MRC Lifecourse Epidemiology Unit

UNIVERSITY OF Southampton

Overview of pQCT

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www.theSAMSON.org

SAMSON Sub-Saharan African MuSculOskeletal Network

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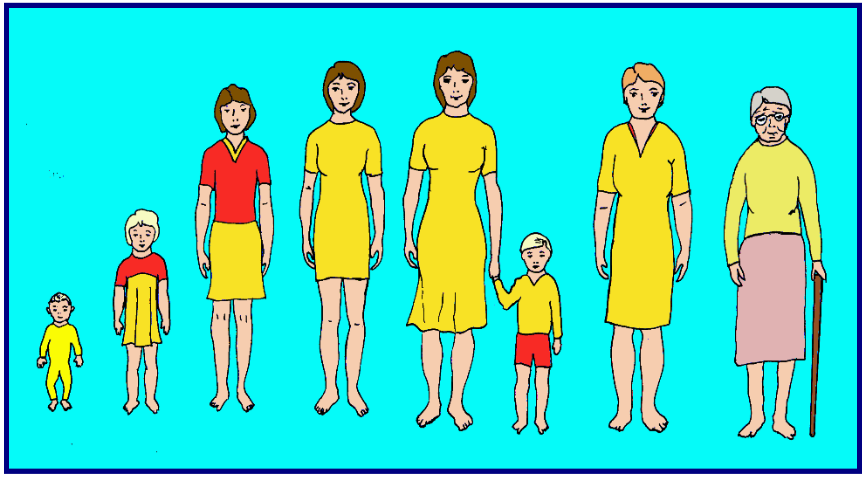
Objectives

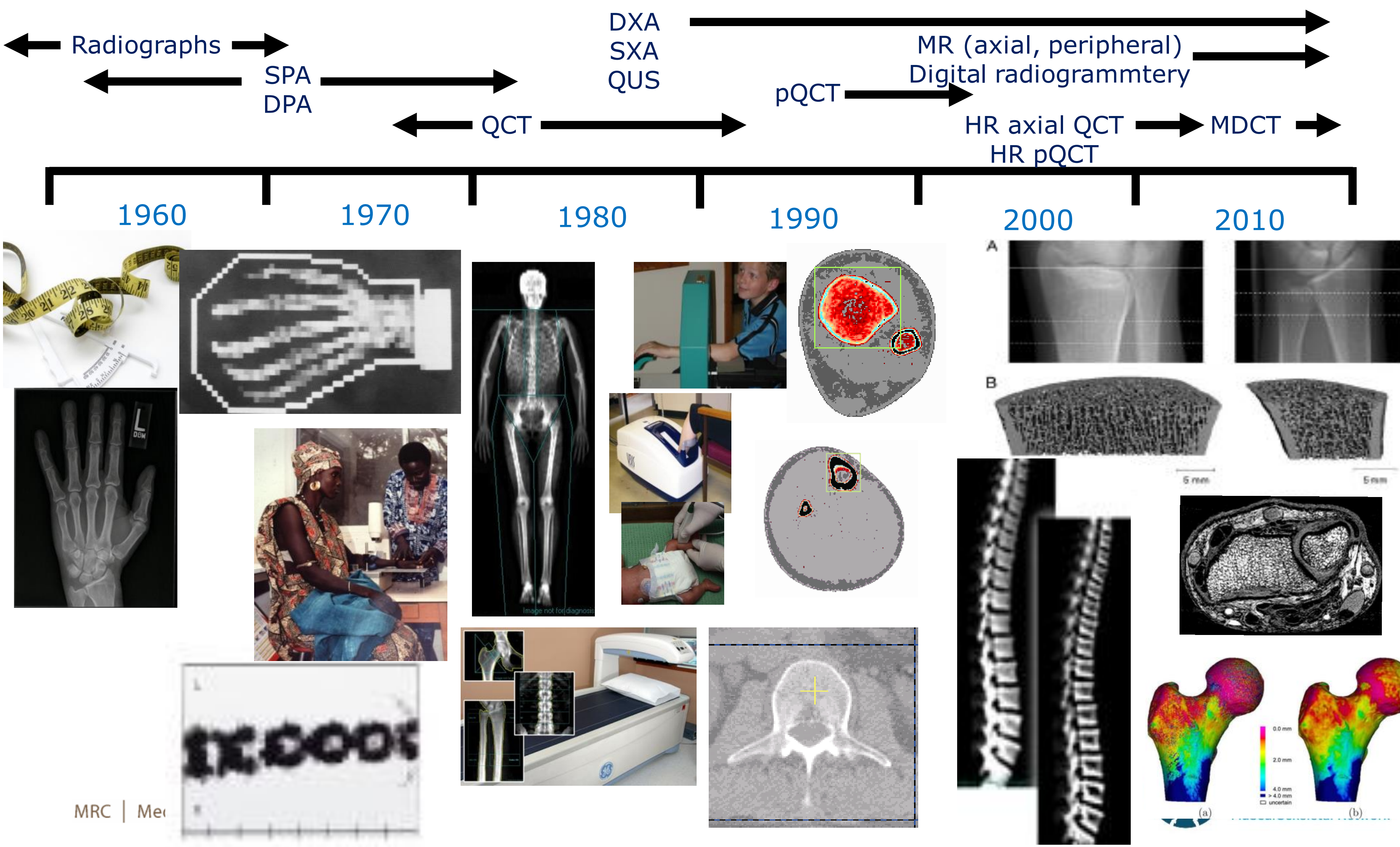
- Understand different methods of assessing bone in children and adults
- Optimise technique when performing pQCT
- Understand how to process and analyse the outputs generated by pQCT
- Understand and interpret assessments of bone age

How do we assess the skeleton?

- What do we want to measure?
- Clinically relevant sites
- Interpretation and what does it tell us?
- What is our research question?
- Population we want to measure

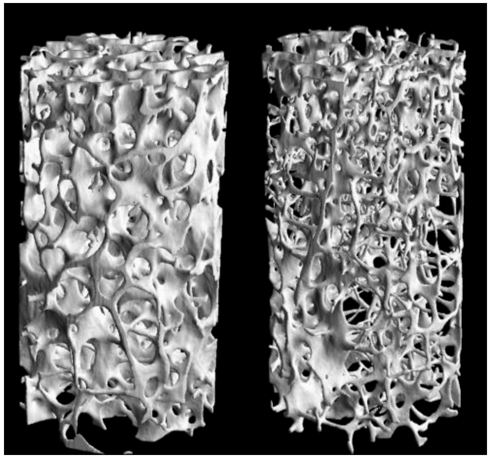


Timeline of quantitative assessment of bone

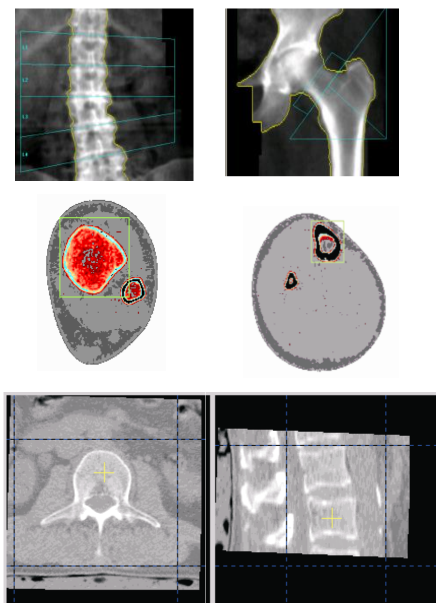


Clinical role of bone densitometry

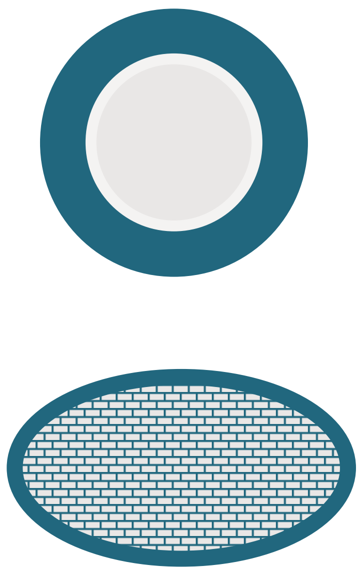
- Diagnosis of osteoporosis
- Prognosis - to predict fracture risk
- Therapeutic intervention
- Monitoring treatment / change



What are we measuring?

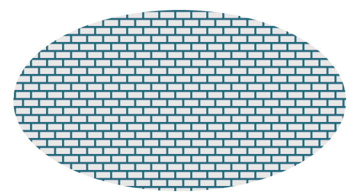


BMD_{TOTAL}



$BMD_{COMPARTMENT}$

Cortical



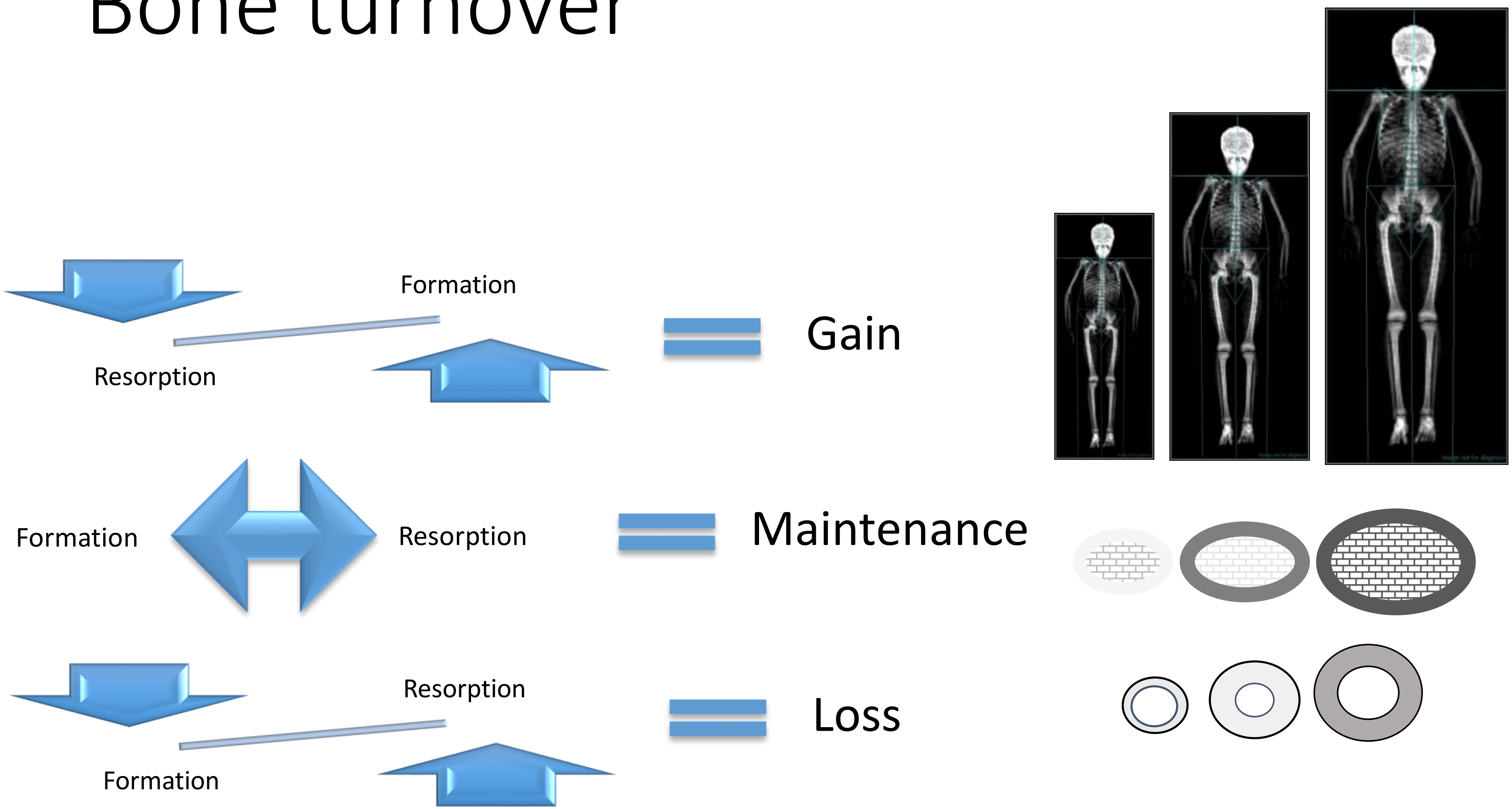
Trabecular

$BMD_{MATERIAL}$

		Cort	Trab	
DXA (g/cm²)	✓	✓	×	×
QCT(g/cm3)	✓	✓	✓	✓ (CtTBMD)

Adapted from Rauch & Schonau JBMR 2001

Bone turnover



Bone 87 (2016) 19–26

Contents lists available at ScienceDirect

Bone

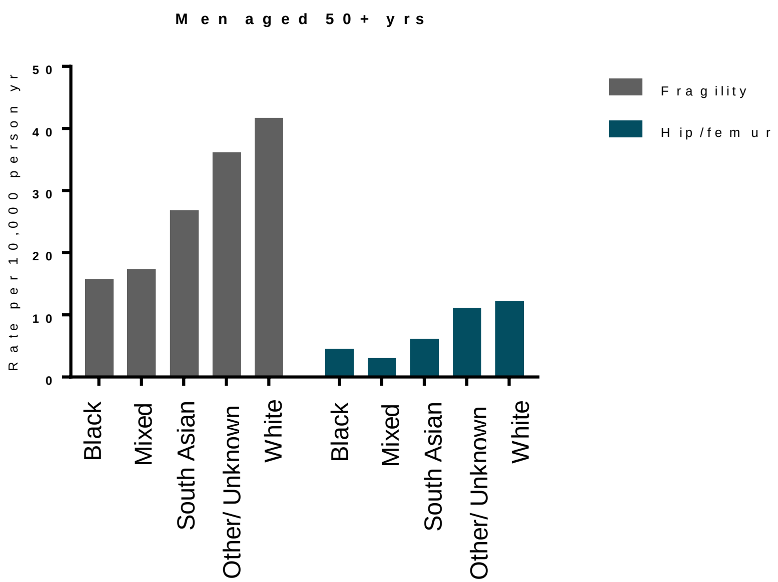
journal homepage: www.elsevier.com/locate/bone

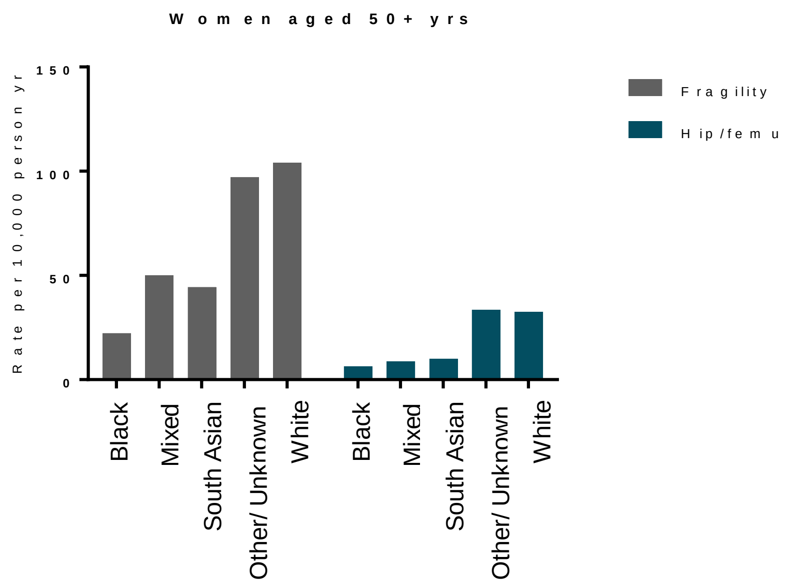
National Institute for Health Research

National Osteoporosis Society
30th Anniversary

Epidemiology of fractures in the United Kingdom 1988–2012: Variation with age, sex, geography, ethnicity and socioeconomic status

Elizabeth M. Curtis [a], Robert van der Velde [b], Rebecca J. Moon [a,c], Joop P.W. van den Bergh [b,d], Piet Geusens [e,f], Frank de Vries [g,h], Tjeerd P. van Staa [h,i], Cyrus Cooper [a,j,k,*,1], Nicholas C. Harvey [a,j,1]





