Other Ways of Detecting and Learning More About Bone Fragility

LECTURE 12

Quantitative computed tomography(QCT)

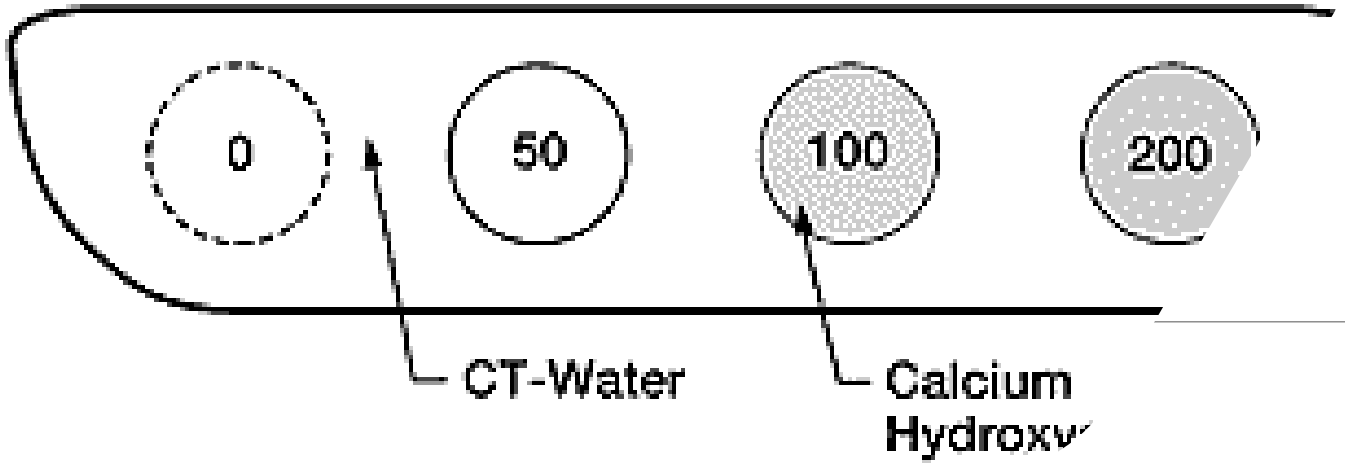
QCT in bone imaging is a Bone mineral density measurement technique in which the CT scanner is calibrated using solid phantoms (made of calcium hydroxyapatite, representing various bone mineral densities)then placed under the patient in a pad when doing the scan.

Quantitative computed tomography(QCT)

There are two main types of QCT:

- Standard QCT: This type of QCT gives you a BMD measurement just as a DXA does. However, It uses a CT image instead of a 2D DXA areal image.
- Volumetric or 3D: QCT provides a volumetric BMD measure of the trabecular vertebral bone in isolation as well as the Cortical bone. This is ideal for looking at trabecular bone micro architecture and cortical bone thickness.

QCT


0
50
100
200
CT-Water
Calcium
Hydroxy


120 KV
70 MA
AZ 90
0 TILT
37.5 MM/S
15:50:16
P
EXAM 1803
PRS 1
XY -102.0MM
IMAGE 4
NO C
DFOV 40.0
STND
UCSF RESEARCH SYS 9800
GENANT, HARRY
L1,2 FIXTILT
8 OCT 90
512
MAGNIFY
F 1.0
X -1.0
Y -1.1

Advantages of QCT

Many people who cannot undergo DXA testing for various reasons can safely have a QCT scan. QCT scans are safe and offer reliable BMD measurements for patients who have:

Arthritis

Scoliosis

Disc space narrowing

Spinal degenerative diseases

Aortic calcification

Osteophytes

Obesity

Disadvantages of

High radiation doses!!! However, QCT protocols are within the low-dose range for a Normal CT scan. It is more comparable to that of mammograms.

Typical radiation values are in the order of 80–120 kVp and between 50 and 200 mAs. Using these parameters, the dose has been estimated using pharmaceutical clinical trials protocols with 1-mm slice width to be as high as 1.5 mSv for the spine and 2.5–3 mSv for the hip.

A limitation is that the World Health Organization (WHO) definition of osteoporosis in terms of bone densitometry (*T* score −2.5 or below using DXA) is not applicable.

QCT Procedure

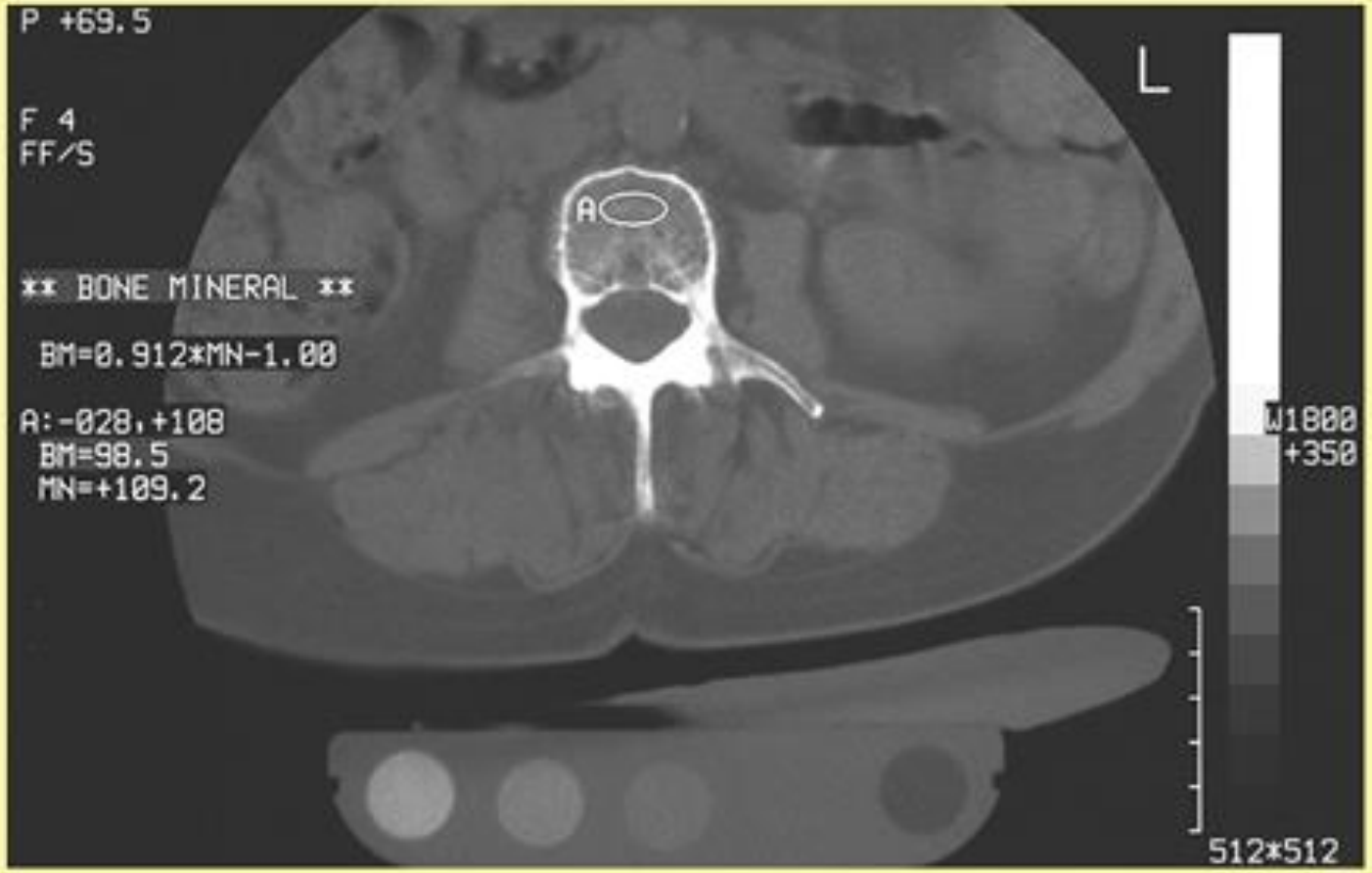
Patient is positioned just like imaging of the lumbar spine.

A scanogram is done to evaluate which vertebrae are to be measured.

Selected vertebrae are imaged.

