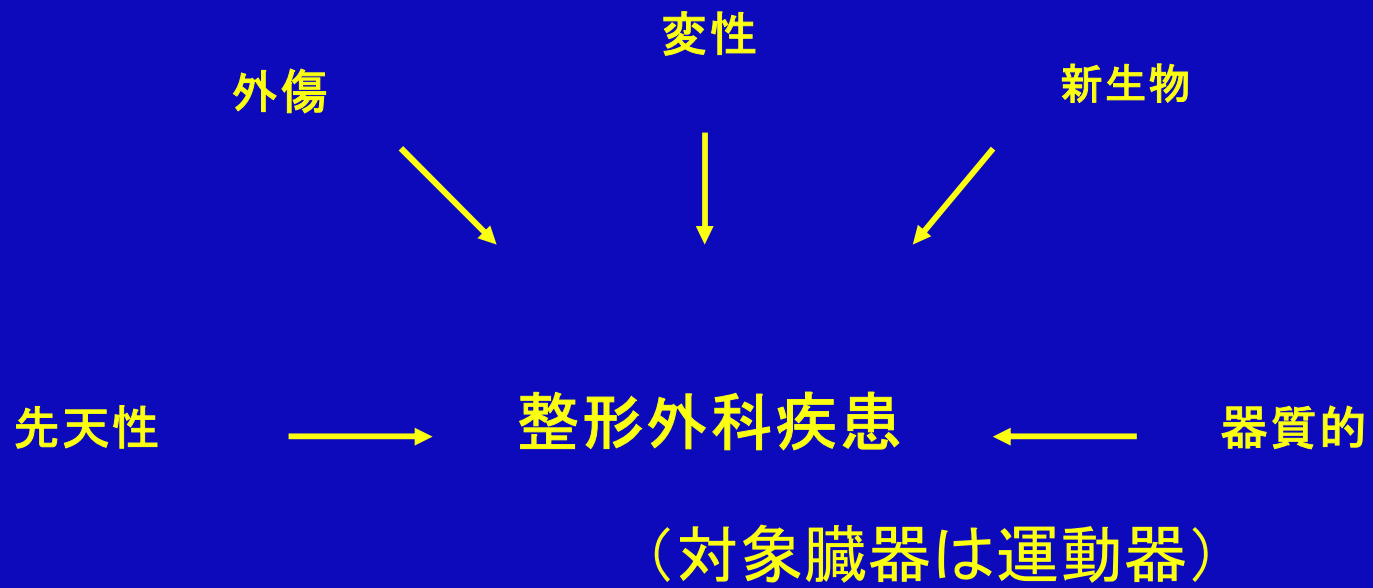


整形外科における新世代の診断装置

大阪大学医工学治療学
菅本 一臣

整形外科疾患



整形外科疾患に対する治療

1. 痛み
2. 変形
3. 運動機能障害

整形外科疾患に対する治療

1. 痛み
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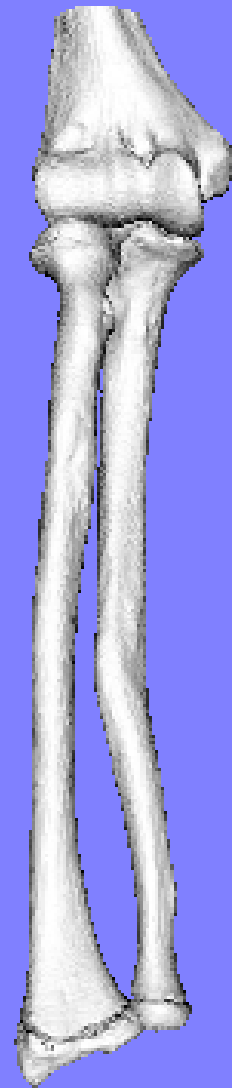
ACR Guidelines (2000)

Baseline Non-pharmacologic Management (Exercise-Weight Loss-Avoidance of Overuse)		
Mild-to-moderate pain Simple analgesics Topical creams	Additional therapies IA <u>hyaluronan</u> IA steroids	Moderate-to-severe pain COX-2 selective inhibitions NASIDs + gastroprotection

Surgery
Chondroplasty
Biologic resurfacing
Osteotomy
Joint replacement

整形外科疾患に対する治療

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整形外科疾患に対する治療

1. 痛み
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X線、イメージ装置

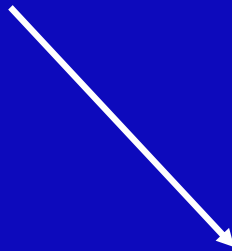


骨格の2次元平面への投影像

CTまたはMRI



骨格の3次元静止像

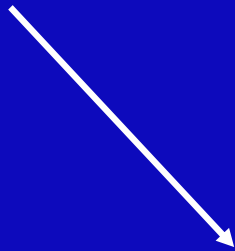


三次元的動態評価は不可能である

X線、イメージ装置



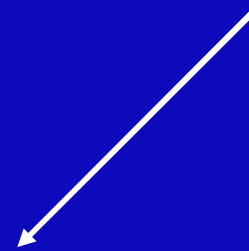
骨格の2次元平面への投影像



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骨格の3次元静止像



三次元的動態評価は不可能である

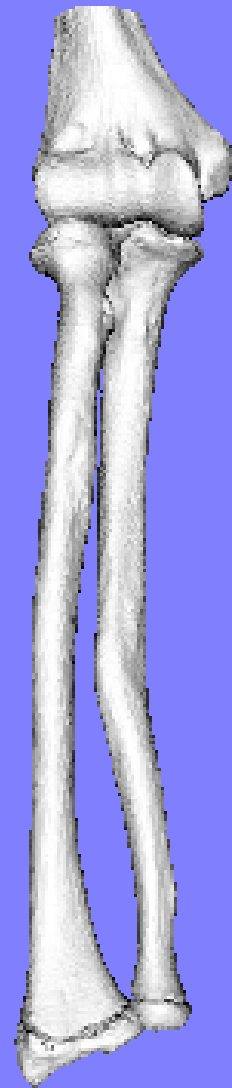
骨関節の変形、動態異常の診断



新世代の診断装置の必要性



コンピュータを用いた解析ソフトの開発







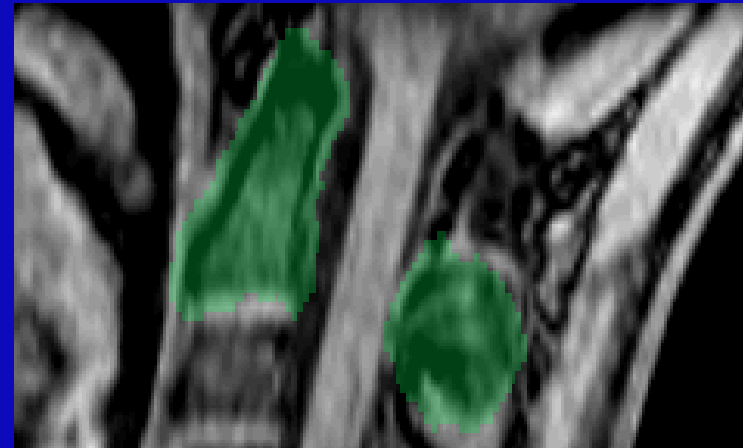
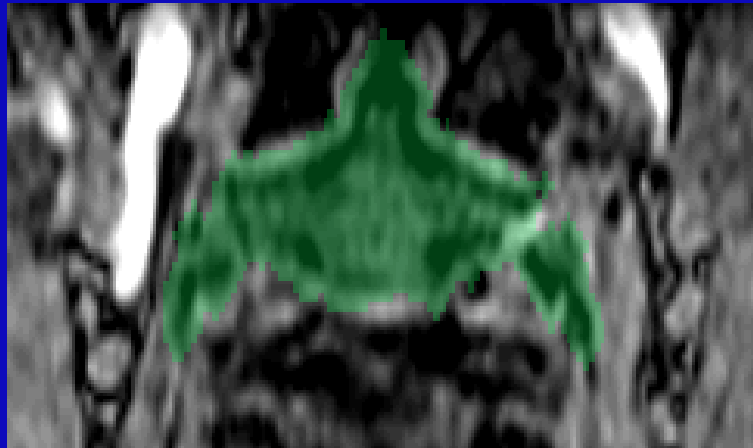
コンピュータを用いた変形および動態の解析

3D-MRIまたは3D-CT



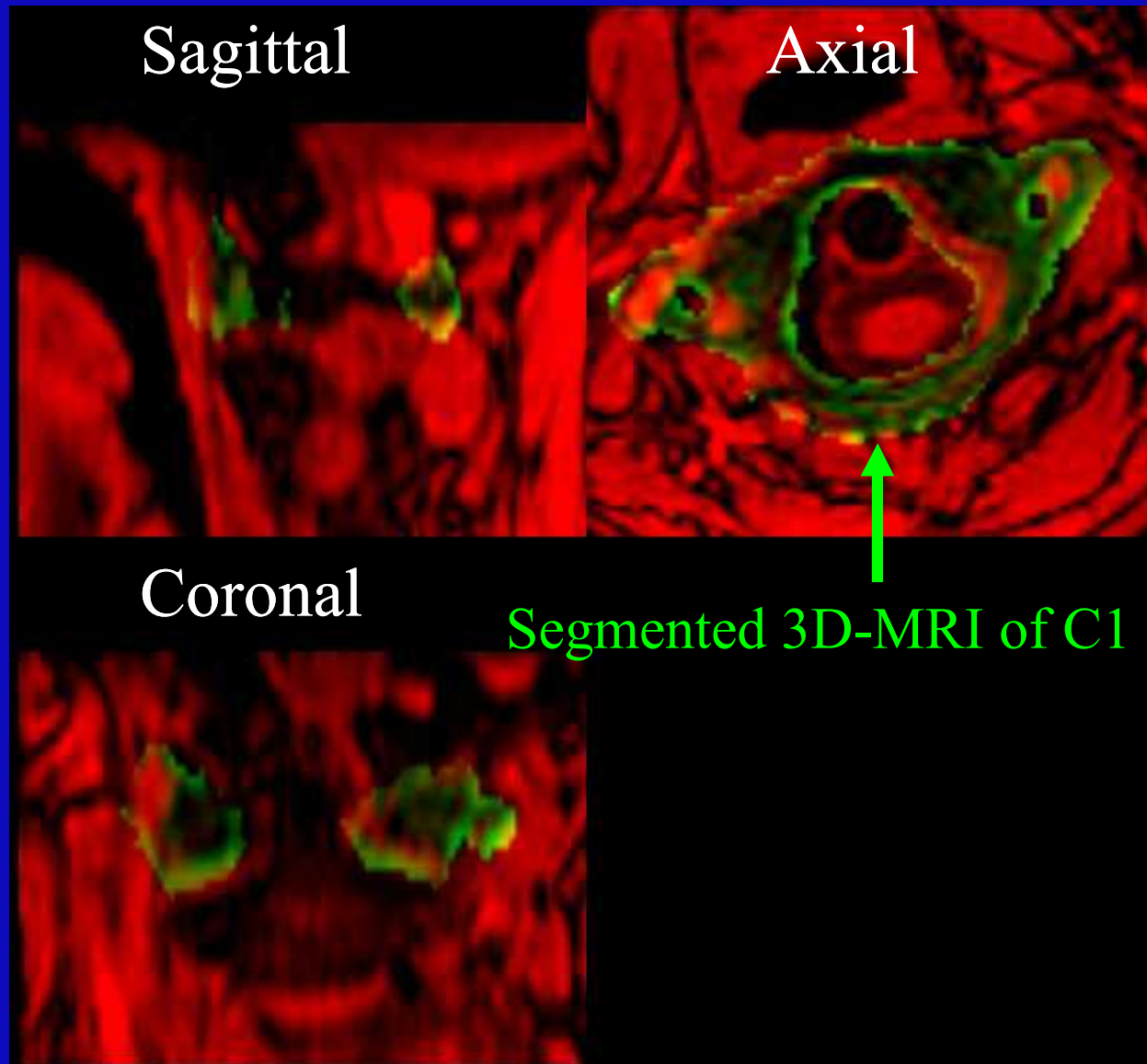
Segmentation

Extracting the contours

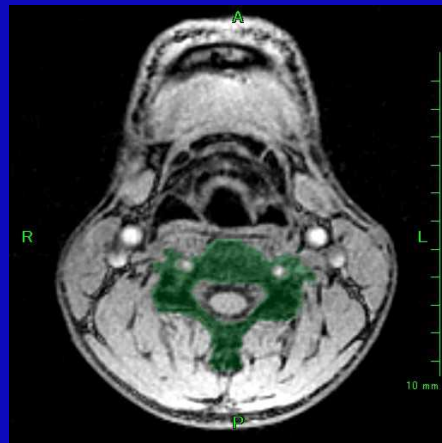


Using **Virtual Place-M[®]** Software
developed in our laboratory

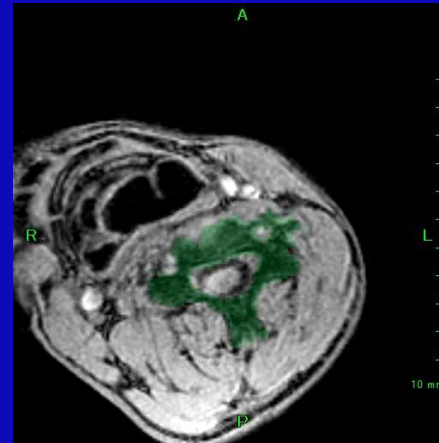
Volume Registration



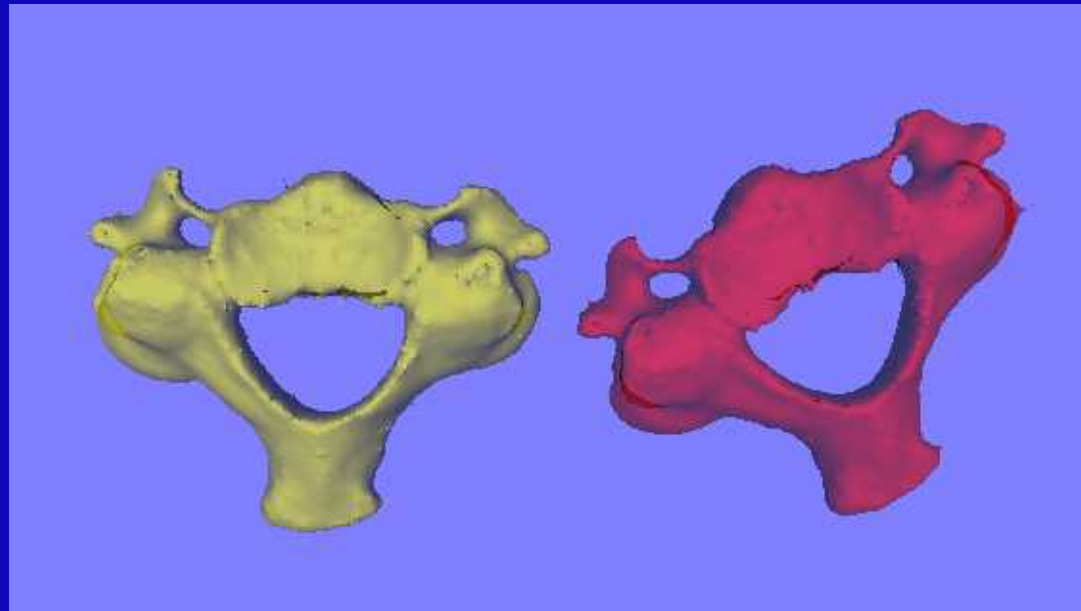
-画素値の類似度を基に3D画像を自動的にマッチング

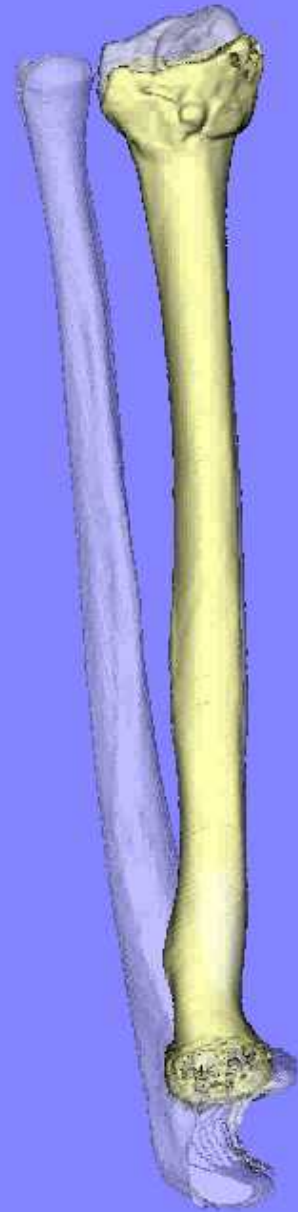
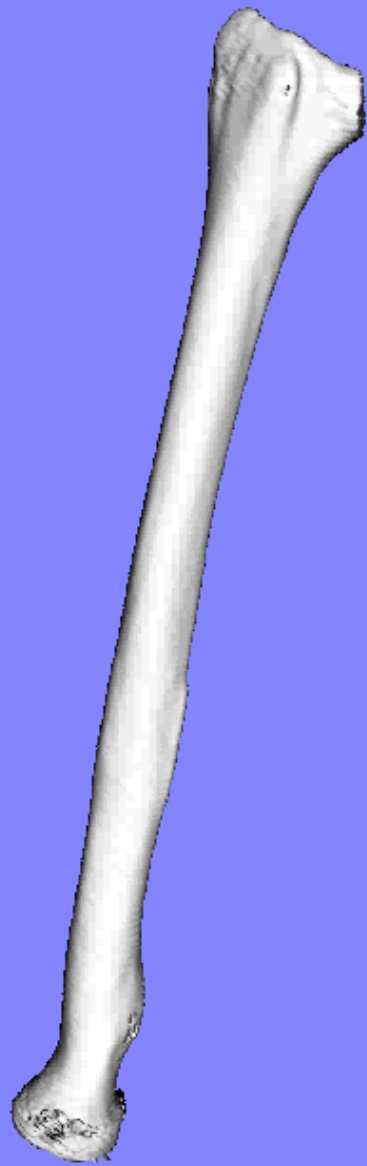
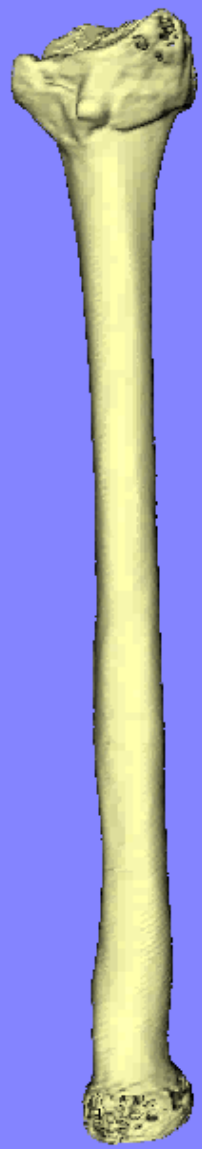