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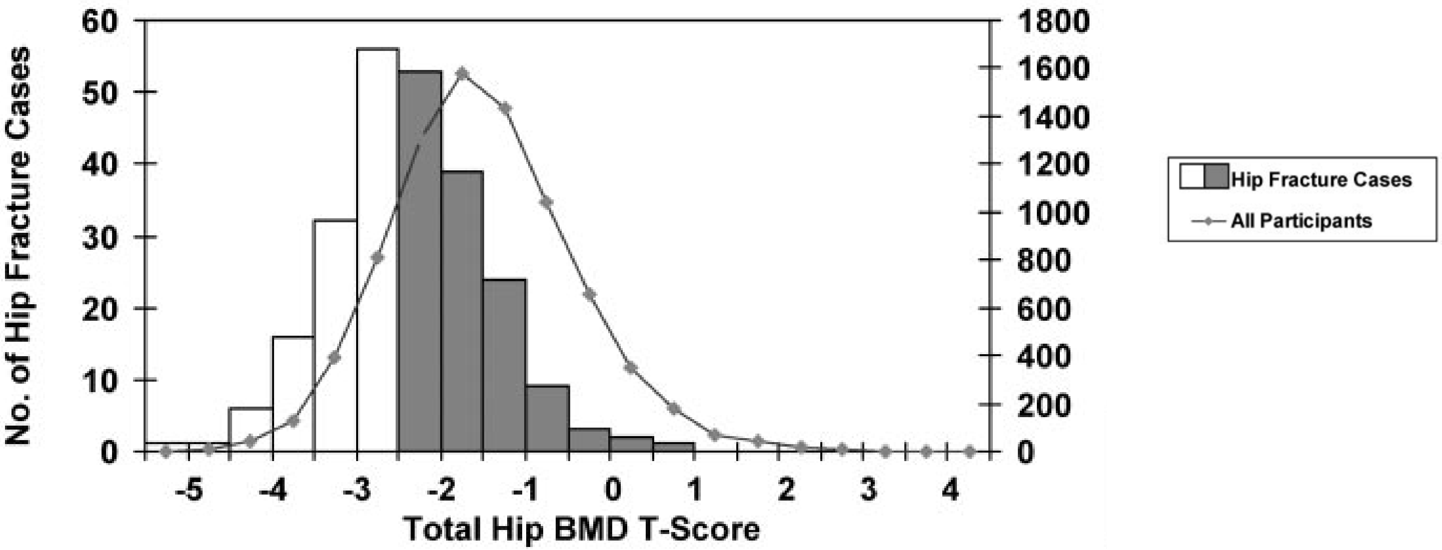
BMC/BMD & Fracture risk

- Bone mass (70%) : Independent predictor of fracture risk
- Adults: 1SD↓ ≈ 1 ½ to 3-fold↑
- Children:1SD↓ ≈ 2-fold↑
- > 50% individuals who fracture (excluding severe trauma do not have osteoporosis (T score < -2.5)

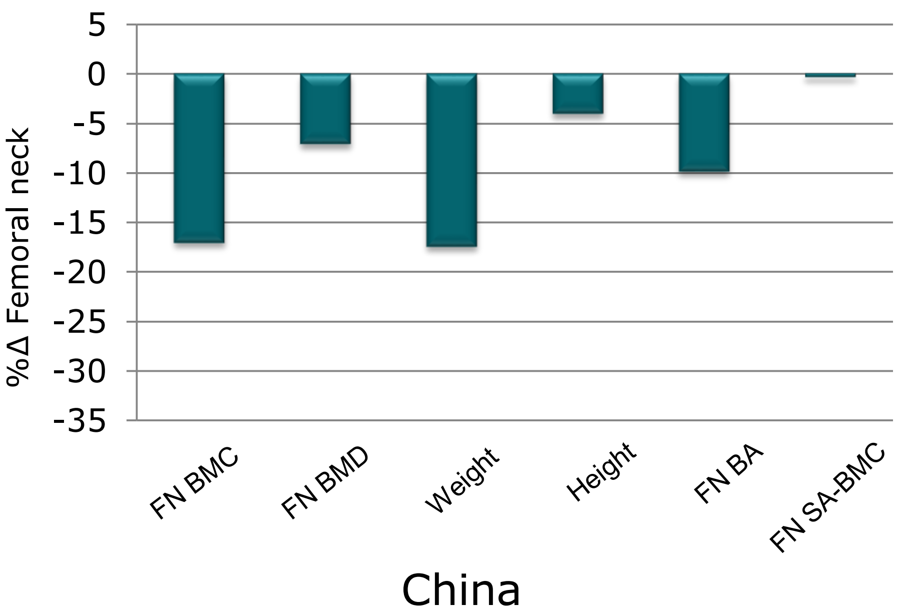


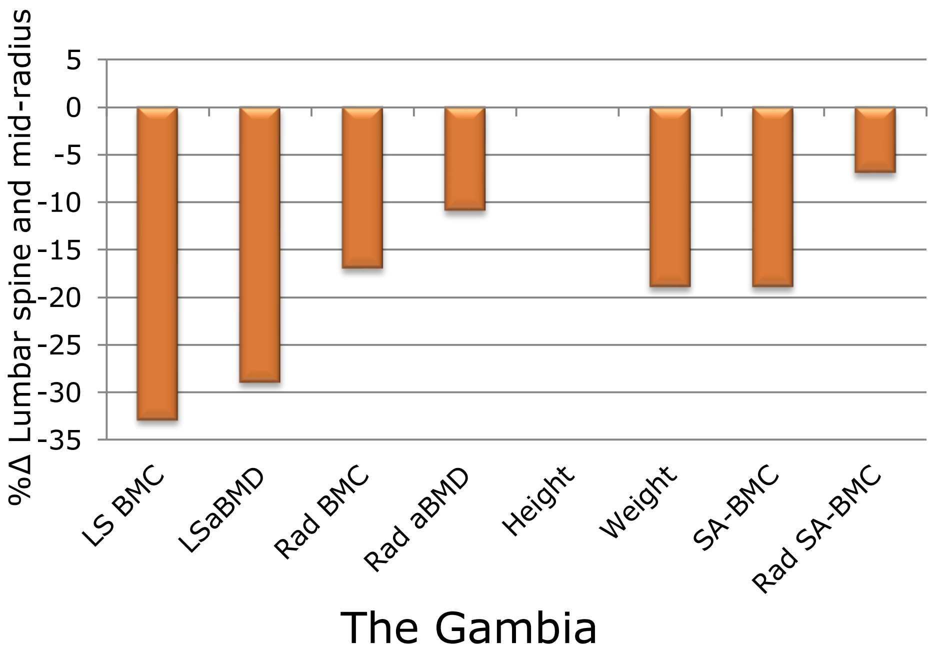
Compston et al 1995 BMJ 310: 1507-1510
Goulding et al. 2000 JBMR 15(10):2011-2018
Wainwright SA et al, JCEM 2005

BMC/BMD & Fracture risk

Does not apply across populations

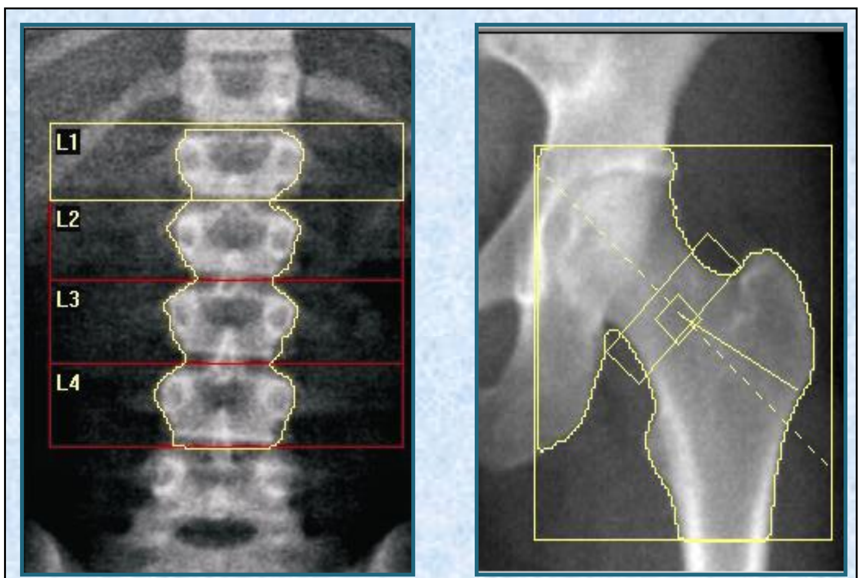
- Low BMC/BMD in The Gambia & China
- Importance of bone and body size
- Low risk of fragility fracture in The Gambia & China

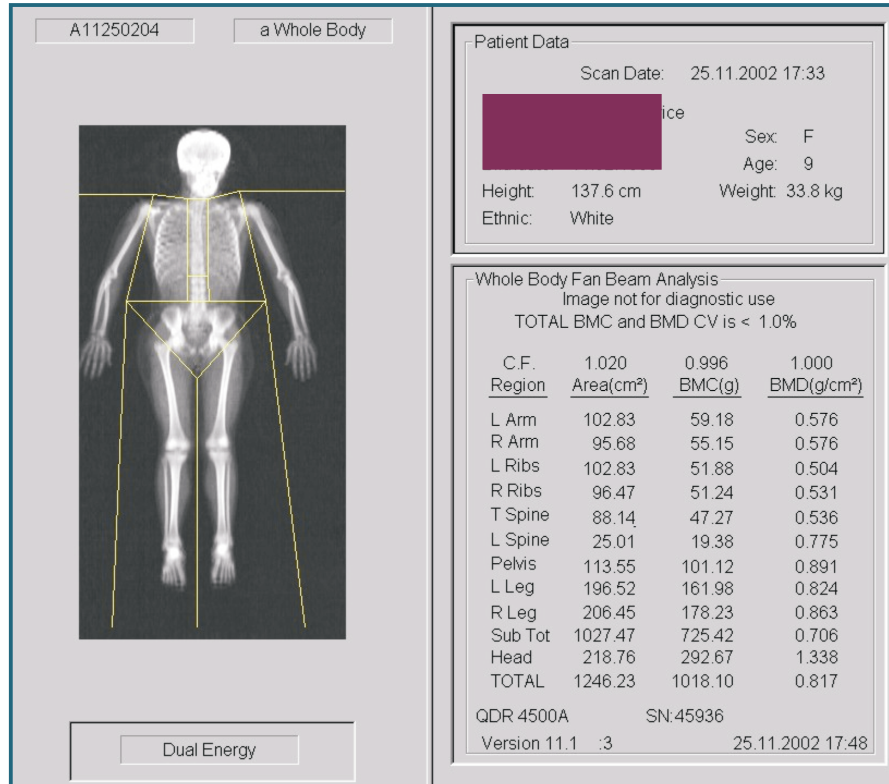




Prentice, Parsons, Cole. AJCN 1994 ; Aspray et al, JBMR 1996
Dibba, Prentice et al. Ann Human Biol 1999; Yan, Prentice et al. Bone 2004

Dual Energy X-ray Absorptiometry




A11250204 | a Whole Body

Dual Energy

Patient Data

Scan Date: 25.11.2002 17:33

[redacted] ice

Sex: F

Age: 9

Height: 137.6 cm

Weight: 33.8 kg

Ethnic: White

Whole Body Fan Beam Analysis

Image not for diagnostic use

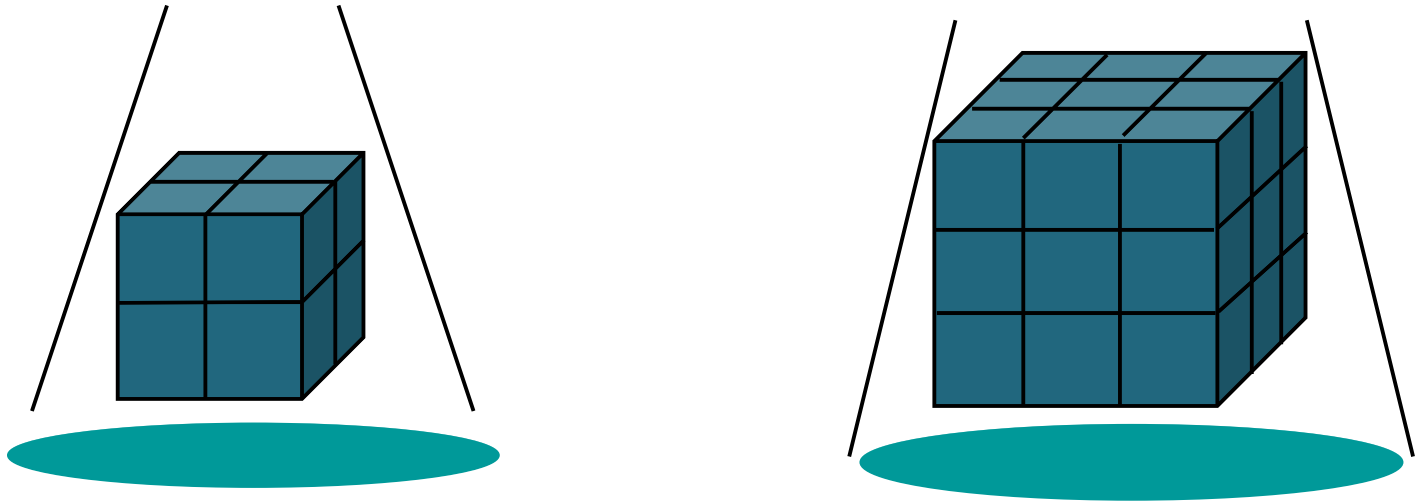
TOTAL BMC and BMD CV is < 1.0%

C.F.	1.020	0.996	1.000
Region	Area(cm²)	BMC(g)	BMD(g/cm²)
L Arm	102.83	59.18	0.576
R Arm	95.68	55.15	0.576
L Ribs	102.83	51.88	0.504
R Ribs	96.47	51.24	0.531
T Spine	88.14	47.27	0.536
L Spine	25.01	19.38	0.775
Pelvis	113.55	101.12	0.891
L Leg	196.52	161.98	0.824
R Leg	206.45	178.23	0.863
Sub Tot	1027.47	725.42	0.706
Head	218.76	292.67	1.338
TOTAL	1246.23	1018.10	0.817

QDR 4500A SN:45936

Version 11.1 :3 25.11.2002 17:48

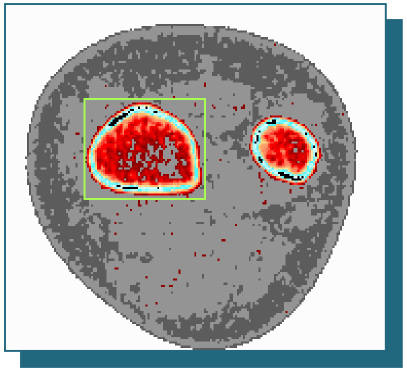
Size dependence of DXA

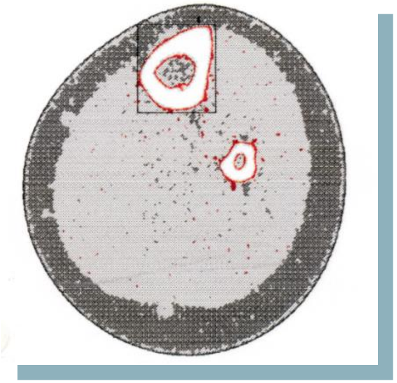


Mineral weight (g)	16	54
Volume (cm^3)	8	27
Projected area (cm^2)	4	9
Volumetric BMD(g/cm^3)	2	2
Areal BMD (g/cm^2)	4	6

Bone strength

- Structural integrity
- Size
- Morphometry
- Internal architecture
- Bone mass
- Loading conditions
- Organisation of material

