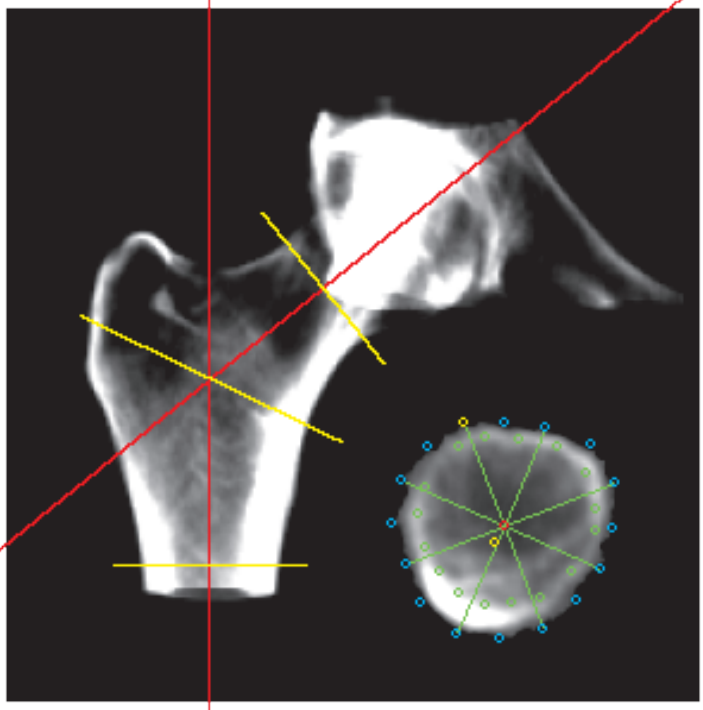
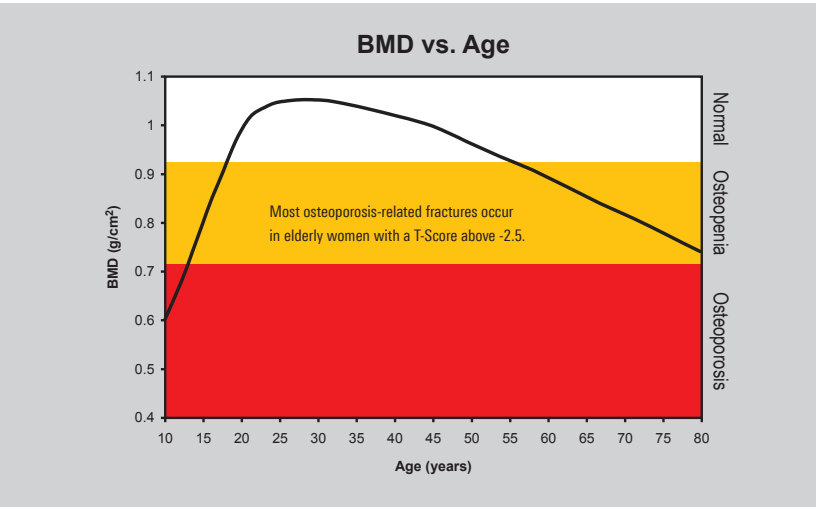
# Bone Investigational Toolkit BIT™



Biomechanical Bone Integrity Assessment

**Mindways**

# The Bone Densitometry Problem




Most elderly women are classified as osteopenic (T-Score between -1 and -2.5) by current WHO guidelines, yet BMD does not do a good job of identifying at-risk individuals in this group.

Bone densitometry is widely used to identify individuals at risk of osteoporosis-related fracture. The World Health Organization, among others, recommends classifying patients with a hip BMD T-score below -2.5 as osteoporotic in the absence of other indications. While hip T-scores may provide a convenient framework for characterizing the prevalence of osteoporosis, this method does not accurately identify many individuals at risk of fracture. It has been reported from numerous fracture studies that the majority of study participants suffering a fracture did not have a hip T-score below -2.5. It has also been found in trials that treatment with various pharmaceuticals can decrease fracture risk much more than would be predicted based on the more modest gains observed in bone mineral density. These and other findings reveal that consideration of factors beyond bone mineral density is necessary to better identify at-risk individuals.

