3D Printing in Orthopaedic Tumour Surgery

Trauma series II - 3Dprinting in Orthopaedics & Traumatology

27-28 February 2016

Orthopaedic Learning Center,

Prince of Wales Hospital, Hong Kong

From 3D Planning to Patient-Specific Surgery: A Paradigm Shift of Limb Salvage Operation in Orthopaedic Oncology

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Hong Kong

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- NO financial disclosure
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  - Stryker
  - BrainLAB
  - Materialise
  - Stanmore implants
  - Mobelife

Content

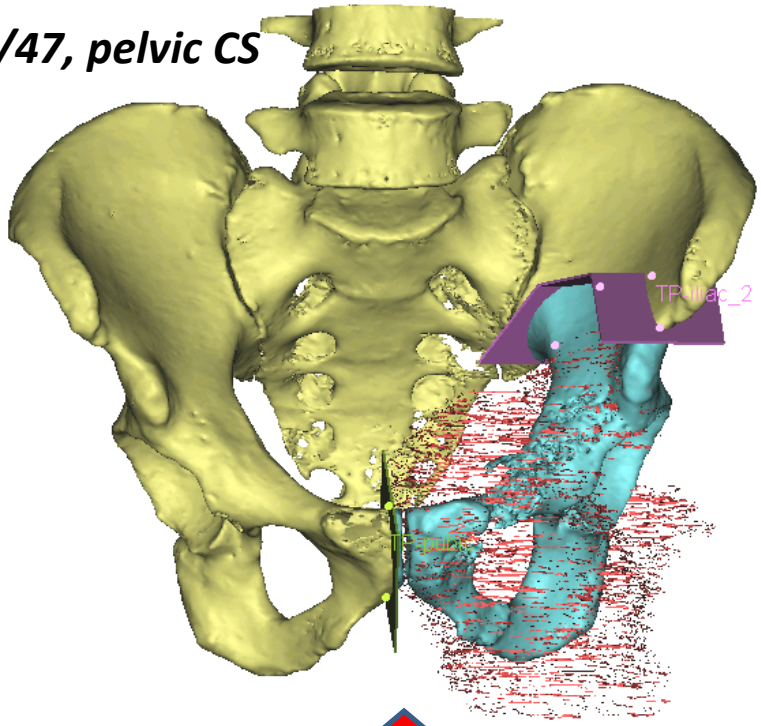
1. **Background (Computer Assisted Tumor Surgery : CATS)**
2. **3D planning**
3. **Execution of 3D planning**
4. **3D printing**
   - Tumor Patient Specific Instruments (PSI)
   - 3D printed implants
5. **Summary**

Talk and information based on the listed publications

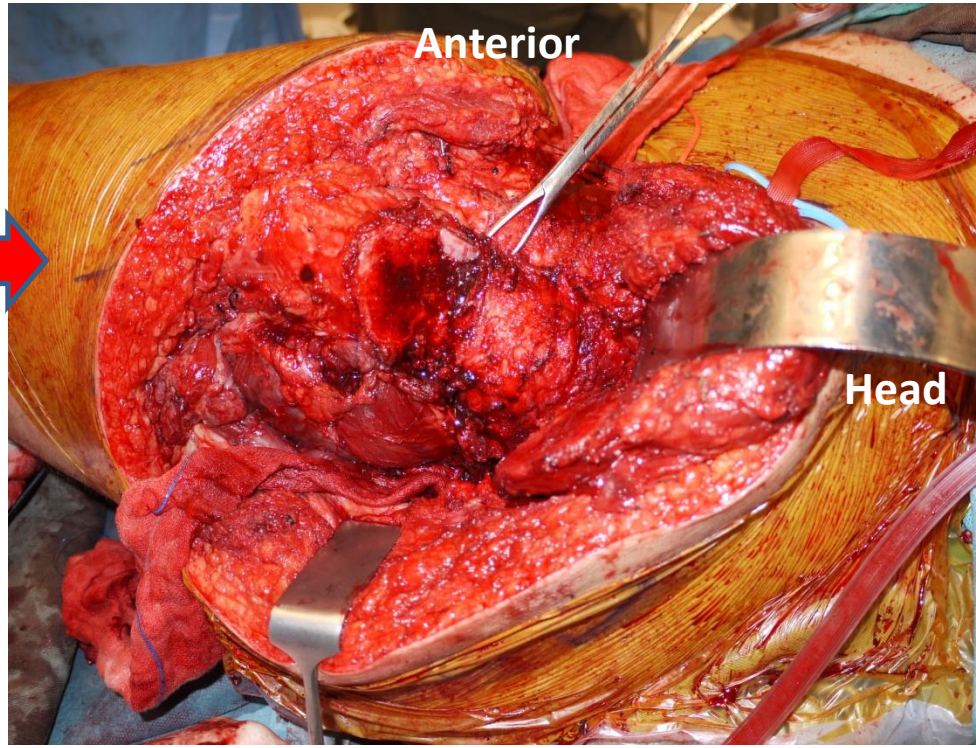
1. ***Wong KC***, Kumta SM, Chiu KH, Cheung KW, Leung KS, Unwin P, Wong MC. Computer assisted pelvic tumor resection and reconstruction with a custom-made prosthesis using an innovative adaptation and its validation. Comput Aided Surg. 2007 Jul;12(4):225-32
2. ***Wong KC,*** Kumta SM, Chiu KH, Antonio GE, Unwin P, Leung KS. Precision tumour resection and reconstruction using image-guided computer navigation. J Bone Joint Surg Br. 2007 Jul; 89(7): 943-7.(+ online video case illustration)
3. ***Wong KC,*** Kumta SM, Antonio GE, Tse LF. Image fusion for computer-assisted bone tumor surgery. Clin Orthop Relat Res. 2008 Oct; 466(10): 2533-41. Epub 2008 Jul 22. (+ suppl online material)
4. ***Wong KC,*** Kumta SM, Leung KS, Ng KW, Ng Eric, Lee KS. Integration of CAD/CAM planning into computer assisted orthopaedic surgery. Comput Aided Surg. 2010;15(4-6):65-74. Epub 2010 Sep 20.
5. ***Wong KC***, Kumta SM, Sze KY, Wong CM. Use of a patient-specific CAD/CAM surgical jig in extremity bone tumor resection and custom prosthetic reconstruction. Comput Aided Surg. 2012; 17(6):284-93.
6. ***Wong KC***, Kumta SM. Computer-assisted tumor surgery in malignant bone tumors. Clin Orthop Relat Res. 2013 Mar; 471(3):750-61.
7. ***Wong KC***, Kumta SM. Joint-preserving tumor resection and reconstruction using image-guided computer navigation. Clin Orthop Relat Res. 2013 Mar; 471(3):762-73. (+ suppl online material)
8. ***Wong KC***, Kumta SM. Use of computer navigation in orthopaedic oncology. Curr Surg Rep. 2014 Feb 22;2:47. eCollection 2014. Review
9. ***Wong KC***, Sze KY, Wong IO, Wong CM, Kumta SM. Patient-specific instrument can achieve same accuracy with less resection time than navigation assistance in periacetabular pelvic tumor surgery: a cadaveric study. Int J Comput Assist Radiol Surg. 2015 Jul 7.
10. ***Wong KC***, Kumta SM, Geel NV, Demol J. One-step reconstruction with a 3D-printed, biomechanically evaluated custom implant after complex pelvic tumor resection. Comput Aided Surg. 2015 Aug 20:1-10.

Mental planning

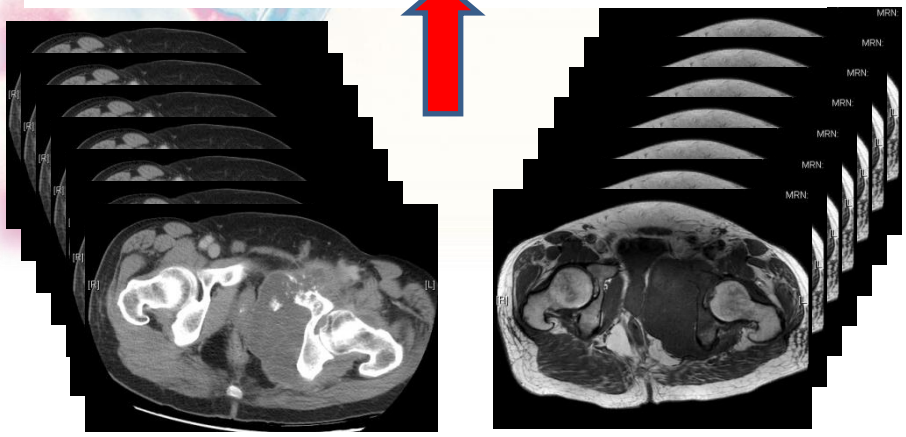
M/47, pelvic CS



? Translate planned resection at OR (Pelvis / Sacrum)



