



Roma, 9-12 novembre 2017



ITALIAN CHAPTER



# Densitometry (DXA) and trabecular bone score (TBS)

STEFANIA BONADONNA



**ISTITUTO AUXOLOGICO ITALIANO**  
Istituto di Ricovero e Cura a Carattere Scientifico



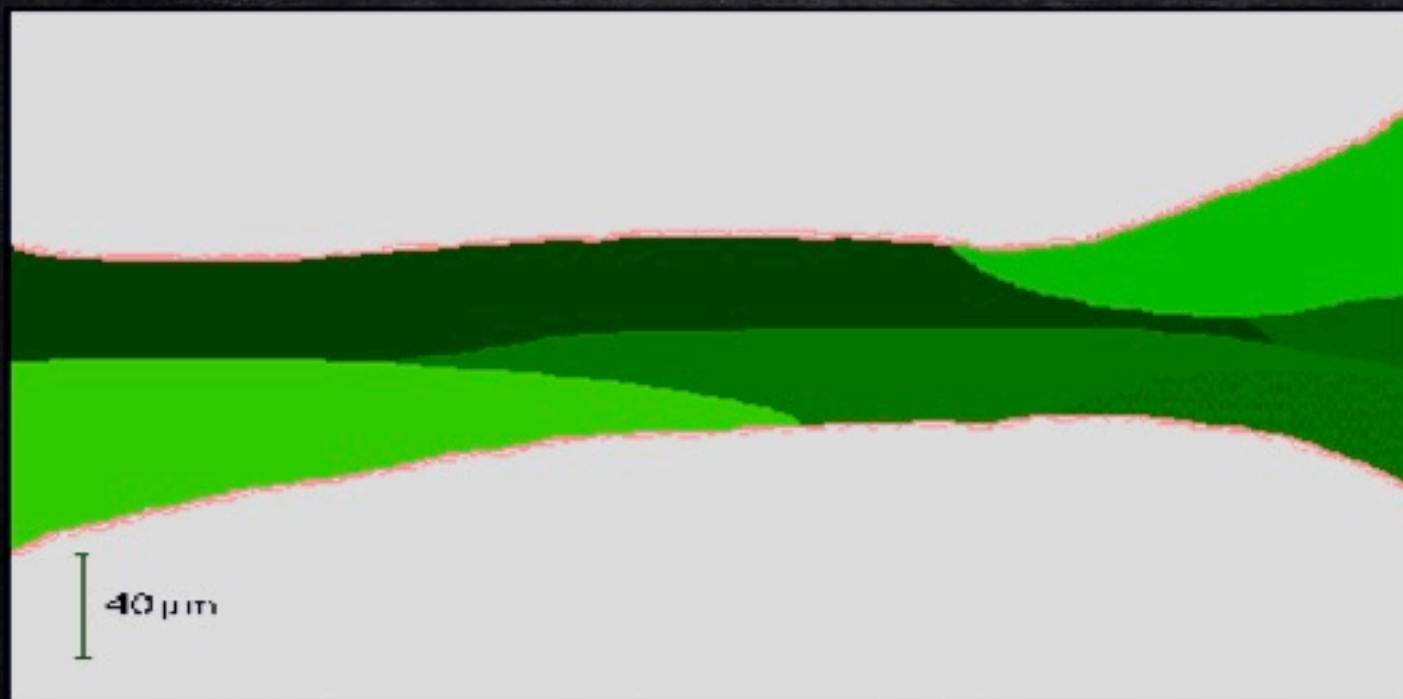


Roma, 9-12 novembre 2017

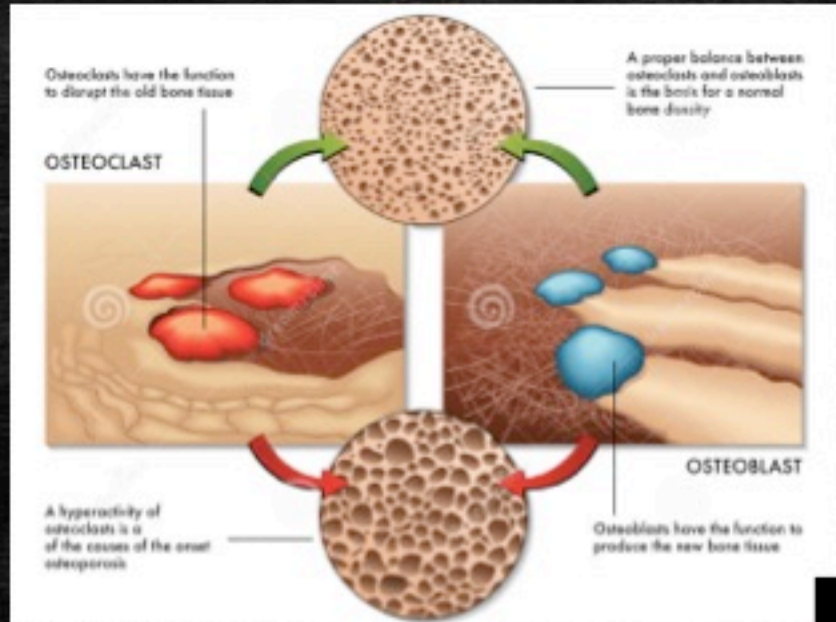
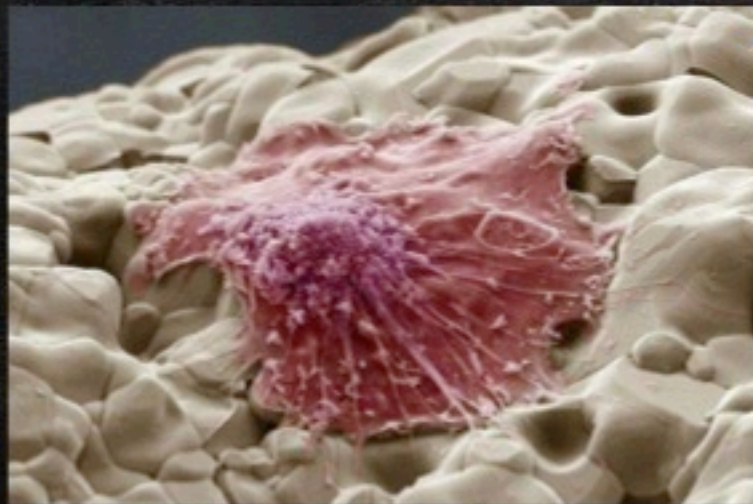