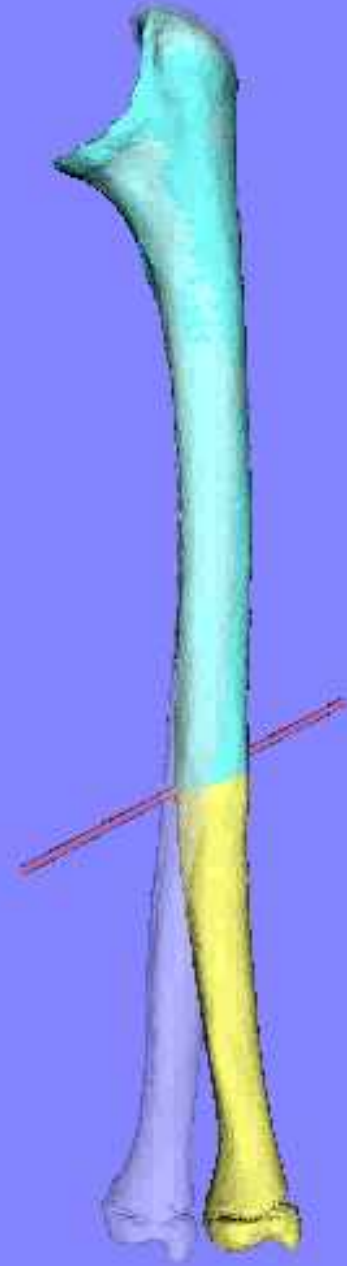
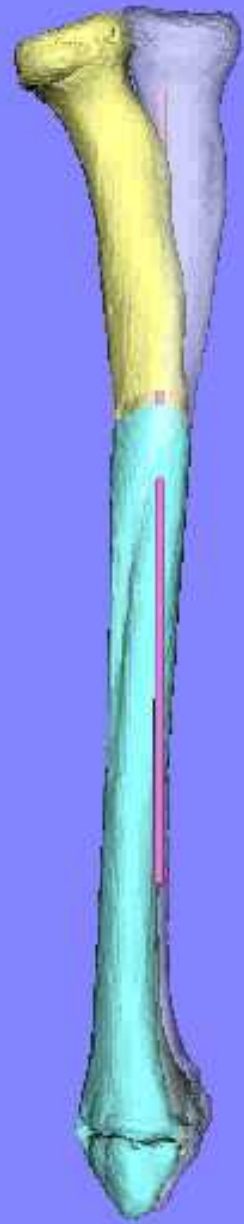
中間位



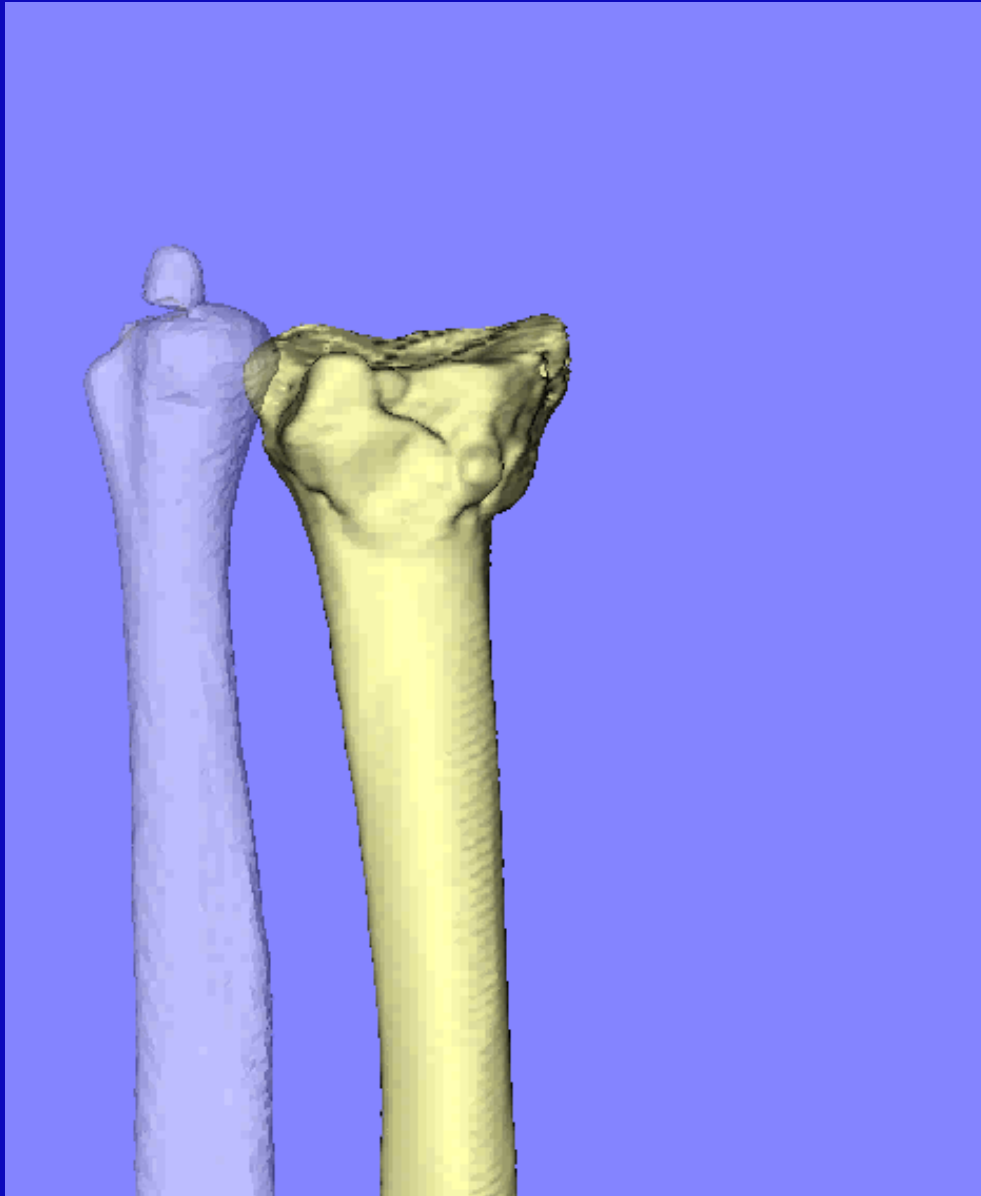
回旋位



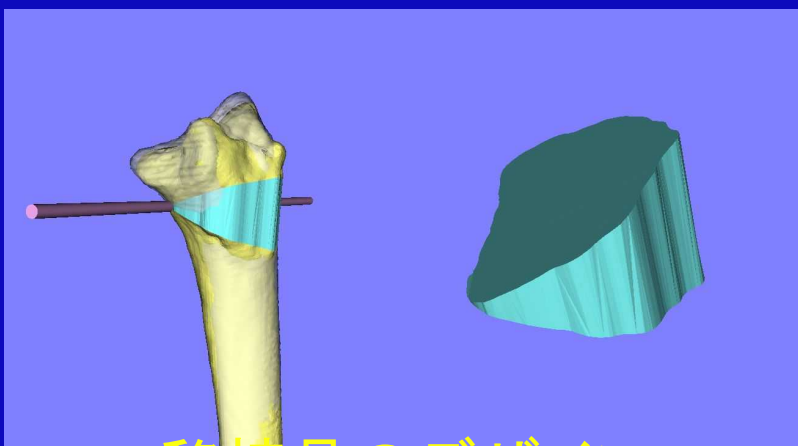
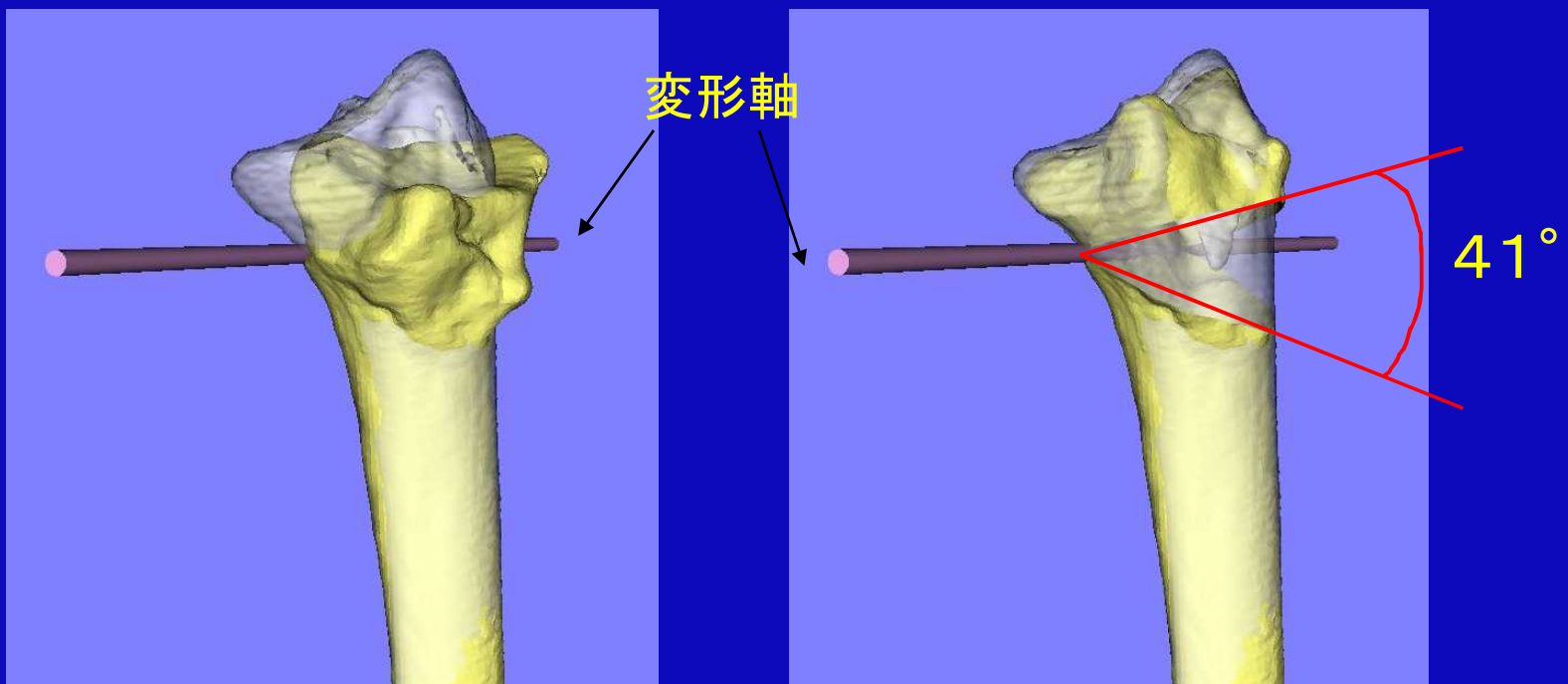




骨切ガイドのデザイン



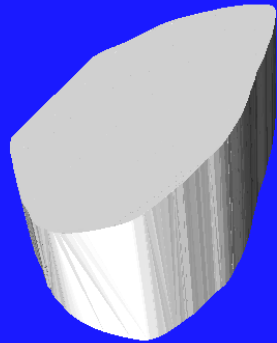
3次元変形解析



移植骨のデザイン



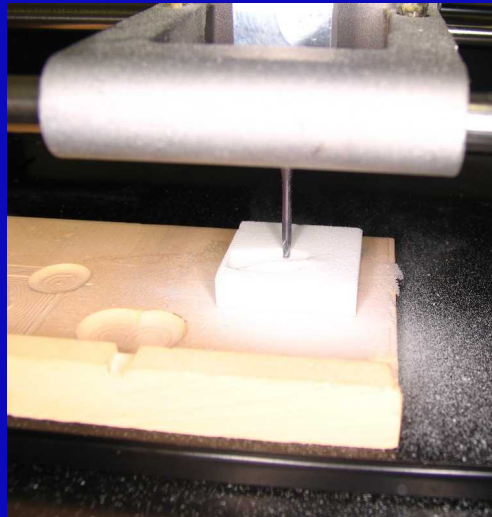
移植骨の術前設計と加工



CADデータ



Roland社製3次元スキャンニング・モデリング装置



連通多孔体ハイドロキシアパタイト
(NEOBONE®)

整形外科疾患に対する治療

1. 痛み
2. 変形
3. 運動機能障害

整形外科疾患に対する治療

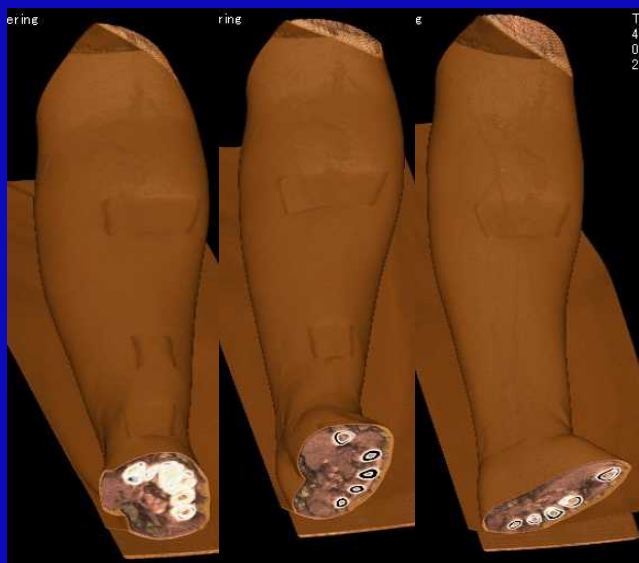
1. 痛み
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整形外科疾患に対する治療

