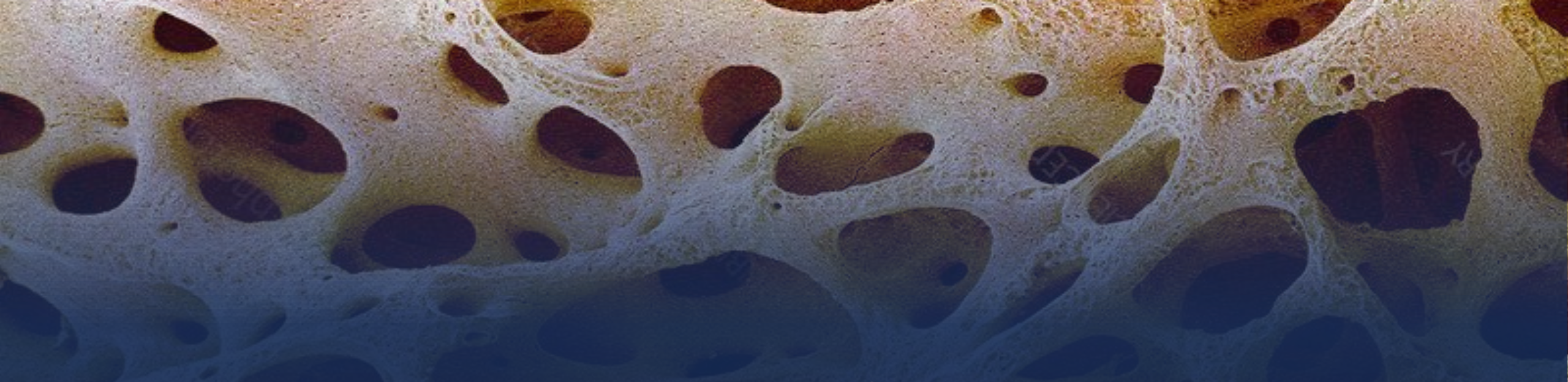
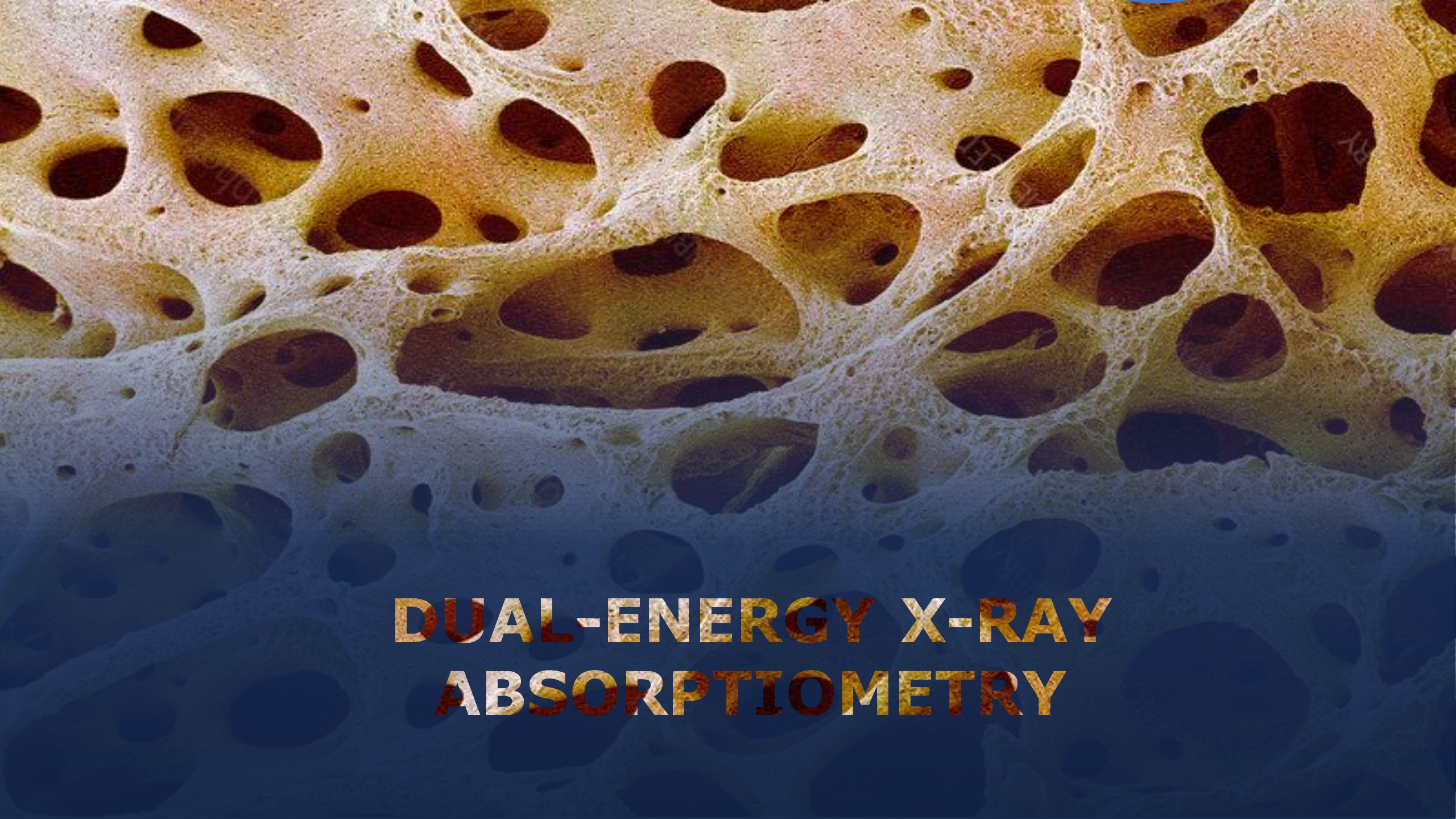


DUAL-ENERGY X-RAY ABSORPTIOMETRY

Dott. Aldo Carnevale

Section of Radiology
Department of Translational Medicine
University of Ferrara


DUAL-ENERGY X-RAY
ABSORPTIOMETRY

01.

02.

03.

DUAL-ENERGY X-RAY ABSORPTIOMETRY

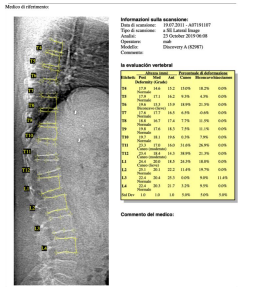
DXA – general principles

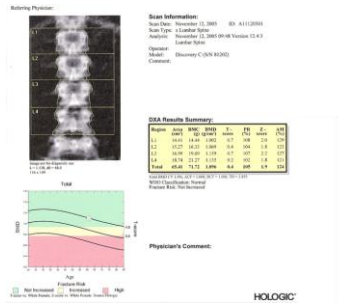
01.

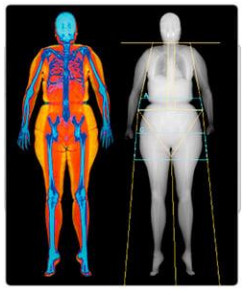
Dual-energy X-ray absorptiometry (DXA) is a **quantitative radiological technique** for measuring **bone mineral density** (BMD).

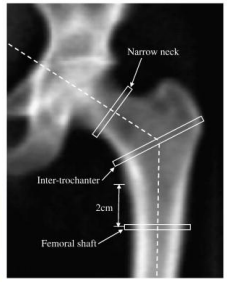
General applications:

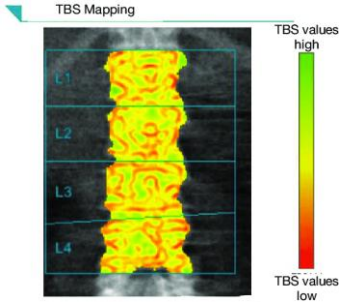
- BMD testing and osteoporosis diagnosis
- Prediction of fracture risk (femoral neck BMD included in the FRAX tool)
- Vertebral fracture assessment (VFA)
- Analysis of body composition
- Trabecular bone score (TBS) determination
- Hip structural analysis











DXA - osteoporosis

01.

DXA: Why It Matters in Clinical Practice?

Osteoporosis is a major non-communicable disease and the most common bone disease, affecting one in three women and one in five men over the age of 50 worldwide.

Across Europe in 2019, 32 million individuals age 50+ are estimated to have osteoporosis (5.6% of the total European population age +50), or approximately 25.5 million women (22.1% of women aged +50).

The clinical consequence of osteoporosis is **fragility fractures**; it has been shown that an initial fracture is a major risk factor for a new fracture.

With the rapid ageing of the population worldwide and the changes in lifestyle habits, the incidence of osteoporosis and related fractures has significantly increased and **will continue to increase** markedly in the future.

DXA - osteoporosis

01.

