



TRABECULAR BONE SCORE (TBS) ROLE IN DX & RX

A.R.Rajaei MD

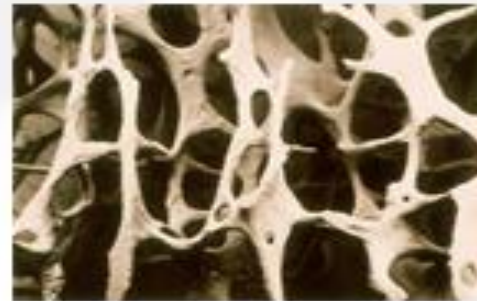
arrajaei@gmail.com



A.R. Rajaei MD

Current Definition of Osteoporosis

Osteoporosis is defined as a skeletal disorder characterized by compromised bone strength predisposing a person to an increased risk of fracture. Bone strength primarily reflects the integration of bone density and bone quality.

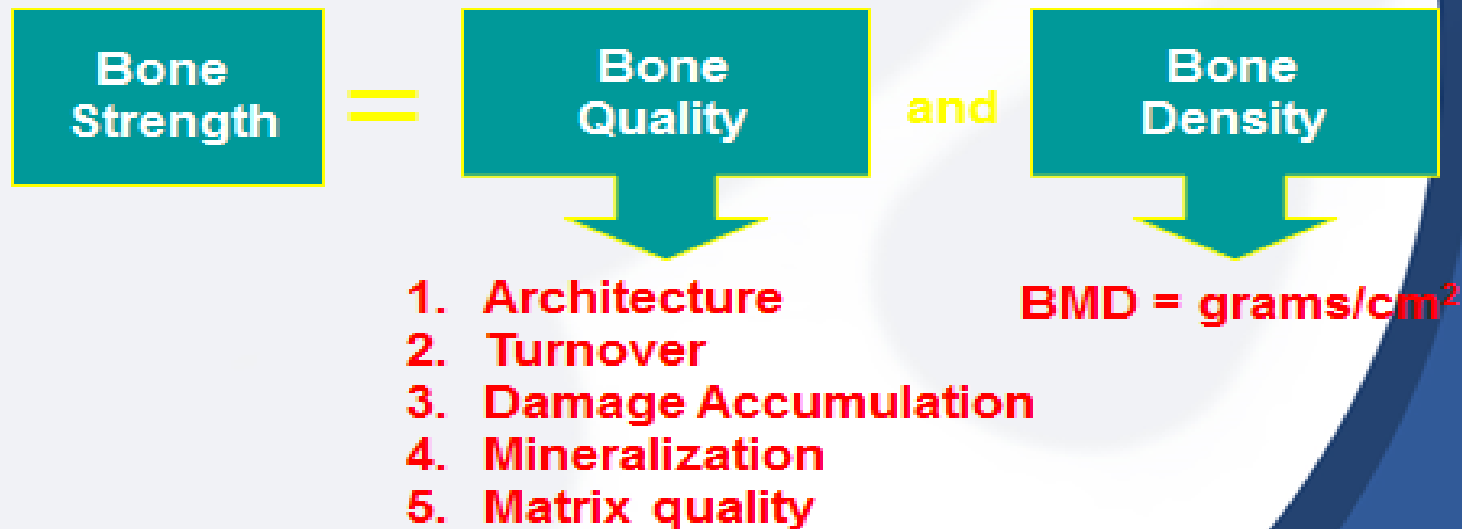


NIH Consensus Development Panel on Osteoporosis. *JAMA* 285 (2001): 785-95

Shifting the Osteoporosis Paradigm

Bone Strength

NIH Consensus Statement 2000



Routine

Research Only

Time + radiation + cost

DXA

HR-RX

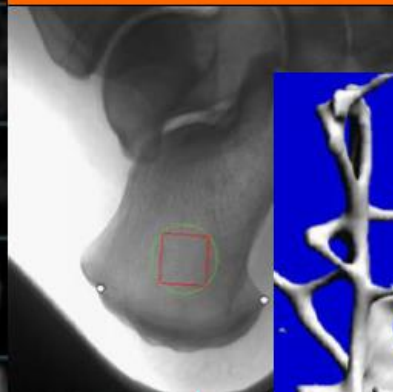
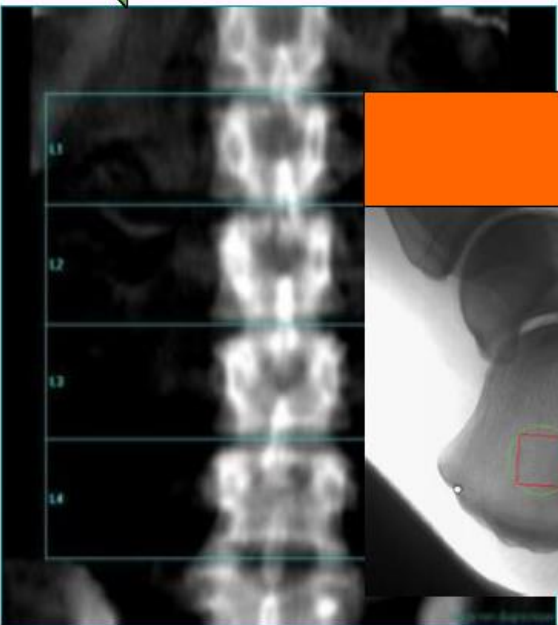
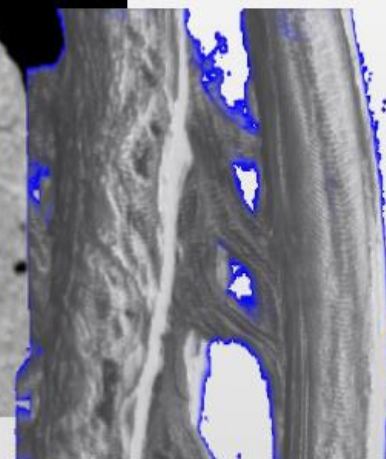
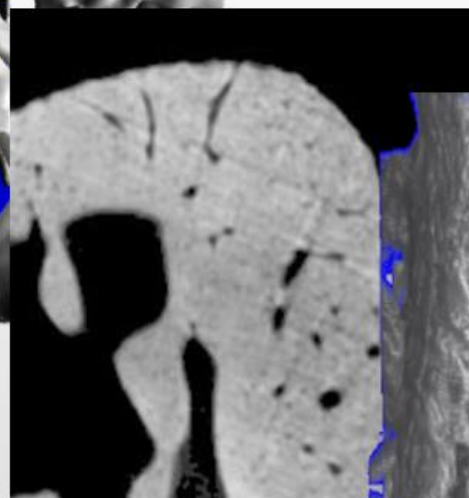
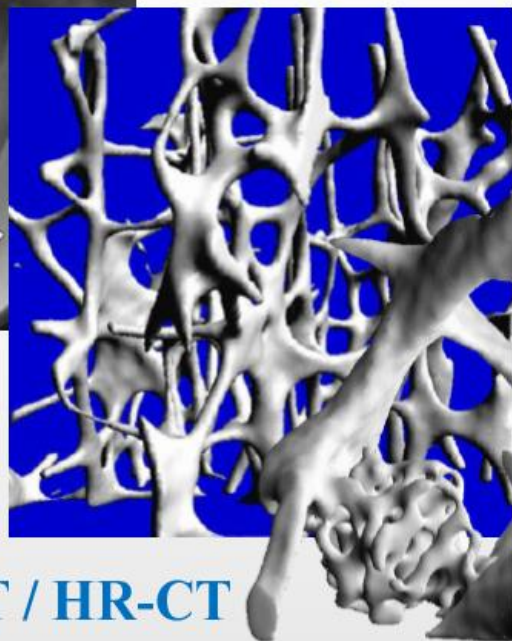
v-CT / HR-CT

