

Lecture : Computing Assisted Surgery

# 人工関節のコンピュータ支援手術 ～ 最小侵襲手術に向けて～

大阪大学大学院医学系研究科  
器官制御外科(整形外科)

菅野伸彦

平成16年12月9日 帝国ホテル東京

# 人工関節とは？



# コンピュータ支援手術とは？

Computer Aided (Assisted) Surgery : CAS

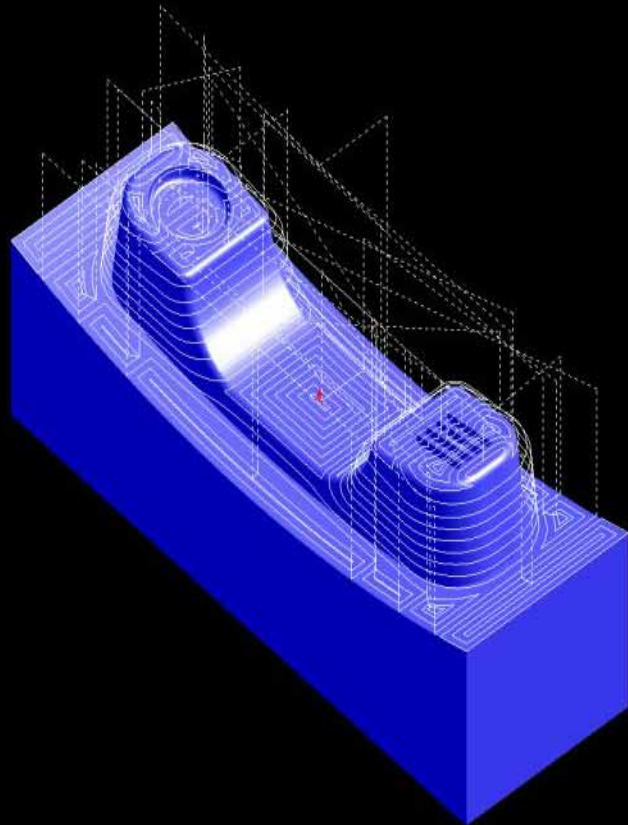
- 術前計画
- Navigation
- Medical Robotics

# 最新の製造技術



Computer aided design / Computer aided manufacturing

CAD/CAM



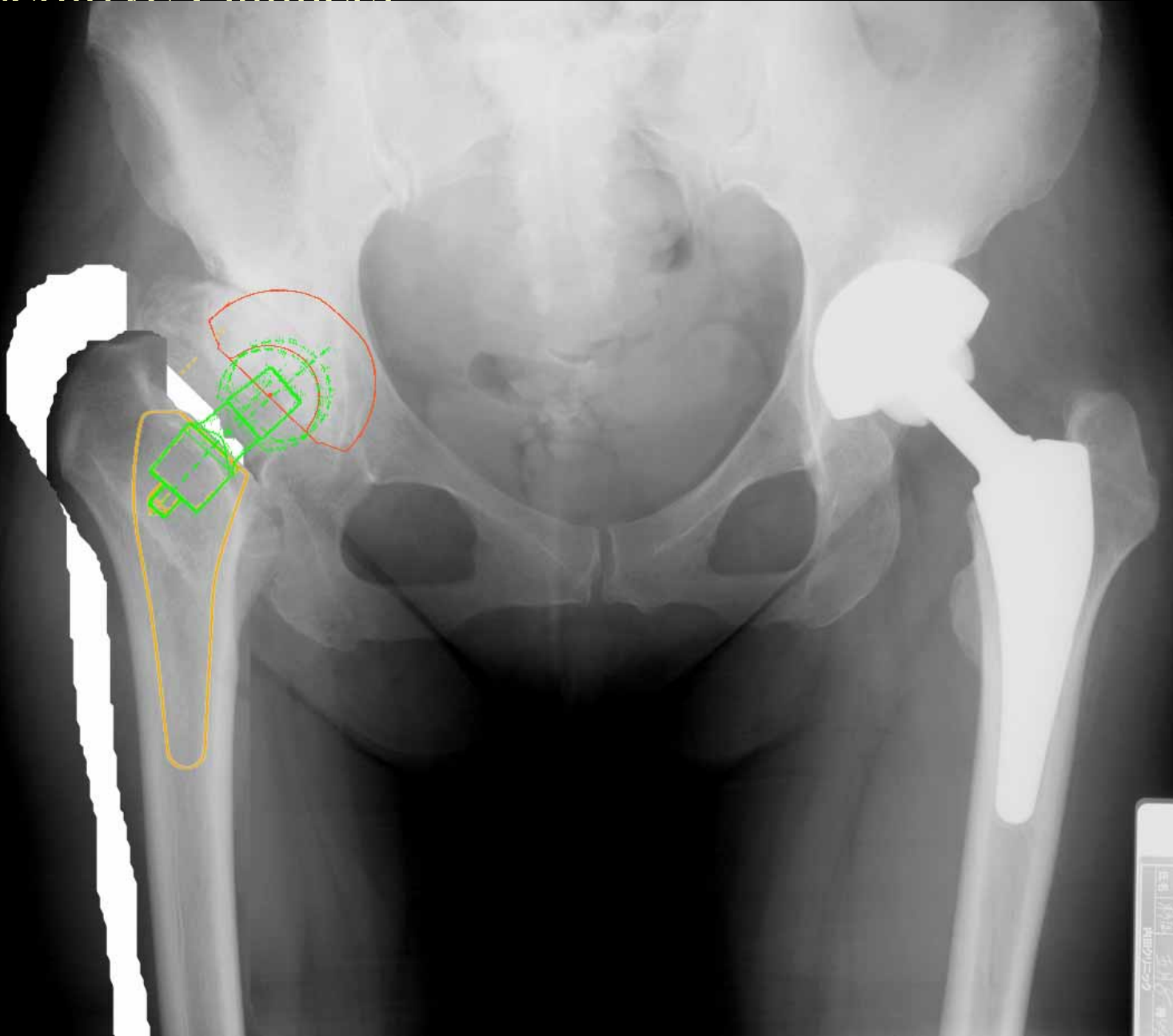
NC工作機



# CAS : 手術室でのCAD/CAM

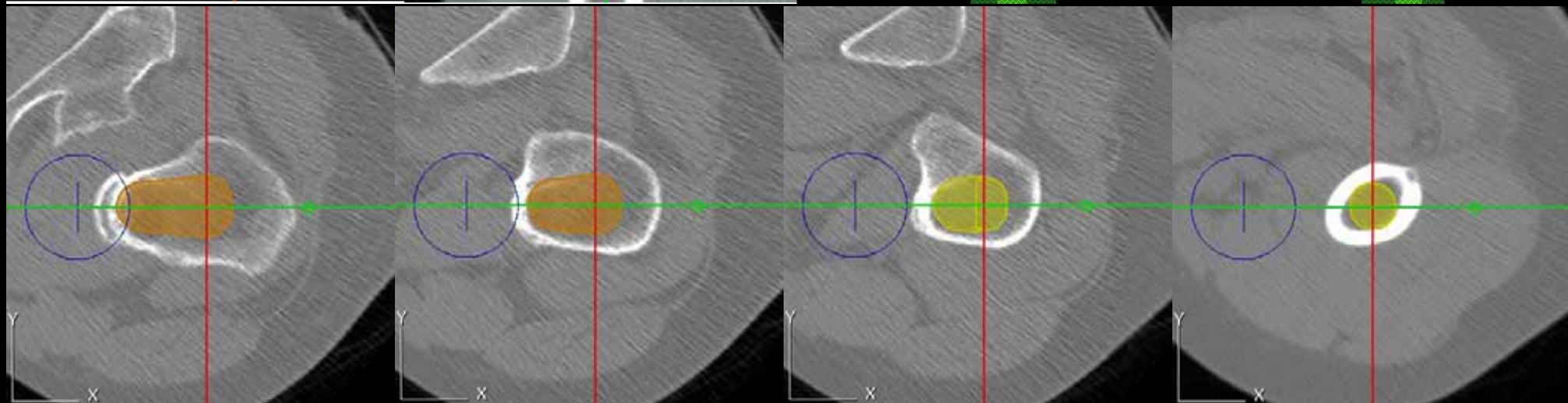
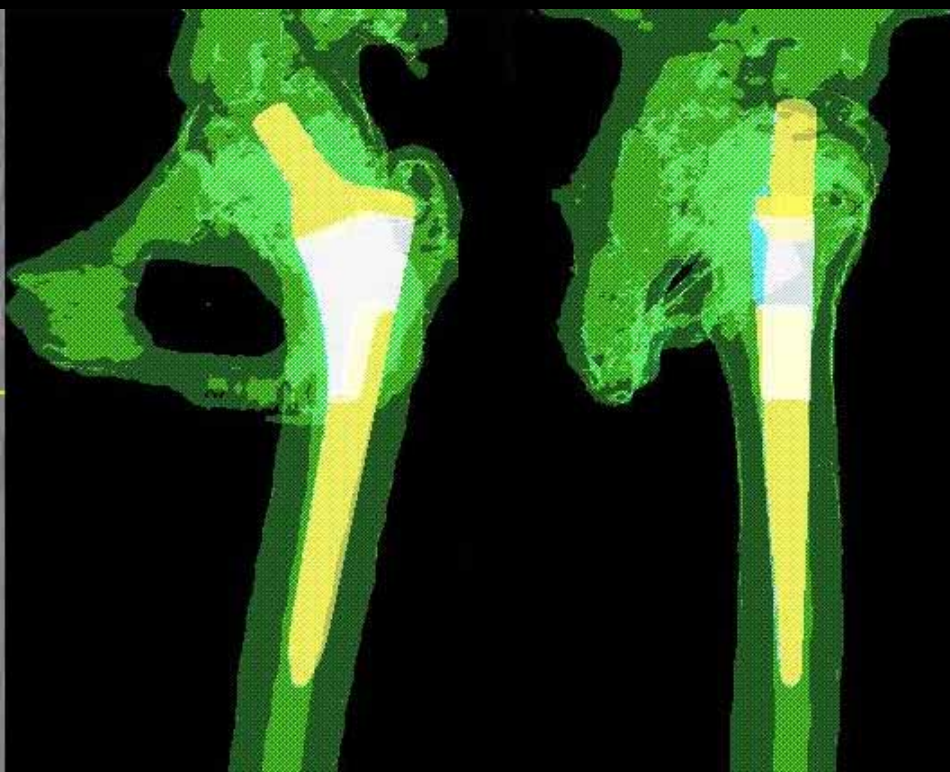
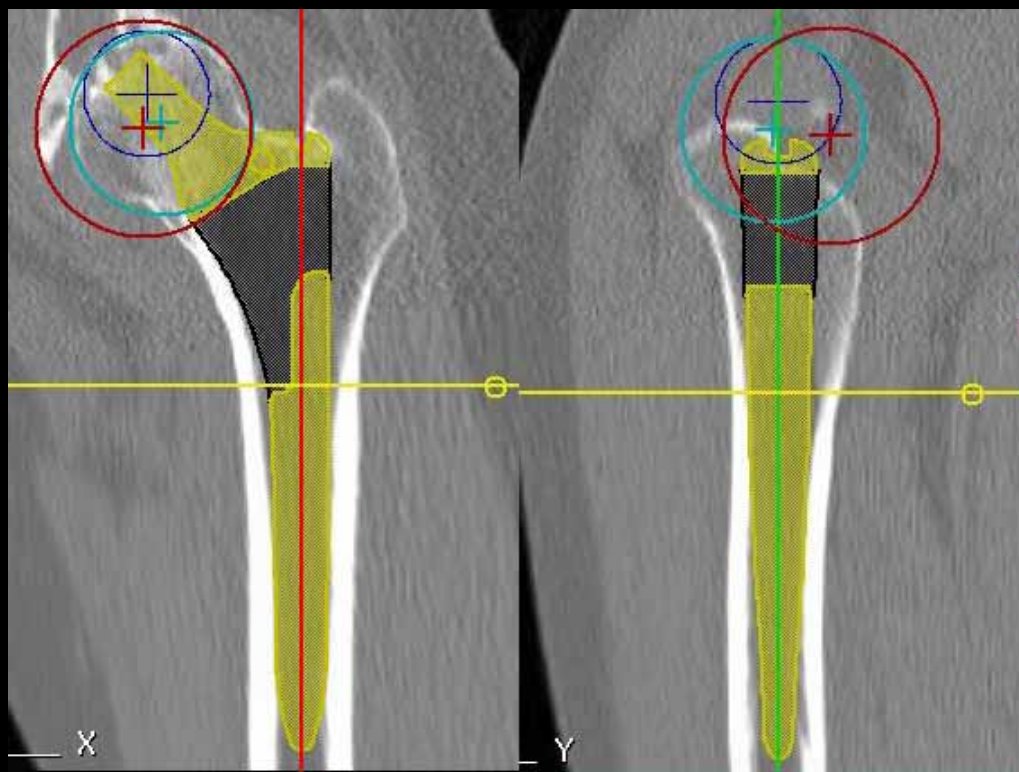
- Supervision (三次元画像解析)
- Superbrain (手術計画 & シミュレーション)
- Supersensor (ナビゲーション)
- Superhand (手術支援ロボット)

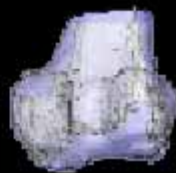
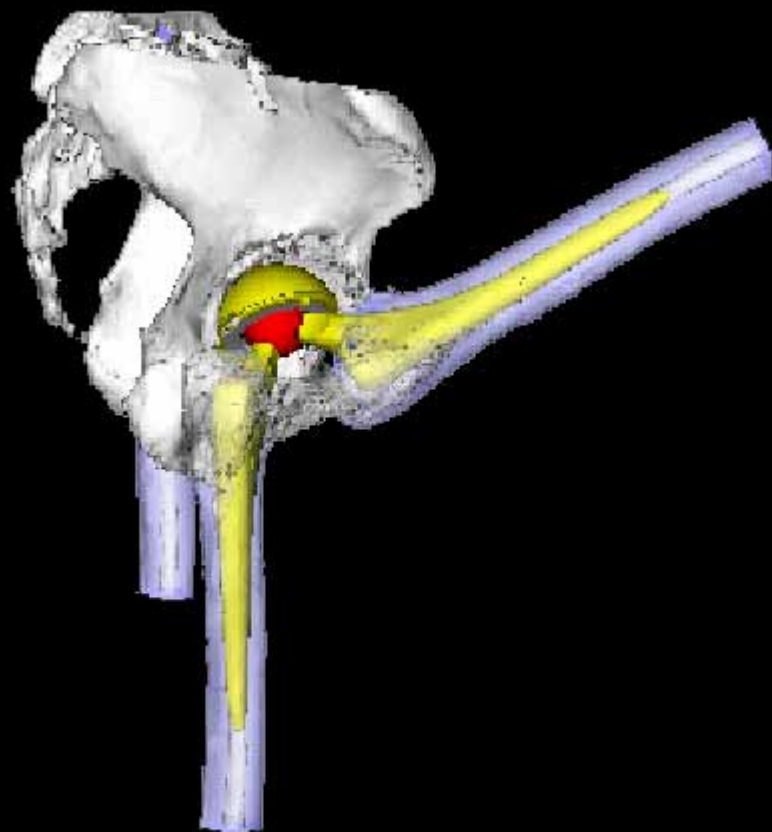
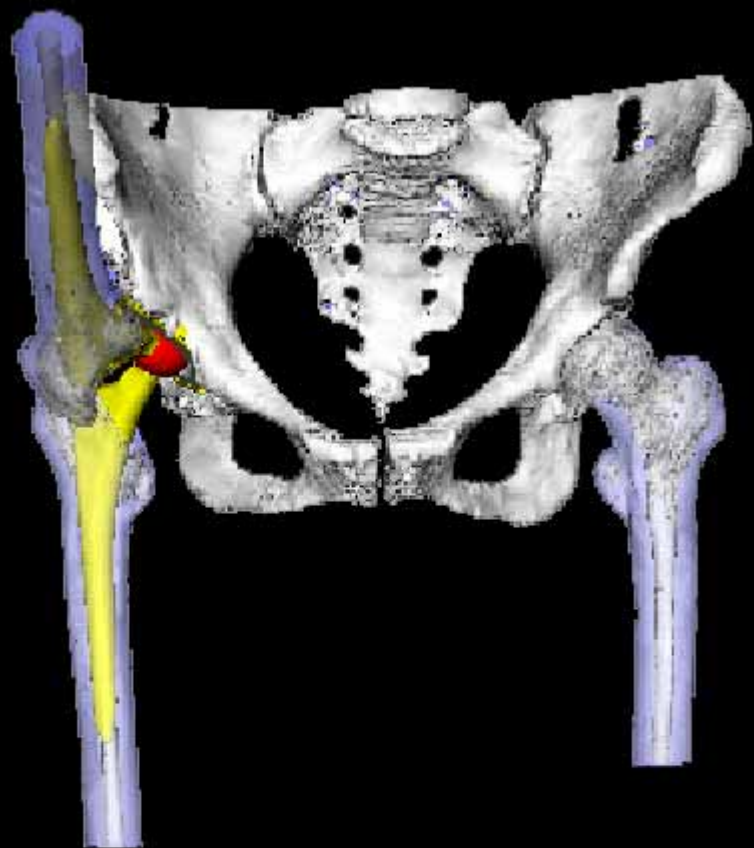
# Preoperative Planners