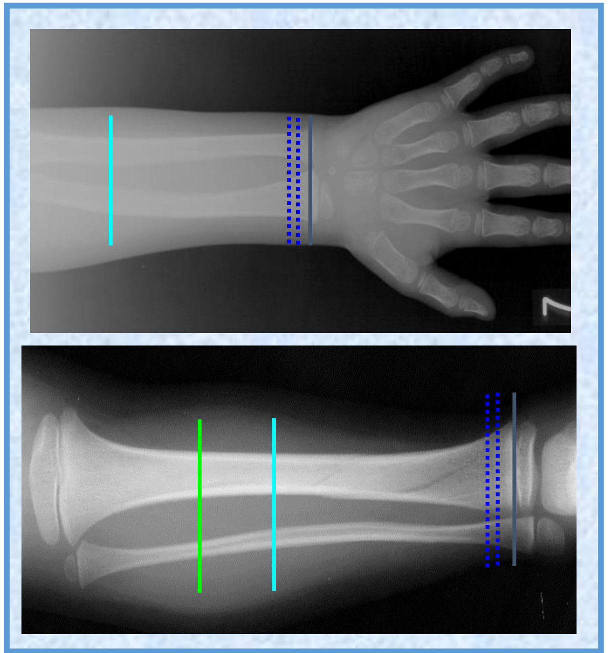


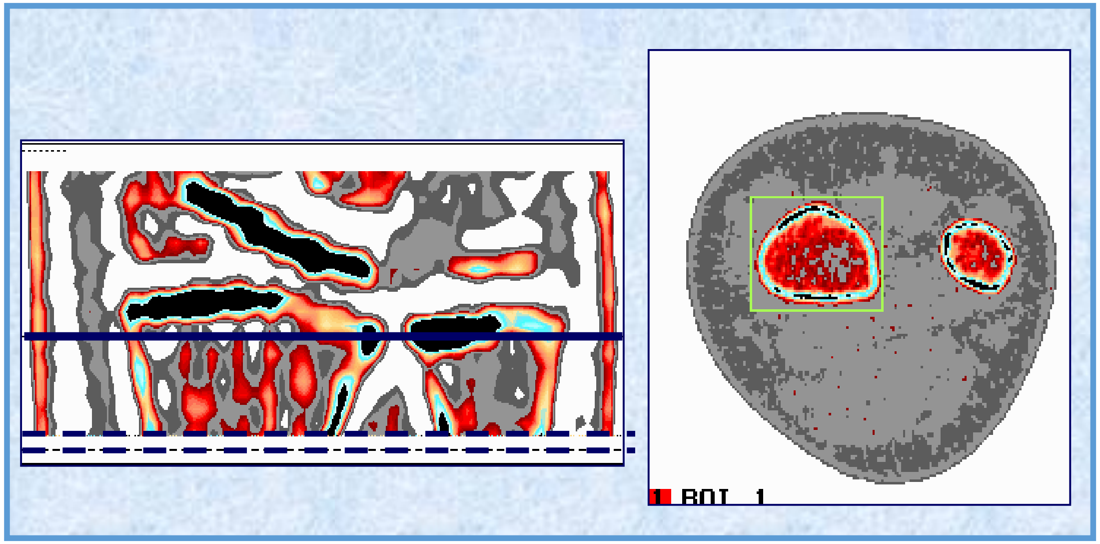


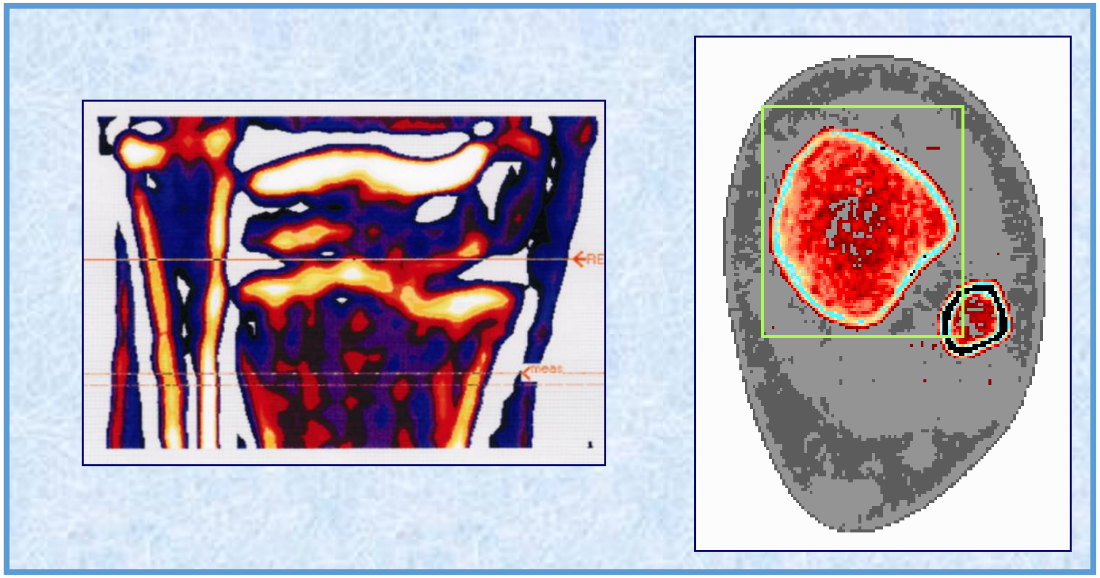
Bone mass (70%) : Independent predictor of fracture risk

Adults: 1SD ↓	≈ 1 ½ to 3-fold ↑	Compston et al 1995 BMJ 310: 1507-1510
Children:1SD ↓	≈ 2-fold ↑	Goulding et al. 2000 JBMR 15(10):2011-2018

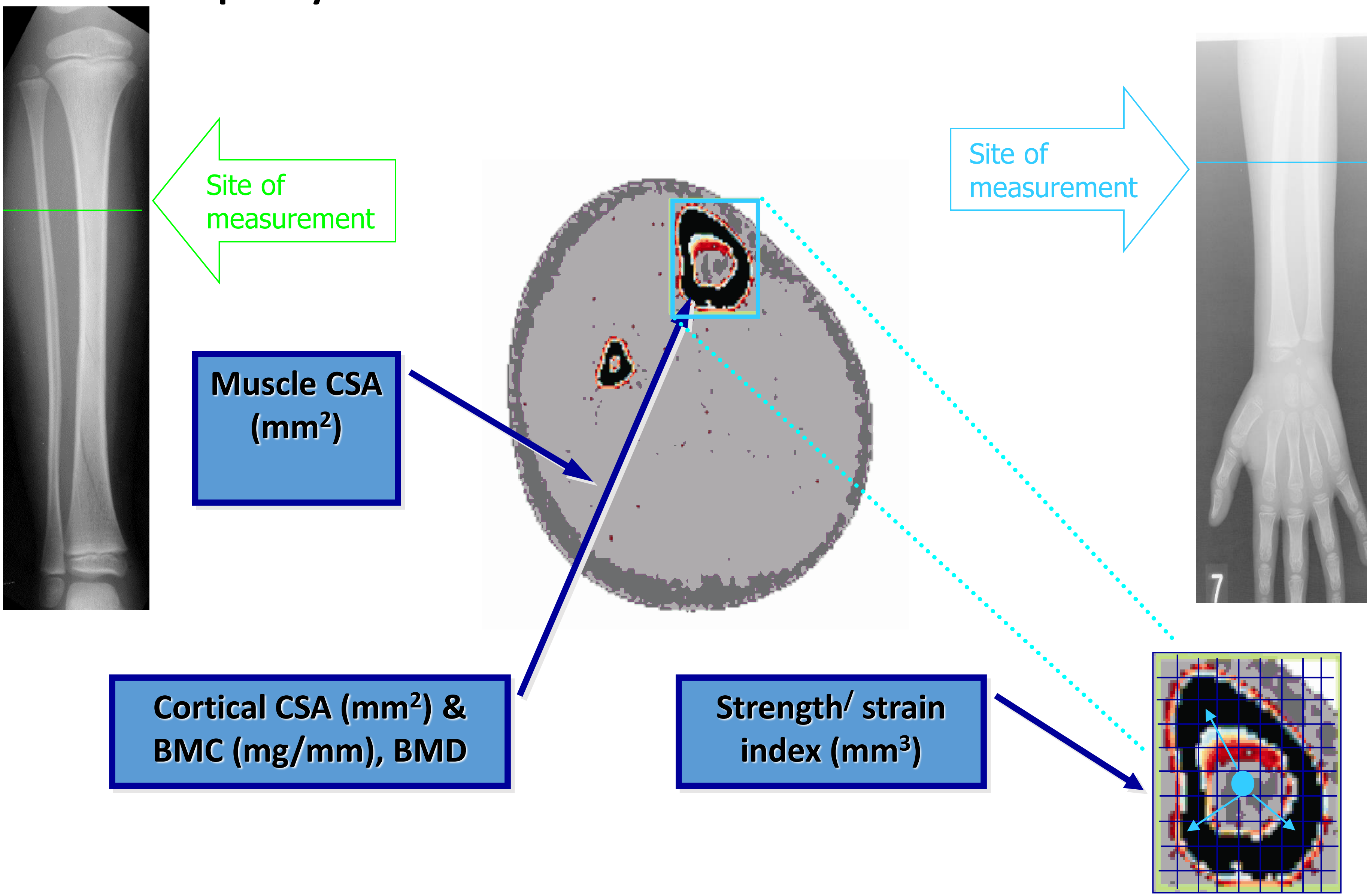
Epiphysis outcome measures





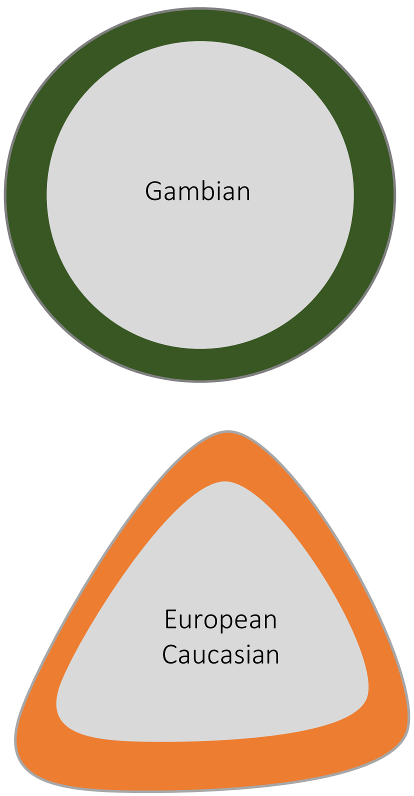


Diaphysis outcome measures



Ethnic differences in bone geometry in pre-menopausal women

Low vs moderate/high Ca



	G vs EC	BA vs EC
vBMD	↑	
BMC	↓	
Med area	↑	
Cort thk	↓	
SSI	↔	

vBMD = cortical volumetric bone mineral density, BMC = bone mineral content, Med area = medullary area, Cort thk = cortical thickness, SSI = bone strength

Ward et al; Bone 2007; 41: 117-121

Laskey et al; J Clin Densitom. 13(3): 247-55

Ward, Proc Nutr Soc (2012), 71, 27-37

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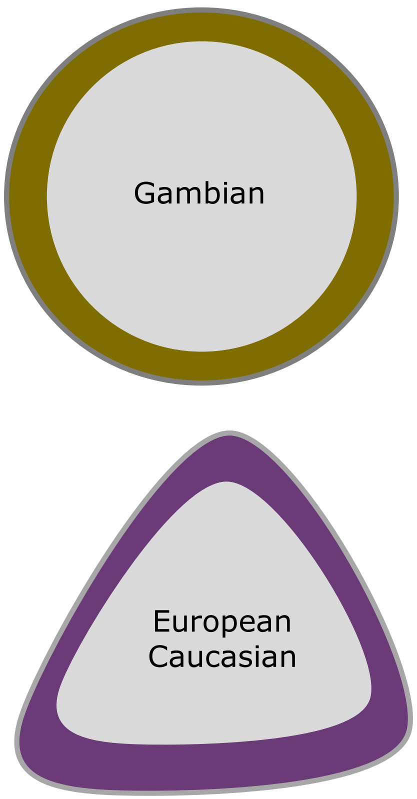
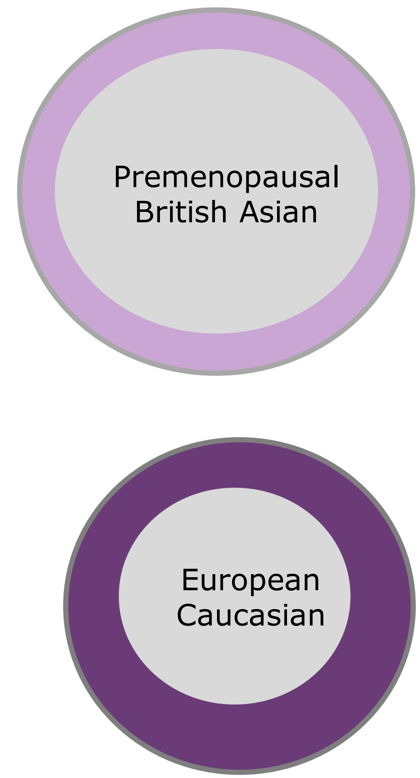


Low vs adequate 25(OH)D



	G vs EC	**BA vs EC**
vBMD	↑	↓
BMC	↓	↓
Med area	↑	↑
Cort thk	↓	↓
SSI	$\boxed{\leftrightarrow}$	$\boxed{\leftrightarrow}$

vBMD = cortical volumetric bone mineral density, BMC = bone mineral content, Med area = medullary area, Cort thk = cortical thickness, SSI = bone strength

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Ward et al; Bone 2007; 41: 117-121

Laskey et al; J Clin Densitom. **13**(3): 247-55

Ward, Proc Nutr Soc (2012), 71, 27-37

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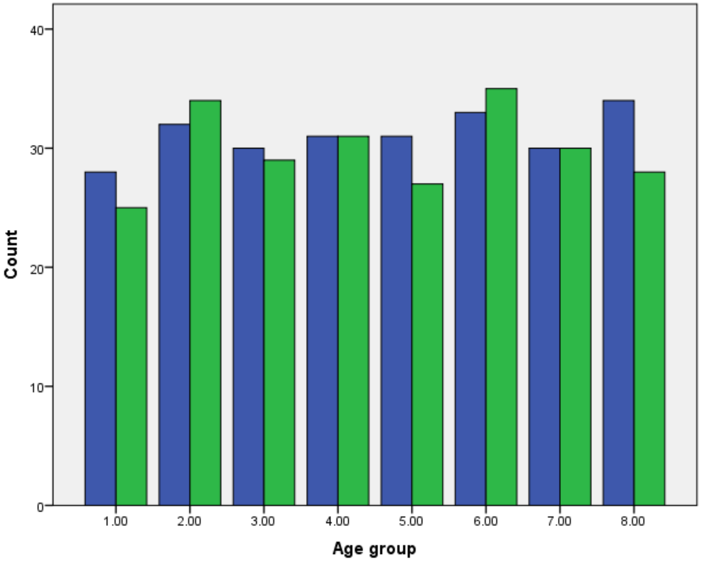
Global NCD risk - GamBAS

Growth, adult environment, musculoskeletal phenotype and fracture risk in Sub-Saharan Africa

AIM

- To characterise the individual change in bone strength (BMC/D, bone geometry) during ageing in Gambian males and females
- Define ageing process in muscle
- Understanding the interaction between mechanical and non-mechanical factors (nutrition, lifestyle, hormones)

- Prospective study, M&F, 8, 5yr age range bands - 40 to 75+. Stratified by age band and gender, randomised follow-up 1.5 to 2 years. 240 per gender, ~ 30 per age band
- DXA (+LVA), pQCT, jumping mechanography and grip strength. Fasting bloods, 2hr & 24hr urine, lifestyle and medical history
- Baseline data collection complete October 2012; n=488 (227M, 262F).

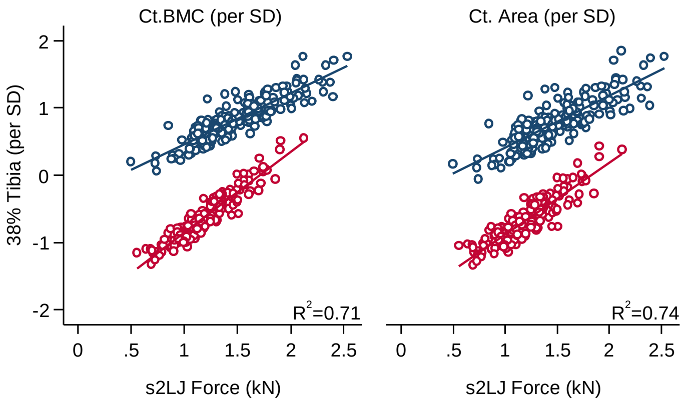


Muscle and bone

Table 3: Sub-analysis of participants who were "able" and "unable" to perform m1LH and s2LJ tests

	n	Able	n	Unable	p-value
Body Habitus					
Sex (n, M/F)	362	185/177	126	54/72	0.111
Age (yr)	362	57.1 ± 10.6	126	72.0 ± 10.5	<**0.0001**
Body Weight (Kg)	362	58.4 ± 10.6	126	54.0 ± 10.0	**0.0001**
Height (cm)	362	164.3 ± 8.3	126	160.6 ± 9.1	<**0.0001**
BMI (kg/cm^2)	362	21.6 ± 3.5	126	20.9 ± 3.1	0.052
Whole body Fat Mass (kg)	358	12.7 ± 8.2	119	12.8 ± 7.5	0.913
Whole body Fat Mass (%BW)	358	22.3 ± 12.2	119	24.1 ± 11.7	0.148
Whole body Lean Mass (kg)	358	42.9 ± 8.9	119	38.7 ± 7.7	<**0.0001**
Appendicular Lean mass (kg)	362	19.8 ± 4.8	124	17.2 ± 4.0	<**0.0001**
38% Tibia					
Ct. BMC (mg/mm)	326	314.7 ± 76.3	120	271.1 ± 80.3	<**0.0001**
Ct. Area (mm^2)	327	261.8 ± 58.6	120	229.8 ± 60.7	<**0.0001**
CSA (mm^2)	326	411.1 ± 72.3	120	389.8 ± 62.3	**0.005**
CSMI (mm^4)	326	13063.7 ± 5241.0	120	10911.6 ± 4152.7	**0.0001**
SSI (mm^4)	326	1686.8 ± 455.9	120	1489.4 ± 416.7	<**0.0001**
66% Tibia					
CSMA (mm^2)	319	5368.8 ± 1131.3	118	4665.2 ± 1077.0	<**0.0001**
Muscle Density (mg/cm^3)	311	70.4 ± 2.8	117	68.5 ± 2.8	<**0.0001**
Grip strength (kg)	362	27.6 ± 9.3	126	20.1 ± 7.2	<**0.0001**
CRT					
Relative force (N/kg)	357	1.4 ± 0.3	126	1.3 ± 0.4	0.352
Relative power (W/kg)	357	8.0 ± 2.8	126	5.8 ± 1.7	<**0.0001**
Time per test (s)	357	4.7 ± 1.5	126	6.3 ± 1.9	<**0.0001**

All values are mean ± SD. Bold indicates p<0.05. BMI, body mass index; BW, body weight; Ct, cortical; BMC, bone mineral content; CSA, cross-sectional area; CSMI, cross-sectional moment of inertia; SSI, stress strain index; CSMA, cross-sectional muscle area; s2LJ, single two-legged jump; SD, standard deviation; m1LH, multiple one leg hop; CRT, chair rise test.



