THE POTENTIAL OF POINT-OF-CARE DIGITAL TOMOSYNTHESIS FOR IMAGING INJURIES AND OTHER CONDITIONS OF THE DISTAL EXTREMITIES USING A PORTABLE DESKTOP SYSTEM

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Financial Disclosure

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Introduction
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Clinical Potential
Summary and Outlook
Challenges in Orthopedic X-ray Imaging

2D X-ray
Provides only a 2D view of our 3D bodies, but is easily available and in general inexpensive.

Computed Tomography (CT)
Provides a 3D image of our 3D bodies, but is an expensive technology with often high radiation exposure. CT is mainly limited to hospitals and imaging departments.
Suggested Solution

A new way of producing X-rays + A different imaging technique – Digital Tomosynthesis (DT) = Mobile, low-cost and low-dose 3D
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Why a different way of making X-rays

X-ray tubes have not changed fundamentally for a century

1895

Traditional X-ray tubes:

- Heavy
- Expensive
- Bulky
- Need to be moved for 3D acquisition

2019
Using space technology

... developed by the European Space Agency

Cold-cathode field emitter
- Compact
- Don’t require heat to generate X-rays

Multiple Emitters
- Can be arranged in different geometric shapes
- Cost effective production
Compact Flat Panel Sources

- 6x6 cm
- Multiple Cold Cathode Emitters per source
- 60-70kVp
- Does not require external cooling
- Can be operated from a regular power outlet
- System weight less than 25 lbs.

To be integrated into a point-of-care device for imaging distal extremities.
Why a different Imaging Modality

Computed Tomography (CT)

In CT or Cone Beam CT, a conventional X-ray tube will be rotated around the patient over a full 360 degree circle.

Digital Tomosynthesis (DT)

In conventional DT, a traditional X-ray tube is physically moved through different positions in order to acquire images over a 30-50 degrees angle.
Stationary DT using Flat Panel Sources

A square array of cold cathode emitters avoids the need for physical movement. The geometry allows the source to be closer to the patient.

- **Closer** to patient reduces *power requirement*
- **No need for special power supply** or big batteries
- **No need for active cooling**
Using a Flat Panel Source for DT

- Gives additional reductions in cost and weight
- Allows creation of a compact and truly portable 3D Imaging Device, in particular for hand and foot imaging, inclusive weight bearing imaging
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Digital Tomosynthesis is not new ...

Well established in breast imaging
   Screening as well as diagnostic

Promising results in chest imaging
   Reduces need for CT in up to 75% of all ambiguous Chest X-rays
   Can save costs and dose

Plays and increasing role in Orthopedic Imaging
   Detect occult fractures
   Assess bone healing
   Evaluate Rheumatoid Arthritis and Osteoarthritis
DT in Orthopedics is not new ...

**Orthopaedic Imaging**

**Digital Tomosynthesis (DT) continues to demonstrate its clinical potential in detecting and monitoring bone injuries and assessing postsurgical challenges.**

DT has a superior diagnostic accuracy to digital 2D X-ray in detecting and assessing otherwise occult fractures, such as those in the wrist where it can reduce the need for complex imaging methods. Recent publications consider DT as a valid imaging tool to assess scaphoid fractures, as it is less expensive and more accessible than Computed Tomography (CT). As a low exposure exam that can be easily integrated into a clinical workflow, DT could play an increasing role in monitoring fracture healing and other postsurgical changes. DT does not suffer from the metal streak artifacts seen on CT and current research shows how the slight shadows around metal objects can be suppressed.

In patients with rheumatoid arthritis (RA), DT is accurate in visualizing and monitoring bone erosions and destruction, in particular in patients with deformed arthritic joints. In osteoarthritis, DT demonstrates improved visualization compared with planar X-ray for subtle fractures, cysts and osteophytes. It can also better assess the extent of joint space and bone to bone contact on weightbearing images. The move away from traditional thermionic X-ray tubes to more compact novel emitters should enable the benefits of DT to be given to patients more easily using lightweight, mobile DT devices.