μ -MRI / μ -CT

η -CT

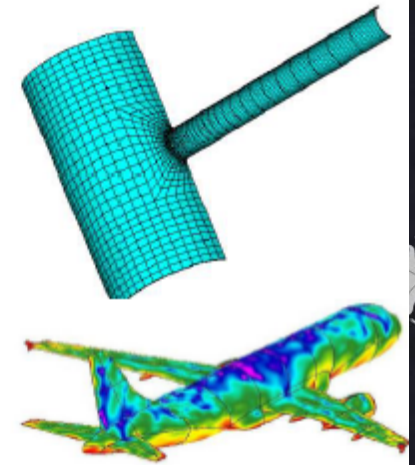
TBS

Fractal



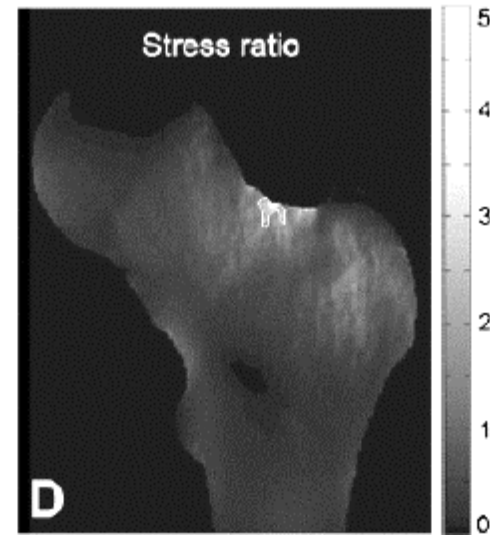
Finite Element Analysis

- Computer model of a material or design
- Material and structural properties are programmed
- Stressed and analysed
- Needs a lot of computing time
- Most sophisticated models expensive to run



FEA from hip DXA

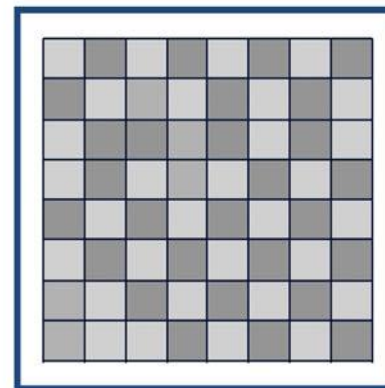
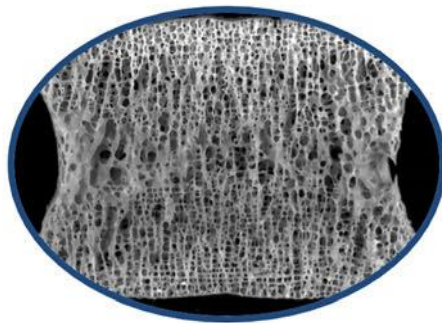
Yang et al JBMR 2008; 24: 33-42



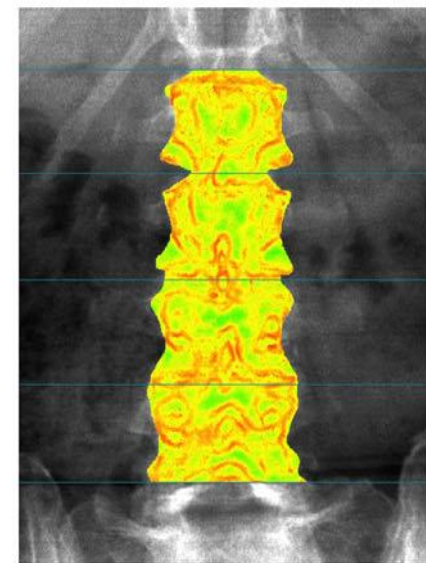
BMD= 0.972



Illustration of
Well-structured
trabecular bone



TBS= 1.459



BMD= 0.969

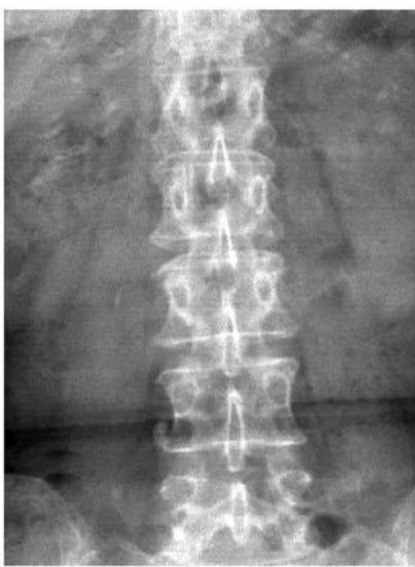
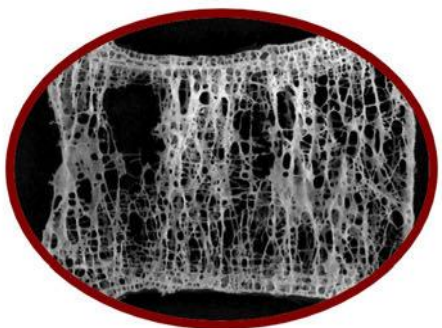
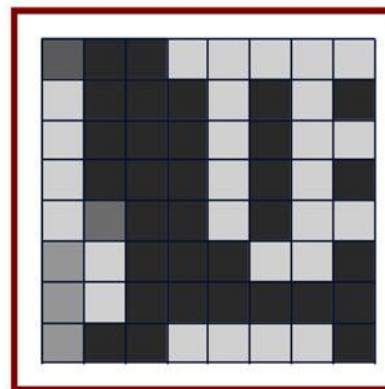


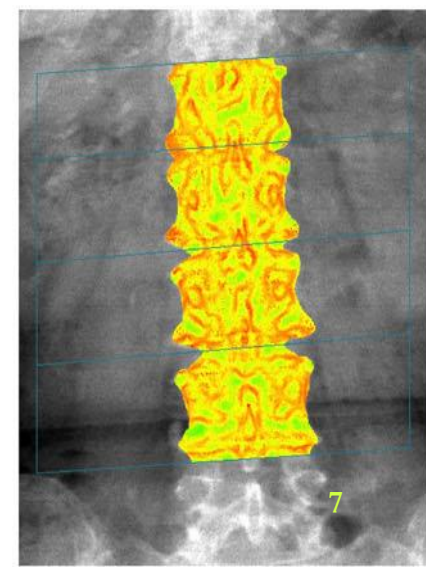
Illustration of
Altered
trabecular bone



Experimental
variogram



TBS= 1.243



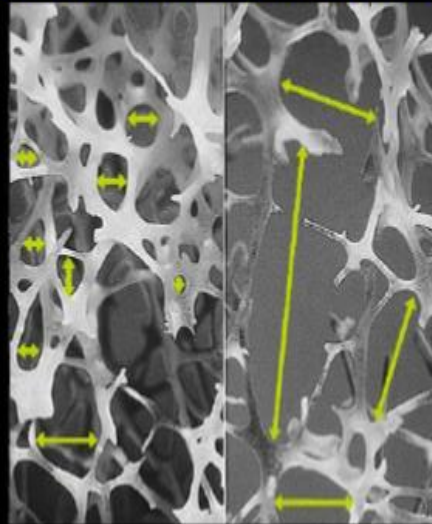
TBS, typically measured at the lumbar spine, is determined using the same region of interest as the BMD measurement, so that vertebrae excluded from the BMD calculation, eg, vertebrae with fractures or osteoarthritis, are also excluded from the TBS analysis. Although the TBS result is given for each vertebra, the TBS value reported represents the average of L1 to L4.

DEFINITION

The trabecular bone score (TBS) 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 related to bone microarchitecture and provides skeletal information that is not captured from the standard bone mineral density (BMD) measurement. Based on experimental variograms of the projected DXA image, TBS has the potential to discern differences between DXA scans that show similar BMD measurements.