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How do we analyse a pQCT scan?

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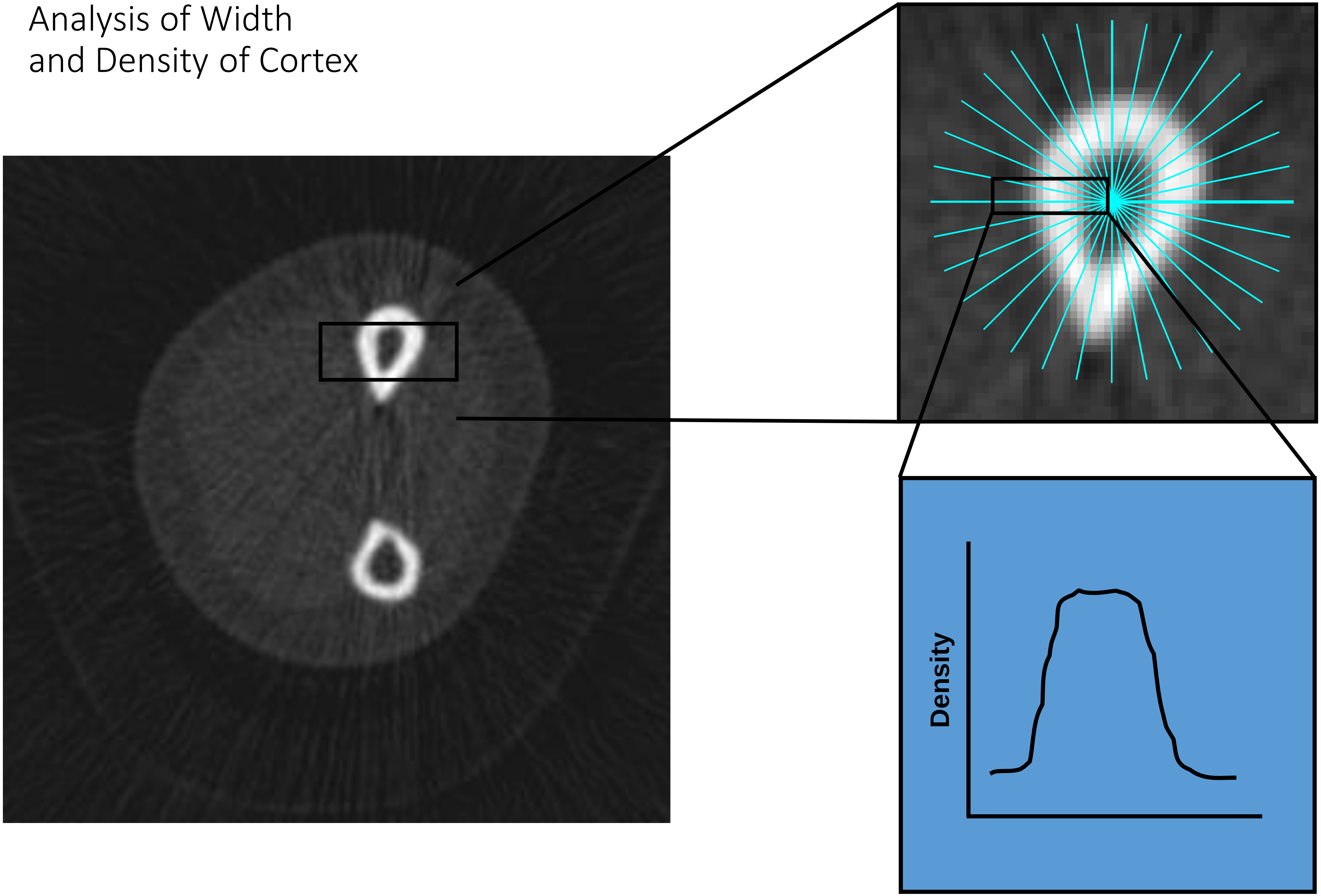
Objectives

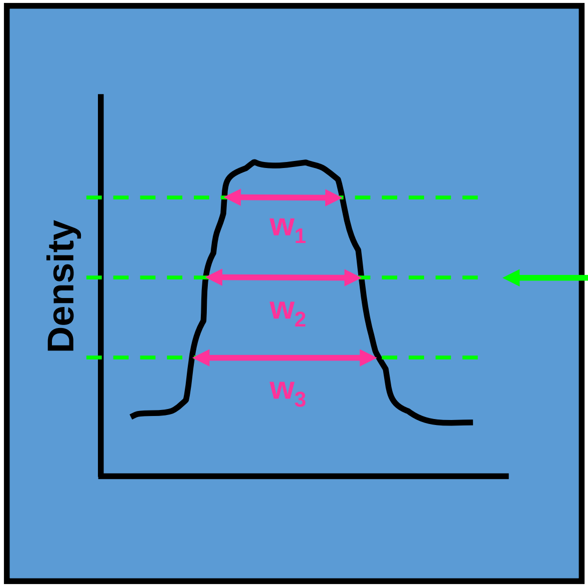
- Understand different methods of assessing bone in children and adults
- Optimise technique when performing pQCT
- Understand how to process and analyse the outputs generated by pQCT
- Understand and interpret assessments of bone age

Analysis of Width and Density of Cortex

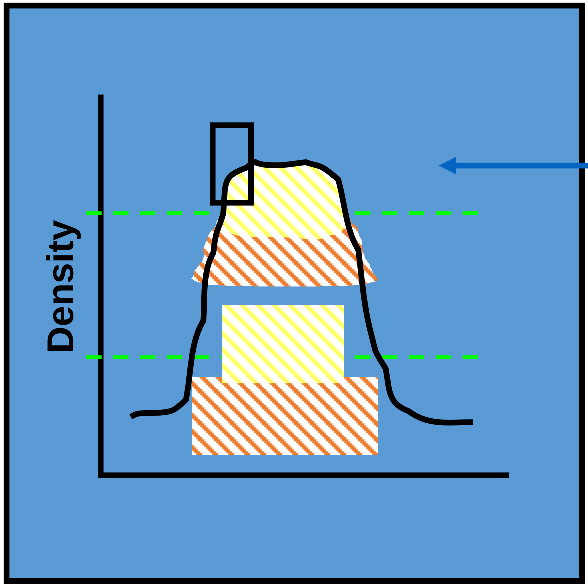


T. N. Hangartner, Wright State University, Dayton, OH

Thresholding of Image



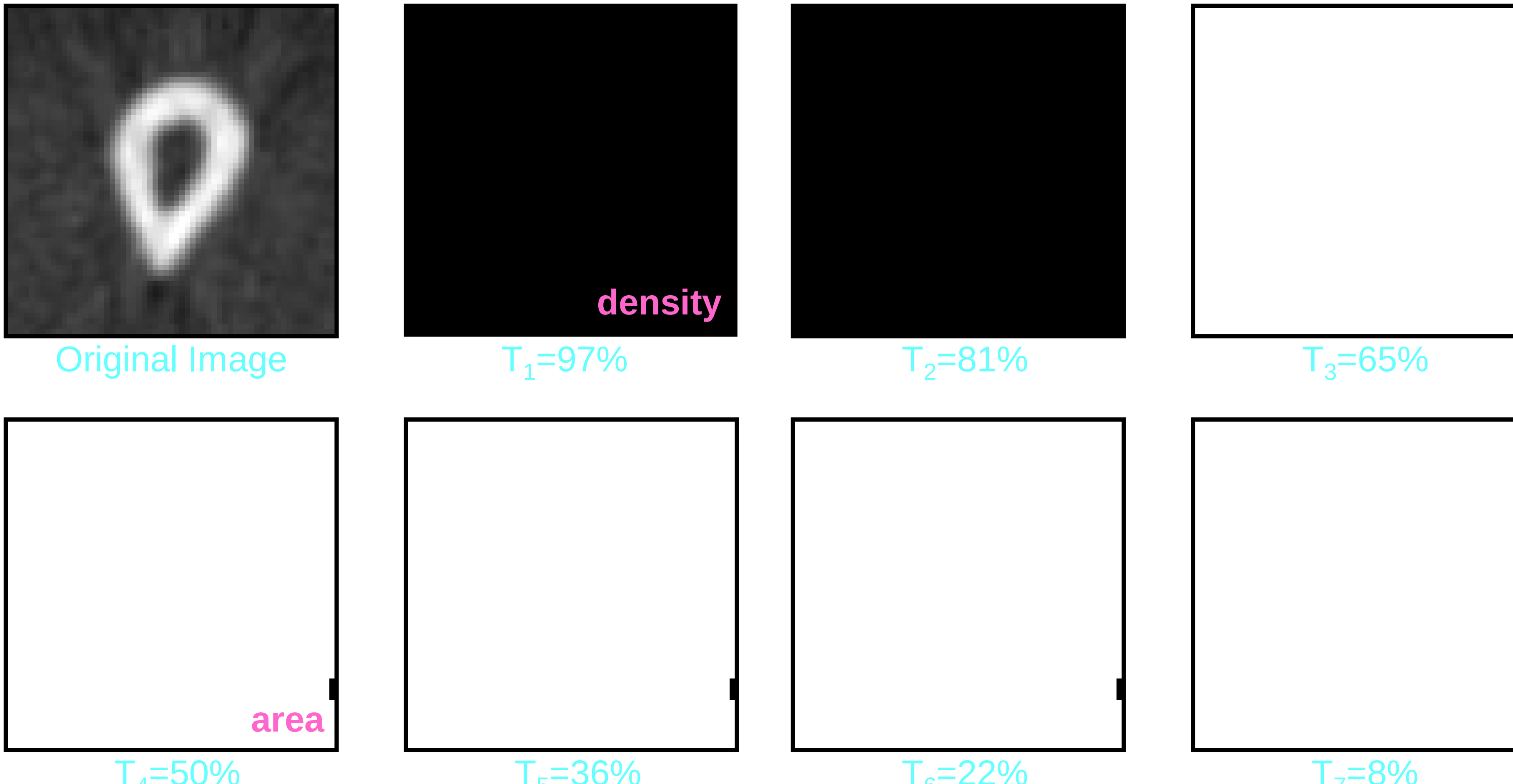
correct threshold for width



correct region for density

- Need separate approach for analyzing cortical width and cortical density.

Threshold Influences Measured Size and Density



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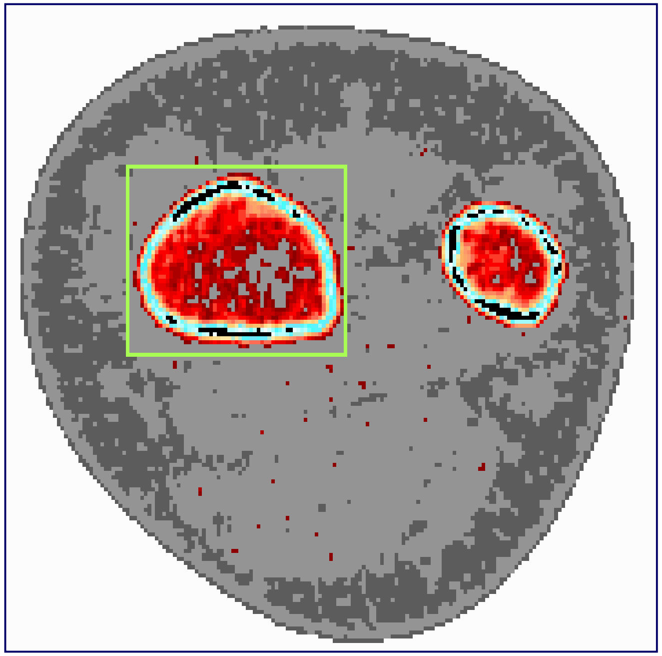
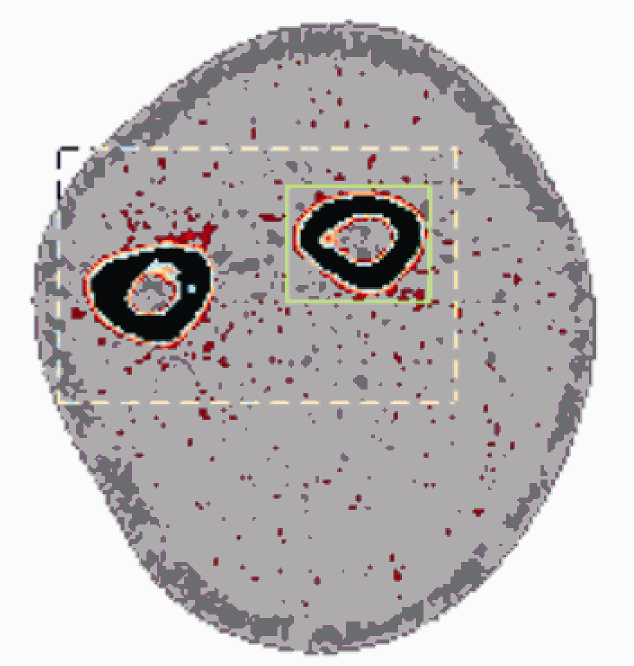
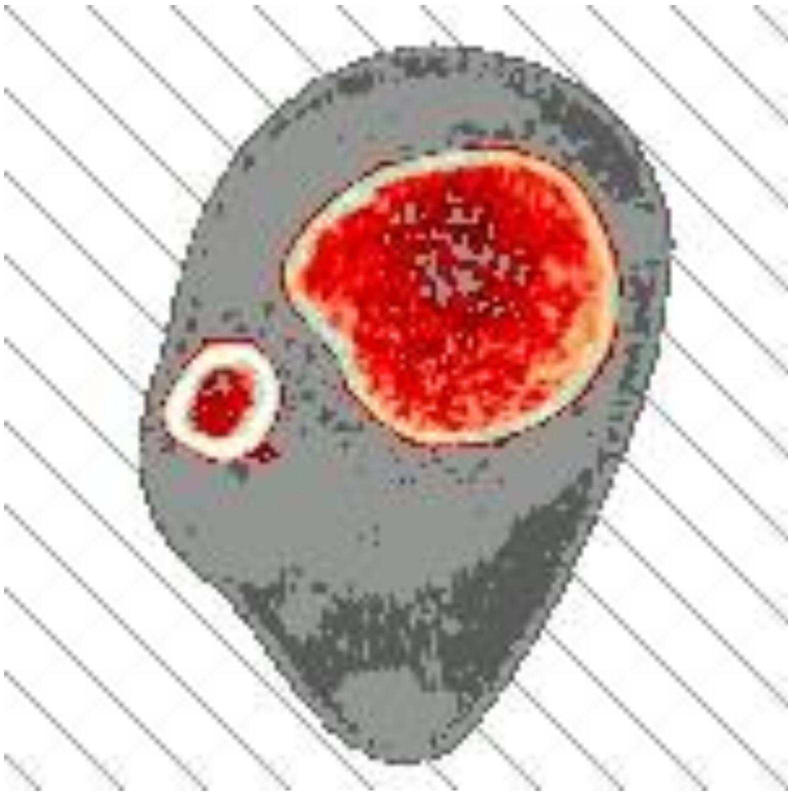
Regions of Interest (ROI)