Modern helical and multi-slice CT scanners quickly generate volumetric data sets containing a wealth of information about bone mineral density, bone distribution and geometry, and biomechanical integrity. QCT PRO has been used for years to provide clinical estimates of bone mineral density (BMD) of the spine and proximal femur from such volumetric data sets. Mindways now provides the QCT PRO Bone Investigational Toolkit (BIT) to enable researchers and others to access data heretofore inaccessible to QCT PRO users.

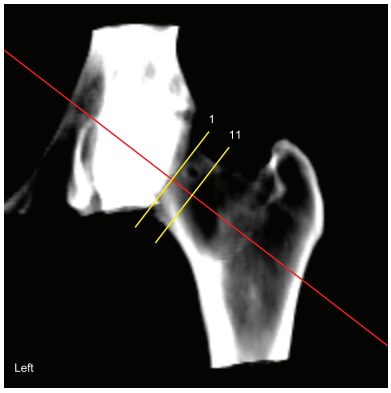
# Bone Strength

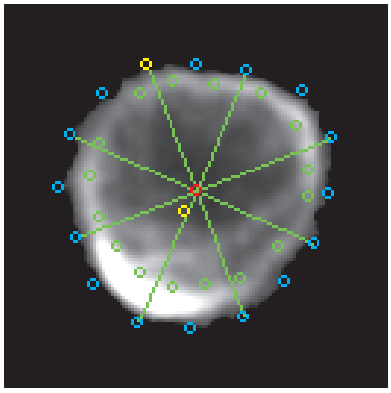
There is a well established, significant correlation between bone mineral density and bone strength, but bone mineral density is only one of many factors that determine bone strength. Other factors such as bone distribution (geometry) play significant roles in determining bone strength and ultimately fracture risk for an individual. These observations and the wide availability of DXA have motivated numerous, extensive, studies involving the use of DXA to estimate properties of biomechanical relevance such as cross-sectional moment of inertia, section modulus and cross-sectional area to characterize the distribution of bone with the goal of improving fracture risk assessment. The results of these studies, however, show little improvement in fracture risk assessment beyond that achieved with bone density testing. Failure to improve fracture risk assessment with these methods has been attributed to limitations associated with DXA including critical patient-positioning requirements and limitations of using a 2D imaging method to accurately characterize complex 3D structures such as the spine and hip.

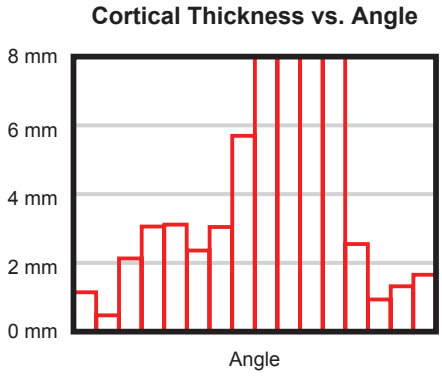
**Volumetric QCT imaging is the key to surmounting the limitations of DXA for accurately characterizing bone geometry.**

Volumetric QCT provides a detailed, 3D representation of bone structure, and the QCT PRO Bone Investigational Toolkit provides the means for extracting density, distribution and geometry information relevant to understanding bone strength or characterizing the change in bone distribution as well as in BMD in response to therapy.

| Image | 1 | 2 | 3 |
|---|---|---|---|
| Trabecular BMD (mg/cm³) | 145 | 149 | 154 |
| Cortical BMD (mg/cm³) | 374 | 392 | 407 |
| Total CSA (cm²) | 13.600 | 12.761 | 12.022 |
| Total Bone CSA (cm²) | 1.572 | 1.581 | 1.576 |
| Cortical CSA (cm²) | 2.377 | 2.591 | 2.664 |
| Cortical Bone CSA (cm²) | 0.556 | 0.634 | 0.677 |
| Max CSMI, bone (cm⁴) | 1.57 | 1.57 | 1.51 |
| Max Z, bone (cm³) | 0.85 | 0.81 | 0.86 |
| Max CSMI, geo, cort (cm⁴) | 2.22 | 2.53 | 2.51 |
| Max Z, geo, cort (cm³) | 1.20 | 1.44 | 1.48 |
| Avg. Cort. Thick (mm) | 3.31 | 3.33 | 3.24 |
| Max/Min Thick | 4.4 | 4.0 | 3.9 |
| Geo to CM Disp (mm) | 1.47 | 1.50 | 1.89 |
| Buckling Ratio | 5.9 | 5.7 | 5.7 |
| Eccentricity | 1.18 | 1.14 | 1.12 |
| FC1 Magnitude (mm) | 4.16 | 3.97 | 3.85 |
| FC1 Phase (degrees) | 212 | 211 | 208 |