TBS is a texture analysis parameter
correlated to the bone micro-architecture parameters: PARFITT

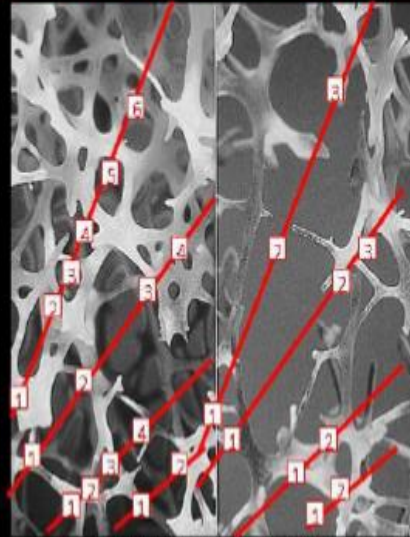
TbSp : Trabecular Spacing (mm)



Courtesy of the International Osteoporosis Foundation

$r=-0.65$

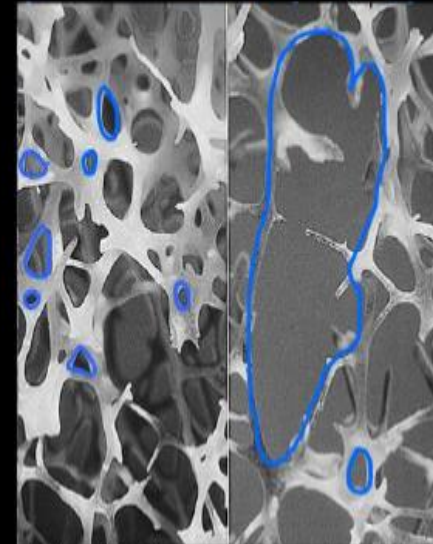
TbN : Trabecular Number (1/mm)



Courtesy of the International Osteoporosis Foundation

$r=0.73$

ConnD: connectivity density (mm-3)



Courtesy of the International Osteoporosis Foundation

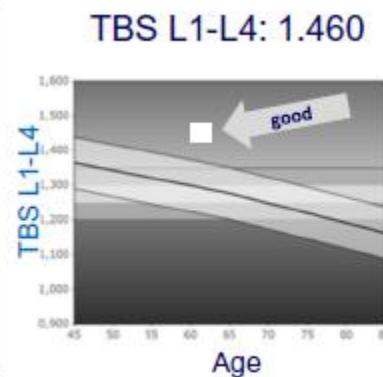
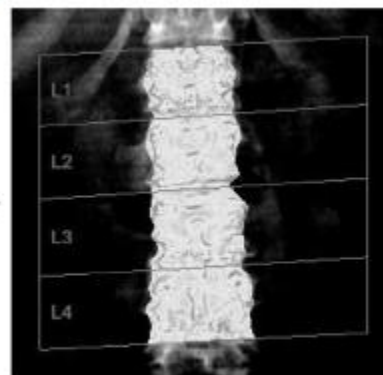
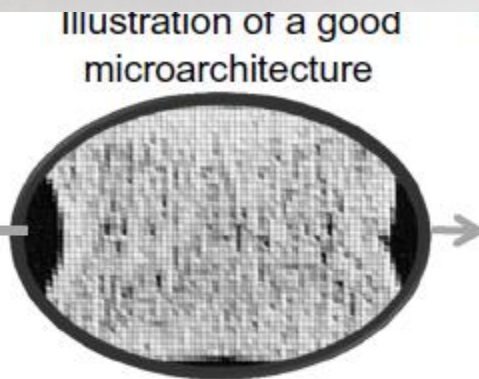
$r=0.79$

HIGH TBS means: TbSp ↘ TbN ↗ connD ↗
LOW TBS means: TbSp ↗ TbN ↘ connD ↘

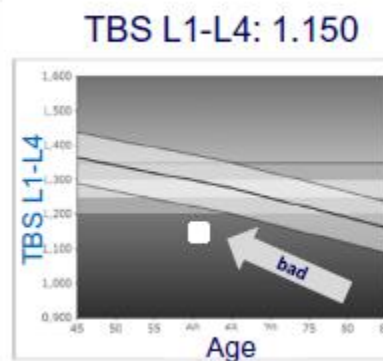
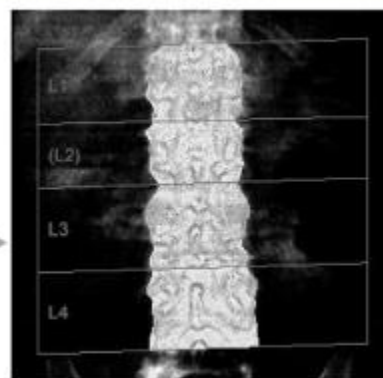
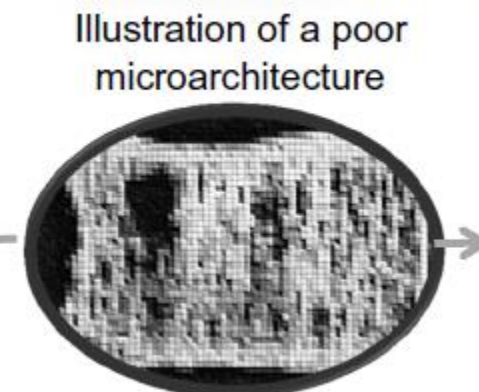
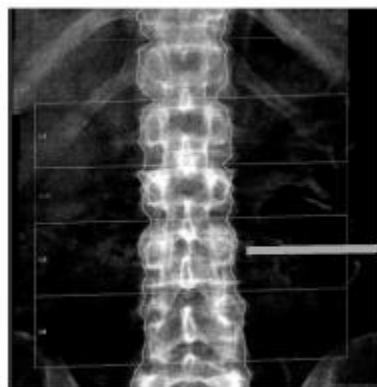
Can TBS be considered as a major CRF of osteoporotic fracture ?



Identical BMD



Quantification of the texture using a modified experimental variogram approach



Because the DXA image is usually retrievable, even though it might have been obtained years before, TBS can be readily applied to any available DXA image obtained from **GE Lunar (Prodigy and iDXA; Madison, WI, USA) and Hologic (Delphi, QDR 4500, and Discovery; Waltham, MA, USA) densitometers.** TBS, typically measured at the lumbar spine, is determined using the same region of interest as the BMD measurement, so that vertebrae excluded from the BMD calculation, eg, vertebrae with fractures or osteoarthritis, are also excluded from the TBS analysis. Although the TBS result is given for each vertebra, the TBS value reported represents the average of L1 to L4.

INDICATIONS

- ❖ Recent glucocorticoid use
- ❖ Prior major fracture
- ❖ Rheumatoid arthritis
- ❖ Chronic obstructive pulmonary disease
- ❖ High alcohol intake,
- ❖ Higher body mass index(<35)
- ❖ Hyperparathyroidism
- ❖ Diabetes Mellitus

IS TBS AFFECTED BY DEGENERATIVE VERTEBRAL OSTEOARTHRITIS?

These results suggest that OA and its severity have little effect on TBS but markedly influence the LS BMD measurement.

Although these observations suggest that TBS may have utility in assessing bone texture even in the presence of OA, additional studies are necessary to confirm these findings. To date, there are no studies that have investigated the potential impact of vertebral fracture on TBS.

TBS IN ISCD 2015 GUIDELINE

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

TBS

HOW TO PERFORM?

- ❖ Scan acquisition
- ❖ Step 1: ID checking
- ❖ Step 2: Good scan criteria
- ❖ Step 3: ROI replacement OR Labeling
- ❖ Step 4: Area rules
- ❖ Step 5: Interpretation

Spine positioning



A.R. RAJAEI MD

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Analyze Setup – Choose an Analysis Method or Compare to Previously Analyzed Scan

Patient: Masoodi, Aghdas

Scan Type: f Lumbar Spine

Pat Id: 96.08.29

Scan Id: A1023171N

DOB: 16.03.1936

Scan Date: 23.10.2017 14:55

☒ Choose Analysis Method

Spine

☐ Compare to Previously Analyzed Scan

<< Back

Next >

Cancel

HOLOGIC



New examination detected

Patient: Aghdas Masoodi

Prescriber: Dr.Rezaei

WARNING : FRAX is not available

Cancel Next

Global ROI 

Bone Map 

Vertebral Lines 

Results

Image Toolbox

L 54

D

W 29

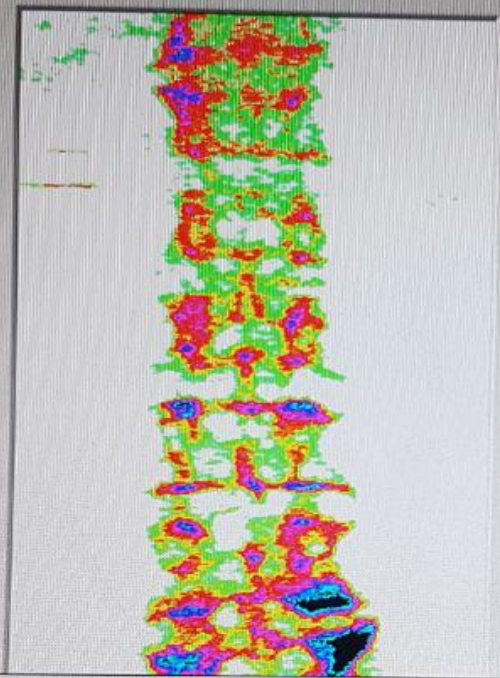
Invert

SE/DE

om 100

A1023171N

f Lumbar Spine



DXApro

One or more vertebrae have been found to have large Z-score differences.

