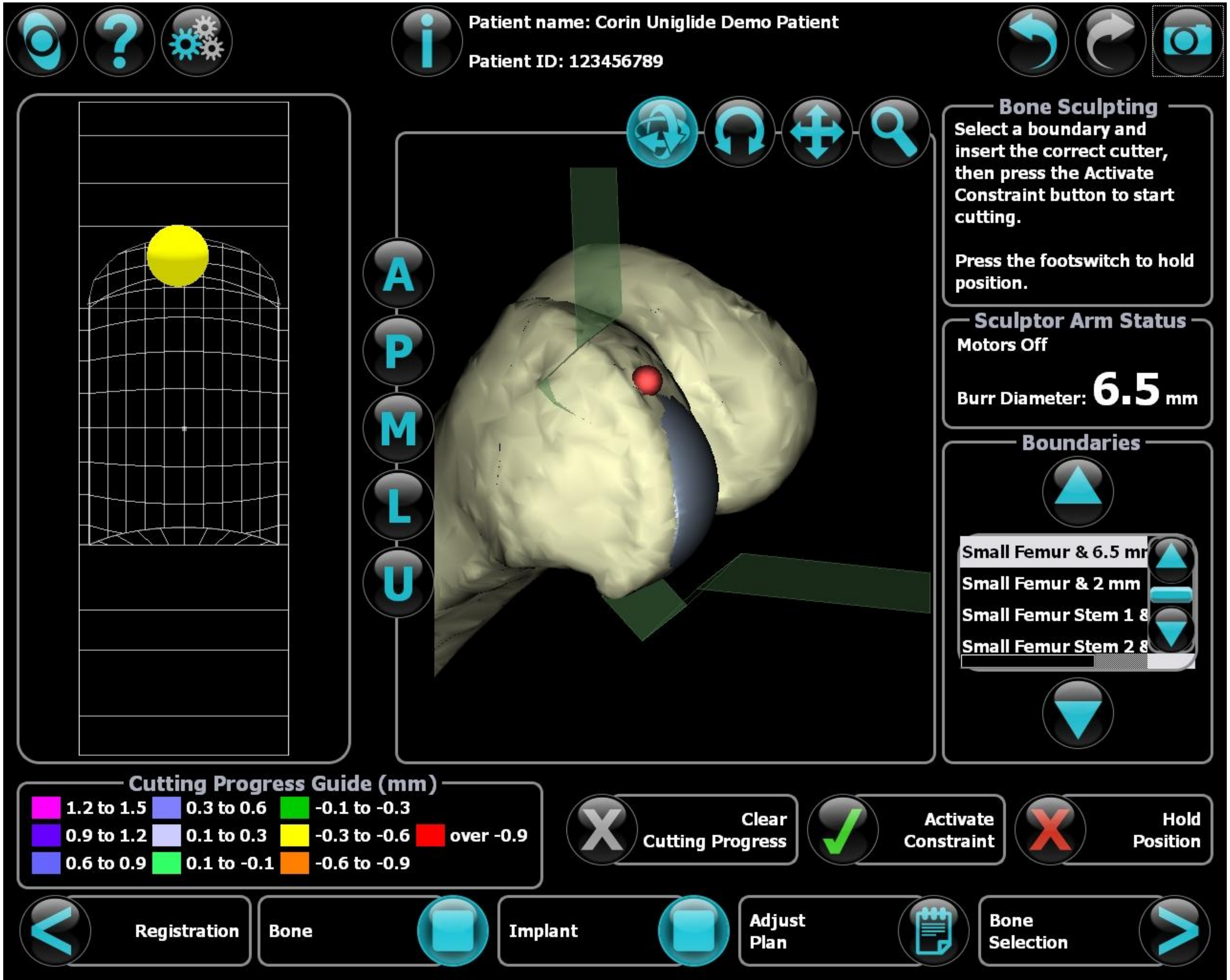




Registration process for:

- Matching the CT data to the bone
- Relationship between the robot and the bone

Sculptor – planning and active constraints

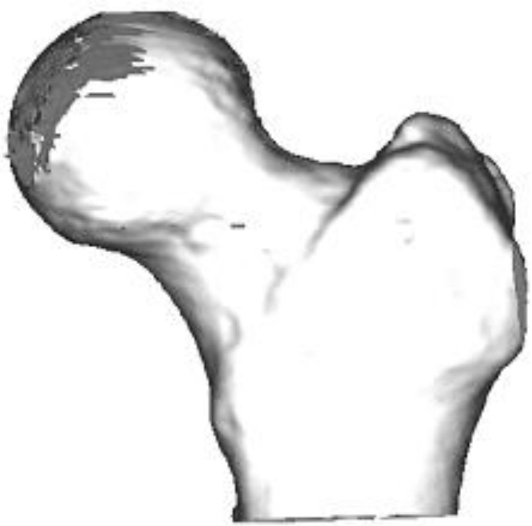


Current Developments

Using Acrobot Sculptor

Background/Objective

- Cam impingement is the commonest cause of OA
- Preventing OA development by correcting cam
- Use Acrobot Sculptor

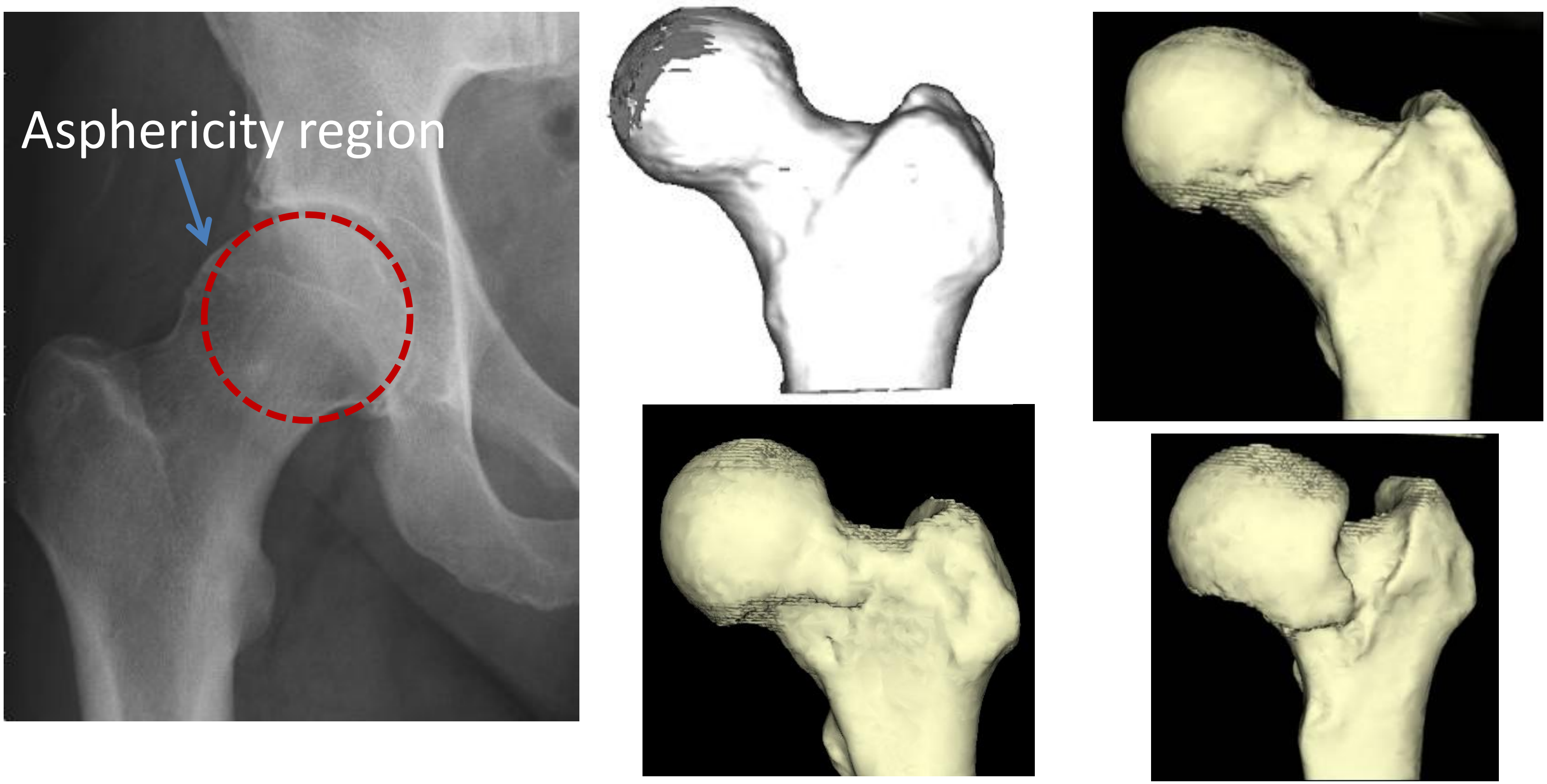


Normal femur

Cam femur

Femoro-Acetabular Impingement /cam