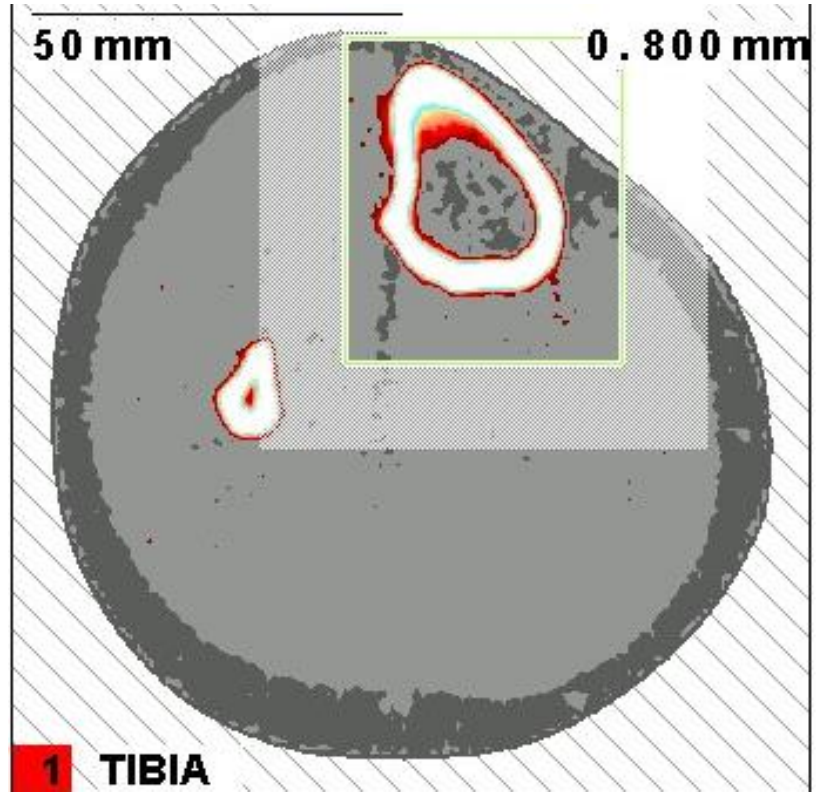


Radius

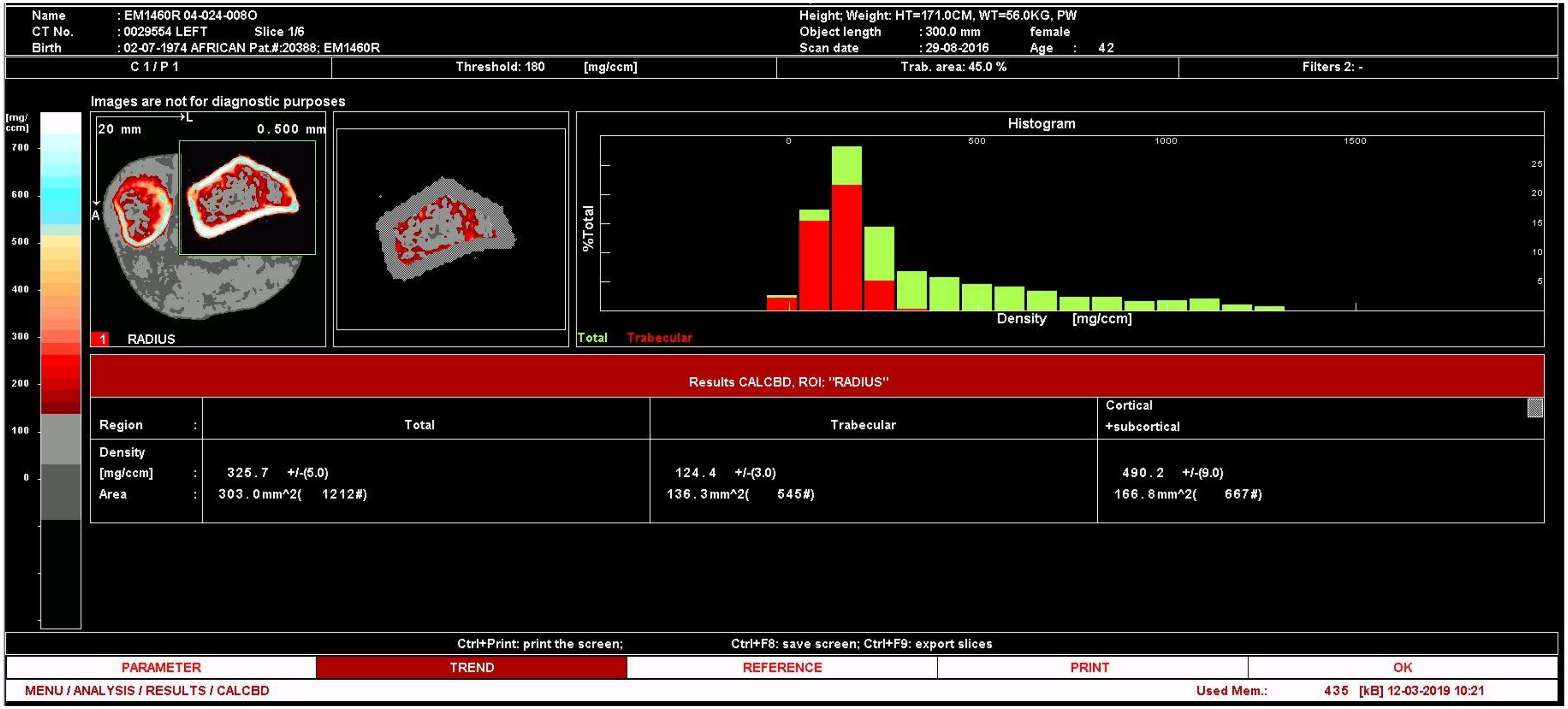
Regions of Interest (ROI)



Tibia



CALCBD

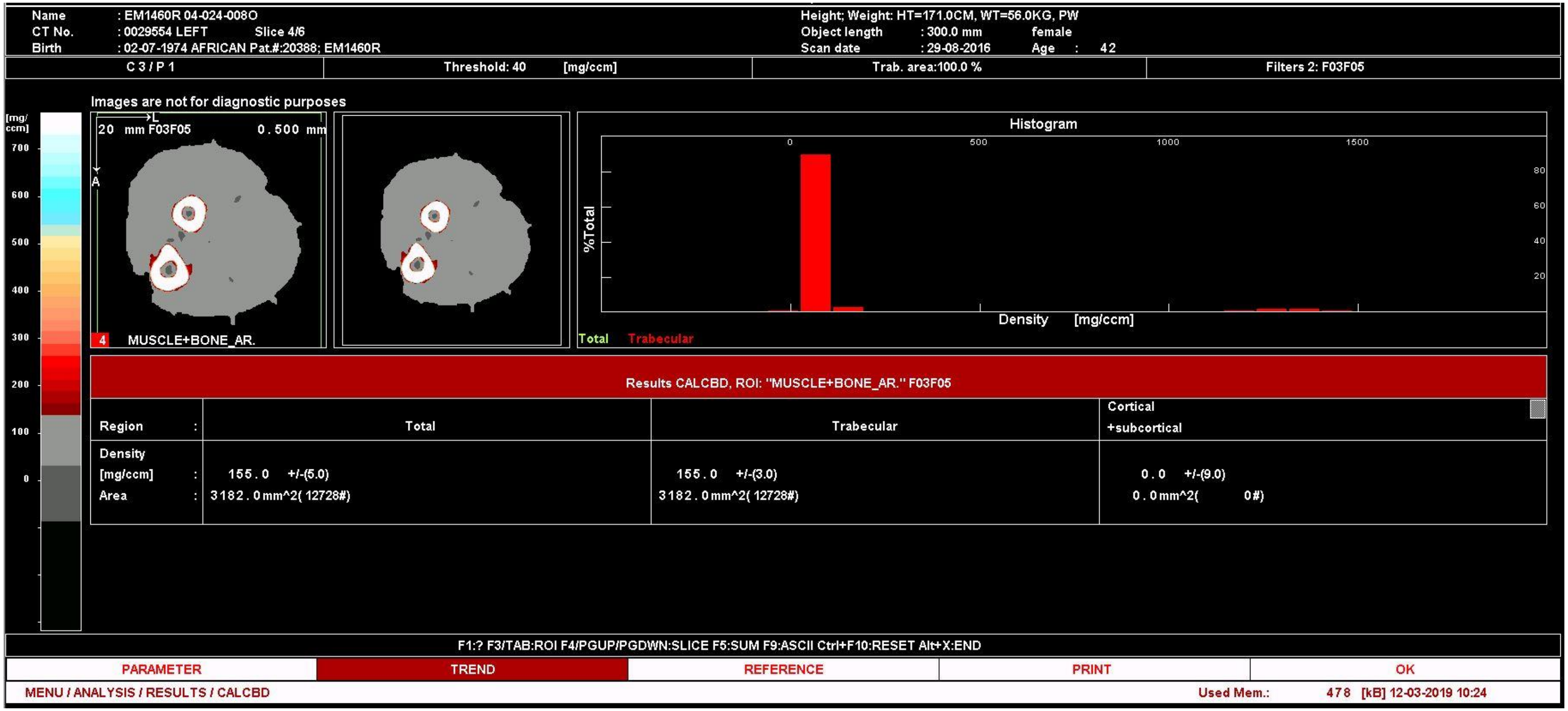


Name : EM1460R 04-024-008O
CT No. : 0029554 LEFT Slice 1/6
Birth : 02-07-1974 AFRICAN Pat.#:20388; EM1460R
Height; Weight: HT=171.0CM, WT=56.0KG, PW
Object length : 300.0 mm female
Scan date : 29-08-2016 Age : 42
C 1 / P 1
Threshold: 180 [mg/ccm]
Trab. area: 45.0 %
Filters 2: -
Images are not for diagnostic purposes
20 mm
0.500 mm
1 RADIUS
Histogram
%Total
Density [mg/ccm]
Total Trabecular
Results CALCBD, ROI: "RADIUS"
Region : Total Trabecular Cortical +subcortical
Density [mg/ccm] : 325.7 +/-(5.0) 124.4 +/-(3.0) 490.2 +/-(9.0)
Area : 303.0mm^2(1212#) 136.3mm^2(545#) 166.8mm^2(667#)
Ctrl+Print: print the screen; Ctrl+F8: save screen; Ctrl+F9: export slices
PARAMETER
TREND
REFERENCE
PRINT
OK
MENU / ANALYSIS / RESULTS / CALCBD
Used Mem.: 435 [kB] 12-03-2019 10:21

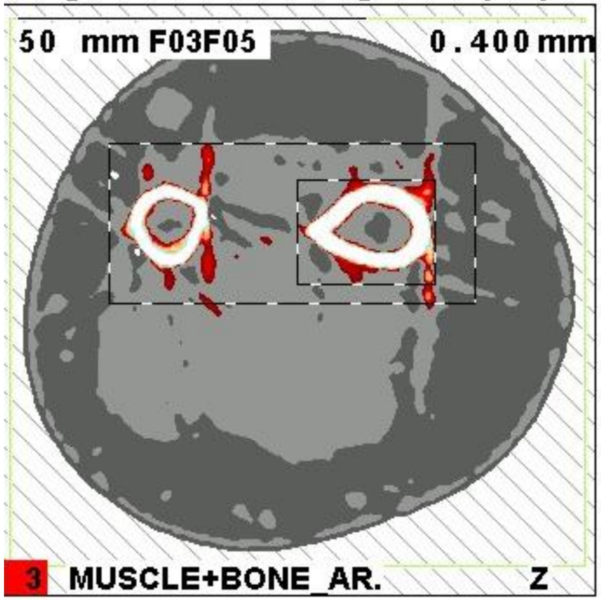
CORTBD

Name : EM1460R 04-024-008O
CT No. : 0029554 LEFT Slice 2/6
Birth : 02-07-1974 AFRICAN Pat.#:20388; EM1460R
Height Weight: HT=171.0CM, WT=56.0KG, PW
Object length : 300.0 mm female
Scan date : 29-08-2016 Age : 42
Threshold: 711 [mg/ccm]
Separation mode: 1
Filters 2: -
Images are not for diagnostic purposes
20 mm
0.500 mm
RADIUS
Histogram
%Total
Density [mg/ccm]
Results CORTBD, ROI: "RADIUS"
Density: 1264.0 [mg/ccm] +/-(9.0)
Area: 84.3mm^2(337#)
Attenuat.: 0.920 [1/cm]
F1:? F3/TAB:ROI F4/PGUP/PGDWN:SLICE F5:SUM F9:ASCII Ctrl+F10:RESET Alt+X:END
PARAMETER
TREND
PRINT
OK
MENU / ANALYSIS / RESULTS / CORTBD
Used Mem.: 436 [kB] 12-03-2019 10:22

Muscle


Name : EM1460R 04-024-008O
CT No. : 0029554 LEFT Slice 4/6
Birth : 02-07-1974 AFRICAN Pat.#:20388; EM1460R
Height; Weight: HT=171.0CM, WT=56.0KG, PW
Object length : 300.0 mm female
Scan date : 29-08-2016 Age : 42
C 3 / P 1
Threshold: 40 [mg/ccm]
Trab. area:100.0 %
Filters 2: F03F05
Images are not for diagnostic purposes
20 mm F03F05 0.500 mm
MUSCLE+BONE_AR.
Histogram
%Total
Density [mg/ccm]
Total Trabecular
Results CALCBD, ROI: "MUSCLE+BONE_AR." F03F05
Region : Total Trabecular Cortical +subcortical
Density [mg/ccm] : 155.0 +/-(5.0) 155.0 +/-(3.0) 0.0 +/-(9.0)
Area : 3182.0mm^2(12728#) 3182.0mm^2(12728#) 0.0mm^2(0#)
F1:? F3/TAB:ROI F4/PGUP/PGDWN:SLICE F5:SUM F9:ASCII Ctrl+F10:RESET Alt+X:END
PARAMETER TREND REFERENCE PRINT OK
MENU / ANALYSIS / RESULTS / CALCBD
Used Mem.: 478 [kB] 12-03-2019 10:24

Muscle & bone - example



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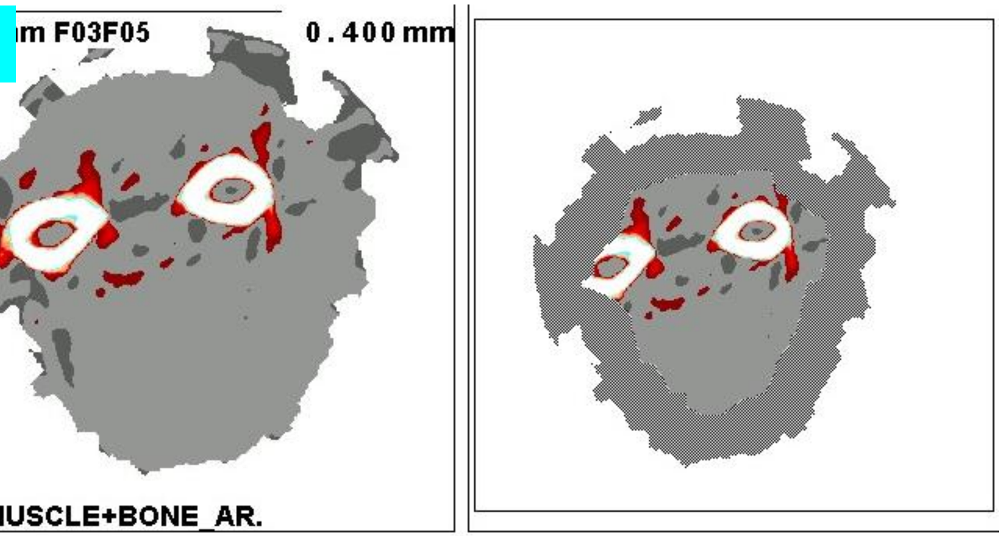

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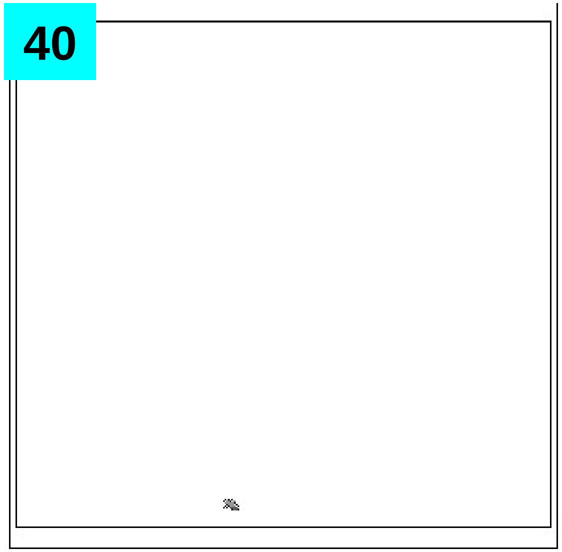

