Bone microarchitecture scanners
MicroCT - XtremeCT

Audrey Berthier - MEDES
audrey.berthier@medes.fr
MEDES- French institute for Space Physiology and Medicine

In space
- Bone loss of astronauts
- Supporting research - Effects of mechanical constraints on bone remodeling

Context for studies on bone
- DEXA: information on density only - idea on bone quantity
- Bone markers
- Bone biopsies / histomorphometry
→ Need for an imaging tool for:
  ➢ Information on bone quality
  « Virtual biopsies »
  ➢ Longitudinal studies on bone microarchitecture changes (trabecular bone)
  ➢ Estimation of fracture risk
  ➢ In vitro / in-vivo / clinical device

SCANCO products: μCTs, vivaCT, XtremeCT
Added value of microCT scans

- **Bone microarchitecture imaging**
  - Bone geometry
  - Information on bone structure -> Contribution to the bone quality

- **High resolution**
  - From 10µm (µCT) to about 100 µm depending on size of sample/image area, device and use.

- **Quantitative structural information on cancellous and cortical bone**

- **Analysis of the true 3D structure of trabecular bone + morphological properties**

- **Allows further data processing**
  - FEA
  - Other image analyses

**Warning:** Big size of data (several GBs), need very good computers + storage capacities for further processing
µCTs

<table>
<thead>
<tr>
<th>Feature</th>
<th>µCT 35</th>
<th>µCT 40</th>
<th>µCT 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak/Mean Energy</td>
<td>30-70 kVp / 20-50 keV</td>
<td>30-70 kVp / 20-50 keV</td>
<td>30-70 kVp / 20-50 keV</td>
</tr>
<tr>
<td>Max. Scan Diam. / Len.</td>
<td>36.9 mm / 120 mm</td>
<td>36.9 mm / 80 mm</td>
<td>75.8 mm / 120 mm</td>
</tr>
<tr>
<td>Resolution (Nominal, 10% MTF)</td>
<td>1.75-72 µm / &lt;5 µm</td>
<td>6-72 µm / 9 µm</td>
<td>10-74 µm / 15-90 µm</td>
</tr>
<tr>
<td>Minimal Scan Time per Slice</td>
<td>3 s</td>
<td>2 s</td>
<td>3 s</td>
</tr>
<tr>
<td>Image Matrix</td>
<td>512 x 512</td>
<td>512 x 512</td>
<td>512 x 512</td>
</tr>
<tr>
<td></td>
<td>1024 x 1024</td>
<td>1024 x 1024</td>
<td>1024 x 1024</td>
</tr>
<tr>
<td></td>
<td>2048 x 2048</td>
<td>2048 x 2048</td>
<td>2048 x 2048</td>
</tr>
</tbody>
</table>

- Highest resolution - less than 5 µm
- 9 µm at 10mm object size - 20µm at 36 mm diameter, 8 cm length
- High resolution for large samples 78mm scan diameter - possibility to evaluate complete human bones

Compromise between sample size and resolution
# VivaCT - XtremeCT

<table>
<thead>
<tr>
<th>Feature</th>
<th>vivaCT 40</th>
<th>vivaCT 75</th>
<th>XtremeCT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>in vivo (animal)</td>
<td>in vivo (animal)</td>
<td>in vivo (human)</td>
</tr>
<tr>
<td><strong>Geometry</strong></td>
<td>Cone-Beam</td>
<td>Cone-Beam</td>
<td>Cone-Beam</td>
</tr>
<tr>
<td><strong>Peak/Mean Energy</strong></td>
<td>30-70 kVp / 20-50 keV</td>
<td>30-70 kVp / 20-50 keV</td>
<td>60 kVp / 40 keV</td>
</tr>
<tr>
<td><strong>Max. Scan Diameter</strong></td>
<td>20-38 mm</td>
<td>40-78 mm</td>
<td>125 mm</td>
</tr>
<tr>
<td><strong>Max. Scan Length</strong></td>
<td>145 mm</td>
<td>145 mm</td>
<td>150 mm</td>
</tr>
<tr>
<td><strong>Nominal Resolution</strong></td>
<td>10 µm</td>
<td>20 µm</td>
<td>42 µm</td>
</tr>
<tr>
<td><strong>Resolution (10% MTF)</strong></td>
<td>20 mm Ø: 16 µm</td>
<td>40 mm Ø: 32 µm</td>
<td>125 mm Ø: 100 µm</td>
</tr>
<tr>
<td><strong>Slice Thickness</strong></td>
<td>10-38 µm</td>
<td>20-79 µm</td>
<td>41-246 µm</td>
</tr>
<tr>
<td><strong># of Slices</strong></td>
<td>&lt; 10000</td>
<td>&lt; 10000</td>
<td>&lt; 10000</td>
</tr>
<tr>
<td><strong>Minimal Scan Time per Slice</strong></td>
<td>3 s</td>
<td>2 s</td>
<td>1 s</td>
</tr>
<tr>
<td><strong>2D-Image Matrix</strong></td>
<td>512 x 512, 1024 x 1024, 2048 x 2048</td>
<td>512 x 512, 1024 x 1024, 2048 x 2048</td>
<td>512 x 512, up to 3072 x 3072</td>
</tr>
</tbody>
</table>
XtremeCT