Quantitative Computed Tomography (QCT)

- 8 to 10 mm slices – through four separate vertebral bodies
  OR
- 20 to 30 continuous 5 mm slices over 2 to 3 vertebral bodies



QCT scan through L1 (phantom)

QCT Procedure

Selected vertebrae have an ROI placed in the middle of the vertebral body

Measurement is made of trabecular bone only

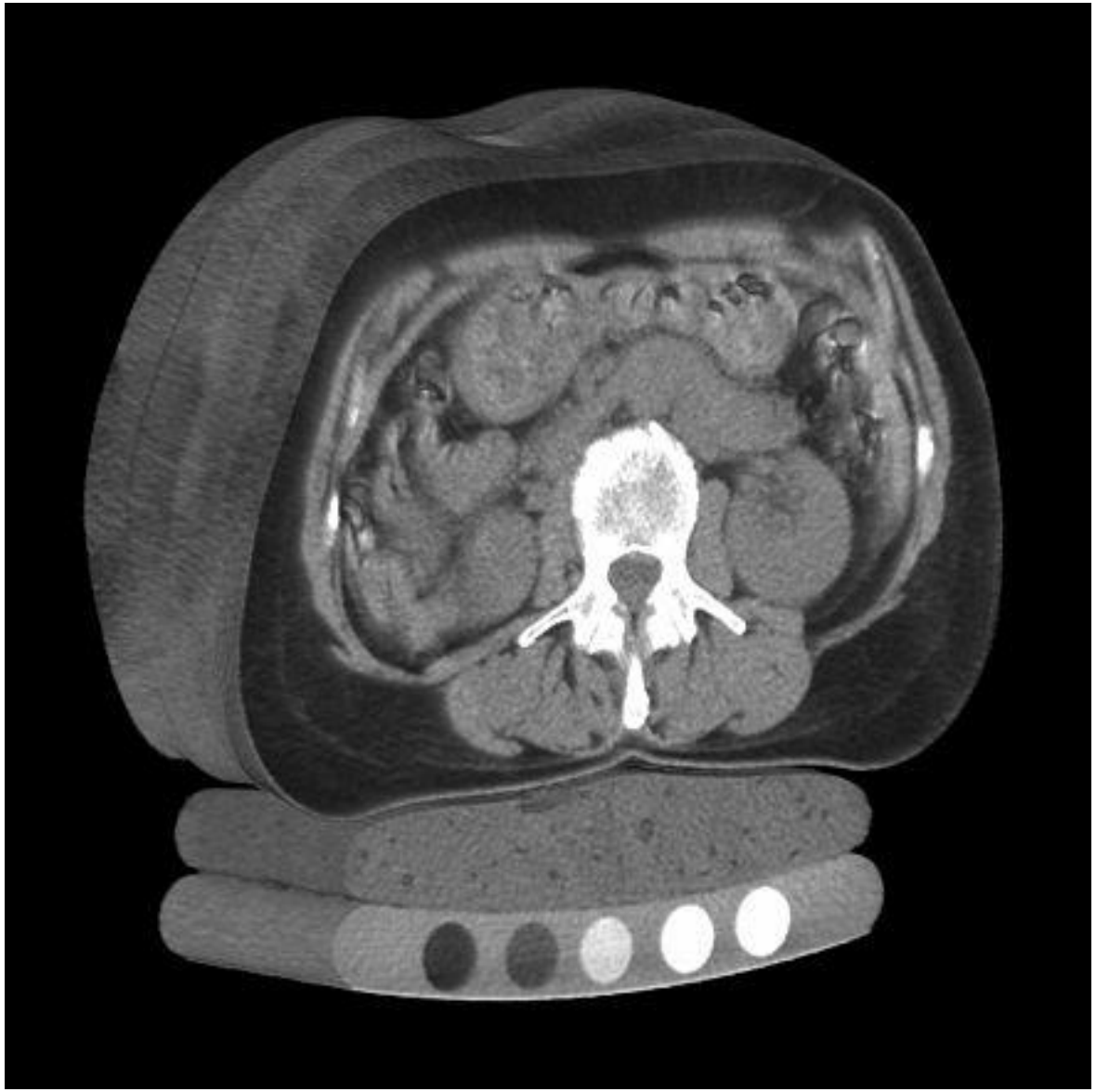
Analysis produces a T and Z score in the same manner as DXA

You can also do a QCT on the hip.

With the QCT scan you can use the images for Finite Element Modeling.

Examples of QCT Phantoms

Take pictures



CTXA™ Hip Bone Mineral Densitometry

Name: JONES, GRANDMA

Sex: Female
Age: 69
Comments:

DOB: 8/21/1943
Date: 5/17/2013

ID: 12345
Exam: 1

Radiologist: Red
Referring Physician: Green

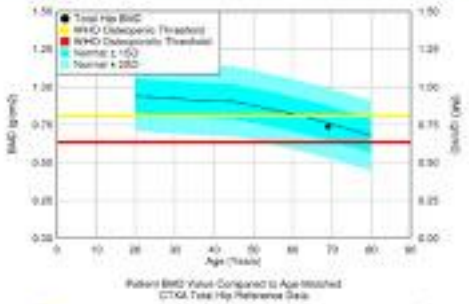
Analysis Results

Hip Analyzed: Left

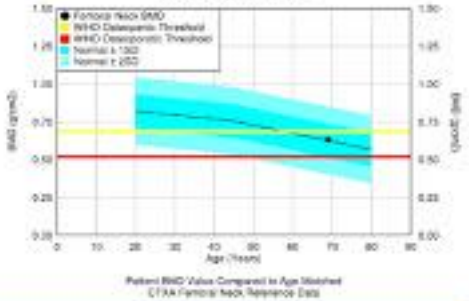
ROI	BMD (g/cm²)	T-Score	Z-Score
Total Hip	0.734	-1.62	-0.19
Femoral Neck	0.631	-1.48	0.05
Trochanter	0.594	-1.02	0.13
Intertrochanter	0.904	-1.40	-0.11

Reference Data: CTXA

Interpretation: A T-score for the Total Hip region of interest between -1 and -2.5 is defined as osteopenia, or low normal bone density, by World Health Organization (WHO) guidelines.



Patient BMD Value Compared to Age Matched CTXA Total Hip Reference Data



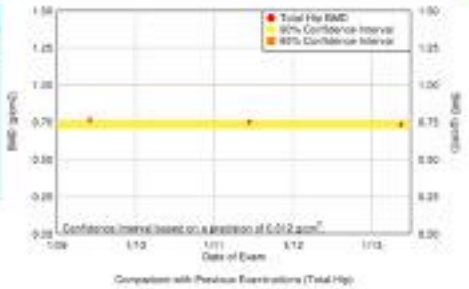
Patient BMD Value Compared to Age Matched CTXA Femoral Neck Reference Data

The WHO classification criteria for T-scores

T-score	Classification
greater than -1.0	Normal
between -1.0 and -2.5	Osteopenia
below -2.5	Osteoporosis
below -2.5 with fracture	Severe Osteoporosis

Comparison with Previous Examinations

	BMD (g/cm²)		Change (g/cm²)	
Date	Neck	Total	Neck	Total
6/4/2009	0.653	0.763	--	--
6/14/2011	0.641	0.752	-0.013	-0.012
5/17/2013	0.631	0.734	-0.009	-0.018
Change per Year, all (g/cm²/year):			-0.006	-0.007
Change per Year, last (g/cm²/year):			-0.005	-0.008



Comparison with Previous Examinations (Total Hip)

Mindways Software, Inc. • 3001 S Lamar Blvd., Ste 302 • Austin, Tx 78704 • Tel (512) 912-0871 Fax (512) 912-0872

Finite Element Modeling of Bone (FEM)

Journal of Biomedical Engineering

Volume 12, Issue 5, September 1990, Pages 389-397

Automated three-dimensional finite element modelling of bone: a new method

Author links open overlay panel
J.H.Keyak*J.M.Meagher†H.B.Skinner*‡C.D.MoteJr§

Finite Element Modeling of Bone

Three-dimensional finite element stress analysis of bone is a key to understanding bone remodeling, assessing fracture risk, and designing prostheses.

