SUBCHONDRAL BONE CHANGES in HAND and KNEE OA DETECTED BY RADIOGRAPHY
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EARLY BONE CHANGES DETECTED BY IMAGING

Bone Scintigraphy
Isotope uptake identifies sites of bone remodeling prior to onset of X-ray changes.

Radiography
Reveals changes that have occurred in joint anatomy with a spatial resolution for:
- Standard X-ray: > 0.1-2 mm
- Microfocal X-ray: > 0.02 - 0.05 mm
BONE SCINTIGRAPHY

Scans identified osteophyte growth and remodeling*

BONE SCINTIGRAPHY

Scans detected increased subchondral sclerosis*

Osteophytes and subchondral sclerosis occur many months before changes in articular cartilage thickness measured as JSN*. 

WHICH ARE THE EARLIEST RADIOGRAPHIC CHANGES IN BONE?

In OA joints

Difficulty in determining the start of the disease.

Knees with ACL rupture

• 60-90% of patients develop X-ray changes of OA in 10-15 yr. [Neyret et al. J.B.J.S. 1993;B75:36-40]

• advantage of post-traumatic OA is that start of disease is identified by date of injury [Roos et al. Osteoarthritis Cart 1995;3:261-7]
EARLY RADIOGRAPHIC FEATURES IN PATIENTS WITH ACL RUPTURE*

Cross sectional macroradiographic study of 19 patients with ACL rupture in one knee confirmed by arthroscopy.

1. Minimum JSW, Cortical Plate Thickness & Osteophytes were measured by computer techniques.
2. FSA was used to quantify horizontal and vertical trabecular structures within Subchondral Cancellous Bone.

X-ray Features in ACL Rupture

1. Horizontal trabeculae increased significantly ($p<0.01$) in thickness in the medial compartment by 3-4 yr.
X-ray Features in ACL Rupture

2 - Osteophytes develop in the medial compartment of ACL knees by 3\textsuperscript{rd} yr.

3 - No changes detected in:
   – cortical plate thickness
   – minimum JSW
Earliest changes appear in the medial compartment by 3-4 yr. post injury as:

- increased horizontal trabecular thickness
- marginal osteophytes
SUBCHONDRAL SCLEROSIS IN HAND OA*

From cross-sectional and longitudinal (18 mths) macro-radiographic studies of 45 patients with hand OA


SUBCHONDRAL SCLEROSIS (SCS) IN HAND OA

Cross-sectional analysis
SCS was advanced in patients with very early OA, i.e. increased sclerosis was present in joints with larger JSW than healthy non-OA group*

SUBCHONDRAL SCLEROSIS (SCS) IN HAND OA *

Compared to healthy non-OA hands
SCT > dominant  \( p < 0.003 \): non-dominant  \( p < 0.002 \)
SCT greatest:

per joint : 2\textsuperscript{nd} DIP

per phalangeal rays : 2\textsuperscript{nd} & 3\textsuperscript{rd} > 4\textsuperscript{th} & 5\textsuperscript{th}

per hand : dominant 2\textsuperscript{nd} & 3\textsuperscript{rd} >
non-dominant 2\textsuperscript{nd} & 3\textsuperscript{rd} phalanges (\( p < 0.045 \))

Association Between Radiographic Features and Hand Function*

**Subchondral Cortical thickness was greatest:**

- 2nd DIP pulp pinch
- 2nd & 3rd phalanges finger tripod
- dominant hand hand function

Subchondral cortical plate thickness

• increased in 2/3\(^{rd}\)s of the patients

• decreased in 1/3\(^{rd}\) of the patients
Conclusion

SCS is a very early feature associated with early articular cartilage changes.

SCS is linked to pattern of forces associated with hand function and possibly synovial inflammation.
ADVANCEMENT in the ZONE of CALCIFIED CARTILAGE in OA HANDS of PATIENTS
ADVANCEMENT in the ZCC in Hand OA

ZCC steps were present in 48% of hands in 64% of patients
By 18 mths new ZCC steps had formed in 73% of hands
ZCC steps were more numerous in the
• non-dominant hand
• present where JSW was large i.e. MCP joints
• located at the convex articular surfaces.

ADVANCEMENT in the ZCC in Hand OA

Attributed to vascular invasion into ZCC due to:

- subchondral bone remodelling [Meachim et al, 1984; Radin et al, 1990]
- effect of lipid associated venous thrombosis [Cheras et al, 1993; Jones, 1997]

Changes in cartilage are intimately related to those in the cortical plate [Sokoloff, 1989]
SUBCHONDRAL CORTICAL SCLEROSIS
IN KNEE OA*

From cross-sectional and longitudinal (18 mths) macro-radiographic studies of 45 patients with knee OA

### Mean (SD) Cortical Plate Thickness (mm) in Medial Tibiofemoral Compartment*

<table>
<thead>
<tr>
<th>Knees</th>
<th>No</th>
<th>Femur</th>
<th>Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>28</td>
<td>0.29 (0.07)</td>
<td>0.37 (0.06)</td>
</tr>
<tr>
<td>JSW &gt; 3 mm</td>
<td>36</td>
<td>0.54 (0.14)</td>
<td>0.53 (0.11)</td>
</tr>
<tr>
<td>JSW &lt; 3 mm</td>
<td>39</td>
<td>0.59 (0.21)</td>
<td>0.50 (0.09)</td>
</tr>
<tr>
<td>JSW &lt; 1.5 mm</td>
<td>15</td>
<td>0.53 (0.21)</td>
<td>0.76 (0.16)</td>
</tr>
</tbody>
</table>