Femoral head/neck junction has an abnormal large radius



Degeneration of labarum and cartilages might lead to OA

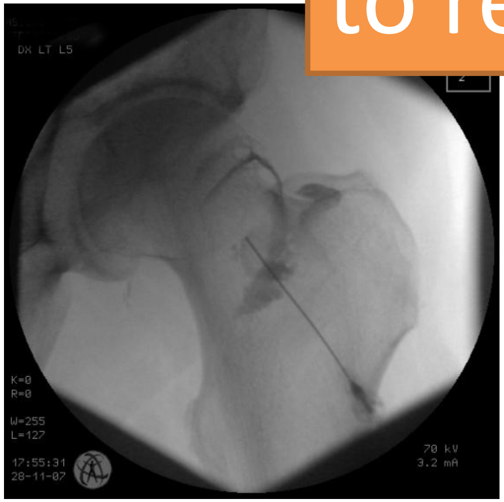
Common methods of CAM diagnosis

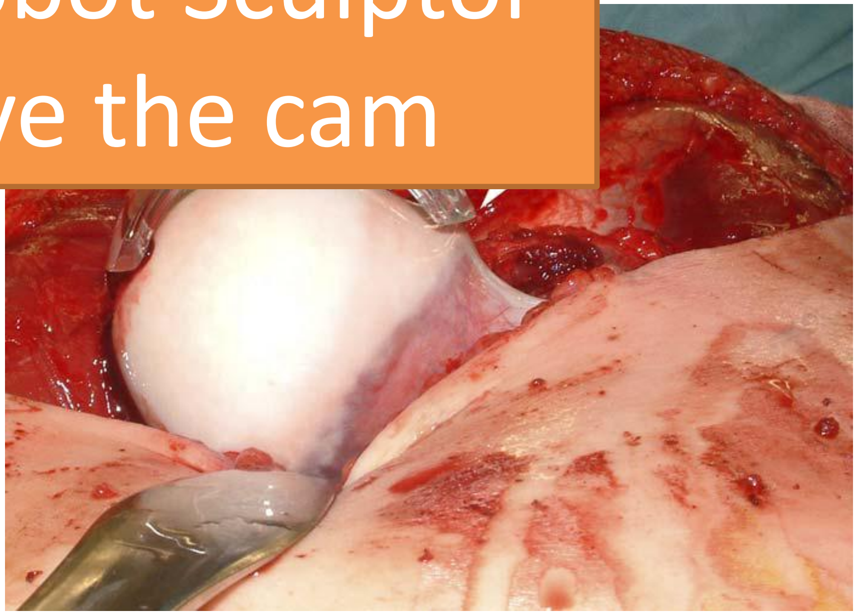
- 2D Assesses the degree of asphericity of the femoral head neck junction
  - Assessment of the angle between neck axis and a line drawn from the point where head deviates from sphere
  - Normal anatomy
    - $\alpha < 50$ deg.
- Impingement test