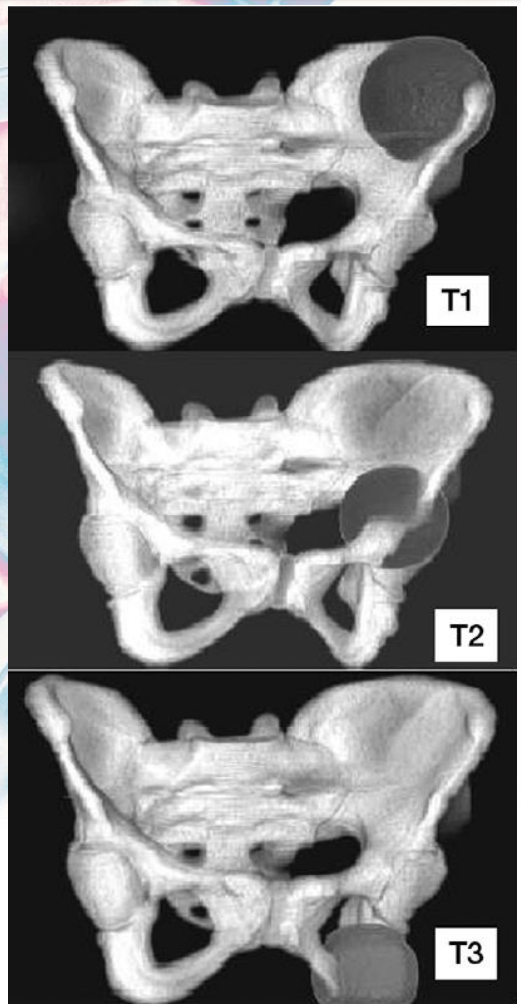
Lateral view



CT images

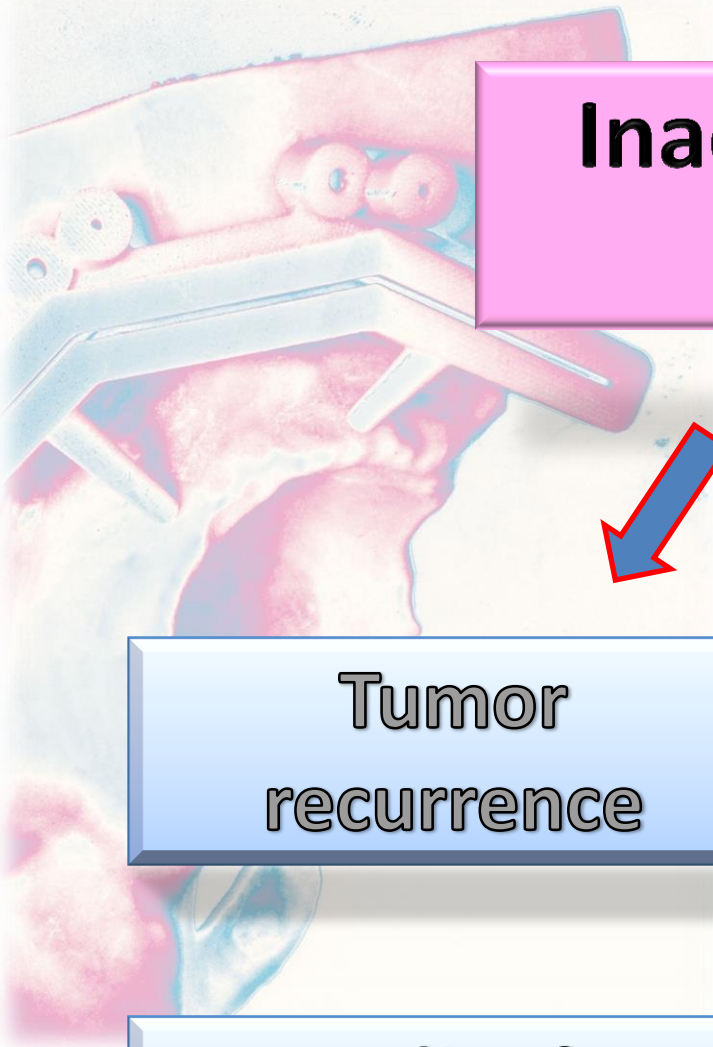
MR images

Surgical inaccuracy in pelvic resection



- The **probability** of an experienced surgeon obtaining a 10-mm surgical margin with a 5-mm tolerance above or below was **only 52 %** (95 % CI 37–67).
- Also, the degree of host-graft contact for reconstruction was found to be poor.

Cartiaux O et al. Surgical inaccuracy of tumor resection and reconstruction within the pelvis: an experimental study. Acta Orthop. 2008 Oct;79(5):695-702



Inaccurate tumor resection

Tumor recurrence

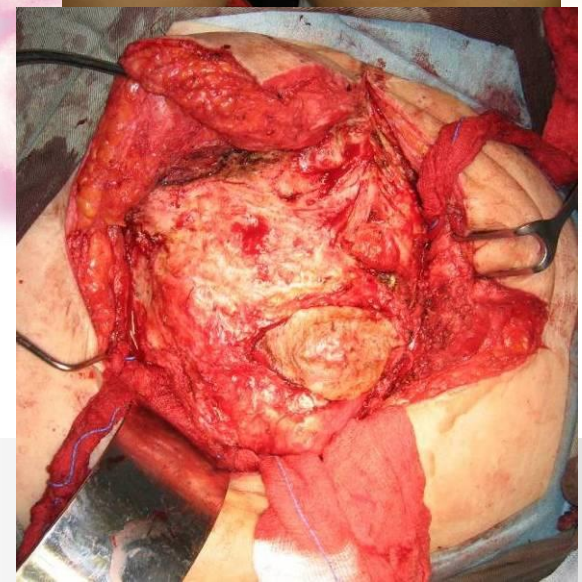
Mortality from disease

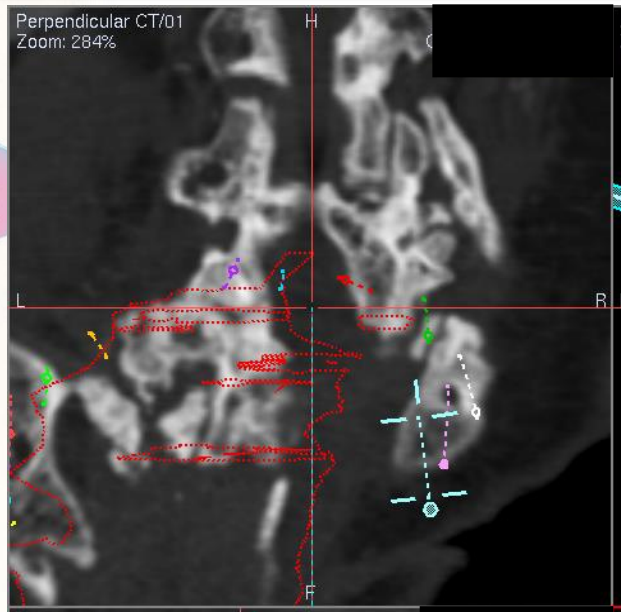
Poor fitting to bone reconstruction

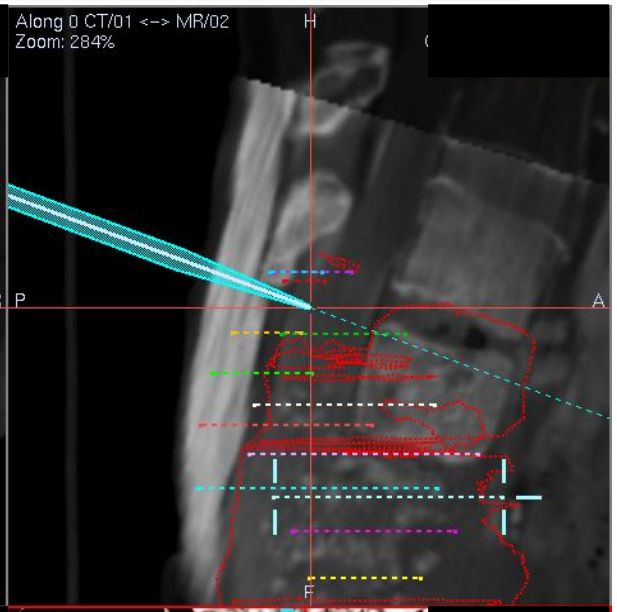
Poor function

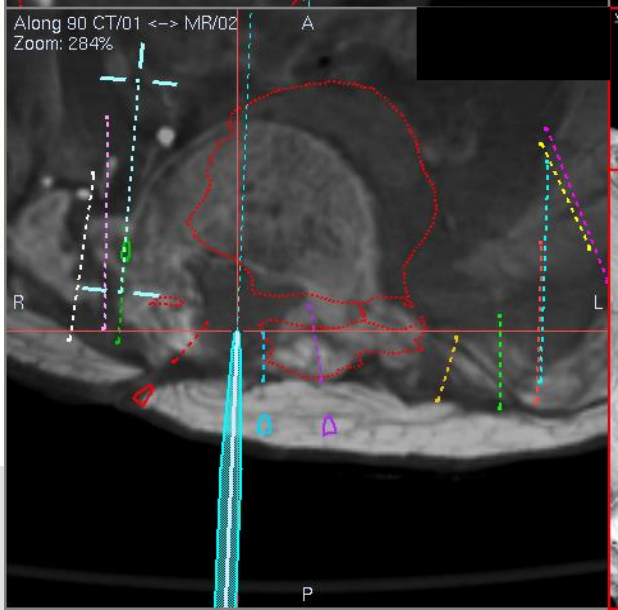
Recurrent tumor with distorted anatomy

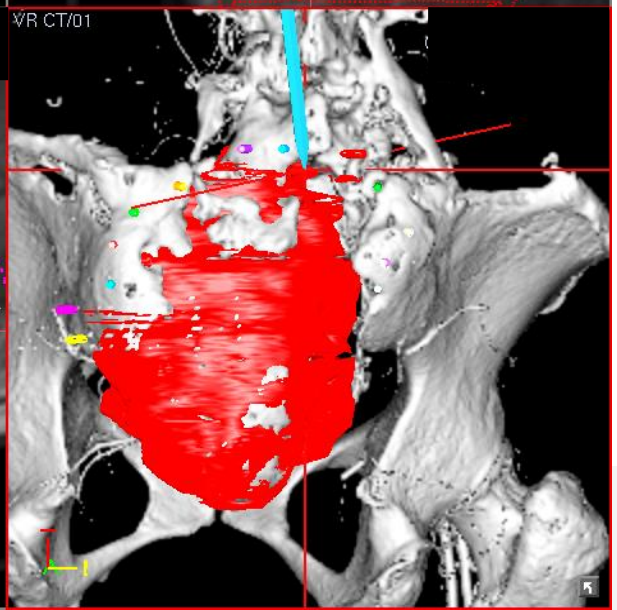
(intralesional resection & sacrifice vital structures)



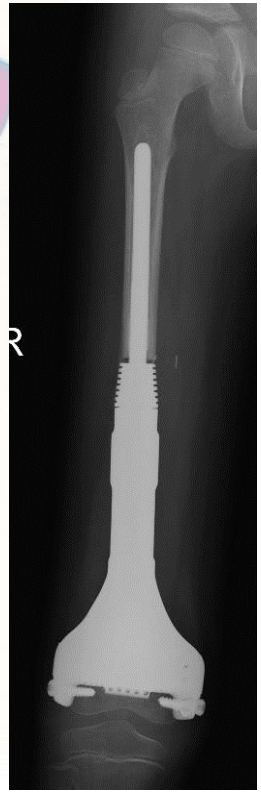




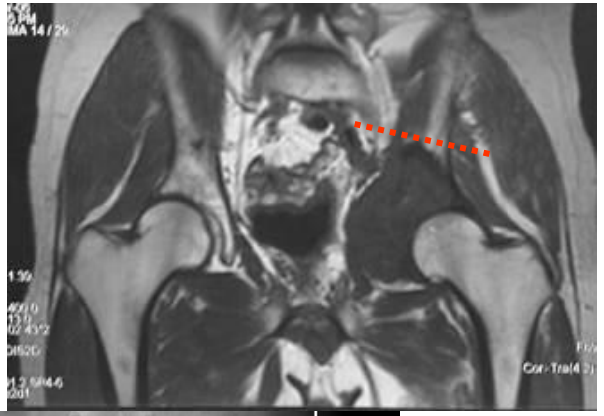


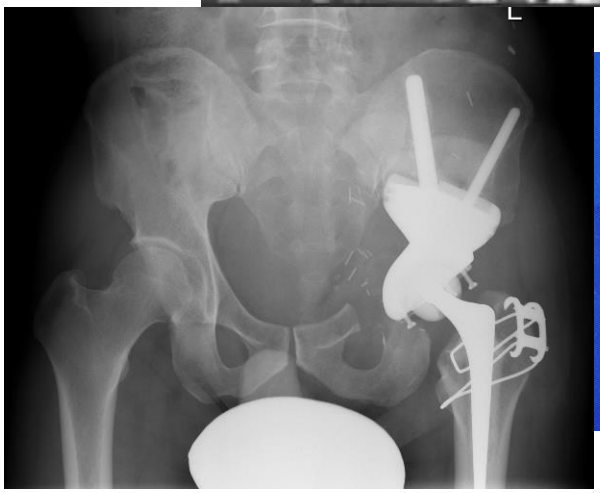


Sacrifice normal tissues (joints)
Two-staged operations; NO custom implants



Joint saving resection





Pelvic resection

Planned = ***Achieved***

Preoperative planning

? ?

Surgeon experience

Intraoperative execution

CAS: Navigation ?
PSI ?