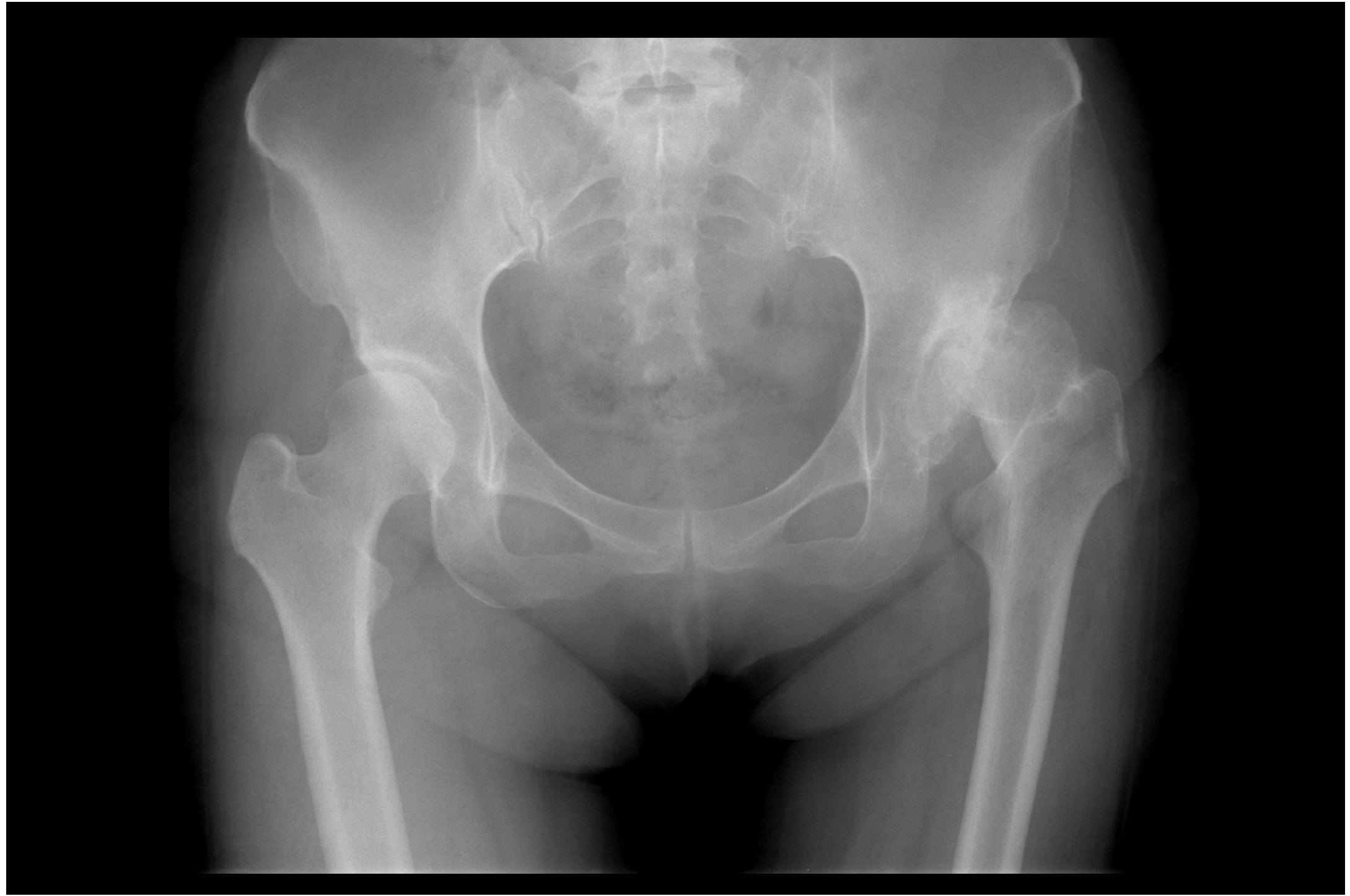






# CAS : CAD/CAM in OR

- Supervision (三次元画像解析)
- Superbrain (手術計画 & シミュレーション)
- Supersensor (ナビゲーション)
- Superhand (手術支援ロボット)

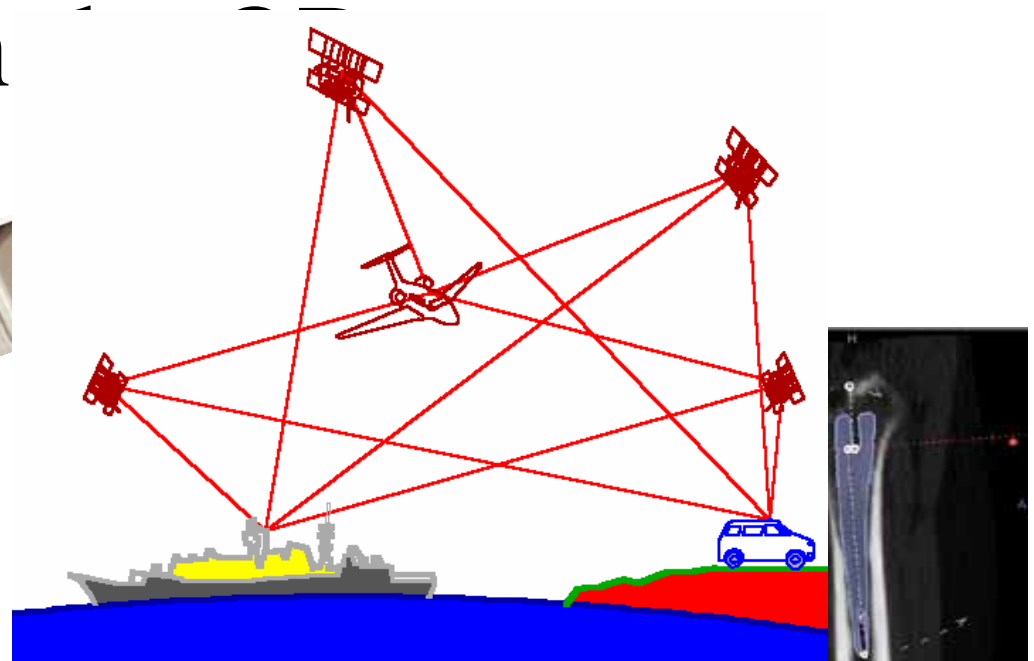
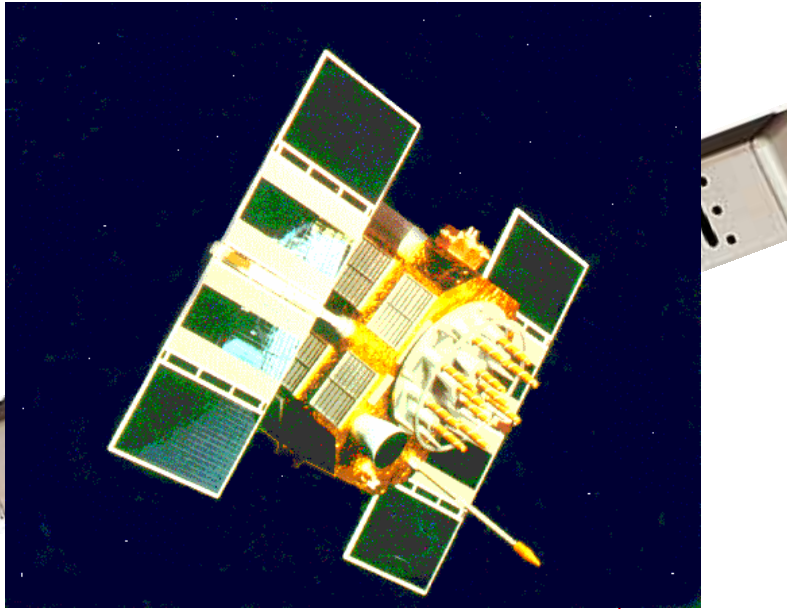




# Navigation



# GPS in

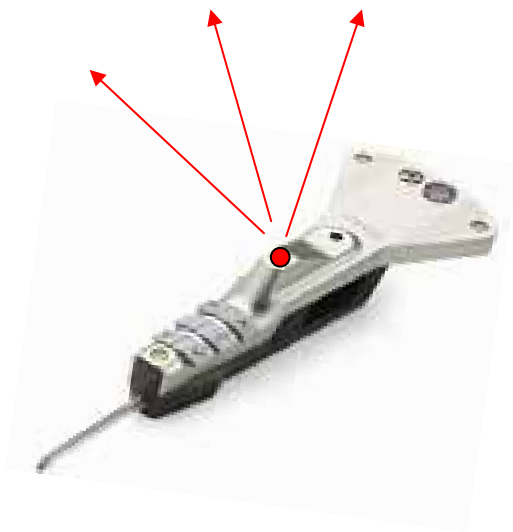


# GPS in the OR

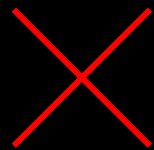
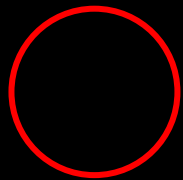




# GPS in the OR

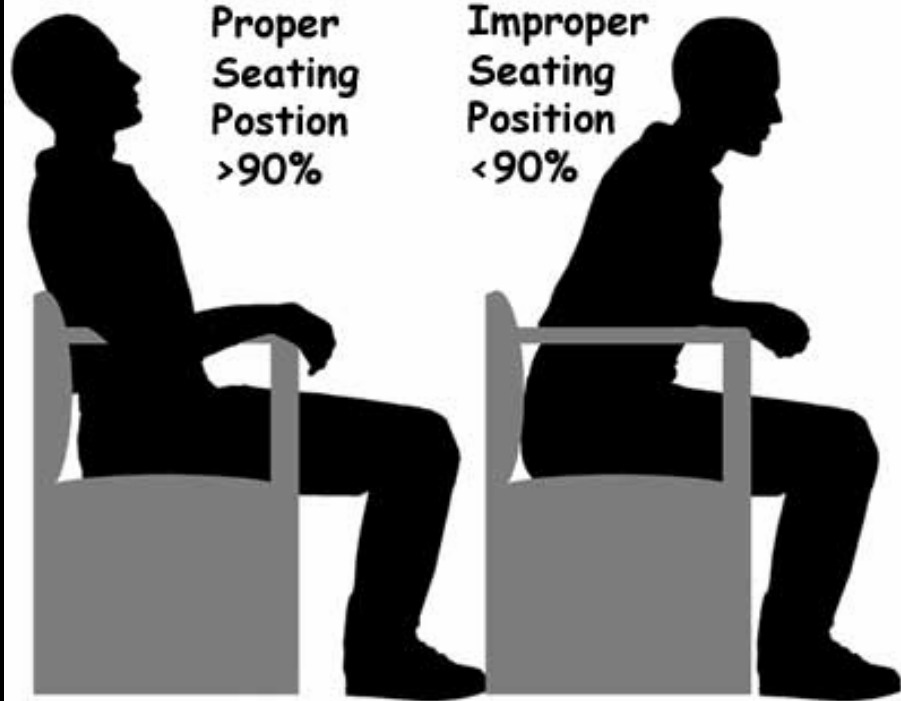


# 人工股関節術後の患者の動作制限

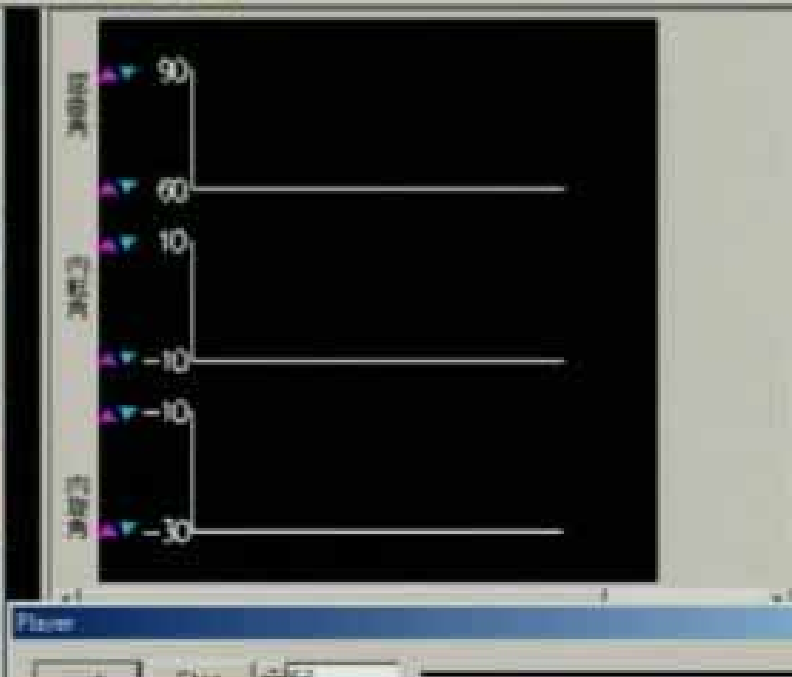
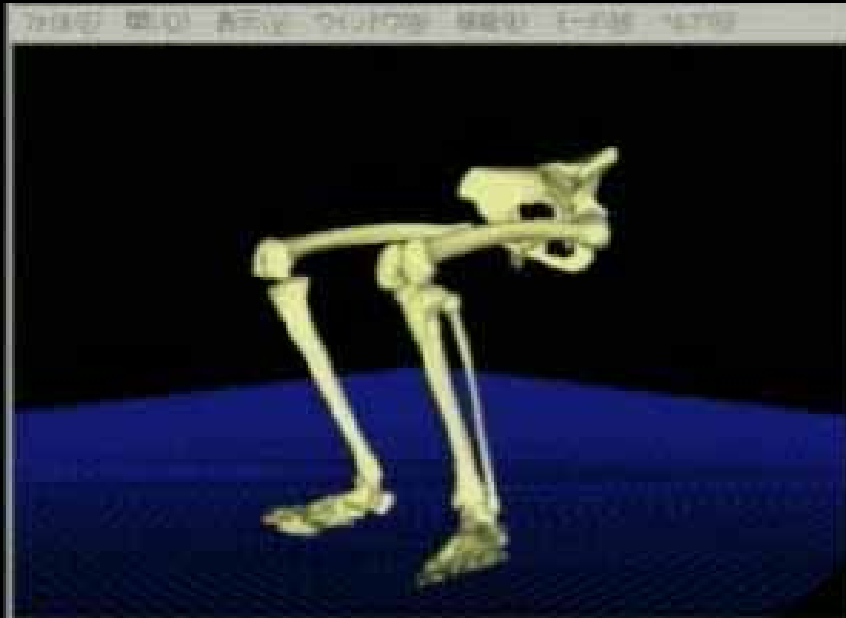