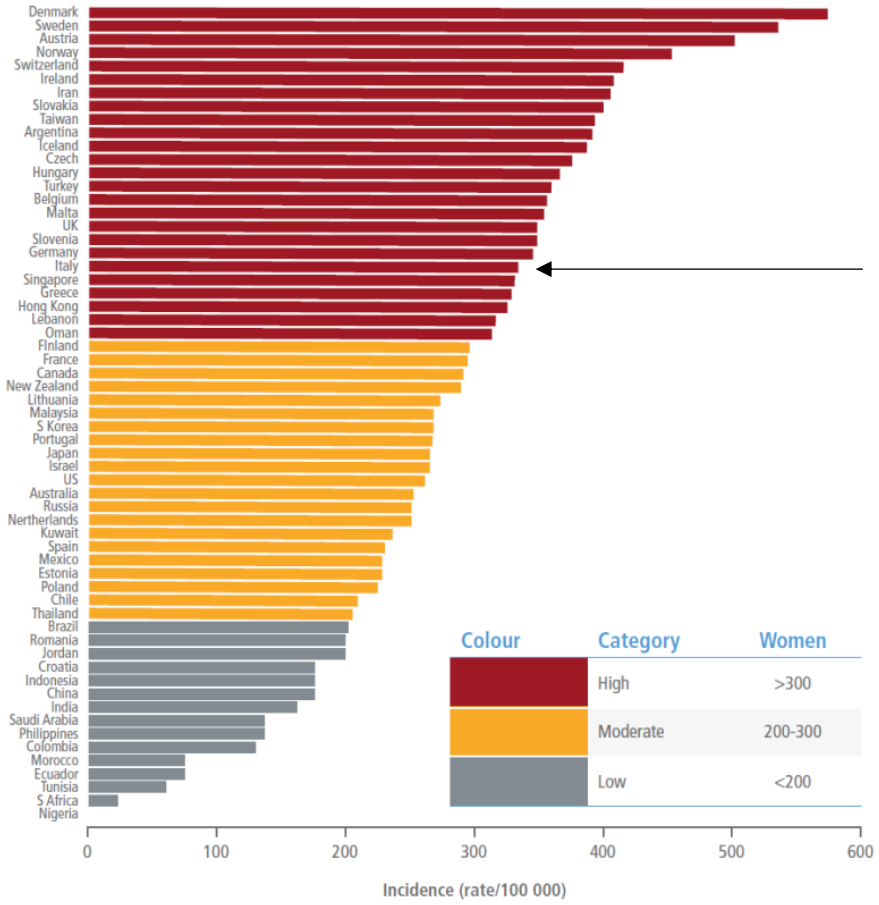
DXA: Why It Matters in Clinical Practice?

Evidence suggests that many women who sustain a fragility fracture **are not appropriately diagnosed and treated** for probable osteoporosis.

Hip: A study of 29 European countries found that the remaining lifetime probability of hip fracture at the **age of 50 years** was **15.0%** (varied by country: 7.0 - 25.1%) **in women**, and 5.7% (varied by country: 3.8 - 10.9%) in men.

A 10% loss of bone mass in the hip can result in a 2.5 times greater risk of hip fracture.

Up to 20% of patients die in the first year following hip fractures; less than half those who survive regain their previous level of function.

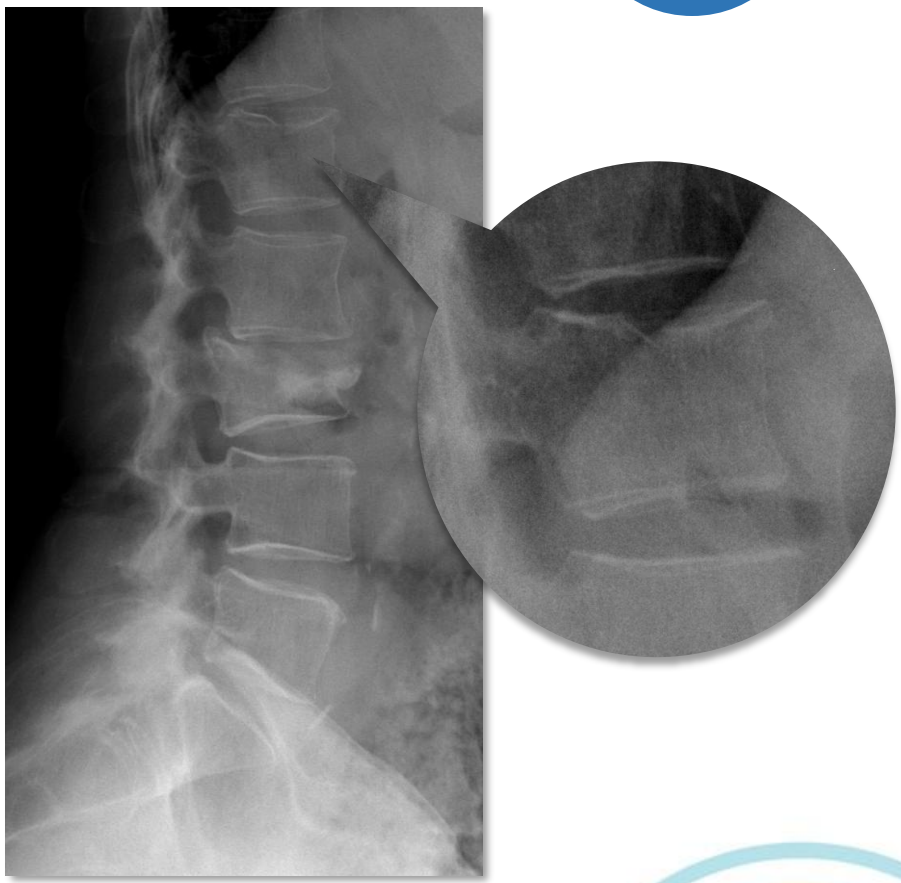


Age-standardised annual incidence of hip fractures in women (per 100.000) according to country, colour-coded as high, moderate or low incidence.

International Osteoporosis Foundation website

DXA - osteoporosis

01.



DXA: Why It Matters in Clinical Practice?

Spine: Vertebral fractures are the most common osteoporotic fractures.

A 10% loss of bone mass in the vertebrae can double the risk of vertebral fractures.

Women who develop a vertebral fracture are at substantial risk for additional fracture within the next 1-2 years. Over 55% of patients with hip fracture have evidence of a prior vertebral fracture.

Vertebral fractures are associated with an 8-fold increase in age-adjusted **mortality**.

Vertebral fractures can lead to back pain, loss of height, deformity, immobility, increased number of bed days, and even reduced pulmonary function.

Under-diagnosis of vertebral fracture is a worldwide problem: only one-third of vertebral fractures come to clinical attention.

International Osteoporosis Foundation website

01.

DXA - basics

DXA or DEXA?

DXA – not DEXA.

Advantages of DXA:

- **High accuracy and precision** – Excellent reproducibility of bone mineral density (BMD) measurements.
- **International standardization** – Recognized methodology in major clinical guidelines.
- **Low radiation dose** – Minimal exposure compared to other radiological techniques.
- **Fast examination** – Quick scan with immediate assessment.
- **Ease of execution** – Non-invasive and well-tolerated by patients.
- **Fracture risk assessment** – Provides prognostic parameters such as T-score and FRAX algorithm.
- **Osteoporosis monitoring** – Enables follow-up of bone density and treatment response.
- **Global assessment** – Bone quality (TBS), vertebral fracture (VF) assessment.

How it works?

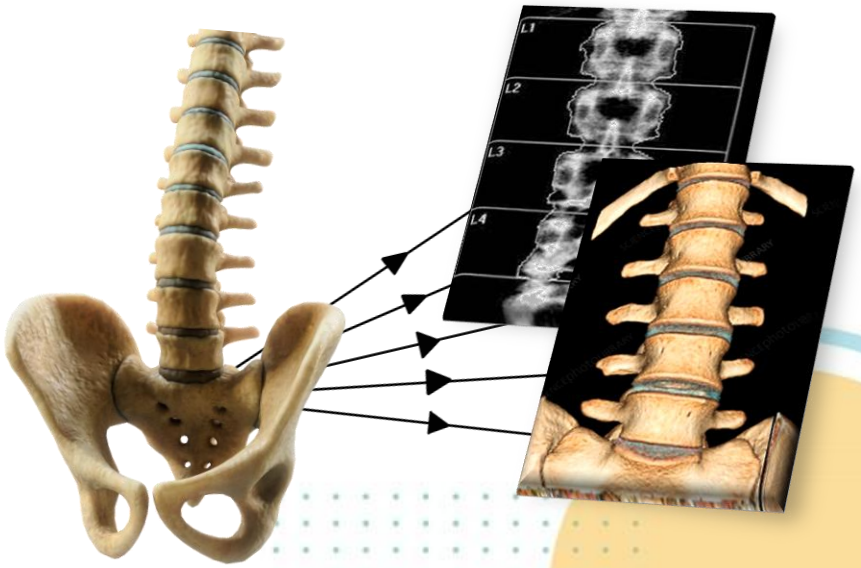
DXA system is that it creates a **planar (two dimensional) image** that is the combination of low and high energy attenuations.

DXA - basics

01.

DXA parameters:

- **Bone mineral content (BMC; g):** BMC is the mineral mass component of bone in the form of hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$.
- **Bone area (BA; cm^2):** BA is the projected area of the bone onto the image plane.
- **Areal bone mineral density (aBMD; g/cm^2):** aBMD is the mineral mass of bone per unit image area (aBMD = BMC/BA). Volume density, the mineral mass per unit bone volume, cannot be directly measured by DXA but can be measured by QCT.



DXA - basics

01.

DXA parameters:

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- **T-score:** the difference between the patient's aBMD and a young reference aBMD in units of the population SD.
- **Z-score:** the difference between the patient's aBMD and an age and typically ethnicity matched reference aBMD and SDs.

$$T\ \text{score} = \frac{\text{aBMD}_{\text{patient}} - \text{aBMD}_{\text{Young Adult Mean}}}{\text{SD}_{\text{Young Adult Mean}}}$$

$$Z\ \text{score} = \frac{\text{aBMD}_{\text{patient}} - \text{aBMD}_{\text{age-, ethnicity-matched adult mean}}}{\text{SD}_{\text{age-, ethnicity-matched adult mean}}}$$

Radiation dose

01.

Low-dose radiation technique:

Patient effective doses depend on the type of unit (pencil beam, fan beam, cone beam), the protocol or mode used for the scan, and the body site.

Lumbar spine, hip or whole body scans each result in an effective dose of about 1 µSv (pencil beam unit) and up to about 10 µSv (fan beam unit).

DXA scans of the forearm are very low, <1 µSv.

Radiation dose

01.