CAOS-int 2008: Best Clinical Paper Award

Computer Assisted Tumor Surgery (CATS)

Preoperative planning

Image fusion

CAD prosthesis data

Allograft

3D Bone Tumor planning model

Resection / Reconstruction Planning

Intraoperative execution

Image-to-patient registration

Implement planning (navigated tools)

Postoperative validation

Achieved versus planned resection (CT images of patients / resected specimens)

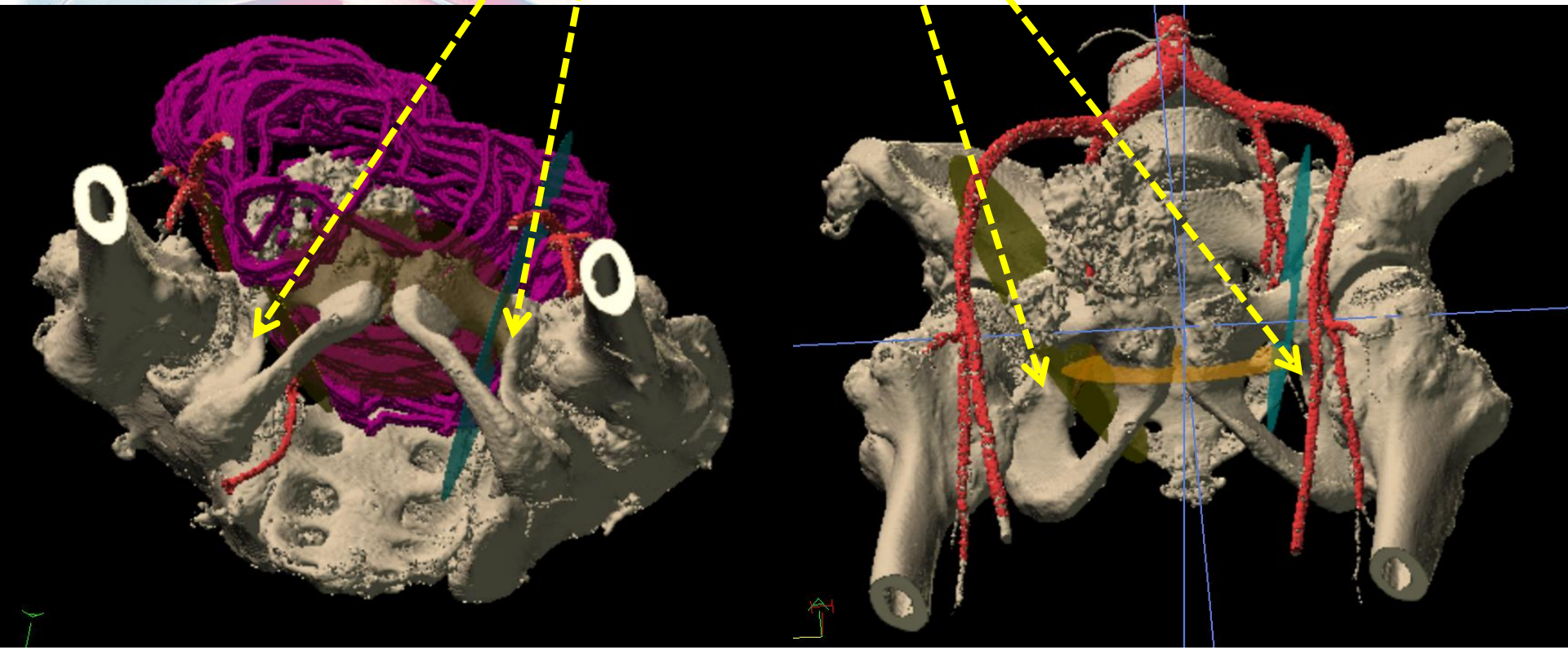
Wong KC, Kumta SM. Use of computer navigation in orthopaedic oncology. Curr Surg Rep. 2014 Feb 22;2:47. eCollection 2014. Review

1. 3D planning & execution

Pelvic tumor resection

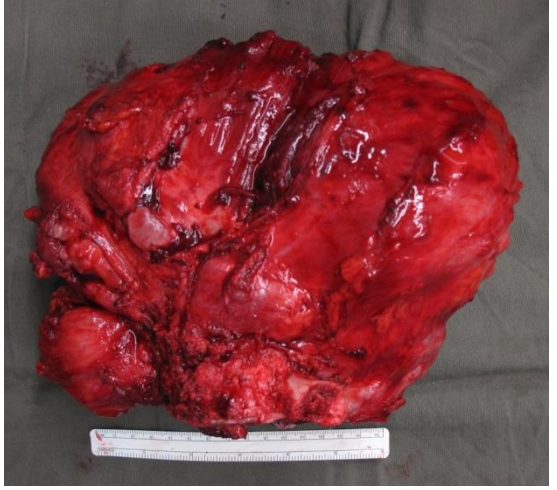
- ***Cho HS, et al.*** The outcomes of navigation assisted bone tumour surgery: minimum three-year follow-up. JBJS (Br) 2012;94(10):1414–20.
- ***Wong KC***, Kumta SM. Computer-assisted tumor surgery in malignant bone tumors. CORR 2013; 471(3):750–61.
- ***Jeys L, et al.*** Can computer navigation-assisted surgery reduce the risk of an intralesional margin and reduce the rate of local recurrence in patients with a tumour of the pelvis or sacrum? Bone Joint J. 2013;95- B(10):1417–24.
- ***Jasper G Gerbers, et al.*** Computer-assisted surgery in orthopedic oncology: Technique, indications, and a descriptive study of 130 cases. Acta Orthopaedica 2014; 85 (6)

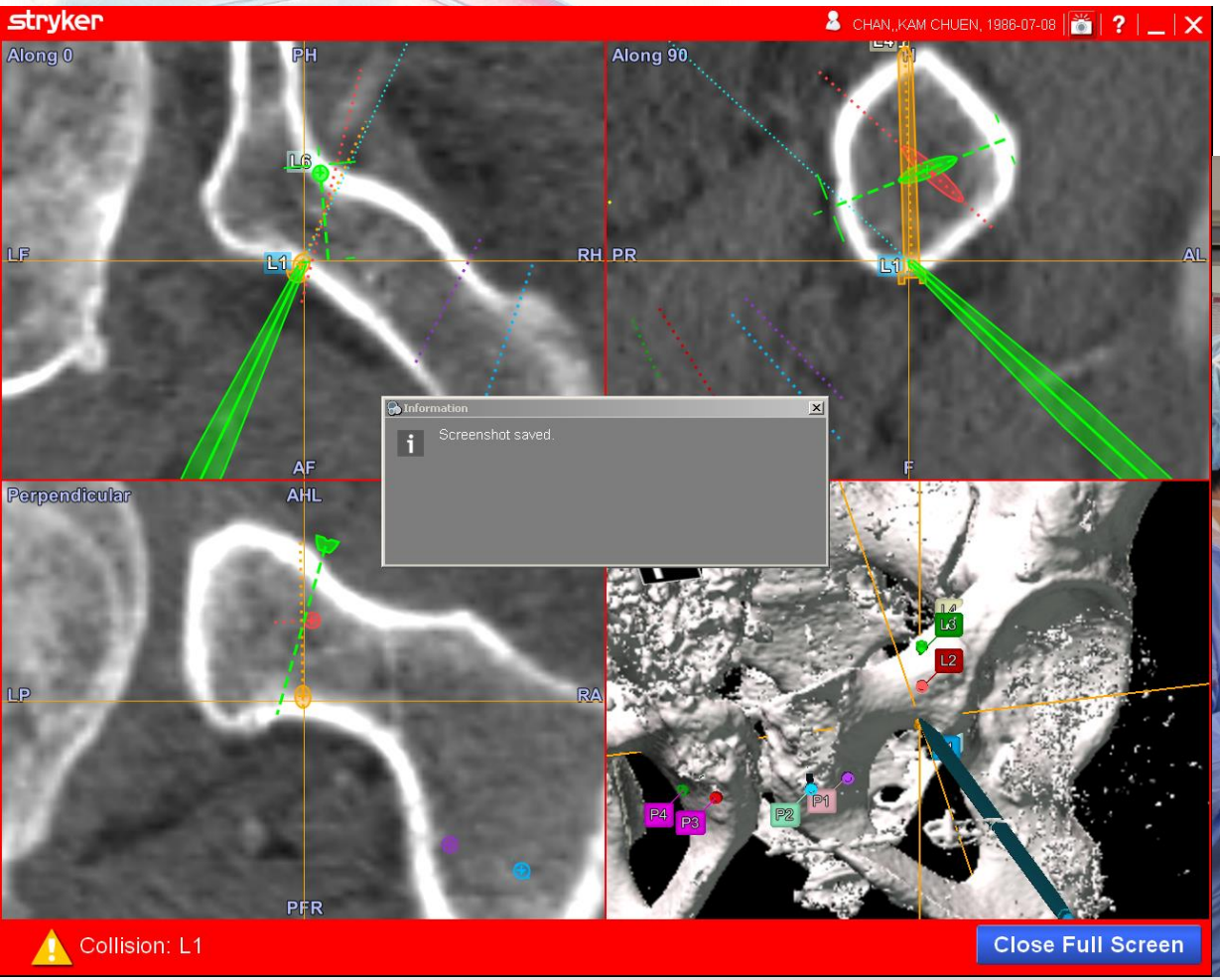
Pubic rami resection preserve hip joints