Socks Aid

Reacher







# 整形外科での Robotics 起源

- ROBODOCが最初

1980年代後半に開発

初回セメントレスTHRの大腿骨側

その後revision THR, Primary TKR, and Uni-KRが可能

# ROBODOC

## ORTHODOC



The screenshot shows the ORTHODOC software interface. It features a central 3D view of a femur with a green stem model. The interface is divided into several sections:

- Left Panel:** A vertical toolbar with icons for Move, Rotate, Settings, Markers, Parameters, and Snap to Axis.
- Top Left:** A 3D view of the femur and stem in a sagittal plane, with a red box highlighting the stem area.
- Top Right:** A 3D view of the femur and stem in a coronal plane.
- Bottom Left:** A 3D view of the femur and stem in an axial plane.
- Bottom Right:** A 3D view of the stem model in isolation.
- Right Panel:** A control panel with the following sections:
  - Stem Parameters:**

Type	CoCr
Size	26.00 mm
Neck Length	3.50 mm
  - Zoom:** 0.76, UnZoom, 0.0
  - Rotate (deg.):** 1.0
  - Translate:**

X	-22.98 mm
Y	27.23 mm
Z	-30.60 mm
  - Buttons:** Change View Plane, Center Window

## ROBODOC



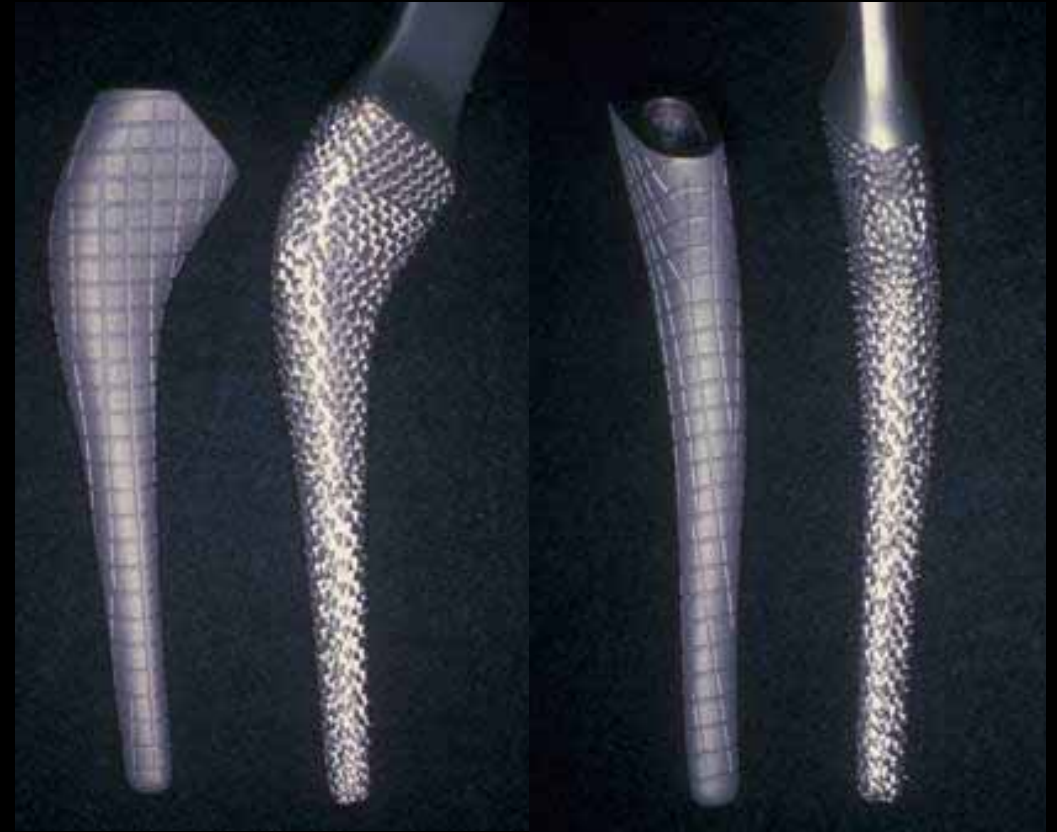
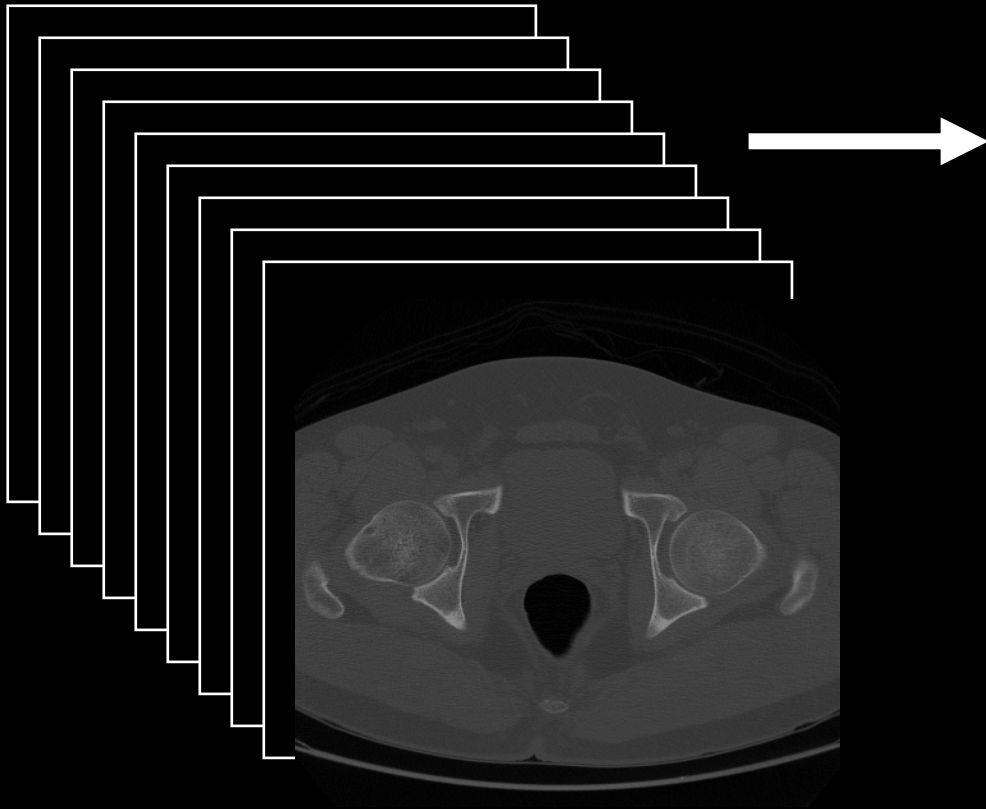
# ROBODOCの開発背景