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CTまたはMRI撮影 → モデルの作成

回内位 中間位 回外位



3ポジションで撮影

3D-CT

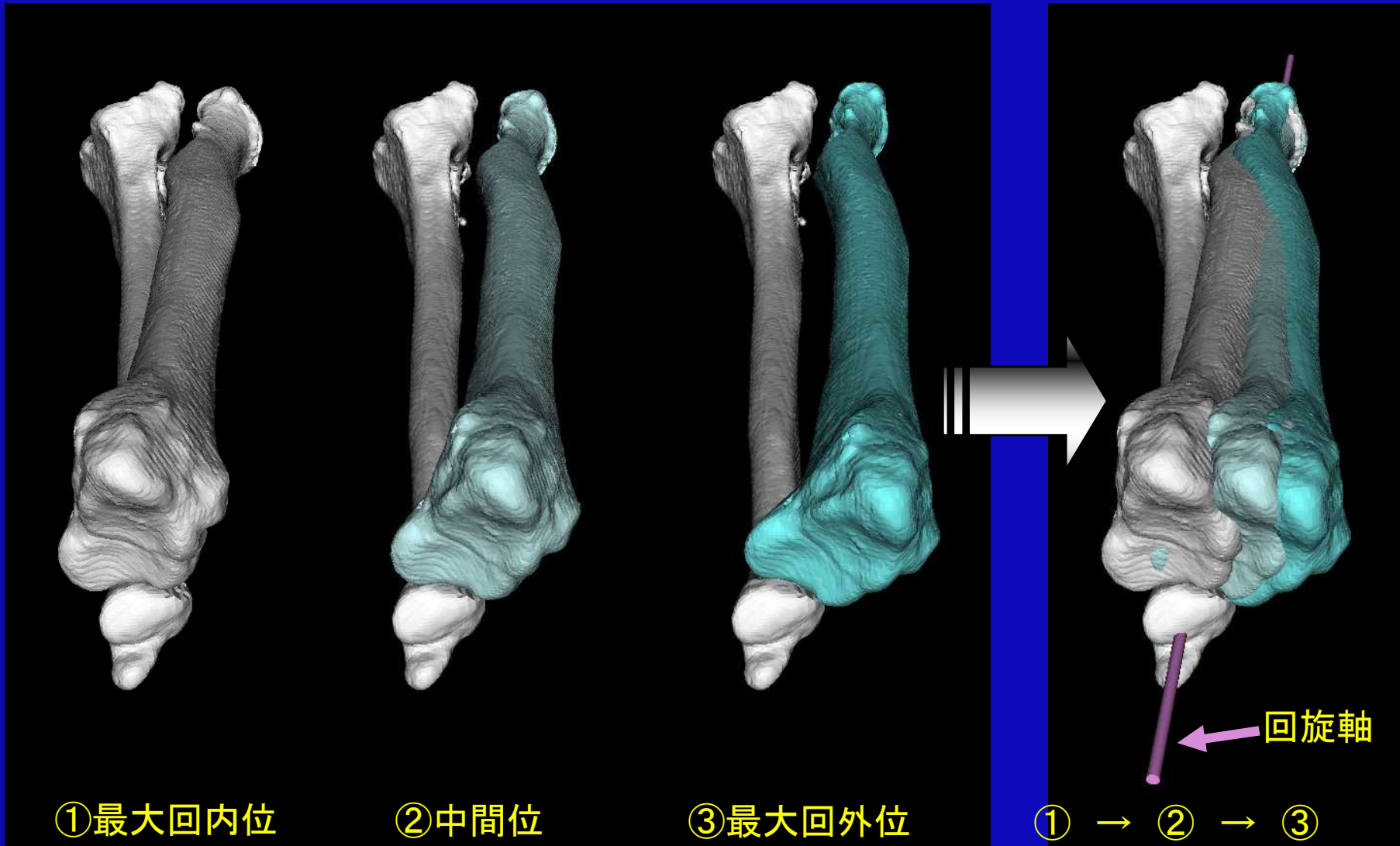


セグメンテーション

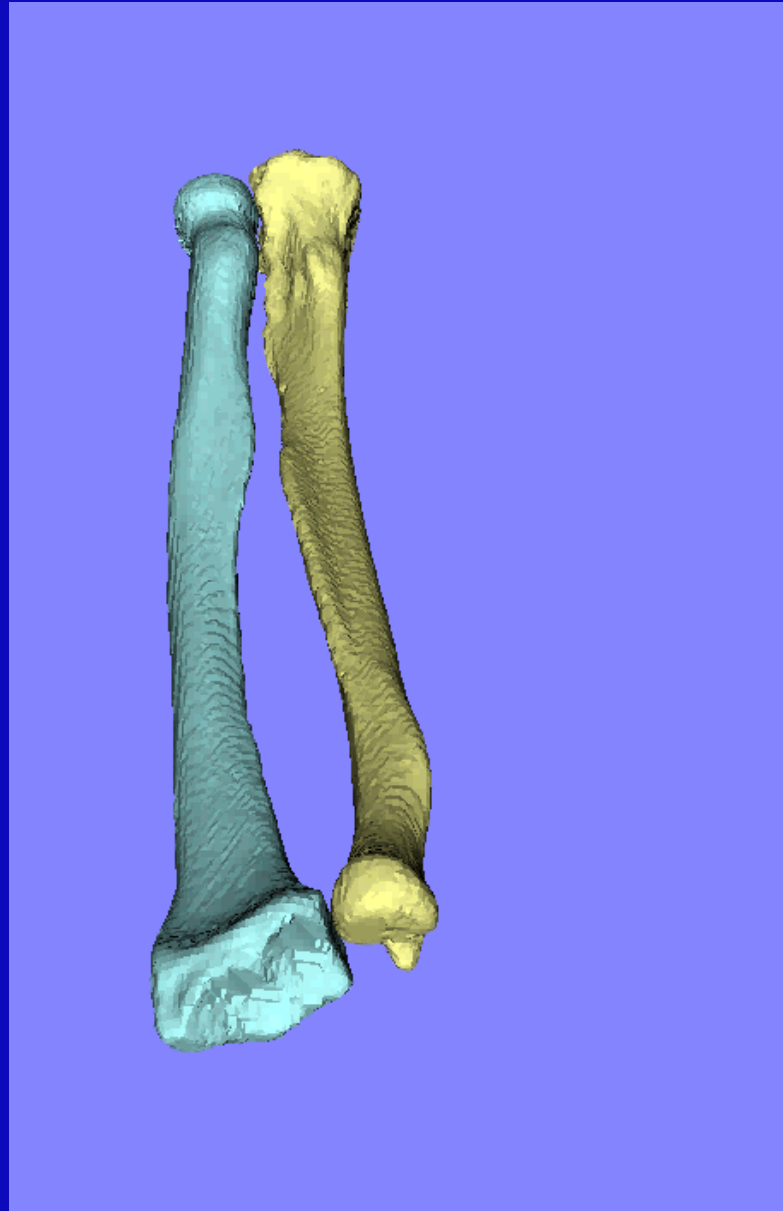


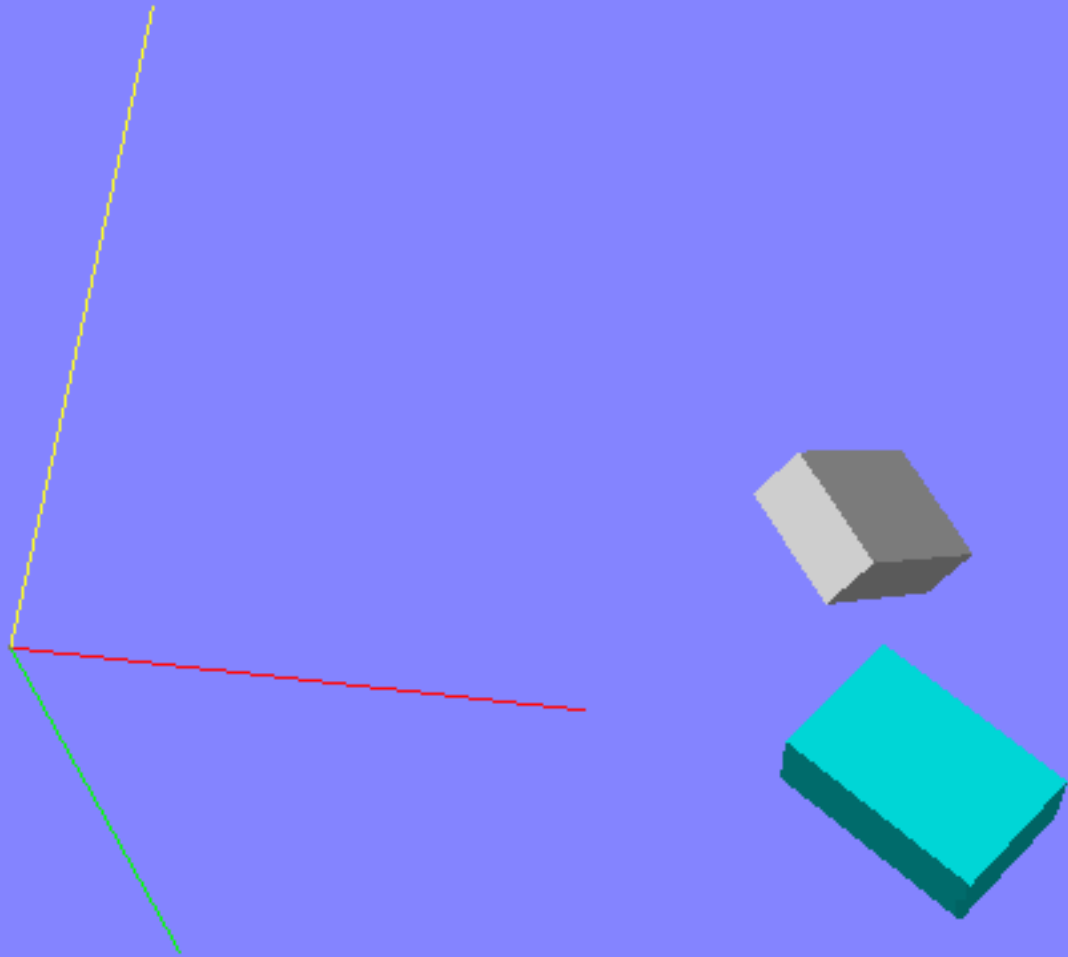
3D骨モデル

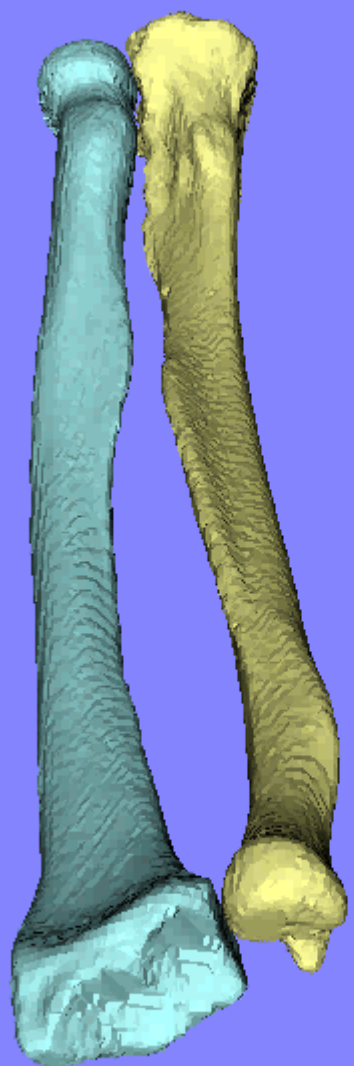
Registration



コンピュータによる動きの補完



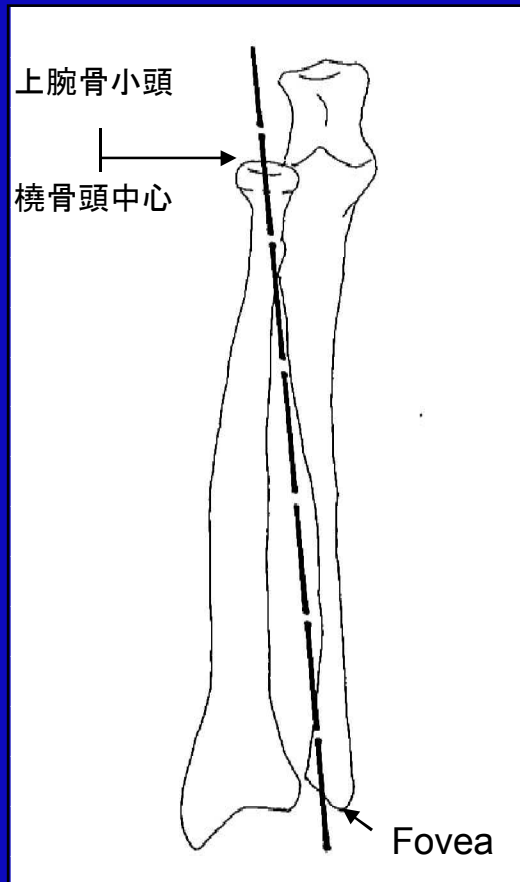




問題点

- 1. 橈骨変形治癒 . . . 橈骨頭の脱臼
- 2. 尺骨変形治癒 . . . 前腕回旋軸の偏位

前腕回旋軸



橈骨の変形



解析手順

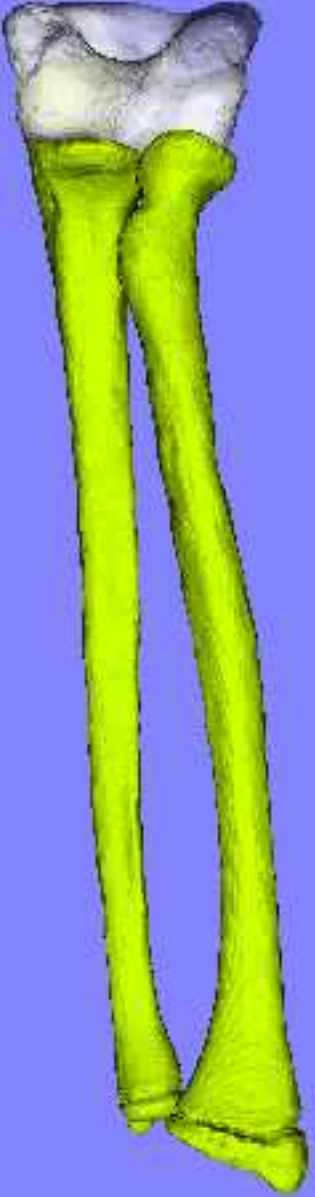
1. 両前腕骨モデルをCTにて作成