A new, automated method of generating patient-specific three-dimensional finite element models of bone is presented in this study

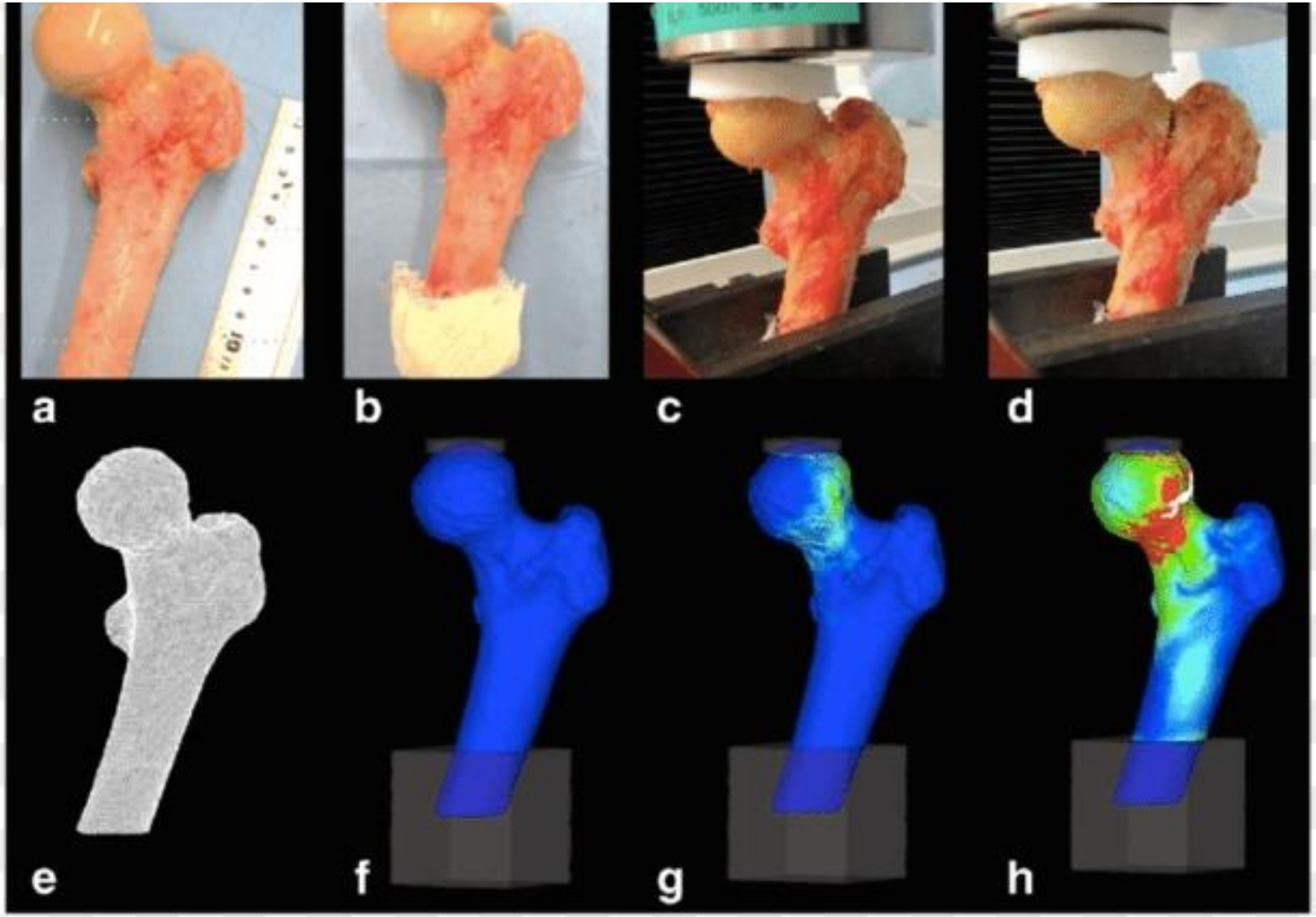
FEM uses digital computed tomographic (CT) scan data to derive the geometry of the bone and to estimate its inhomogeneous material properties.

FEM

The method is demonstrated by predicting the stress, strain, and strain energy in a human proximal femur *in vivo*.

Maximum principal compressive stresses of 8–23 MPa were computed for the medial femoral neck.

Automated generation of additional finite element models with larger numbers of elements was used to verify convergence in strain energy.


a
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Opportunistic Biomechanical CT (BCT)

This is a bone density application that can be applied to any non- contrast CT scan of the spine or the hips.

A CT can be applied "opportunistically" to most existing CT scans that include the spine or hip regions and were previously obtained for an unrelated medical indication

It is a finite element analysis of a patient's clinical-resolution computed tomography (CT) scan

BCT is now nationally covered and reimbursed as a BMM preventative services benefit.

No additional scanning is need which means no more radiation exposure.

VirtuOst
Fracture Risk Assessment

Patient Name:	Patient ID #:	Date of Birth:	Age:	Sex:
P1294 1001 1006	279425	Apr 07, 1951	70	F

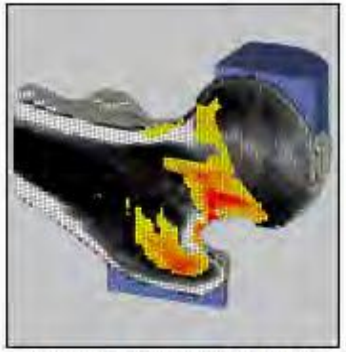
Institution Name:	Physician(s):	Analysis Date:	VirtuOst:
F.L.E.N.I.	Dr. Jones	Aug 31, 2018	2.3

SUMMARY OF PATIENT RESULTS

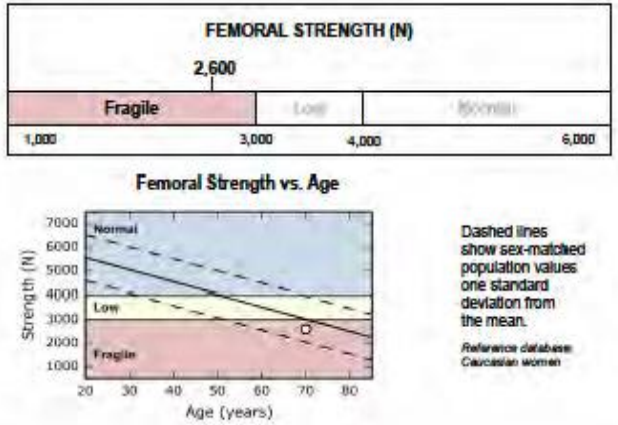
This patient is at **High Risk of Fracture**, based on his/her highest risk classification for Bone Strength or Bone Mineral Density (BMD).

High

FEMORAL STRENGTH RESULTS: Left Femur



Patient image shows the results of the finite element analysis after virtual stress testing for a sideways fall; the colors depict regions of failure. *Not for diagnostic use.*

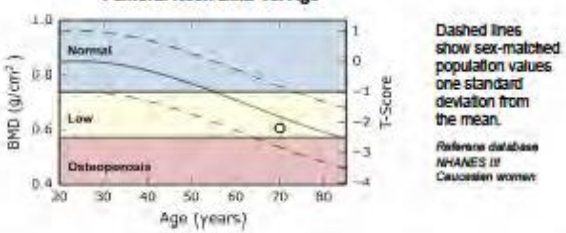


BONE MINERAL DENSITY (BMD) RESULTS: Left Femur

Patient image shows the DXA-equivalent projection of the isolated femur and regions of the BMD measurements. *Not for diagnostic use.*

DXA-EQUIVALENT HIP BMD

Region	BMD (g/cm²)	Z-Score	T-Score	WHO Classification
Femoral Neck	0.606	-0.4	-2.2	Low Bone Mass
Total Hip	0.669	-0.8	-2.2	Low Bone Mass



Additional Observations/Comments:

VirtuOst
Fracture Risk Assessment

Patient Name:	Patient ID #:	Date of Birth:	Age:	Sex:
Doe, Jane	24689753	Feb 27, 1954	65	Female

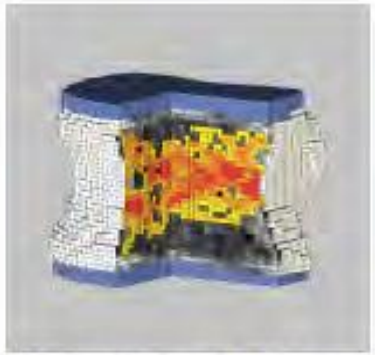
Institution Name:	Physician:	Analysis Date:	VirtuOst:
Berkeley Medical Center	Smith, Michael	Apr 16, 2019	2.3