Patient Data

Scan Date: 23.10.2017 14:55

Name: Masoodi, Aghdas

Pat Id: 96.08.29 Sex: F

Birthdate: 16.03.1936 Age: 81

Height: 159.0 cm Weight: 63.0 kg

Ethnic: Caucasian

Spine Analysis

Image not for diagnostic use

$k=1.108$ $d0=46.8$ $t=6.941$

TOTAL BMD CV for L1 - L4 1.0%

C.F.	1.051	1.016	1.000		
Region	Area (cm ²)	BMC (g)	BMD (g/cm ²)	T- score	Z- score
L1	12.34	9.56	0.775	-2.0	0.5
L2	14.69	12.58	0.856	-1.6	1.1
L3	15.48	13.70	0.885	-1.8	1.0
L4	19.50	19.73	1.012	-0.4	2.5
TOTAL	62.01	55.57	0.896	-1.4	1.4

New examination detected

Patient: Aghdas Masoodi

Prescriber: Dr.Rezaei

WARNING : FRAX is not available

Cancel Next

167

23.10.2017 15:05

Global
ROIBone
MapVertebral
Lines

Results

Global ROI Toolbox

Whole Mode

Line Mode

Point Mode

Select a line



Reset

Undo



Cancel

A1023171N

f Lumbar Spine



DXApro



One or more vertebrae have been found to have large Z-score differences.



New examination detected



Patient: Aghdas Masoodi

Prescriber: Dr.Rezaei



WARNING : FRAX is not available

Cancel

Next

Patient Data

Scan Date: 23.10.2017 14:55

Name: Masoodi, Aghdas

Pat Id: 96.08.29 Sex: F

Birthdate: 16.03.1936 Age: 81

Height: 159.0 cm Weight: 63.0 kg

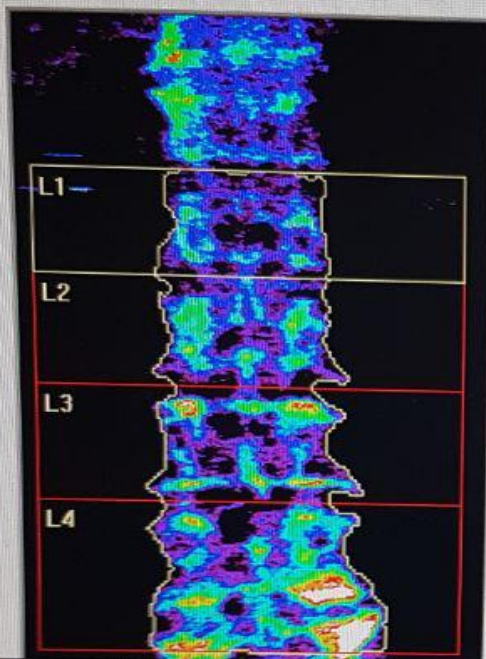
Ethnic: Caucasian

Global
ROIBone
MapVertebral
Lines

Results

A1023171N

f Lumbar Spine



DXApro

One or more vertebrae have been found to have large Z-score differences.

Label Toolbox

Select Label



Include

Exclude

First Label

L1



Auto Analyze



Close

For Help, press F1

Patient Data

Scan Date: 23.10.2017 14:55

Name: Masoodi, Aghdas

Pat Id: 96.08.29

Sex: F

Birthdate: 16.03.1936

Age: 81

Height: 159.0 cm

Weight: 63.0 kg

Ethnic: Caucasian

Spine Analysis

Image not for diagnostic use

k=1.108 d0=46.8 t=6.972

TOTAL BMD CV for L1 - L4 1.0%

C.F.	1.051	1.016	1.000		
Region	Area (cm ²)	BMC (g)	BMD (g/cm ²)	T- score	Z- score
L1	13.09	10.06	0.769	-2.0	0.4
L2	14.82	12.89	0.870	-1.4	1.3
L3	16.71	14.43	0.864	-2.0	0.8
L4	26.99	29.30	1.086	0.2	3.1
TOTAL	71.61	66.68	0.931	-1.1	1.7



New examination detected

Patient: Aghdas Masoodi

Prescriber: Dr. Rezaei



WARNING: FRAX is not available

Cancel

Next



167

23.10.2017 15:00

Help

23.10.2017 15:04

Global
ROIBone
MapVertebral
Lines

Results

Label Toolbox

Select Label



Include

Exclude

First Label

L1



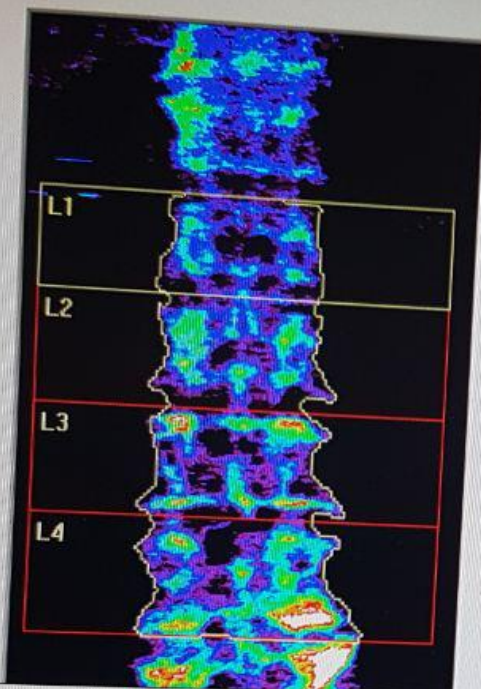
Auto Analyze



Close

A1023171N

f Lumbar Spine

DXA_{pro}

One or more vertebrae have been found to have large Z-score differences.

Patient Data

Scan Date: 23.10.2017 14:55
 Name: Masoodi, Aghdas
 Pat Id: 96.08.29 Sex: F
 Birthdate: 16.03.1936 Age: 81
 Height: 159.0 cm Weight: 63.0 kg
 Ethnic: Caucasian

Spine Analysis

Image not for diagnostic use
 $k=1.108$ $d0=46.8$ $t=6.941$
 TOTAL BMD CV for L1 - L4 1.0%

	C.F.	1.051	1.016	1.000		
Region	Area	BMC	BMD	T-	Z-	
	(cm ²)	(g)	(g/cm ²)	score	score	
L1	12.34	9.56	0.775	-2.0	0.5	
L2	14.69	12.58	0.856	-1.6	1.1	
L3	15.48	13.70	0.885	-1.8	1.0	
L4	19.50	19.73	1.012	-0.4	2.5	
TOTAL	62.01	55.57	0.896	-1.4	1.4	



New examination detected

Patient: Aghdas Masoodi

Prescriber: Dr.Rezaei



WARNING : FRAX is not available

Cancel

Next



167

23.10.2017 15:05

For Help, press F1

Help

23.10.2017 15:05

Patient : Masoodi, Aghdas
 Date of birth: 03/16/1936 81.6 years
 Height / Weight: 159.0 cm / 63.0 kg
 Gender / Ethnicity: Female / caucasian

Patient ID: 30.08.23
 Acquisition date: 10/23/2017
 Prescribing doctor: Dr.Rezaei