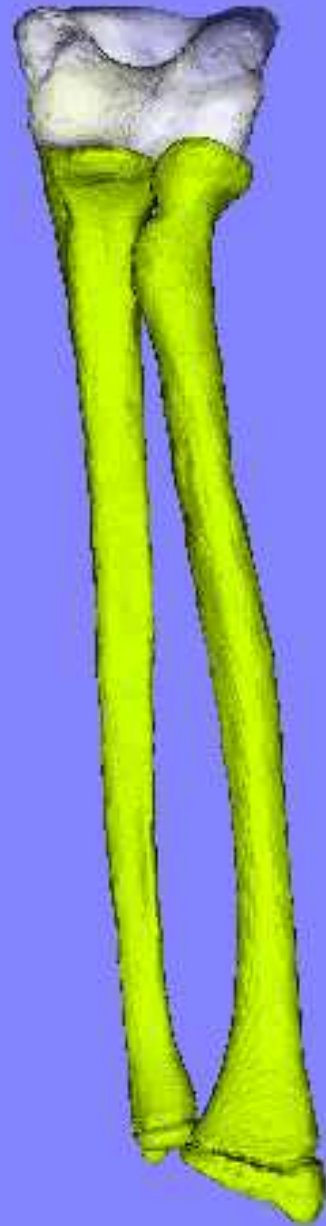
2. 動態解析 MRI 回外～回内

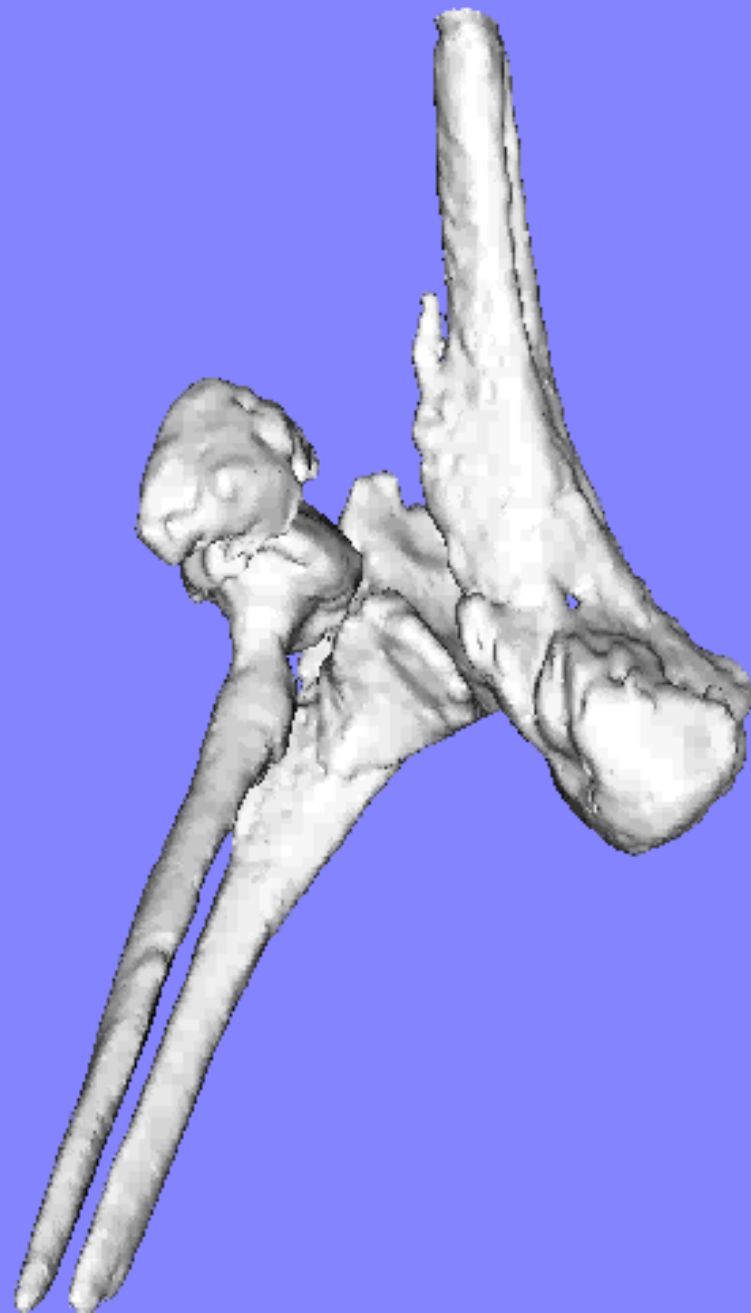
4 Position



前腕回旋軸の同定





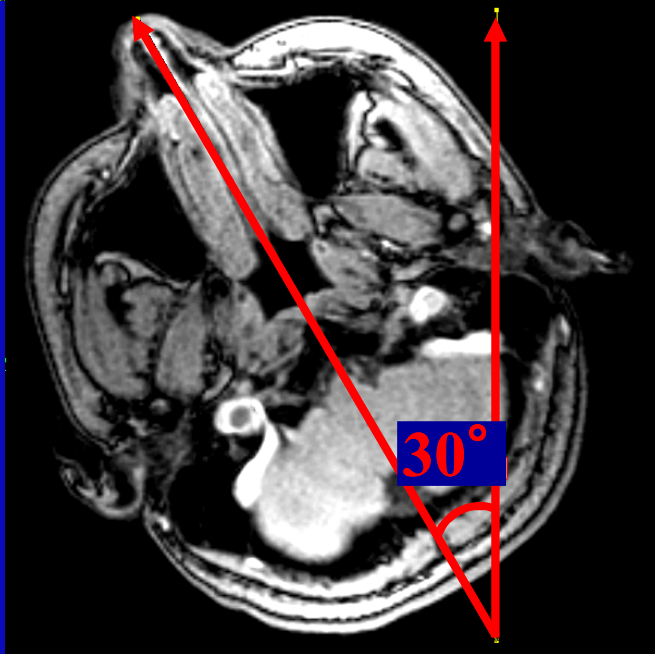
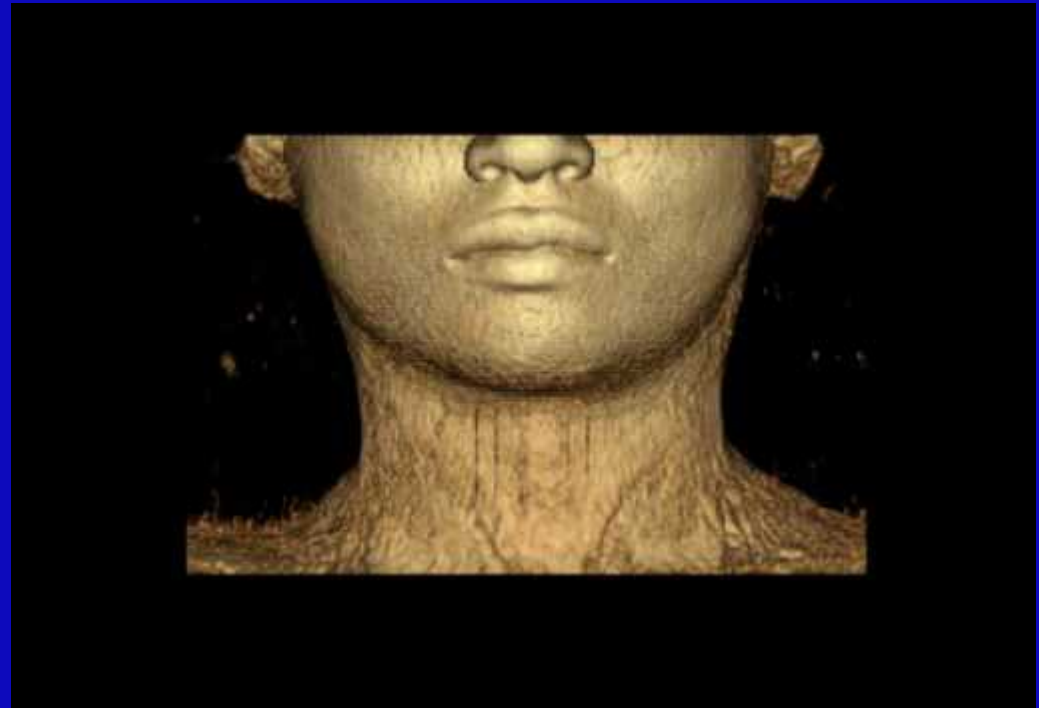
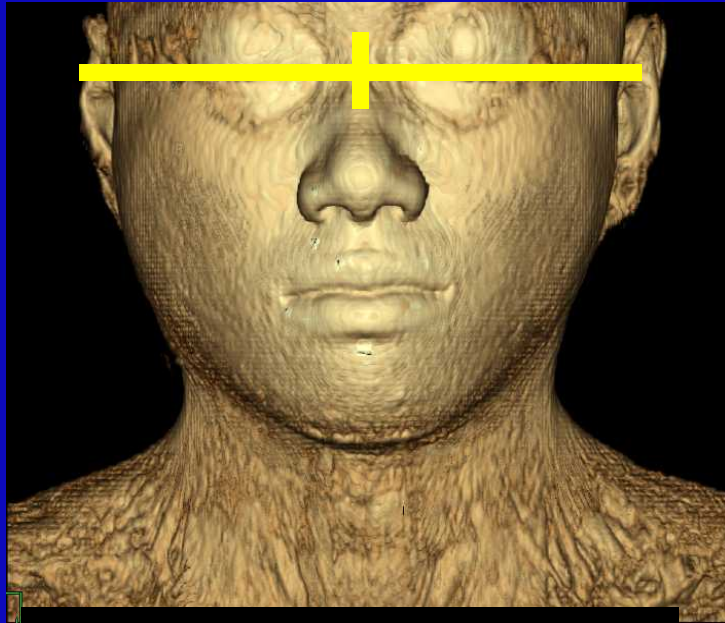


整形外科疾患に対する治療

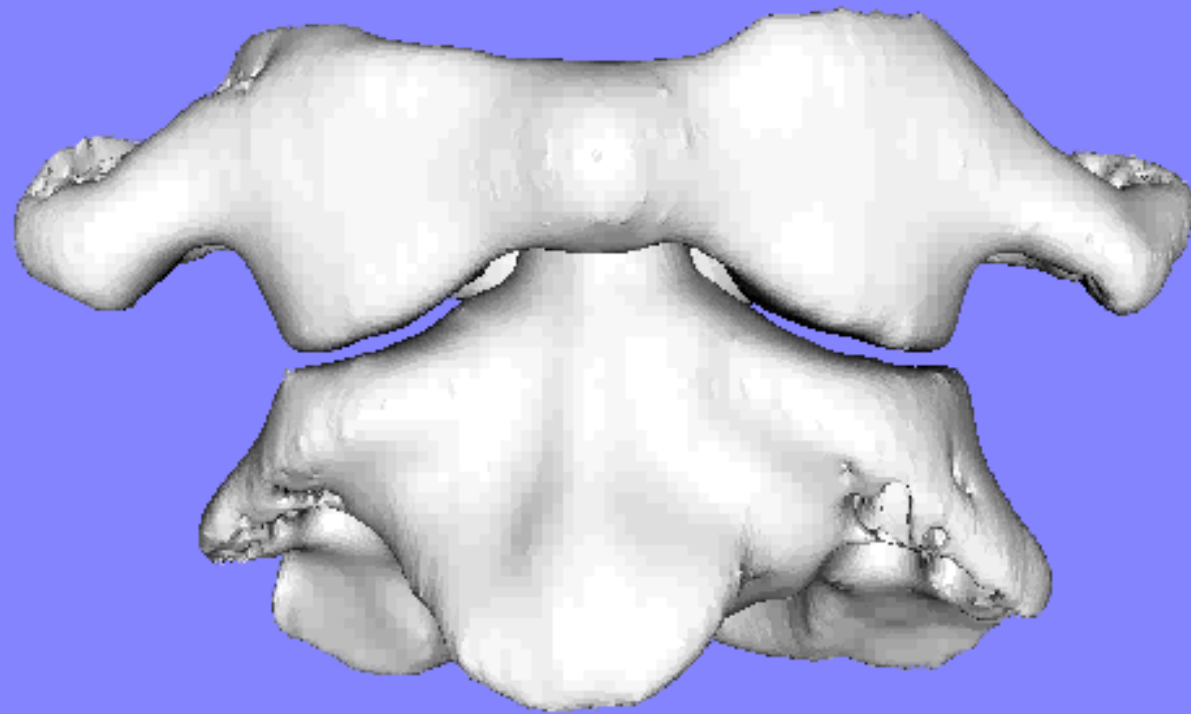
1. 痛み
2. 変形
3. 運動機能障害



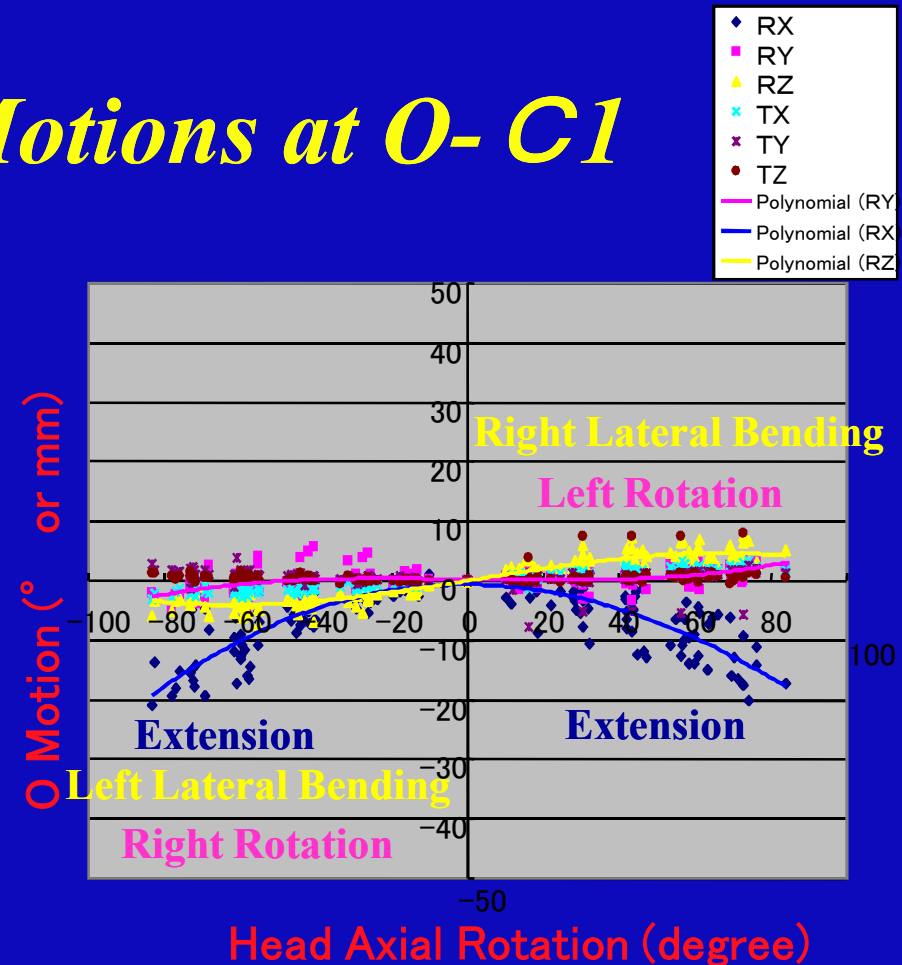
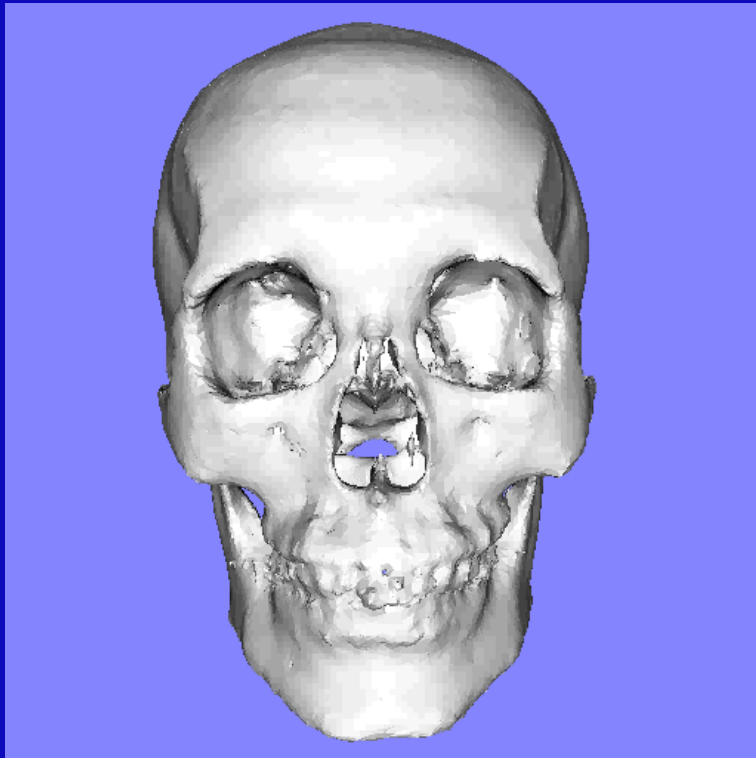
運動（動態）？



From Neutral to Maximum
Rotation in **15° Steps**
(**0° ,15° ,30° ,45° ,60° ,max**)