ITALIAN CHAPTER

# BONE REMODELLING -THE KEY!

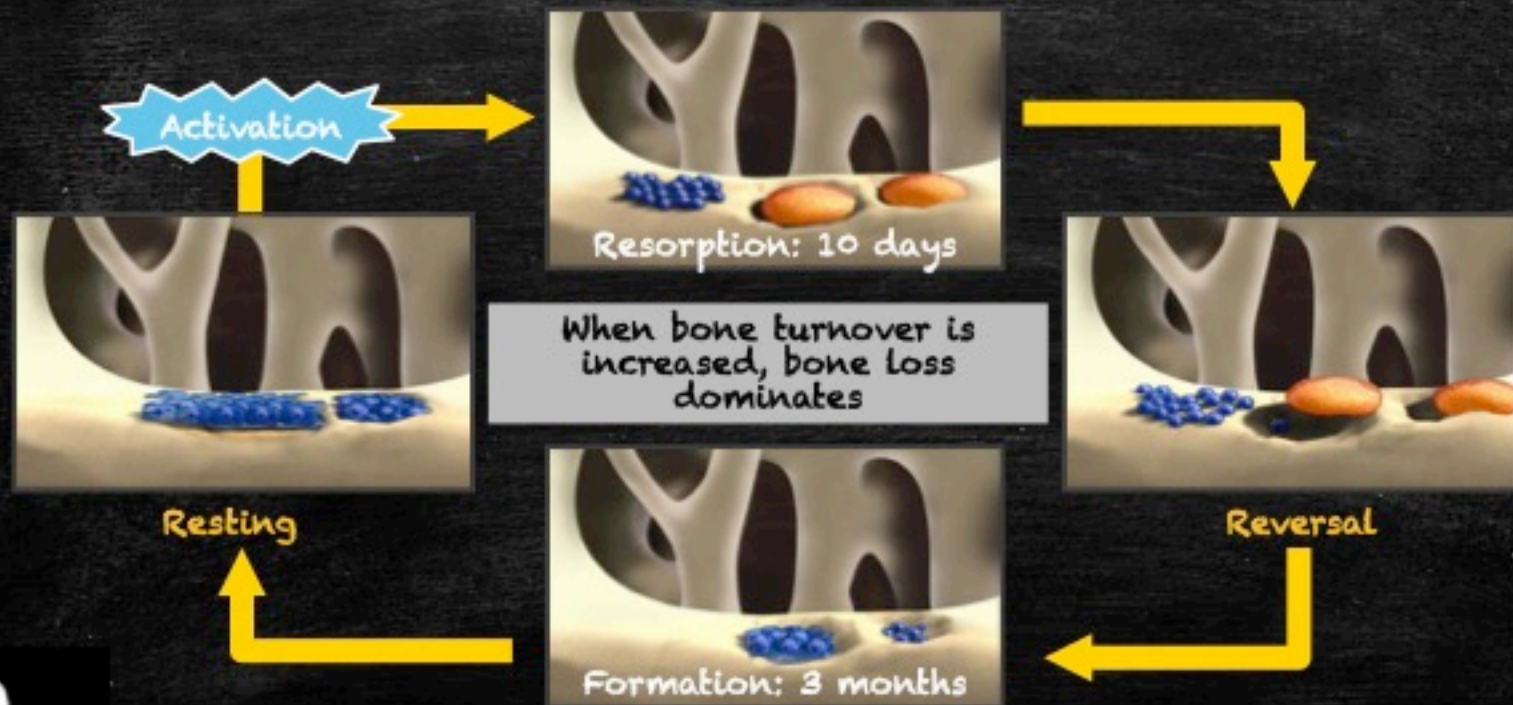


# BONE REMODELLING: THE KEY



Adapted from: [http://www.brsoc.org.uk/gallery/arnett\\_osteoclast.jpg](http://www.brsoc.org.uk/gallery/arnett_osteoclast.jpg).  
Electron micro-graph photo reproduced with permission. © Tim Arnett, The Bone Research Society

# A HEALTHY SKELETON REQUIRES A BALANCE OF BONE RESORPTION AND BONE FORMATION



# OSTEOPOROSIS / OSTEOPENIA

---

OSTEO = BONE  
POROUS = VOID SPACES  
OSIS = CONDITION OF

OSTEOPENIA - LOW BONE MASS

ISCD recommend that reports should use the term  
low bone mass and not osteopenia



# PHYSIOLOGICAL REMODELLING - BONE QUALITY

## INSUFFICIENT TURNOVER

- Accumulation of microdamage
- Increased brittleness due to excessive mineralization

## EXCESSIVE TURNOVER

- Increase in stress risers (weak zones)
- Increase in perforation
- Loss of connectivity

BONE  
STRENGTH



BONE TURNOVER

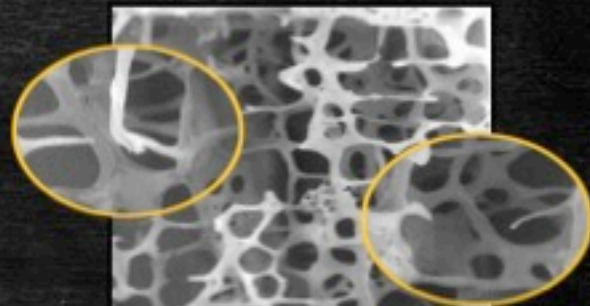
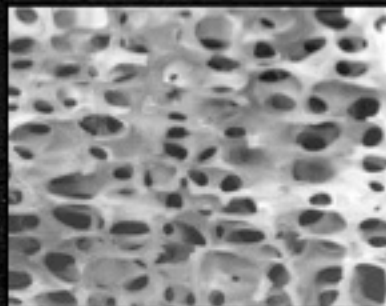
# EXCESSIVE REMODELLING CONTRIBUTES TO OSTEOPOROSIS



Normal Quantity  
and Architecture

Loss of  
Quantity

Loss of Quantity  
and Architecture



Increased bone  
remodelling

Structural  
deterioration

Increased  
skeletal  
fragility

Increased  
fracture risk





Roma, 9-12 novembre 2007



## SCOPE OF THE PROBLEM

Osteoporosis is estimated to affect 200 million women worldwide - approximately:

one-tenth of women aged 60,  
one-fifth of women aged 70,  
two-fifths of women aged 80 and  
two-thirds of women aged 90



Osteoporosis affects an estimated 75 million people in Europe, USA and Japan



# OSTEOPOROSIS RELATED FRACTURES

A fracture that should have not happened:

Metatarsal bones while dancing

Fibula while walking

Lumbar spine while lifting water

Fragility fractures or low-trauma fractures occurring with minimal trauma - a force equal to or less than falling from standing height



# INCIDENCE OF OSTEOPOROTIC FRACTURE

## Incidence of osteoporotic fractures

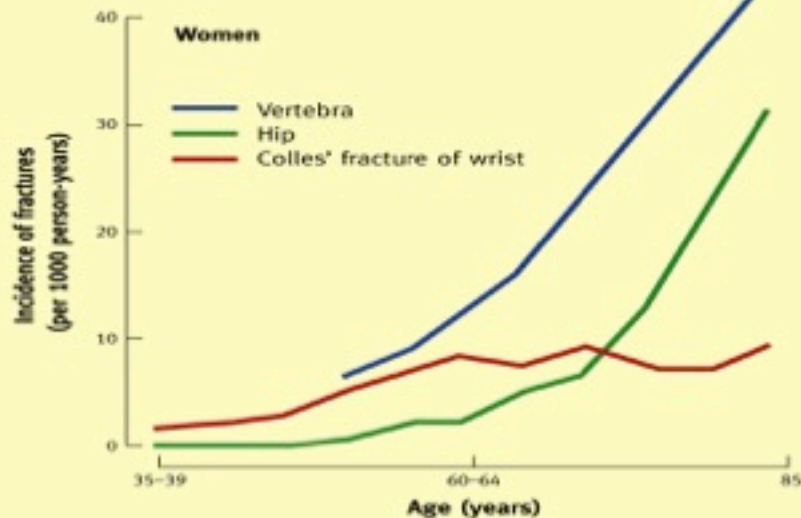
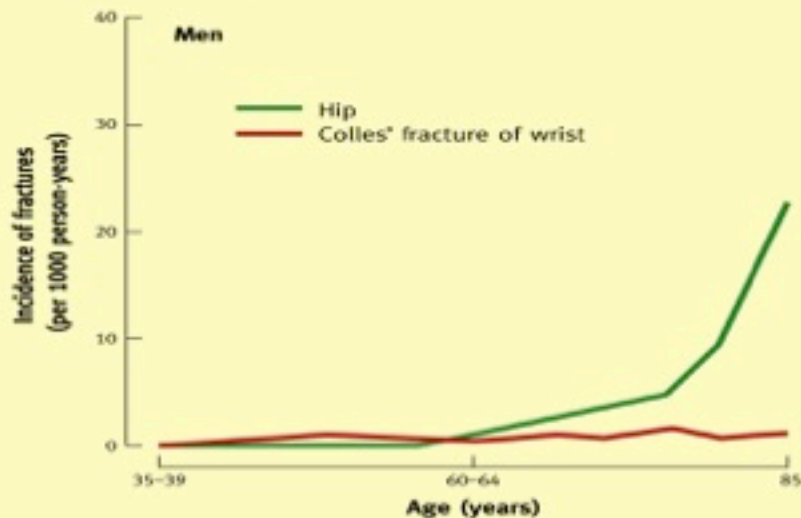


Figure 2 Incidence of osteoporotic fractures.



Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# HIP FRACTURE

By 2050, the worldwide incidence of hip fracture in men is projected to increase by 310% and 240% in women, compared to rates in 1990



Hip strength and flexibility protect against hip fracture

# MORTALITY and DISABILITY

## MORTALITY

- 5% immediately
- 25% in 1 year (as breast cancer)

## DISABILITY

- 20% compromised functional status
- 50% reduction in mobility and related functions
- if invalid 20-25% hospitalization

Table 4

### Cause of Death 1 Year After Proximal Femoral Fracture

Cause of Death	No. (%)	
	Surgically Treated Patients (n=53)	Nonsurgically Treated Patients (n=9)
Deterioration of preexisting comorbidities	10 (18.9)	6 (66.7)
Cerebrovascular disease	9 (17)	0 (0)
Aspiration pneumonia	11 (20.8)	2 (22.2)
Pneumonia	4 (7.5)	0 (0)
Malignancy	1 (1.9)	0 (0)
Insensescence	6 (11.3)	1 (11.1)
Sepsis	2 (3.8)	0 (0)
Acute myocardial infarction	2 (3.8)	0 (0)
Multiple organ failure	2 (3.8)	0 (0)
Pulmonary embolism	1 (1.9)	0 (0)
Unknown	5 (9.4)	0 (0)

# BONE DENSITY AND BONE QUALITY



- Bone density is a part of bone quality
- Bone quality extends beyond bone density
- Sound nutrition: vitD-vitK-Mg-Ca...
- Digestive health
- Exercise
- Collagen disorder



Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# PREVIOUS NON-TRAUMATIC FRACTURES

Regardless of the bone density,  
a previous non traumatic fracture



predicts future fractures



Roma, 9-12 novembre 2017



ITALIAN CHAPTER

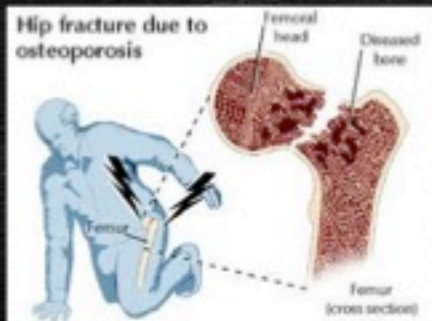


Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# BONE DENSITOMETRY



risk of fracture

osteoporosis diagnosis



effect of treatment

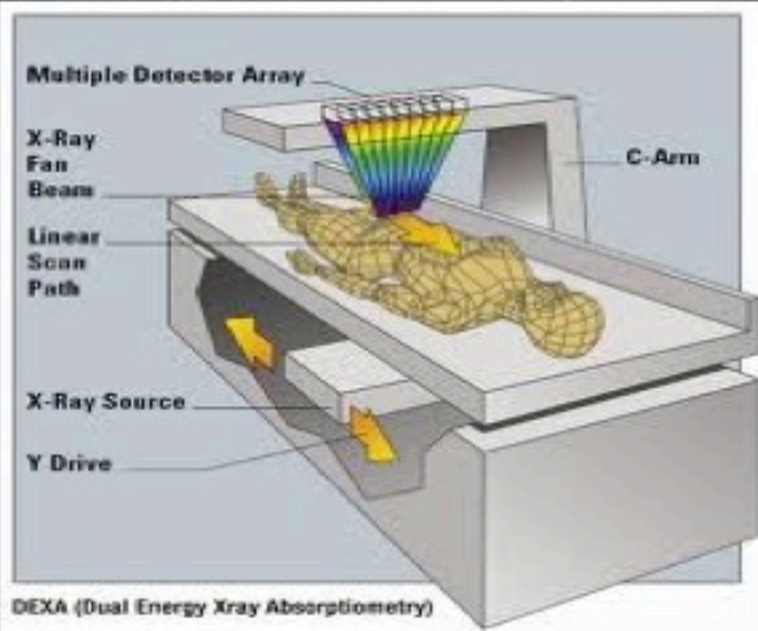


# BONE DENSITOMETRY: DXA

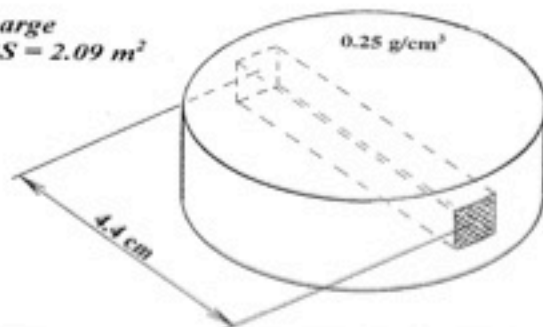
## HOLOGIC LUNAR

DXA itself uses an X-ray tube to generate two energy X-ray beams of different energies: one "low-energy" X-ray beam of 40 keV and one "high-energy" X-ray beam >70 keV.

Using two energy beams enables subtraction of the soft tissue component. Both energy beams are then transmitted through the human body, where they become attenuated differently and the remaining attenuation energies of both beams are recorded by a flexible detector arm



Large  
 $BS = 2.09 \text{ m}^2$

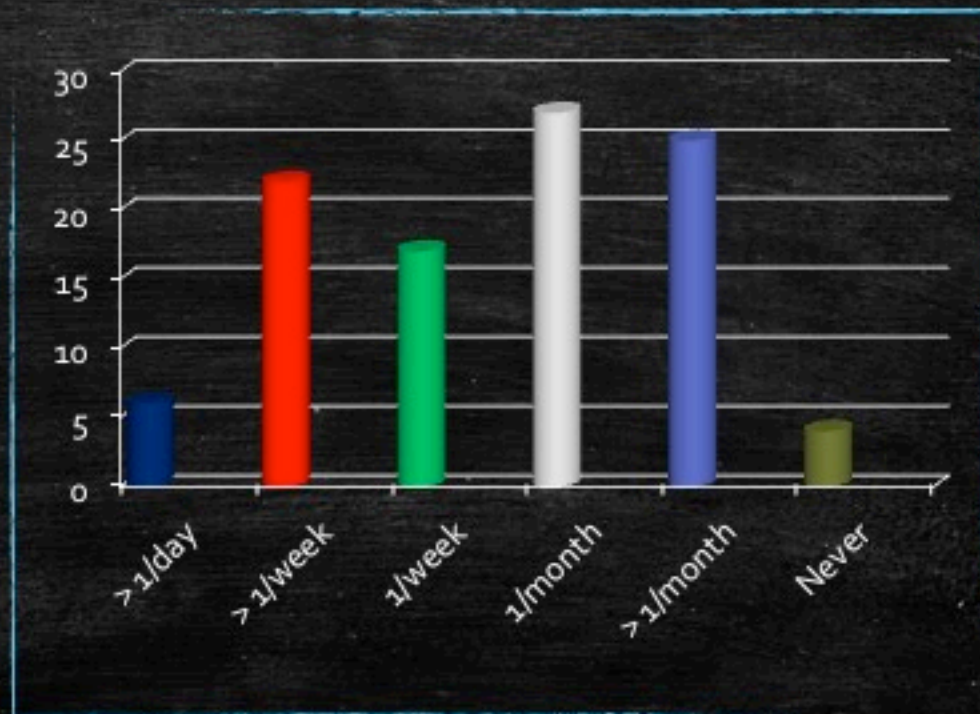


$$\text{BMD}_{\text{corr}} = 0.76 \text{ g/cm}^2 \cdot \text{m}$$
$$= \frac{1.10 \text{ g/cm}^2}{\sqrt{2.09 \text{ m}^2}}$$



# DEXA ISCD HIGH RATE OF INCORRECT INTERPRETATION

how often do you see a patient with a previous dxa report interpretation that is incorrect?



