From 3D Model Planning to Patient Specific Orthopaedic Surgery

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Traditional Orthopaedic Surgery

Normal model
Orthopaedic Training

Mental 3D planning

M/47, pelvic chondrosarcoma

2D CT images

2D MR images

Anterior

Head

Lateral view
Computer Navigation in Orthopaedic surgery

- CUHK Introduced to Hong Kong (PWH) in 2002
- **Improved Surgical Accuracy**
  - Better outcome
    - Spine surgery (pedicle screws placement)
    - Joint arthroplasty *
    - Fracture fixation
Achievements and awards

**Bone tumor surgery with computer navigation**

- was chosen as *one of the two leaders medical science* and a pioneering member of international medical fraternity in applied research and practice in Hong Kong. It is published by *Information Services Department* – Hong Kong Special Administrative Region (HKSAR) Government in 2008.
- was also chosen as *one of the ten academic and research achievements* at the 45th anniversary of CUHK.
- “Navigation assisted Bone tumor surgery” was chosen as *one of the medical advancement at 30th Anniversary of Prince of Wales Hospital* in 2014

**Four international paper awards, one best paper award in CORR 2012 and five local best papers awards**

**Hospital Authority Best Team award 2014**

- (Paediatric cancer service at Children Cancer Center, PWH)
1st Navigation assisted surgery 2006
(Pelvic Bone tumor with resection & custom implant)

3D printed Pelvic model made from patient CT data
CATS: Navigation guidance (limitations)

- Navigation facilities
- Instruments
- System operator
- Learning curve
- \( ? \uparrow \) operating time

Patent in 3D printing expired in 2009!
Digital CAD files ➔ “sliced” into layers ➔ 3D models
1. IMAGE ACQUISITION

CT / MR images

Tumor

2. IMAGE POST-PROCESSING

Axial images in DICOM

3D bone model
Image segmentation
2. IMAGE POST-PROCESSING:
3D CAD models with surgical simulation

Analyze bony and pathological anatomy

Plan osteotomies with clear margin

Design a patient-specific instrument for the osteotomies
2. IMAGE POST-PROCESSING:
3D CAD models with surgical simulation

Design a custom implant for the bone defect

3. 3D PRINTING

3D printing machine
3. 3D printing

Personalized treatment (patient’s data)

Patient’s surgical model

3D printed custom metal implant
1. 3D surgical models

- Complex surgical procedures
  - Preoperative planning & rehearsal
- Enhance education / training
- ↑ communication among care providers
- ↑ patients’ safety / outcomes
- Patient consent
3D Model (Sacral tumor)

Surgical planning
Surgical training
Patient consent

Navigation

2D MR images
2. Patient-specific Instruments (PSI)

*Cutting guides*: easily replicate surgical plans
Simplify OT instruments preparation

Traditional preparation

3D printed cutting guides
3. 3D printed custom implants

off-the-shelf implants not fitting
Anatomically conformed to patients
Complex geometry with porous lattice
Pelvic fracture
Pelvic fracture model

- Better diagnosis
- Surgical planning
- Precontour fracture plates on mirror model

Acknowledgements: Trauma team, ORT, PWH
Dysplastic Hip with osteoarthritis

Virtual 3D model

2D images
Hip arthroplasty

• Surgical planning / simulation
  – ? Surgical approach
  – Off-the-self implants OK?
  – ? Implant size
Reduce surgical time & anxiety

Acknowledgements: AJR team, ORT, PWH
Deformity Correction
Distal Tibia Malunion
Personalized models / guides

Acknowledgements:
F&A team, ORT, PWH
M/18, left tibia Ewing sarcoma in 2015

3D printed Patient Specific Instrument
Custom metal implant
Postop 1.5 years
normal leg function
M/70, Chondrosarcoma, one-staged surgery (3D-printed implant + PS Cutting Guides) 2013

CT/MRI

Planning in Mimics
PS modeling → 3D-printed implant

Biomechanically verified by FEA!

PSI for resection & screws

Postop 4 years
# 3D printing ortho cases in PWH (since 2013)

<table>
<thead>
<tr>
<th>Orthopaedic subspecialties</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor</td>
<td>22</td>
</tr>
<tr>
<td>Paediatric</td>
<td>18</td>
</tr>
<tr>
<td>Trauma</td>
<td>16</td>
</tr>
<tr>
<td>Hand</td>
<td>3</td>
</tr>
<tr>
<td>Foot and ankle</td>
<td>2</td>
</tr>
<tr>
<td>Sports</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>62</strong></td>
</tr>
</tbody>
</table>

Other departments: 35; total: 97 cases
3D printing (potential benefits)

- Patient Satisfaction / Safety
- Improved Patient Throughput
- Specialty focus: Rare, Complex cases
- Cost Reduction / Avoidance: ↓ OT time ↓ LOS

Solid evidence of better outcomes pending……
Practical issues (Sterilization for OT use)

- ? 3D printed Materials
- ? Methods of 3D printing (FDM / SLS)
- ? High / low temperature sterilization
- ? Time for sterilization
  - → elective / emergency OT
3D printing in orthopaedic applications current limitations

- The *lead time* in design & manufacturing
- Lack of *intraoperative flexibility*
- *Post 3D printing steps*
  - ? Finishing ? cleaning
- *Regulatory considerations*
  - ? safety
- *High cost* of the implants
3D printing (in hospitals)

Hospital vs Department based

In-house vs out-source service
3D printing (in hospitals)

PRS
CTS
P&O

ORT

Radiology

Engineer

ENT
Cardiology
Surgery

University
Hospital
Industry

CONNECT ↔ Patient-centred care!
Potential future developments of 3D printing in Patient-Specific Ortho

- Advances in *biomimetic materials*
- 3D-printed *scaffold + biomolecules / drugs*
- Structure $\rightarrow$ function (+ tissue engineering)
- Develop an integrated *all-in-one computer platform* for easy planning and seamless communication

$\rightarrow$ *Translational to patient care*
Conclusions

The advent of image processing and 3D printing

• ↑ Opportunities in patient-specific applications in Orthopaedics
• Improve surgical accuracy
• Reduce surgical time and safety
• ? Better clinical outcomes
• Practical issues
Acknowledgements

• Hong Kong Poly University (3D printing team)
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• CUHK ORT CASM team, OLC
• PWH ORT (F&A, Paediatric, AJR)
• PWH Radiology Department
• PWH OT nursing team
• HA Corporate Communication
Public media interview 13/5/2017

• TVB: 醫院引入3D打印提升手術準確度

• NOW TV: 威院引3D打印增加手術準確性
  – http://news.now.com/home/local/player?newsId=220963&home=1

• Cable TV: 3D打印製骨骼模型開刀位置更準