Examination	Effective dose (mSv)	Organ dose (mGy)	Relevant organs
Adult spine DXA	0.013	0.003	BM, ovaries
Adult hip DXA	0.009	0.005	LLI
Paediatric spine DXA	0.027	0.008	Ovaries
(5-year-old child, scan length 11.7 cm)		0.007	Stomach
Paediatric hip DXA	0.022	0.015	Testes
(5-year-old child, scan length 9.0 cm)		0.009	LLI
Paediatric spine DXA	0.021	0.006	Ovaries
(10-year-old child, scan length 14.5 cm)		0.005	Stomach
Paediatric hip DXA	0.018	0.010	Testes
(10-year-old child, scan length 12.4 cm)		0.008	LLI
Thoracic spine AP radiograph	0.4	0.8	Lungs
Thoracic spine LAT radiograph	0.3	1.2	Lungs
Lumbar spine AP radiograph	0.7	2.5	Stomach
Lumbar spine LAT radiograph	0.3	2.3	Liver

Paediatric doses are given for scans lengths adjusted to the size of the child's body

AP anterior-posterior, *LAT* lateral, *BM* bone marrow, *LLI* lower large intestine

Examination	Effective dose (mSv)	Organ dose (mGy)	Relevant organs
Dental radiography (intraoral)	0.005	0.005	Brain
Chest radiography (posterior-anterior)	0.02	0.01	Lung
X-ray mammography	0.4	3	Breast
Adult abdominal CT	8	10	Stomach

Damilakis J et al. Radiation exposure in X-ray-based imaging techniques used in osteoporosis. Eur Radiol (2010)

Indications for BMD testing

01.

- Women aged 65 and older
- For post-menopausal women < 65yo, a bone density test is indicated if they have a risk factor for low bone mass such as:
  - Low body weight
  - Prior fracture
  - High risk medication use
  - Disease or condition associated with bone loss
- Women during the menopausal transition with clinical risk factors for fracture (such as low body weight, prior fracture, or high-risk medication use)
- Men aged 70 and older
- For men < 70yo a bone density test is indicated if they have a risk factor for low bone mass such as above
- Adults with a fragility fracture
- Adults with a disease or condition associated with low bone mass or bone loss
- Adults taking medications associated with low bone mass or bone loss
- Anyone being considered for pharmacologic therapy
- Anyone being treated, to monitor treatment effect
- Anyone not receiving therapy in whom evidence of bone loss would lead to treatment

Indications for BMD testing

01.

All women 65 years of age or older (IOF: guided by FRAX probability [80]
Postmenopausal women < 65 years with additional risk factors (ISCD [4], ACR [79] USPSTF [81], ACOG [82], NICE [83] or guided by FRAX probability (IOF [80])
≥ 50 years AACE [35]
≥ 50 years with degenerative changes (ACR)
≥ 50 years with non-traumatic fractures (ACR)
Postmenopausal women with osteopenia identified radiographically (AACE)
Women during a menopausal transition who have one or more risk factors for osteoporosis (ISCD)
Premenopausal women or men < 50 years with risk factors (ACR)
Men ≥ 70 years (ISCD, BHOF [84], ACR)
Men ≥ 75 years (NICE)
Men < 70 years with risk factors (ISCD, BHOF, ACR);
Men < 75 years with risk factors (NICE)
Postmenopausal women and men aged 50–69 years based on risk profile (BHOF)
Postmenopausal women and men aged ≥ 50 years with history of adult-age fracture (BHOF)
Individuals of any sex or age who develop one or more insufficiency fractures (ACR)
High FRAX score calculated without BMD (NOGG [85])
Osteoporosis risk assessment tools- OST, SCORE, OSIRIS, ORAI, body weight criterium [86].

Indications for bone mineral density measurements multisociety

Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

Indications for BMD testing

01.

CODICE	DESCRIZIONE	NOTA	Codice Indicazione	Branca1	Branca2	Branca3	Branca4	Branca5	Tariffa
88.99.3	DENSITOMETRIA OSSEA. DXA TOTAL BODY		29	Diagnostica per immagini					43,35
88.99.4	DENSITOMETRIA OSSEA. TC MONODISTRETTUALE		29	Diagnostica per immagini					79,70
88.99.6	DENSITOMETRIA OSSEA. DXA LOMBARE		29	Diagnostica per immagini					36,00
88.99.7	DENSITOMETRIA OSSEA. DXA FEMORALE			Diagnostica per immagini					36,00
88.99.8	DENSITOMETRIA OSSEA. DXA ULTRADISTALE			Diagnostica per immagini					36,00

29	CONDIZIONE EROGABILITA'	Secondo indicazioni dell'allegato 4 A del DPCM 12/1/2017

Nomenclatore Tariffario - Regione Emilia Romagna (dal dicembre 2024)

Indications for BMD testing

01.

Fattori di rischio per l'erogazione delle prestazioni di densitometria ossea

L'indagine densitometrica è indicata in presenza di uno dei seguenti

Fattori di rischio maggiori

1. Per soggetti di ogni età di sesso femminile e maschile:
   a. Precedenti fratture da fragilità (causate da trauma minimo) o riscontro radiologico di fratture vertebrali.
   b. Riscontro radiologico di osteoporosi
   c. Terapie croniche (attuate o previste)
      - Cortico-steroidi sistemici (per più di 3 mesi a posologie >/= 5 mg/die di equivalente prednisonico).
      - Levotiroxina (a dosi soppressive).
      - Antiepilettici.
      - Anticoagulanti (eparina).
      - Immunosoppressori.
      - Antiretrovirali.
      - Sali di litio.
      - Agonisti del GnRH.
      - Chemioterapia in età pediatrica [1]
      - Radioterapia in età pediatrica2
   d. Patologie a rischio di osteoporosi:
      - Malattie endocrine con rilevante coinvolgimento osseo (amenorrea primaria non trattata, amenorrea secondaria per oltre un anno, ipogonadismi, iperparatiroidismo, ipertiroidismo, sindrome di Cushing, acromegalia, deficit di GH, iperprolattinemia, diabete mellito tipo 1).
      - Rachitismi/osteomalacia.
      - Sindromi da denutrizione, compresa l'anoressia nervosa e le sindromi correlate,
      - Celiachia e sindromi da malassorbimento,
      - Malattie infiammatorie intestinali croniche severe,
      - Epatopatie croniche colestatiche.
      - Fibrosi cistica,
      - Insufficienza renale cronica, sindrome nefrosica, nefrotubulopatie croniche e ipercalciuria idiopatica.
      - Emopatie con rilevante coinvolgimento osseo (mieloma, linfoma, leucemia, thalassemia, drepanocitosi, mastocitosi).
      - Artrite reumatoide (incluso Morbo di Still), spondilite anchilosante, artropatia psoriasica, connettiviti sistemiche.
      - Patologie genetiche con alterazioni metaboliche e displasiche dell'apparato scheletrico.
      - Trapianto d'organo.
      - Allettamento e immobilizzazioni prolungate (>3 mesi).
      - Paralisi cerebrale, distrofia muscolare, atrofia muscolare e spinale.

2. Limitatamente a donne in menopausa
   a. Anamnesi familiare materna di frattura osteoporotica in età inferiore a 75 anni.
   b. Menopausa prima di 45 anni.
   c. Magrezza: indice di massa corporea < 19 kg/m2 .

L' indagine densitometrica è, inoltre, indicata in presenza di:
3 o più fattori di rischio minori per le donne in menopausa

1. Età superiore a 65 anni.
2. Anamnesi familiare per severa osteoporosi.
3. Periodi superiori a 6 mesi di amenorrea premenopausale.
4. Inadeguato apporto di calcio (<1200 mmg/die).
5. Fumo > 20 sigarette/die
6. Abuso alcolico (>60 g/die di alcool).

3 o più fattori di rischio minori per gli uomini di età superiore a 60 anni

1. Anamnesi familiare per severa osteoporosi.
2. Magrezza (indice di massa corporea < a 19Kg/m2.
3. Inadeguato apporto di calcio (<1200 mmg/die).
4. Fumo >20 sigarette/die
5. Abuso alcolico (>60 g/die di alcool).

Allegato 4 A del DPCM 12/1/2017

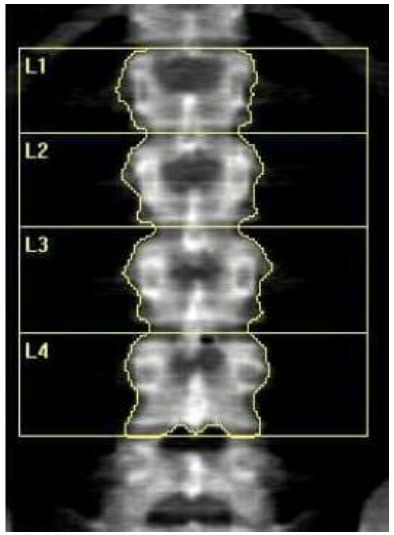
Controindications to DXA

01.

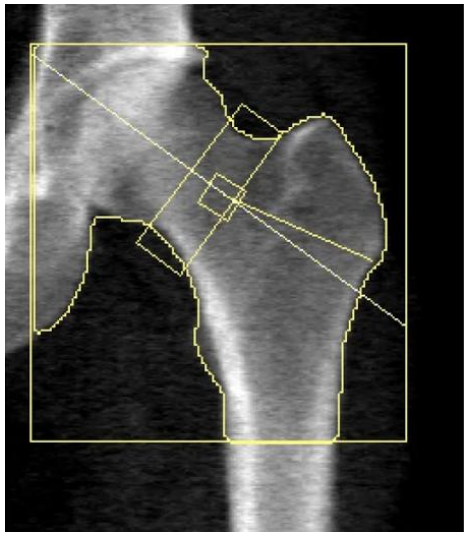
- Pregnancy
- Use of contrast agents within the past 7 days

Target sites

01.



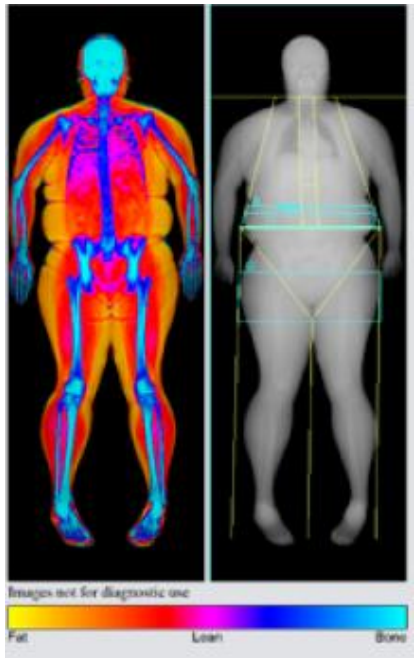
LUMBAR SPINE



HIP

FOREARM

(sometimes)



WHOLE BODY

(body composition analysis)

Target sites

01.