- 1980年代 セメントレスTHR
- 形状不適合が問題
- CT-based Custom Implants



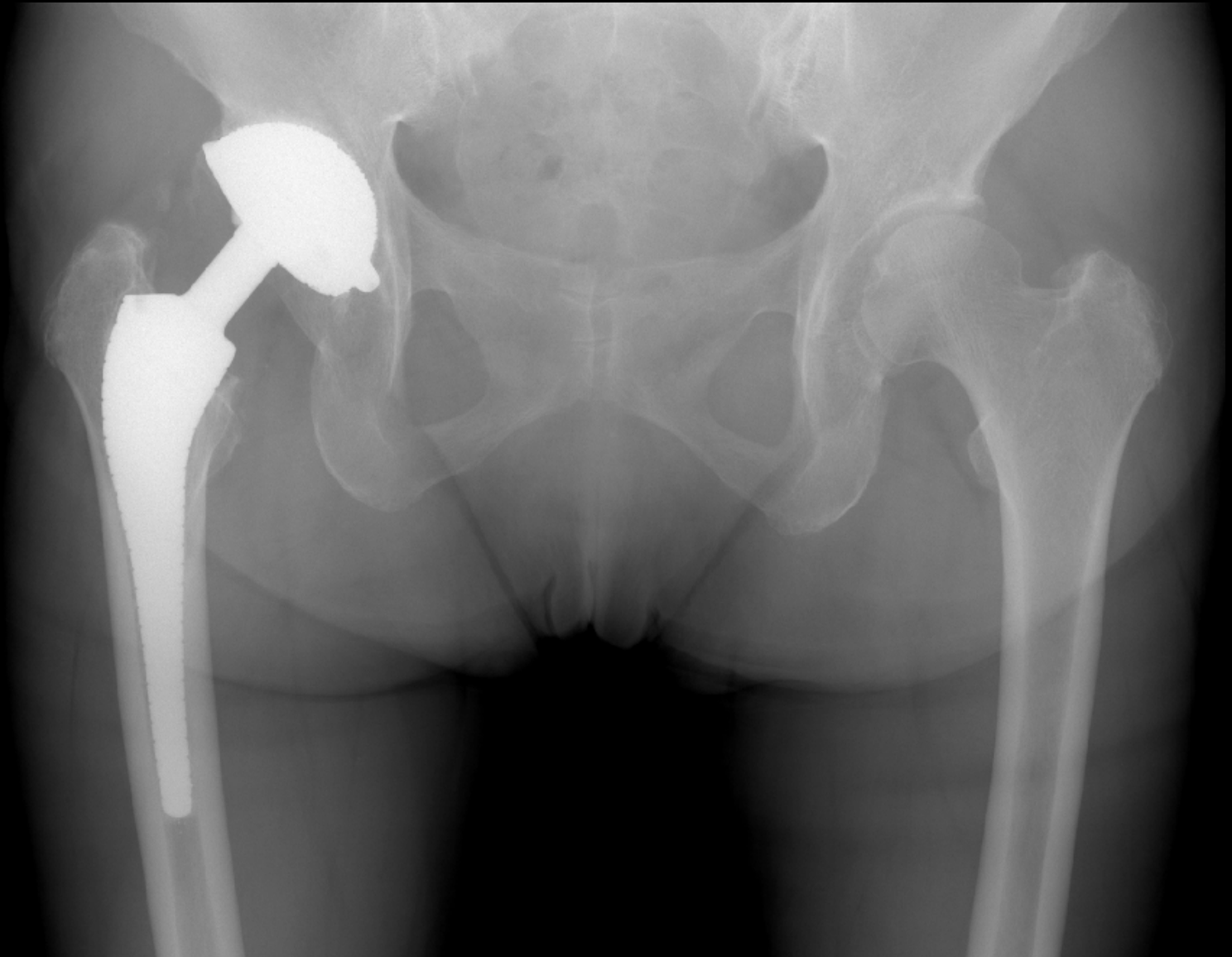
# Custom-made hip from CAT scan images

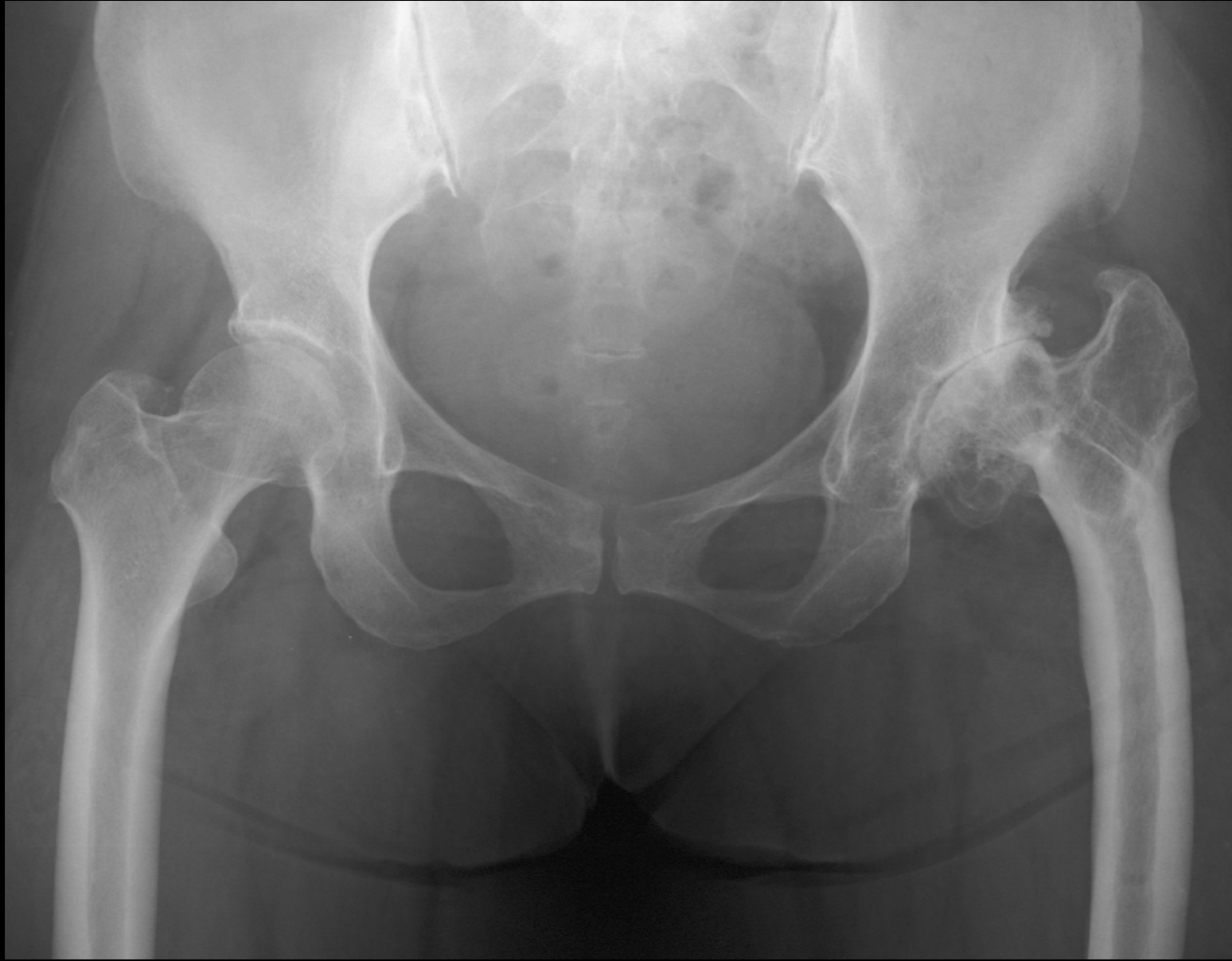
## CAD-CAM Machining





# Custom-made Hip





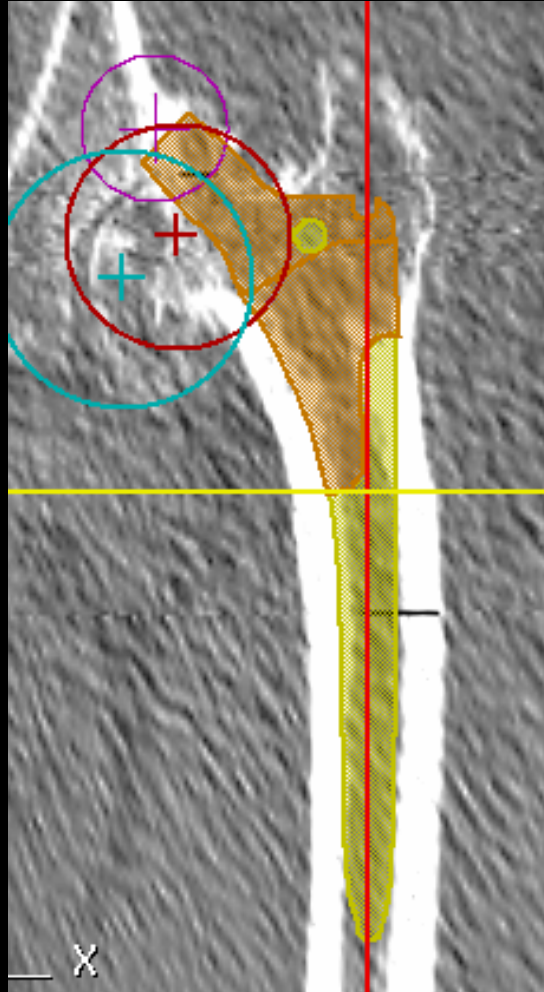
# CAD-CAM Machining in the OR: ROBODOC



# Previous varus osteotomy



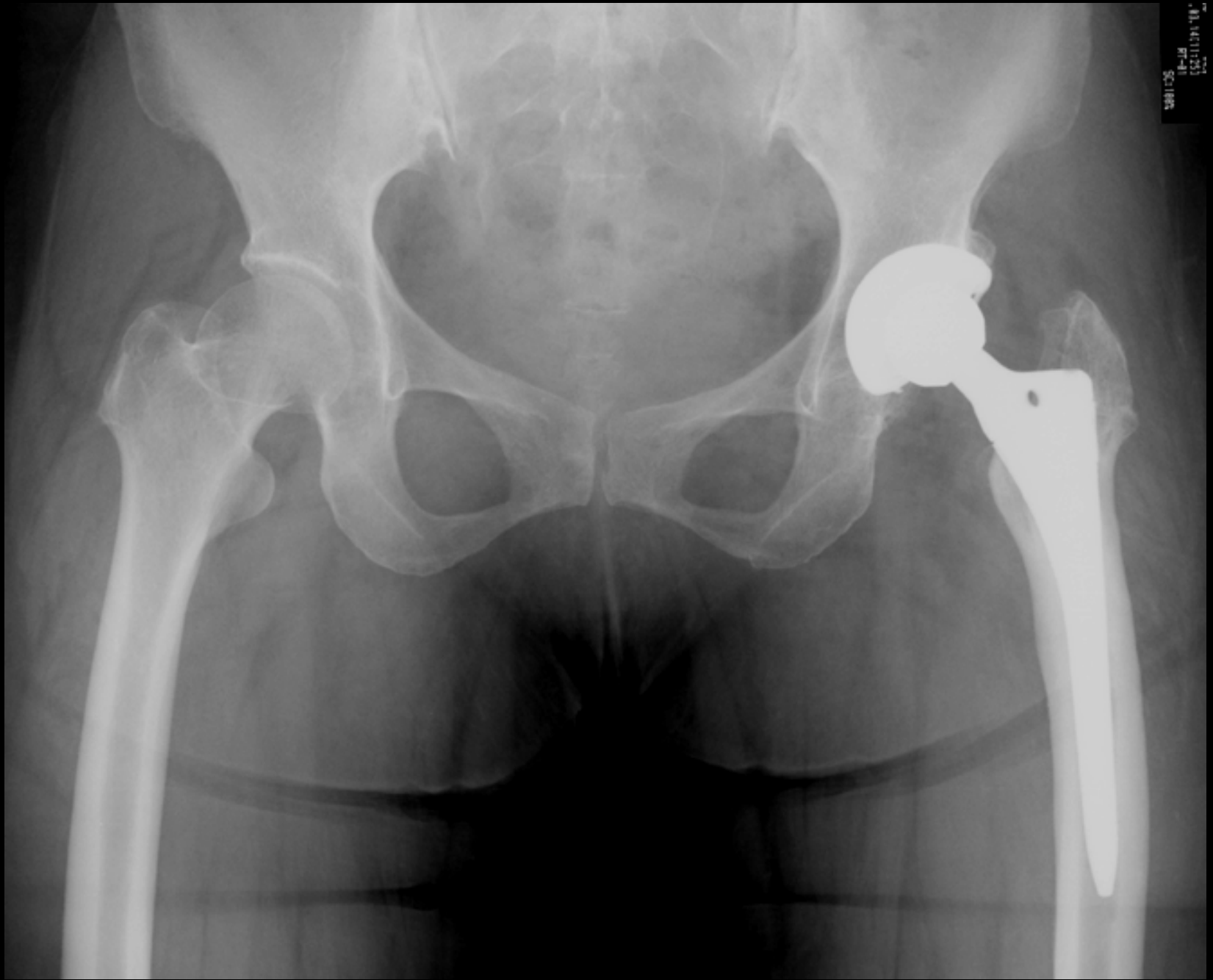
**Preop.**



**Plan**



**Postop.**



01.14.11.231  
Pr. 4  
Sc. 1828

## ROBODOCの日本での成績

Group	患者数 ( Femora )	性別 ( Men : Women )	年齢 # ( yr )
Robotic milling	73 ( 78 )	14 : 64 ¶	58 ( 27 to 81 ) †
Hand-broaching	67 ( 78 )	14 : 64 ¶	58 ( 29 to 77 ) †

¶有意差なし ( Chi-squared test ).

†有意差なし ( Mann-Whitney U test ).

*Nishihara S, Sugano N; J Orthop Sci (in press)*

# 結果

- 臨床的には、股関節機能評価点数で術後6ヶ月時の回復が早く、術後2年で従来法94点に対しロボット法96点と有意に高かった。
- ロボット法で大腿骨骨折はなく、従来法よりもX線評価で人工関節がより大腿骨に適合していた。
- ロボット法は経食道心エコーで術中肺塞栓の程度が有意に低かった。
- 再置換術でのセメント除去が大腿骨を割ることなく施行でき、術後リハビリも短縮できた。

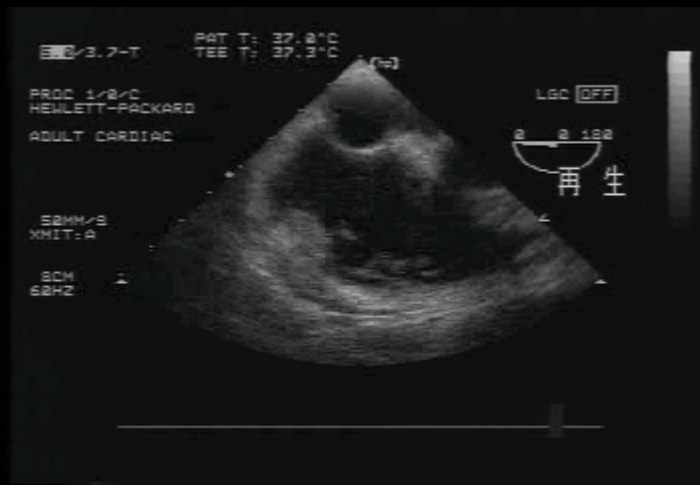
# Classification of Echogram Findings



Grade 0



Grade 1



Grade 2



Grade 3

*Pitto RP, CORR 1998*



## 経食道心エコーでの肺塞栓の程度と頻度

Grade	ROBODOC			CONTROL			P-value *
	1	2	3	1	2	3	
<b>大腿骨掘削時</b>							
No.(%) of hips	4(8)	0	0	16(64)	8(32)	1(4)	p<.0001
<b>ステム挿入時</b>							
No.(%) of hips	18(36)	0	0	17(68)	4(16)	1(4)	p<.0001
<b>脱臼整復時</b>							
No.(%) of hips	29(58)	4(8)	0	13(52)	11(44)	1(4)	p<.0001

\* Mann-Whitney U test

# セメントレスシステム使用による 死亡例の報告

- Fatal Marrow Embolization Following a Porous-coated Bipolar Hip Endoprosthesis

Julian S.Arroyo, MD, Kevin L.Garvin, MD, Michael H. McGuire, MD  
(J. Arthroplasty 1994)



セメントだけが危険因子ではない

# Controversy in Germany!

## Comparison of Robotic-Assisted and Manual Implantation of A Primary Total Hip Replacement

Honl M, Schwieger K, Gauck CH, Carrero V, Dierk O, Dries S, Hille E, Morlock MM  
*Department of Orthopaedic Surgery, Barmbeck General Hospital, Hamburg, Germany*

*JBJS 2003*

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	ROBODOC	従来法
脱臼	11/61 (18%)	3/80 (4%)
再置換	9/61 (15%)	0/80 (0%)

理由(再発脱臼とは行)

---

1年での機能評価点数、ステムの設置、脚長差はロボットのほうが優れていた。

WHY???

## Initial ROBODOC FDA Multi-center Randomized Controlled Trial

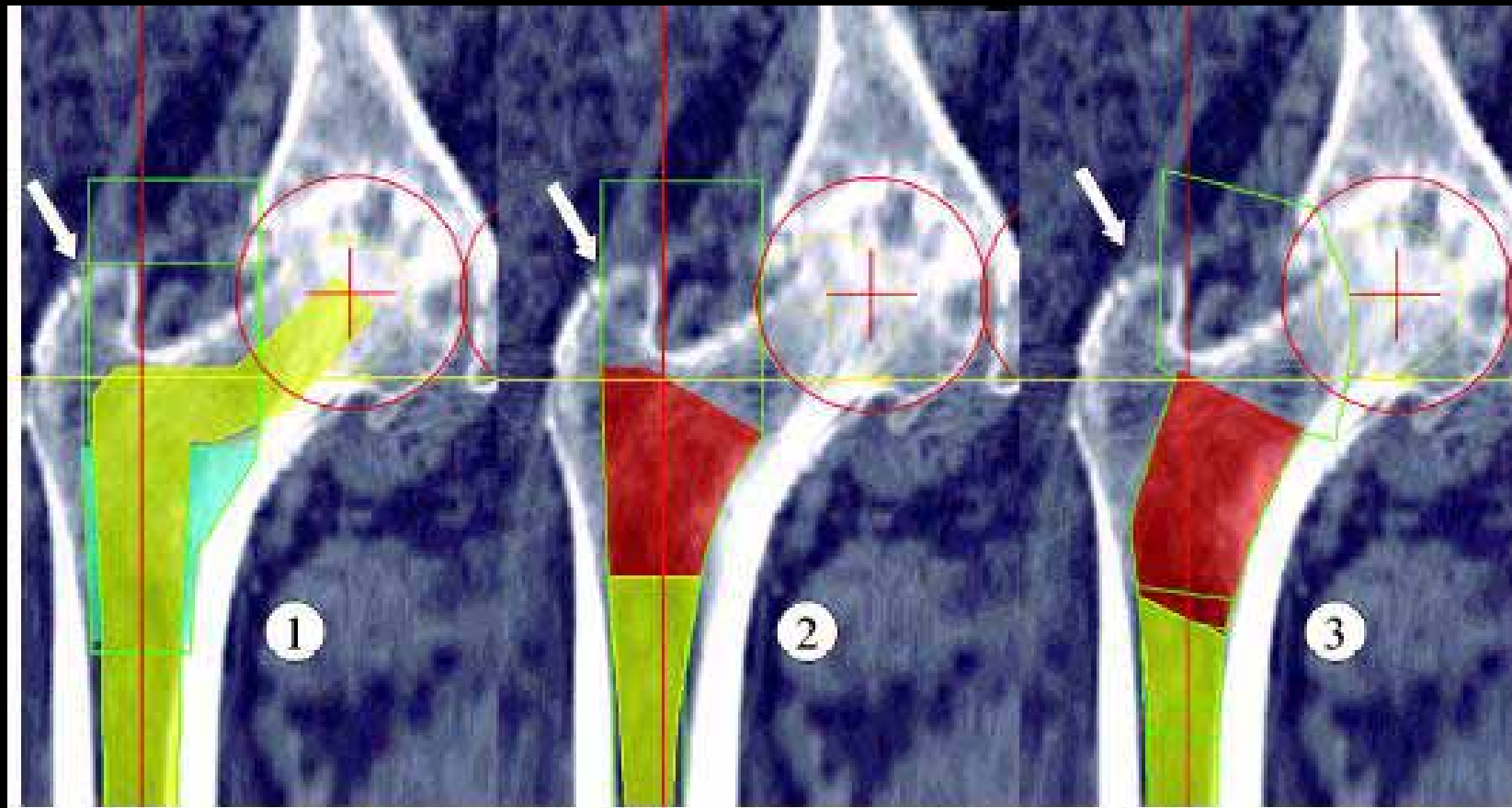
- **Dislocation rate ~4% in each group. (No diff.)**
- **0% Revision Rate in both Groups.**
- **Better fit and alignment for ROBODOC group.**
- **No diff. in Hip Scores at 24 months.**

Bargar WL, CORR 1998

**• No Difference in Incidence of Limp or Use of  
Ambulatory Aids**

Bargar WL, ISTA 2003

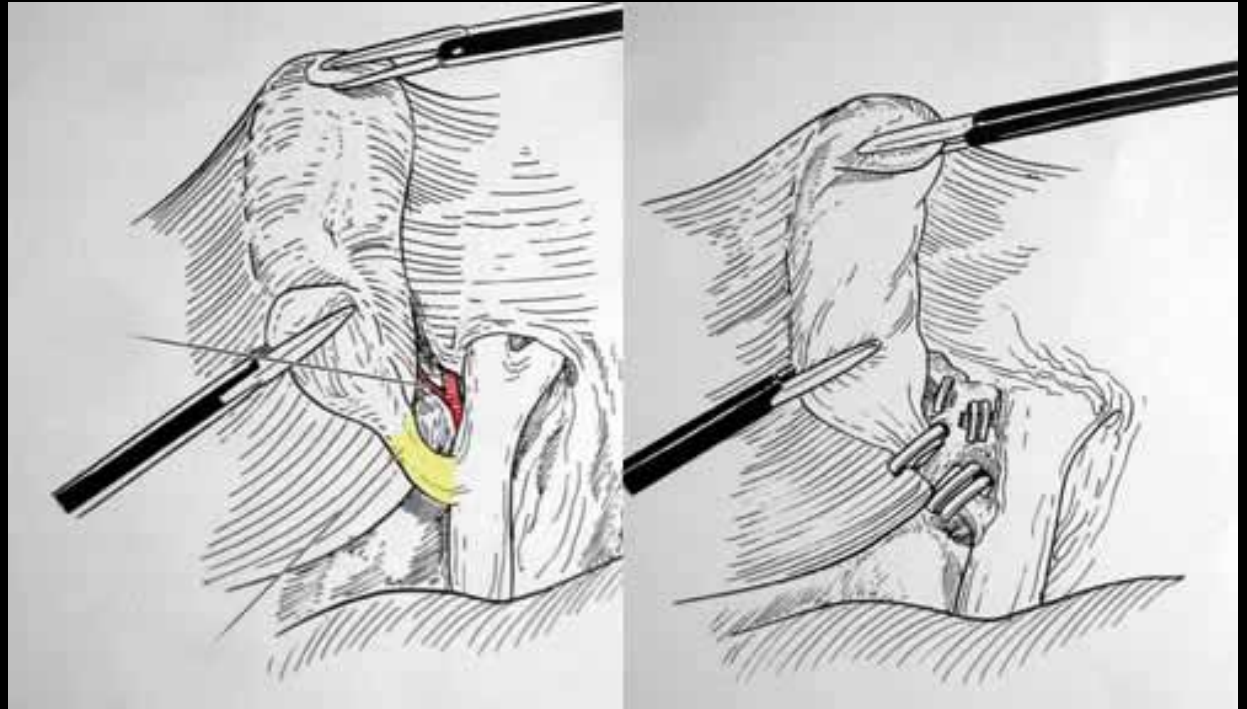
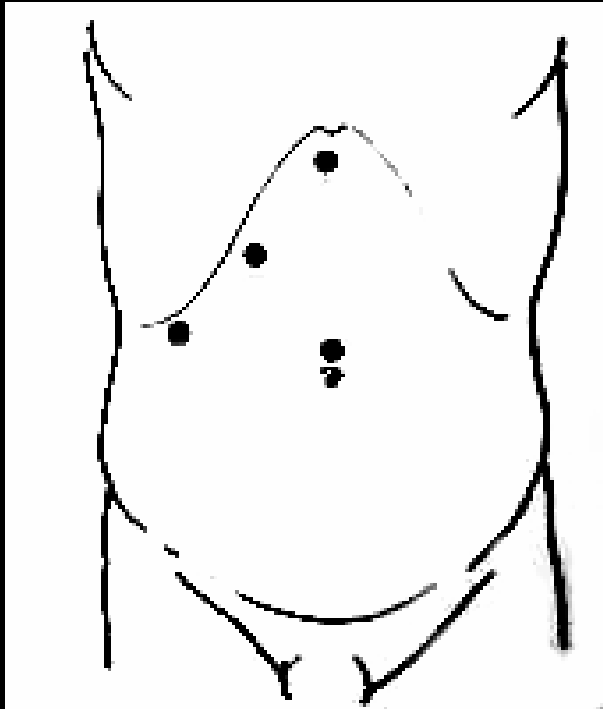
# The Reason:



# ROBODOC使用時の外科医の責務

- 適切なデザインの人工関節の選択
- 適切な計画
- 適合しない場合は使用しない
- 手術中軟部組織の保護

# Minimum Invasive Surgery *or* Mini-Incision Surgery

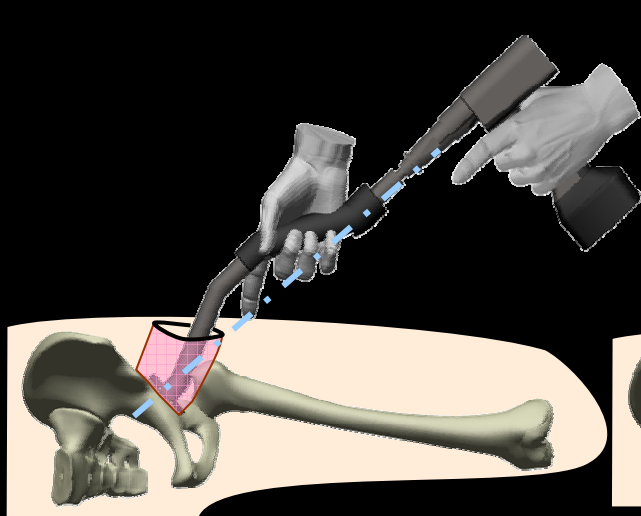


開腹手術: 内視鏡手術

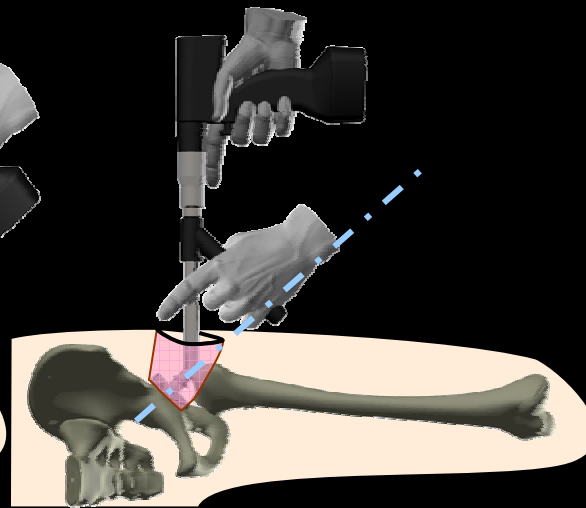
= 10cm + 1cm : 0.5cm X 4 + 1cm

= 11:3

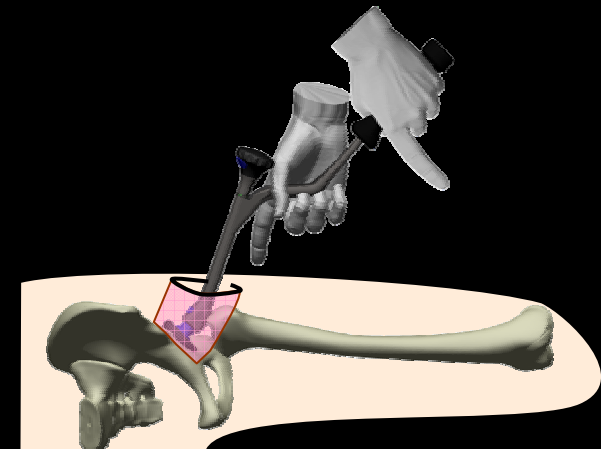
# MIS THA : Hype or Fact ?



25 Degree Driver



45 Degree Driver

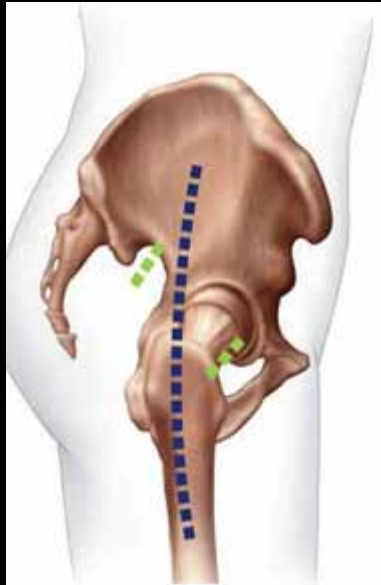


25 Cup Introducer





# Comparing Hip Replacement Procedures



Zimmer MIS 2-Incision



Traditional

Incision

Two 1.5- to 2-inch

One 10- to 12-inch

Tissue Trauma

Muscles and Tendons  
avoided or separated

Muscles and Tendons  
cut

Hospital Stay

1-2 days

3-5 days

# Two-Incision MIS THR



# “Learning Curve for the Two-Incision Total Hip Replacement”

*Archibeck MJ and White RE, Jr, CORR 2004*

2000年10月 - 2004年4月 159名の外科医による851 例

## •術中合併症

•4.1% 大腿骨頸部の骨折 (35)

•1.1% 大転子の骨折 (9)

•0.8% 大腿骨骨幹部貫通 (7)

•1.3% 大腿骨骨幹部骨折(11)

**7.3% 大腿骨骨折または貫通!**

•3.2% 神経麻痺 (27)

# “Learning Curve for the Two-Incision Total Hip Replacement”

*Archibeck MJ and White RE, Jr, CORR 2004*

## •術後合併症

•0.9% 脱臼 (8) : 3例再置換

•0.9% 血腫 (8)

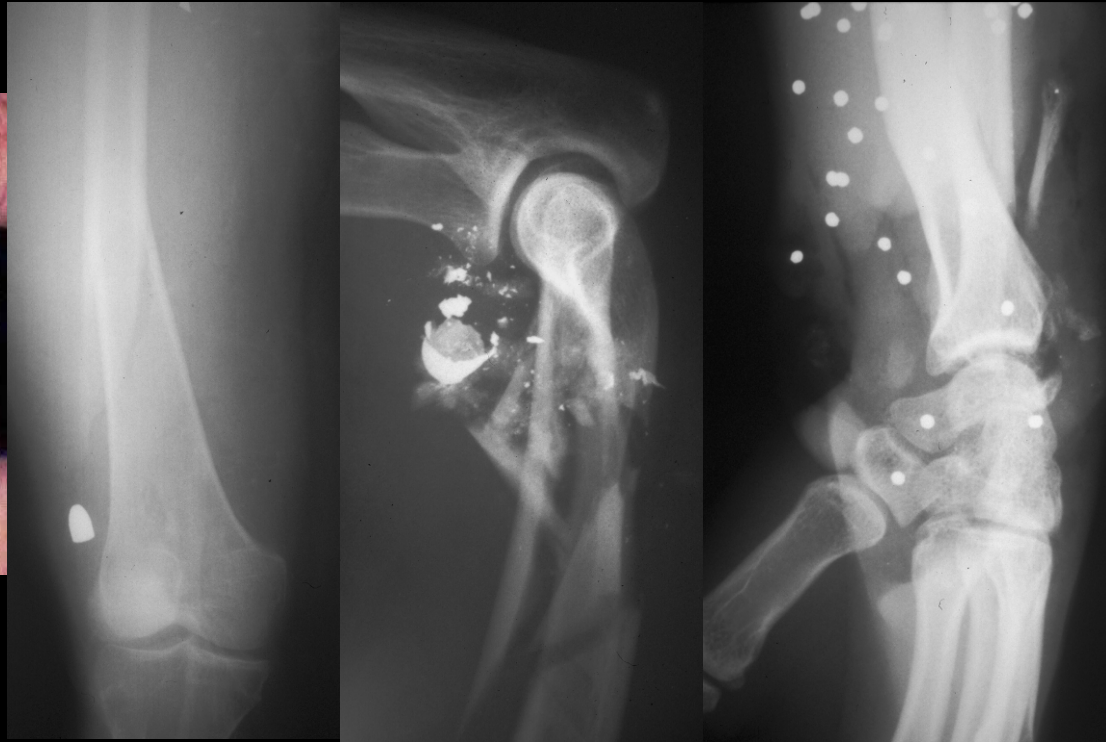
•0.2% 術後骨折 (1 大転子, 1 骨幹部): 2例とも再置換

•0.8% 感染 (7) : 3 深部 and 4 浅部

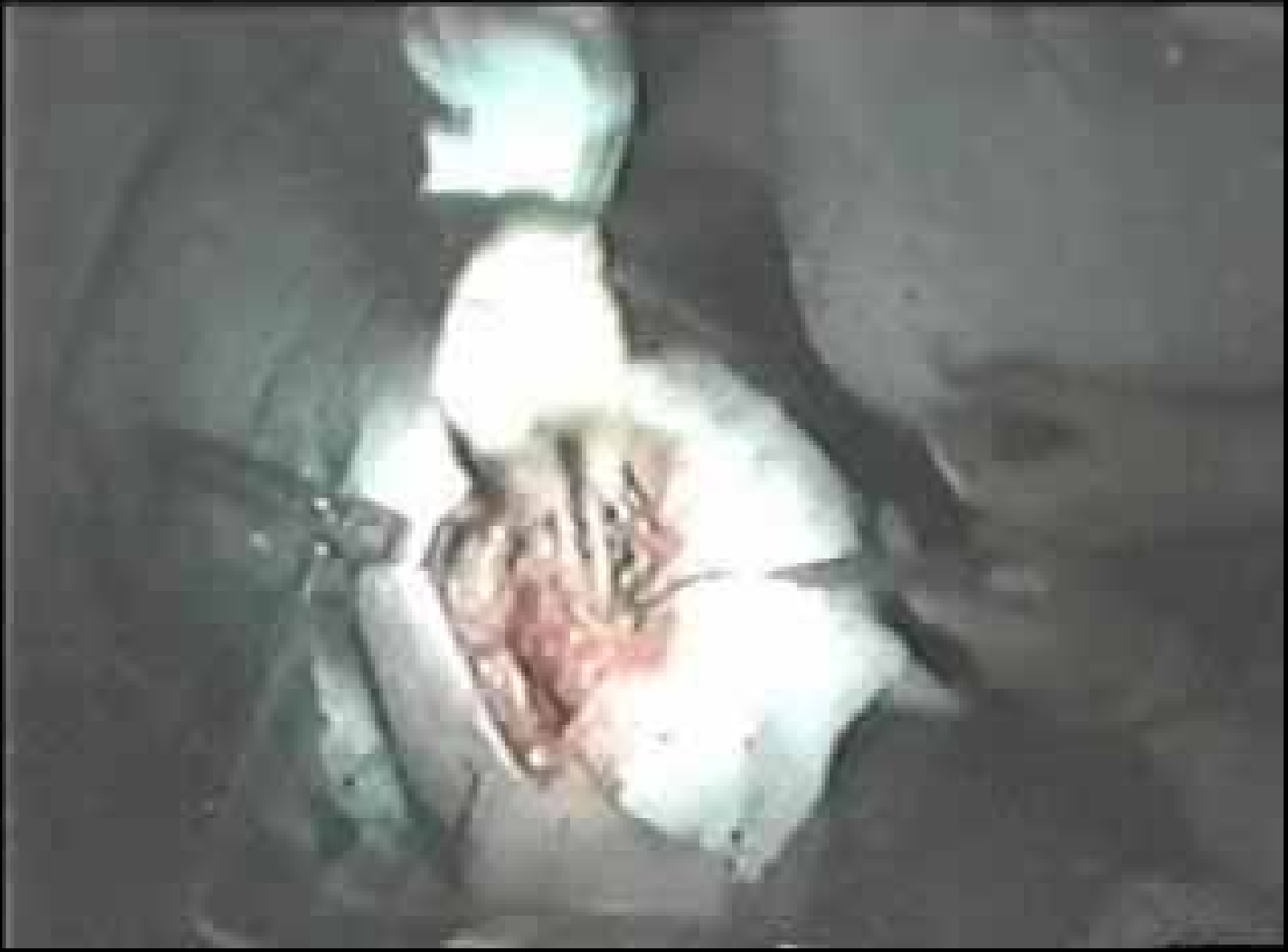
•Death (2) presented at the Hip Society 04 was not written in this paper

# MISとは?

- Mini-Incision Surgery ?
- Minimally Invasive Surgery ?
- 侵襲とは？骨, 筋, 靭帯？



侍の極意？肉を切らせて骨を切る！



# Comparison of Primary Total Hip Replacements Performed with a Standard Incision or a Mini-Incision

Woolson ST, et al. JBJS-Am 2004

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	Mini-incision [ $<10$ cm]	Standard incision
No. of patients	50 (selected)	85 (remaining)

---

- BMI ( $p = 0.008$ ), ASA rating ( $p = 0.006$ )
- No differences in surgical time, blood loss, in-hospital transfusion rate, length of hospital stay, or the patients' disposition after discharge.
- Wound complication ( $p = 0.02$ ), Acetabular component malposition ( $p = 0.04$ ), and Poor fit and fill of femoral components inserted without cement ( $p = 0.0036$ ).