* Buckland-Wright et al *J Rheumatol* 1994;21:1734-41
Mean (SD) SCT Measurements (mm) in Tibiofemoral Compartment*

**SCT was greatest**
- In OA *versus* healthy reference knees $p < 0.0001$
- In medial *versus* lateral compartment $p < 0.0001$

**SCT increased in medial compartment of OA knees where**
- JSW $< 1.5$ mm standing & tunnel *versus* other groups $p < 0.0001$

* Buckland-Wright et al J Rheumatol 1994;21:1734-41
Mean (SD) SCT Measurements (mm) in Tibiofemoral Compartment*

Longitudinal study (18 mths)
SCT did not alter significantly in either medial or lateral compartments during study period.

SUBCHONDRAL CANCELLOUS BONE CHANGES IN KNEE OA*

From cross-sectional study of 45 patients with knee OA; combining techniques of macroradiography and FSA to quantify separately horizontal and vertical trabeculae.

Region of interest for measurement of FSA for horizontal and vertical trabeculae
FSA for horizontal trabeculae
in the medial compartment of knees with no, mild (JSW >3 mm),
definite OA in standing (JSW <3 mm) and tunnel (JSW <3 mm) views
FSA for vertical trabeculae in the medial compartment of knees with no, mild (JSW >3 mm), definite OA in standing (JSW <3 mm) and tunnel (JSW <3 mm) views.
SUBCHONDRAL CANCELLOUS BONE CHANGES IN KNEE OA*

Medial - OA- Compartment

Horizontal trabeculae thickness increased in early OA and preceded changes in vertical trabeculae observed in knees with definite OA

Lateral Compartment

FSA for horizontal and vertical trabeculae was similar in all groups.

Sub-articular or peri-articular subchondral bone

• BMD is lower in this region regardless of BMD of the spine*

• lower than normal BMD in knee OA appears related to changes at the joint*

Subchondral bone in the tibia of knee with moderate OA
Subchondral bone in the tibia of knee with advanced OA
SUBCHONDRAL BONE IN ADVANCED KNEE OA

Marked articular cartilage loss: JSW < 1.5 mm

Subchondral cortical bone in the medial, diseased compartment, becomes deformed seen as:

– corrugations at the articular surfaces,

later:

– articular surface becomes shallower and flattened
SUBCHONDRAL BONE IN OA

New bone formation in OA*

– formed rapidly
– coarse fibred or woven (callous) bone
– attempt at repair

SUBCHONDRAL BONE IN OA

Subchondral bone quality changes in OA*

Biomechanical tests reveal bone to have reduced:
– stiffness
– density
– mineral content

Increased
– porosity

Subchondral bone is weaker in OA than normal or osteoporotic bone.

SUBCHONDRAL BONE IN ADVANCED OA

With JSW loss and weaker subchondral bone:
- flattened articular surface
- larger contact area & load transmission is improved

Results in:
- greater congruity between joint surfaces
- increased mechanical stress in articular tissues

SUBCHONDRAL SCLEROSIS IN KNEE OA

Effect of subchondral sclerosis on the sub-articular cancellous bone

- Weaker than normal bone in the cortical plate and trabecular sclerosis absorbs local stresses

- Reduced load transmission to the sub-articular region results in a localised osteoporosis, similar to stress shielding observed in prostheses
HYPOTHESIS:
The weaker than normal bone within thickened subchondral cortical plate and trabeculae results in deformation of the joint surfaces and local absorption of stress, resulting in sub-articular osteoporosis detected in a reduced BMD.

-Bone deformation
-Cortical plate and trabecular sclerosis
-Subarticular osteoporosis from stress shielding
SUBCHONDRAL BONE CHANGES IN KNEE OA

Long term effect of:
• subchondral sclerosis
• altered bone quality
• sub-articular osteoporosis

-leads to collapse of the compartment and joint malalignment.
Summary

CORTICAL PLATE

Increase in thickness coupled with changes in articular cartilage. [Patel et al, 1999; Westacott et al, 1999; Pelletier et al, 1999]

CANCELLOUS BONE

Horizontal trabeculae increase in thickness. [Buckland-Wright et al 1996; 2000]
SUBCHONDRAL BONE IN OA PROGRESSION

Summary

**CORTICAL PLATE**

Changes in late stage, JSW < 1.5 mm, thickness of plate increases significantly [Buckland-Wright et al, 1994]

**CANCELLOUS BONE**

Vertical trabeculae increases in number,

Horizontal trabeculae increases in thickness.

[Buckland-Wright et al, 1996]
SUBCHONDRAL BONE IN OA

Summary

SUB-ARTICULAR BONE

Has reduced BMD and is locally osteoporotic


This phenomenon, it is hypothesised, is due to the stress shielding effect of the subchondral sclerosis upon the underlying bone.
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