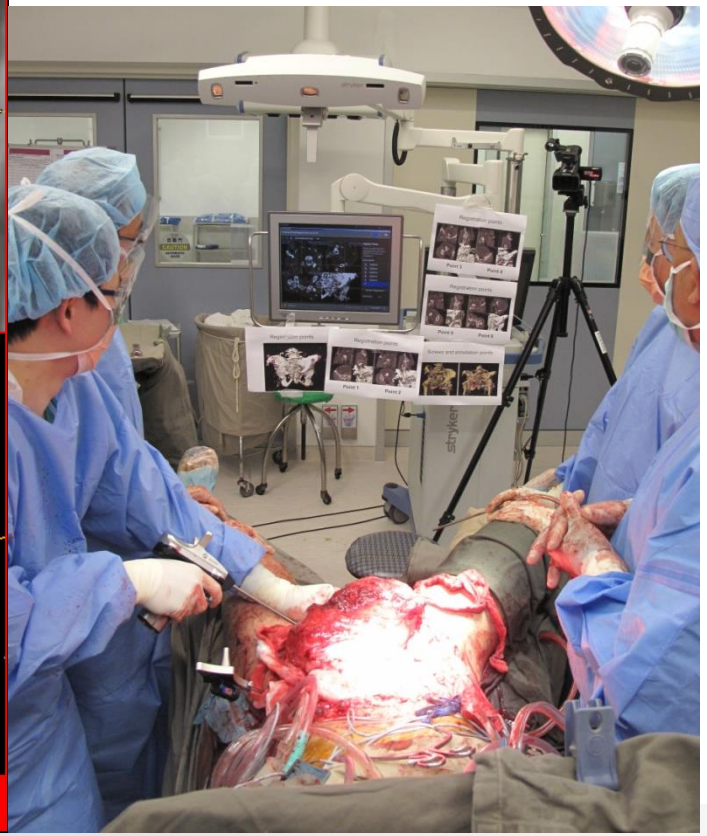


OrthoMap 3D, Stryker Navigation

Navigation guided







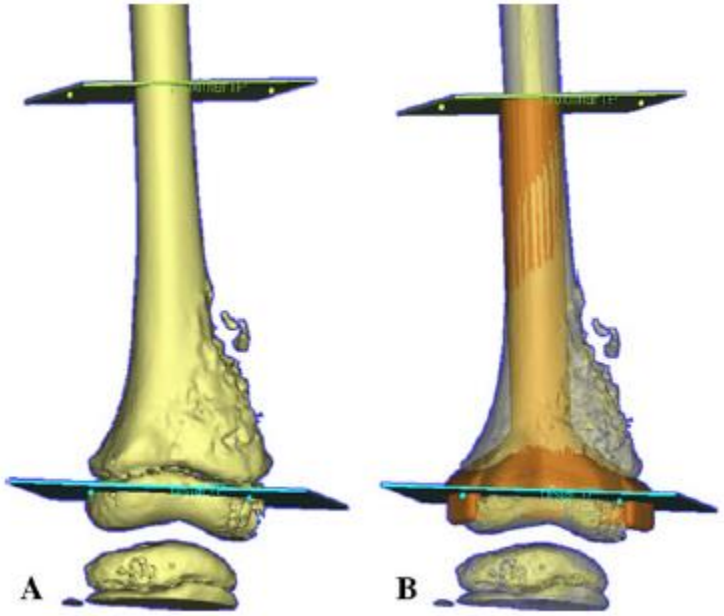
2. Execution of 3D planning

Joint-preserving / multiplanar tumor resection

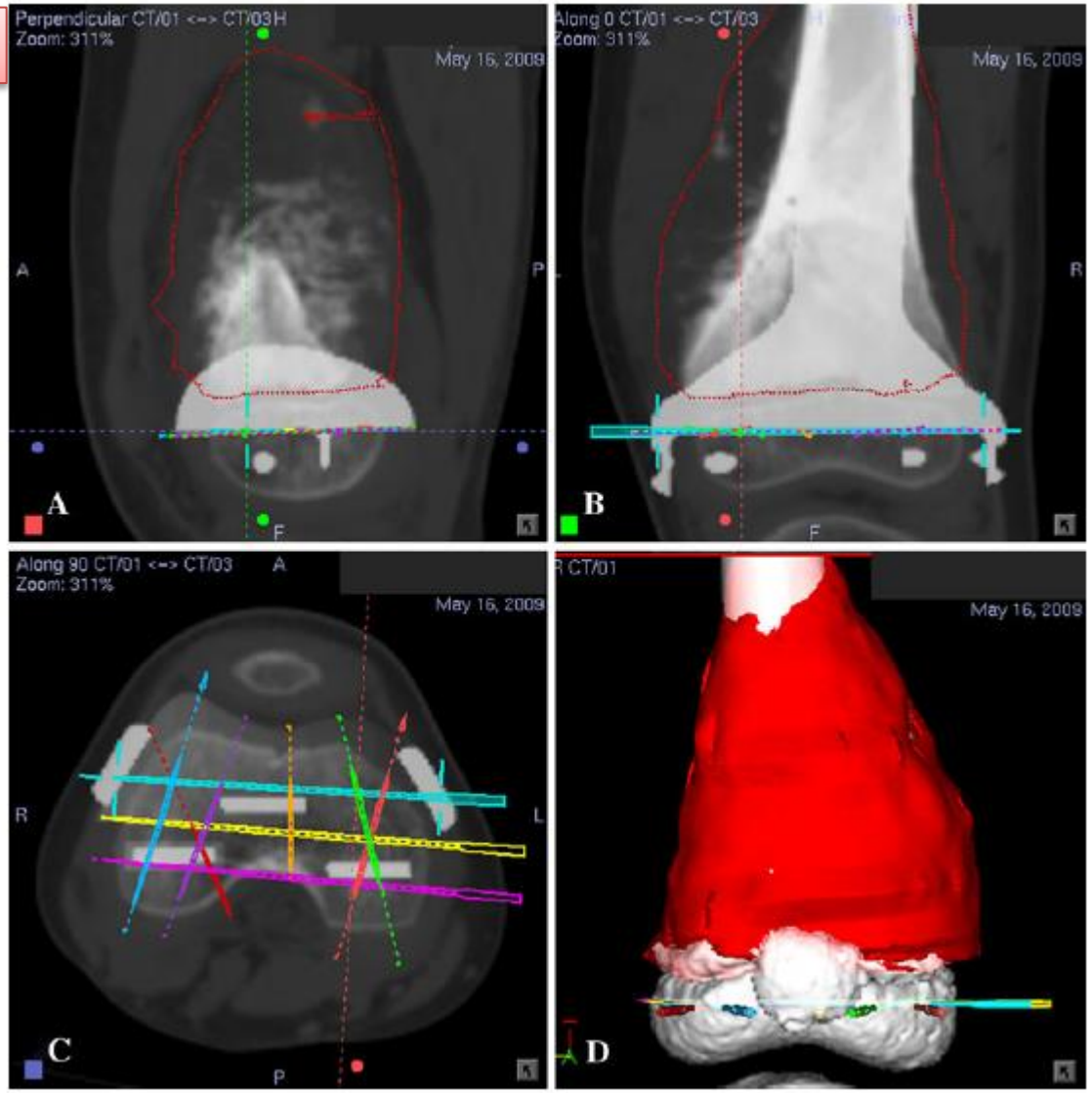
- ***Wong KC et al.*** Integration of CAD/CAM planning into computer assisted orthopaedic surgery. Comput Aided Surg. 2010;15(4-6):65-74.
- ***Wong KC***, Kumta SM. Joint-preserving tumor resection and reconstruction using image-guided computer navigation. Clin Orthop Relat Res. 2013 Mar; 471(3):762-73. (+ suppl online material)
- ***Aponte-Tinao LA et al***. Multiplanar osteotomies guided by navigation in chondrosarcoma of the knee. Orthopedics. 2013;36(3):e325–30.

Virtual CAD planning ⟺ Execution

M/6, right distal femur osteosarcoma

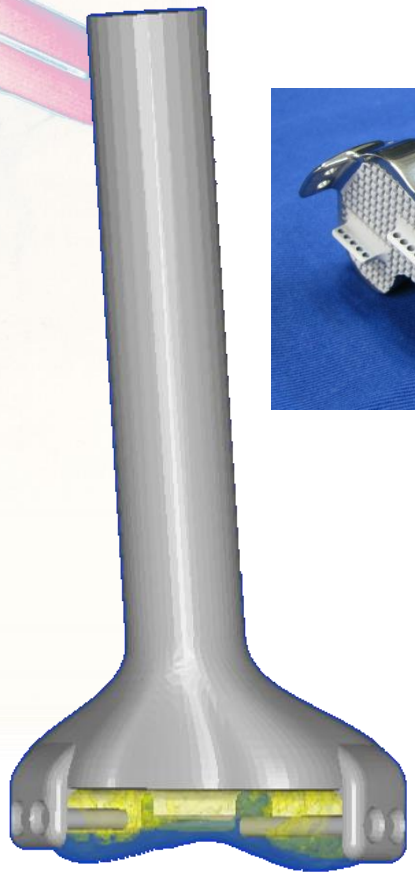


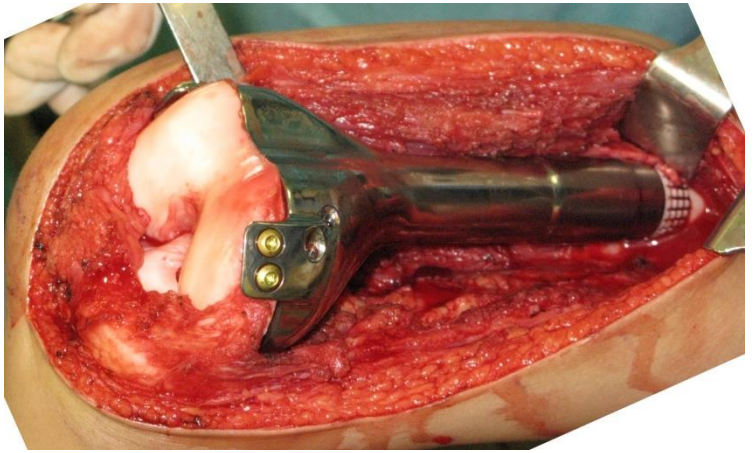
Mimics

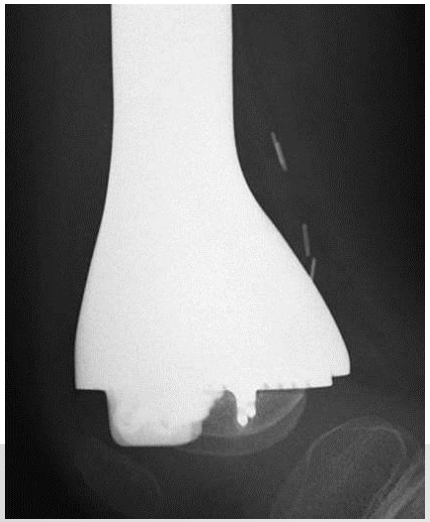


Reference:
Wong KC, Kumta SM et al. Integration of CAD/CAM planning into computer assisted orthopaedic surgery. Comput Aided Surg. 2010;15(4-6):65-74. Epub 2010 Sep 20.

Navi: Precise custom-fit prosthesis

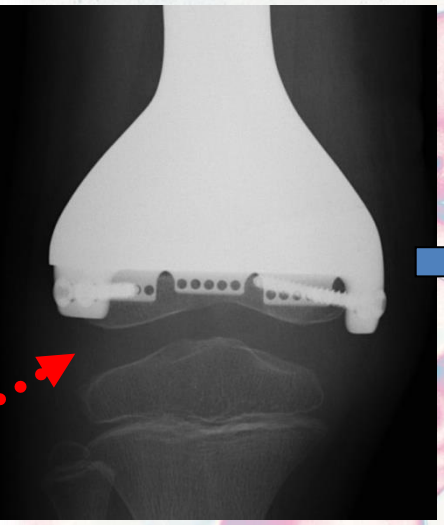




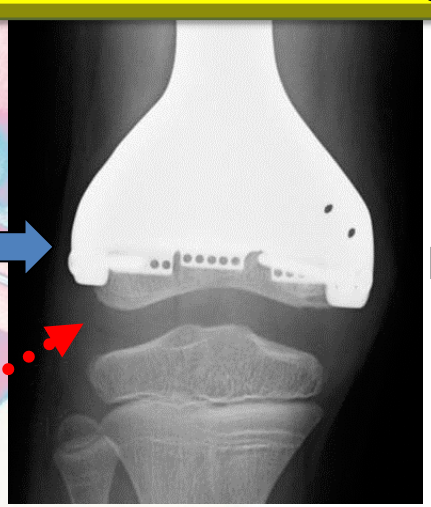


4 weeks

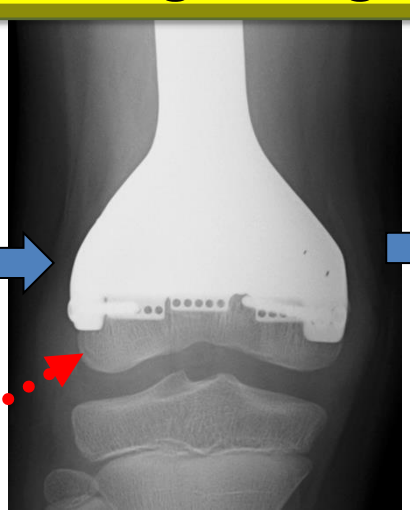
The remaining joint is growing!