**Selected Publications:**


Hayashi D. et al: Detection of Osteophytes and Subchondral Cysts in the Knee with Use of Tomosynthesis Radiology. 2012 Apr;263(2):204-15


- Superior compared to digital 2D X-ray in detecting and assessing otherwise occult fractures

- Less expensive and more accessible CT

- Low exposure exam that can be easily integrated into a clinical workflow

- Potential role in monitoring fracture healing

- Accurate in visualizing and monitoring bone erosions and destruction in patients with Rheumatoid Arthritis

- Demonstrates improved visualization of subtle fractures, cysts and osteophytes in osteoarthritis.
21-year-old man with severe diffuse carpal pain after acute trauma.

A, Posteroanterior radiograph shows suspicion of scaphoid fracture (arrow). Other bones appear unremarkable.

B, Coronal tomosynthesis image shows fracture of mid third of scaphoid (arrow).

21-year-old man with severe diffuse carpal pain after acute trauma. 

C, Lateral tomosynthesis image reveals fractures of capitate (black arrow) and lunate (white arrow). 

D, Coronal multiplanar reformation (MPR) image from CT highlights fracture of capitate (arrow) 

Here, CT did not reveal the lunate fracture, which was confirmed with Sagittal T2-weighted fat saturated MRI 

### DT and Scaphoid / Wrist Fractures

<table>
<thead>
<tr>
<th>Publication</th>
<th>Conclusion</th>
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<tbody>
<tr>
<td>Ottenin et al, 2012</td>
<td>DT has potential to provide reliable diagnoses and to reduce the need for other expensive imaging methods</td>
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<td>Noel et al, 2011</td>
<td>Biplane DT delivered less radiation a standard five-view radiographic examination and a substantial radiation reduction compared to CT</td>
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<td>Geijer et al, 2011</td>
<td>Tomosynthesis was able to demonstrate occult scaphoid fractures not visible at 2D digital radiography</td>
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<td>De Silvestro et al, 2018</td>
<td>DT - compared to 2D Digital Radiography - allows better postoperative assessment of bone healing in hand and wrist; also higher inter observer agreement</td>
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<tr>
<td>Compton et al, 2018</td>
<td>DT considered as valid diagnostic tool for the diagnosis of scaphoid fractures.</td>
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Limitations include missing ability to provide multiplanar reconstruction and a limited contrast resolution and the **restriction to hospitals and imaging centers**
A portable and compact device that provides 3D DT imaging using a Flat Panel X-ray source has the potential to play an important diagnostic role in the community.
First imaging using a prototype with a Flat Panel Source Geometry

Antique human bones (holes & fishing line to hold them together)

2D X-ray shows bony overlap, making assessment difficult

3D tomosynthesis slice shows features that are invisible in 2D
First imaging using a prototype with a Flat Panel Source Geometry

Antique human calcaneus & talus

2D X-ray shows bony overlap, making assessment difficult

3D tomosynthesis slice shows joint space at each depth
First imaging using a prototype with a Flat Panel Source Geometry

Antique wrist bones plus metal screw

DT slices do not show streaks. No metal artifact reduction algorithm has been applied
First imaging using a prototype with a Flat Panel Source Geometry

Antique human radius/ulna + padding /plaster)

3D tomosynthesis slice clearly shows bone structure at each depth
First imaging using a prototype with a Flat Panel Source Geometry

Antique human bones - arranged as a shoulder joint and wrapped with ham to simulate soft tissue

DT (without smoothing) images demonstrate the ability to also include shoulder pathologies
Beyond clinical orthopedics - prototype with a Flat Panel Source Geometry

Frozen pig trotter

3D DT shows anatomy at each depth

Frozen mouse

DT shows potential for preclinical imaging
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Summary

Digital Tomosynthesis (DT) has shown potential in Orthopedic Imaging

Using innovative X-ray technology, DT could become portable and available for point-of-care 3D imaging
References and suggested reading

- **Malavankar, A. et al**: Operating high-current field emitters in a commercial X-ray source. 2017, 30th International Vacuum Nanoelectronics Conference (IVNC).
- **Quaia E. et al**: Diagnostic imaging costs before and after digital tomosynthesis implementation in patient management after detection of suspected thoracic lesions on chest radiography Insights Imaging. 2014 Feb;5(1):147-55
- **Sharpe Jr. et al**: Increased Cancer Detection Rate and Variations in the Recall Rate Resulting from Implementation of 3D Digital Breast Tomosynthesis into a Population-based Screening Program. Radiology (2016); 278: 3
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