Interpreting DEXA Scan and the New Fracture Risk Assessment Algorithm

Prof. Samir Elbadawy
*Osteoporosis affect 30%-40% of women in western countries and almost 15% of men after the age of 50 years.
**WHO Definition**¹

“Osteoporosis is a systemic skeletal disease characterized by low bone density and microarchitectural deterioration of bone tissue with a consequent *increase in bone fragility*”

**NIH Definition**²

“Osteoporosis is defined as a skeletal disorder characterized by compromised bone strength predisposing a person to an *increased risk of fracture*”

The Osteoporosis Continuum

Healthy spine

50 Menopausal
Experiencing vasomotor symptoms

55+ Postmenopausal
At greater risk for vertebral fracture than any other type of fracture

75+ Kyphotic
At risk for hip fracture

Kyphotic spine
Clinical Practice of Osteoporosis: Where are we today?

Risk factors
- Well documented
- Independent from BMD

BMD
- The reference standard for diagnosis of osteoporosis
- Additional option for risk assessment

Bone Turnover Markers
- Additional option for risk assessment
BMD Testing Techniques

A. Traditional methods
Conventional radiography • Radiographic absorptiometry (RA) • Ultrasound densitometry • Dual-energy X-ray absorptiometry (DEXA) •

B. Non traditional methods
New DEXA techniques • Quantitative computed tomography (QCT) • Finite Element Analysis MRI.
BMD Testing Techniques

A. Traditional methods
Conventional radiography
Radiographic absorptiometry (RA)
Ultrasound densitometry
Dual-energy X-ray absorptiometry (DEXA)

B. Non traditional methods
New DEXA techniques
Quantitative computed tomography (QCT)
Finite Element Analysis MRI.
RADIOGRAPHIC ASSESSMENT OF BONE DENSITY
Vertebral shapes and grading

Shape

N (Normal)
EP (Endplate)
W (Wedge)
C (Crush)

These changes in shape are often combined

% change in shape

Grade 1
~ 20-25%

Grade 2
~26-40%

Grade 3
~40% +

The higher the grade of fracture the higher the risk of future fracture
BMD Testing Techniques

A. Traditional methods
Conventional radiography
Radiographic absorptiometry (RA)
Ultrasound densitometry
Dual-energy X-ray absorptiometry (DEXA)

B. Non traditional methods
New DEXA techniques
Quantitative computed tomography (QCT)
Finite Element Analysis MRI.
The Basics of BMD Measurement

Measurement of BMD at any skeletal site has a value in predicting fracture risk. A variety of densitometers are in clinical use and provide reliable assessment of fracture risk.

However, hip BMD is the best predictor of hip fractures, and spine BMD is the best predictor of spine fractures.
DEXA Technique
DEXA: Dual-energy X-ray Absorptiometry

- X-ray source
- High-intensity beam
- Fast scans, low dose
- High image quality

- Excellent precision
- Can measure all skeletal sites: central and peripheral
- Best Clinical Utility
Dual energy X-ray Absorptiometry
DEXA
Clinical uses:

Site-specific measurements, essential for prediction of BMD, fracture risk and rate of bone loss.

Comprehensive evaluation (traditional sites):
• Lumbar spine
• Proximal femur
• Forearm
• Total body (important in children, metabolic bone disease and severe osteoporosis).
DEXA allows us to determine:

**Bone Tissue** –
- BMD \( \text{g/m}^2 \)
- Bone Mass \( \text{g} \)
- Area

**Soft Tissue** –
- %Fat (R Value)
- Soft Tissue Mass \( \text{g} \) (Fat Free Mass)
- Fat Mass \( \text{g} \)
- Lean Mass \( \text{g} \) (Fat free and Bone free Mass)
DEXA allows us to determine:

**Bone Tissue**
- BMD (g/m²)
- Bone Mass (g)
- Area

**Soft Tissue**
- %Fat (R Value)
- Soft Tissue Mass (g) (Fat Free Mass)
- Fat Mass (g)
- Lean Mass (g) (Fat free and Bone free Mass)
Variables Measured by DEXA

\[
\text{BMC} = \text{Bone Mineral Content (g)} \quad \cdot
\]

\[
\text{BMC} = \frac{\text{BMC}}{\text{Area}} = \text{BMD}.
\]

\[
\text{BMD} = \text{Bone Mineral Density (g/cm}^2\text{)} \quad \cdot
\]
BMD measurement:

1. Dual-Energy X-Ray Absorptiometry:

Results expressed as
- **T-SCORE** is the number of SD the measurement is above or below the YOUNG-NORMAL MEAN BMD.
- **Z-SCORE** is the number of SD the measurement is above or below the AGE-MATCHED MEAN BMD.