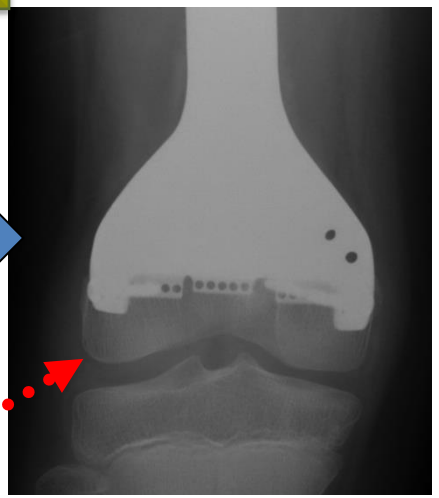
1 Mo: age 6



1 year



3 years



6 years: age 12

Viable joint

Safe tumor resection
? Better oncological / functional results

Cho HS, et al. The outcomes of navigation assisted bone tumour surgery: minimum three-year follow-up. JBJS (Br) 2012;94(10):1414–20.

Wong KC, Kumta SM. Computer-assisted tumor surgery in malignant bone tumors. CORR 2013; 471(3):750–61.

- **Safe procedure and improve accuracy of bone resection**

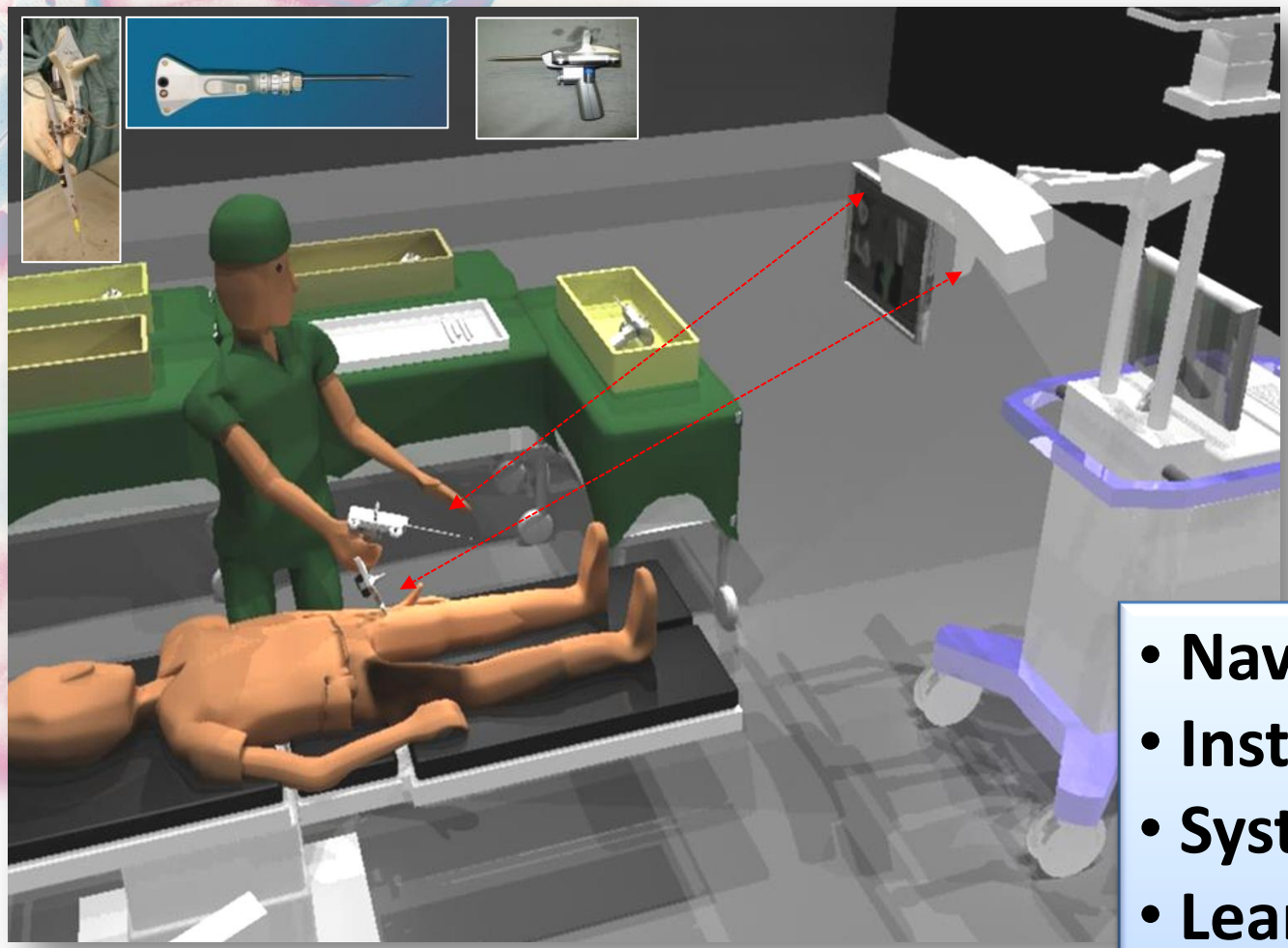
Jeys L, et al. Can computer navigation-assisted surgery reduce the risk of an intralesional margin and reduce the rate of local recurrence in patients with a tumour of the pelvis or sacrum? Bone Joint J. 2013;95- B(10):1417–24.

- **↓ intralesional resection from 29% to 8.7%**

Aponte-Tinao L, et al. Does Intraoperative Navigation Assistance Improve Bone Tumor Resection and Allograft Reconstruction Results? CORR 2014 Apr 8.

- **↓ allograft nonunion to 6%**

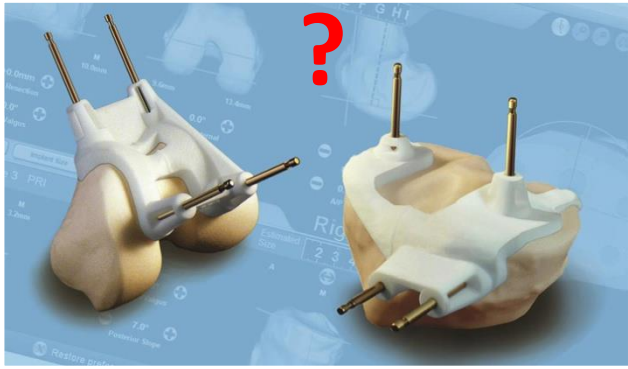
CATS: Navigation guidance (limitations)

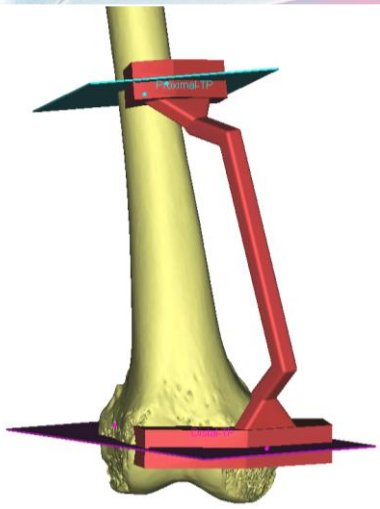


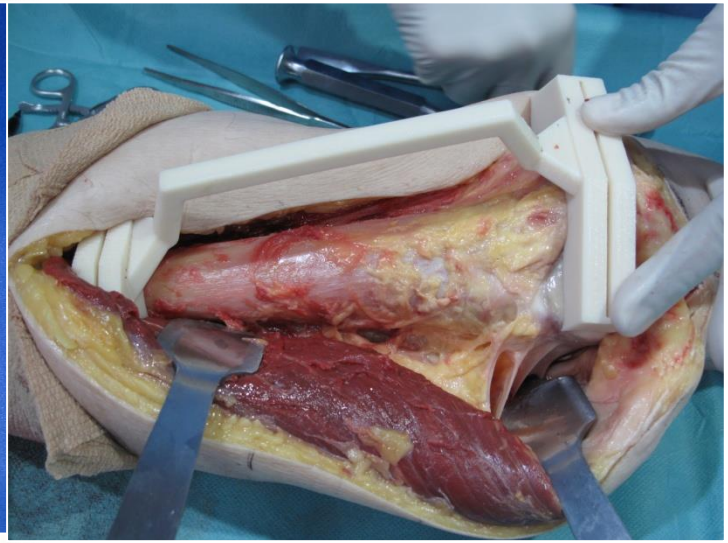
2011

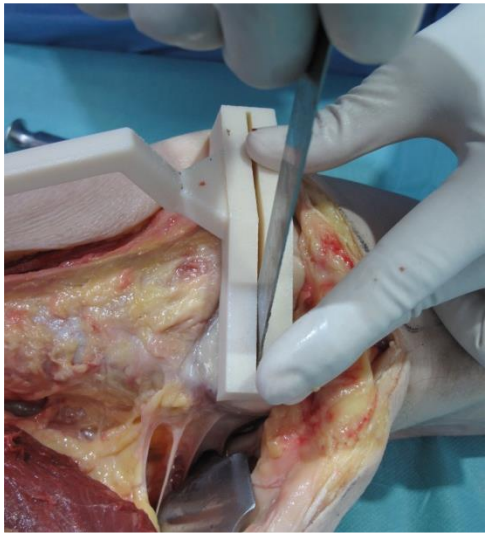
- Navigation facilities
- Instruments
- System operator
- Learning curve
- ? ↑ operating time
- ……

4. 3D-printed Tumor Patient-Specific Instruments (Tumor PSI)









Computer Aided Surgery, November 2012; 17(6): 284–293

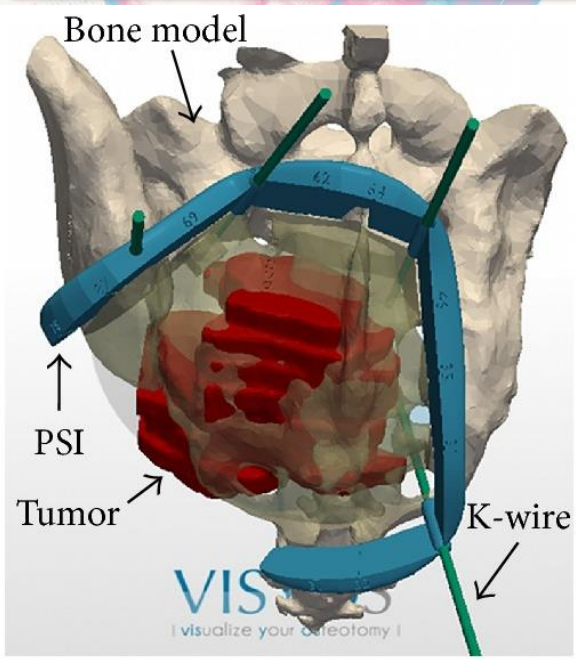
informa
healthcare

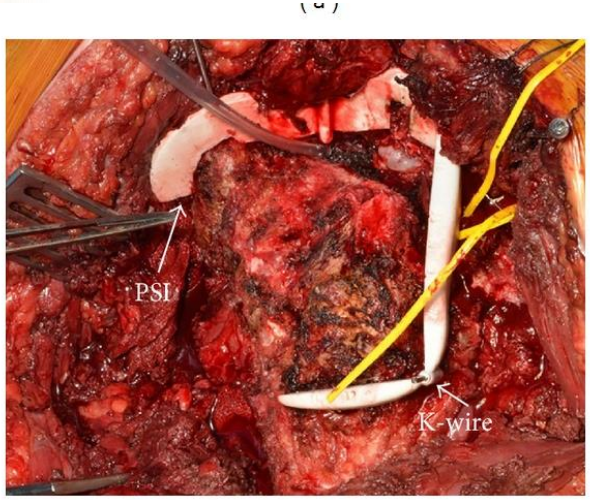
Use of a patient-specific CAD/CAM surgical jig in extremity bone tumor resection and custom prosthetic reconstruction

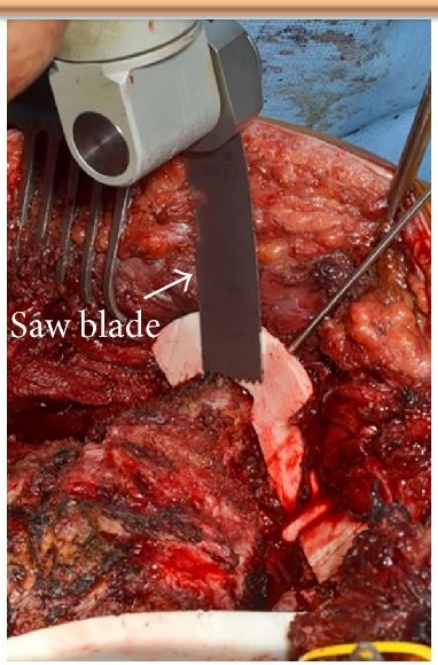
Proof of concept!