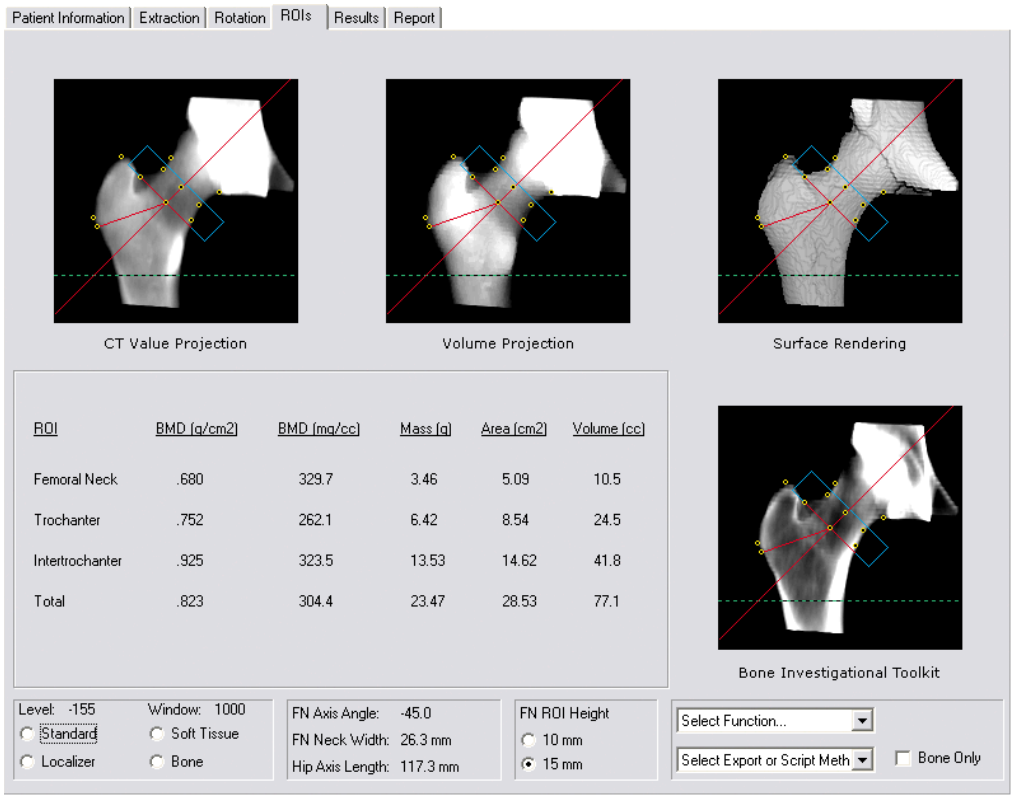


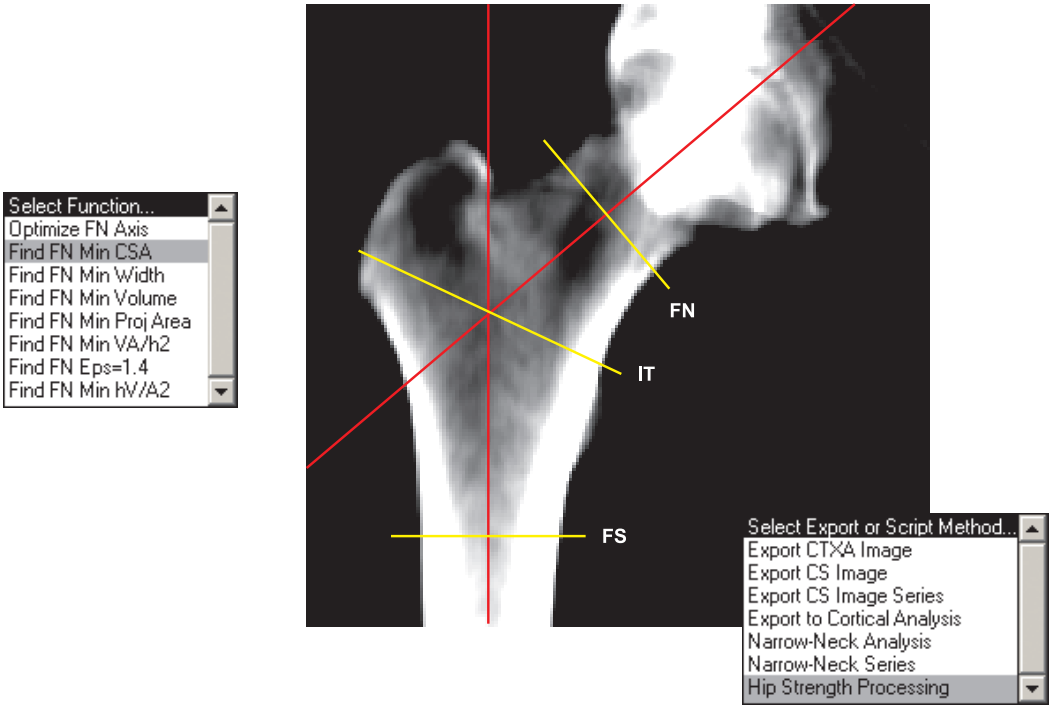
# Moving Beyond Bone Densitometry

The QCT PRO Bone Investigation Toolkit (BIT) provides you access to a vast array of measures and capabilities for characterizing the proximal femur. Volume density, in addition to DXA-like area density, in cortical, trabecular and total bone compartments are just a start. Tools to facilitate consistent femoral-neck region-of-interest analysis in serial studies, femoral neck cross-sectional image analysis, and characterization of femoral-neck