Sites used for measurement per WHO criteria:
- Total proximal femur
- Femoral neck
- Lumbar spine
- 33 percent(1/3rd) radius

Peripheral skeletal sites predict global # risk however not used in WHO/FRAX criteria therefore limited value. Changes to therapy at these sites are slow.
The difference between the patient’s score and norm (T-score or Z-score) is expressed as a standard deviation (SD) above or below the mean.

(Usually, 1 SD equals a 10% to 12% difference in bone density).
Bone density measurements

4 diagnosis categories following WHO

<table>
<thead>
<tr>
<th>T-Score</th>
<th>Diagnostic Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>NORMAL</td>
</tr>
<tr>
<td>-1.0</td>
<td>OSTEOPENIA</td>
</tr>
<tr>
<td>-1.5</td>
<td>OSTEOPOROSIS</td>
</tr>
<tr>
<td>-2.0</td>
<td>SEVERE OSTEOPOROSIS</td>
</tr>
<tr>
<td>-2.5</td>
<td>SEVERE OSTEOPOROSIS (with fragility fractures)</td>
</tr>
</tbody>
</table>
Measurement Sites

AP Spine
Measurement Sites

Femur

Example: Femur
Born 10/3/1947  66.0 in.  217.0 lbs.  White Female
Measurement Sites

Dual Femur Measurement Sites

Dual Femur

[Image of a medical scan showing measurement sites on the femur with a chart indicating bone density and T-scores.]
Measurement Sites

Forearm
Measurement Sites

Total Body BMD
In general, when talking about fracture risk, we talk in terms of **T-score**.

T-score is used because fracture risk increases as BMD declines from young normal levels.

Because in older adults, low BMD is very common, comparison with age matched levels (Z-score) can be misleading.
For any particular test, for example (DXA) of the spine, the T- and Z-scores can be directly translated into percentages of young normal or age matched values, respectively.

Thus, for lumbar spine BMD by DXA, one SD equals about 12%.

A T-score of -2.5 is the same as a BMD value 30% below the average value in a young adult.
Examples

BMD g/cm²

SPINE L2-L4

AGE

### T, Z

- \( T = -2.0 \)
- \( Z = -2.0 \)

Mean Adult Value

BMD g/cm²

SPINE L2-L4

AGE

### T

- \( T = -2.0 \)

### Z

- \( Z = -0.5 \)
ID: ALI IBRAHIM, ZENAB
Age: 62
Sex: Female
Height: 156 (cm)
Weight: 79 (kg)
System: 5185

<table>
<thead>
<tr>
<th>Scan Date</th>
<th>Age</th>
<th>BMD (g/cm²)</th>
<th>Change %</th>
<th>Change /SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.02.98</td>
<td>61.9</td>
<td>0.753</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>23.08.98</td>
<td>62.4</td>
<td>0.792</td>
<td>5.2</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Site: AP Spine
Region: L2 - L4
DEXA allows us to determine:

**Bone Tissue** –
- BMD \((g/m^2)\)
- Bone Mass \((g)\)
- Area

**Soft Tissue** –
- %Fat \((R\ Value)\)
- Soft Tissue Mass \((g)\) (Fat Free Mass)
- Fat Mass \((g)\)
- Lean Mass \((g)\) (Fat free and Bone free Mass)
**Fig. 36.1.** (a) Dual-energy X-ray absorptiometry measurement of the body composition. X-rays are used for assessing percentages of body fat in the different areas (gynoid versus android), important cardiovascular risk factors in the metabolic syndrome.