K.C. WONG[1], S.M. KUMTA[1], K.Y. SZE[2], & C.M. WONG[3]

Gouin F et al. Computer-Assisted Planning and Patient-Specific Instruments for Bone Tumor Resection within the Pelvis: A Series of 11 Patients. Sarcoma 2014; 2014:842709



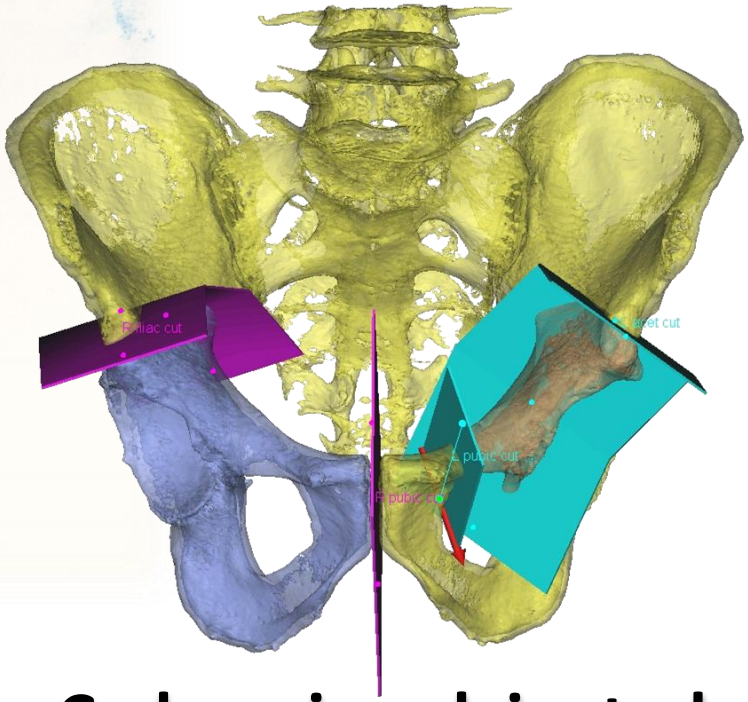


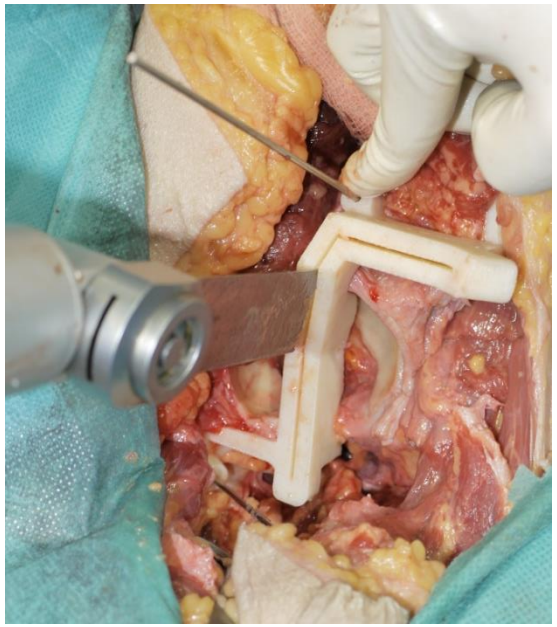


- **The location accuracy averaged 2.5 mm**.
- Errors in safe margin averaged -0.8 mm.
  - ***One intralesional: 9%***
- May improve bone tumor surgery within the pelvis by providing good cutting accuracy and clinically acceptable margins.

PSI: Similar accuracy but shorter resection time

Navigation **vs** **PSI**





Cadaveric pelvic study

Wong KC, Sze KY, Wong IO, Wong CM, Kumta SM. Patient-specific instrument can achieve same accuracy with less resection time than navigation assistance in periacetabular pelvic tumor surgery: a cadaveric study. Int J Comput Assist Radiol Surg. 2015 Jul 7.

3D printing (3rd industrial revolution)

