Next generation clinical imaging of bone with XtremeCT II

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Next Generation HR-pQCT
## Second Generation HR-pQCT

<table>
<thead>
<tr>
<th>Feature</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Generation</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of view</td>
<td><strong>Wider</strong></td>
<td>12.6 cm</td>
</tr>
<tr>
<td>Gantry length</td>
<td><strong>Longer</strong></td>
<td>0.93 m</td>
</tr>
<tr>
<td>Scan time @ Std Acquisition</td>
<td><strong>Faster</strong></td>
<td>2.8 min</td>
</tr>
<tr>
<td>Radiation Dose @ Std Acquisition</td>
<td>≈ <strong>Dose</strong></td>
<td>5 μSv</td>
</tr>
<tr>
<td>Voxel size @ Std Acquisition</td>
<td><strong>Improved Resolution</strong></td>
<td>82.0 μm</td>
</tr>
<tr>
<td>Minimum voxel size</td>
<td></td>
<td>45.0 μm</td>
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</table>
Spatial Resolution

A) XCTIM @82.0 µm
B) XCTII @60.7 µm
C) HR @30.3 µm

10% MTF Resolution = 141.4 µm
95.1 µm
55.9 µm
Standard Scan Sites - Radius

1<sup>st</sup> Generation @ 82 μm  2<sup>nd</sup> Generation @ 61 μm
Can we accurately assess trabecular microarchitecture using 2nd generation HR-pQCT?

Gold Standard
(30 μm, 200 ms IT)

Standard Patient Acquisition
(61 μm, 43 ms IT)
XtremeCTII

\[
y = -0.021 + 1.2 \cdot x \\
\]  
\[
x^2 = 0.99 \\
\]

XtremeCT

\[
y = -0.015 + 1.1 \cdot x \\
\]  
\[
x^2 = 0.89 \\
\]
XtremeCTII

\[ y = -0.19 + 1 \cdot x \]
\[ r^2 = 0.93 \]

XtremeCT

\[ y = -0.12 + 1.3 \cdot x \]
\[ r^2 = 0.98 \]
XtremeCTII

\[ y = 0.019 + 1.2 \cdot x \]

\[ r^2 = 0.97 \]

XtremeCT

\[ y = -0.056 + 0.83 \cdot x \]

\[ r^2 = 0.33 \]
### Graphs and Equations

**XtremeCTII**
- **Graph A**: 
  - Equation: \( y = -0.21 + 1.4 \times x \)
  - \( r^2 = 0.98 \)

- **Graph C**: 
  - Equation: \( y = -0.3 + 1.1 \times x \)
  - \( r^2 = 0.99 \)

**XtremeCT**
- **Graph B**: 
  - Error (XCTII-HR)
    - Mean Tb.Sp (mm)
      - \( \bar{x} \pm 2s = 0.6 \)
      - \( \bar{x} = 0.2 \)
      - \( \bar{x} - 2s = -0.19 \)

- **Graph D**: 
  - Error (XCTIM-HR)
    - Mean Tb.Sp (mm)
      - \( \bar{x} \pm 2s = -0.068 \)
      - \( \bar{x} = -0.2 \)
      - \( \bar{x} - 2s = -0.33 \)
Is microarchitecture linked to osteoarthritis?

- The sequence of events leading to joint degeneration after ACL injury is poorly understood.
- Subchondral bone changes may precede cartilage loss\(^1,2\).
- Derived trabecular microarchitecture abnormal in ACL deficient patients, in absence of joint space narrowing\(^3\).

Can we detect early signs of knee osteoarthritis using 3D assessment of trabecular microarchitecture in the second generation HR-pQCT?

\(^1\) Baker-LePain 2012 Bone; \(^2\) Frobell 2010 Arthritis Care Res; \(^3\) Buckland-Wright 2000 Ann Rheum Dis
## Second Generation HR-pQCT

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Cadaveric Testing

• ‘Standard’ settings produced poor image quality
  • 43 ms integration time
  • 900 projections/180°
  • 61 μm voxel size

• Increased integration time to 100 ms
  • Radiation dose 70 μSv for 6 cm scan
Leg Positioning in FOV

First

Current
In Vivo Knee Scanning

Acquired 2 separate scans:
- Integration time: 100 ms
- 900 projections/180 deg
- Voxel size: 61 μm
- Length: 3 cm/scan (overlapped)
- Scan time: ~ 12 min/scan
- Radiation dose: ~ 35 μSv/scan
Contralateral Leg Positioning
Scans were acquired over a 61.5 mm length using:

- 6 x 10.2 mm ‘stacks’ encompassing distal femur and proximal tibia (Figure 3)
- Scan time of ~30 min

OR

- 2 separate scans (each 3 x 10.2 mm ‘stacks’) of each bone
- Some overlap
- Scan time 2 x ~12 min
- Scans registered after acquisition for visualization purposes
In Vivo Knee Scanning

![Image of knee scan]
In Vivo Knee Scanning

Axial Tibia

Axial Femur

Sagittal

Coronal
Can we detect early signs of knee osteoarthritis *in vivo*?

Does bone microarchitecture play a role in disease onset and progression?

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1Bousson 2012 Osteoporos Int, 2Johnston 2010 Skeletal Radiol
Joint Imaging Future Directions

Cartilage Volume and Thickness with Arthrogram

HR-pQCT of Elbow

Tunnel Widening after ACL Reconstruction
Acknowledgements

Dr. Steven Boyd

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N Mohtadi   K Archibold    D Chan

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