<table>
<thead>
<tr>
<th>Date measured</th>
<th>Age (years)</th>
<th>Android (% fat)</th>
<th>Gynoid (% fat)</th>
<th>A/G Ratio</th>
<th>Whole body (% fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.09.2004</td>
<td>57.3</td>
<td>19.3</td>
<td>35.2</td>
<td>0.55</td>
<td>24.9</td>
</tr>
</tbody>
</table>

World Health Organization BMI classification

<table>
<thead>
<tr>
<th>BMI</th>
<th>Weight (kg) for height=166.0 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Underweight</td>
</tr>
<tr>
<td>19.5</td>
<td>Normal</td>
</tr>
<tr>
<td>25</td>
<td>Normal</td>
</tr>
<tr>
<td>30</td>
<td>Overweight</td>
</tr>
<tr>
<td>40</td>
<td>Obese</td>
</tr>
</tbody>
</table>

Reference: Total
Bone density measurements

Applications

Determine bone loss •

Assist in diagnosis of osteoporosis •

Support treatment decision •

Monitor treatment response •

Enhance patient therapy compliance •
Who should be tested?

1- All **postmenopausal women** under age 65 who have one or more additional **risk factor** for osteoporosis.

2- All **women aged 65 and older** regardless of additional risk factors.

3- **Postmenopausal women** who present with **fractures** (to confirm diagnosis and determine disease severity)

4- Women who are considering **therapy** for osteoporosis, if BMD testing would facilitate the decision.

5- Women who have been on **hormone replacement therapy** for prolonged periods.
**DXA Interval**

**Annual:**
- Post-menopausal osteoporosis, appropriate for age.

**Biannual:**
1. Post-menopausal osteoporosis not appropriate for age.
2. Steroid induced Osteoporosis
3. Hyperthyroidism
4. Hyperparathyroidism
5. Therapy other than HRT
When To Treat?

Initiate therapy to reduce fracture risk in:

- Women with BMD T-score below -2.0 (Osteopenia) in the absence of risk factors.
- Women with T-scores below -1.5 if other risk factors are present.
Problems in the interpretation of BMD by DEXA

- Osteomalacia
- Osteoarthritis (especially the spine)
- Vascular calcification (especially the spine)
- Overlying metal objects
- Contrast media (spine)
- Previous fracture (spine, hip and wrist)
- Severe scoliosis
- Vertebral deformities due to osteoarthrosis, Scheuermann`s disease
### Ancillary Results

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD (g/cm²)</th>
<th>Young-Adult (%)</th>
<th>T-Score</th>
<th>Age-Matched (%)</th>
<th>Z-Score</th>
<th>Est. BMC (g)</th>
<th>Est. Area (cm²)</th>
<th>Est. Width (cm)</th>
<th>Est. Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12</td>
<td>0.885</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.1</td>
<td>8.0</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>L1</td>
<td>0.930</td>
<td>82</td>
<td>-1.7</td>
<td>102</td>
<td>0.1</td>
<td>9.5</td>
<td>10.3</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>L2</td>
<td>1.262</td>
<td>105</td>
<td>0.5</td>
<td>126</td>
<td>2.3</td>
<td>13.7</td>
<td>10.8</td>
<td>3.9</td>
<td>2.8</td>
</tr>
<tr>
<td>L3</td>
<td>1.465</td>
<td>122</td>
<td>2.2</td>
<td>148</td>
<td>4.0</td>
<td>18.0</td>
<td>12.3</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>L4</td>
<td>1.682</td>
<td>140</td>
<td>4.0</td>
<td>171</td>
<td>5.8</td>
<td>21.7</td>
<td>12.9</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td>L1-L2</td>
<td>1.101</td>
<td>96</td>
<td>-0.4</td>
<td>118</td>
<td>1.4</td>
<td>23.2</td>
<td>21.1</td>
<td>3.6</td>
<td>5.8</td>
</tr>
<tr>
<td>L1-L3</td>
<td>1.235</td>
<td>106</td>
<td>0.5</td>
<td>129</td>
<td>2.3</td>
<td>41.2</td>
<td>33.4</td>
<td>3.9</td>
<td>8.5</td>
</tr>
<tr>
<td>L1-L4</td>
<td>1.360</td>
<td>115</td>
<td>1.5</td>
<td>141</td>
<td>3.3</td>
<td>63.0</td>
<td>46.3</td>
<td>4.1</td>
<td>11.4</td>
</tr>
<tr>
<td>L2-L3</td>
<td>1.370</td>
<td>114</td>
<td>1.4</td>
<td>139</td>
<td>3.2</td>
<td>31.7</td>
<td>23.1</td>
<td>4.2</td>
<td>5.5</td>
</tr>
<tr>
<td>L2-L4</td>
<td>1.482</td>
<td>123</td>
<td>2.3</td>
<td>150</td>
<td>4.1</td>
<td>53.4</td>
<td>36.1</td>
<td>4.3</td>
<td>8.4</td>
</tr>
<tr>
<td>L3-L4</td>
<td>1.576</td>
<td>131</td>
<td>3.1</td>
<td>160</td>
<td>4.9</td>
<td>39.8</td>
<td>25.2</td>
<td>4.5</td>
<td>5.6</td>
</tr>
</tbody>
</table>
### Ancillary Results