mandible

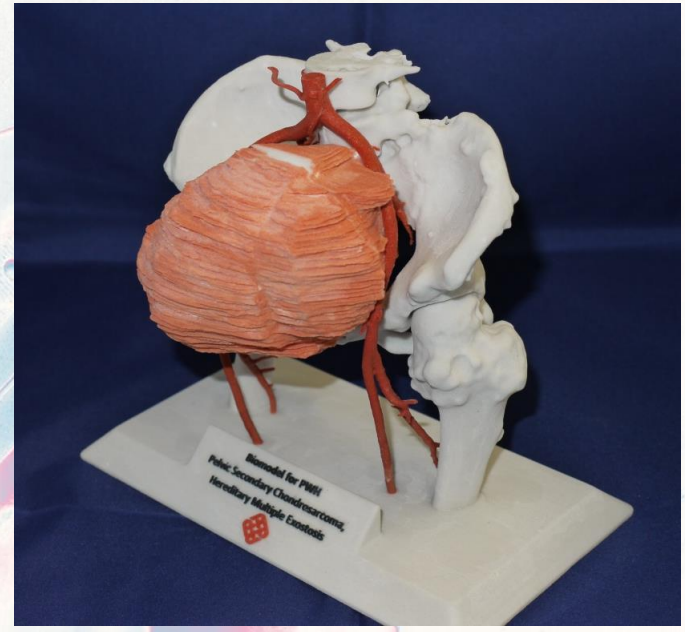
Trachea

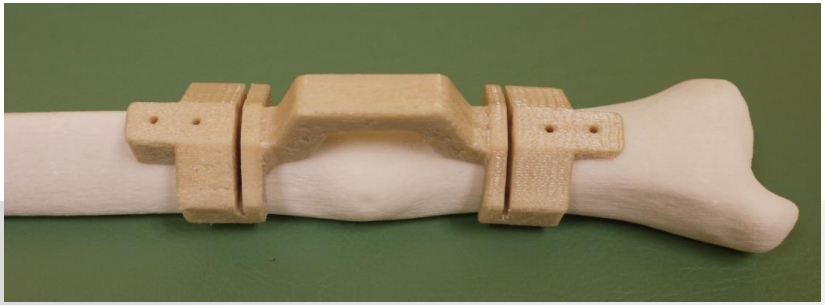
Cast

Orthosis

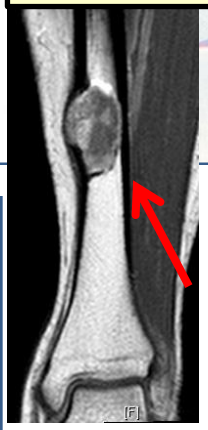
Ortho implant

3D-printed surgical models / guides

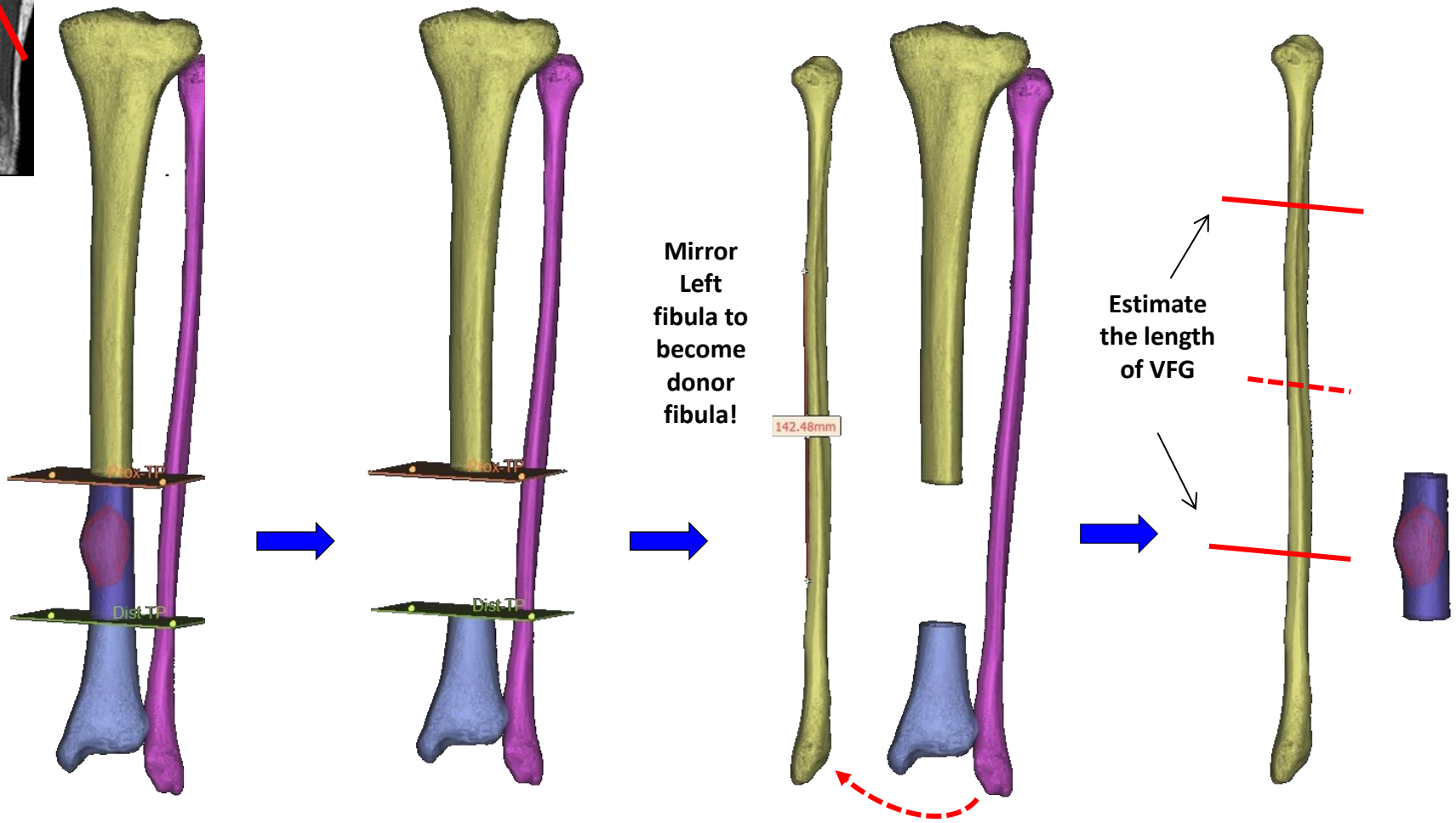




F/25, low grade OS

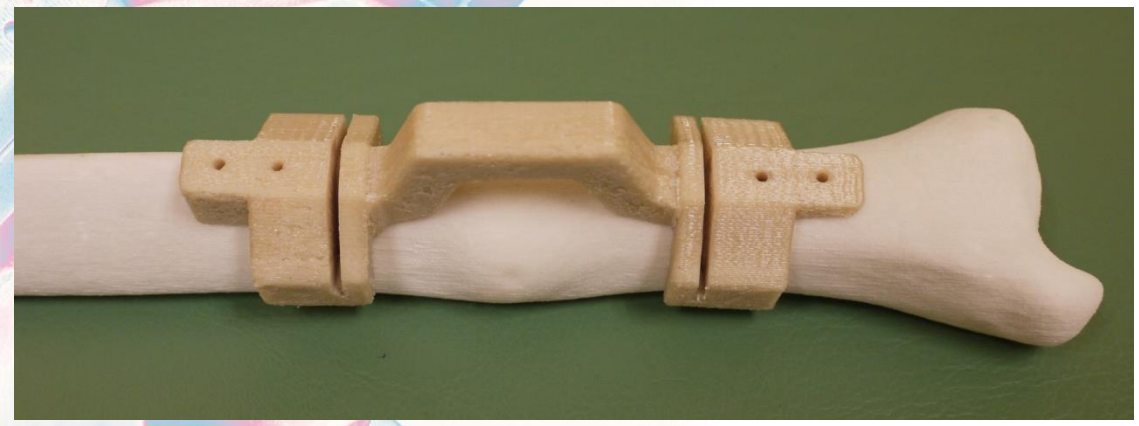


Virtual resection in Mimics

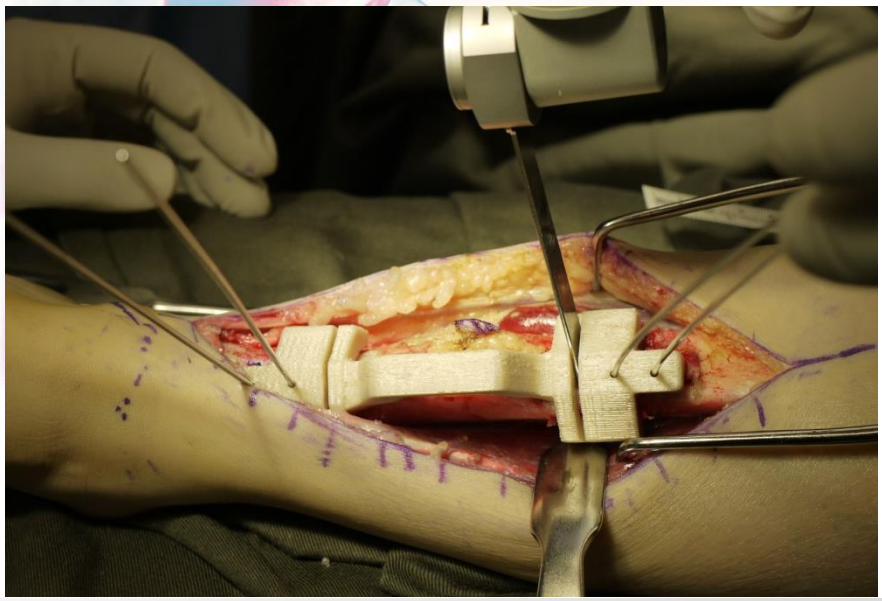


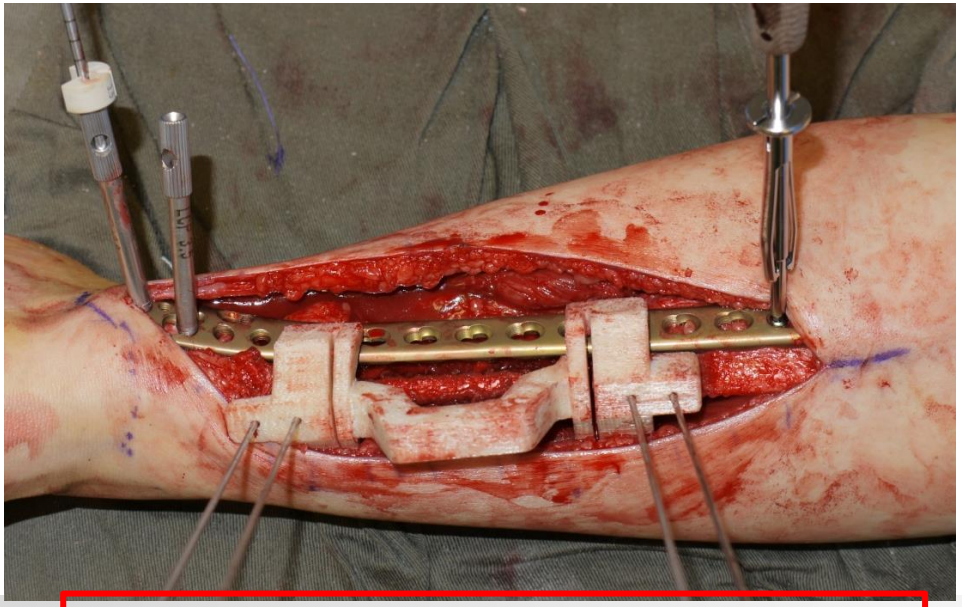
Double-barrel vascularized fibula graft

Guided resection, bone length & alignment!



Guide based on surgeons-defined bone resection!

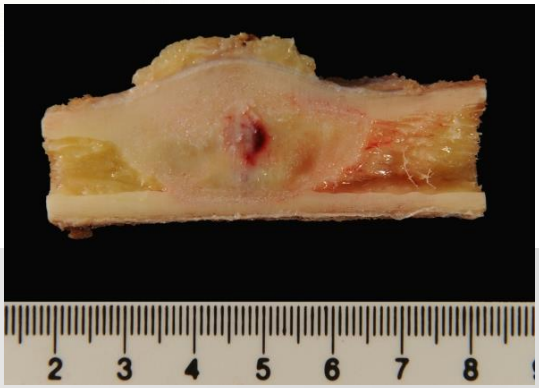




Guided bone resection in few minutes!

Guided bone length & alignment prior to plate fixation !

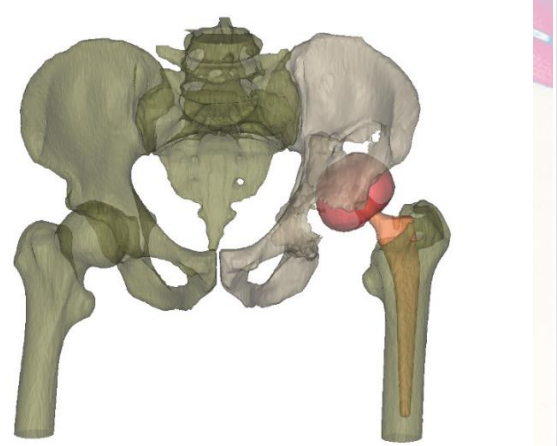
Resection within 2mm error from planned!

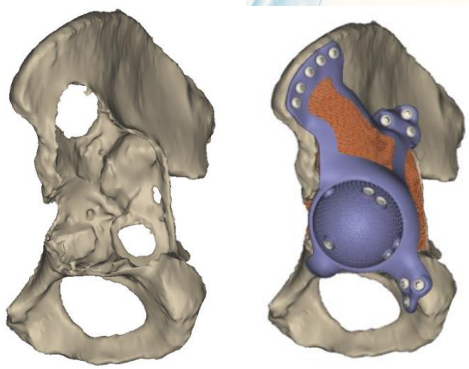


3 years

3D printing for Massive pelvic bone defects

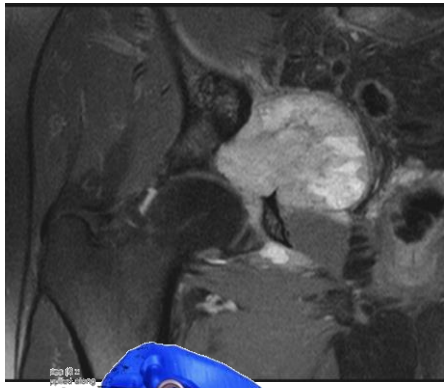
Revision THA

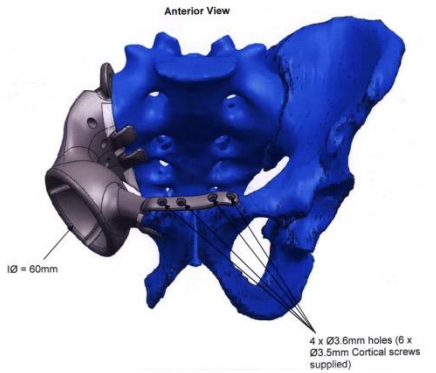


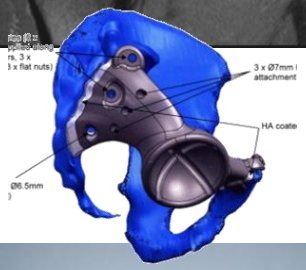


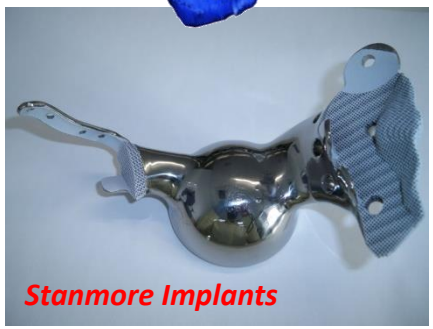
Dr. Slåstad, the Rikshospitalet Oslo, Norway (2013) (http://www.mobelife.be/clinical-cases/case/detail/detail/18)