SUMMARY OF PATIENT RESULTS

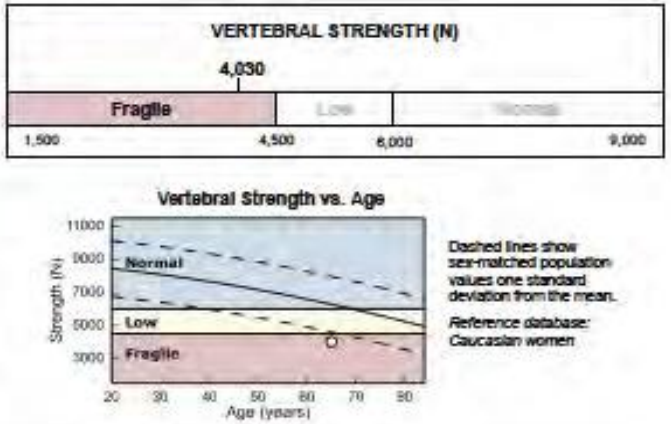
This patient is at **High Risk of Fracture**, based on his/her highest risk classification for Bone Strength or Bone Mineral Density (BMD).

High

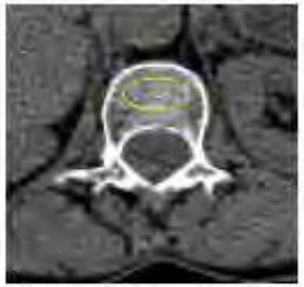
VERTEBRAL STRENGTH RESULTS: L1

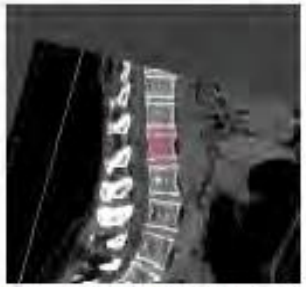


Patient image shows the results of the finite element analysis after virtual stress testing for a compression overload; the colors depict regions of failure. *Not for diagnostic use.*



BONE MINERAL DENSITY (BMD) RESULTS: L1



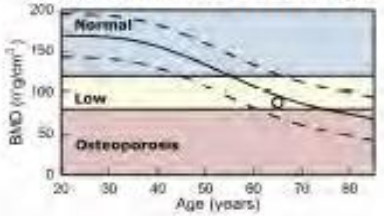


Above left: Patient image shows a transverse cross-section of the vertebral body and measurement region outlined in yellow. **Above right:** Patient image shows a sagittal section with the analyzed vertebral body highlighted in red. *Not for diagnostic use.*

Right chart: Dashed lines show sex-matched population values one standard deviation from the mean. *Reference database: UCSF Caucasian women*

VERTEBRAL TRABECULAR BMD

BMD (mg/cm³)	Z-Score	ACR Classification
88	-0.3	Low Bone Mass



Additional Observations/Comments:

peripheral quantitative computed tomography (PQCT)

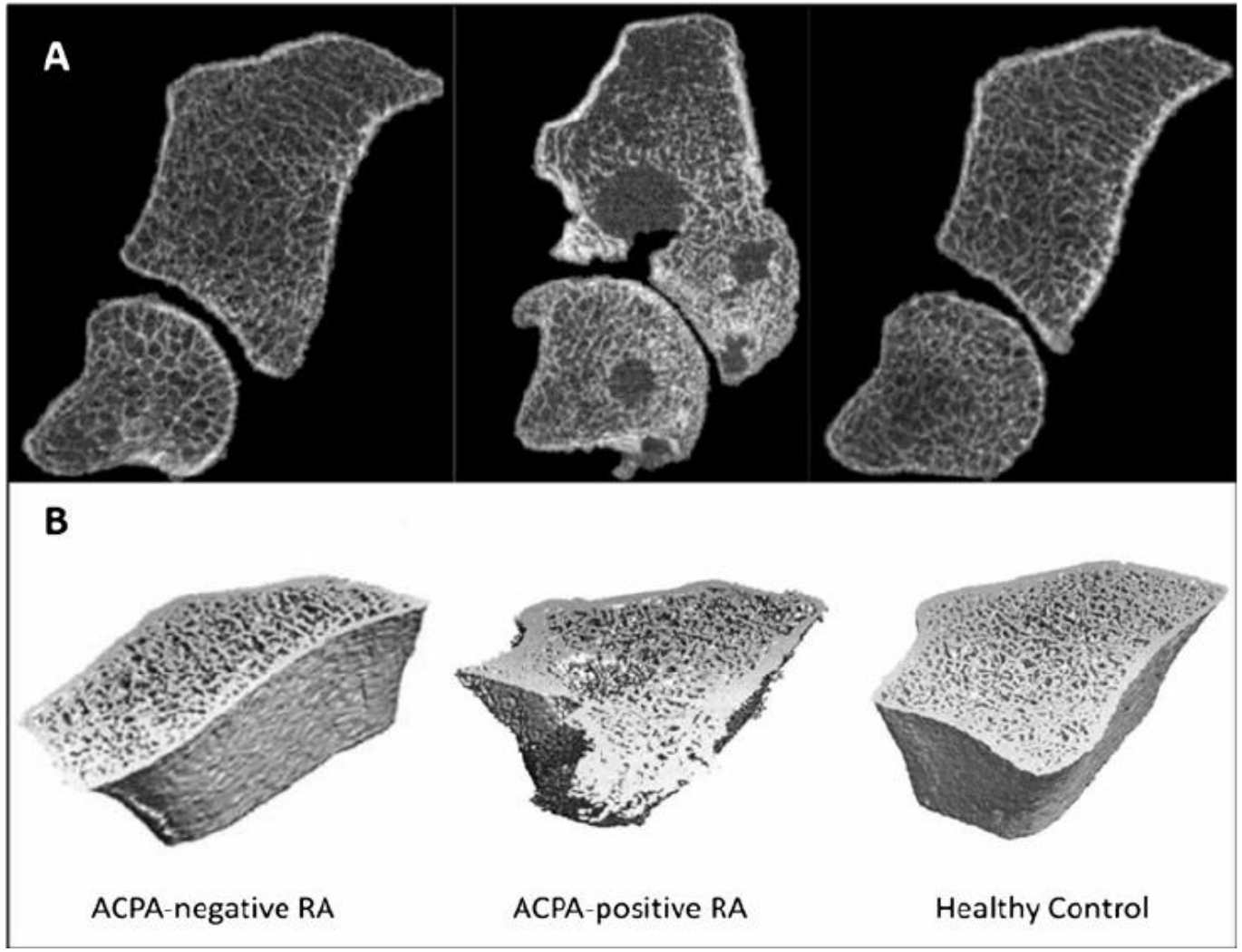
Peripheral quantitative computed tomography provides an automatical scan analysis of trabecular and cortical bone compartments, calculating not only their bone mineral density (BMD), but also bone geometrical parameters, such as marrow and cortical Cross-Sectional Area (CSA), Cortical Thickness (CoTh), both periosteal and endosteal circumference.

PQCT continued

Areas normally scanned are Wrist, Ankle and knee.

PQCT is normally just done in research. Not widely used in a clinical setting.

radiation exposure from pQCT is low (0.01 mSv), although slightly higher if compared with DXA (0.004–0.005 mSv). PQCT radiation emission must be calibrated by the daily scanning of a phantom.


A
B
ACPA-negative RA
ACPA-positive RA
Healthy Control

Radiofrequency Echographic Multi Spectrometry (REMS)

REMS is a non-ionizing technology for the densitometric assessment of osteoporosis.

REMS is a relatively recent technology that performs the analysis of bone quantity and quality through a non-ionizing approach, being based on the analysis of ultrasound signal backscattering.

BMD is calculated through advanced comparisons of the patient's specific spectrum of the target bone against a proprietary database of reference ultrasound spectral models and the corresponding T-score and Z-score values are derived using a normative reference database, i.e. the National Health and Nutrition Examination Survey.