Lewiecky em J clin endocrinol 2006



Roma, 9-12 novembre 2017



ITALIAN CHAPTER



Roma, 9-12 novembre 2017



# A SINGLE BONE DENSITY DOES NOT MEAN THAT BONE LOSS IS OCCURRING

Serial bone density comparison and lab test help to establish if bone is stable or if bone loss is occurring



MAY BE THEY NEVER GAINED A GOOD PEAK BONE MASS



## DEXA REPORTS

---

- BMD = bone mineral density
- SD = standard deviation (1 SD = 10-15% of bone)
- T-score = young normal controls (26-29y F or M)
- Z-score = age matched controls

Comunque i vent'anni  
te li godi molto di  
più dopo i quaranta...





Roma, 9-12 novembre 2017

## BONE MASS DEFINITION



+1 SD

- SD = from normal young control

- 1 SD  $\approx$  12% of bone mass

0 SD

-1 SD

- NORMAL = -1 SD below peak bone mass or better

- OSTEOPENIA = -1.1 SD to -2.4 SD

-2.5 SD

- OSTEOPOROSIS = -2.5 SD below peak bone mass or lower

- ESTABLISHED (SEVERE) OP = osteoporosis + fragility fractures

Low bone mass is the single best predictor of future fracture risk

## DEXA REPORT - OSTEOPOROSIS DEFINITION

---

- Diagnosis of OP can be made if the T-score is  $-2.5$  SD or lower in any of the following anatomical site:
  - Femoral Neck
  - Total Hip
  - Lumbar Spine - minimum of 2 vertebra
  - Forearm distal 1/3 site. Non dominant arm.

Previous fracture can increase BMD as much as 20%

## DUAL ENERGY X-RAY ABSORPTIOMETRY DEXA

---



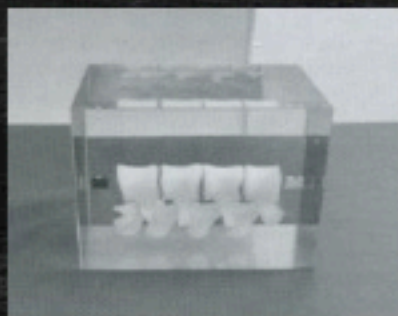
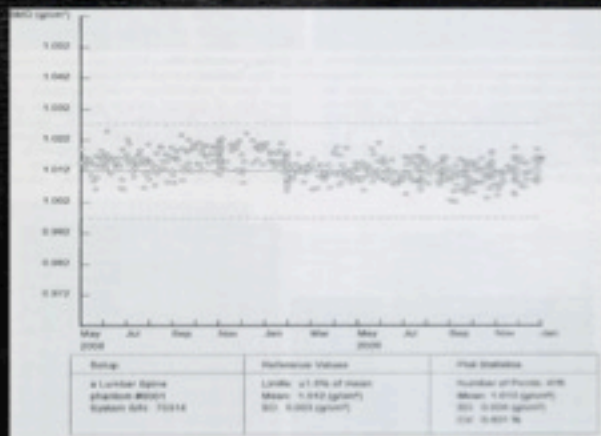
- DXA is the best for follow-up testing
- Low radiation
- Best if the facility has conducted a precision assessment, quantifying their least significant change (LSC). If they have done this, the LSC will be on the radiological report.



# DXA FACILITY

The quality control (QC) program at a DXA facility should include adherence to manufacturer guidelines for system maintenance

- Perform periodic (at least once a week) phantom scans for any DXA system
- Plot and review data from calibration and phantom scans



- Each DXA facility should determine its precision error and calculate the LSC
- If more than 1 technologist an average precision error and LSC should be used

# DEXA: GOLD STANDARD?

- YES AND NO!!!
- The usefulness of DEXA depends on:
  - The skill of the technician - patient set up and analysis of scans
  - The clinician's skill to oversee and correct the technician errors
  - Radiologists efforts to analyze computerized report carefully much like looking at x-rays





# DXA

---

- Request hip and lumbar spine
- Return to the same exact machine if possible





Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# DXA: LUMBAR SPINE

---



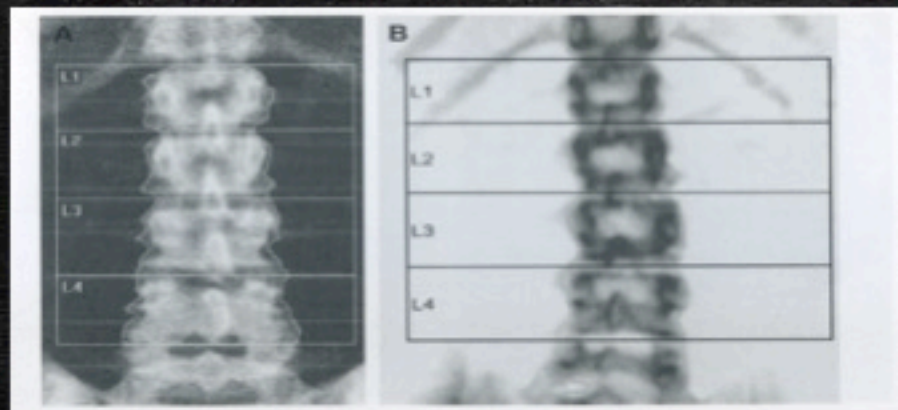


Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# LUMBAR SPINE



## Anatomic Regions of Interest (ROIs)

Name: Express Scans, 2

Patient ID:

DOB: August 24, 1941

Sex: Female

Ethnicity: White

Height: 65.0 in

Weight: 156.0 lb

Age: 61

Referring Physician:



Image size: 512 (display) x 448 (raw) x 192  
170 x 190

### Scan Information:

Scan Date: November 12, 2005 ID: A31120001

Scan Type: x Lumbar Spine

Analysis: November 12, 2005 09:48 Version 12.4.3

Lumbar Spine

Operator:

Model: Discovery C (SN 81202)

Comment:

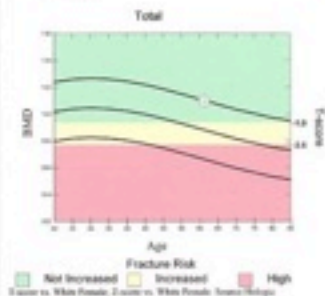
### DXA Results Summary:

Region	Area (cm <sup>2</sup> )	BMC (g/cm <sup>2</sup> )	BMD (g/cm <sup>3</sup> )	T-score	FR (%)	Z-score	AM (%)
L1	14.41	14.44	1.002	0.7	108	2.0	129
L2	15.27	16.33	1.069	0.4	104	1.8	123
L3	16.99	19.49	1.159	0.7	107	2.2	127
L4	18.74	21.27	1.135	0.2	102	1.8	121
Total	65.41	71.72	1.096	0.4	105	1.9	124

Scan BMD: V 1.0%, AC3 = 1.066, AC7 = 1.066, T6 = 1.066

WHO Classification: Normal

Fracture Risk: Not Increased



Physician's Comment:



## ISCD: numerical results - SPINE

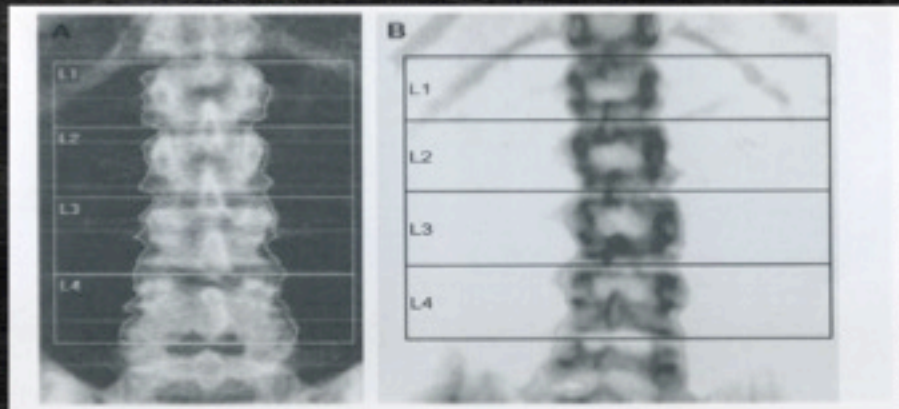
---

- Individual vertebral T-score should be within 1 SD
- Do not report individual T-score
- Instead report T-score of L1-L4 if no exclude





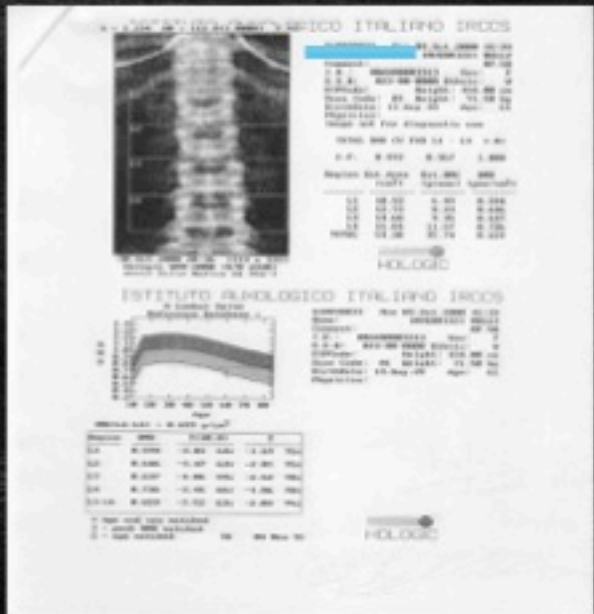
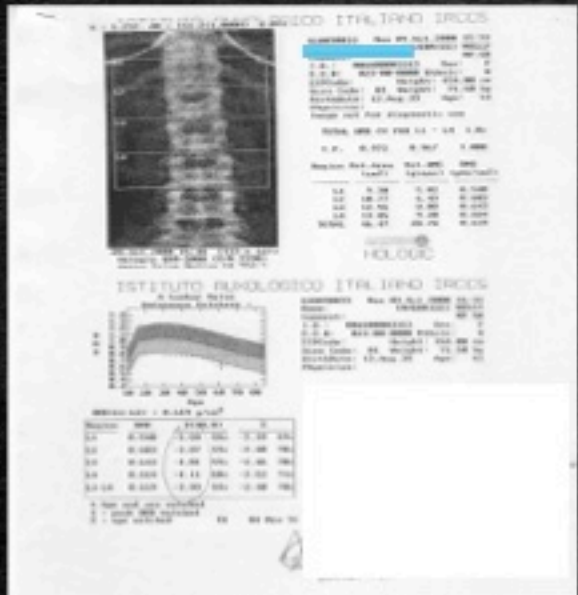
## LUMBAR SPINE: OPTIMAL POSITIONING



- Spine is centered
- Spine is straight (NO tilted)
- Both iliac crests are visible
- Scan includes middle L5 and middle T12



# LUMBAR SPINE: GOOD FOLLOW-UP SCAN ?



• SAME EXACT TEMPLATE



Roma, 9-12 novembre 2017



ITALIAN CHAPTER

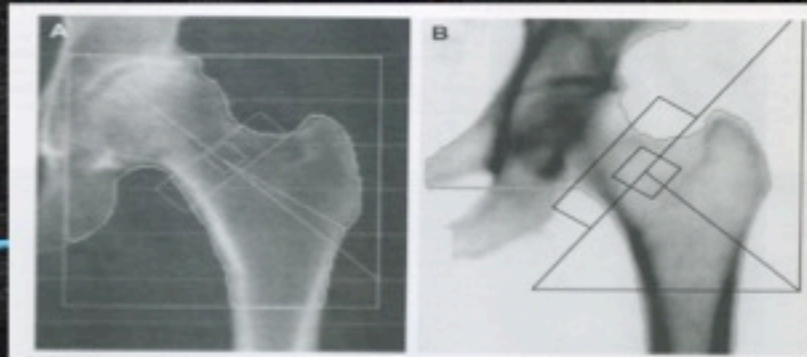


# HIP

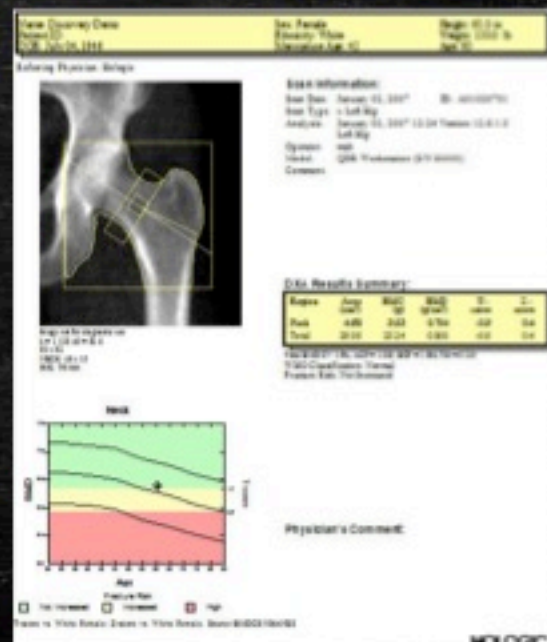
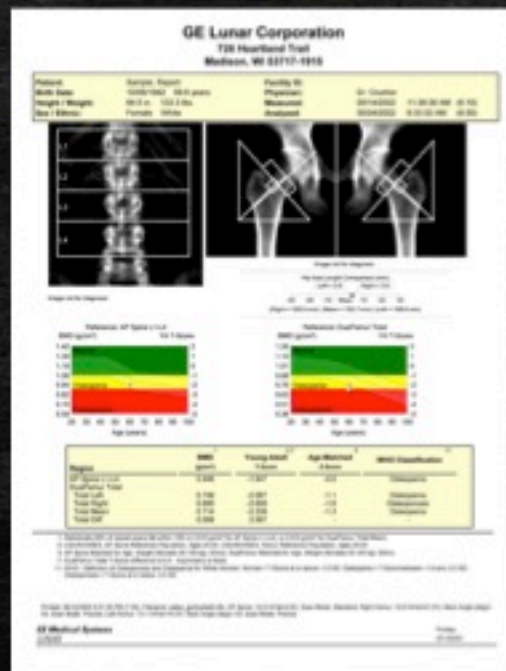
HIP MUST BE INTERNALLY ROTATED