Pelvic tumor resection





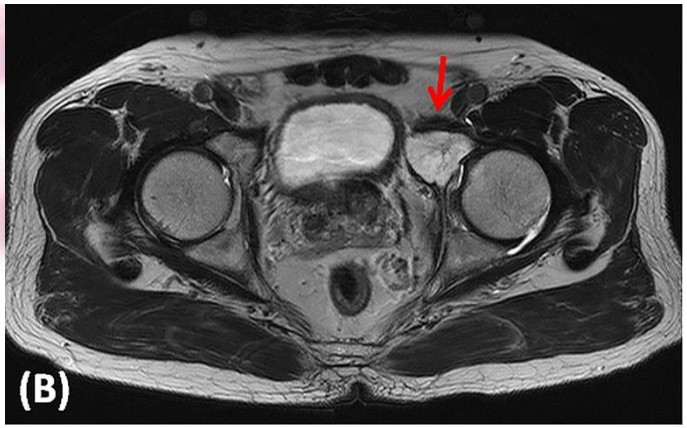


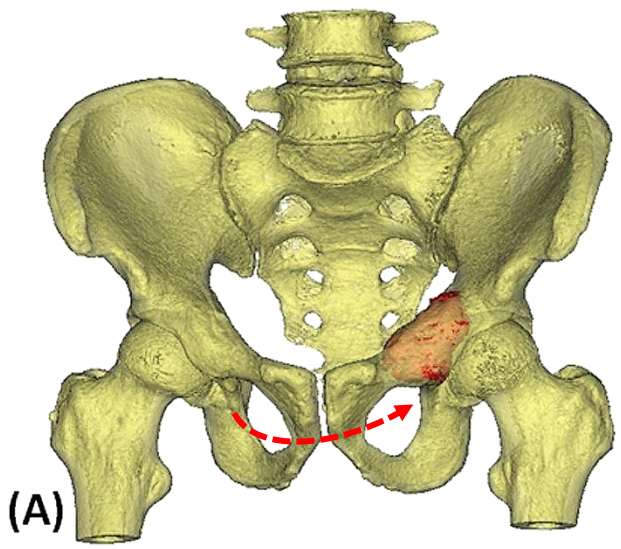


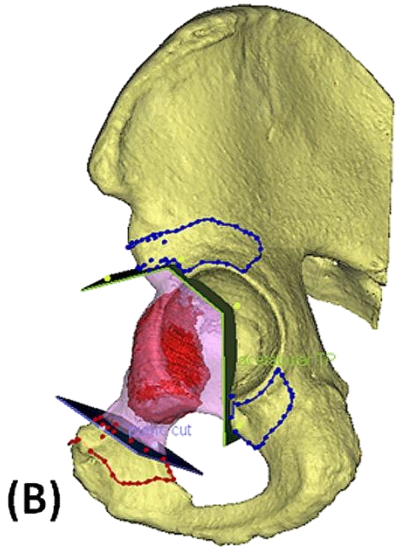
Mr. Craig Gerrand, Newcastle, UK. Customized ALM pelvic implant (2012)

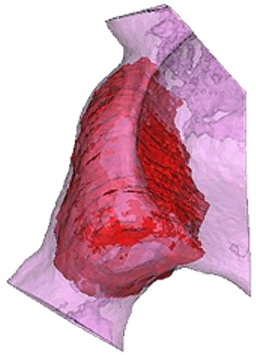
M/70, grade II CS, one-staged surgery

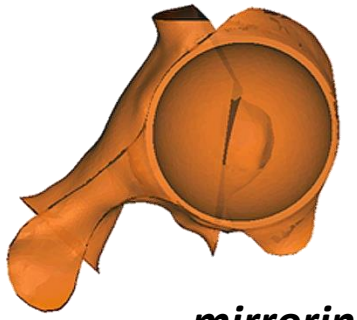
(PS modeling + 3D-printed implant + PSI) 2013









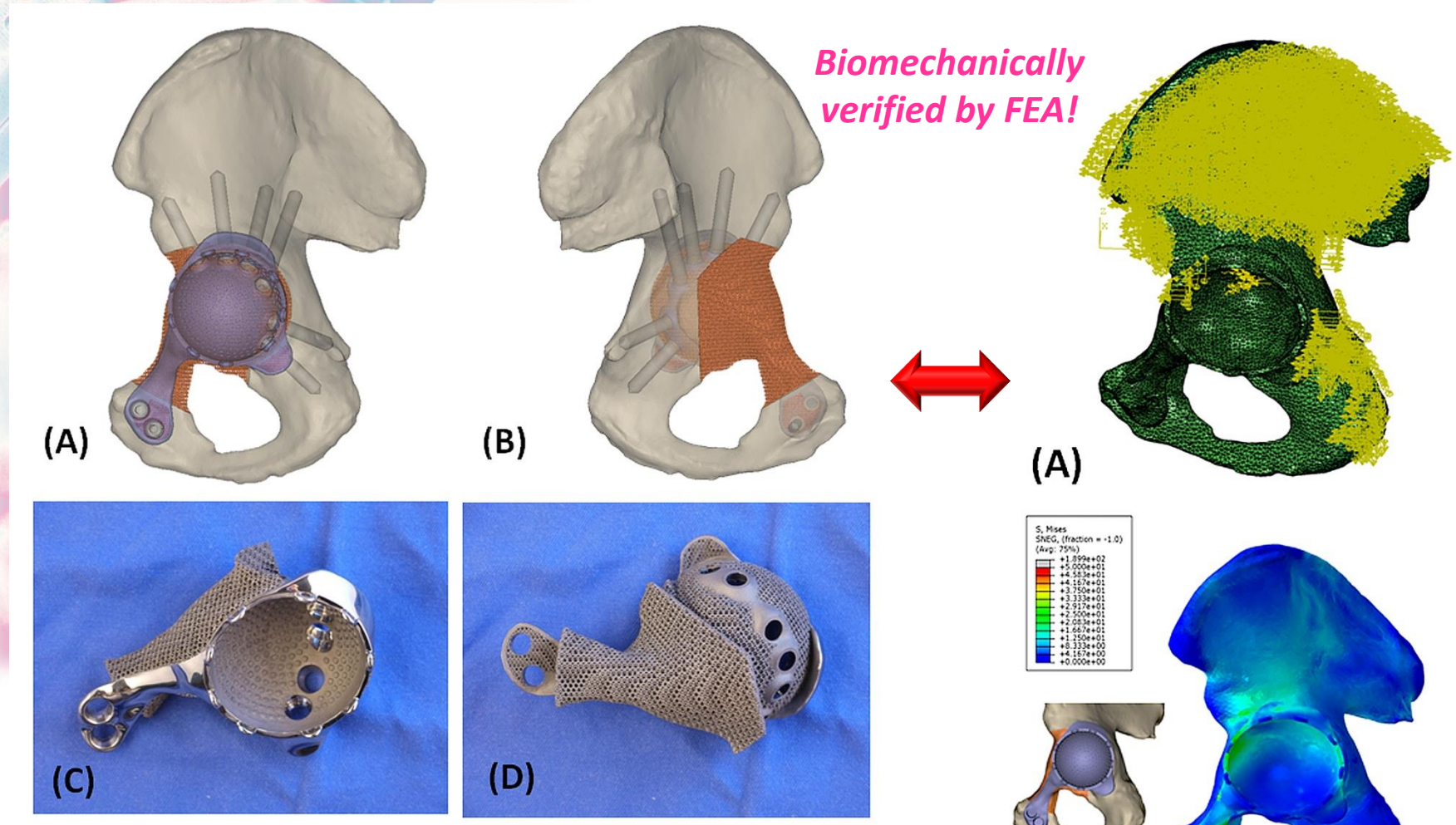


mirroring

CT/MRI

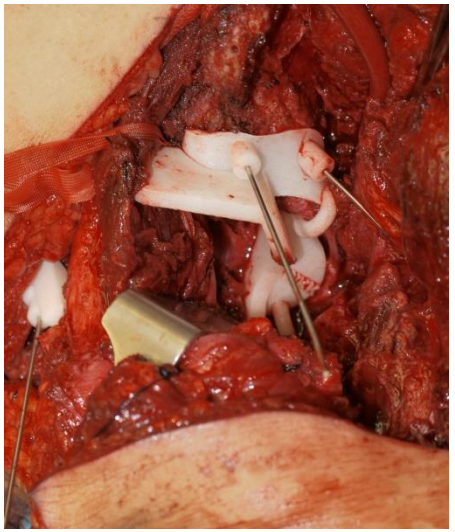
Planning in Mimics

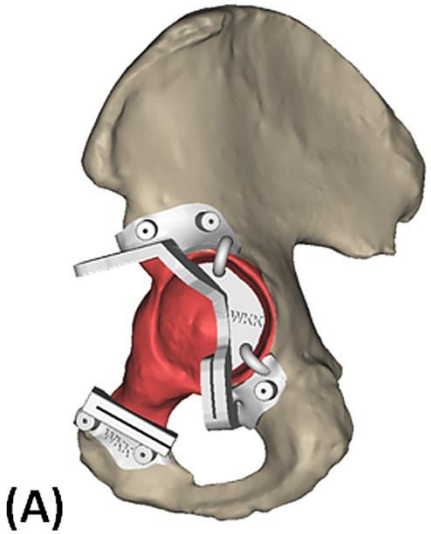
PS modeling →3D-printed implant

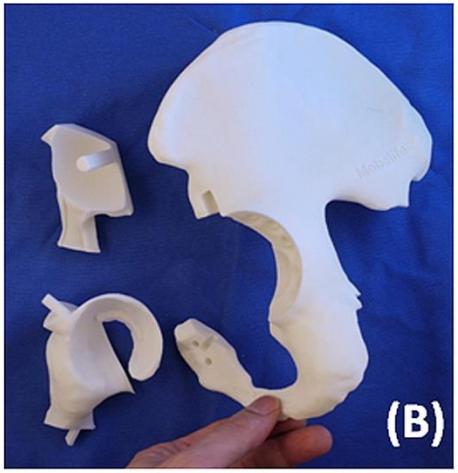


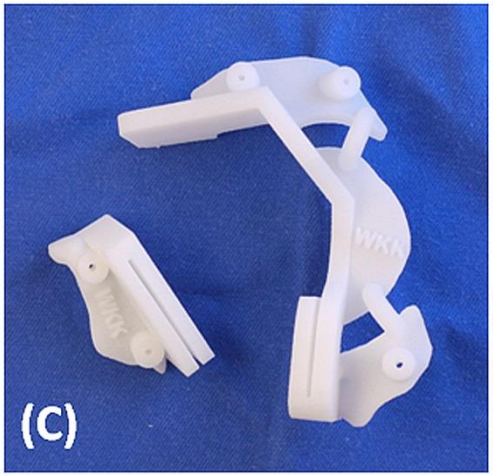
Wong KC, Kumta SM, Geel NV, Demol J. One-step reconstruction with a 3D-printed, biomechanically evaluated custom implant after complex pelvic tumor resection. Comput Aided Surg. 2015 Aug 20:1-10.

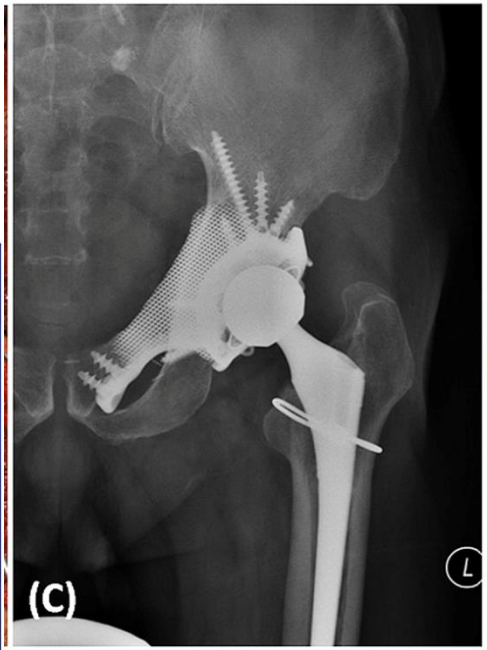
PSI for resection & screws











Postop 2 years

Limb Salvage Surgery in Orthopaedic Oncology

Patient specific surgery

- ***3D planning***
  - Platform between surgeons & engineers
  - *Resection*: clear tumor and preserve normal tissue
  - *Reconstruction*: Anatomically & Biomechanically verified
- ***3D printing***
  - Anatomically conformed implant
  - Scaffolds for best osteointegration
  - PSI for accurate transfer of surgical plan