Central DXA for diagnosis:

Osteoporosis may be diagnosed **in postmenopausal women and in men age 50+** if the **T-score of the lumbar spine, total hip, or femoral neck is -2.5 or less**.

Measure BMD at **both the PA spine and hip in all patients**.

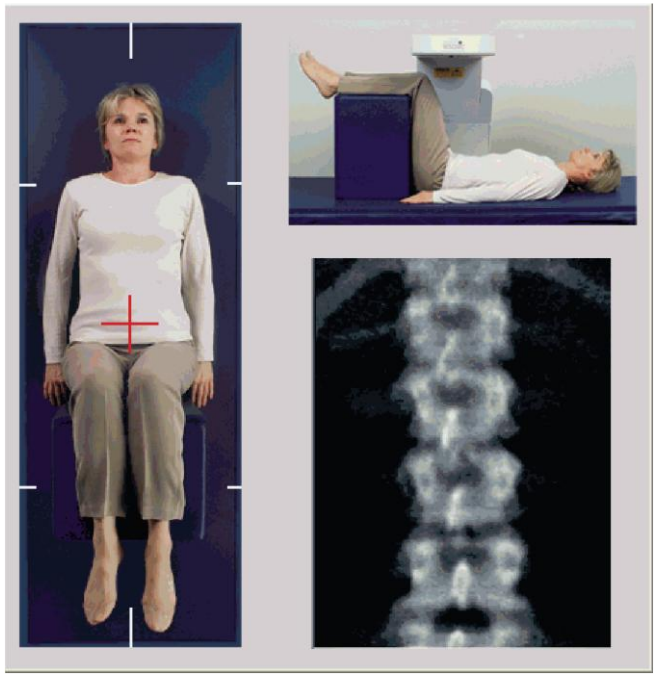
In certain circumstances the **33% radius** (also called **1/3 radius**) may be utilized.

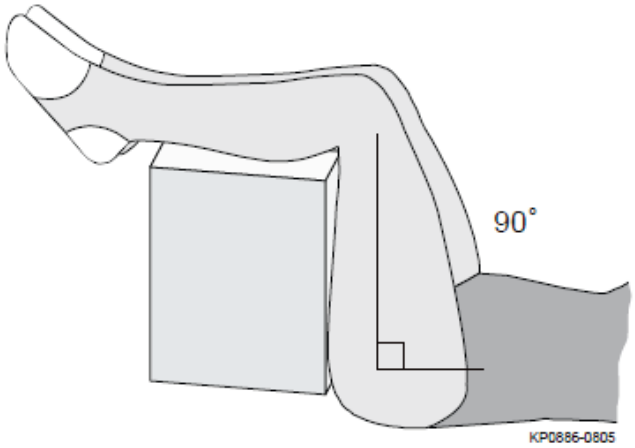
Forearm BMD **should be measured** under the following circumstances:

- Hip and/or spine cannot be measured or interpreted.
- Hyperparathyroidism
- Very obese patients (over the weight limit for DXA table)

Target sites: lumbar spine

01.





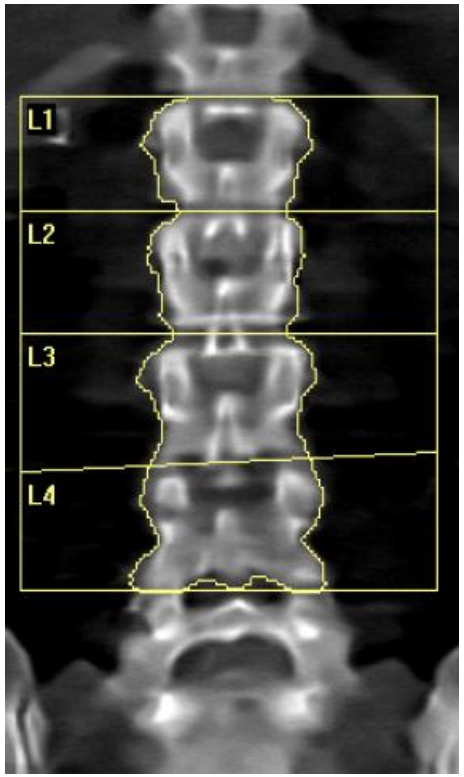
The hip and knees are flexed to 90° to reduce the physiological lumbar lordosis and increase the intervertebral spaces and maximize the area of each of the lumbar vertebra.

Target sites: lumbar spine

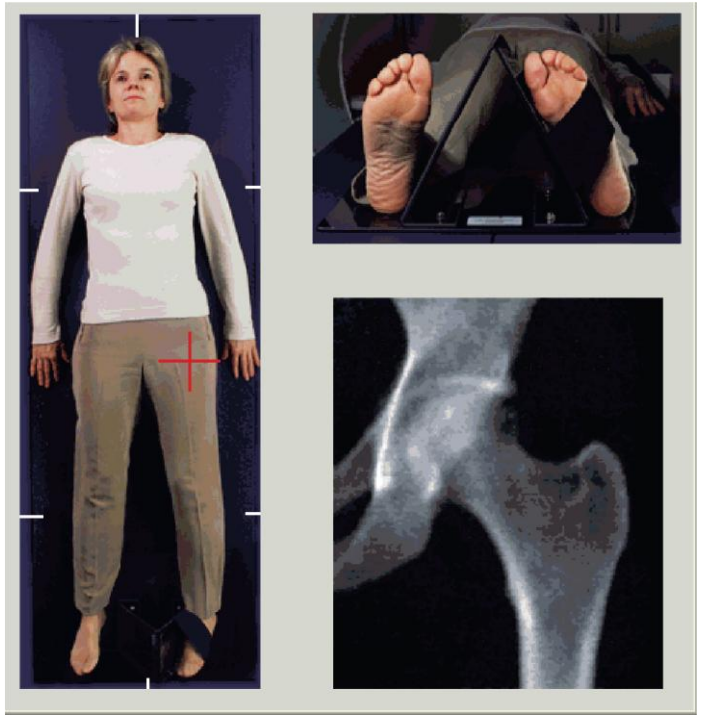
01.

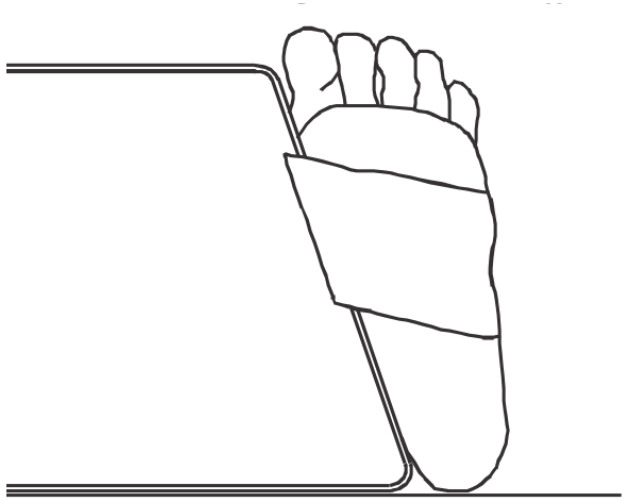
Proper acquisition is mandatory to perform an accurate analysis:

- the spine should be **straight and unrotated**, with the same amount of soft tissue at both sides;
- **iliac crests** should be visible (even a small part) in the lower part of the image, as well as **thoracic ribs** in the upper part.



Target sites: hip





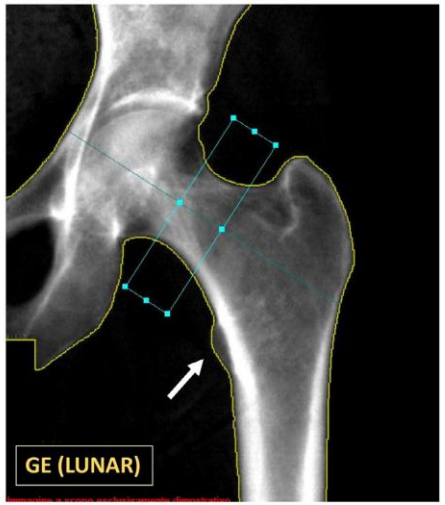
Use the **left side**. It is also important to state that the same side should be used for longitudinal measurements.

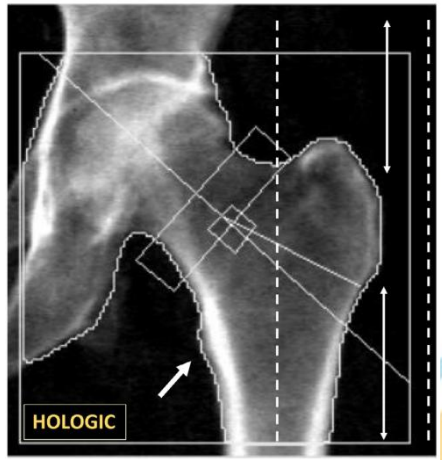
Target sites: hip

01.