PRODUCT CHARACTERISTICS - BONE MINERAL DENSITY (BMD)	DXA	REMS
Radiation Exposure	YES	NO
Measurement at Vertebrae and Femur	YES	YES
BMD Assessment	YES	YES
BMD Independent of Bone Size	NO	YES
Patient Position Critical to Exam Resuts	YES	NO
Diagnosis Affected By Spinal Artifacts	YES	NO
BMD affected by non-uniform soft tissue composition surrounding the bone (Fat Error)	YES	NO
Bone Quality Assessment	NO	YES
Body Composition Index	YES	YES
Operator Independent	NO	YES
Accuracy	HIGH	VERY HIGH
Primary Care	NO	YES
Cost	HIGH	LOW
Operator Certification Needed	YES	NO
Dedicated Shielded Room	YES	NO
Annual Maintenance Costs	YES	NO
Diagnostic Tool	YES	YES
Appropriate for Monitoring and Follow Up	NO	YES
Portable	NO	YES

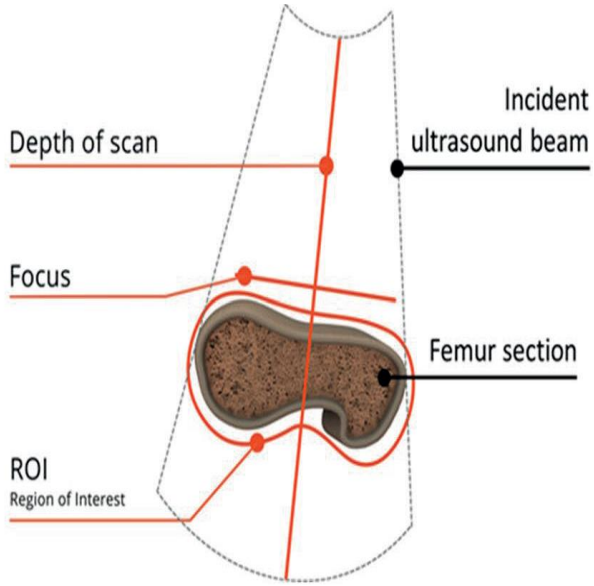
Areas Scanned and Patient Prep

AP Lumber spine L1-L4

Bilateral Hips

Patient will need to be put in a gown.

Patient lays supine on a table



A X-Ray scan patient N°1

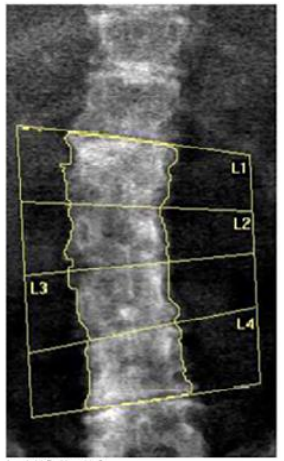
B DXA scan patient N°1

Patient ID:
DOB: 08 January 1951

Ethnicity: White

Weight: 62.0 kg
Age: 68

Referring Physician: SP



k = 1.117, d0 = 46.5
114 x 131
DAP: 4.6 cGy*cm²

Scan Information:

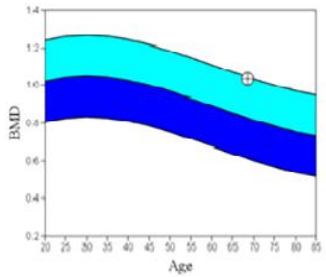
Scan Date: 17 July 2019 ID: C07171908
Scan Type: a Lumbar Spine
Analysis: 17 July 2019 14:39 Version 13.3:3
Spine
Operator:
Model:

DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)	T-score	PR (%)	Z-score	AM (%)
L1	15.24	17.92	1.176	1.7	119	3.5	148
L2	12.54	10.99	0.877	-1.4	85	0.6	108
L3	13.46	13.08	0.972	-1.0	90	1.1	114
L4	14.43	15.65	1.084	0.2	102	2.4	131
Total	**55.68**	**57.65**	**1.035**	**-0.1**	**99**	**1.9**	**125**

Total BMD CV 1.6%, ACF = 1.037, BCF = 1.008, TH = 6.884

Total



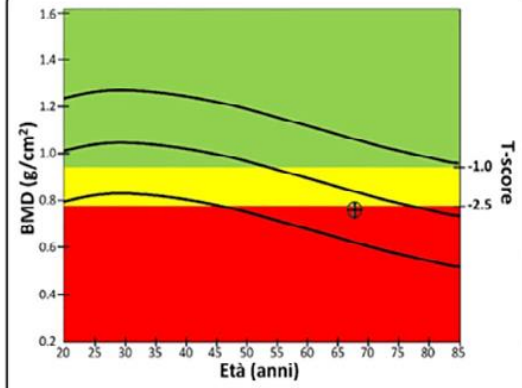
Comment:

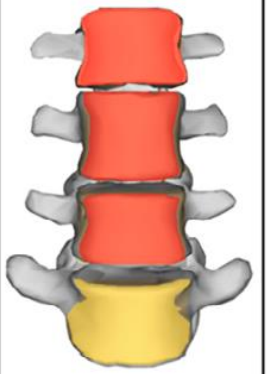
C REMS scan patient N°1

ECHOLIGHT

COGNOME:
DATA DI NASCITA: 08/01/1951
ETÀ: 68 ETA' MENOPAUSA: 38
SESSO: F PESO: 62 kg ALTEZZA: 160 cm BMI: 24.22 kg/m²

Densitometria REMS: COLONNA

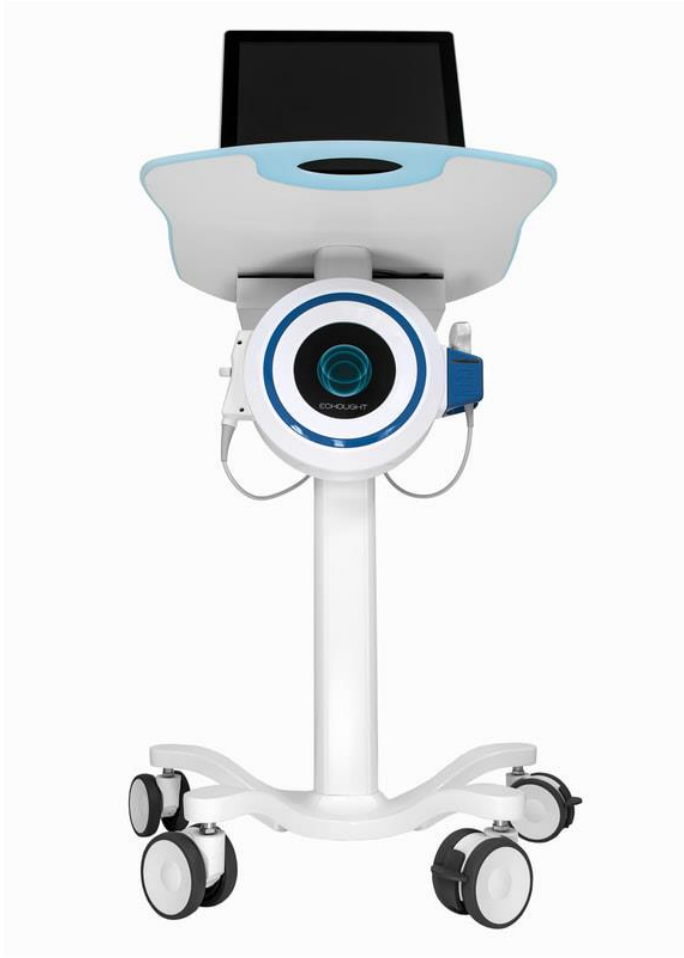




	BMD (g/cm²)	T-score	Z-score	Diagnosi	Rischio di frattura
Totale	0.758	-2.6	-0.6	Osteoporosi	Alto