Treatment

- CAM- Open Surgery
  - Guess
  - Using Guides
- Arthroscopy
  - Using the flu
    images

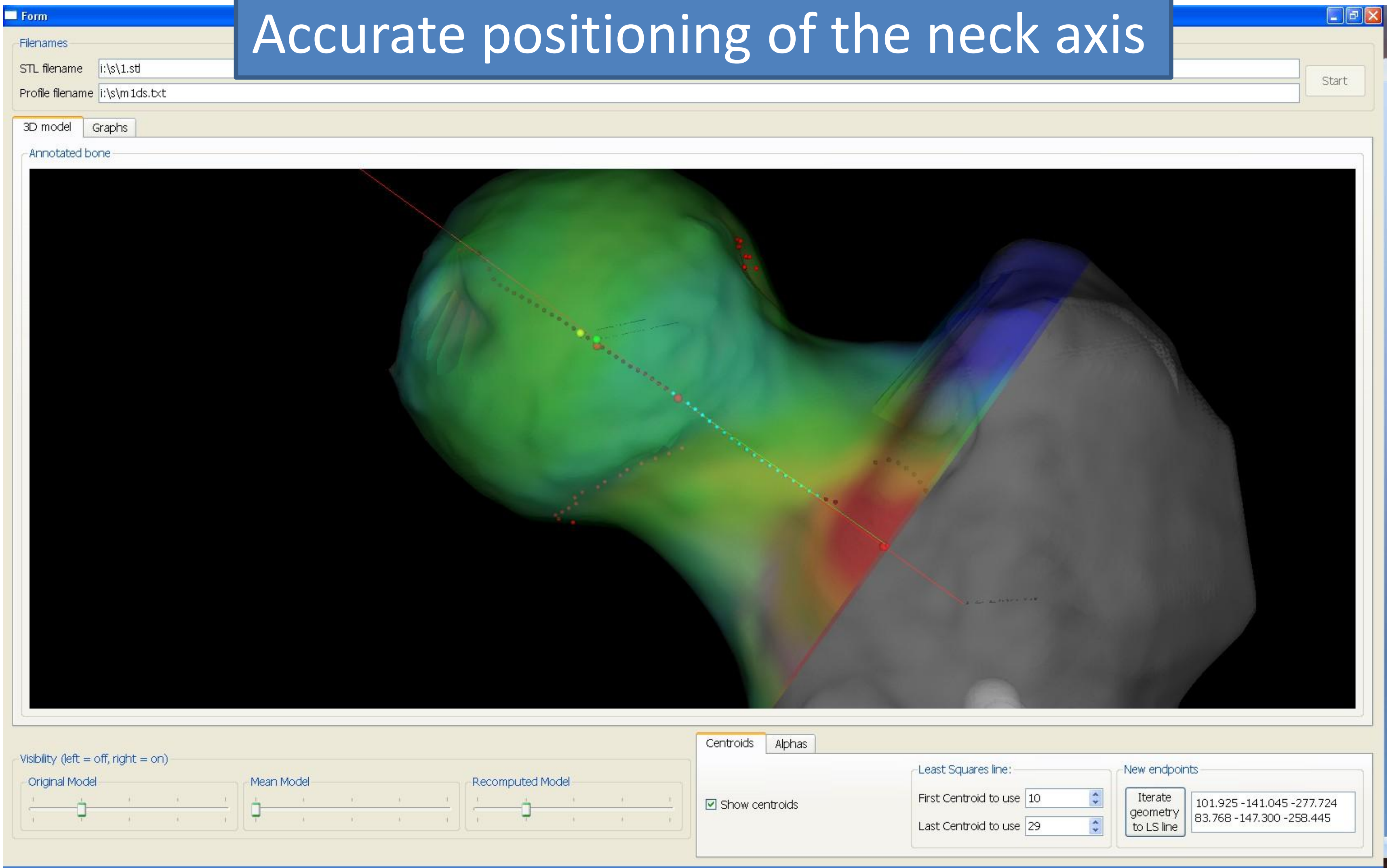
Use Acrobot Sculptor to remove the cam