cortical-bone thickness and distribution are included. Or you can develop your own sophisticated measurement algorithms based on calibrated image data exported from BIT. BIT includes analysis scripts to help you customize and automate your analyses and apply the analyses consistently to large sets of data.

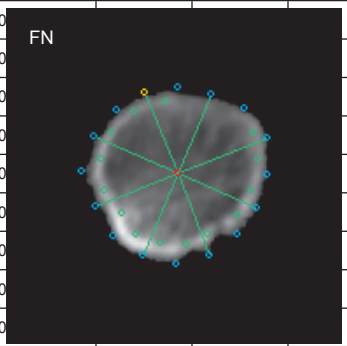
## BIT Cross-Sectional Image Measurements

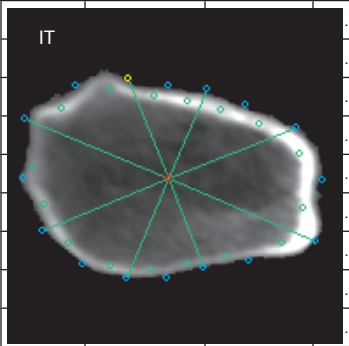
- Cortical Area
- Trabecular Area
- Cortical Thickness
- Principal Axes
- Bending Moments (CSMI)
- Section Moduli
- Buckling Ratio