FRAX®	
Principali osteoporotiche	14.0%
Frattura d'anca	4.5%

	BMD (g/cm²)
L1	0.644
L2	0.731
L3	0.781
L4	0.855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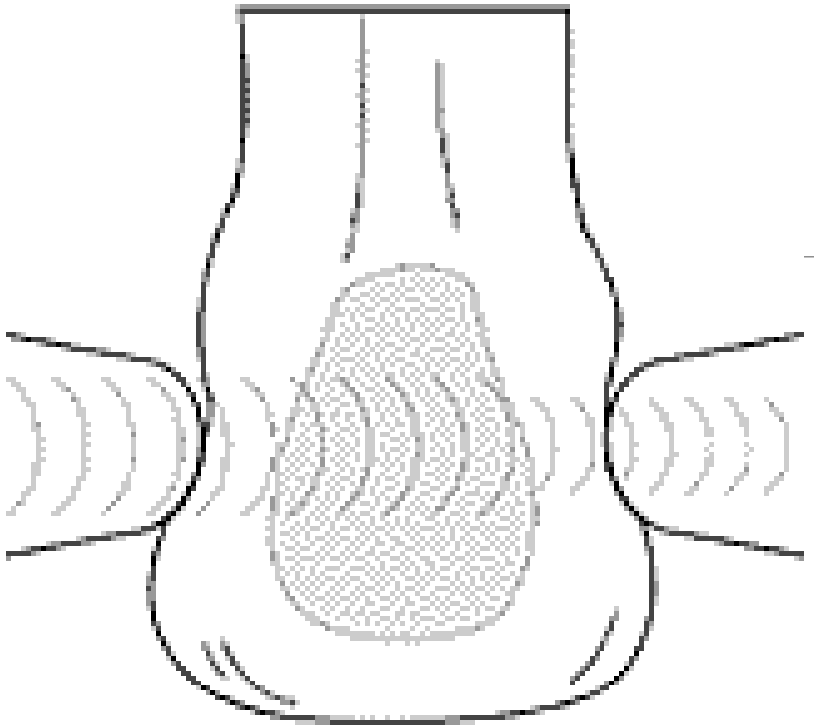
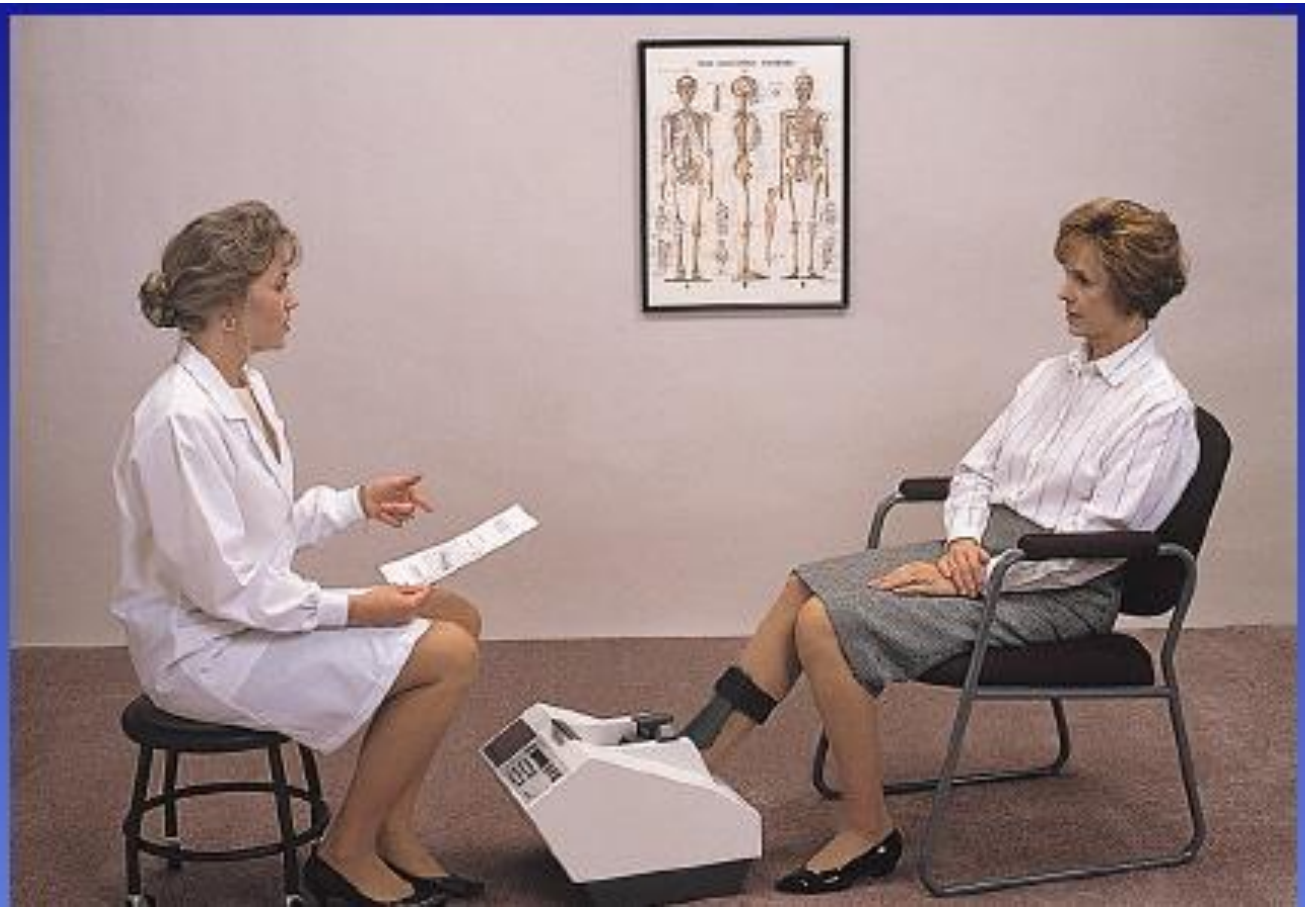


QUS

- Nonionizing technique using ultrasound
- Peripheral site selections such as the os calcis
- Provides quick and simple measurements for screening purposes



Ultrasound Measurements QUS

Known as Quantitative Ultrasonography
- QUS

Measures Bone Stiffness-Not Bone Mass
- Broadband Ultrasound Attenuation (BUA)
- Speed of Sound (SOS)
- Quantitative Index (QUI) or Stiffness

MRI

MRI is coming around in research

Information is presented frequently now at annual meetings at the:

ISCD

ASRT

NOF

And others

What does this mean?

Research has shown data such as this.

- An increase in marrow fat may represent a compensation for trabecular thinning
- Increasing fat could be compressing the intraosseous veins, thereby diminishing blood flow.

At this time

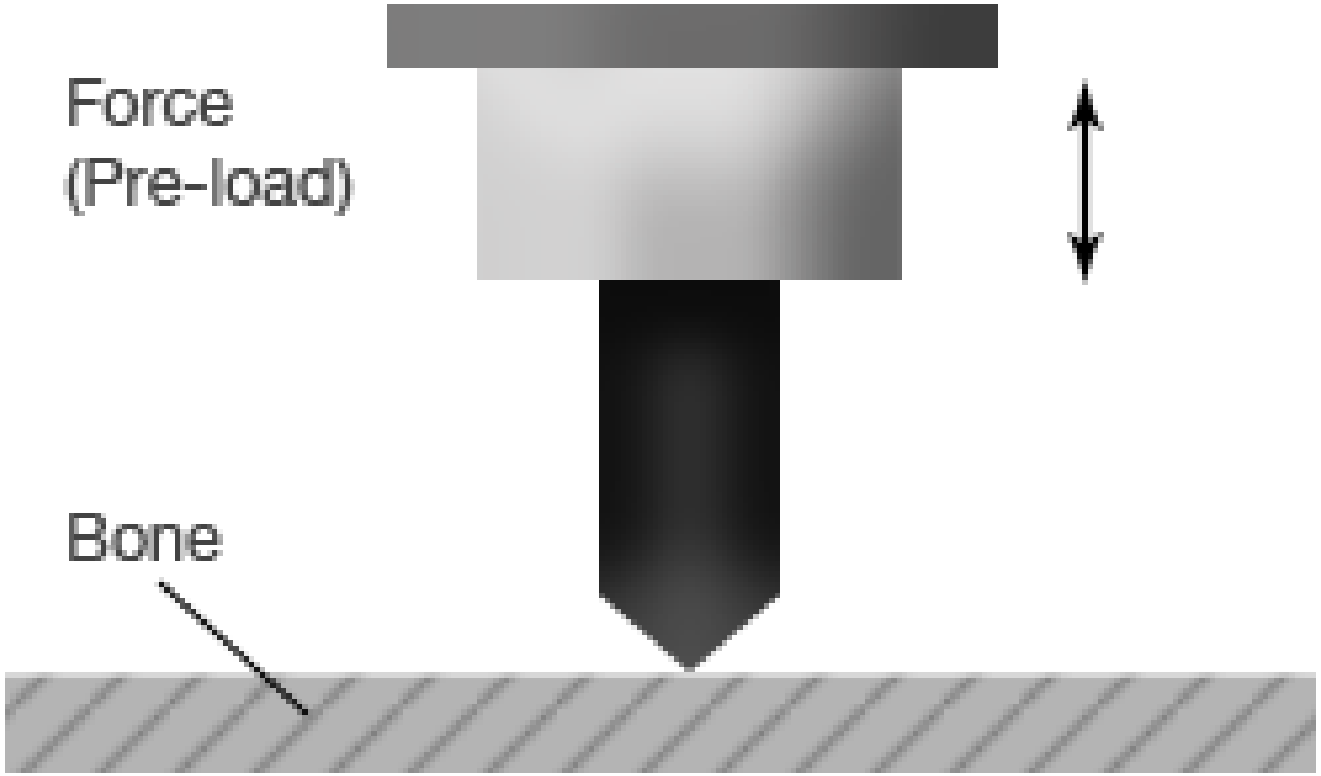
It is not projected that MRI will become a standard for diagnosing osteoporosis

It does give us another non-ionizing option to look at bone mass

We'll see what happens!!!!!!!