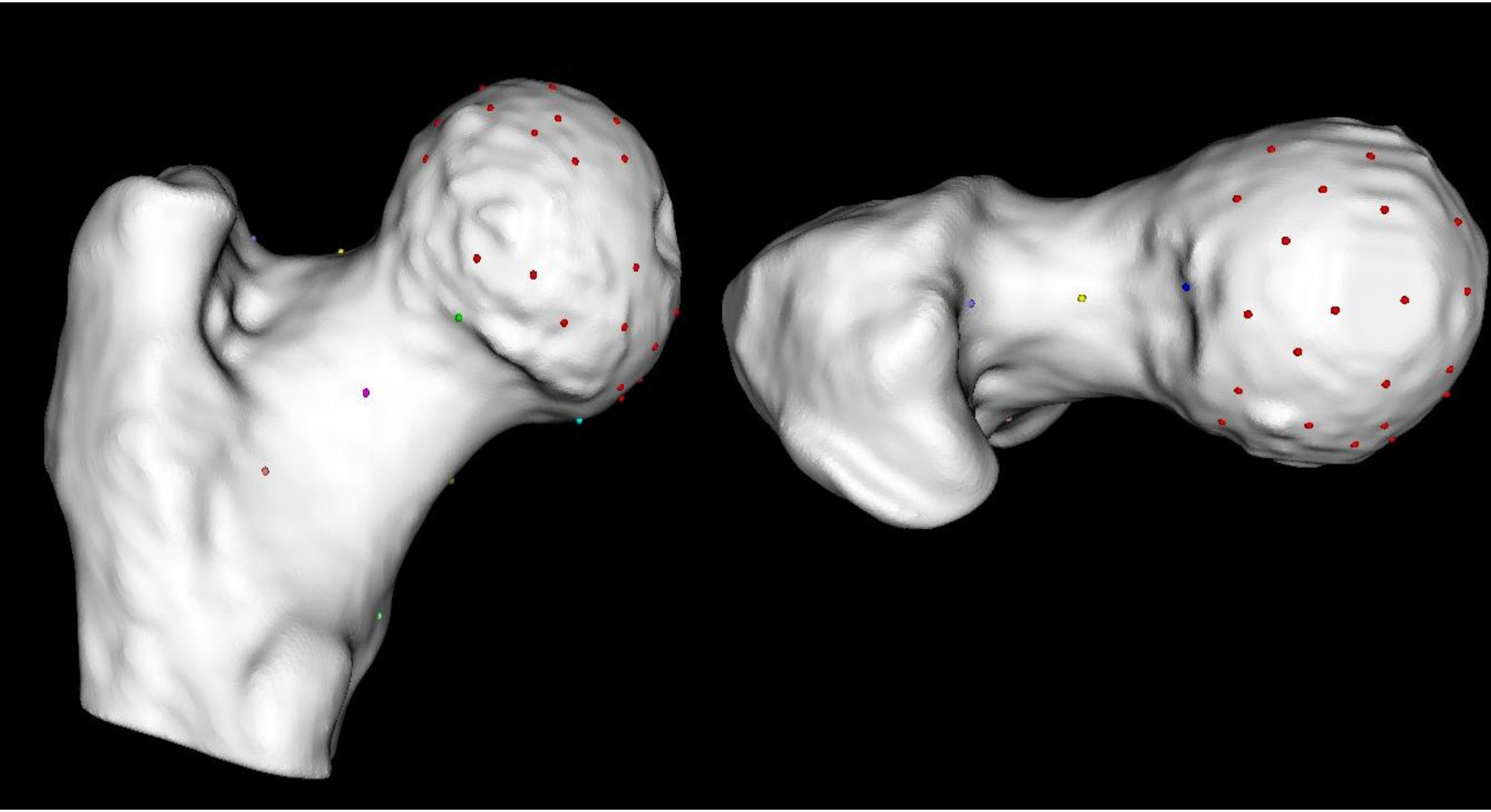


Newly developed software

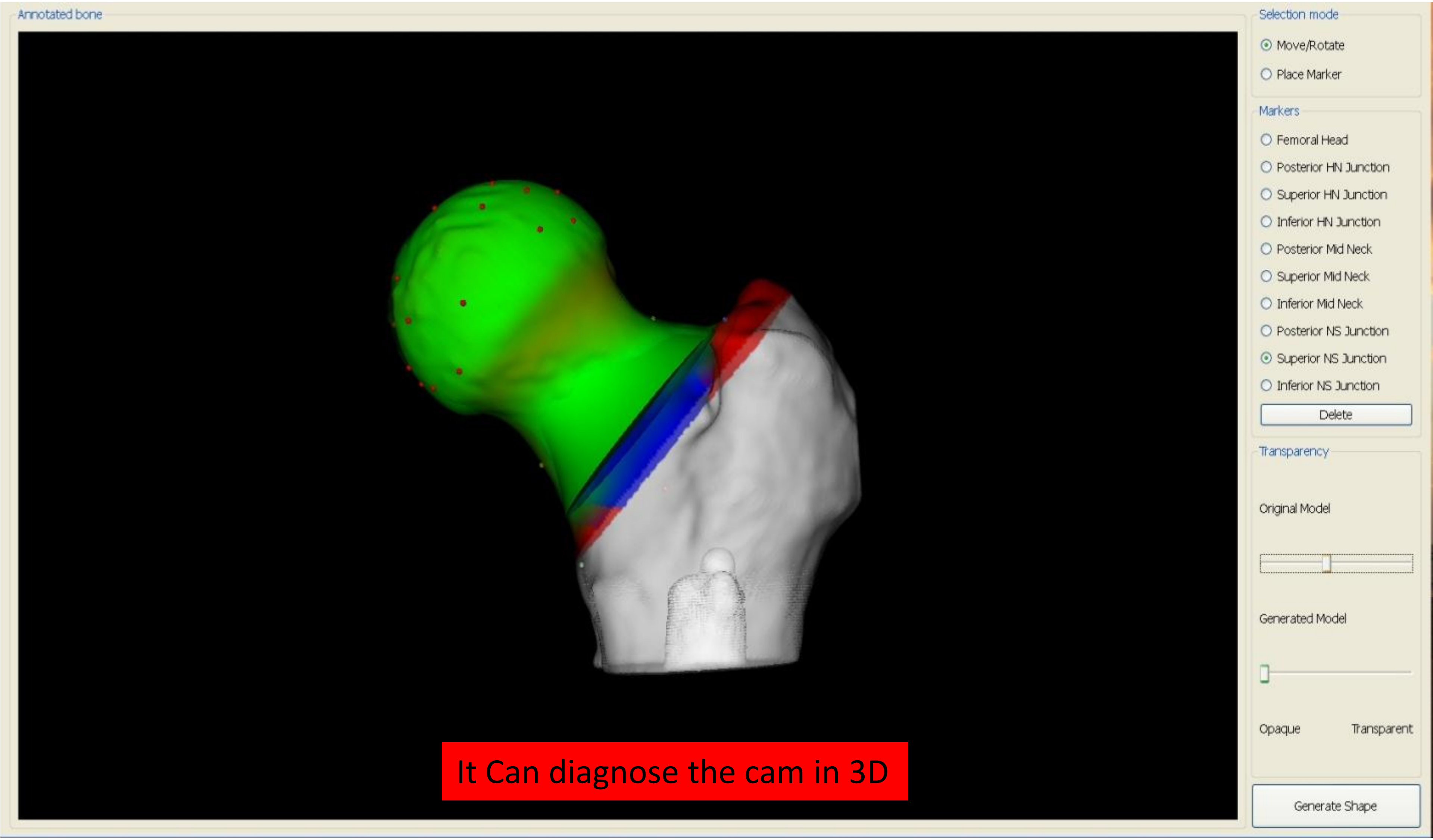
Accurate positioning of the neck axis



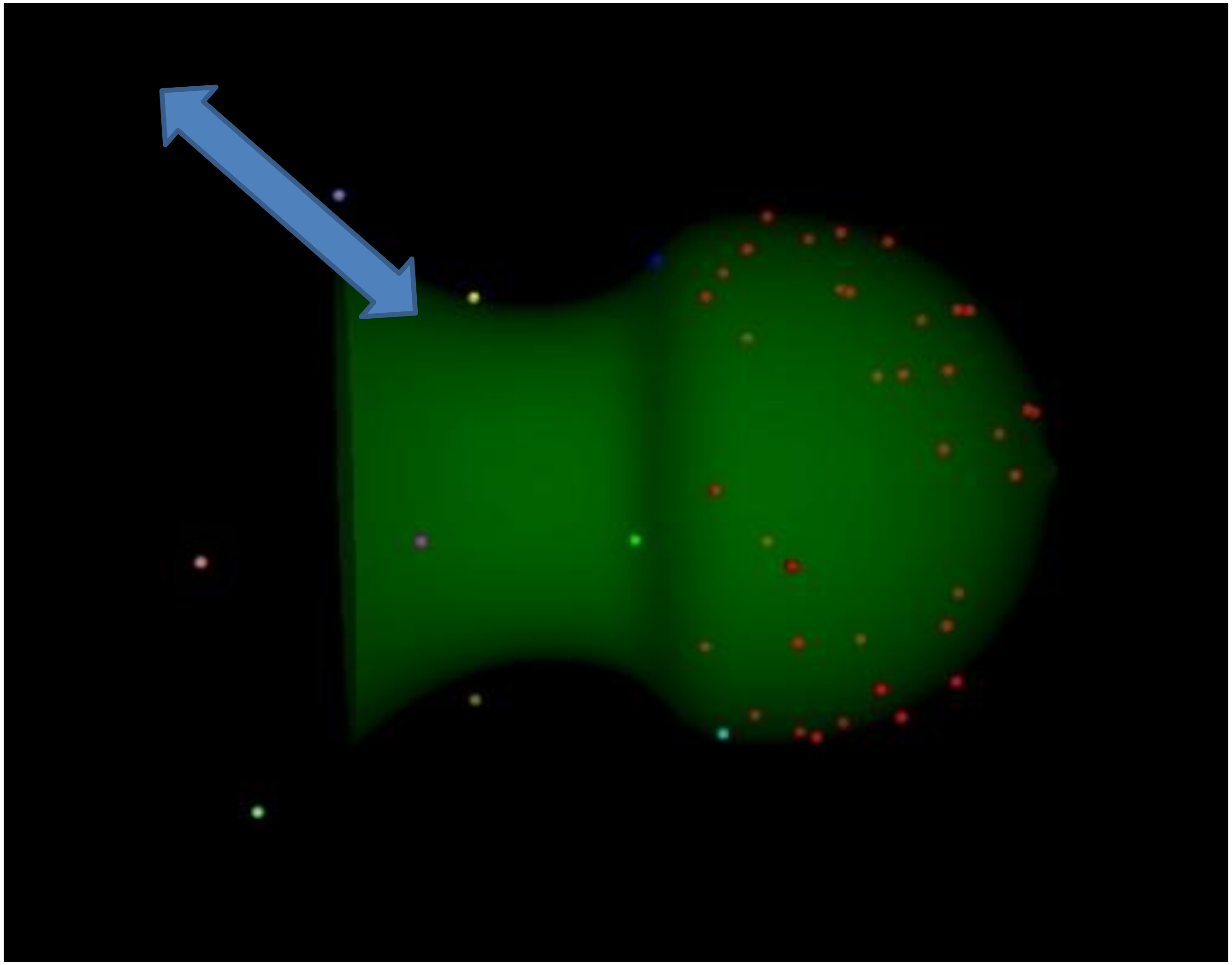