- In vivo system for human extremities (Radius and Tibia)
- Interesting for analysing « big » samples
- Measures both density and structure
- Isotropic Resolution: ~100 µm
- Scan time:
  - 2-3 min for 110 sections (clinical use) (9 mm, 1536 x 1536)
  - For bigger samples - (ex mandibles Pr. Braga) - 2834 slices - 5 hours 1/2 - reconstruction time - 80 hours
- FOV: 128 mm
- Scan Length: 150 mm

- Image Matrix:
  - 1536x1536 (default), possible up to 3072x3072
- Transfer to DICOM files
XtremeCT features

- 82 μm pixelsize allows to image the three-dimensional trabecular network in the human forearm and lower leg
- Isotropic 3D resolution

Radius of 65 year old male volunteer
Method of Use

- **Warmup incl. QC (~30 min)**
- **Calibration Scan**
- **Positioning**
  - Scout-View (Radiograph)
  - Laser Positioning
- **Scan**
- **Automatic Launch of reconstruction**
- **Evaluation**
  - Drawing outline of first slice
  - Automatic Calculation of Parameters offline
Automatic standard evaluations

- Trabecular and cortical evaluation of radius
- Density as well as structural indices such as Tb.N, Tb.Th(derived), Tb.Sp(derived) and C.Th
- Matching of Region of Interest between scans
Automatic standard evaluations

<table>
<thead>
<tr>
<th>Densities</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>D100 [mg HA/ccm]</td>
<td>BV/TV [1]</td>
</tr>
<tr>
<td>Dtrab [mg HA/ccm]</td>
<td>Tb.N [1/mm]</td>
</tr>
<tr>
<td>Dmeta [mg HA/ccm]</td>
<td>Tb.Th [mm]</td>
</tr>
<tr>
<td>Dinn [mg HA/ccm]</td>
<td>Tb.Sp [mm]</td>
</tr>
<tr>
<td>Ratio: Meta/Inn [1]</td>
<td></td>
</tr>
<tr>
<td>Dcort [mg HA/ccm]</td>
<td>C.Th [mm]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Densities</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bone Density</td>
<td>Trab. Bone Volume to Tissue Volume</td>
</tr>
<tr>
<td>Trabecular Bone Density</td>
<td>Number of Trabeculae</td>
</tr>
<tr>
<td>Meta Trab. Bone Density</td>
<td>Trabecular Thickness</td>
</tr>
<tr>
<td>Inner Trab. Bone Density</td>
<td>Trabecular Separation</td>
</tr>
<tr>
<td>Ratio Meta to Inner Density</td>
<td>Cortical Thickness</td>
</tr>
<tr>
<td>Cortical Bone Density</td>
<td>C.Th</td>
</tr>
</tbody>
</table>

19/06/2008
Local thickness
Other examples of images (μCT, vivaCT)
Potential issues for labs...

- **Computer « power » for scanning (at XtremeCT computer level)**
  - Sized for clinical samples
  - For anthropology
    - Much longer scanning time
    - Much longer duration for reconstruction
    - Need for high storage capacity

- **For further processing by labs:**
  - No problem to export data into DICOM files
  - Definition of ways to retrieve data from XtremeCT location to the lab.
  - Need for high storage capacity (scans of several GB)
  - Need for high processing capacity
    - To read data
    - To process data
      - Image analysis
      - FEA
      - ...

- **For exchanges between lab?**
  - Further exploitation of data
  - On-line databases?
Perspectives

- Possible evolution of the devices that would be interested for your field?
- Type of parameters of interest for you?
- Further processing?
- Databases
- ...

Contact SCANCO:
Bruno KOLLER
bkoller@scanco.ch
+41 44 837 07 10