Proper acquisition is mandatory to perform an accurate analysis:

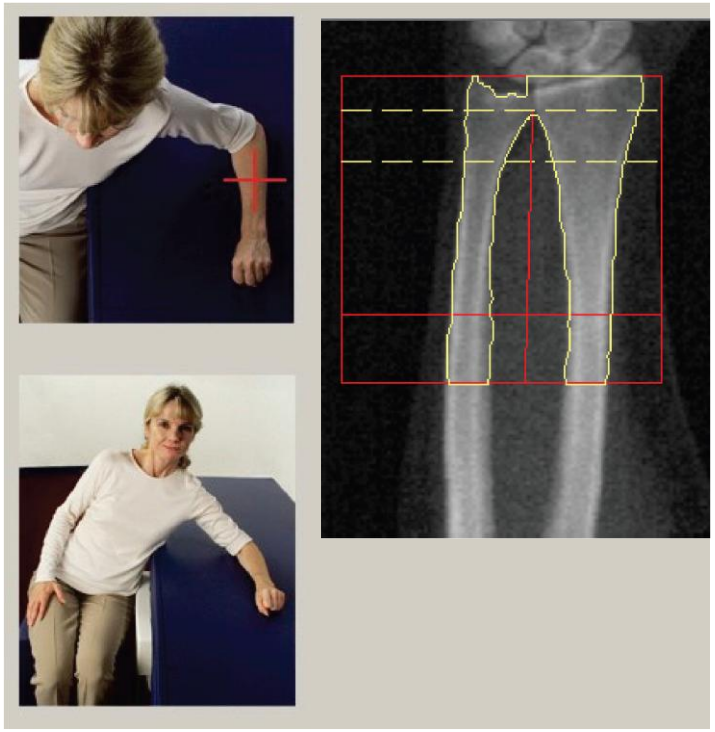
- Hip scans must be acquired to ensure a certain degree **of internal rotation** of the leg, usually of about **15°-20°**, which serves to position the femoral neck parallel to the scan table plane.
- Internal rotation is necessary to make the **lesser trochanter barely visible** on the image scan: insufficient internal rotation usually increases femoral neck BMD values.
- Another important suggestion is to keep the **femoral shaft straight** to have it parallel to the image edges.

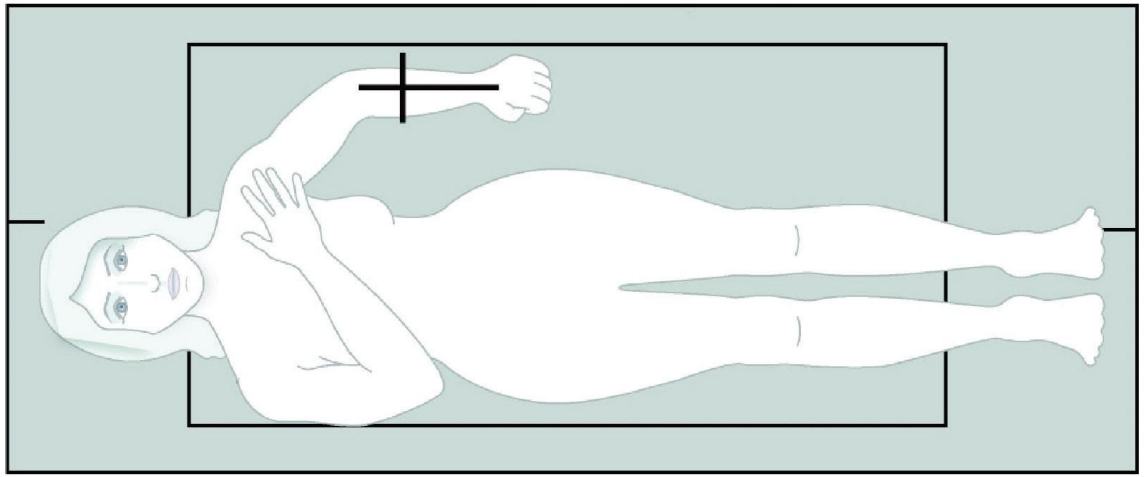




Albano D et al. Operator-Related Errors and Pitfalls in Dual Energy X-Ray Absorptiometry: How to Recognize and Avoid Them. Acad Radiol. 2021

Target sites: forearm





Use the **non-dominant arm**.

Interpretation and analysis

02.

The acronym **PARED** has been utilized to guide interpretation of DXA studies.:

P – Positioning: Is the positioning of the patient correct?

A – Artifacts: Are there any artifacts present within the region of interest scanned or in the soft tissue?

R - Regions of Interest: Are the regions of interest correct? On a follow-up scan are the regions of interest analogous?

E - Edge Detection: Is the edge detection correct?

D – Demographics (patient and risk factors for fracture) **and Database**: Are the demographics properly recorded, including risk factors for fracture and is the correct database for comparison used?

Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

Interpretation and analysis

02.

The role of the radiology technician: key to accurate bone density assessment

- **Patient Positioning & Preparation**

Ensures correct positioning to avoid artifacts

Minimizes errors from improper limb placement

- **Scan Acquisition & Quality Control**

Adheres to standardized protocols (ISCD guidelines)

Identifies and mitigates technical errors

- **Analysis & Precision**

Ensures reproducibility in serial measurements

Recognizes artifacts and degenerative changes affecting results

- **Clinical Impact**

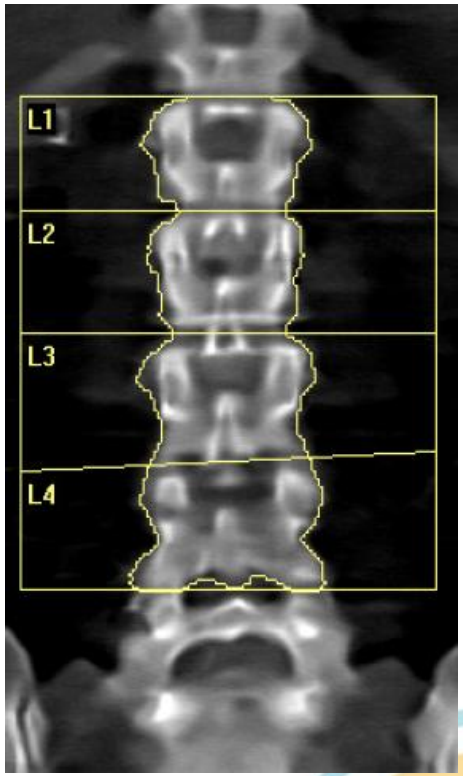
A well-trained technician improves diagnostic reliability

Reduces variability, enhancing patient management

Interpretation and analysis

02.

The lumbar spine is in general the site most frequently affected by artifacts that may bias BMD estimates. In most cases, artifacts in the lumbar spine will cause a spurious **increase in BMD values.**



Use **L1-L4** for spine BMD measurement.

Use all evaluable vertebrae (**at least two**) and only exclude vertebrae that are affected by **local structural change** or **artifact**.
If only one evaluable vertebra remains, diagnosis should be based on a different valid skeletal site.

When do I have to exclude a vertebra from analysis?

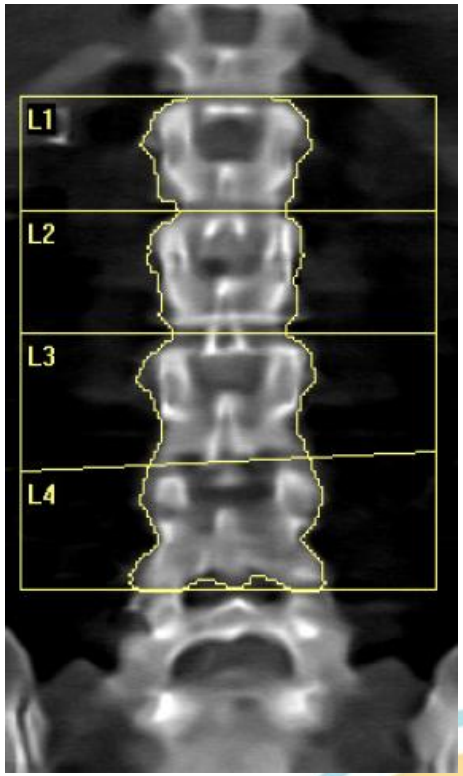
- **clearly abnormal** and non-assessable within the resolution of the system; or
- there is **more than a 1.0 T-score difference** between the vertebra in question and adjacent vertebrae.

Interpretation and analysis

02.

Abnormalities to be considered: severe osteoarthritic changes, compression fracture, laminectomy, or artifacts (e.g. fusion hardware, vertebroplasty cement, obscured by other implantable devices).

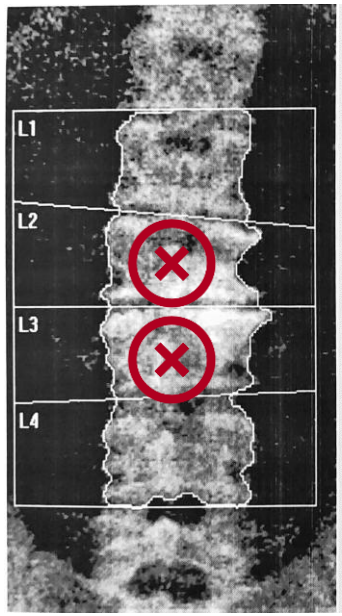
In **osteoarthritis**, osteophytes, hypertrophy and sclerosis of the facet joints develop and **may increase BMD**. Approximately 40% of women aged 55 and 85% of those age > 75 years will have spine osteoarthritis.



ISCD guidelines 2023

Interpretation and analysis

02.