# HIP POSITIONING



## Anatomic Regions of Interest (ROIs)







Roma, 9-12 novembre 2017



ITALIAN CHAPTER

## FEMUR: INTERNALLY ROTATED

---

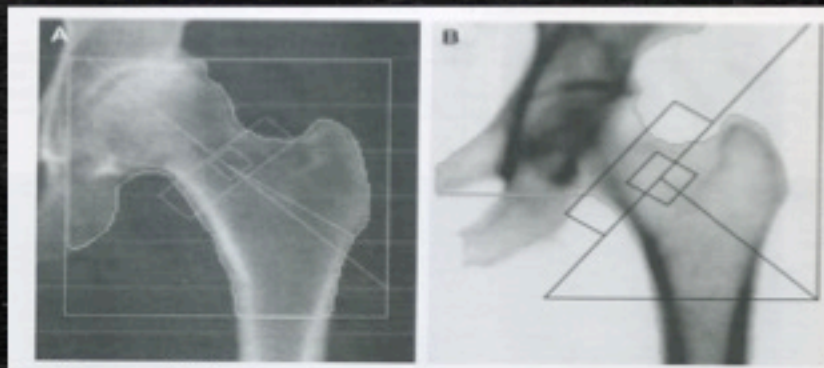
- Shaft of femur should be parallel with the long axis of the table
- Hip must be internally rotated of 15°
- If patient cannot rotate, then make sure technician tries to reproduce the same positioning for the follow-up scans





## PROXIMAL FEMUR: OPTIMAL POSITIONING

- Femur shaft is straight
- Leg internally rotated
  - Lesser trochanter small or not seen  
(lesser trochanter is a posterior structure)
  - Its size is the best indicator of internal rotation
- Scan includes
  - Ischium
  - Greater trochanter





Roma, 9-12 novembre 2017



ITALIAN CHAPTER

# HIP REPOSITIONING



2013  
1.009 g/cm<sup>2</sup>



2015 Initial  
1.017 g/cm<sup>2</sup>  
+ 0.008



2015 Repositioning  
+0.966 g/cm<sup>2</sup>  
-0.043



# COMPARE

If the precision assessment has been performed on the facility, future scans should be compared to previous scans using the quantitative comparison system

## L1-L3

Rate of Change/yr	$\pm$ SD**	% Change /yr	$\pm$ % SD
+0.8281	0.0821	+2.78	0.29

## DXA Results Summary: L4

Source: Hologic

Scan Date	Age	BMD (g/cm <sup>3</sup> )	T-Score	BMD Change	
				vs Baseline	vs Previous
12.04.2005	77	0.684	-3.9	14.3%#	9.4%#
26.11.2003	75	0.625	-4.5	4.5%*	0.4%
07.10.2002	74	0.623	-4.5	4.2%*	-6.1%*
01.06.2001	73	0.663	-4.1	10.9%*	6.5%*
19.04.2000	72	0.623	-4.5	4.1%*	4.1%*
24.07.1997	69	0.598	-4.7		

Total BMD CV 1.0%

\* Denotes significant change at the 95% confidence level.

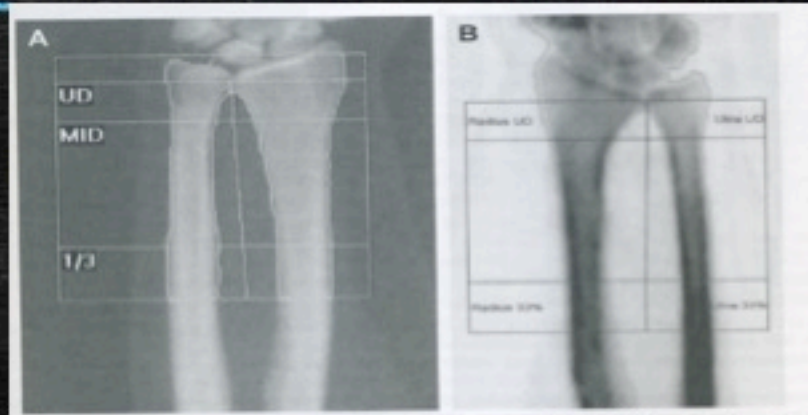
# Denotes dissimilar scan types or analysis methods.

Rate of change results reflect vertebral levels common to all scans.



## FOREARM: OPTIMAL POSITIONING

- Forearm is centered
- Radius and ulna straight
- Distal cortex of radius and ulna
- No available artifacts

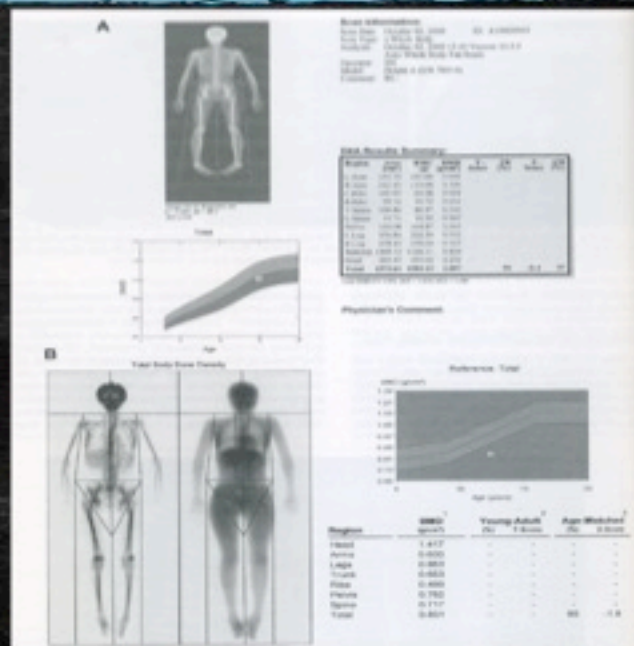
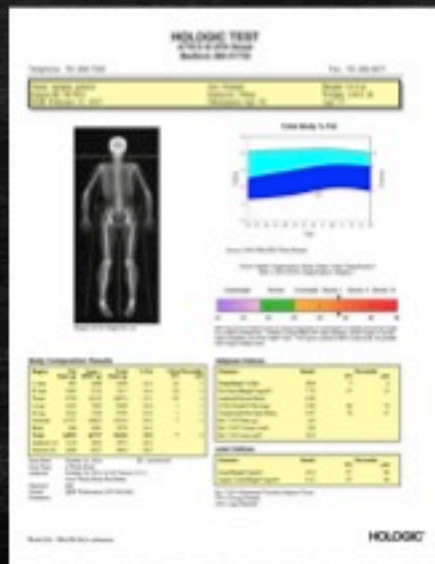


Forearm 1/3 radius accepted as diagnostic if it is osteoporotic  
Forearm loss may be indicative of hyperparathyroidism



# TOTAL BODY

## ONLY IN SELECTED PATIENTS





Roma, 9-12 novembre 2017

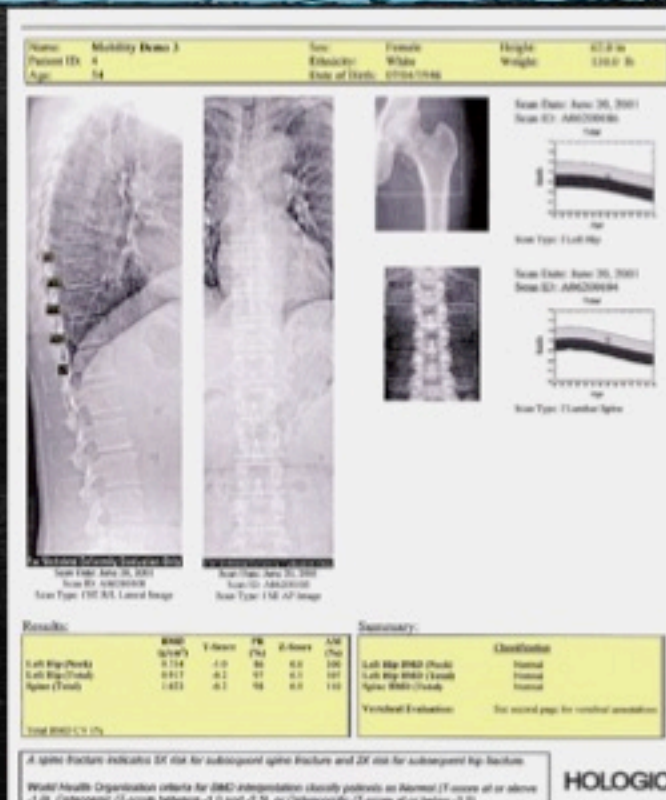


ITALIAN CHAPTER

# VFA: VERTEBRAL FRACTURE ASSESSMENT

Vertebral Fracture Assessment (VFA) is the correct term to denote densitometric spine imaging performed for the purpose of detecting vertebral fractures.