Export

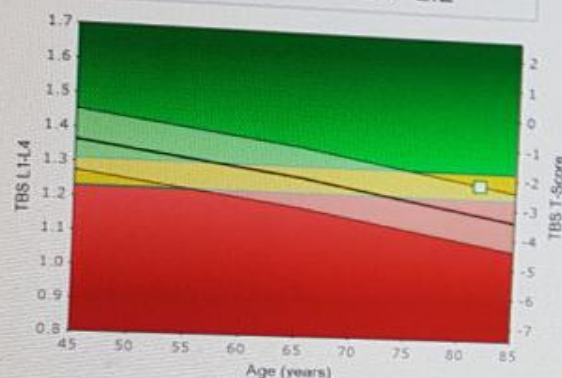
Print

SPINE TBS REPORT

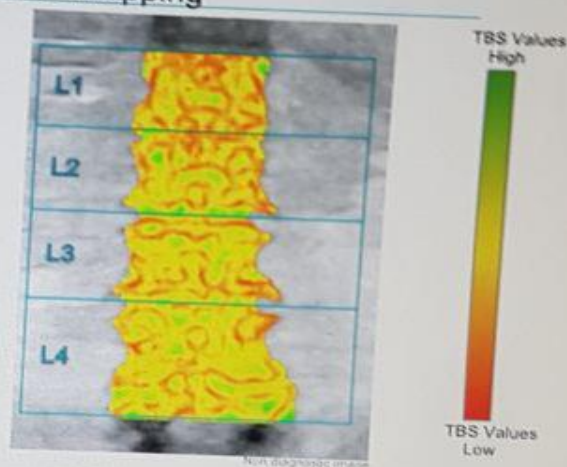
TBS reference graph

Reference population: European (Medinaps)

TBS T-Score L1-L4: -2.2



TBS Mapping



Additional results

Region	TBS	TBS T-Score	TBS Z-Score	BMD
L1	1.122	---	---	0.759
L2	1.293	---	---	0.870
L3	1.287	---	---	0.864
L4	1.387	---	---	1.086
L1-L4	1.272	-2.2	1.0	0.931
L1-L3	1.234	-2.9	1.0	0.838
L1-L2	1.207	-3.1	1.2	0.822
L2-L3	1.290	-2.5	1.0	0.866
L2-L4	1.322	-1.7	1.3	0.968
L3-L4	1.337	-1.3	1.1	1.001

FRAX

The 10 year probability of fracture, adjusted for TBS:
 Major Osteoporotic Fracture: 16.5 %
 Hip Fracture: 5.6 %

FRAX web site: <https://www.shef.ac.uk/FRAX/?lang=en>

To be used only if FRAX is displayed on the BMD report

Comments

The TBS is derived from the texture of the DXA image and has been shown to be related to bone microarchitecture and fracture risk.



ROLE OF TBS IN DX

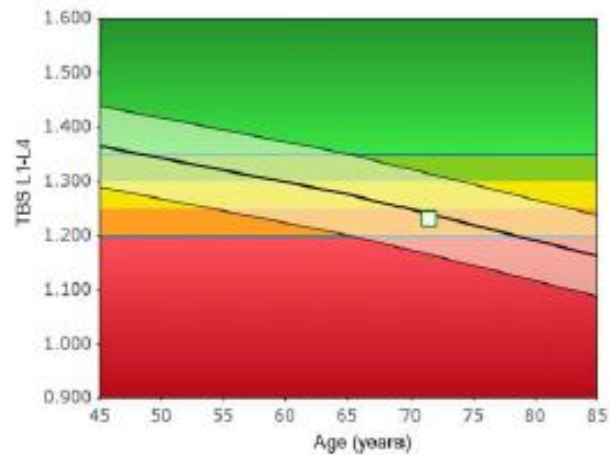
TBS: How is the Number Interpreted?

BMD	TBS
normal T-score ≥ -1	normal TBS ≥ 1.350
low bone mass $-1 < \text{T-score} < -2.5$	partially degraded $1.200 < \text{TBS} < 1.350$
osteoporosis T-score ≤ -2.5	degraded TBS ≤ 1.200

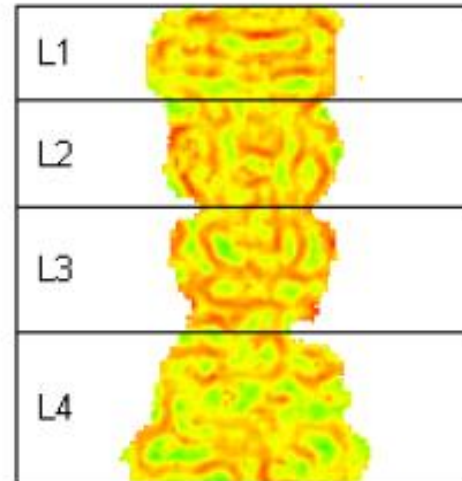
TBS reference graph

Reference population: European

TBS L1-L4:1.233



TBS Mapping



TBS Values
High

TBS Values
Low

Non diagnostic image

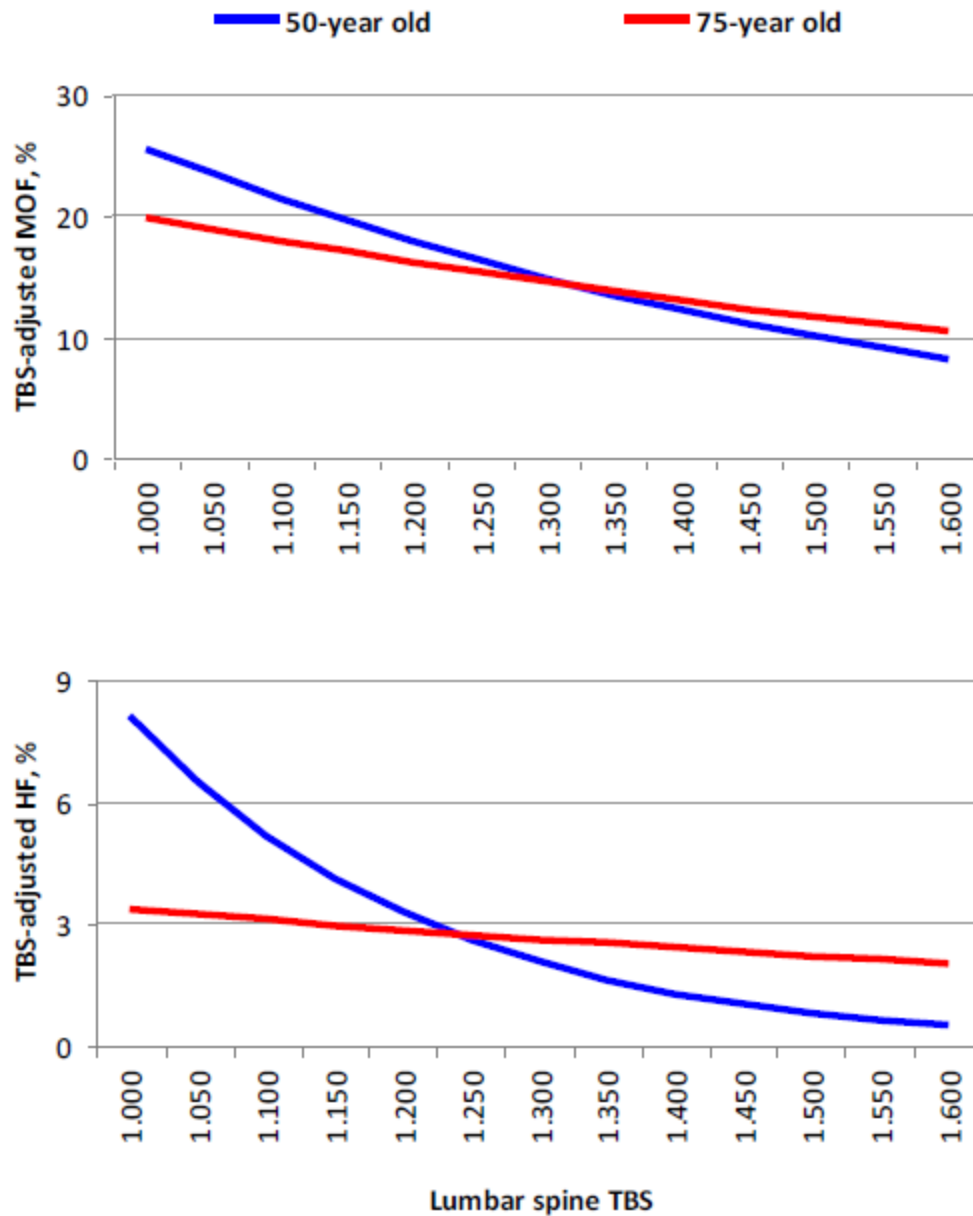
Additional results

Region	TBS	BMD
L1	1.206	0.939
L2	1.166	0.678
L3	1.130	0.571
L4	1.429	0.805
L1-L4	1.233	0.756
L1-L3	1.167	0.727
L1-L2	1.186	0.808
L2-L4	1.242	0.708
L2-L3	1.148	0.623
L3-L4	1.280	0.719