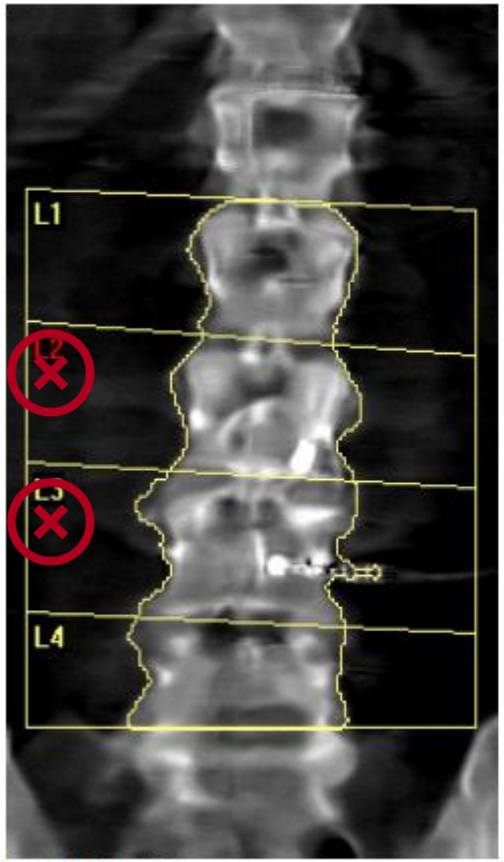


Riepilogo risultati DXA:

Regione	Area (cm^2)	BMC (g)	BMD (g/cm^2)	T - score	Z - score
L1	17.14	14.62	0.853	-2.0	-1.5
L2	16.08	18.54	1.153	0.5	1.1
L3	17.03	20.74	1.218	1.0	1.6
L4	18.65	15.44	0.828	-2.4	-1.8
Totale	**68.90**	**69.33**	**1.006**	**-0.8**	**-0.2**

Interpretation and analysis

02.



k = 1.140, d0 = 47.5
116 x 127
DAP: 4.0 cGy*cm²

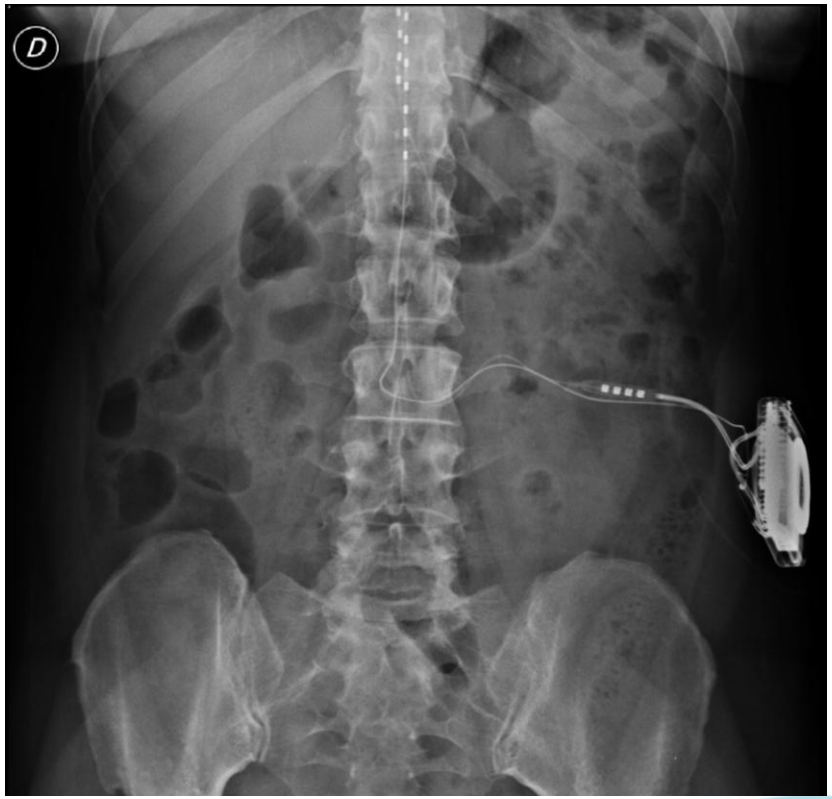
Informazioni sulla scansione:

Data scansione: 04 Luglio 2023 ID: A0704230F
Tipo di scansione: a Lombare
Analisi: 04 Luglio 2023 11:39 Versione 13.6.0.5:7
Col. T
Operatore: LS
Modello: Horizon W (S/N 301644M)
Commento:

Riepilogo risultati DXA:

Regione	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	Z - score
L1	12.48	12.78	1.024	0.3	1.2
L3	17.57	19.03	1.083	0.0	1.0
L4	13.57	12.27	0.904	-1.4	-0.4
Totale	**43.62**	**44.08**	**1.010**	**-0.4**	**0.6**

Totale BMD CV 1.0%, ACF = 1.036, BCF = 1.014, TH = 7.274



Interpretation and analysis

02.

Look carefully at the images!

Interpretation and analysis

02.

k = 1.139, d0 = 46.8
116 x 134
DAP: 4.0 cGy*cm²

Informazioni sulla scansione:

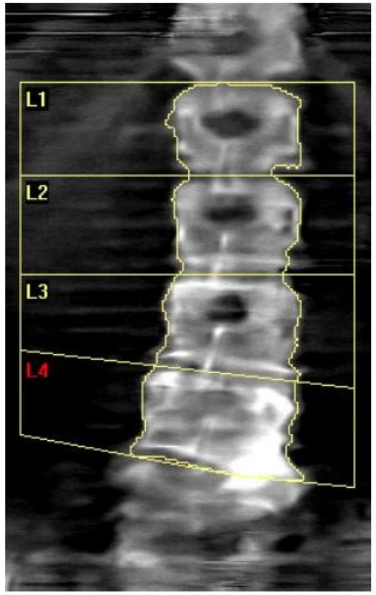
Data scansione: 30 Gennaio 2024 ID: A0130240H
Tipo di scansione: a Lombare
Analisi: 06 Febbraio 2024 15:25 Versione 13.6.0.5:7
Col. T
Operatore: LS
Modello: Horizon W (S/N 301644M)
Commento:

LOOK HERE!

Riepilogo risultati DXA:

Regione	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	Z - score
L1	13.08	7.82	0.597	-3.6	-1.7
L2	14.62	10.17	0.695	-3.0	-0.9
Totale	**27.71**	**17.99**	**0.649**	**-3.0**	**-1.0**

Totale BMD CV 1.0%, ACF = 1.036, BCF = 1.014, TH = 7.108



k = 1.139, d0 = 47.2
116 x 140
DAP: 4.0 cGy*cm²

Informazioni sulla scansione:

Data scansione: 21 Settembre 2020 ID: A0921200B
Tipo di scansione: a Lombare
Analisi: 21 Settembre 2020 10:37 Versione 13.6.0.5:7
Col. T
Operatore: LS
Modello: Horizon W (S/N 301644M)
Commento:

Riepilogo risultati DXA:

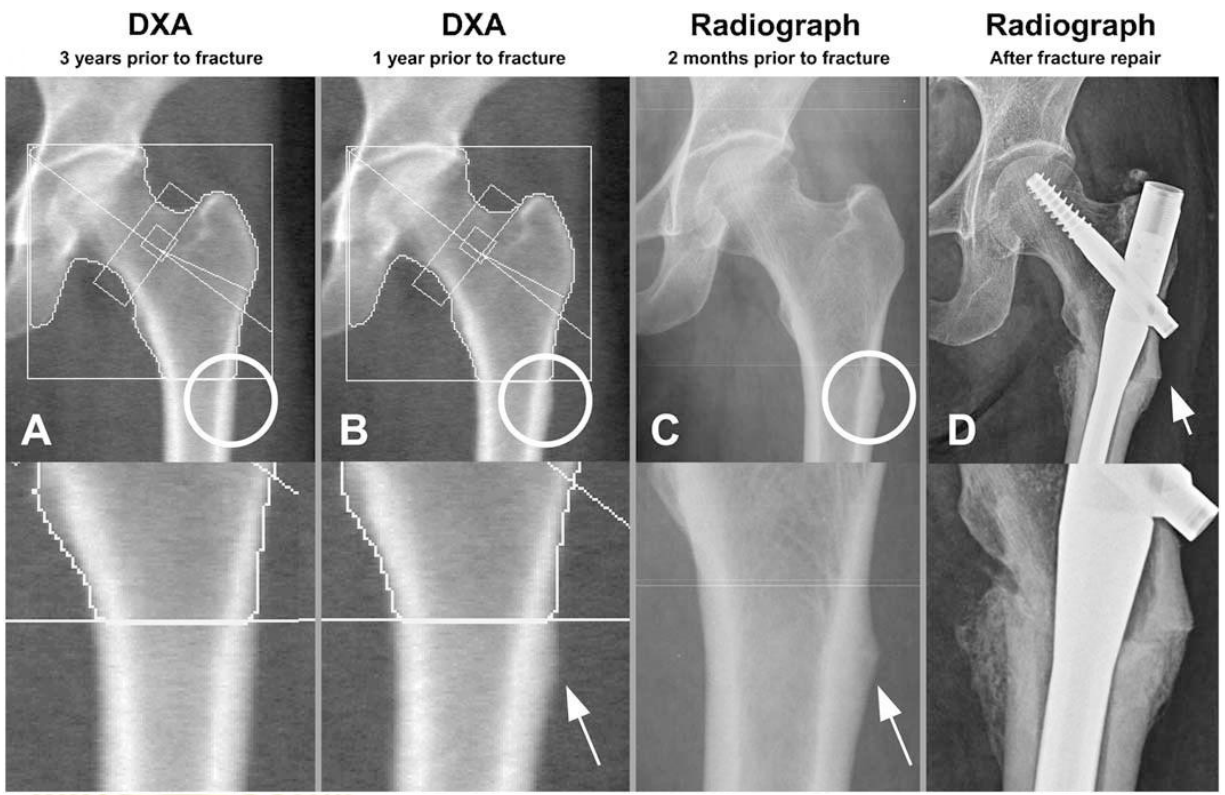
Regione	Area (cm²)	BMC (g)	BMD (g/cm²)	T - score	Z - score
L1	12.96	7.98	0.615	-3.4	-1.7
L2	13.94	9.02	0.647	-3.5	-1.6
L3	15.91	11.48	0.721	-3.3	-1.3
Totale	**42.81**	**28.47**	**0.665**	**-3.2**	**-1.4**

Totale BMD CV 1.0%, ACF = 1.036, BCF = 1.014, TH = 7.183

PREVIOUS EXAM (2020)

Interpretation and analysis

02.



Atypical femoral fracture

Incomplete atypical femur fractures are **low trauma fractures** characterized by focal periosteal or endosteal thickening of the lateral femoral cortex.

Predominantly observed in **bisphosphonate users**, but may also occur in patients on denosumab, romosozumab and in non-users of osteoporosis pharmacotherapy.

They can be detected as an active lesion with a **lucent line ("beaking") in the middle of the cortical thickening**.

Ahlman MA. Evolution of bisphosphonate-related atypical fracture retrospectively observed with DXA scanning. J Bone Miner Res. 2012
Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

Interpretation and analysis

02.

Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

Interpretation and analysis

02.

How to report?

Implementing a **DXA reporting template** may reduce major errors, shorten reporting time and improve report quality.

Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

Interpretation and analysis

02.

T-score or Z-score?