<table>
<thead>
<tr>
<th>Region</th>
<th>BMD (g/cm²)</th>
<th>Young-Adult T-Score (%)</th>
<th>Age-Matched Z-Score</th>
<th>Est. BMC (g)</th>
<th>Est. Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>0.732</td>
<td>75</td>
<td>94</td>
<td>3.7</td>
<td>5.1</td>
</tr>
<tr>
<td>Wards</td>
<td>0.571</td>
<td>63</td>
<td>93</td>
<td>1.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Troch</td>
<td>0.531</td>
<td>67</td>
<td>79</td>
<td>6.4</td>
<td>12.0</td>
</tr>
<tr>
<td>Shaft</td>
<td>0.917</td>
<td>-</td>
<td>-</td>
<td>12.7</td>
<td>13.9</td>
</tr>
<tr>
<td>Total</td>
<td>0.737</td>
<td>74</td>
<td>90</td>
<td>22.8</td>
<td>31.0</td>
</tr>
</tbody>
</table>
New Regions of Interest
1-Bone mineral density (BMD) tests are safe, painless, and non-invasive tests which evaluate bone density, a measure of bone strength.

2-Bone quality is another important factor involving osteoporotic fractures. New techniques are now developing in order to assess this factor and to evaluate the effect of treatment measures.
Conclusion (2)

3-New technology in DEXA with improved image resolution is now used to evaluate small joints, bone around orthopedic implants and vertebral fracture risk assessment.

4-HR-pQCT, Finite Element Analysis provide better assessment of architecture and density. HR-MRI, MR spectroscopy also evaluate bone trabeculae and bone marrow chemical composition.
FRACTURE RISK ASSESSMENT

1- FRAX.
2- QFracture Score.
FRAX®
WHO Fracture Risk Assessment Tool

Identifying people at high risk of fracture
Teaching material for health professionals
The aim of the clinician in managing osteoporosis

- TO REDUCE THE RISK OF FRACTURES
- To identify patients at increased risk of fracture
- To assess that risk accurately
- To improve the patient’s perception of that risk
- To give advice to aid understanding of the disease, the aims of therapy and the choice of therapy
- Treatment
  - Lifestyle advice
  - Therapeutic agents
WHO fracture risk assessment tool

FRAX®

10-year probability of fracture

Country

Bone mineral density

Age

Gender

Clinical risk factors

- Low body mass index
- Previous fragility fracture
- Parental history of hip fracture
- Glucocorticoid treatment
- Current smoking
- Alcohol intake (3 or more units per day)
- Rheumatoid arthritis
- Other secondary causes of osteoporosis

www.shef.ac.uk/FRAX
The WHO has developed a tool for evaluating fracture risk known as “FRAX”. It reports ten year risk of fracture. **12 risk factors are included.**

- Age.
- Weight.
- Previous fracture.
- Current smoking.
- Rheumatoid Arthritis.
- Alcohol intake.
- Gender.
- Height.
- Parent fractured hip.
- Glucocorticoids.
- Secondary osteoporosis.
- Femoral neck “T” score.
Limitations of FRAX®

- Does not accommodate all known risk factors:
  - Falls, biochemical markers, QUS, etc.
- Lacks detail on some risk factors:
  - Dose response effects of glucocorticoids, smoking, prior fracture, etc.
- Depends on adequacy of epidemiological information
- Limited country models available
- Model relevant only for untreated patients
- Does not replace clinical judgment
Stratification of major osteoporotic fracture risk