OsteoProb (Bone Indentation Technology)

How does OsteoProbe work?



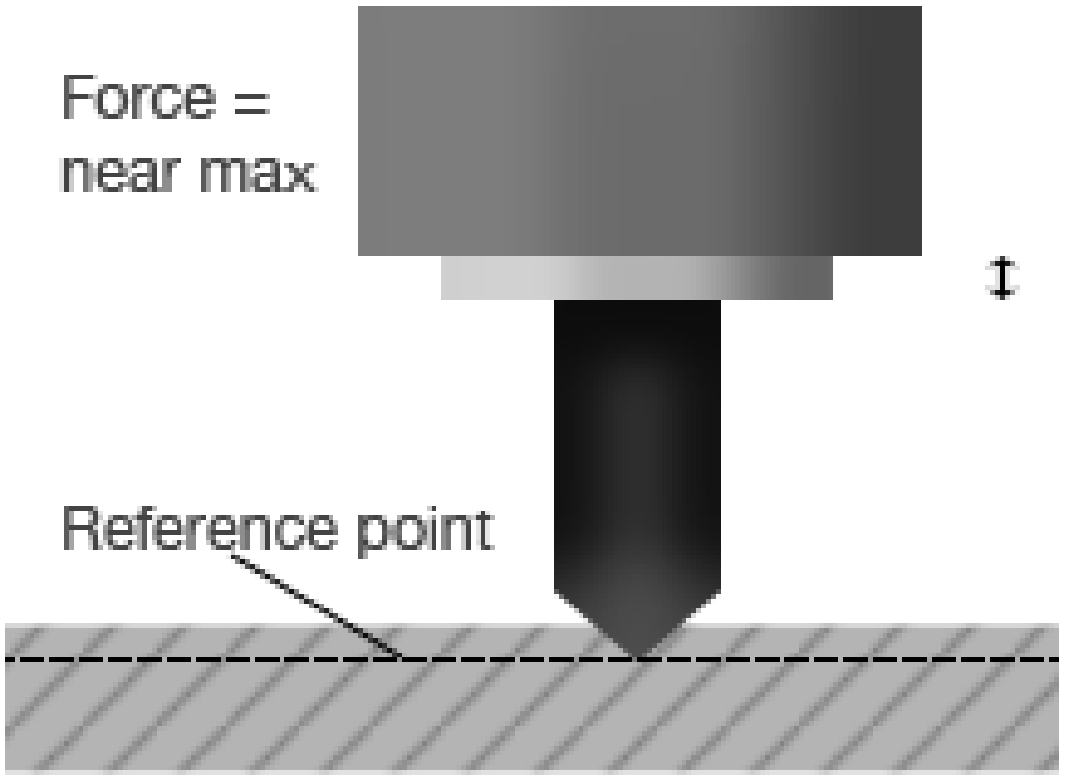
Step 1

The tip assembly is inserted through any soft tissue to the cortical bone surface.

Step 2

The user compresses the outer housing, pressing the tip lightly into the cortical bone surface.

Force



Step 3

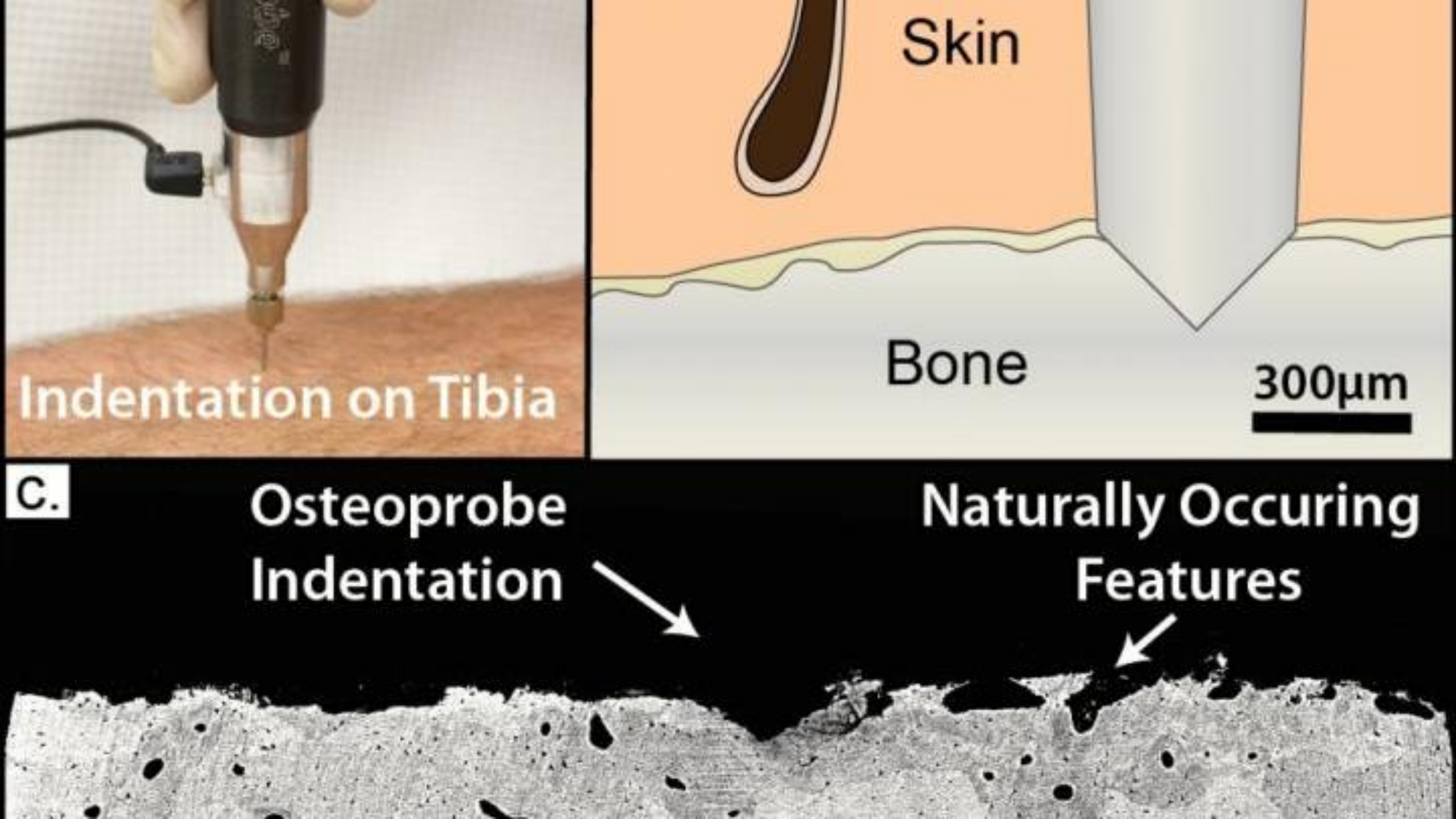
At maximum compression (~10N), the tip is pressed into the bone surface enough to set a reference point.