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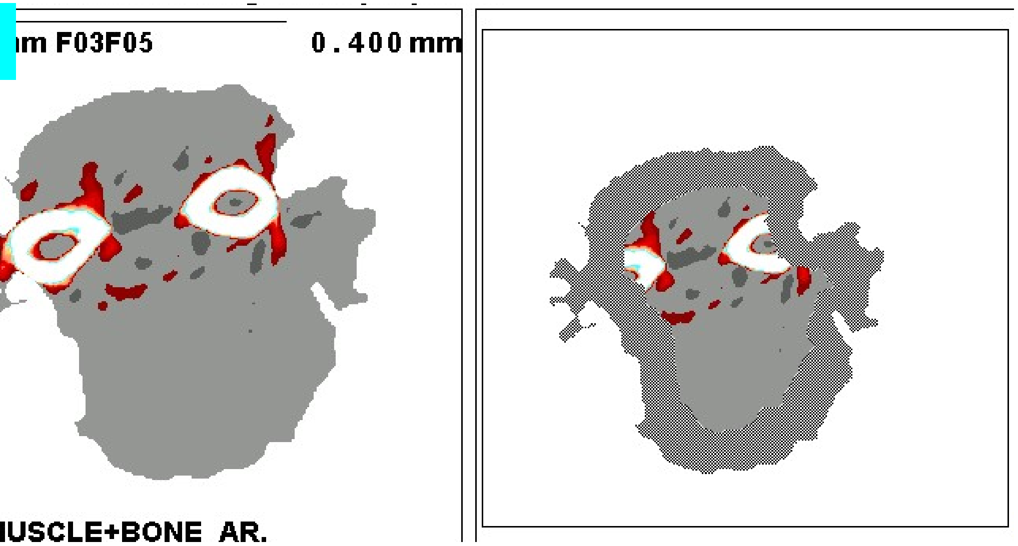
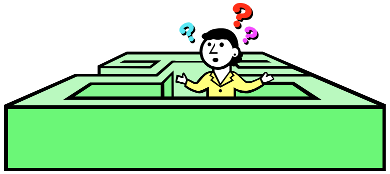
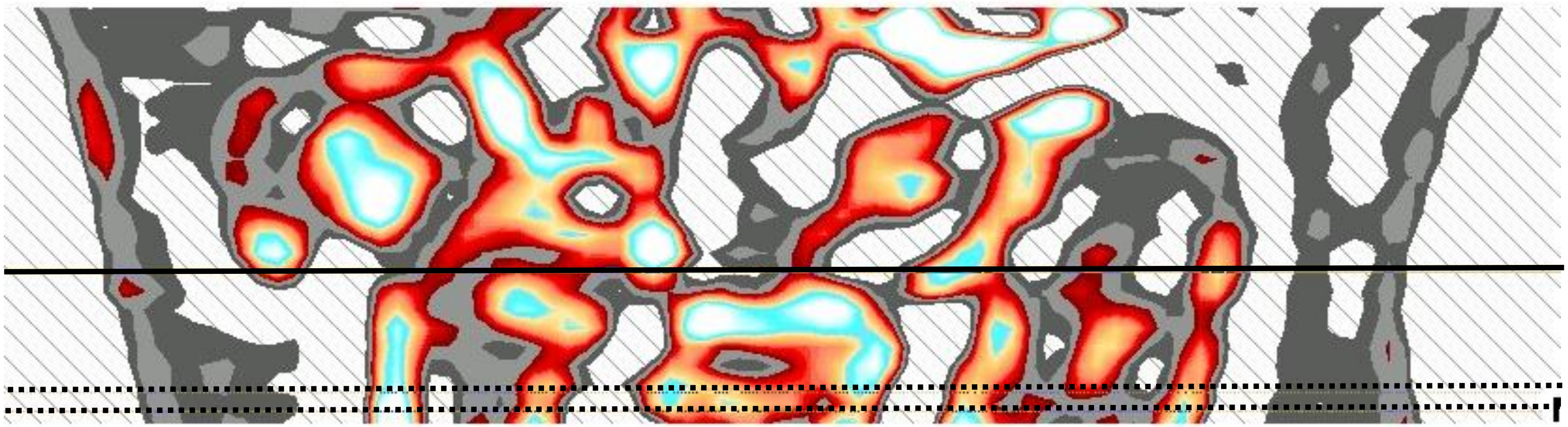


Examples of anomalies

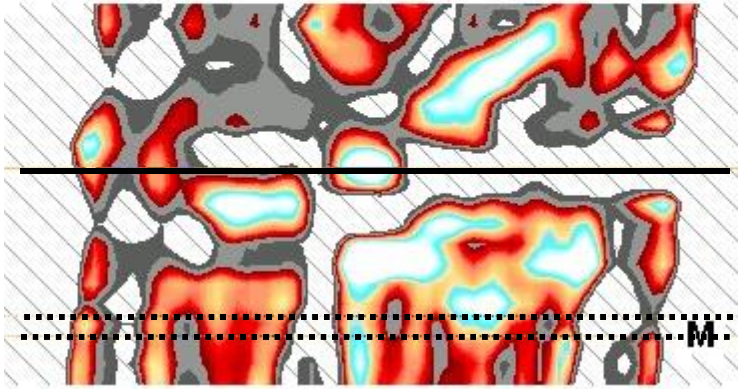


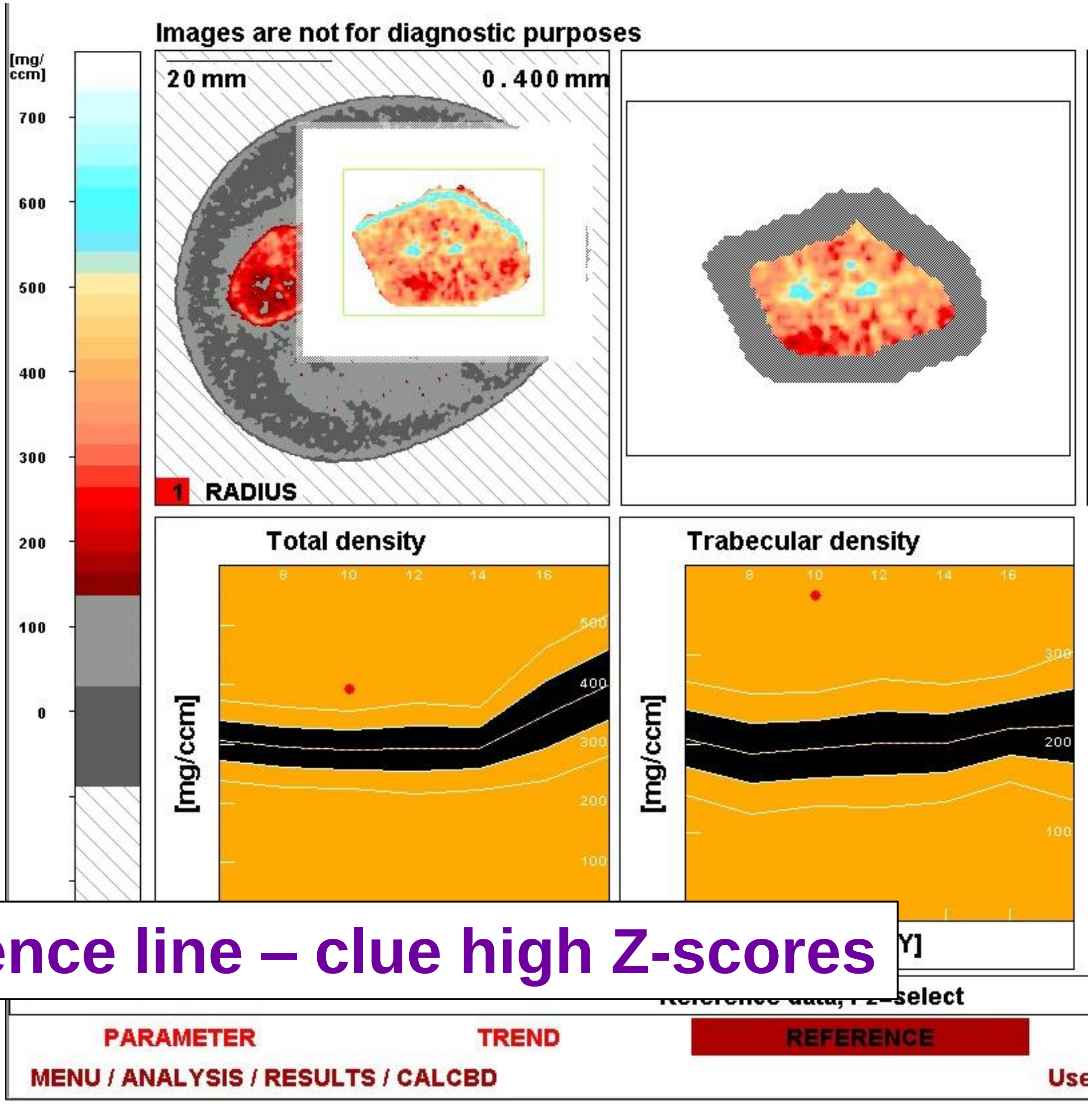
(1)



Madelungs deformity – Turners syndrome

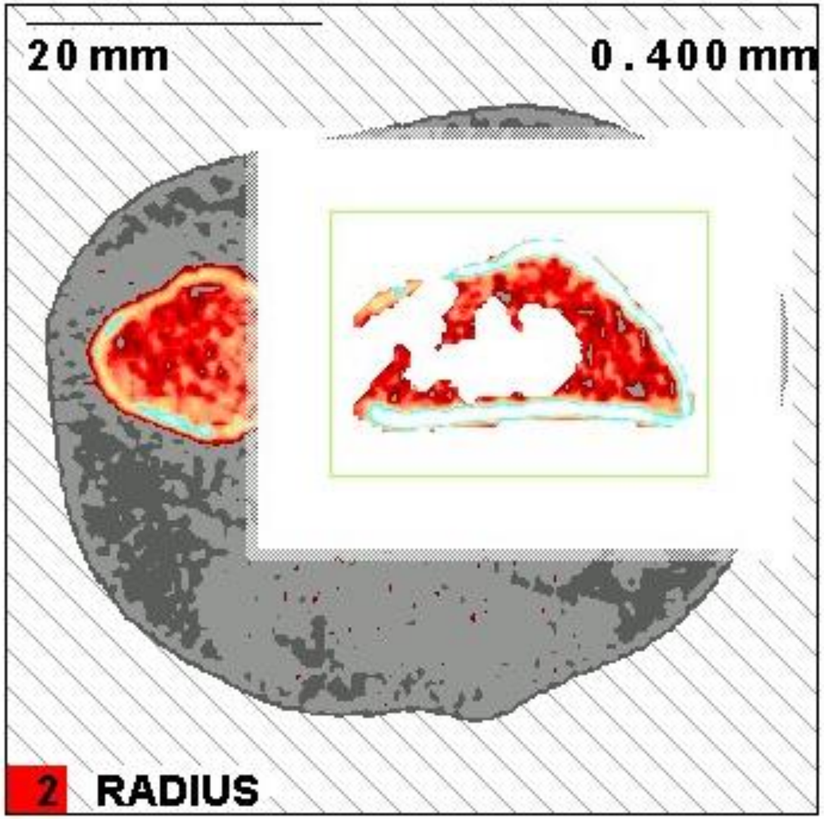
(2)

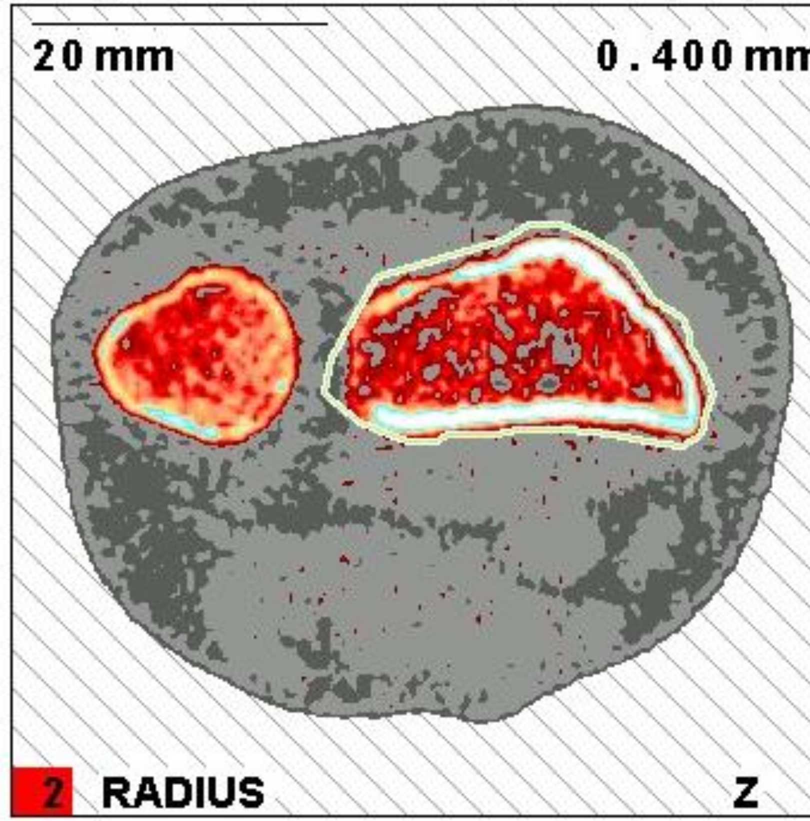




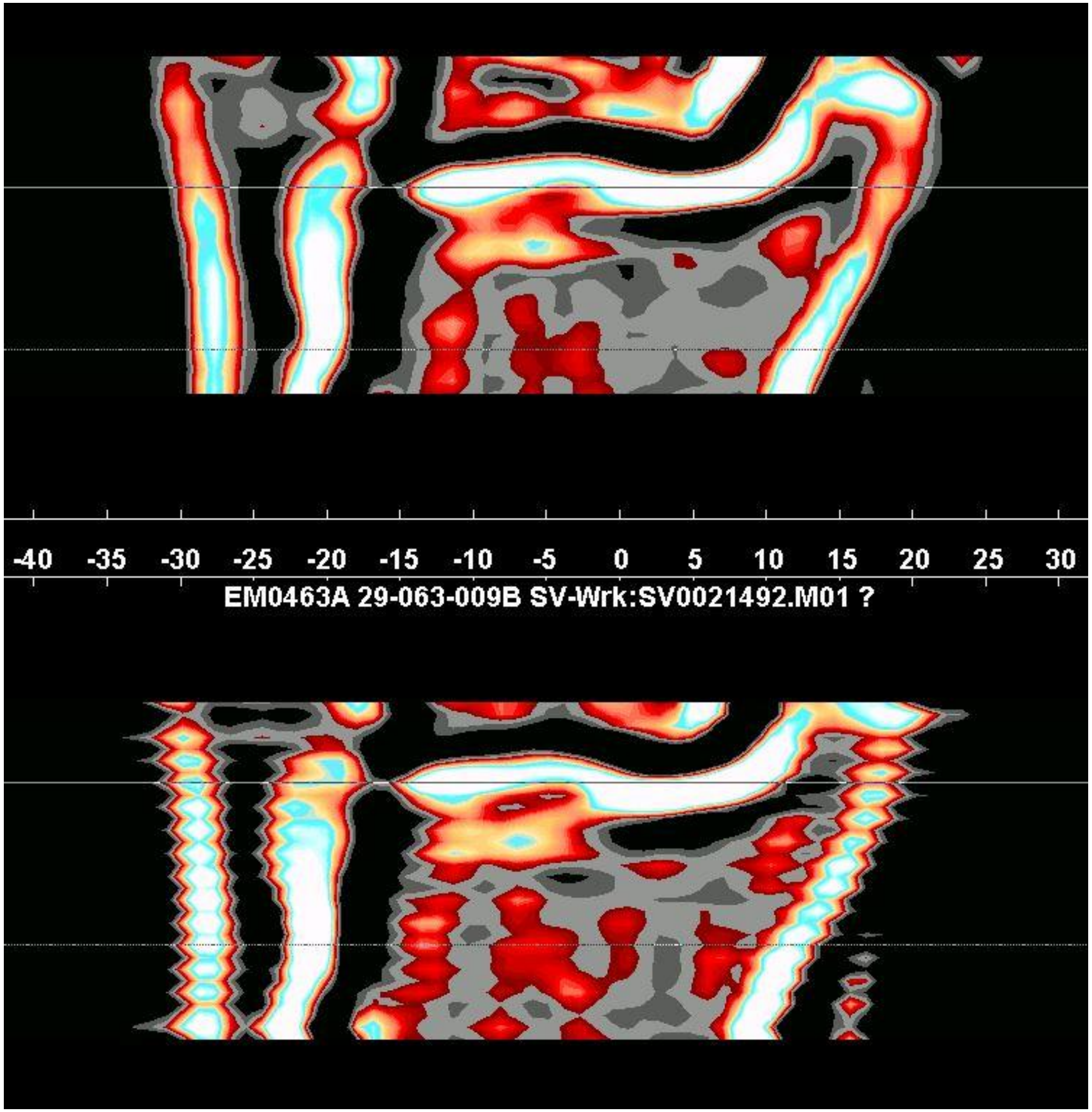
Incorrect reference line – clue high Z-scores

(3)