Osteoporosis may be diagnosed in postmenopausal women and in men age 50 and older if the T-score of the lumbar spine, total hip, or femoral neck is -2.5 or less.

To simplify:

T-score: BMD reporting in postmenopausal women and in men age 50 and older (and women in the menopausal transition)

Z-score: BMD reporting in females prior to menopause and in males younger than age 50

A Z-score of -2.0 or lower is defined as "**below the expected range for age**" and a Z-score above -2.0 is "**within the expected range for age.**"

Osteoporosis cannot be diagnosed in men under age 50 on the basis of BMD alone.

Interpretation and analysis

02.

Standard DXA report components	Example of DXA report
	Previous DXA scan: None
Name	*J.K.*
Medical record ID number	*XX321*
Date of birth/age	*66 years*
Sex	*Female*
Body weight Body height	*70 kg 168 cm*
Menopausal status/age at menopause	*Postmenopausal /age at menopause 52 years*
Requesting provider	*Gynaecologist*
Indications for the test	*Postmenopausal woman age 65 years or older*
Manufacturer and model of instrument and software used	*Hologic Delphi C*
• Technical quality and limitations of the study, stating why a specific site of ROI is invalid or not included. • BMD in g/cm^2 for each site. • The skeletal sites, ROI, and, if appropriate, the side, that were scanned. • The T-score and/or Z-score where appropriate. • WHO criteria for diagnosis in postmenopausal women and in men age 50 years and over. • Interval change (if a follow-up study)	***BMD results***: *good quality* ***Proximal femur***: *Total hip BMD/T-score: 0.809 g/cm^2/ -1.1* *Femoral neck BMD/T-score: 0.680 g/cm^2/ -1.5* *Comments: Due to a previous left hip replacement, scanning of the right hip was performed* ***Lumbar spine***: *Total L1-L4 BMD/T-score: 0.958 g/cm^2/ -0.8* *Comments: there are mild degenerative changes*
• Risk factors including information regarding previous non-traumatic fractures. • A statement about fracture risk [62]. Any use of relative fracture risk must specify the population of comparison (e.g., young-adult or age-matched, race/ethnicity) [63]. Reporting of absolute fracture risk is preferred. Identify the fracture risk calculator used. Include positive fracture risk components that were included in the calculation. • A general statement that a medical evaluation for secondary causes of low BMD may be appropriate. • Reports should contain a statement describing why acquired exams were not reported or when a technically acceptable DXA exam has aspects that might confound BMD results. • Diagnostic classification is an essential component of the report, with application of the WHO diagnostic criteria when appropriate. • When reporting or referring to race, "White" is preferred to "Caucasian". • Recommendations for the necessity and timing of the next BMD study • Recommendations for further non-BMD imaging	*Risk factors: current smoking* ***Fracture risk***: *FRAX 1.5% risk of hip fracture and 15% risk of major osteoporotic fracture* ***CONCLUSIONS***: *Diagnosis: Osteopenia (low bone mass)* *Evaluation of secondary causes of low BMD: suggested* *Treatment recommendations: based on clinical circumstances and national clinical guidelines* *Follow-up DXA: 2–3 years or sooner if clinically indicated* *Other recommendations*:

Slart RHJA et al; International Working Group on DXA Best Practices. Updated practice guideline for dual-energy X-ray absorptiometry (DXA). Eur J Nucl Med Mol Imaging. 2025

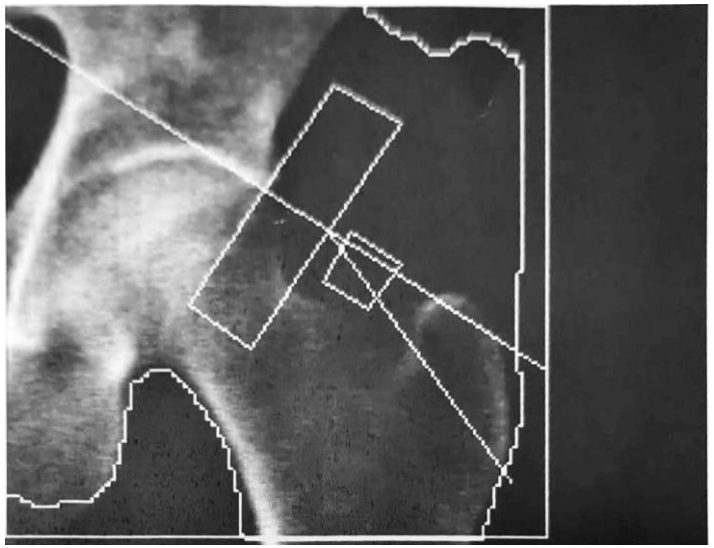
Pitfalls

03.

Errors in DXA are frequent!

More than 90% of DXA examinations performed in clinical practice are affected by at least one error, with potential relevant implications for patients' osteoporosis diagnosis and management.

Regarding the lumbar spine, the most frequent error concerned the **inclusion or exclusion of vertebrae** (46 %); regarding the femur, it was **a poor definition of the analysis box** (30%).



Messina C et al. Prevalence and type of errors in dual-energy x-ray absorptiometry. Eur Radiol. 2015

Pitfalls

03.

We reviewed the DXA examinations of 340 patients with β-TM followed by our institution, acquired in different imaging centers between 2009 and 2019.

Out of 5099 total DXA scans, 12% presented one or more errors. Specifically, the incorrect examinations were 315 out of 1707 (18%) at the lumbar spine level, 113 out of 1697 (7%) at the total hip, 176 out of 1695 (10%) at the femoral neck.

Errors in vertebral inclusion were the most frequently registered (46%).

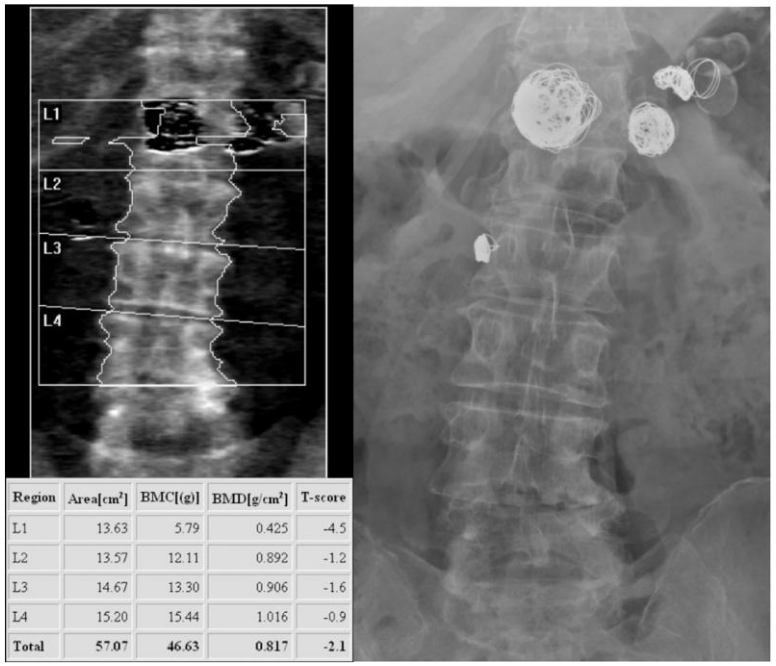
Lucioni E et al. Bone densitometry in Thalassemia major: a closer look at pitfalls and operator-related errors in a 10-year follow-up population. Radiol Med. 2024

Pitfalls

03.

Common **pitfalls and artifacts in lumbar DXA**:

- Degenerative spinal changes
- Vertebral fractures
- Other lumbar spine artifacts (aortic calcifications, previous surgery or other abdominal interventions)



Region	Area[cm²]	BMC[(g)]	BMD[g/cm²]	T-score
L1	13.63	5.79	0.425	-4.5
L2	13.57	12.11	0.892	-1.2
L3	14.67	13.30	0.906	-1.6
L4	15.20	15.44	1.016	-0.9
Total	**57.07**	**46.63**	**0.817**	**-2.1**

Albano D. Operator-Related Errors and Pitfalls in Dual Energy X-Ray Absorptiometry: How to Recognize and Avoid Them. Acad Radiol. 2021

Pitfalls

03.

BMD measurements at **proximal femur** are **less affected by artifacts and structural changes** (hip prostheses or screws)

Albano D. Operator-Related Errors and Pitfalls in Dual Energy X-Ray Absorptiometry: How to Recognize and Avoid Them. Acad Radiol. 2021

Beyond BMD: trabecular bone score

03.

Osteoporosis has historically been defined as “a systemic skeletal disease characterized by **low bone mass** and **microarchitectural deterioration** of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture.”

The inability of DXA to identify poor bone structure con- tributes to this suboptimal ability to identify those who will fracture.

Trabecular bone score (TBS) is a software program used to assess **bone texture** by evaluating gray scale variation in the **lumbar spine DXA image**.

TBS has been extensively studied and enhances fracture prediction independent of BMD, and it has been incorporated into an adjustment of the FRAX tool.