Comments



ROLE OF TBS IN RX



STEP 01 / FRAX Risk of fracture Calculation - with BMD

Questionnaire:

1. Age (between 40 and 90 years) or Date of Birth
 Age: 50
 Date of Birth: M: D: Y:

2. Sex
☒ Male ☐ Female

3. Weight (kg)
 66

4. Height (cm)
 165

5. Previous Fracture
☒ No ☐ Yes

6. Parent Fractured Hip
☒ No ☐ Yes

7. Current Smoking
☒ No ☐ Yes

8. Glucocorticoids
☒ No ☐ Yes

9. Rheumatoid arthritis
☒ No ☐ Yes

10. Secondary osteoporosis
☒ No ☐ Yes

11. Alcohol 3 or more units/day
☒ No ☐ Yes

12. Female neck BMD (g/cm²)
 -1.5

T-score:

BMI: 24.2
The ten year probability fracture (%)

Major osteoporotic	4.2
Hip Fracture	0.4

[View NOGG Guidelines](#) [Adjust with TBS](#)

If you have a TBS link here: [Adjust with TBS](#)

STEP 02 / FRAX Adjusted for TBS Calculation

Calculation tool

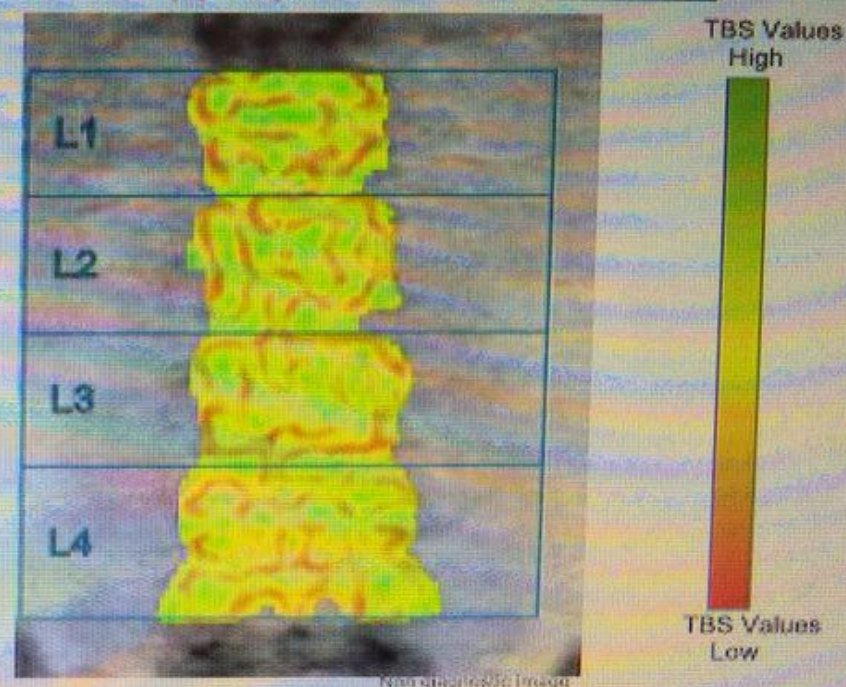
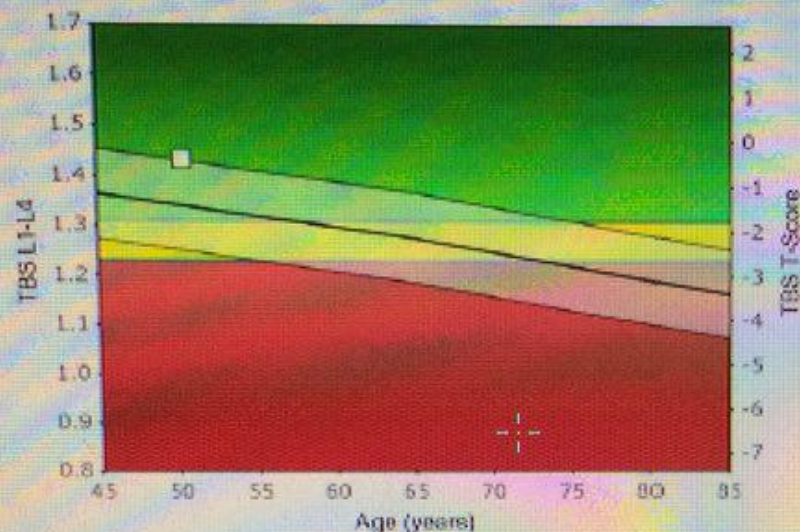
Country: UK
 Name/ID:
 Age: 50
 Sex: Female
 BMI (kg/m²): 24.2

Please enter the Trabecular Bone Score to compute the ten year probability of fracture adjusted for TBS
 Lumbar Spine TBS: 1.142
 Attention: TBS values are accurate only for patients (women and men) with a BMI in the range (15-37 kg/m²)

The 10 year probability of fracture (%)
 Adjusted for TBS
 Major Osteoporotic Fracture: 6.7
 Hip Fracture: 0.8

10 year probability of major osteoporotic fracture (%)
 NOGG Guidelines

TBS T-Score L1-L4: -0.4



Additional results

Region	TBS	TBS T-Score	TBS Z-Score	BMD
L1	1.458	---	---	1.005
L2	1.458	---	---	0.928
L3	1.387	---	---	1.035
L4	1.437	---	---	1.022
L1-L4	1.435	-0.4	1.0	1.001
L1-L3	1.434	-0.6	1.3	0.990
L1-L2	1.458	-0.3	1.9	0.964
L2-L3	1.422	-1.0	0.7	0.984
L2-L4	1.427	-0.5	0.7	1.000
L3-L4	1.412	-0.4	0.4	1.027

FRAX

The 10 year probability of fracture, adjusted for TBS:

Major Osteoporotic Fracture: 3.0 %

Hip Fracture: 0.0 %

FRAX web site: <https://www.shef.ac.uk/FRAX/?lang=en>

To be used only if FRAX is displayed on the BMD report.

Comments

The TBS is derived from the texture of the DXA image and has been shown to be related to bone microarchitecture and fracture risk.

This data provides information independent of BMD value; it is used as a complement to the data obtained from the DXA analysis and the clinical examination.

The TBS score can assist the health care professional in assessment of fracture risk and in monitoring the effect of treatments on patients across time.

Overall fracture risk will depend on many additional factors that should be considered before making diagnostic or therapeutic recommendations.

Calculation Tool

Please answer the questions below to calculate the ten year probability of fracture with BMD.

Country: Iran

Name/ID: Barari.Manizheh

[About the risk factors](#)

Questionnaire:

1. Age (between 40 and 90 years) or Date of Birth

Age:

50

Date of Birth:

Y: 1967

M: 6

D: 14

2. Sex

☐ Male ☒ Female

3. Weight (kg)

70

4. Height (cm)

152

5. Previous Fracture

☒ No ☐ Yes

6. Parent Fractured Hip

☒ No ☐ Yes

7. Current Smoking

☒ No ☐ Yes

8. Glucocorticoids

☐ No ☒ Yes

9. Rheumatoid arthritis

☐ No ☒ Yes

10. Secondary osteoporosis

☒ No ☐ Yes

11. Alcohol 3 or more units/day

☒ No ☐ Yes

12. Femoral neck BMD (g/cm^2)

Hologic

0.874

T-score: 0.1

Clear

Calculate

BMI: 30.3

The ten year probability of fracture (%)

with BMD

Major osteoporotic

4.1

Hip Fracture

0.1

If you have a TBS value, click here:

Adjust with TBS



Weight Conversion

Pounds kg

Convert

Height Conversion

Inches cm

Convert

00010979

Individuals with fracture risk
assessed since 1st June 2011



Print tool and information

FRAX adjusted for TBS

[IO FRAX web site](#)[What is TBS?](#)[Calculation Tool](#)[References](#)[TBS web site](#)[English](#)

Calculation tool

Country:

Name/ID: Barari.Manizheh

Age: 50

Sex: Female

BMI (kg/m²): 30.3

Please enter the Trabecular Bone Score to compute the ten year probability of fracture adjusted for TBS