Selecting points on the head and neck



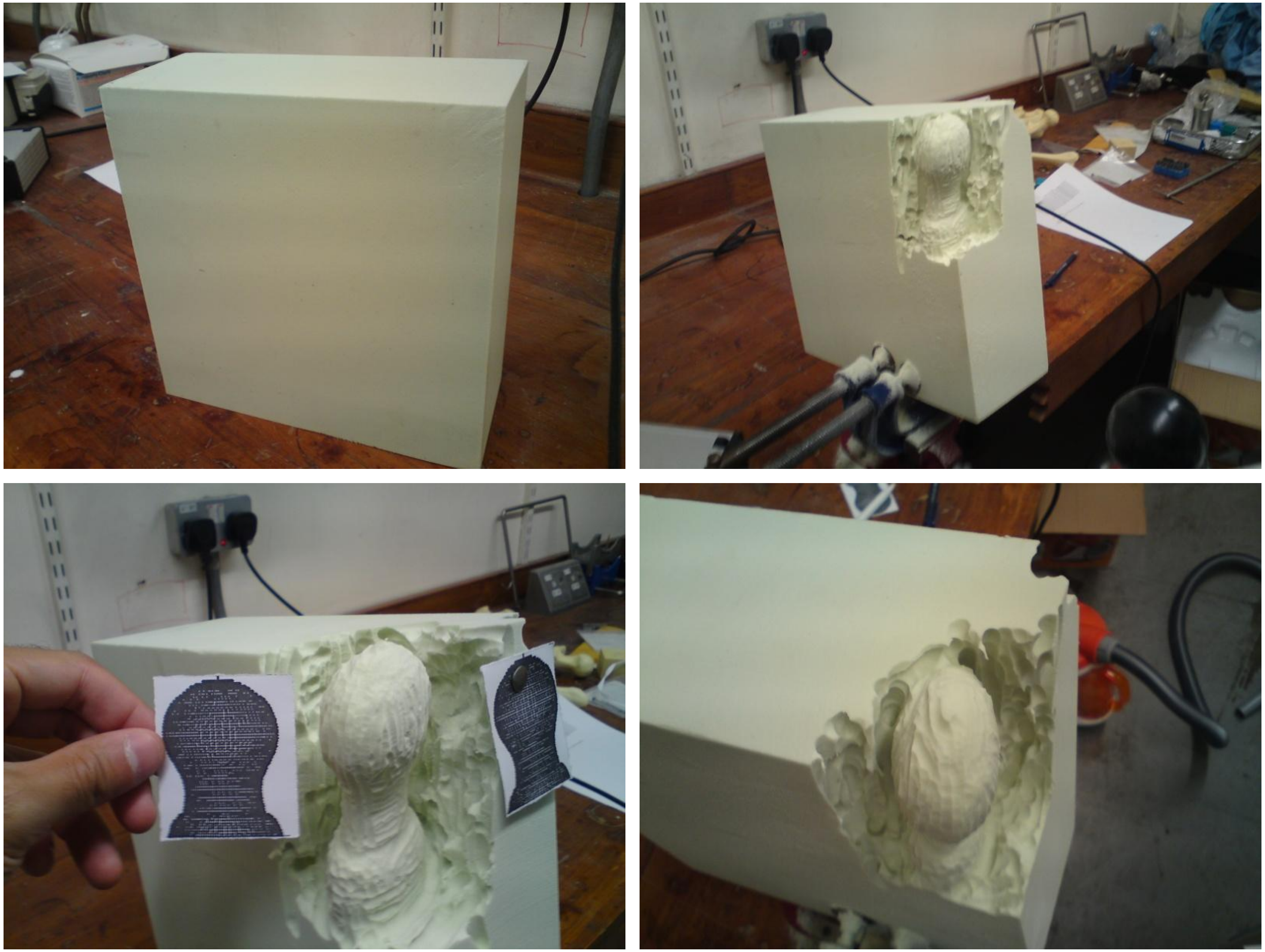
Development of neck shape for sculpting



The plan can be adjusted based on the surgeon's decision



Preliminary Results



Future work

- Dry bone testing
- Clinical trials
- Preventing OA in other joints
- Methods can be extended to other surgery across the human body such as:
  - trochlea- plasty of knee joint, removing tumours bones...

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Thank you

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