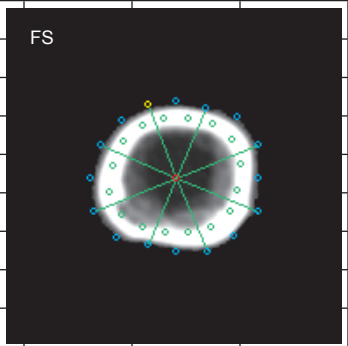





| | Perimeter | BMD | Area | Cortical Width | Norm Width | Avg Cort Arc Length | Cortical Perimeter | Distance To CM | Distance To Center | Tangent Angle | Curvature | Radius of Curvature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | (cm) | (mg/cm$^3$) | (cm$^2$) | (mm) | (mm) | (mm) | (mm) | (mm) | (mm) | (degrees) | (cm$^{-1}$ ) | (cm) |
| 1 | 0.83 | 398.0 | 0.032 | 0.47 | 0.23 | 6.77 | 6.84 | 23.28 | 19.05 | -12.6 | 0.977 | 1.02 |
| 2 | 0.83 | 405.7 | 0.136 | 2.07 | 1.04 | 6.57 | 6.89 | 20.74 | 16.87 | -50.5 | 1.057 | 0.95 |
| 3 | 0.82 | 408.8 | 0.127 | 2.00 | 1.01 | 6.32 | 6.71 | 16.59 | 13.67 | -90.2 | 0.321 | 3.11 |
| 4 | 0.82 | 415.4 | 0.124 | 2.03 | 1.05 | 6.08 | 6.54 | 13.41 | 11.95 | -101.9 | 0.215 | 4.64 |
| 5 | 0 | | | | | | | .59 | | | | 2.57 |
| 6 | 0 | | | | | | | .83 | | | | 1.71 |
| 7 | 0 | | | | | | | .14 | | | | 1.19 |
| 8 | 0 | | | | | | | .89 | | | | 1.01 |
| 9 | 0 | | | | | | | .72 | | | | 1.16 |
| 10 | 0 | | | | | | | .98 | | | | 1.62 |
| 11 | 0 | | | | | | | .51 | | | | 2.11 |
| 12 | 0 | | | | | | | .63 | | | | 2.07 |
| 13 | 0 | | | | | | | .73 | | | | 1.62 |
| 14 | 0.83 | 365.2 | 0.040 | 0.62 | 0.28 | 6.45 | 6.56 | 17.60 | 14.75 | 47.7 | 0.609 | 1.64 |
| 15 | 0.80 | 410.3 | 0.067 | 1.06 | 0.54 | 6.34 | 6.51 | 19.78 | 15.88 | 25.2 | 0.519 | 1.93 |
| 16 | 0.81 | 362.5 | 0.009 | 0.13 | 0.06 | 7.32 | 7.34 | 23.21 | 18.75 | 6.4 | 0.451 | 2.22 |
| Sum | 13.14 | 7854.9 | 2.357 | 38.52 | 27.80 | 99.91 | 108.58 | 250.64 | 247.49 | -187.4 | 10.008 | 30.57 |
| Average | 0.82 | 490.9 | 0.147 | 2.41 | 1.74 | 6.24 | 6.79 | 15.67 | 15.47 | -11.7 | 0.626 | 1.91 |
| Std Dev | 0.02 | 145.0 | 0.108 | 1.75 | 1.72 | 0.45 | 0.47 | 4.10 | 2.31 | 103.1 | 0.251 | 0.95 |