Woman (UK) at age 65 years, BMI = 25 kg/m²

Rheumatoid arthritis

Glucocorticosteroids

Prior fracture

10-year fracture * probability (%)

No

Yes

No

Yes

No

Yes

No

Yes

No

Yes

8

16

14

26

12

22

19

35

*Hip, clinical spine, humerus, forearm

Adapted from Kanis et al., Osteoporos Int. 2008
WHO case finding strategies

Clinical Risk Factors

FRAX® Fracture Probability

High

Intermediate

Low

Consider treatment

BMD

Reassess probability

High

Low

Consider treatment

Adapted from Kanis, WHO Technical Report, 2008
Management of osteoporosis based on fracture probabilities

Without BMD information

- Consider treatment

- Measure BMD

- No treatment

With BMD information

- Consider treatment

- No treatment

Adapted from Kanis et al., Osteoporos Int. 2008, Erratum 2009
Frax-WHO (10 years fracture risk assessment)

Age
Sex
Weight
Height
Previous fractures
Parent Fractures
Glucocorticoid
Current smoking
Rheumatoid Arthritis
Secondary osteoporosis
Alcohol more than 3 units/day
Femoral neck BMD – T score

Calculate

http://www.shef.ac.uk/FRAX/tool.jsp?locationValue=9
### WHO Fracture Risk Assessment Tool (FRAX)

A female patient suffering from Rheumatoid Arthritis without glucocorticoid therapy.

#### Questionnaire:

1. **Age (between 40-90 years) or Date of birth**
   - Age: 50
   - Date of birth: Y: 1959 M: 1 D: 30

2. **Sex**
   - Female

3. **Weight (kg)**
   - 90

4. **Height (cm)**
   - 160

5. **Previous fracture**
   - No

6. **Parent fractured hip**
   - No

7. **Current smoking**
   - No

8. **Glucocorticoids**
   - Yes

9. **Rheumatoid arthritis**
   - Yes

10. **Secondary osteoporosis**
    - Yes

11. **Alcohol 3 or more units per day**
    - No

12. **Femoral neck BMD (g/cm²)**
    - **Hologic**: 0.5
    - **T-score**: -3.0

#### Results:

- **BMI**: 35.2
- **The ten year probability of fracture (%)**
  - **Major osteoporotic fracture**: 3.0%
  - **Hip fracture**: 1.2%
WHO Fracture Risk Assessment Tool (FRAX)

A female patient suffering from Rheumatoid Arthritis with glucocorticoid therapy

The glucocorticoid therapy of RA doubled the fracture risk
FRAX NOF Guidelines - Caveats (1)

= Eight risk factors:
  * Other risk factors important.
  * Bone turnover markers, falls, physical activity, medications, Vitamin “D”.

= Risk factors where “dose” is important:
  * Multiple fractures.
  * Smoking.
  * Alcohol.
  * Steroids.
  * RA.
FRAX NOF Guidelines - Caveats (2)

= Hip centric:
  * Femoral neck not total hip.
  * What if lumbar spine density is low.

= Rapid bone loss:
  * What if the patient is loosing 8% / year (Perimenopausal).
FRAX NOF Guidelines- Caveats (3)

= Not used if on treatment:
  * Can use FRAX if off medication for some period of time.

= Family history (parental hip fracture):
  * What about parents with multiple vertebral fractures.

= Fracture history (self report):
  * Clinical / morphometric vertebral fractures are stronger predictors of future fractures.
FRAX NOF Guidelines- Caveats (4)

= Identifies patients to treat where we have limited evidence of treatment efficacy (non-ost., age)

= There is no confidence interval.

= Secondary OP (no BMD), one condition same as three.

= Fracture risk in 60’s largely wrist, in 80’s in the spine and hip.
Osteoporotic Fracture Rate and Number of Women with Fractures versus BMD

Fracture rate
# Women with Fractures

BMD T-scores

Fractures per 1000 person years

Osteoporotic Fracture Rate and Number of Women with Fractures versus BMD

Siris, et al, NORA study (web site)
QFracture Score

= QFracture was developed in 2009. The algorithm is based on variables that are readily available in electronic health care records.