Intervertebral Motions at O-C1



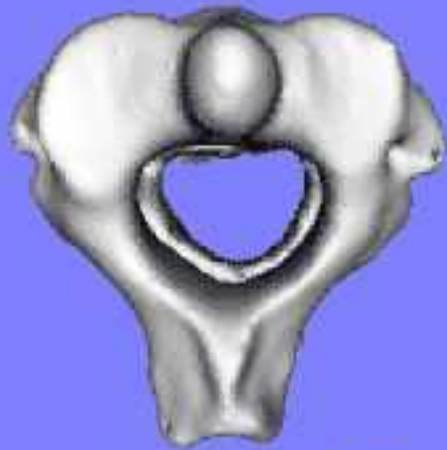
Mean maximum axial rotation

Axial Rotation : 1.7°

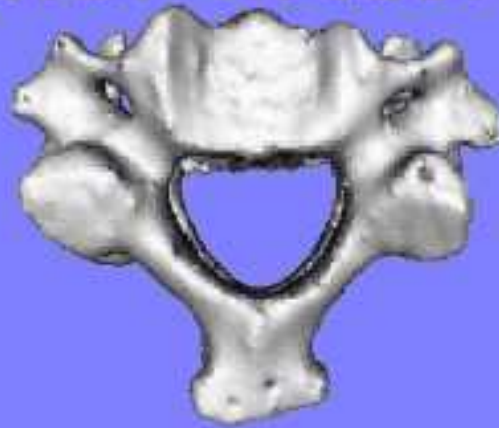
Coupled Lateral Bending : 4.1°

Coupled Extension : 13.4°

Axial Rotation



C2/3; 1.9°



C3/4; 4.3°



C4/5; 4.4°



C5/6; 4.2°



C6/7; 2.5°



C7/Th1; 1.6°

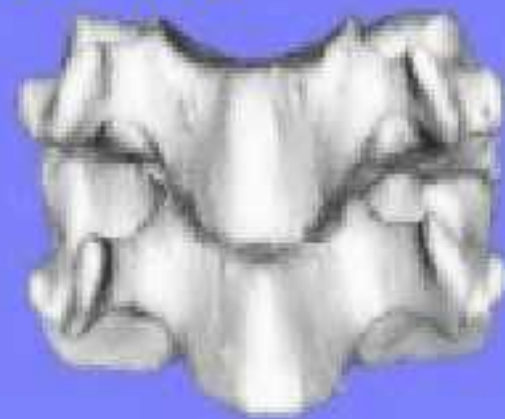
Coupled Lateral Bending



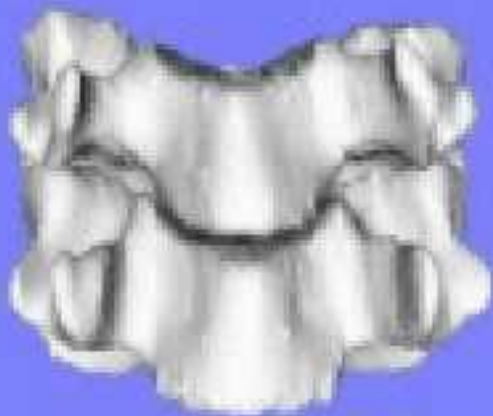
C2/3; 3. 7°



C3/4; 5. 6°



C4/5; 5. 2°



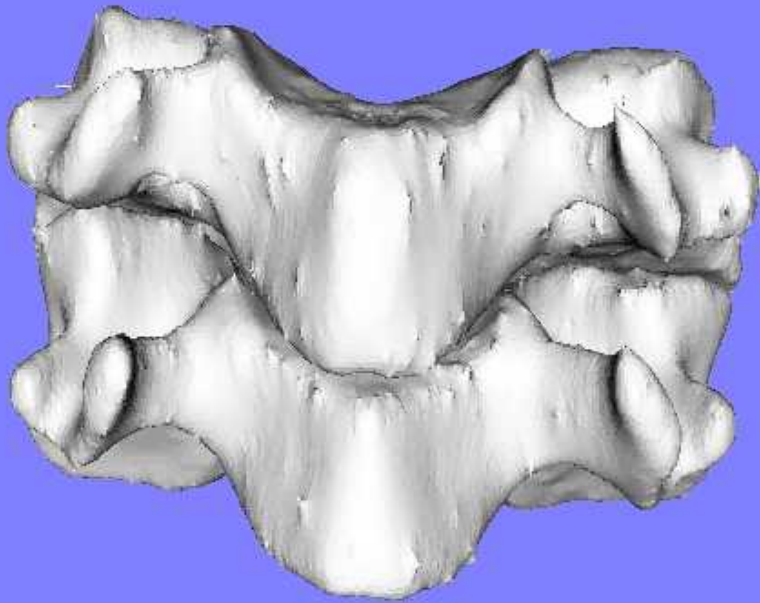
C5/6; 5. 1°



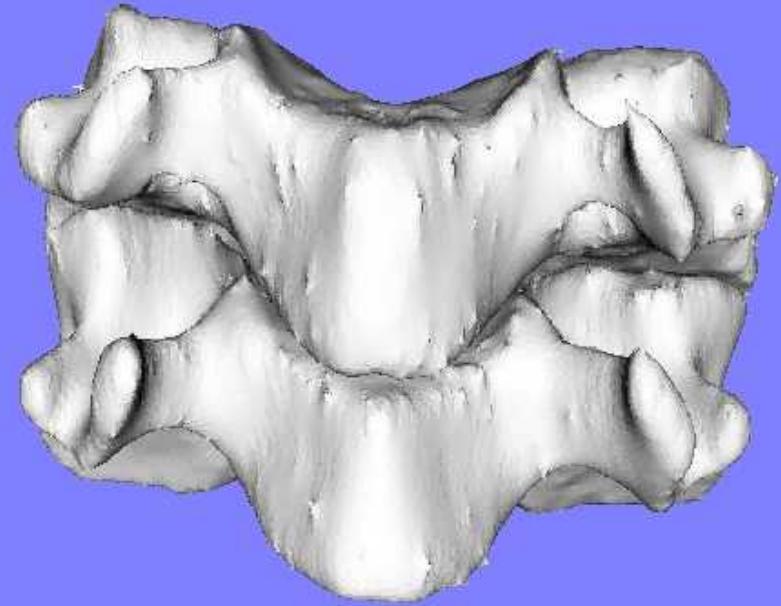
C6/7; 4. 6°



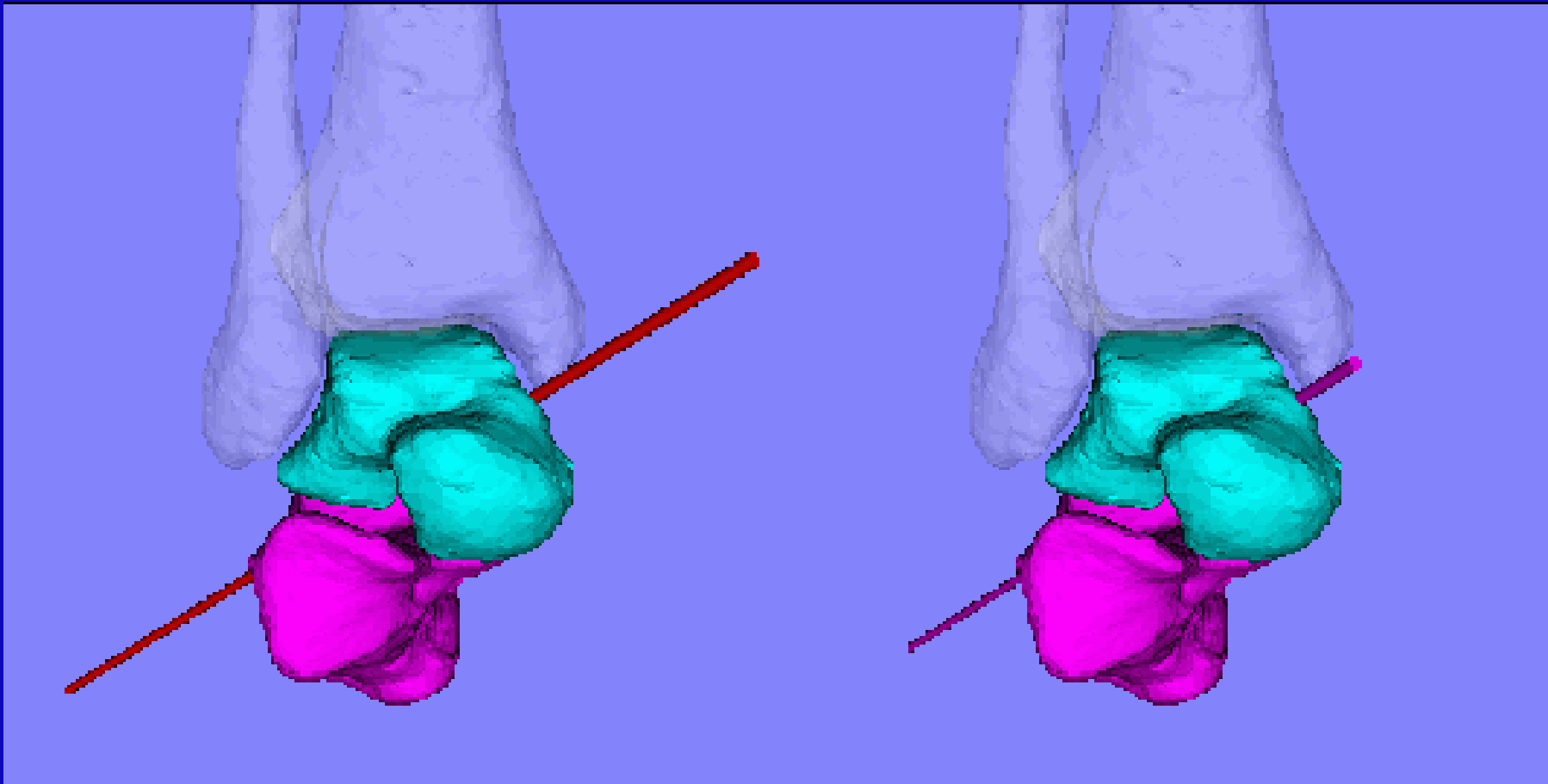
C7/Th1; 1. 1°



Axial Rotation



Lateral Bending



CT、MRIベースの解析で本当に
骨関節の動態をみていることになるの？

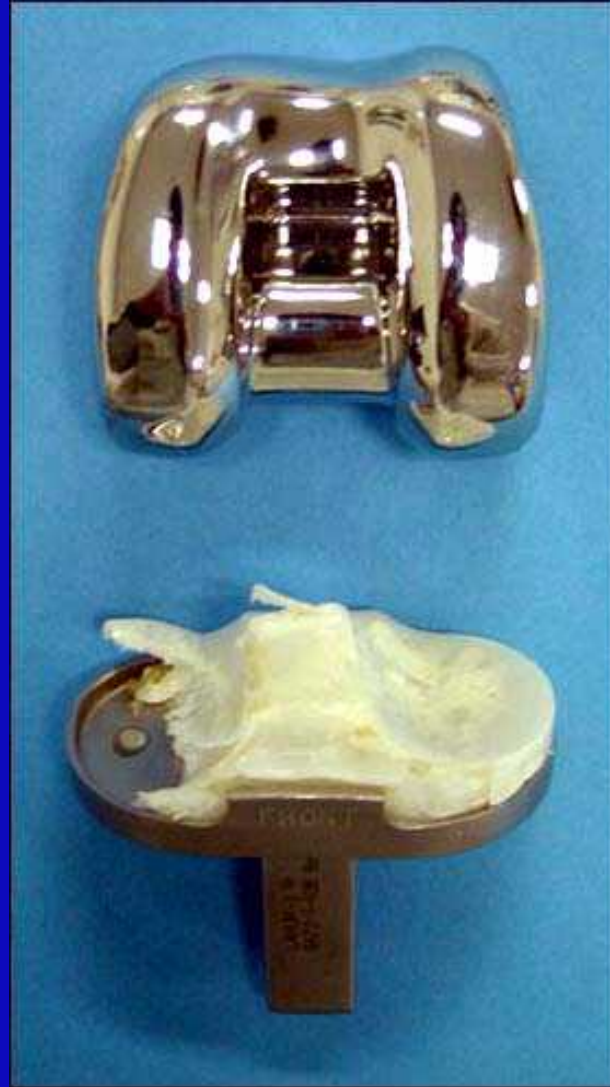


正確には肢位変化に伴う骨関節の位置変化をみたもの



速い動きをさせた場合にゆっくりとした動きと
動態が異なる場合には本手法は適さない

- 1) Instabilityのある関節 （肩不安定症、靱帯損傷）
- 2) 人工物の挿入された関節
- 3) CT、MRIコイル内での制限された動き

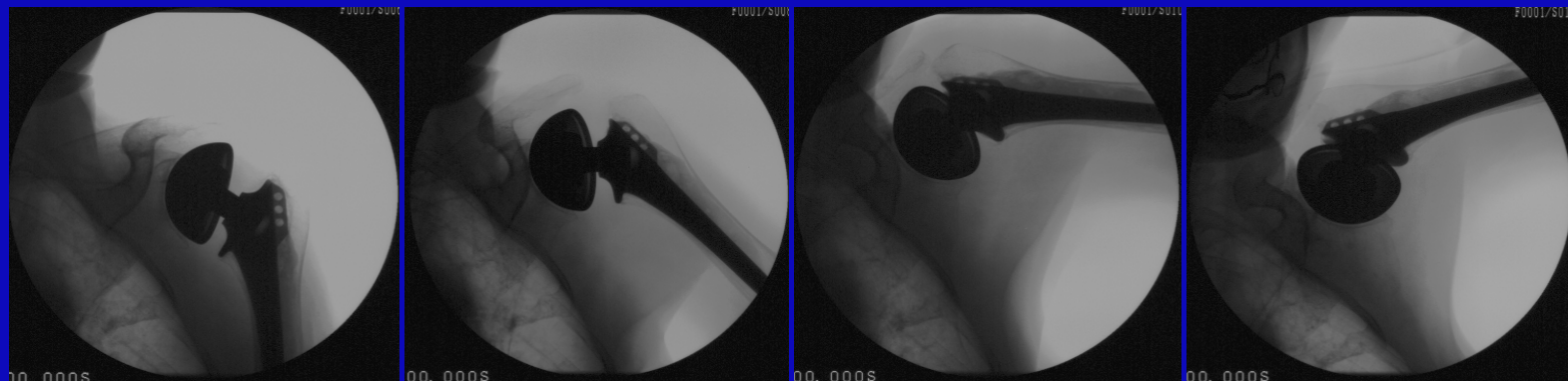


→生体内の術後のdynamic な動態解析の必要性

骨関節の動態解析



動的な条件下での
骨関節の三次元的評価



X線イメージ像



3次元的に構築された骨格の2次元平面への投影像



三次元的動態評価は不可能である

Current kinematic study

X-ray imaging

- 1) fluoroscopic analysis (VTR-2D)
(Perry,1983)
- 2) RSA (roentgen stereophotogrammetric analysis)
(Nilsson et al.,1990)

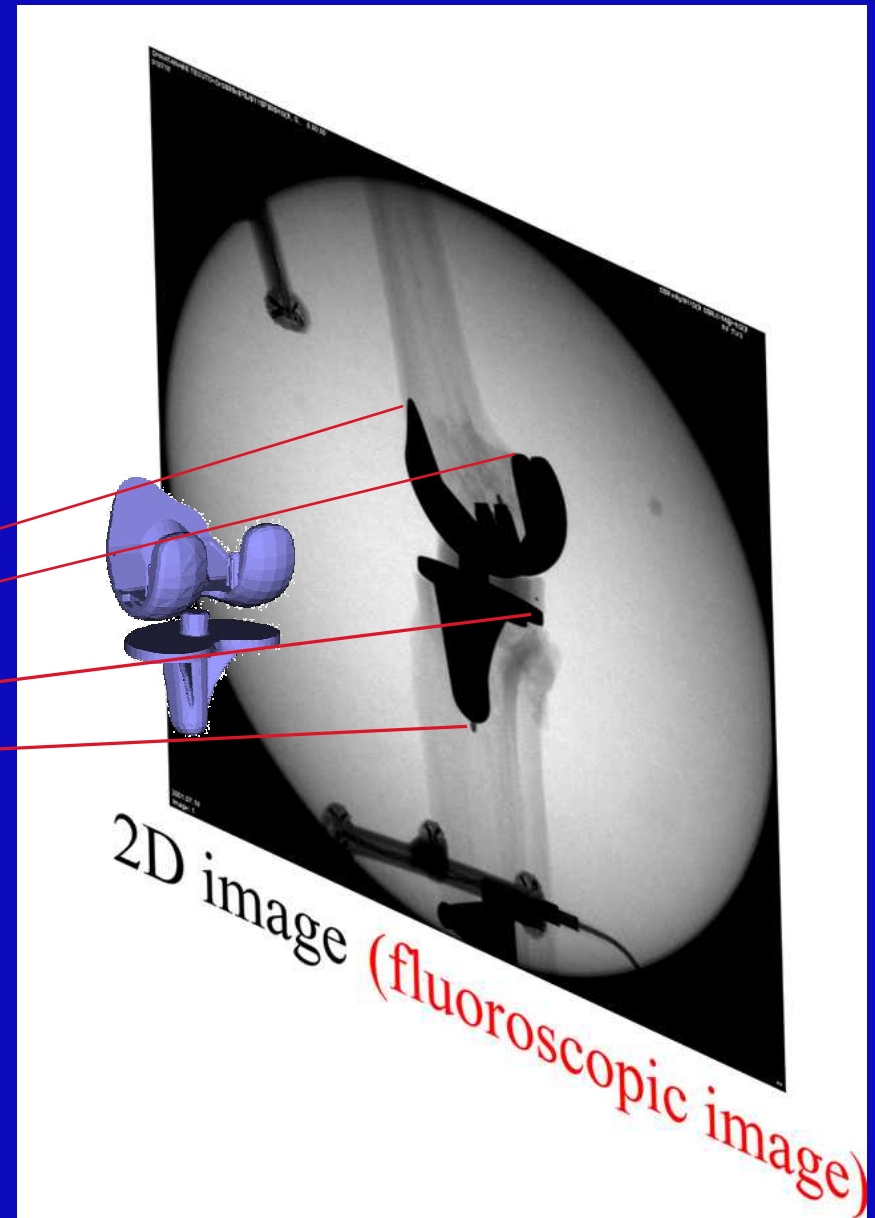
Model-based method

- 1) model-based-method (single-plane fluoroscope \Rightarrow 3D)
(Banks et al.,1996; Hoff et al.,1998; Zuffi et al.,1999)
- 2) model-based-RSA (bi-plane fluoroscope \Rightarrow 3D)
(Valster et al.,2000; You et al., 2001)

Model-based method

Camera parameter
(焦点距離、投影中心)

→空間位置姿勢 (6-DOF)
(six-degree-of-freedom)