- Very low radiation
- Not as good as plain film but good enough to view spine for fractures
- Not all facilities offer this
- Takes about 10-15 minutes



# Indications for VFA

Lateral Spine imaging with Standard Radiography or Densitometric VFA is indicated when T-score is  $< -1.0$  and of one or more of the following is present:

- Women age  $\geq 70$  years or men  $\geq$  age 80 years
- Historical height loss  $> 4$  cm ( $>1.5$  inches)
- Self-reported but undocumented prior vertebral fracture
- Glucocorticoid therapy equivalent to  $\geq 5$  mg of prednisone or equivalent per day for  $\geq 3$  months



The decision to perform additional imaging must be based on each patient's overall clinical picture, including the VFA result.



Roma, 9-12 November 2017

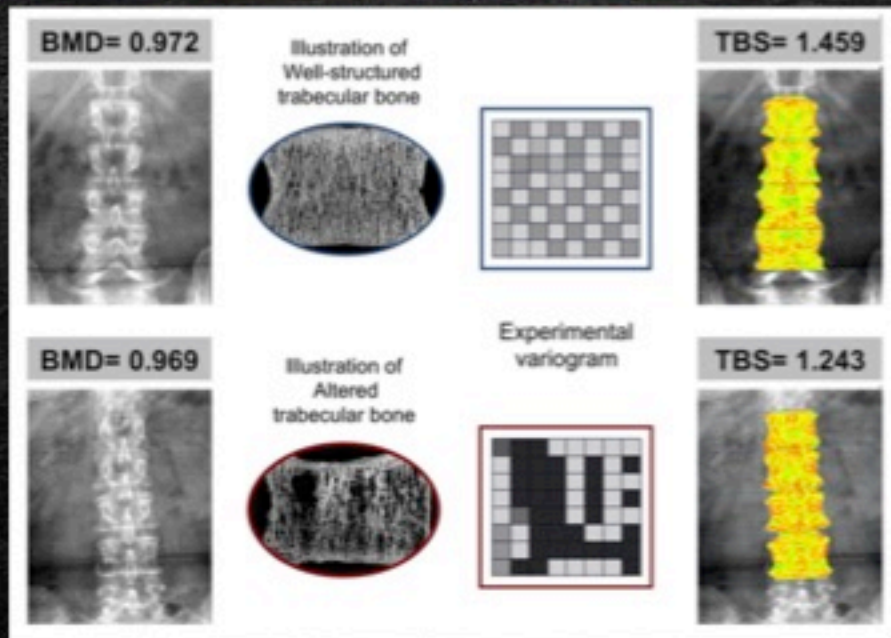


ISCD Official Positions 2015





# TBS TRABECULAR BONE SCORE

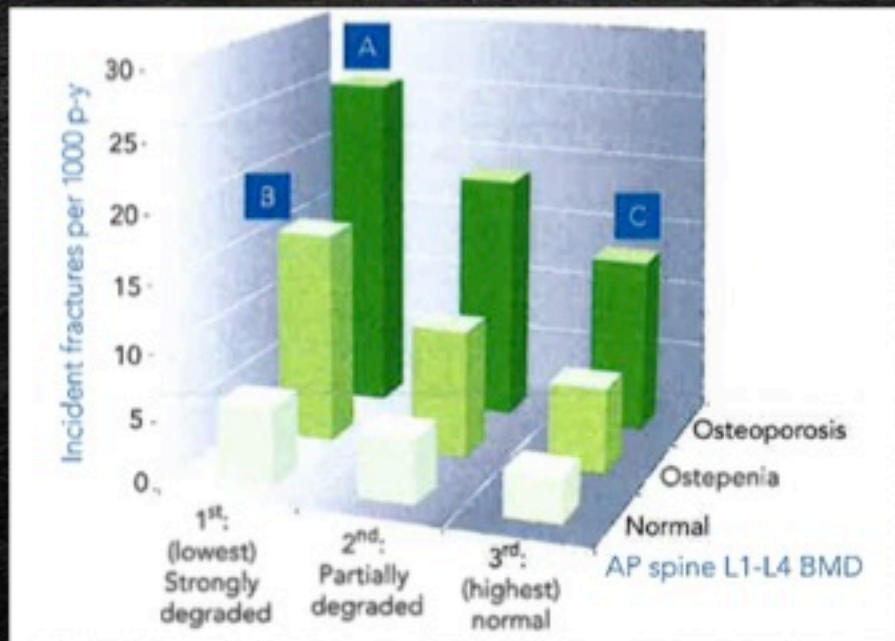


is a gray-level textural metric that can be extracted from the two-dimensional lumbar spine dual-energy X-ray absorptiometry (DXA) image

TBS is undirectly related to bone microarchitecture



## TBS and BMD



### RISK CLASS

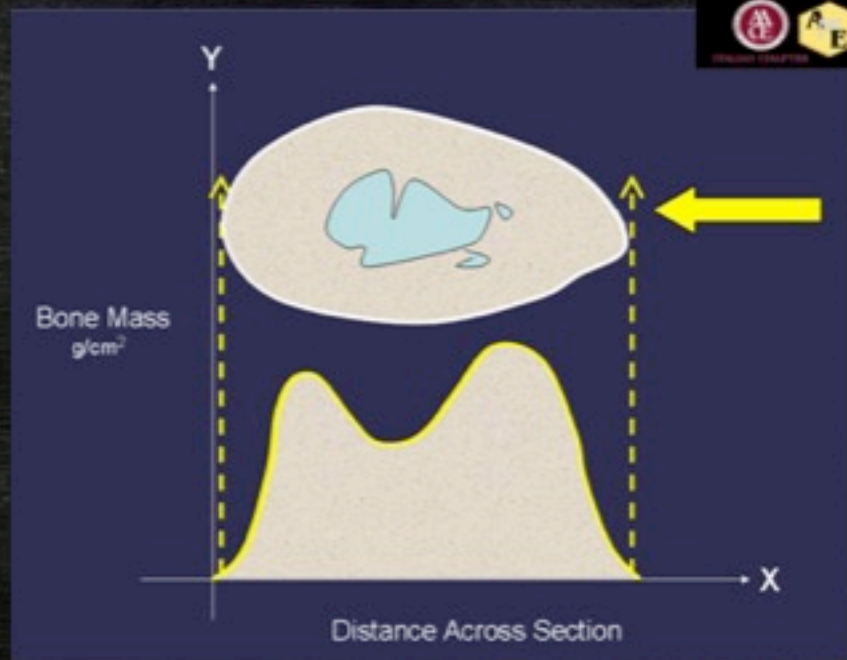
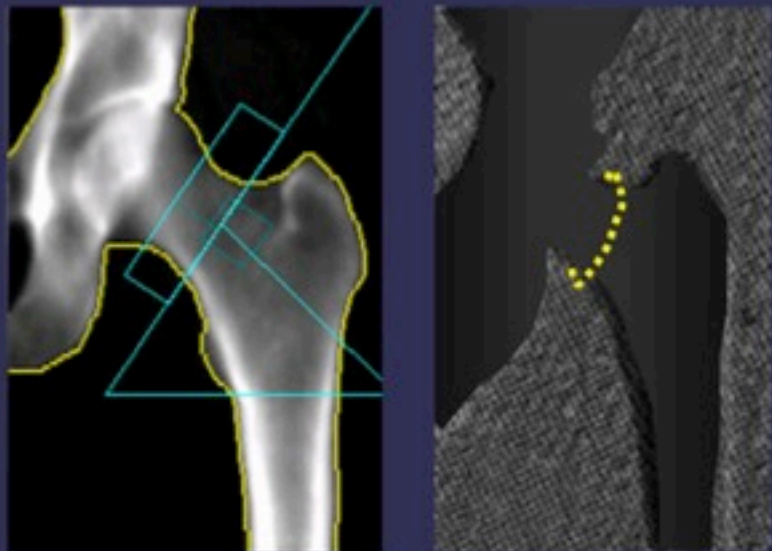
>1,300 - normal