= It estimates an individual’s 10-year risk of developing both hip & major osteoporotic fractures (Hip, Wrist & spine), without BMD measurement. It is applicable to people aged 30-85 years.
Risk factors included in QFracture Algorithms (1)

= Age (in single years).
= Body mass index (BMI).
= Smoking status (non-smoker, ex-smoker, light smoker, heavy smoker).
= Parental history of osteoporosis or hip fracture (in a first degree relative).
= Cardiovascular disease.
= Alcohol intake (none, trivial, light, medium, heavy).
= Rheumatoid Arthritis.
Risk factors included in QFracture Algorithms (2)

- Type 2 diabetes.
- Asthma.
- History of falls.
- Chronic liver disease.
- Gastrointestinal conditions likely to result in malabsorption (Crohn’s disease, ulcerative colitis, coeliac disease, steatorrhoea, blind loop syndrome at baseline).
- Other endocrine conditions (thyrotoxicosis, primary or secondary hyperparathyroidism, Cushing’s syndrome at baseline).
Risk factors included in QFracture Algorithms (3)

= At least two prescriptions for systemic corticosteroids in the six months preceding baseline.

= At least two prescriptions for cyclic antidepressants in the six months preceding the baseline.

= At least two prescriptions for hormone replacement therapy (in women) in the six months preceding baseline.

= Menopausal symptoms in women (including vaginal dryness or hot flushes recorded at baseline).
New factors added updated algorithm (1)

= Self assigned ethnic origin (white, indian, pakistani, bangladeshi, other asian, black african, caribbean, chinese, other).

= Previous fracture (hip, vertebral, proximal humerus, or distal radius).

= Chronic obstructive pulmonary disease.

= Epilepsy.

= At least two prescriptions of anticonvulsants in the six months preceding baseline.
New factors added updated algorithm (2)

= Dementia.
= Parkinson’s disease.
= Any cancer.
= Systemic Lupus Erythematosus.
= Chronic renal disease.
= Type 1 diabetes.
= Care or nursing home.
What QFracture score adds?

1- These new prediction algorithms for hip and osteoporotic fractures do not require laboratory measurement or BMD and so can be used in primary care or individual self assessment (www.qfracture.org).

2- The new algorithms include additional variables and were developed in and could be used in large representative primary care population.
What QFracture score adds?

3- The validation statistics, especially for the hip fracture algorithm, suggest that the QFracture scores are likely to be effective at high risk of fracture within primary care in the UK and showed improved performance compared with FRAX.
Using BMD to Monitor Therapy in Treating Osteoporosis:

Pro

Con
• Many clinical practice guidelines, including those of the NOF, the International Society for Clinical Densitometry, the Institute for Clinical Systems Improvement, American Association of Clinical Endocrinologists, North American Menopause Society, recommend the use of DXA to monitor osteoporosis therapy.
• The suggested interval between baseline and follow-up BMD testing is typically 1 to 2 years, with subsequent intervals determined according to clinical circumstances.

Pro

• DXA is the only technology recognized by Medicare for monitoring patients treated for osteoporosis.

Pro

• BMD is a surrogate marker for bone strength and fracture risk.
• Stability or a significant increase in BMD is an acceptable response to therapy and is associated with a reduction in fracture risk.

• A significant decrease in BMD suggests a suboptimal response to therapy and may require evaluation for factors contributing to bone loss and possibly changing treatment.

• Quantitative morphometric assessment of vertebral fracture follow up by lateral vertebral morphometry.
A valid quantitative comparison of BMD measurements requires that measurements be made on the same DXA machine (or different machines that have been cross-calibrated) according to well-established quality standards that include precision assessment and calculation of the least significant change, the smallest change in BMD that is statistically significant.\textsuperscript{2}

If the least significant change has not been calculated, it is not possible to distinguish an apparent BMD change that is within the range of measurement error from one that is likely to be a genuine biologic change.
An increase in BMD is associated with reduced fracture risk. However, the relationship between BMD and fracture risk is not a linear one. Fracture risk decreases soon after beginning therapy, even preceding a measurable improvement in BMD.

Fracture risk can decrease with no change in BMD.

Studies have even shown a decreased fracture risk despite a slight decrease in BMD.