Full perspective model

Matching algorithm

輪郭matching

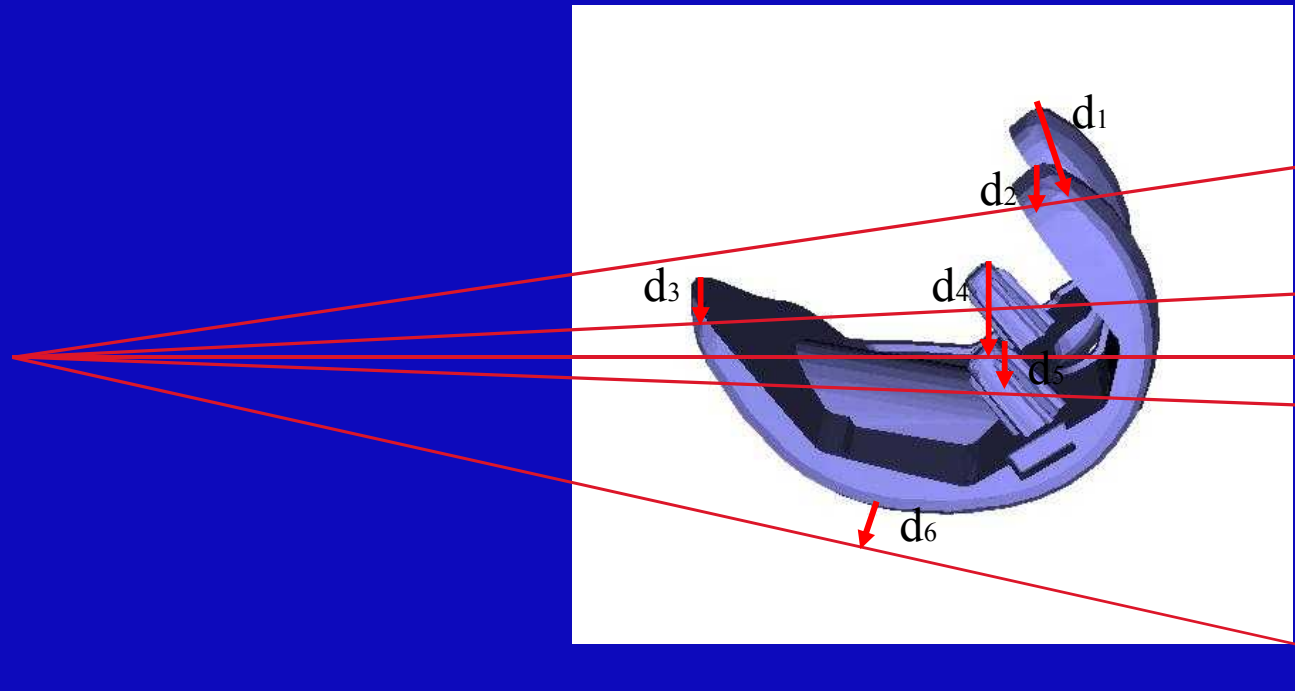
モデル表面-投影光線間距離 = d_i (ICP: Iterative Closest Point)

残差

$$RMSD = \sqrt{\sum_i^n d_i^2}$$

Root Mean Square Distance

残差 $RMSD$ を最小化 (Levenverg-Marquardt非線形最小2乗法)

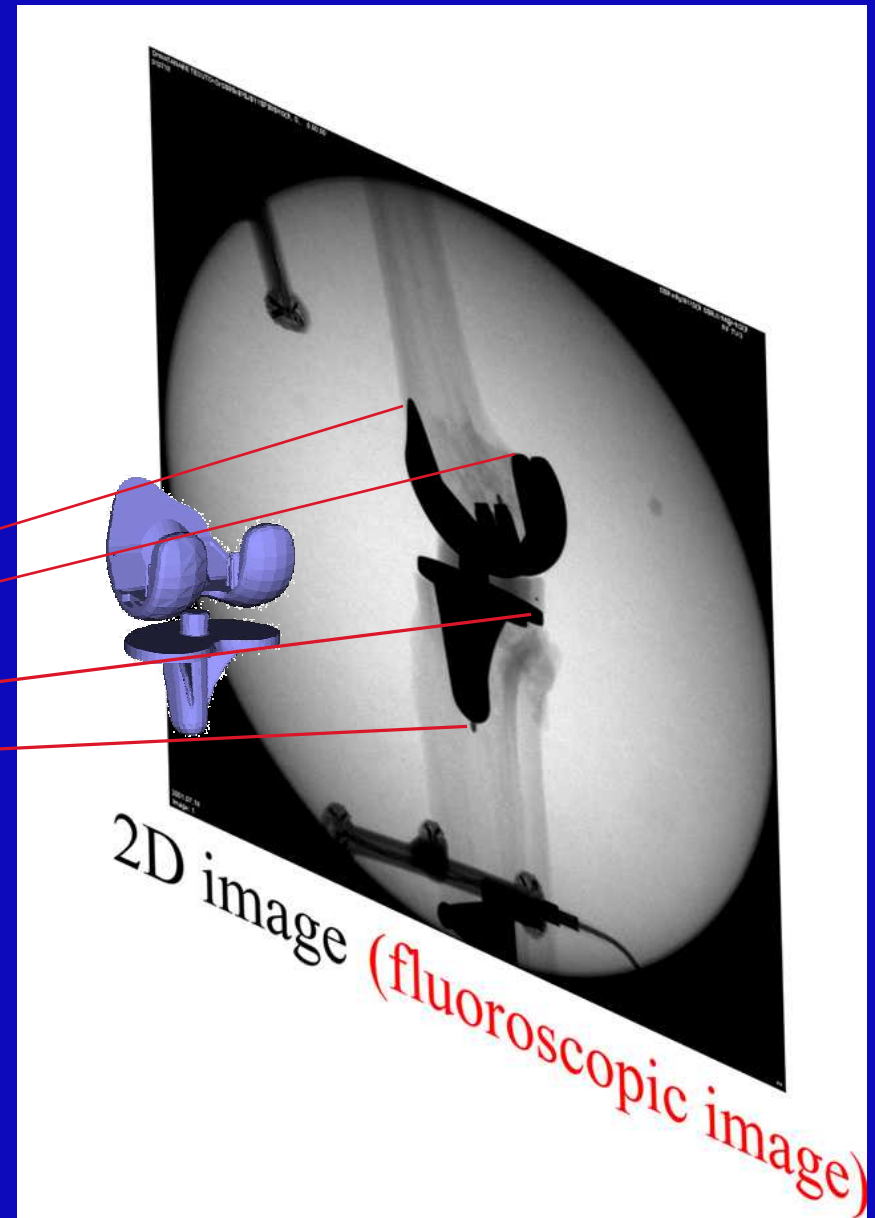


(Zuffi et al., IEEE Trans Med Imag, 1999)

Model-based method

Camera parameter
(焦点距離、投影中心)

→空間位置姿勢 (6-DOF)
(six-degree-of-freedom)



Fluoroscope



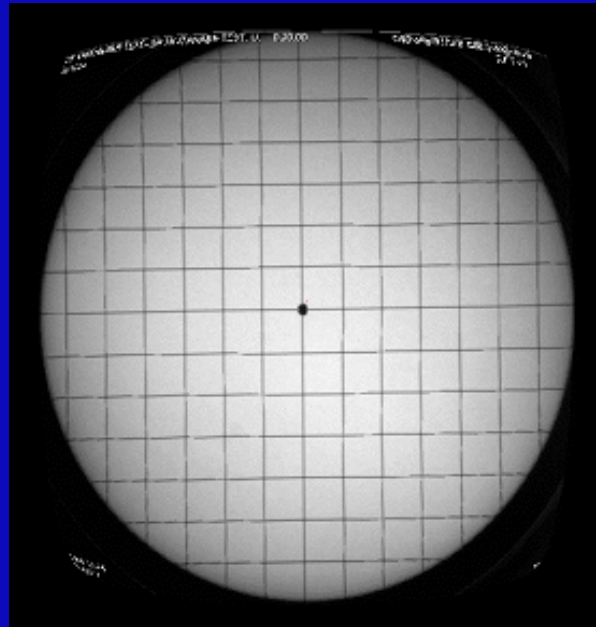
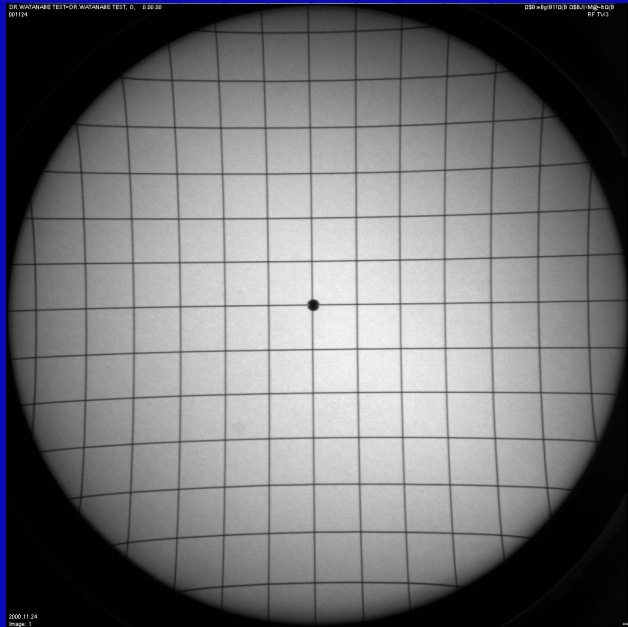
Video output(出力)



Distortion correction(歪み補正)



Edge detector(輪郭抽出)

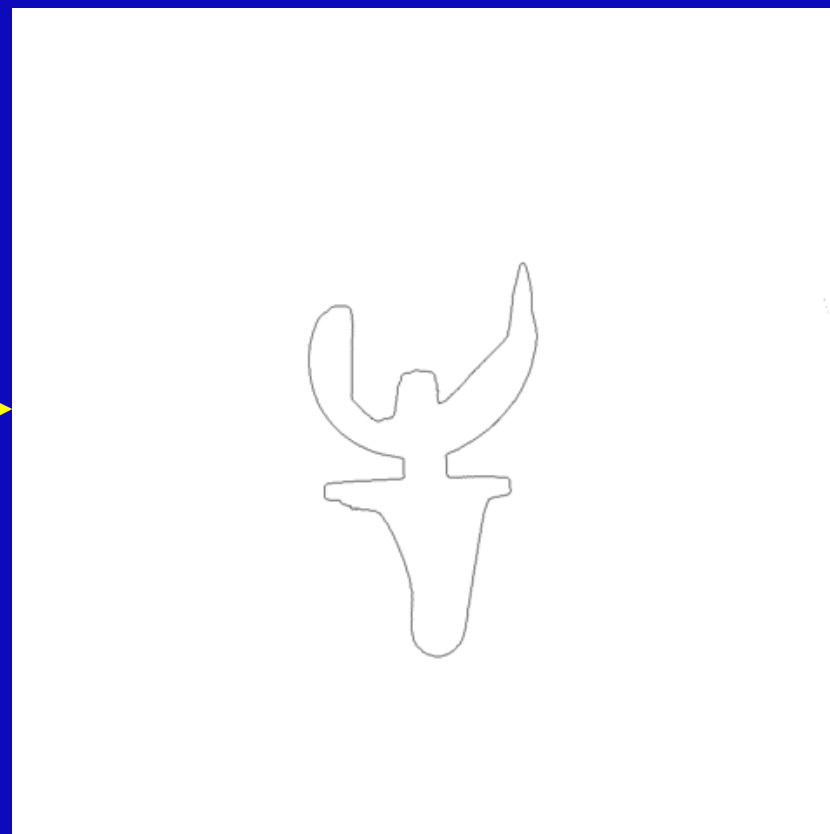
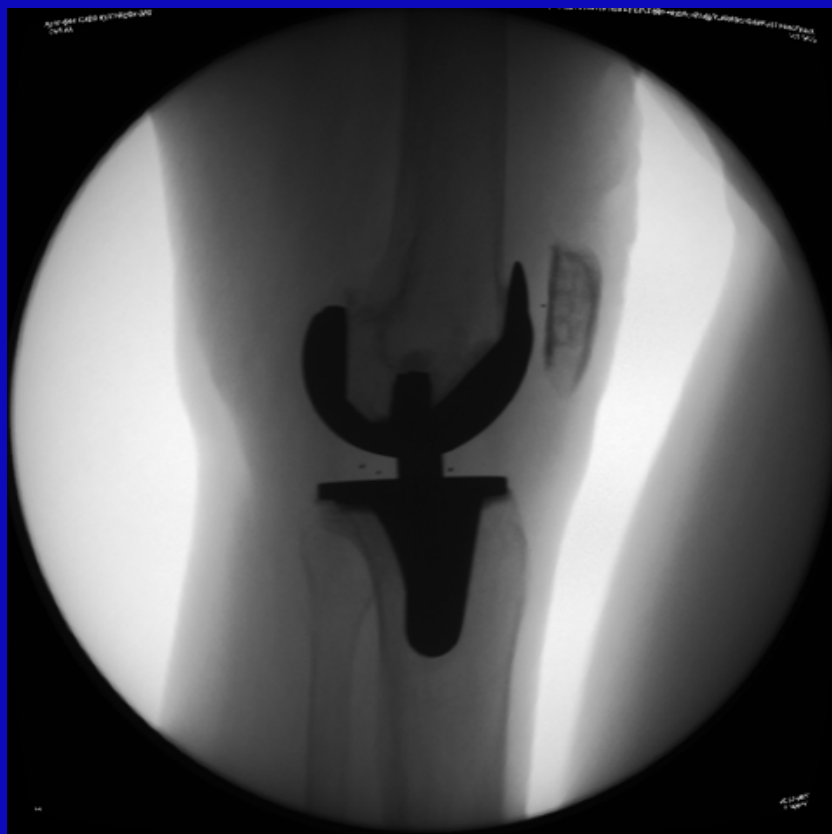


歪み補正

12inch-I. I.
Shimadzu G-vision IVS-100



輪郭描出



マッチング







IWAMOTO KEIKO=0\$84dK, F, 1948.04.06
05784654

0\$B:eBgIB1!0(B 0\$BJ!<M@~!t0(B
XA TV-3

2002.05.24
Image: 1

==

Accuracy test (in vitro)

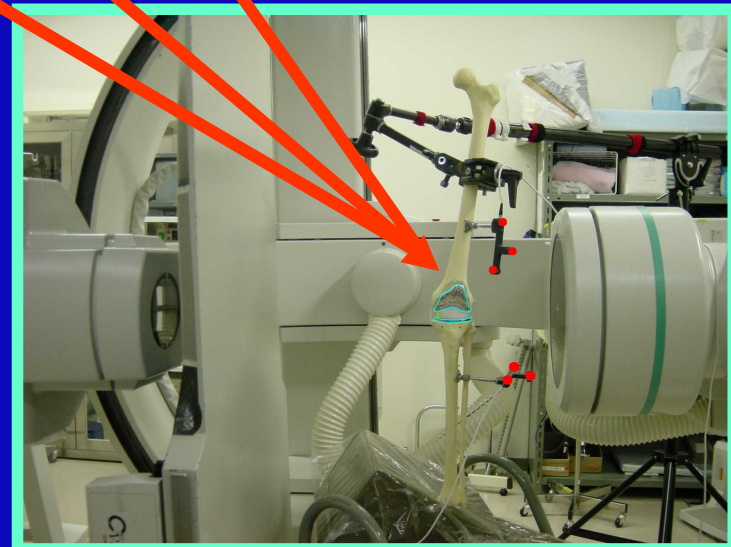
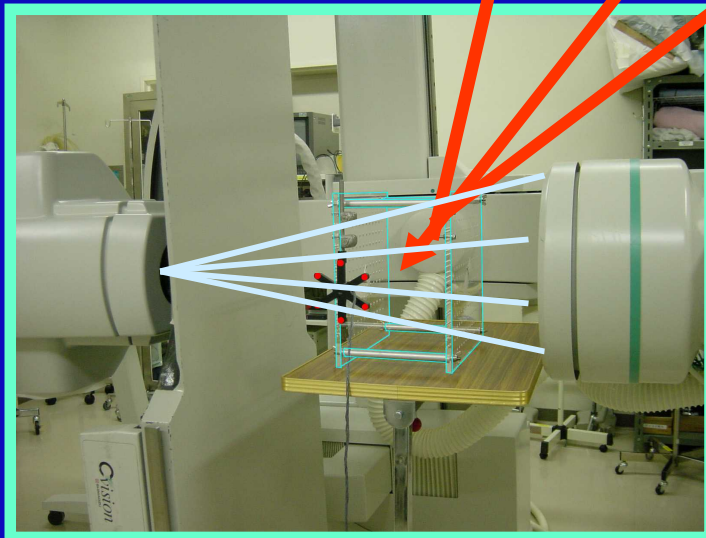
Ground truth

Optical 3D-digitiser 'OPTOTRAK 3020' RMS accuracy to 0.1mm

KneeOpus (DBK, F3L+T3)

surface registration

evaluate an absolute accuracy (6-DOF)