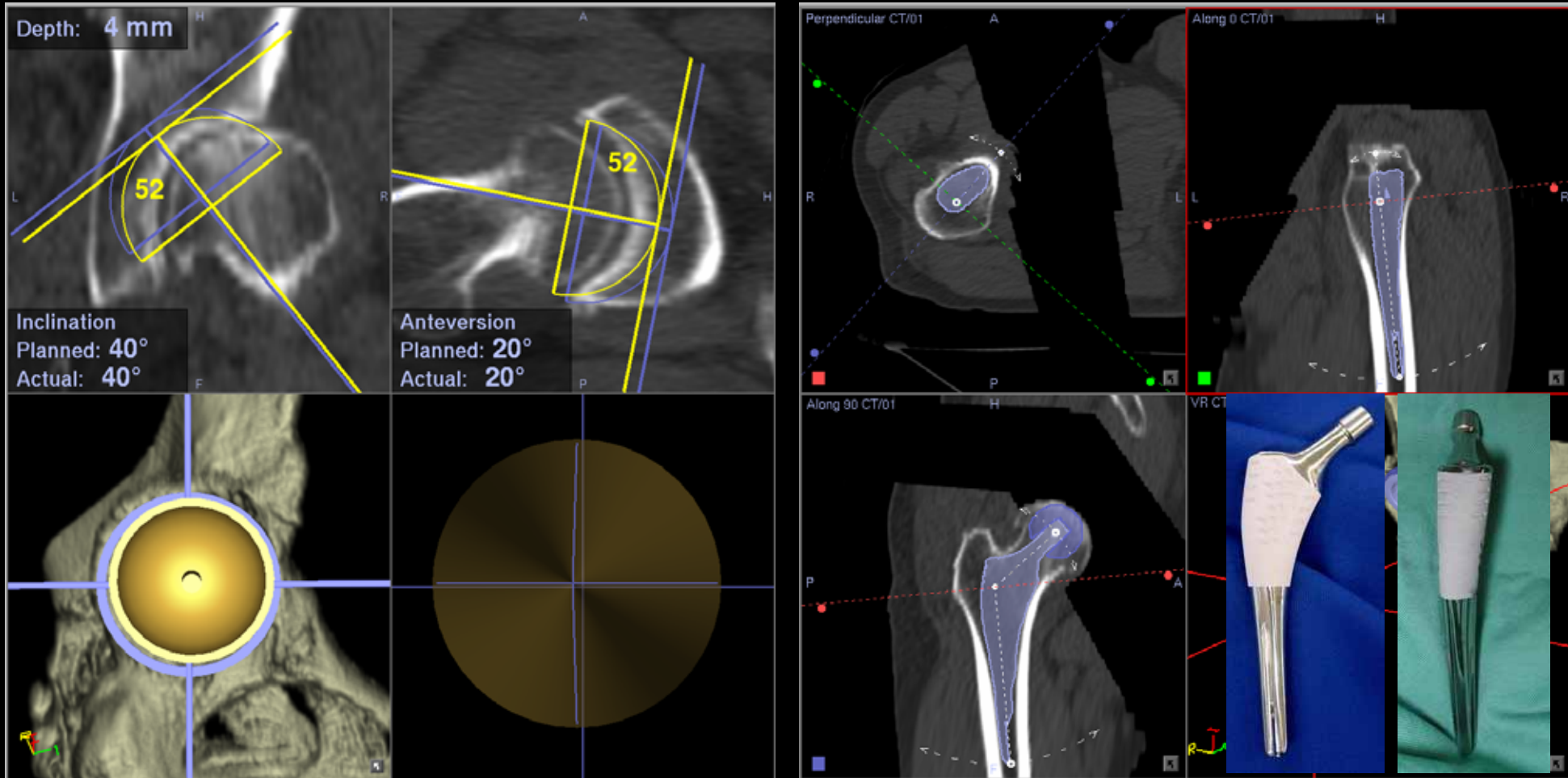
# MIS Meets CAOS



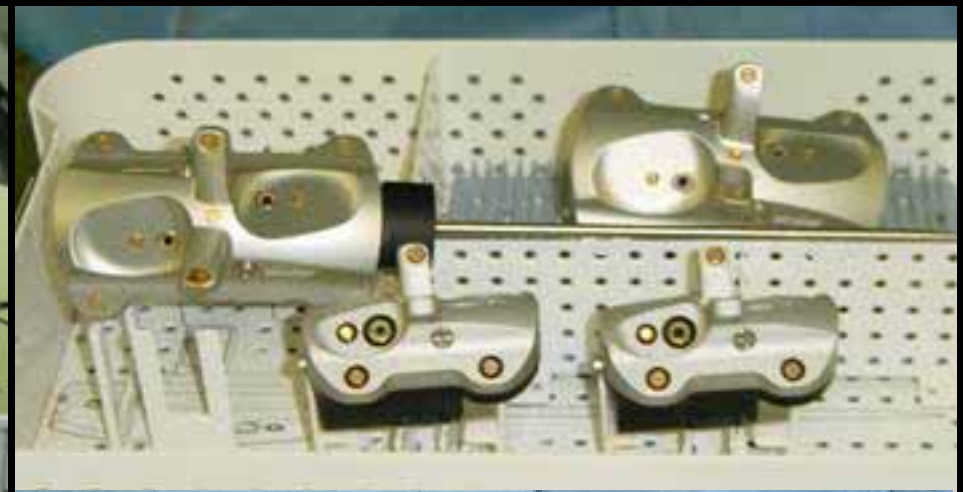
# Approach: A Posterior Mini-Incision Approach (7cm)



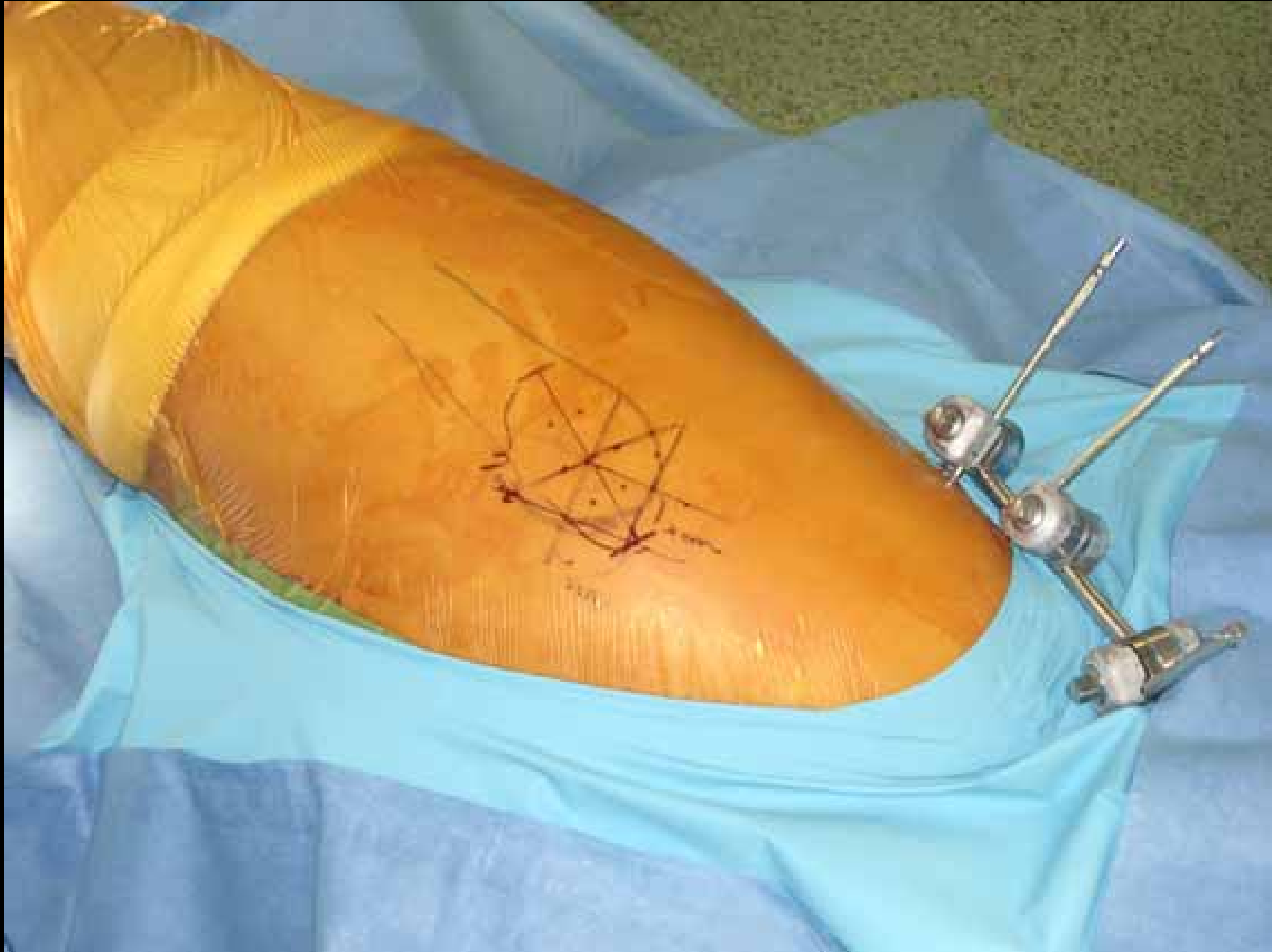
# CentPillar system based on CT study of Japanese hips



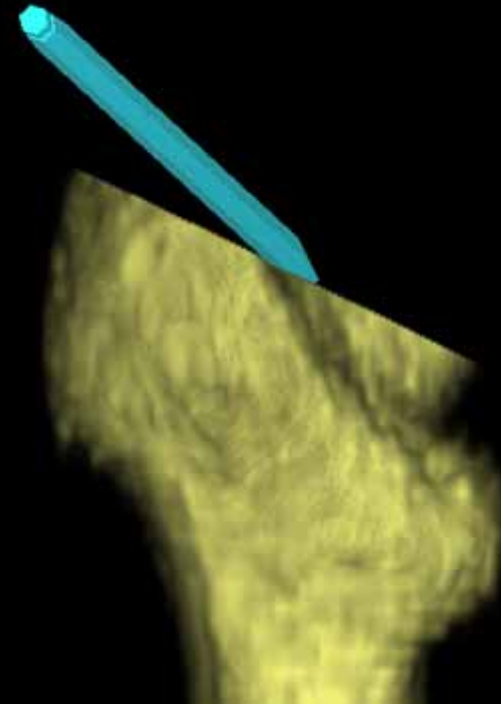
# OR Setting



# Approach: A Posterior Mini-Incision Approach (7cm)

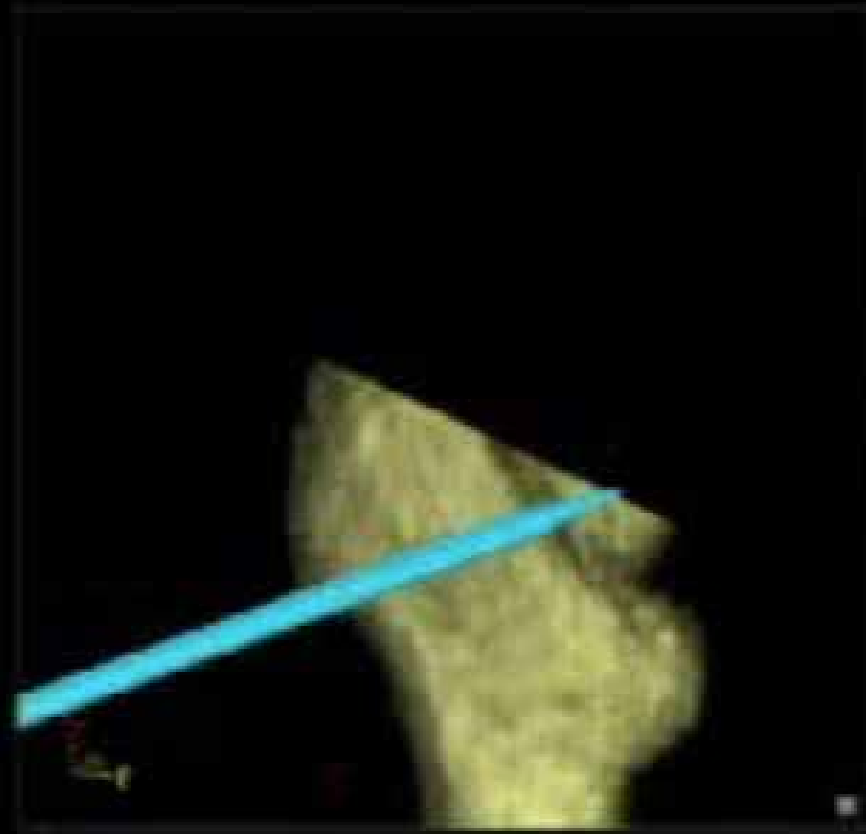


# Femoral Neck Osteotomy



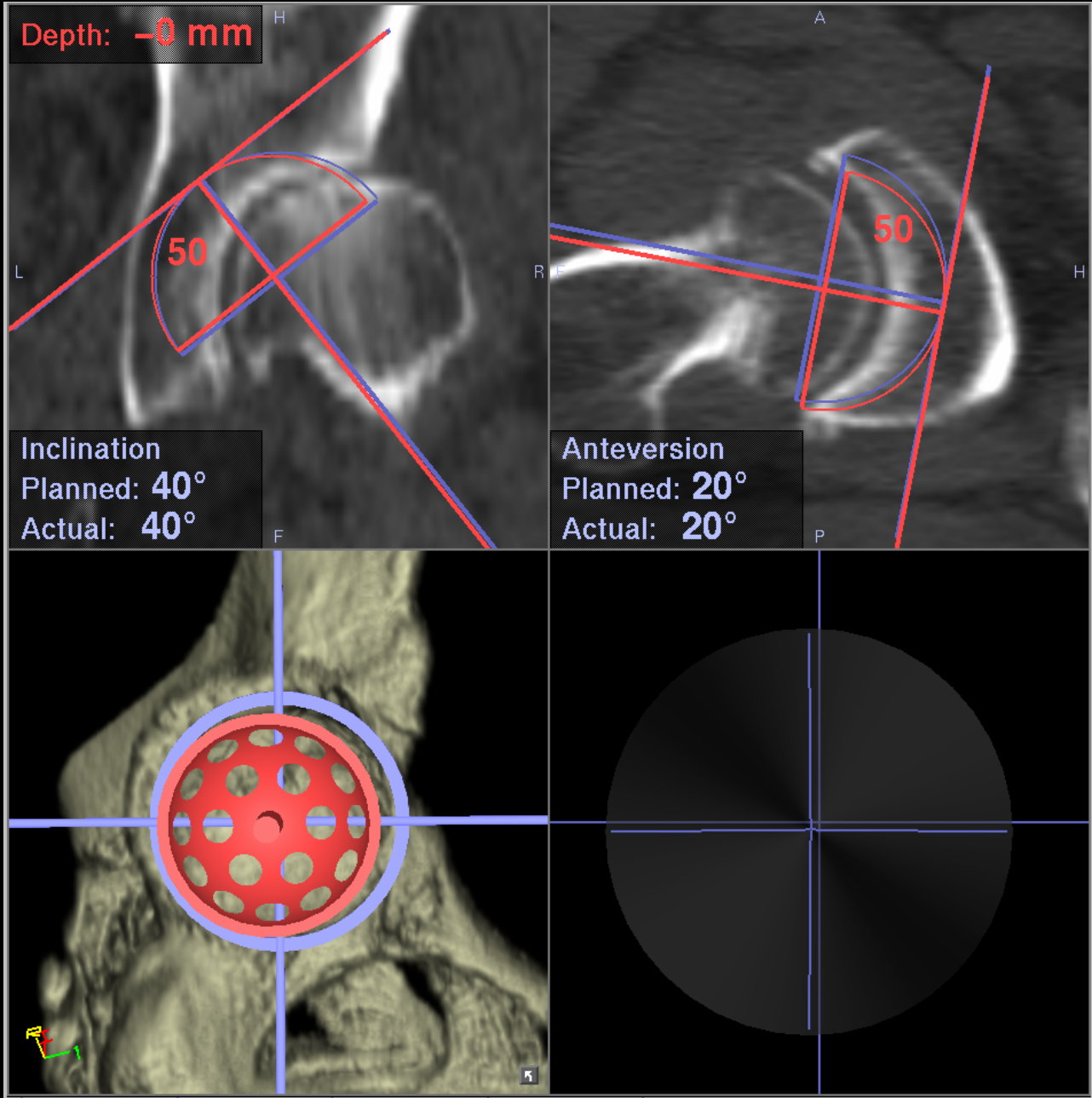
## Neck Resection

TRAPPEZOID TRAPEZOID RESECTION PLANE WITH THE SCAPULAR AND CLAVICULAR BORDERS OF THE BONE.