DXA device manufacturer: Hologic

Lumbar Spine TBS: 1.435

Calculate

Attention: TBS values are accurate only for patients (women and men) with a BMI in the range [15 – 37 kg/m²]

The 10 year probability of fracture (%)
Adjusted for TBS



Major Osteoporotic Fracture: 3.5

Hip Fracture: 0.1

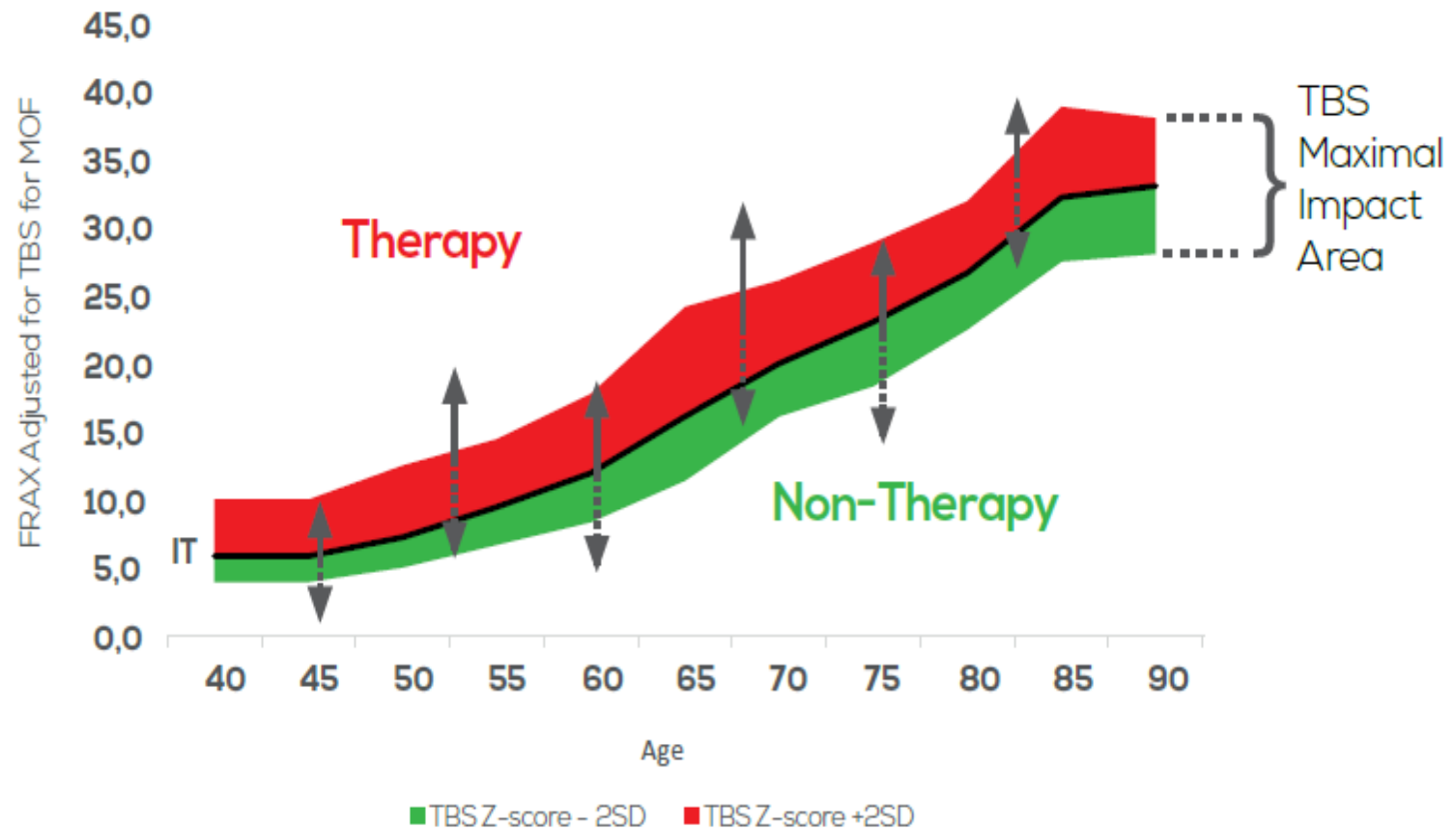
00000043

Individuals with fracture risk assessed

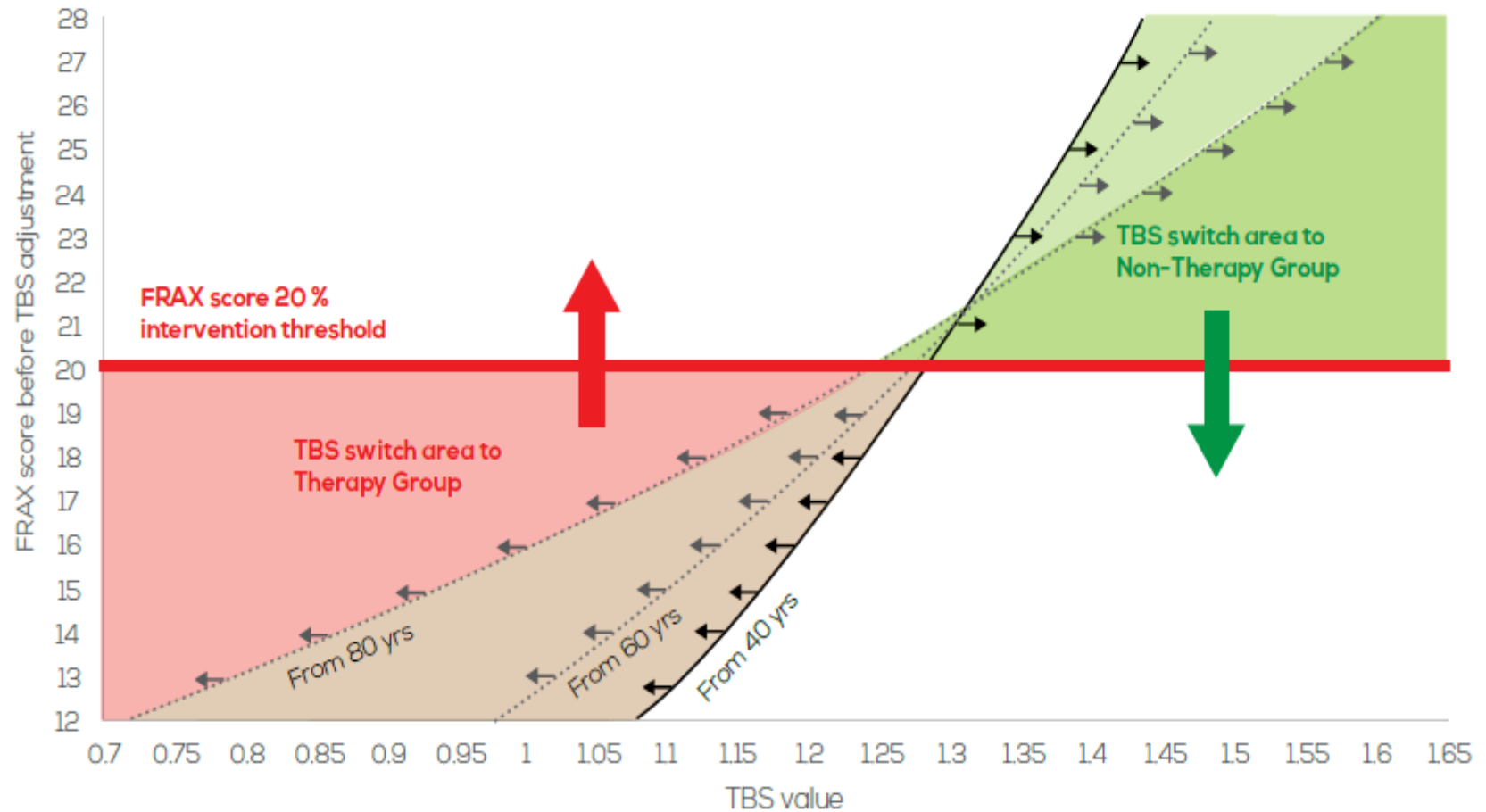
Age (years)	Risk indicator		
	TBS only	Clinical risk factors ^b + BMD	Clinical risk factors ^b + BMD + TBS
✦ Hip fracture			
50	1.51 (0.89–2.55)	3.06 (1.58–5.94)	4.71 (2.14–10.40)
60	1.46 (1.01–2.11)	2.72 (1.59–4.64)	4.45 (2.27–8.73)
70	1.41 (1.12–1.77)	2.41 (1.54–3.77)	4.19 (2.29–7.69)
80	1.36 (1.18–1.57)	2.14 (1.39–3.28)	3.95 (2.16–7.24)
90	1.31 (1.06–1.62)	1.89 (1.17–3.08)	3.73 (1.91–7.28)
Overall	1.44 (1.28–1.62)	2.31 (2.07–2.57)	3.98 (2.90–5.45)
Other major osteoporotic fracture			
50	1.54 (1.18–2.00)	1.46 (1.09–1.96)	1.53 (1.14–2.06)
60	1.51 (1.26–1.79)	1.45 (1.15–1.83)	1.52 (1.20–1.91)
70	1.47 (1.32–1.64)	1.44 (1.18–1.75)	1.50 (1.23–1.83)
80	1.44 (1.29–1.61)	1.42 (1.16–1.75)	1.49 (1.22–1.83)
90	1.41 (1.18–1.68)	1.41 (1.10–1.81)	1.48 (1.15–1.89)
Overall	1.42 (1.33–1.53)	1.42 (1.33–1.52)	1.48 (1.38–1.58)