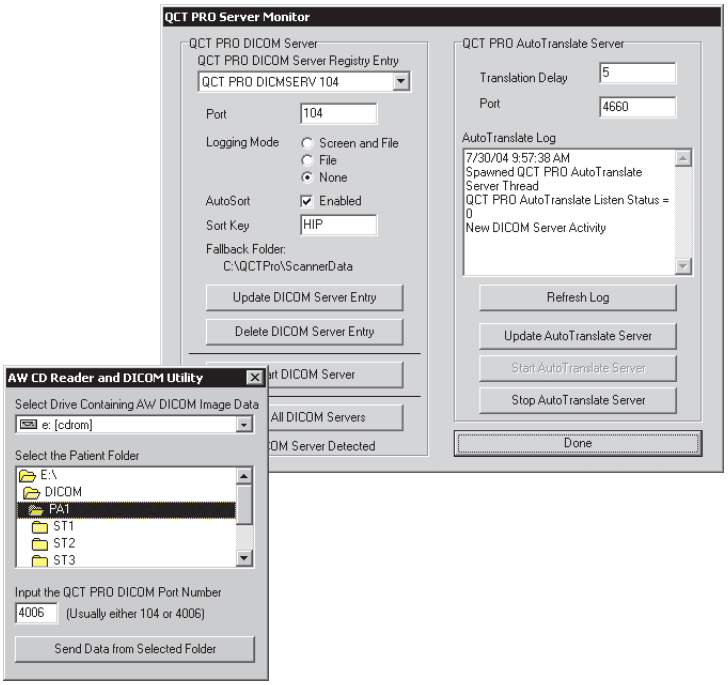



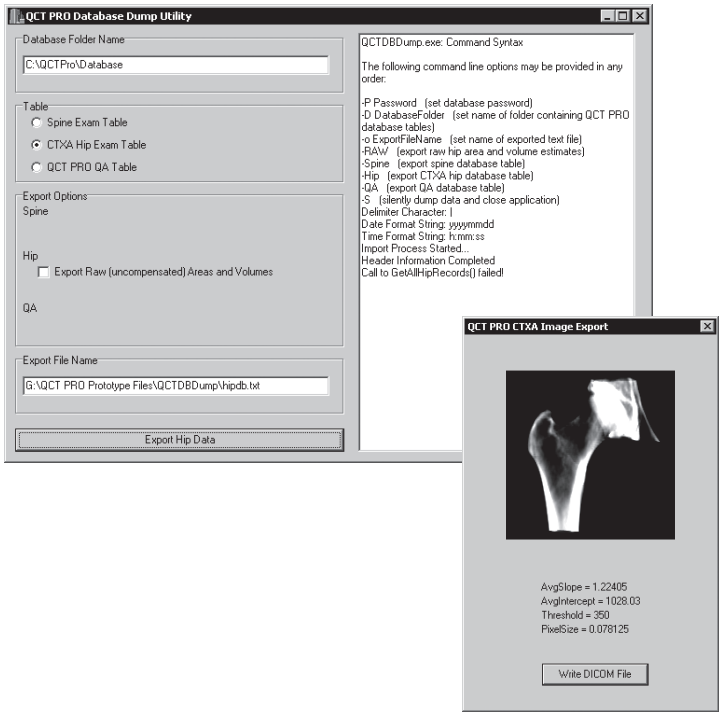



# Compatibility

## Import

QCT PRO is a standalone, Windows-based, application that can be used to analyze data from virtually any whole-body CT scanner. DICOM, pervasive high-speed networks, and inexpensive high-capacity storage media allow data analysis to be untethered from the CT scanner. BIT makes it simple to import CT files received via network, CD or other storage media into QCT PRO running on your laboratory PC.

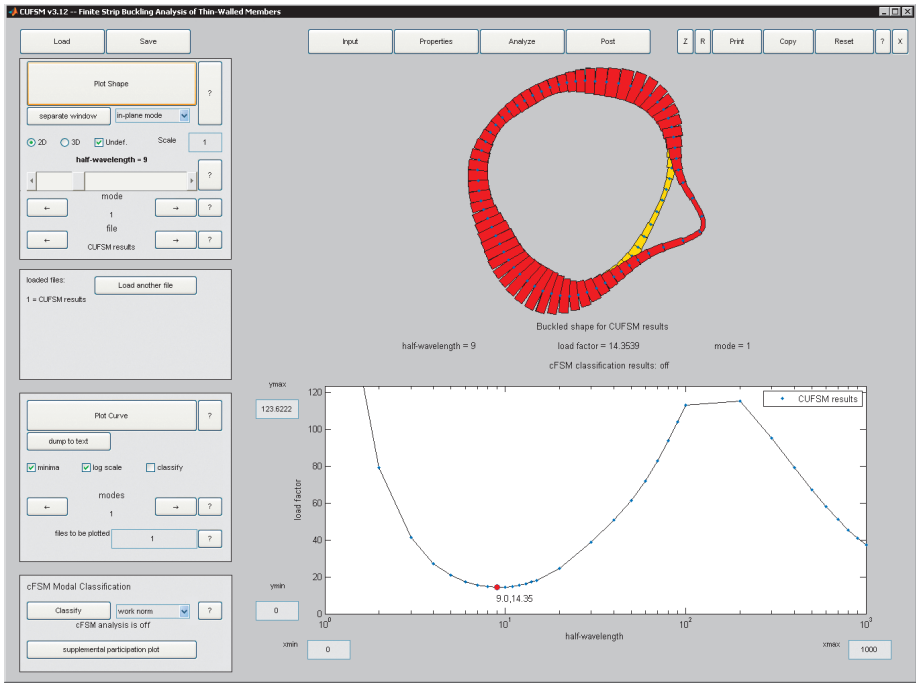



## Export

BIT analysis results are stored in the QCT PRO database. The contents of the QCT PRO database can be exported as delimited text files that can be imported into applications such as SPSS or Microsoft Excel or other applications for further data processing and statistical analysis. Additionally, 2D projection images, cross-sectional images and reformatted volumetric data sets can be exported in DICOM format for use in your own or third-party applications.