Depth: **-0 mm**

**50**

Inclination  
Planned: **40°**  
Actual: **40°**

Anteversion  
Planned: **20°**  
Actual: **20°**

**50**

## Reaming

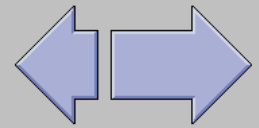
Trident PSL HA Cluster  
Planned Size: 52

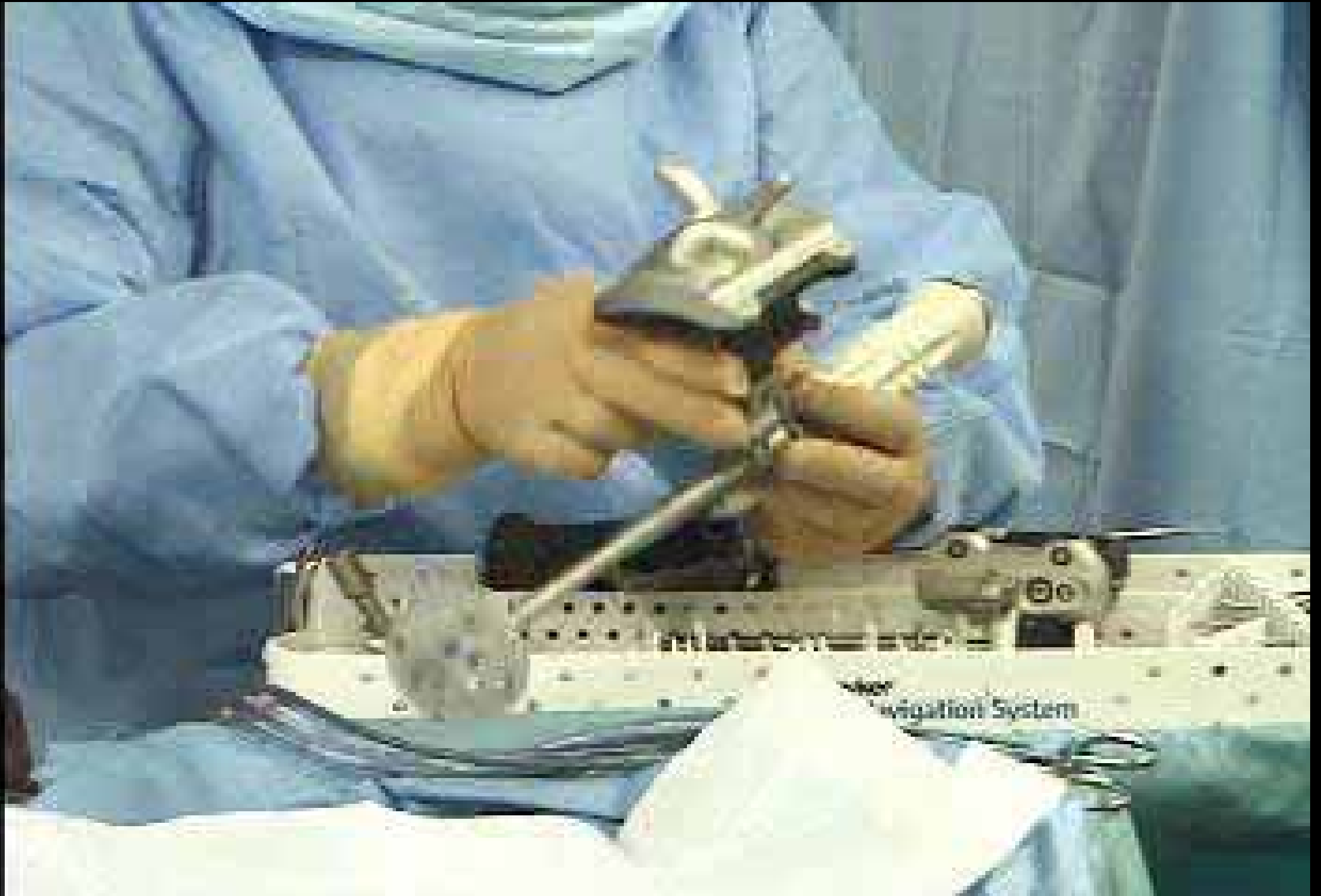
Leg Lengthening (mm)

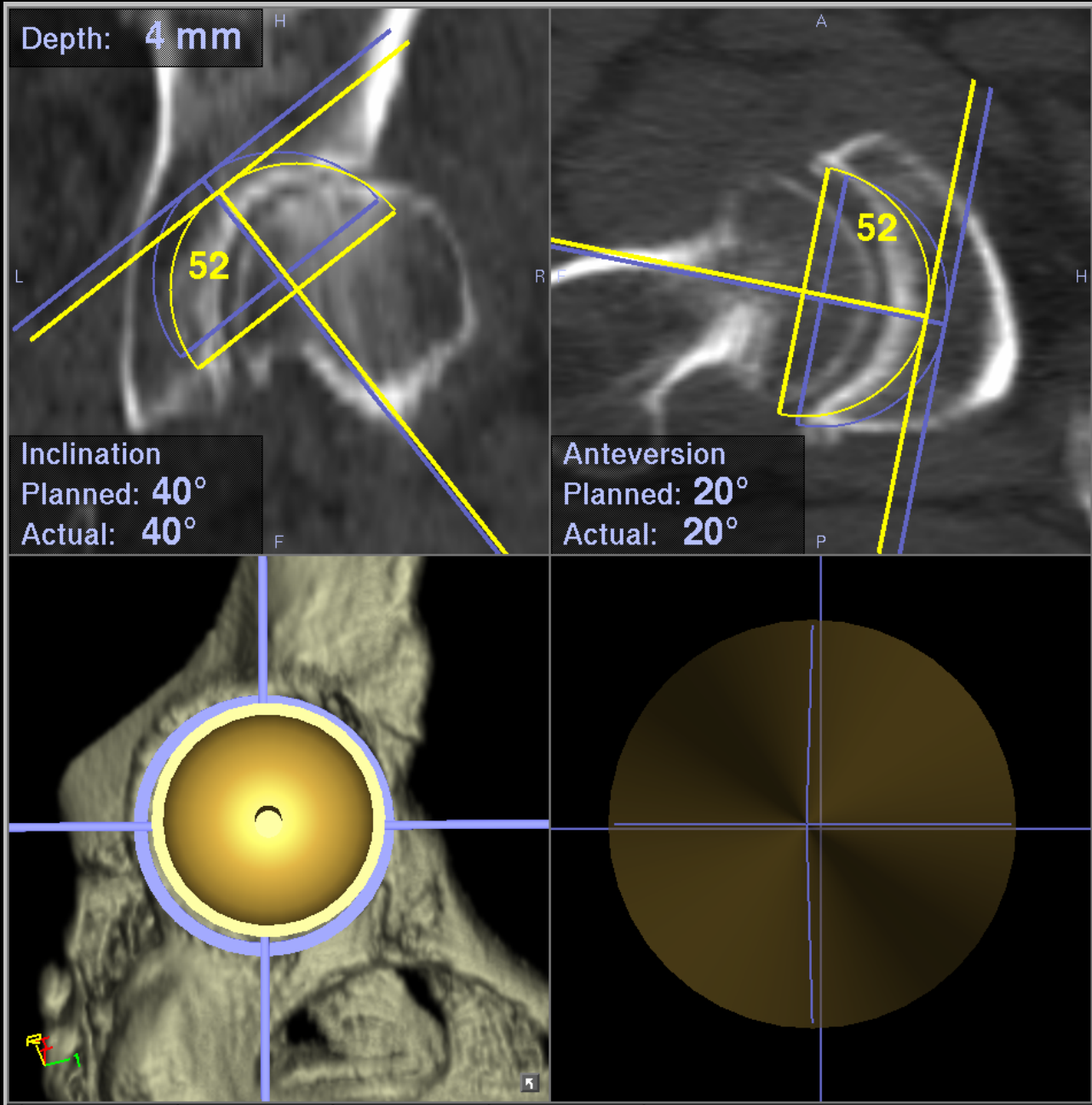
	Actual	Planned
Acetab.:	0	0
Total:	--	6

Leg Lateralization (mm)

	Actual	Planned
Acetab.:	-14	-13
Total:	--	-10







## Cup Placement

Trident PSL HA Cluster  
 Planned Size: 52

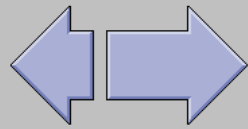
Cup Size **52**

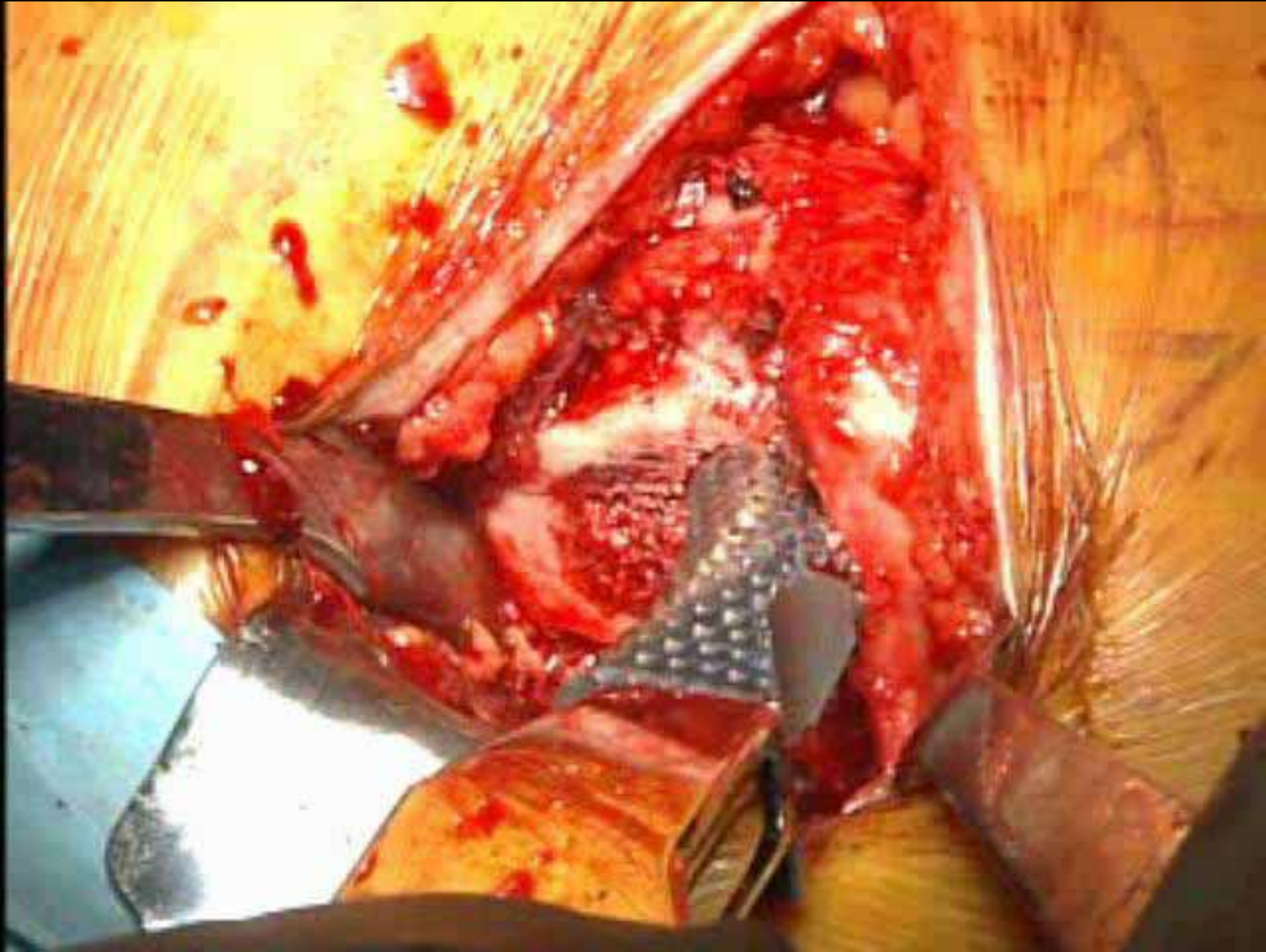
Leg Lengthening (mm)

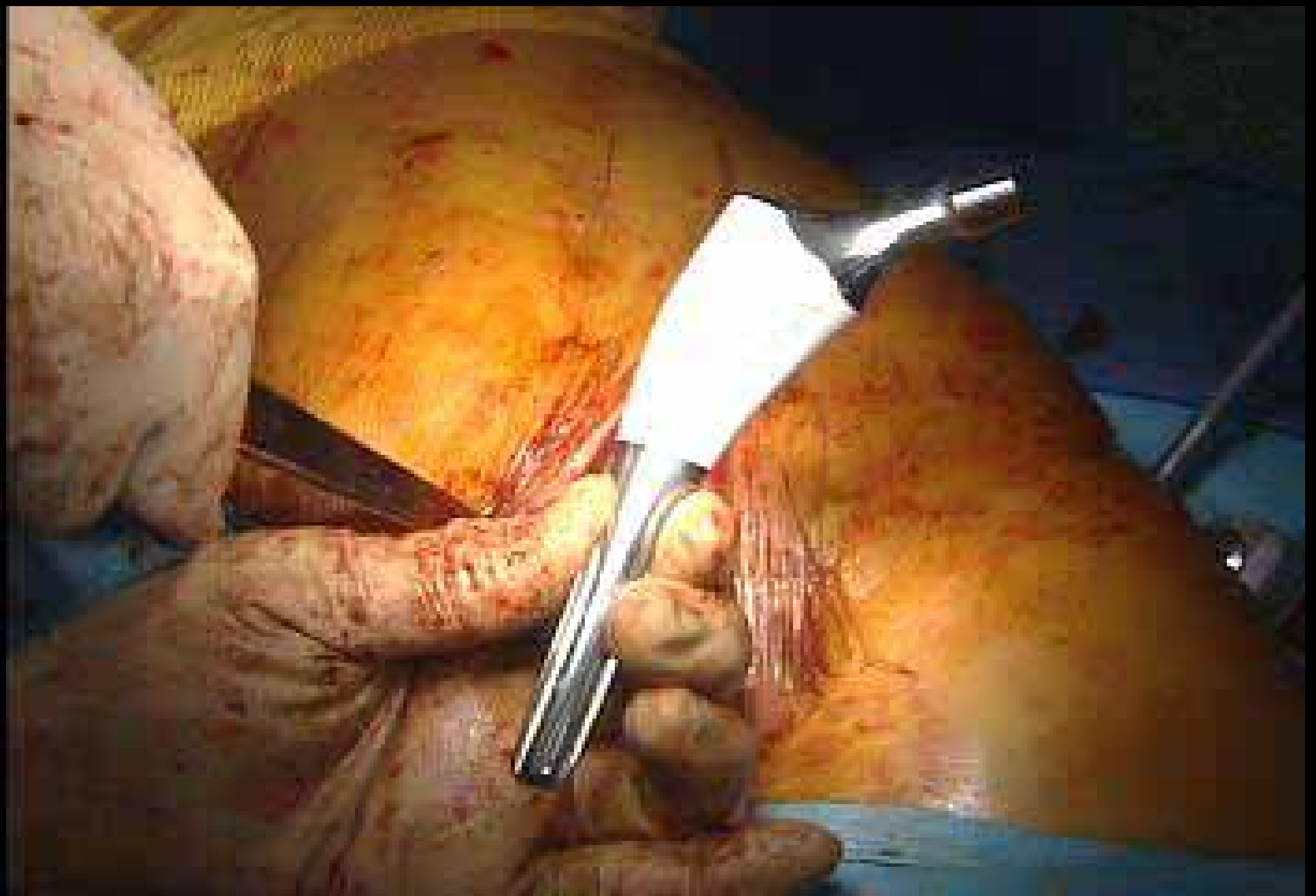
	Actual	Planned
Acetab.:	1	0
Total:	--	6