	HR for MOF (without competing mortality)	HR for MOF (with competing mortality)	HR for Hip Fracture (without competing mortality)	HR for Hip Fracture (with competing mortality)
Adjusted for FRAX score				
All cases	1.20 (1.16-1.24)	1.17 (1.13-1.21)	1.13 (1.06-1.21)	1.09 (1.02-1.17)
Age <65	1.34 (1.26-1.42)	1.32 (1.24-1.40)	1.55 (1.32-1.82)	1.54 (1.31-1.81)
Age > 65	1.13 (1.08-1.18)	1.10 (1.05-1.15)	1.05 (0.98-1.14)	1.01 (0.94-1.09)
P for age interaction	0.016	0.010	<0.001	<0.001
Adjusted for FRAX risk factors				
All cases	1.17 (1.13-1.22)	1.15 (1.11-1.19)	1.14 (1.06-1.22)	1.10 (1.03-1.18)
Age <65	1.31 (1.23-1.39)	1.29 (1.21-1.37)	1.57 (1.33-1.86)	1.57 (1.33-1.86)
Age > 65	1.11 (1.06-1.16)	1.08 (1.03-1.13)	1.06 (0.98-1.15)	1.02 (0.94-1.10)
P for age interaction	0.001	<0.001	<0.001	<0.001

FRAX Adjusted for TBS in patients situated around age-dependant intervention threshold (IT)

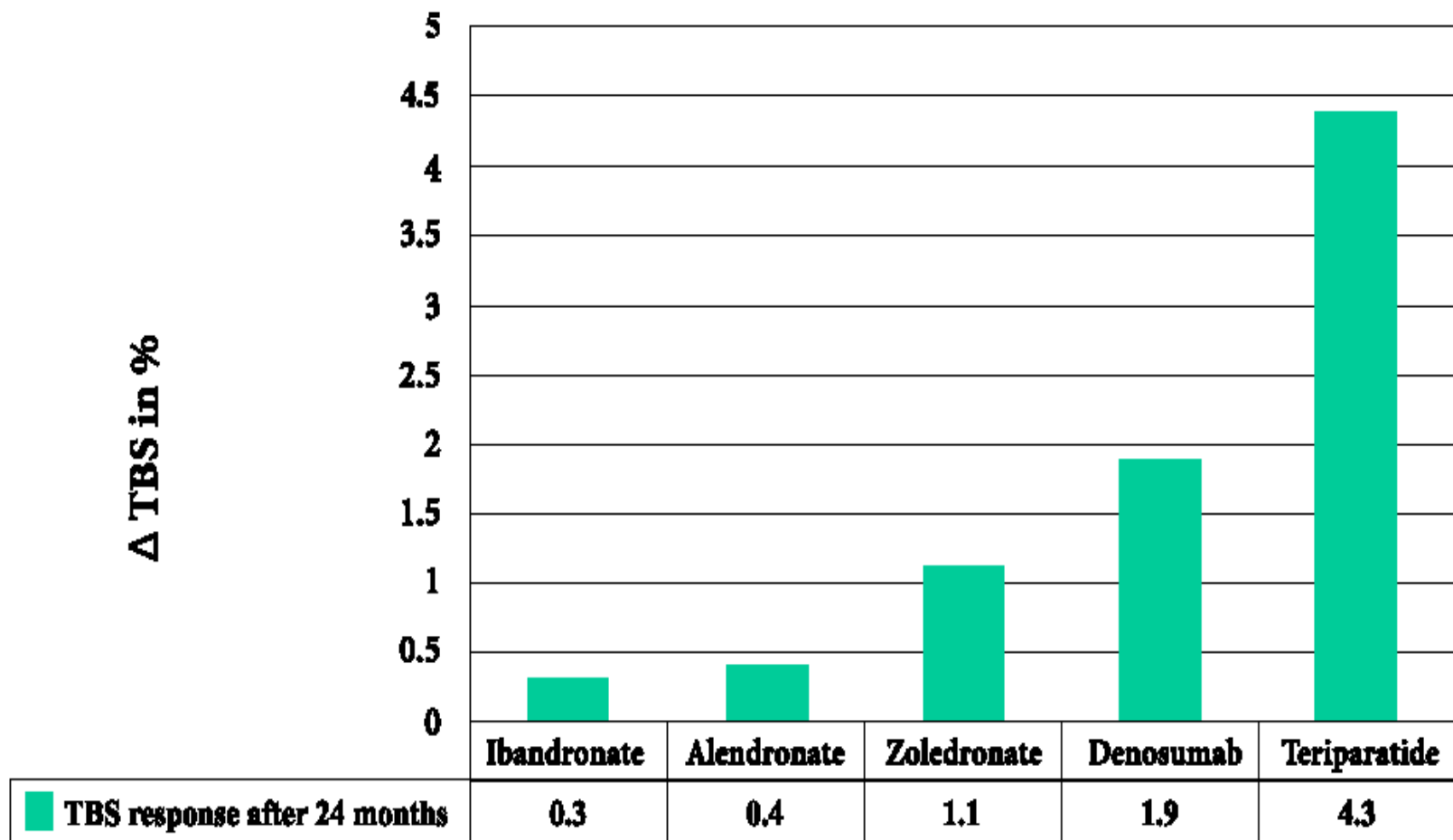


FRAX Adjusted for TBS using fixed intervention threshold



CLINICAL USE OF TRABECULAR BONE SCORE TO MONITOR OSTEOPOROSIS TREATMENT

Changes in TBS are, in general, much smaller than changes in LS BMD during antiresorptive treatment. Although few data suggest that TBS improvements in subjects taking teriparatide are greater than in those using antiresorptives, these were small open-label trials and further studies are needed to confirm these observations. In addition, there are no studies that have shown that change in TBS is associated with a change in fracture risk. Accordingly, the ISCD has recommended against use of TBS for monitoring bisphosphonate therapy.¹⁹ The role of TBS for monitoring patients on teriparatide, denosumab, or newer osteoporotic drugs remains uncertain.



Graphical representation of the change in TBS over a standardized 24-month period.

- At 70 years, 10-year probability MOF FRAX score = 19 % -> MOF FRAX Adjusted for TBS = 21 % with a low TBS of 1.170; switch from “ no treatment zone ” to “ treatment zone ”
- At 70 years, 10-year probability MOF FRAX score = 22 % -> MOF FRAX Adjusted for TBS = 19.3 %) with a high TBS of 1.361; switch from “ treatment zone ” to “ no treatment zone ”
- At 70 years, 10-year probability MOF FRAX score = 21 % -> MOF FRAX Adjusted for TBS = 22.8 % with a low TBS of 1.181; confirmation of established treatment category.

CLINICAL LIMITATION

- ❖ TBS is not recommended for use in patients with BMIs outside of the **range 15–37 kg/m²**.
- ❖ **Patients with scoliosis**
- ❖ **Cannot comparison with two different machine**
- ❖ **For age < 65 yrs results is better**

THANK YOU