1,200-1,300 -  
intermediate risk

<1,200 - high risk

- is associated with vertebral, hip and major osteoporotic - fracture risk in **postmenopausal women**
- is associated with hip fracture and with major osteoporotic fracture risk risk in **men over the age of 50 ys**
- should **not be used alone** to determine treatment recommendations in clinical practice
- **can be used with FRAX and BMD** to adjust FRAX probability of fracture in postmenopausal women or older men
- is **not useful for monitoring** bisphosphonate treatment in postmenopausal women with osteoporosis
- is associated with major osteoporotic fracture risk in postmenopausal women with **type 2 diabetes**

## TRABECULAR BONE SCORE 2015 ISCD Official Position



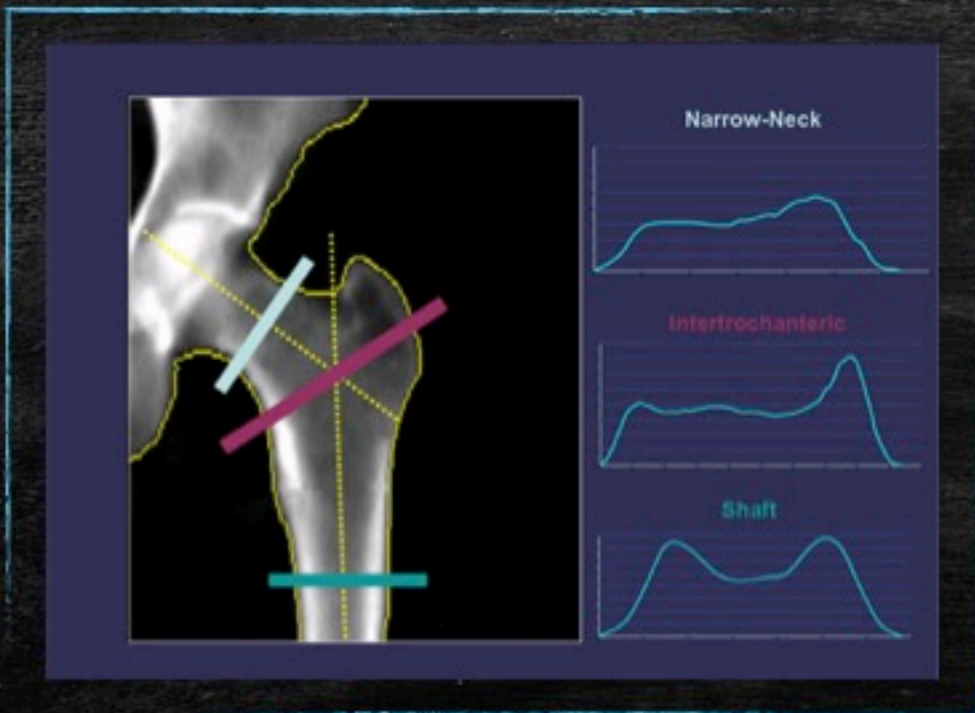
Looking at a crosssection, from the femoral neck a bone profile is created

# HSA

## hip structural analysis/hip strength analysis

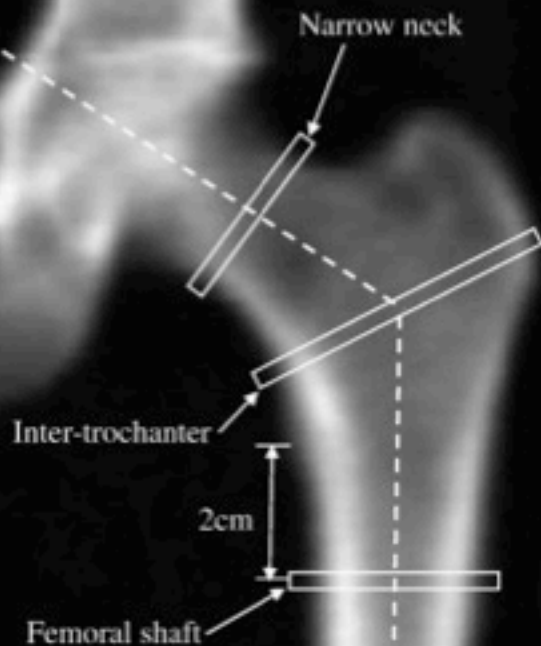
# HSA

## hip structural analysis/hip strength analysis



- Structural parameters are highly correlated with BMD
- Although predictive of fracture risk, structural parameters are not currently better predictors of risk than BMD
- The buckling ratio uniquely reflects the transition from strength homeostasis to skeletal fragility, which cannot be discerned from BMD alone
- Current limitations of HSA primarily reflect limitations of 2-dimensional imaging

HSA can provide unique insights into the pathophysiology of fracture as well as mechanism of therapeutic efficacy



- Quality control  
positioning  
precision

- Fundamental assumptions  
axial asymmetry of cross-section  
bulking ratio calculation assumptions  
tissue mineralization assumptions

## LIMITATIONS OF HSA MEASUREMENTS WITH DEXA



## WHEN DO YOU ORDER A FOLLOW-UP DEXA



- ORDER THE FOLLOW-UP WHEN YOU ANTICIPATE THAT THE LOSS OR GAIN WILL SURPASS THE LEAST SIGNIFICANT CHANGE (LSC) FOR THE DXA CENTER
- MAKE SURE THAT THE FACILITY USES ORIGINAL TEMPLATE - NO NEW ART WORK ON LUMBAR SPINE
- REQUEST THAT THE REPORT INCLUDE THE DIAGNOSTIC PAGES



## DXA REPORT: OPTIMAL ITEMS

---

- Recommendation for further non BMD testing, such as X-ray, magnetic resonance imaging, computed tomography, etc....
- Recommendations for pharmacological and non-pharmacological interventions
- Addition of the percentage compared to reference population
- Specific recommendation for evaluation of secondary osteoporosis







## DXA REPORT: ITEMS THAT SHOULD NOT BE INCLUDED

---

- a statement that there is bone loss without knowledge of previous bone density.
- mention of "mild", "moderate" or "marked" osteopenia or osteoporosis
- separate diagnosis for different roi (e.g. osteopenia at the hip and osteoporosis at the lumbar spine)
- expressions such as "she has the bone of an 80-year-old", if the patient is not 80 years old
- results from skeletal sites that are not technically valid
- the change in BMD if it is not a significant change based on the precision error and Lsc

# GRAZIE