Leg Lateralization (mm)

	Actual	Planned
Acetab.:	-9	-13
Total:	--	-10







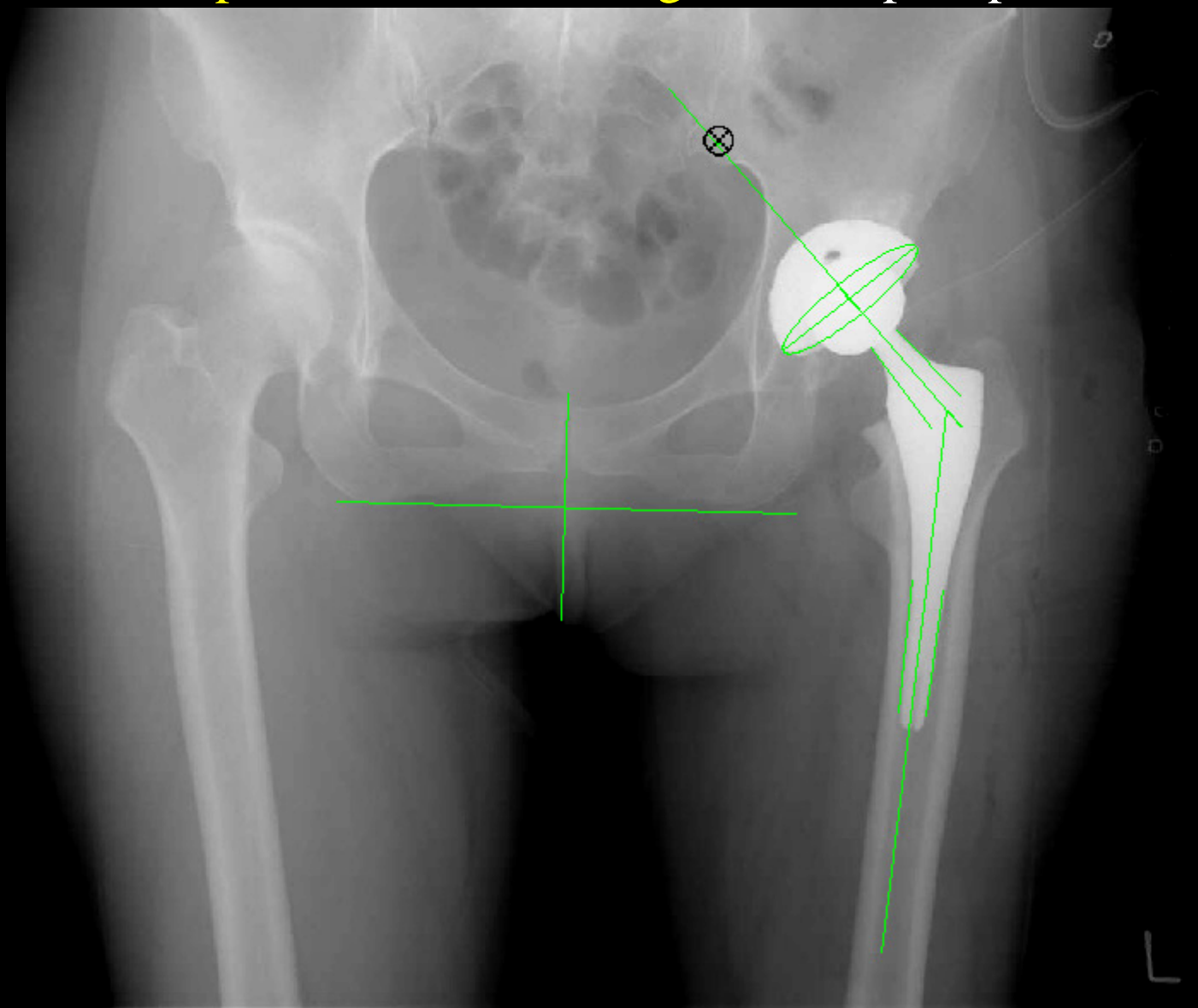
Functional tilt 8 deg

Navi Cup Abduction 40 deg

Navi Cup Anteversion 22 deg

Postop Cup Abduction 40 deg

Postop Cup Anteversion 19 deg



右側 左側 製品情報

人工関節可動範囲( $\theta$ )	135
ステムネック角度(TNSA)	125

カップ開  前  後  なし      ステム捻  前  後

CTから得られたデータを直接入力

カップ開角( $\beta$ CT)	
ネック前捻角(B CT)	

明るさ + -    コントラスト + -    R

**抽出計測**

<input type="checkbox"/> 盤底部	<input type="checkbox"/> ステム	<input type="checkbox"/> ネック	<input type="checkbox"/> カップ	<input type="checkbox"/> ヘッド
------------------------------	------------------------------	------------------------------	------------------------------	------------------------------

中心線    中心線

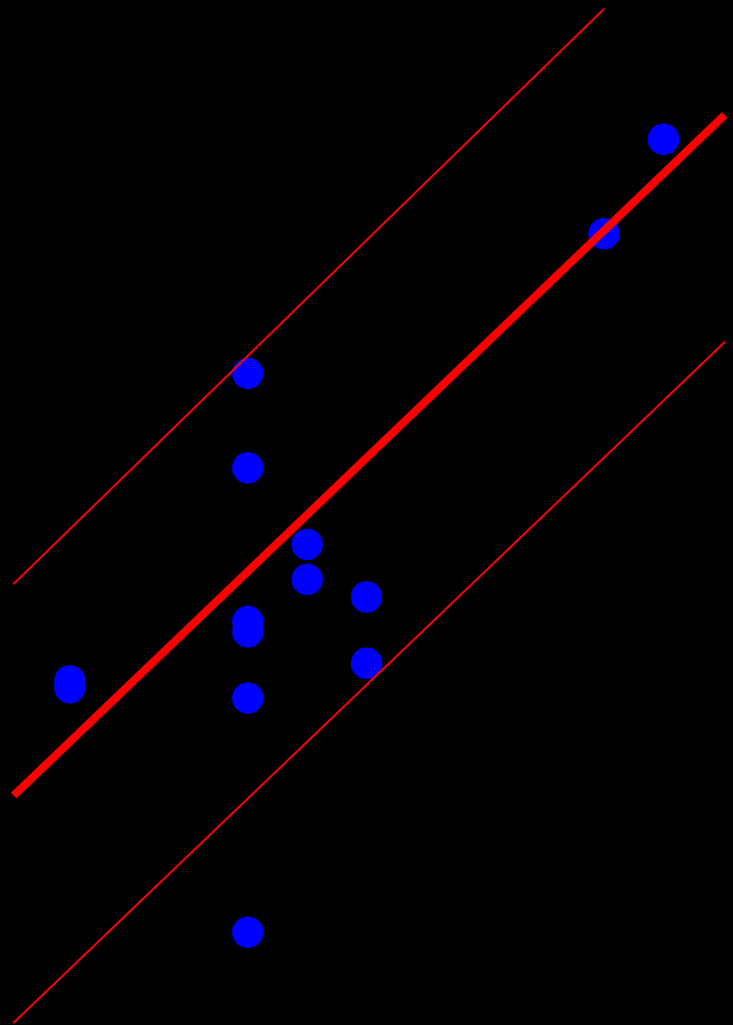
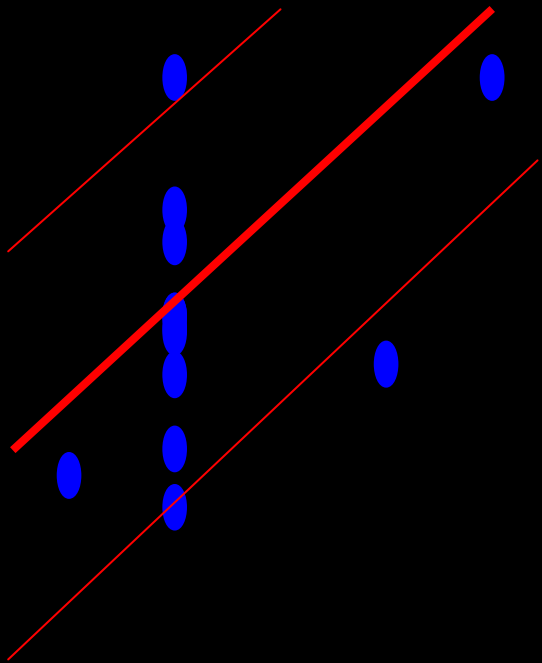
**可動域計算結果**

屈曲	140.718	伸展	37.643
外旋	45.493	90内旋	58.556

**設置角**

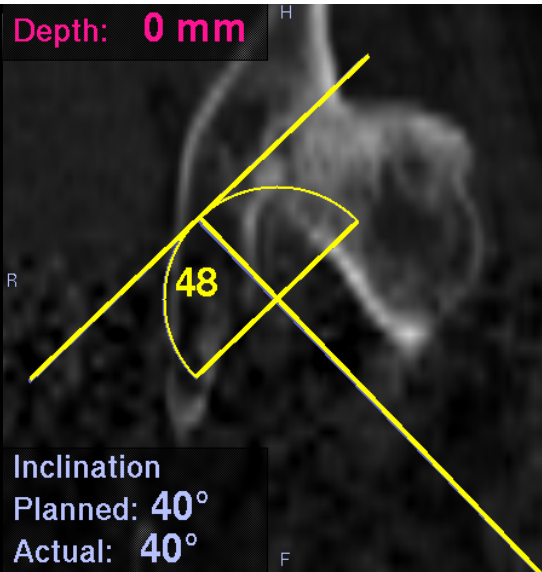
ALPHA	39.763	BETA	12.089
W	5.271	B	38.216
apNSA	132.124		

計算

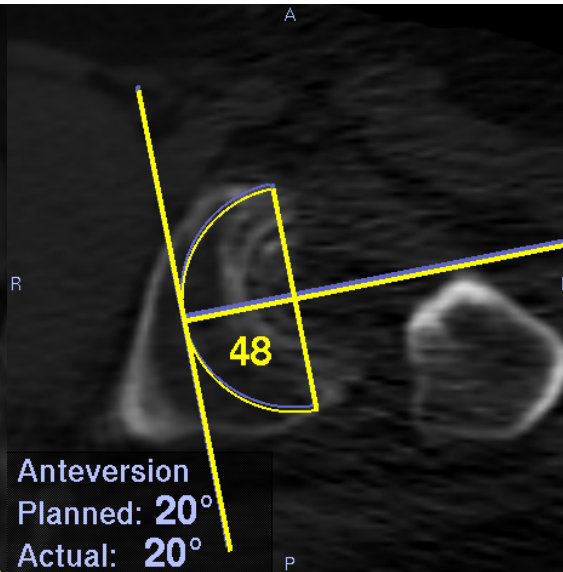


# Robo

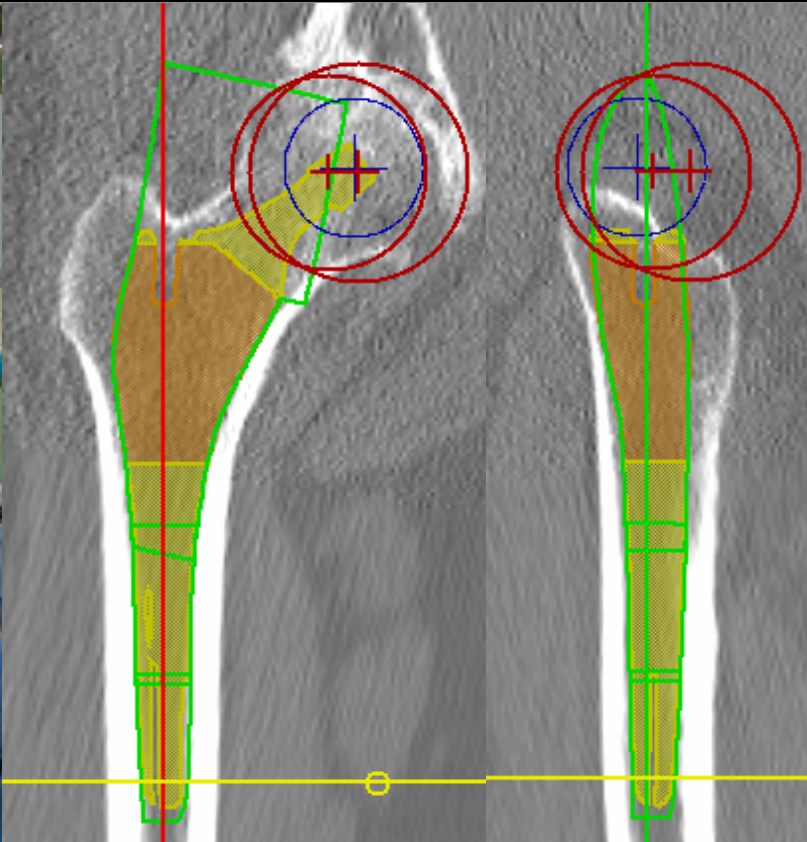
Depth: 0 mm



Inclination  
Planned: 40°  
Actual: 40°



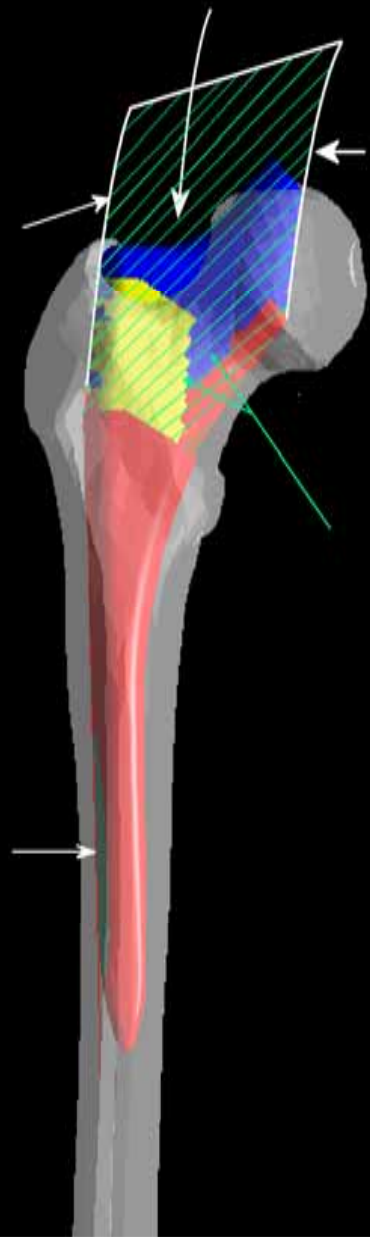
Anteversión  
Planned: 20°  
Actual: 20°



# Navi



# MIS with ROBODOC



# ナビゲーションやロボット

- 機械が手術をするのではなく、あくまでも外科医の能力を高める道具

Beware of the hype because *a fool with a tool is still a fool.*

## 文武両道！

- Costと外科医の理解が課題
- MISや教育に不可欠