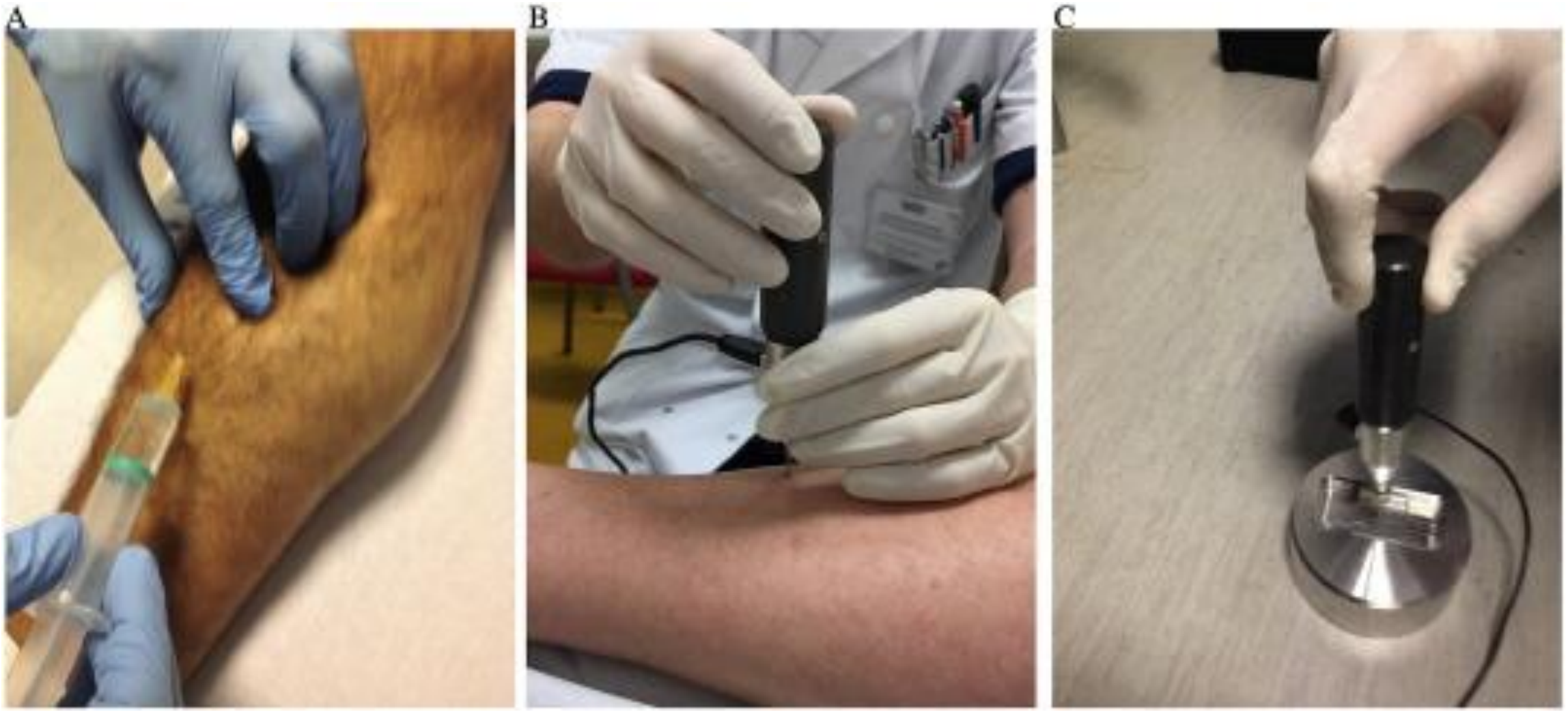
Step 4

Once the reference point is established the device impacts the tip, driving it into the bone. The distance the tip indents the bone is measured (~150-400µm).

Step 5

The user moves the tip to a new location about 1-2mm away and repeats the process. The device software instructs the user how many indentations to make.

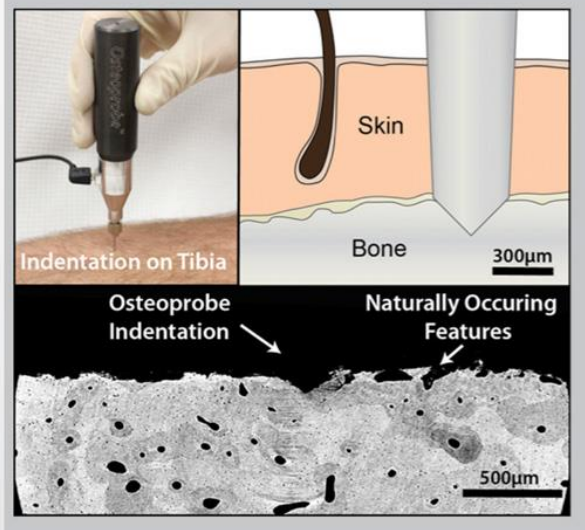

Indentation on Tibia
Skin
Bone
300µm
C.
Osteoprobe Indentation
Naturally Occuring Features


A
B
C

What is the Bone Score?

Patients with harder bone score higher on the scale. Patients with softer bone score lower.

Journal of Bone and Mineral Research
JBMR
Volume 30
Number 9
September 2015
pp. 1539–1746



Can Indentation Techniques Measure Bone Strength In Vivo?

Life Expectancy in People Treated With Bone Protective Drugs

Zinc, Ion Channels and Osteoclastogenesis

WILEY Blackwell

Published monthly by
The American Society for Bone and Mineral Research
ASBMR

Professional Society Annual Meetings and Other Bone Meetings

If you want to learn more about these technologies, I recommend attending these meetings:

ASBMR: American Society of Bone Mineral Research

ISCD: International Society of Clinical Densitometry

NOF: National Osteoporosis Foundation

Santa Fe Bone Symposium

For Providers with Bone Diagnosis and Treatment Questions

Bone Health TeleECHO™ Program

Medical Director: E. Michael Lewiecki, MD

They have a presentation first.

For example Pediatrics: Multicentric Carpotarsal Osteolysis: A Rare Bone to Pick

They have two case studies

You can discuss your case study if you want

Expert bone providers from all over the U.S. participate and give advice.

Other Bone Health TeleECHO Programs

Bone Health Worldwide Weekly Calendar (click for flyer), including the following programs:

MNI Great Lakes ECHO LLC - 4th Friday of the month 12:00 - 1:00 PM (ET)

Email adonnell@greatlakes-echo.com to register. Click for flyer

National Osteoporosis Foundation FLS Bone Health TeleECHO - 2nd Thursday of the month 3:00 - 4:00 PM (ET) Email info@nof.org to register. Click for flyer

***New in October* Osteogenesis Imperfecta TeleECHO - 2nd Wednesday of the month 3:00 - 4:00 PM (ET) Follow this link to register OIF.org/echo/**

Own the Bone Orthopaedic Bone Health TeleECHO - 3rd Thursday of the month 12:00 - 1:15 PM (CT) Follow this link to register www.surveymonkey.com/r/P7V9N7X Click for flyer

Rare Bone Disease TeleECHO - 1st Thursday of the month 3:00 - 4:00 PM (ET) Follow this link to register https://www.surveymonkey.com/r/rareboneECHO

Applications and Manufactures Web Pages and Research article Links

DXA-

https://www.hologic.com/

https://www.gehealthcare.com/products/bone-and-metabolic-health/lunar-idxa

http://www.swissray.com/SRI/menu.php?id=27

FRAX-

https://www.sheffield.ac.uk/FRAX/index.aspx

TBS

https://www.medimapsgroup.com/

3D DXA-

https://www.galgomedical.com/en/3d-shaper.html

VFA-

https://www.hologic.com/

https://www.gehealthcare.com/products/bone-and-metabolic-health/lunar-idxa

HSA-

https://www.medscape.com/answers/330598-83055/what-is-the-role-of-hip-structural-analysis-hsa-in-the-workup-of-osteoporosis

https://wwwn.cdc.gov/nchs/data/nhanes3/17a/hip_methods.pdf

QCT-

https://qct.com/index.php

FEM-

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6894848/

BCT-

https://pubmed.ncbi.nlm.nih.gov/32335687/

https://link.springer.com/article/10.1007/s00198-020-05384-2

PQCT

https://www.scanco.ch/404.html

Echolite (REMS)-

https://www.echolightmedical.com/

QUS-

https://pubmed.ncbi.nlm.nih.gov/28739081/

MRI-

https://pubmed.ncbi.nlm.nih.gov/10602850/

OsteoProb-

http://research.activelifescientific.com/