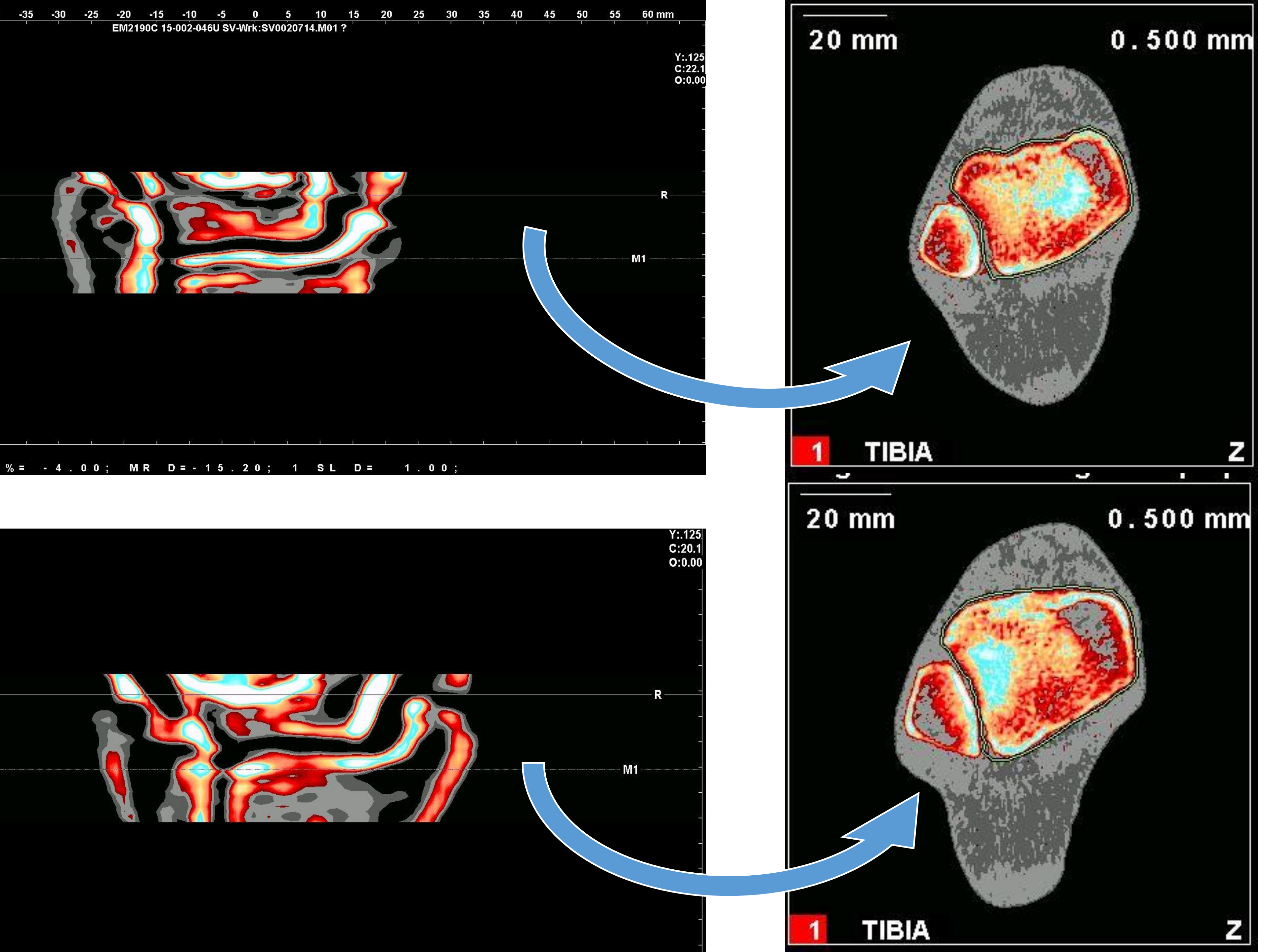




C2P1 not worked – what should we do?

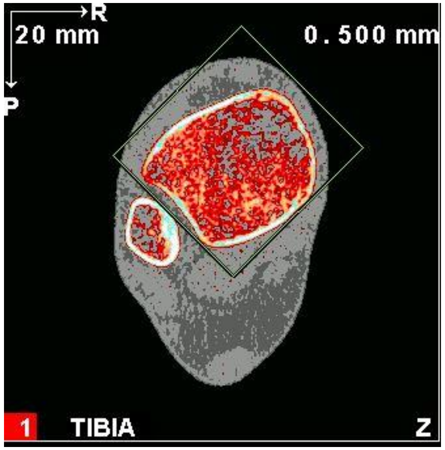


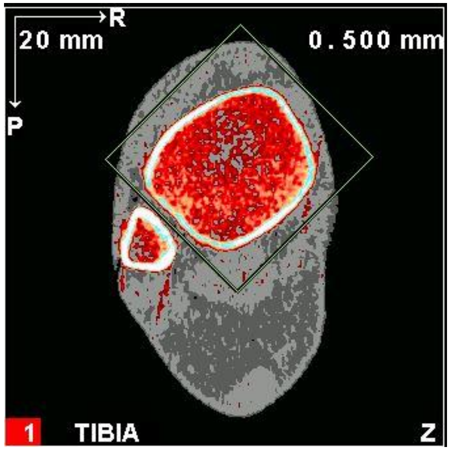
-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30
EM0463A 29-063-009B SV-Wrk:SV0021492.M01 ?

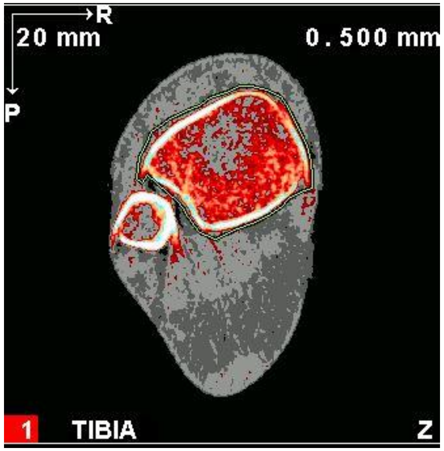


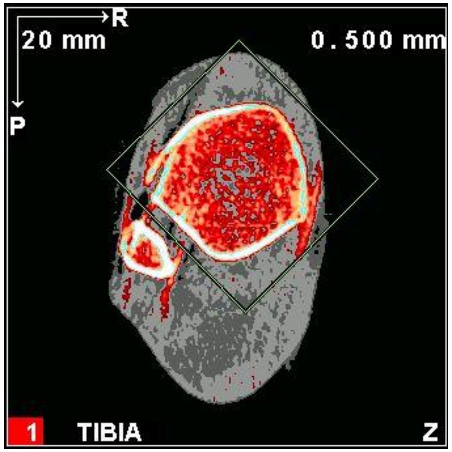
-35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 mm
EM2190C 15-002-046U SV-Wrk:SV0020714.M01 ?
Y:.125
C:22.1
O:0.00
R
M1
% = -4.00; MR D=-15.20; 1 SL D= 1.00;
20 mm
0.500 mm
1
TIBIA
Z
Y:.125
C:20.1
O:0.00
R
M1
20 mm
0.500 mm
1
TIBIA
Z