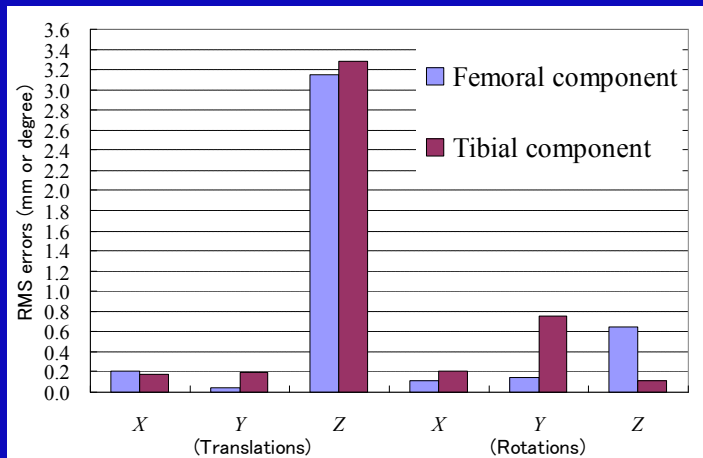


Absolute errors

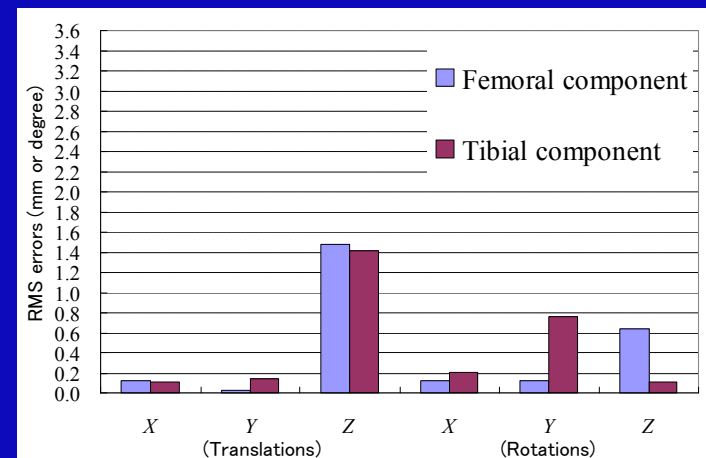
Root-Mean-Square error of 3D pose estimation

Root-Mean-Square errors for *in vitro* tests

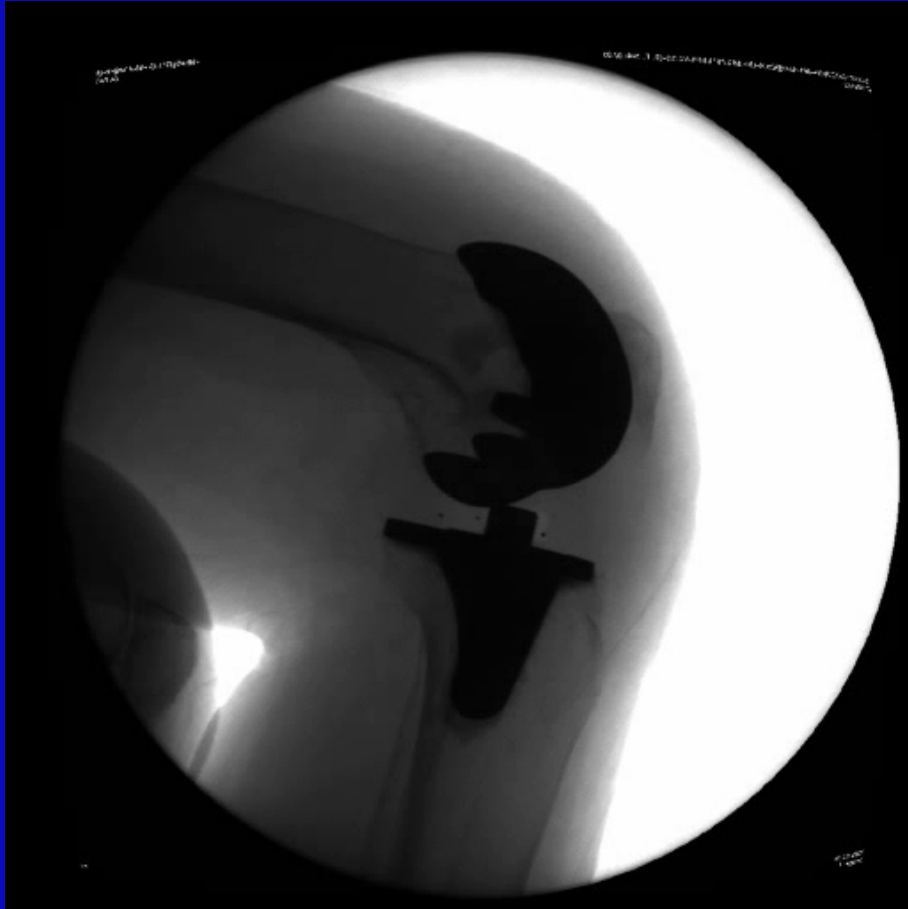
Component		Translation (mm)			Rotation (degrees)		
		<i>X</i>	<i>Y</i>	<i>Z</i>	<i>X</i>	<i>Y</i>	<i>Z</i>
Conventional	Femoral	0.204	0.043	3.154	0.108	0.142	0.647
	Tibial	0.178	0.197	3.281	0.207	0.756	0.108
Proposed	Femoral	0.118	0.030	1.478	0.121	0.125	0.637
	Tibial	0.114	0.142	1.412	0.202	0.764	0.112



Conventional

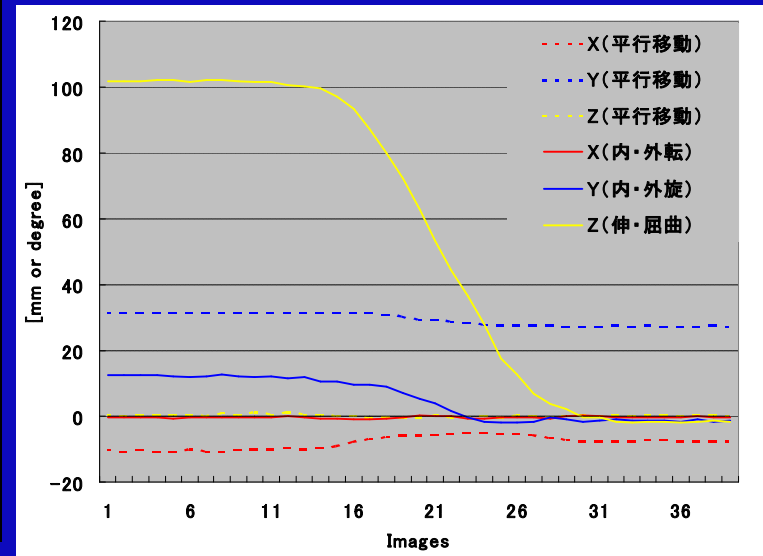
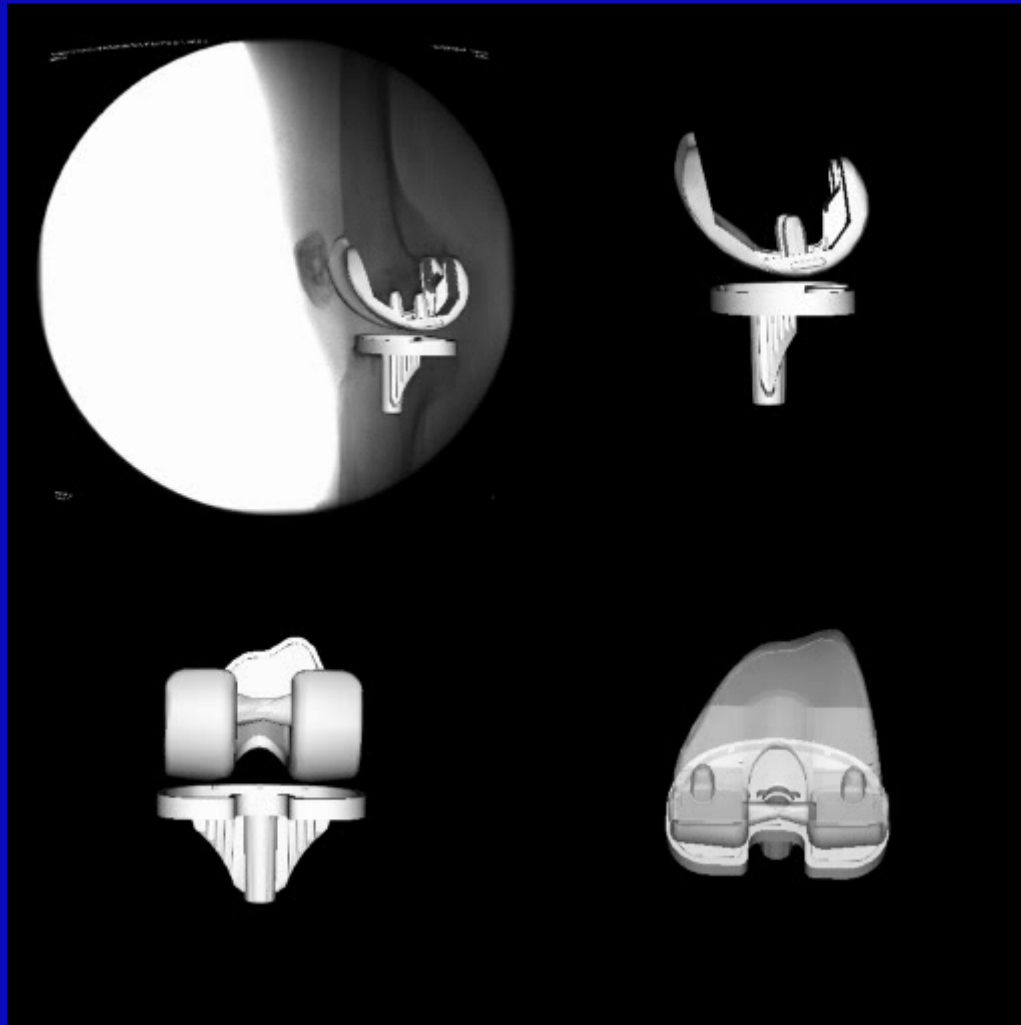