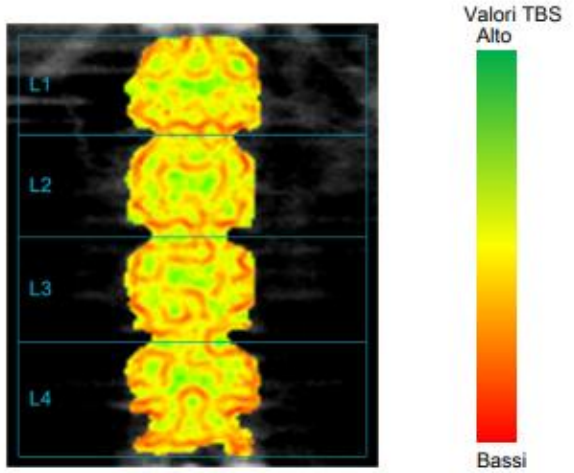
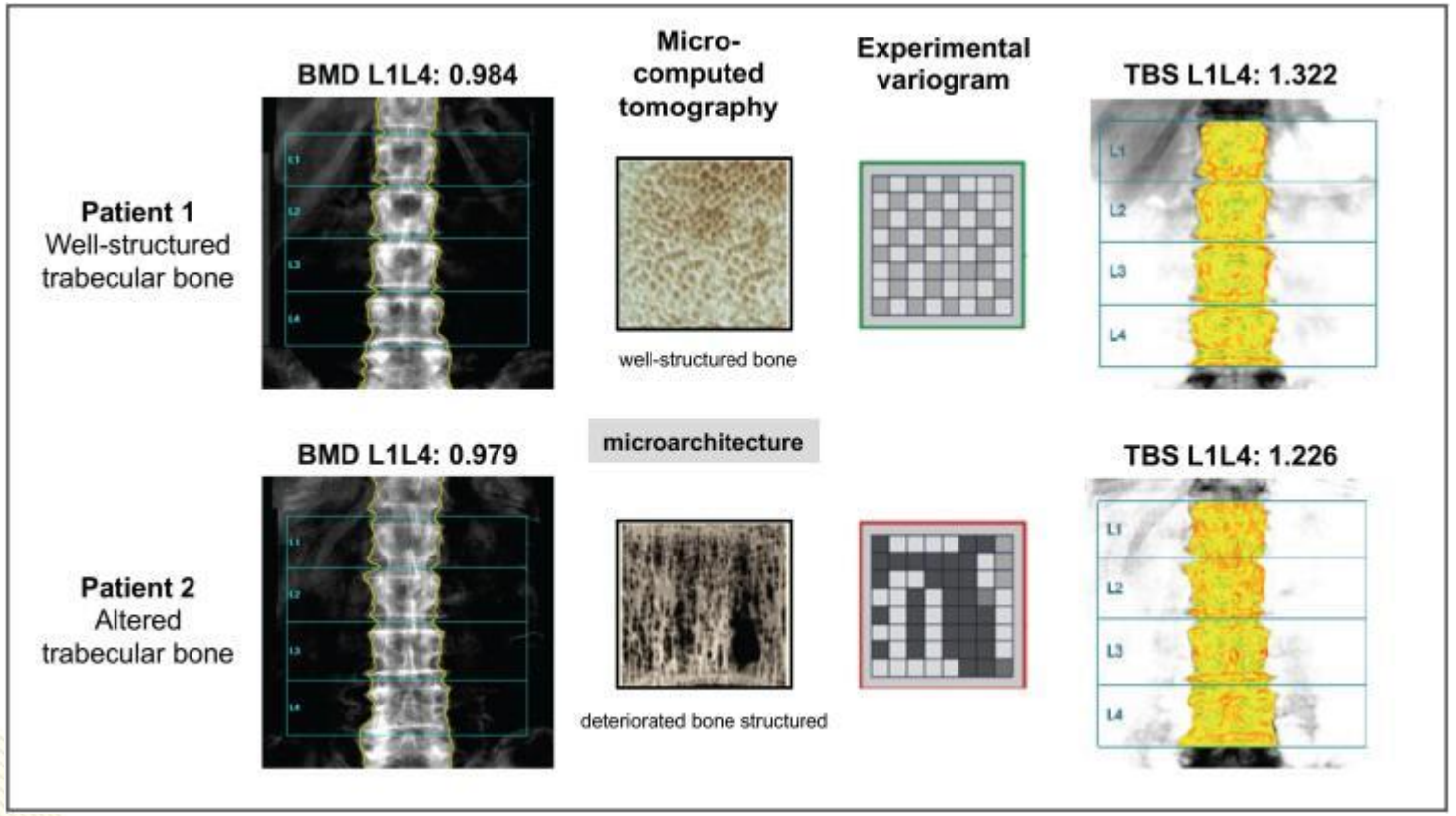


Immagine non per fini diagnostici

Clinical Use of Trabecular Bone Score: The 2023 ISCD Official Positions

Beyond BMD: trabecular bone score



Palomo T. Update on trabecular bone score. Arch Endocrinol Metab. 2022

Beyond BMD: trabecular bone score

03.

TBS is relatively **insensitive to degenerative changes**, ankylosing spondylitis **and vertebral fractures**. There is no strong evidence to suggest that vertebral exclusion would clinically improve fracture prediction using FRAX.

The score may be used as a **continuous variable**, by adjusting FRAX probability or BMD T-score, and has been interpreted clinically with cut-off values at thirds of the distribution:

- Normal microarchitecture: TBS > 1.31;
- Degradaed bone: TBS ≤ 1.23

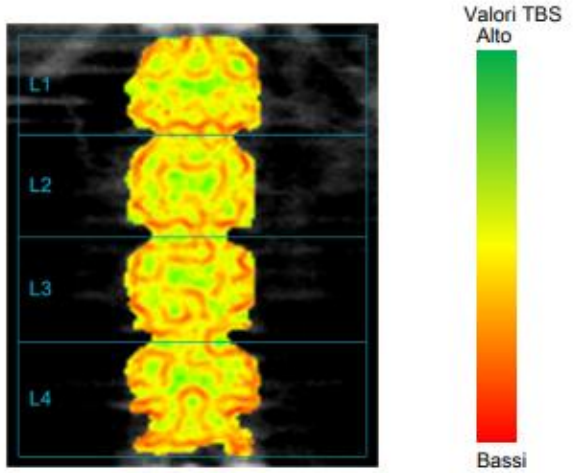


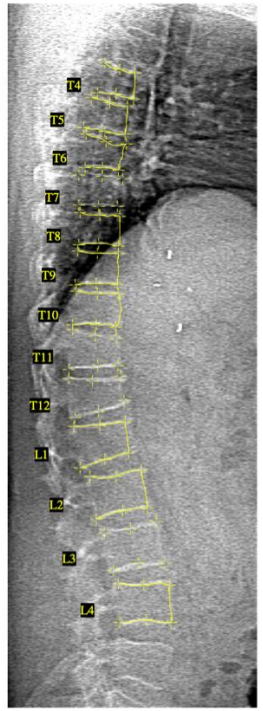
Immagine non per fini diagnostici

Clinical Use of Trabecular Bone Score: The 2023 ISCD Official Positions

Beyond BMD: vertebral fracture assessment

03.

Medico di riferimento:



Informazioni sulla scansione:

Data di scansione:	19.07.2011 - A07191107
Tipo di scansione:	a SE Lateral Image
Analisi:	23 October 2019 06:08
Operatore:	mab
Modello:	Discovery A (82987)
Commento:	

la evaluación vertebral

	Altezza (mm)			Percentuale di deformazione		
Etichetta	Post	Med	Ant	Cuneo	Biconcavo	Rhiacciamen
	Deformity (Grade)					
T4	17.9 Normale	14.6	15.2	15.0%	18.2%	0.0%
T5	17.9 Normale	17.1	16.2	9.3%	4.3%	0.0%
T6	19.6 Biconcavo (lieve)	15.3	15.9	18.9%	21.5%	0.0%
T7	17.6 Normale	17.7	16.5	6.5%	-0.6%	0.0%
T8	18.8 Normale	16.7	17.4	7.7%	11.5%	0.0%
T9	19.8 Normale	17.6	18.3	7.5%	11.1%	0.0%
T10	19.7 Normale	18.1	19.6	0.3%	7.9%	0.0%
T11	23.3 Cuneo (moderato)	17.0	16.0	31.6%	26.9%	0.0%
T12	23.4 Cuneo (moderato)	18.4	14.3	38.9%	21.3%	0.0%
L1	24.4 Cuneo (lieve)	20.0	18.5	24.3%	18.0%	0.0%
L2	25.1 Normale	20.1	22.2	11.4%	19.7%	0.0%
L3	22.4 Normale	20.4	25.3	0.0%	9.0%	11.4%
L4	22.4 Normale	20.3	21.7	3.2%	9.5%	0.0%
Std Dev	1.0	1.0	1.0	5.0%	5.0%	5.0%

Commento del medico:

Beyond BMD: vertebral fracture assessment

03.

Università degli Studi di Ferrara
Scuola di Specializzazione Endocrinologia e Malattie del Metabolismo
Direttore: Prof.ssa Maria Rosaria Ambrosio
U.O. di Endocrinologia e Malattie del Ricambio
Direttore: Prof.ssa Maria Chiara Zatelli
Scuola di Specializzazione in Radiodiagnostica
Direttore: Prof. Aldo Carnevale
Dipartimento di Scienze Mediche
Dipartimento di Medicina Traslazionale e per la Romagna
Dipartimenti di Eccellenza MUR 2023-2027

Responsabili Scientifici: M.R. Ambrosio, A. Carnevale, G. Bonaccorsi

Incontro clinico-scientifico del
5 giugno 2025, ore 14.30-18.30
Aula 3, Arcispedale Sant'Anna di Ferrara (Cona, 1B0)

Diagnostica per immagini nella patologia osteo-metabolica: osteoporosi e oltre

14.45-15.00	**Presentazione del corso**	**Maria Rosaria Ambrosio** *Dipartimento di Scienze Mediche* *Università di Ferrara* **Aldo Carnevale** *Dipartimento di Medicina Traslazionale* *Università di Ferrara*
15.00-15.45	**Morfometria vertebrale: ruolo della DXA e refertazione ragionata**	**Daniele Diacinti** *Università di Roma Sapienza*
15.45-16.15	**La Radiologia nella patologia osteo-metabolica: oltre l'osteoporosi**	**Giuseppe Guglielmi** *Università di Foggia*
16.15-16.30	**Pausa**	
16.30-17.00	**Patologia osteo-metabolica: il ruolo della Medicina Nucleare**	**Ilaria Rambaldi** *Azienda Ospedaliero-Universitaria di Ferrara*
17.00-17.45	**Formazione sul campo dei medici in formazione specialistica e conclusioni**	

Beyond BMD: vertebral fracture assessment

Conclusions

- **PARED acronym** – A structured approach to guide DXA exam interpretation
- **Look at the images!** – DXA is not just numbers; visual assessment is crucial
- **Be a radiologist, but talk to the clinicians!** – Combine imaging expertise with clinical context for accurate diagnosis

DXA is more than T-scores: interpret wisely!

THANK YOU!

contact me at: aldo.carnevale@unife.it