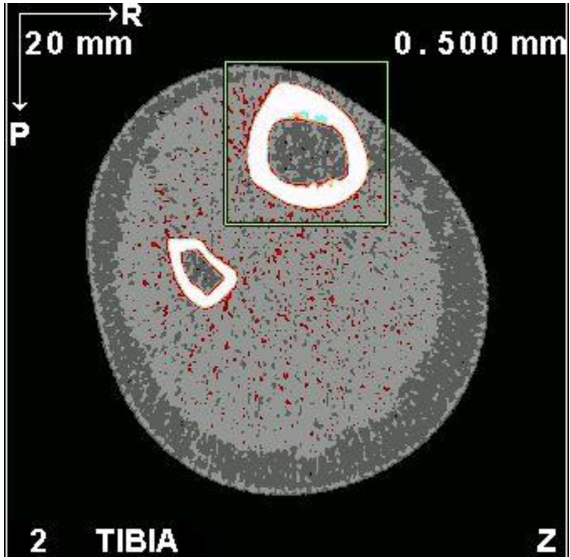
4% Distal tibia scans grade 0 - 3

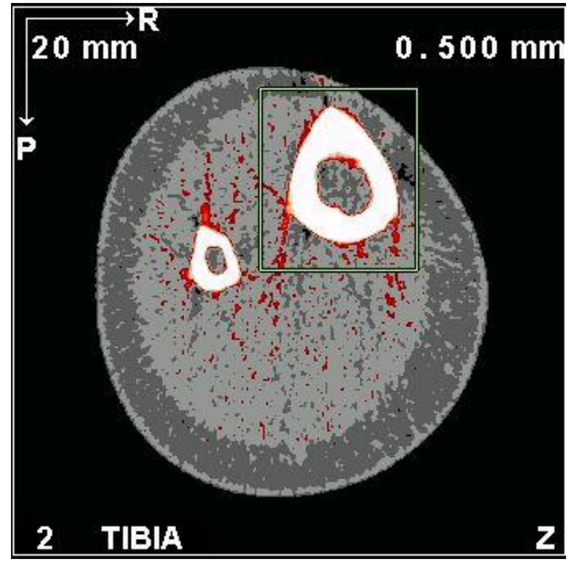


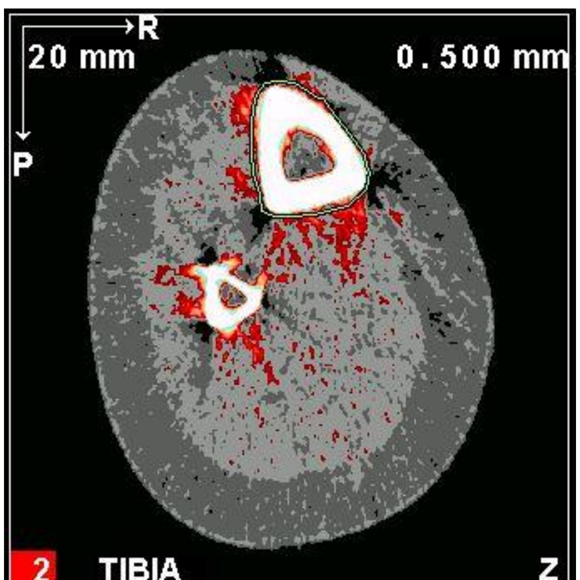


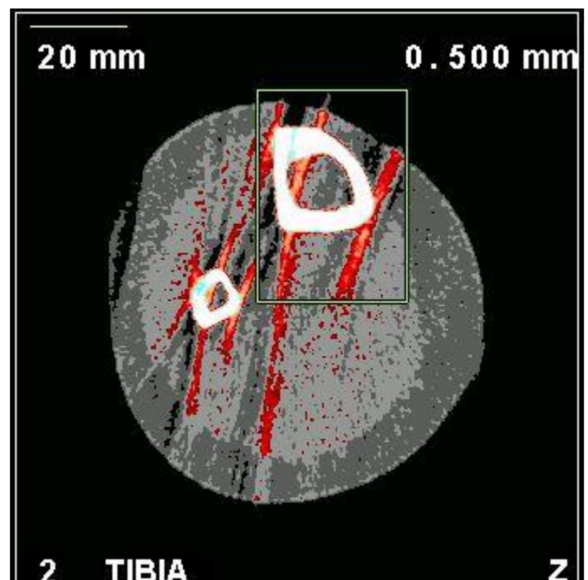




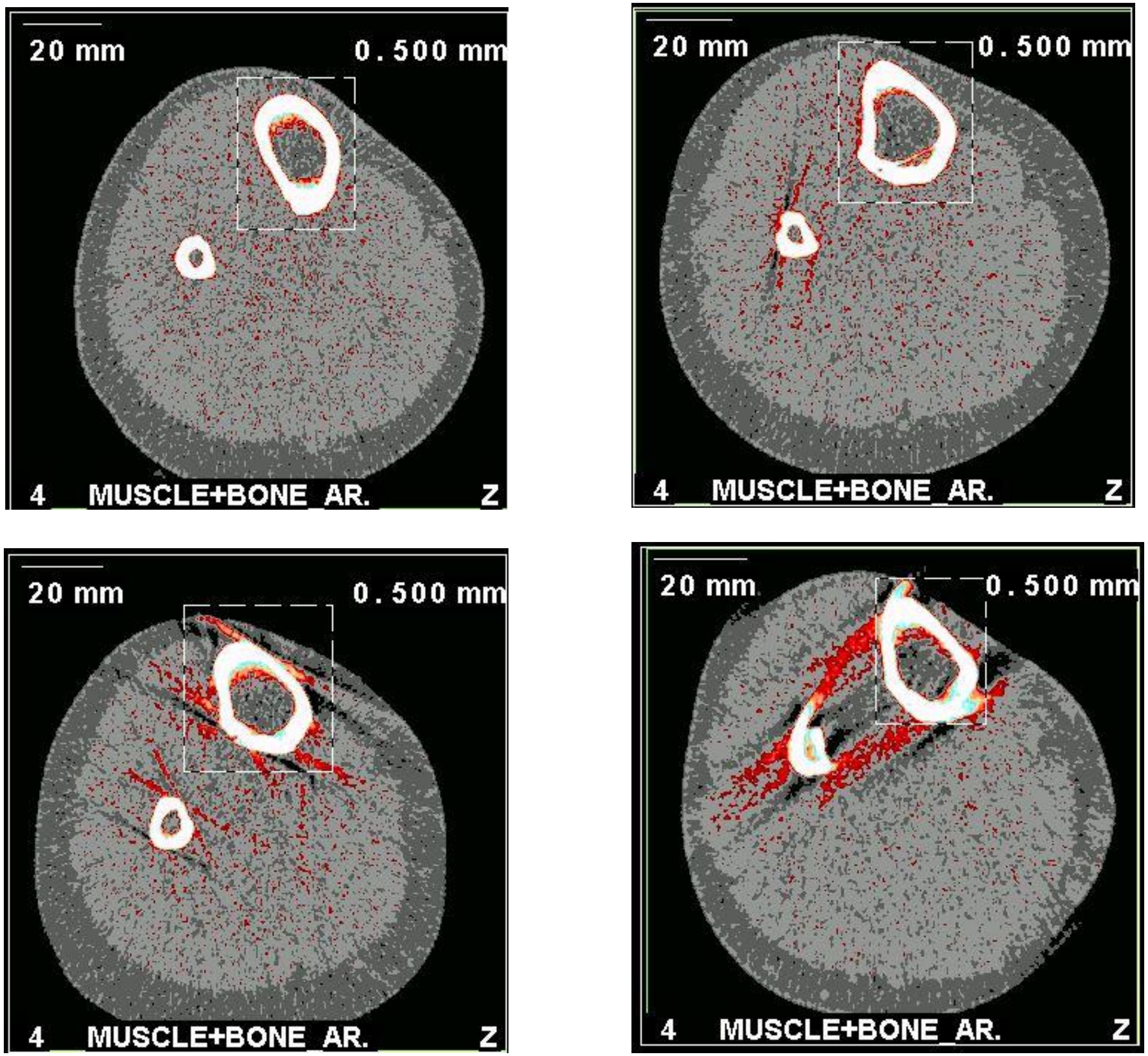

R
20 mm
0.500 mm
P
2
TIBIA
Z

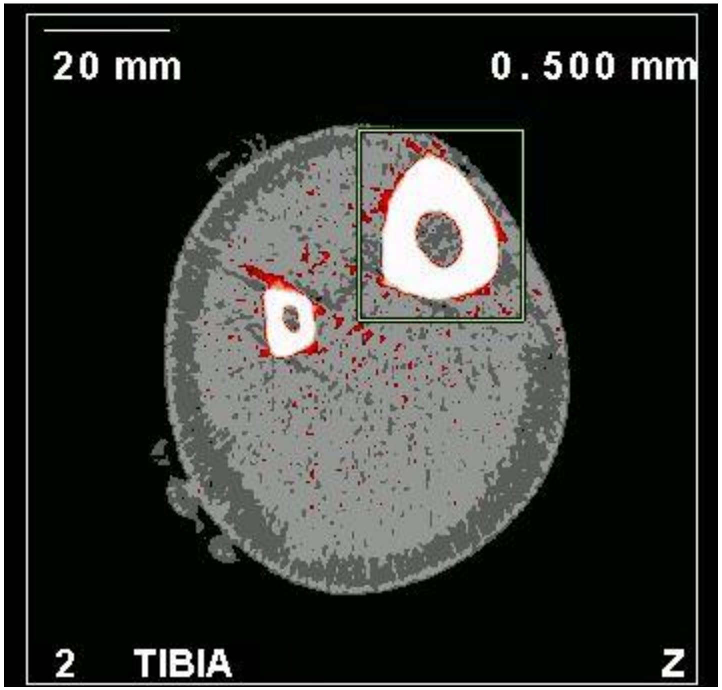

R
20 mm
0.500 mm
P
2
TIBIA
Z

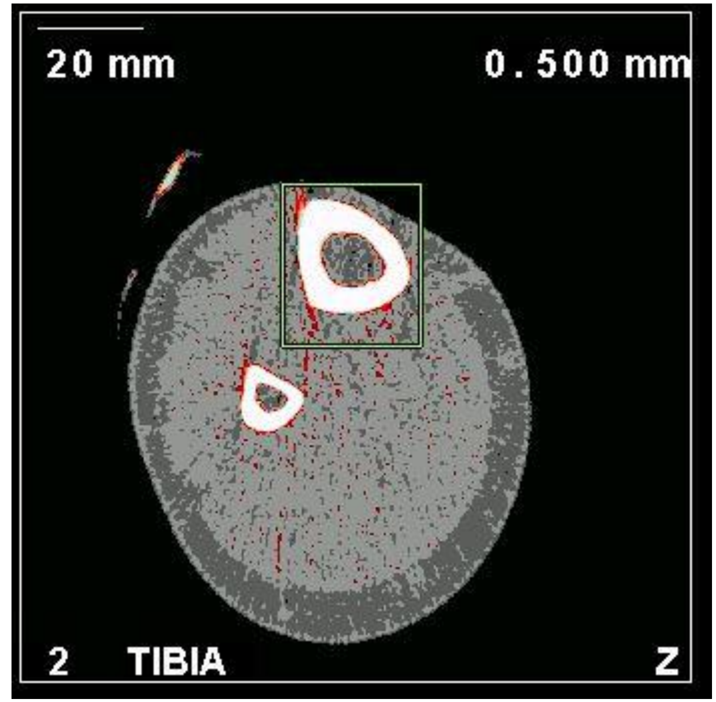

R
20 mm
0.500 mm
P
2
TIBIA
Z


20 mm
0.500 mm
2
TIBIA
Z

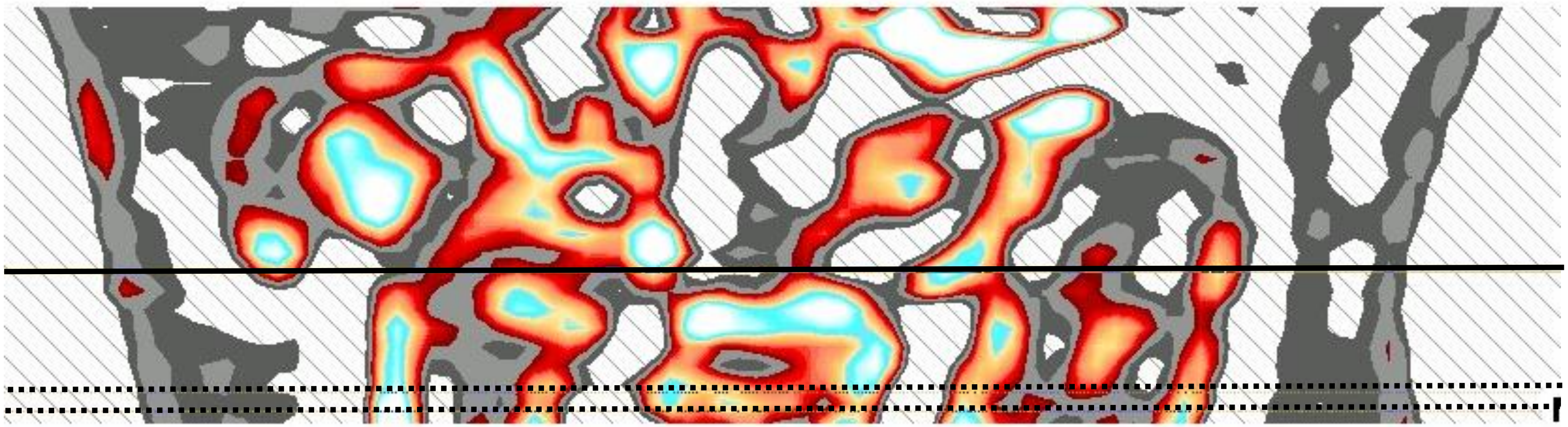
66% Proximal tibia scans grade 0 - 3




20 mm
0.500 mm
2 TIBIA
Z

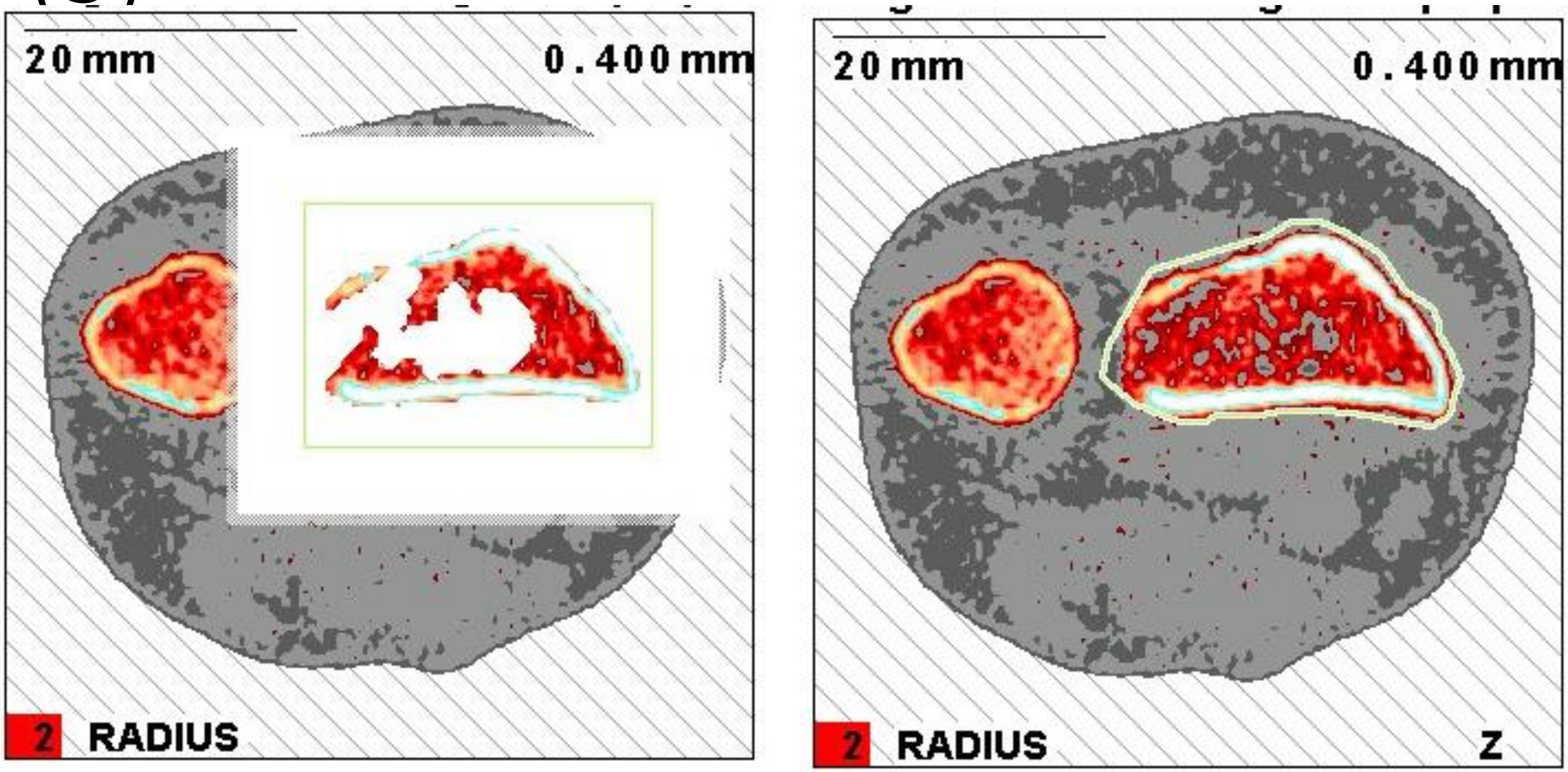

20 mm
0.500 mm
2 TIBIA
Z

(1)



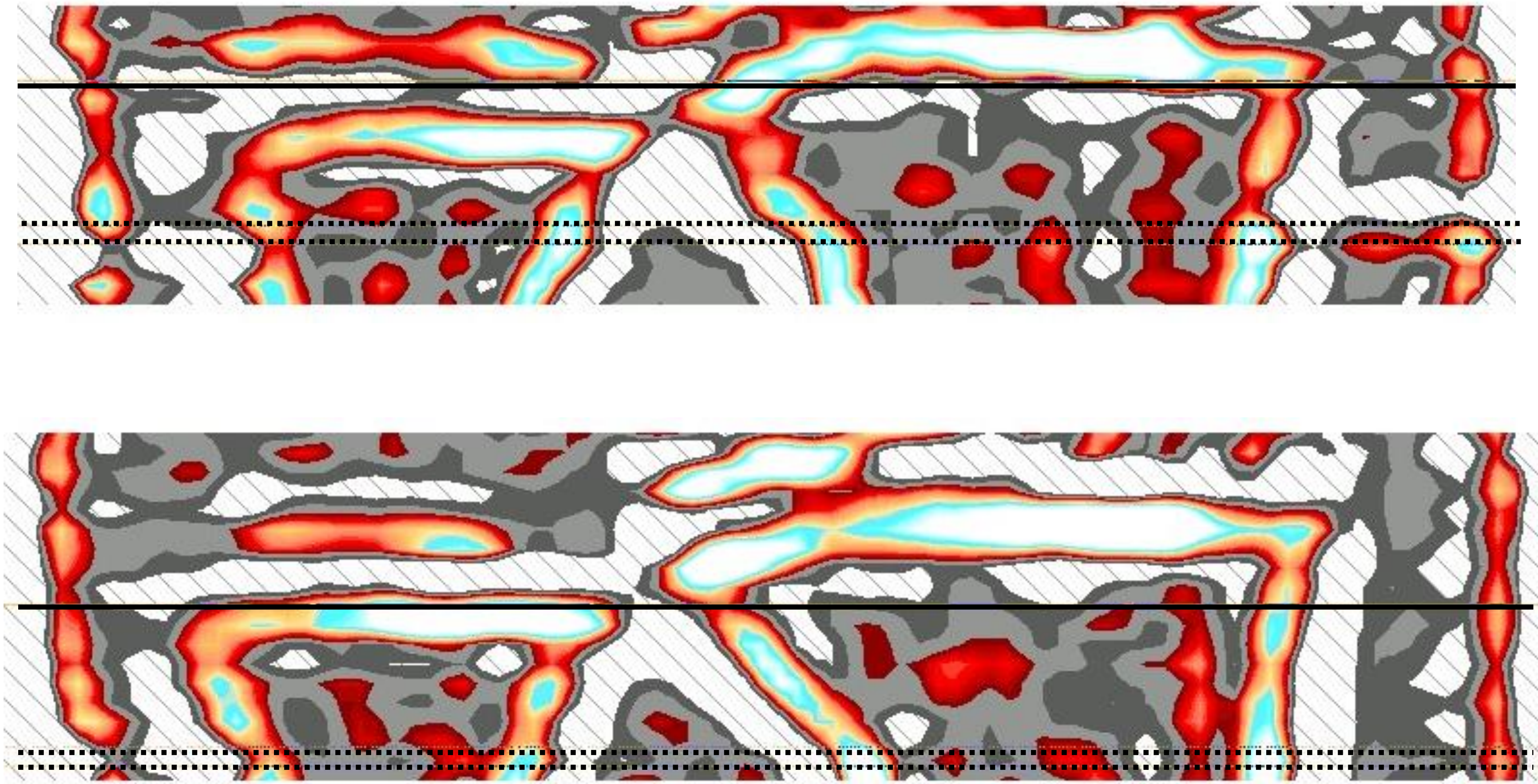
Madelungs deformity – Turners syndrome

(3)



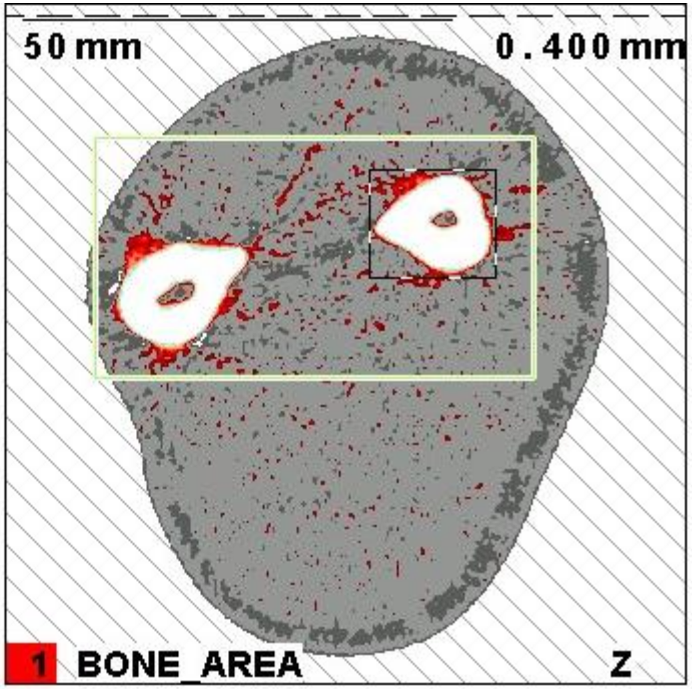
C2P1 not worked – what should we do?

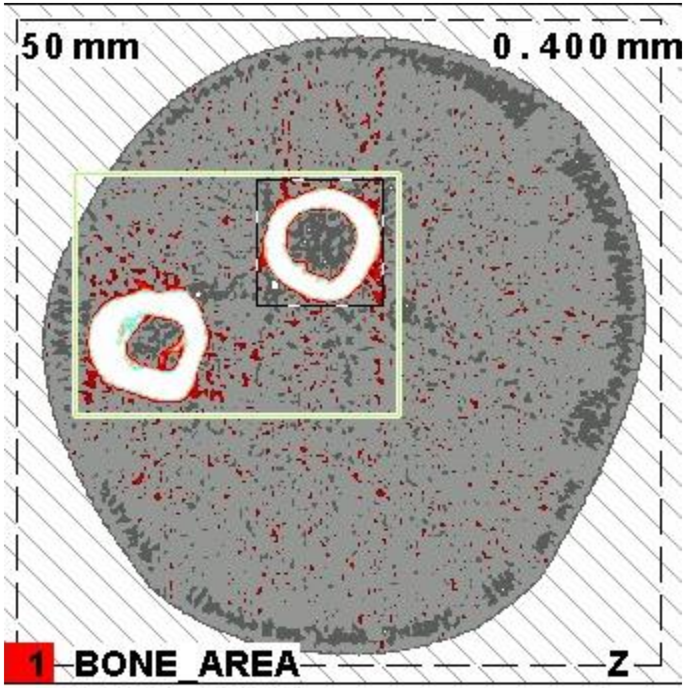
(4)



Reference line position

(5)

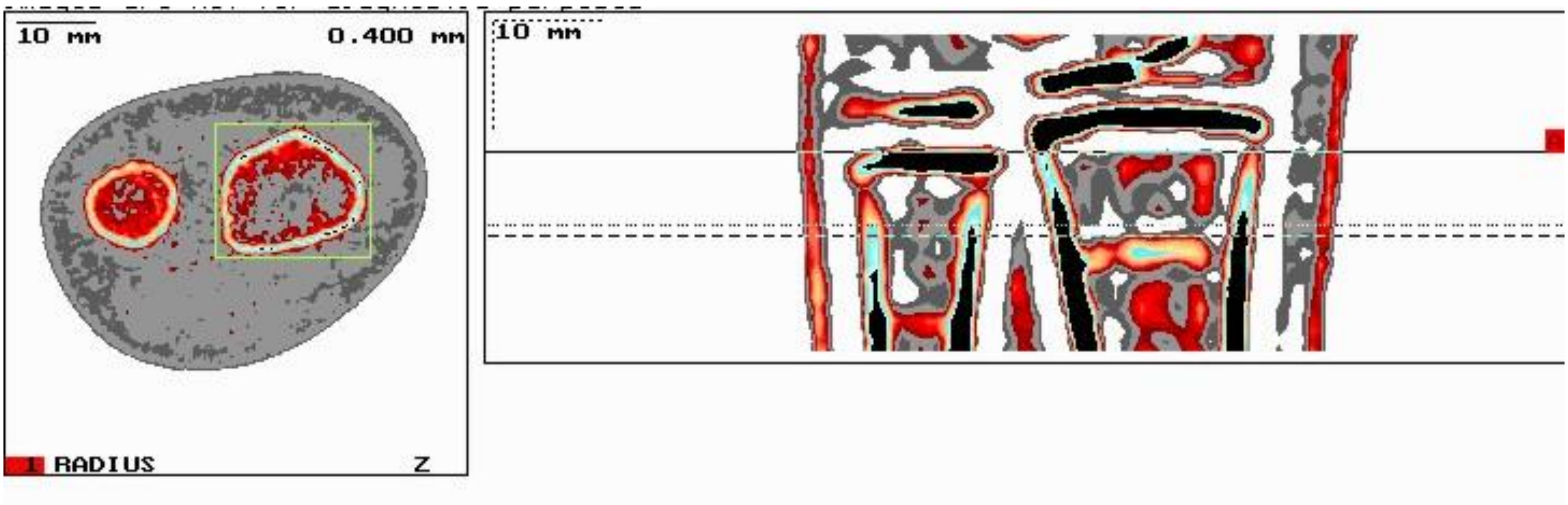




Extra thick cortices

Anatomy different – circular radius & ulna

(6)



Harris growth arrest line – illness, bisphosphonate treatment