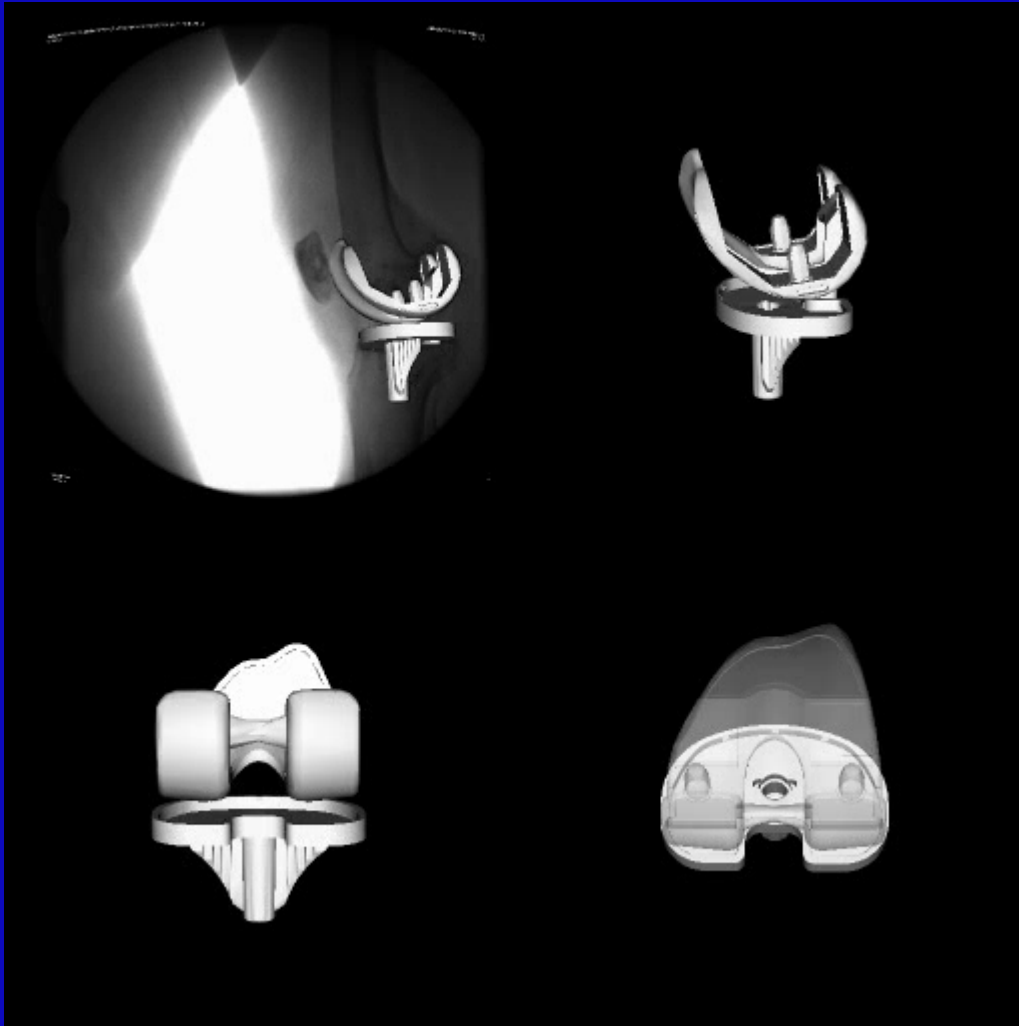
Proposed



椅子からの立ち上がり動作

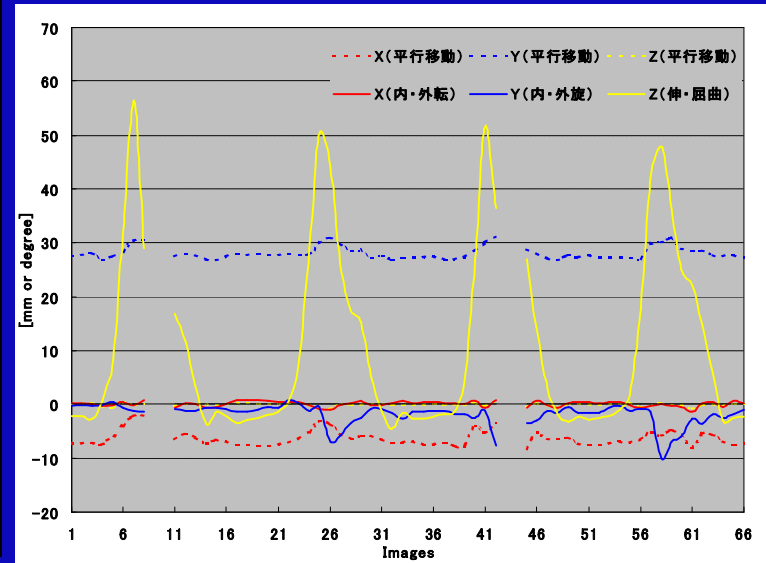
39 images

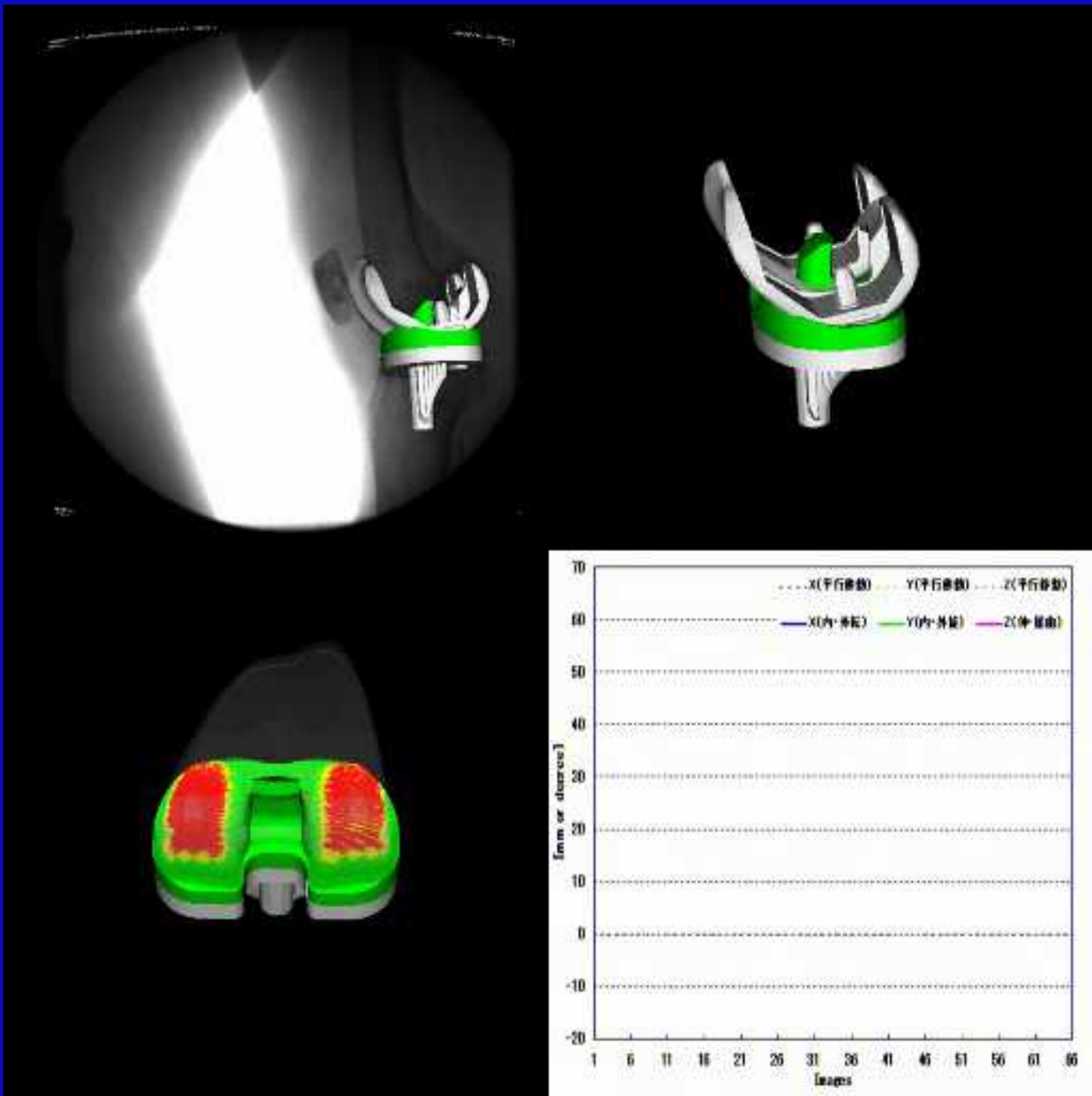




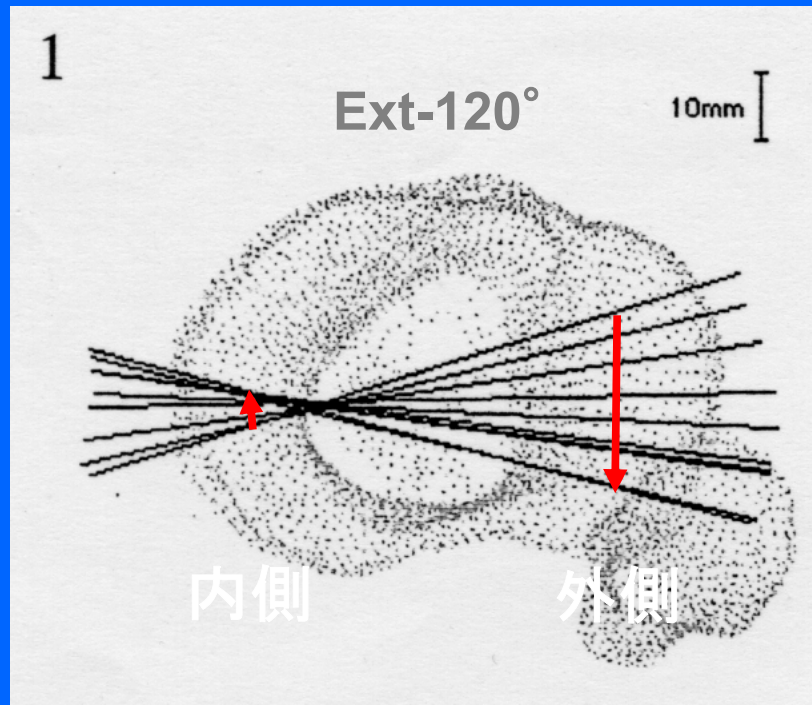
歩行動作

66 images
4 cycles

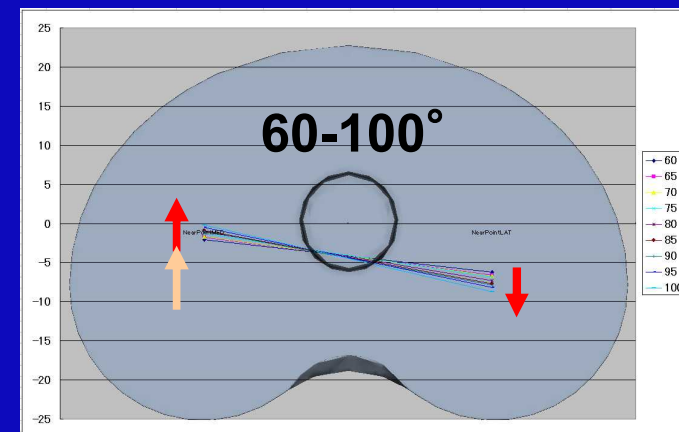
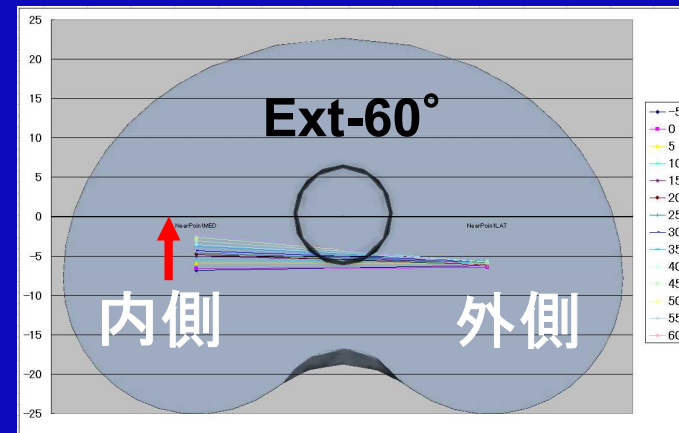




Axial kinematics pattern



Normal knee
(Asano et al: CORR 2001)

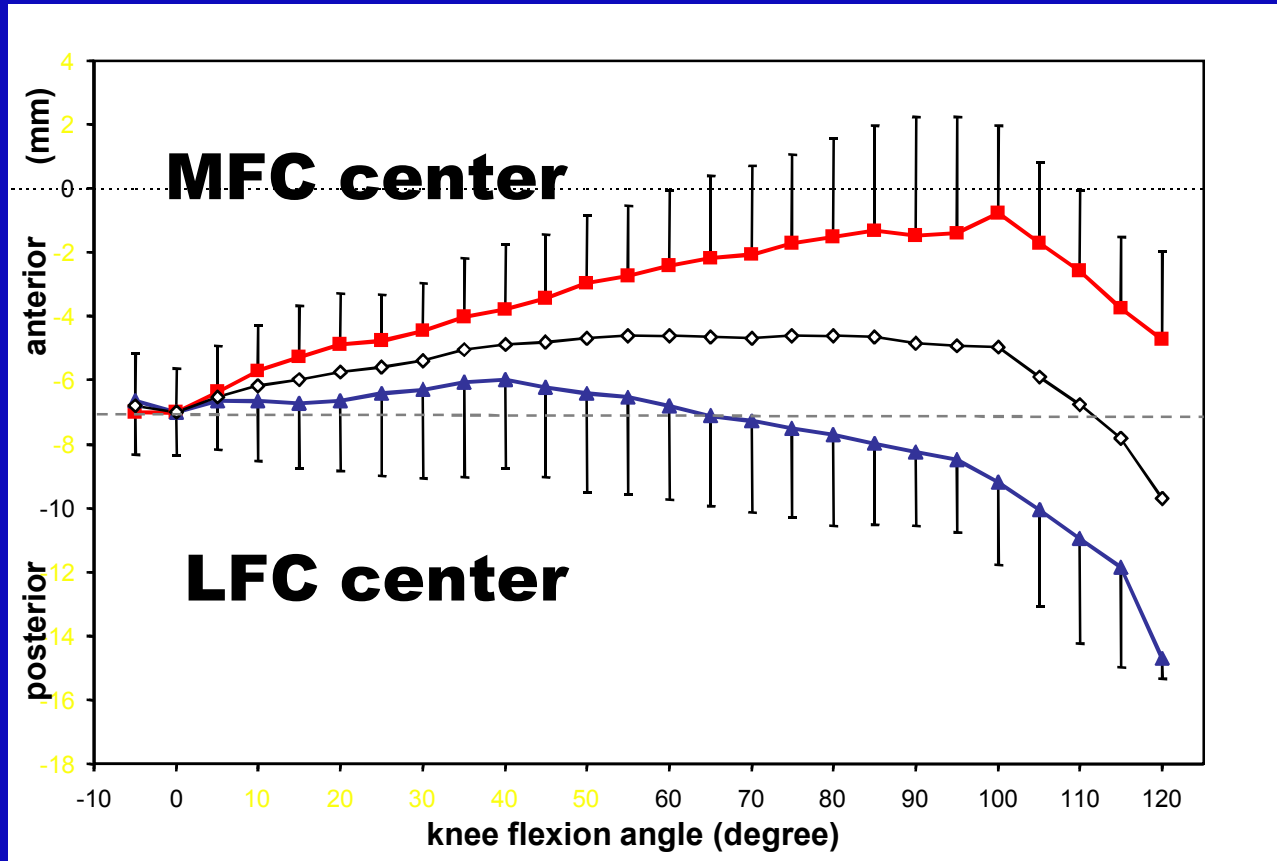


Current study
Kneeopus TKA

内外顆中心の前後移動

前方移動

後方移動

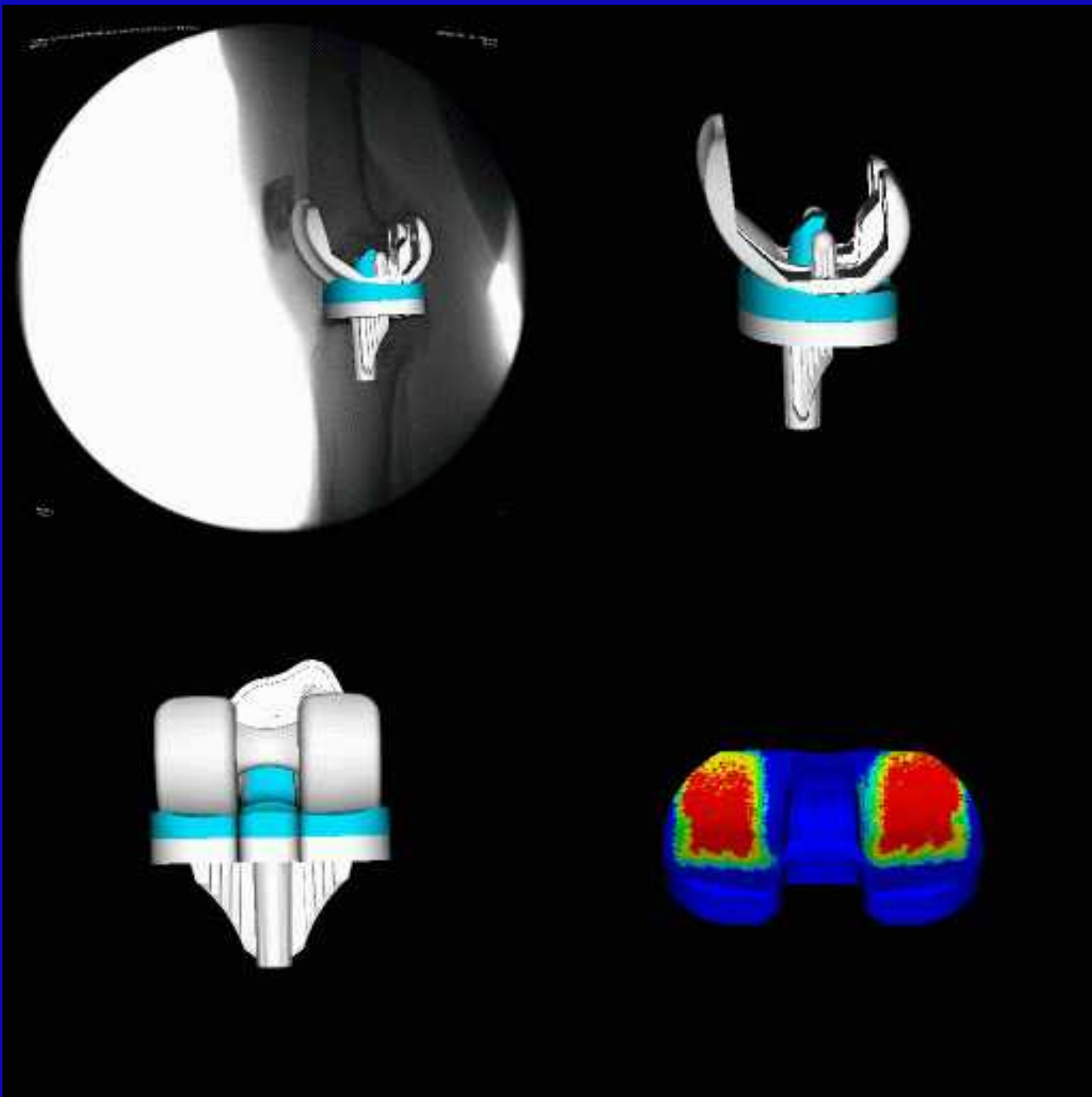


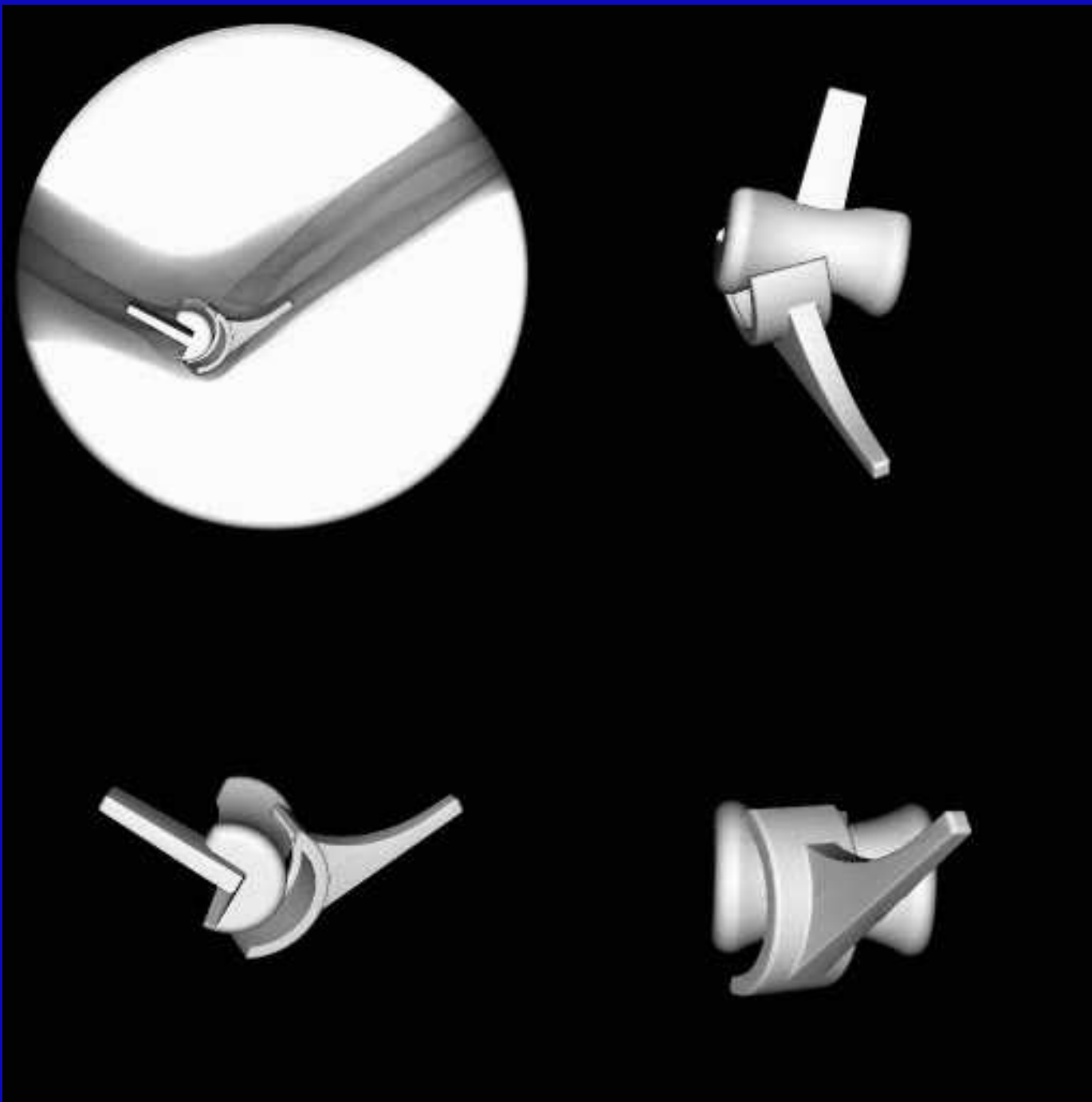
内顆中心

外顆中心

前方移動 : **6.2** (0-100° flex.) **1.0** (100-120° flex.)

後方移動 : **4.0** (0-40° flex.) **8.7** (40-120° flex.)





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