## Modeling of cortical shell failure with third-party engineering models.



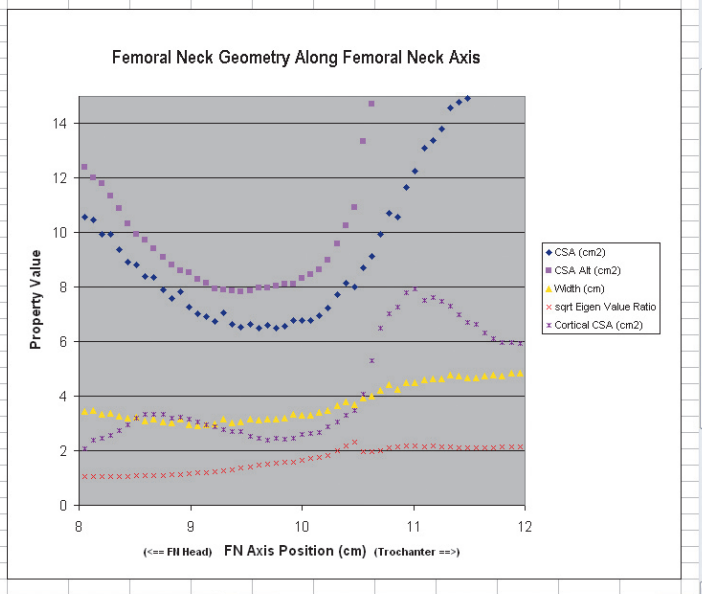

Schafer, B.W., Ádány, S. "Buckling analysis of cold-formed steel members using CUFSM: conventional and constrained finite strip methods." Eighteenth International Specialty Conference on Cold-Formed Steel Structures, Orlando, FL. October 2006.

Microsoft Excel - Book1

| | A |
|---|---|
| 1 | Cortical Cross-Sectional Analysis Data Export |
| 2 | Export Date:\|4/24/2007 2:42:15 PM |
| 3 | |
| 4 | Patient Information |
| 5 | Last Name\|LOCKHART |
| 6 | First Name\|EDITH |
| 7 | Sex\|F |
| 8 | DOB\|3/2/1952 |
| 9 | Age\|52 |
| 10 | MR Number\|HipAnalysisBasics |
| 11 | |
| 12 | Exam Information |
| 13 | Date\|8/5/2004 |
| 14 | Number\|288 |
| 15 | Scanner\|CT |
| 16 | Physician\|GE LightSpeed16 |
| 17 | Radiologist\|Trim x 4 |
| 18 | Technologist\| |
| 19 | |
| 20 | Original Image and CT Calibration Information |
| 21 | Slope\|1.2890 |
| 22 | Intercept\|1016.5 |
| 23 | FUC\|1.0170 |
| 24 | Pixel Size\|0.7422 |
| 25 | Threshold\|1460 |
| 26 | FN ROI Height\|0.945 |
| 27 | |
| 28 | Split Femoral Neck Results |
| 29 | Threshold\|1460 |
| 30 | Region\|Bone\|BMD (g/cm3)\|CSA (cm2)\|Mass (g)\|Volume (cm3) |
| 31 | Superior\|Cortical\|494.4\|1.028\|0.480\|0.971 |
| 32 | Superior\|Trabecular\|184.7\|2.423\|0.423\|2.289 |
| 33 | Superior\|Total\|276.9\|3.451\|0.903\|3.260 |
| 34 | Inferior\|Cortical\|683.6\|1.471\|0.950\|1.389 |
| 35 | Inferior\|Trabecular\|225.4\|1.378\|0.293\|1.302 |
| 36 | Inferior\|Total\|461.9\|2.848\|1.243\|2.691 |
| 37 | |
| 38 | Hip Axis Results |
| 39 | Hip Axis Length (mm)\|117.6 |
| 40 | Hip Axis (X1,Y1):\|35\|21 |
| 41 | Hip Axis (X2,Y2):\|147\|133 |
| 42 | |
| 43 | Cross-Sectional Summary Results |
| 44 | Threshold\|1460 |
| 45 | Pixel Size\|0.3711 |
| 46 | Bone-Center Coordinates |
| 47 | Center\|X (pixels)\|Y (pixels) |
| 48 | Geometric Center\|110.6\|94.1 |
| 49 | Mass Center\|106.8\|101.2 |
| 50 | Cortical Area (cm)\|2.68 |
| 51 | Average Cortical BMD (mg/cm3)\|603.1 |
| 52 | Cortical Perimeter (cm)\|9.67 |
| 53 | |
| 54 | Cross-Sectional Principle Axis Strength Calculation |

Microsoft Excel - fnsrch_example.xls

| | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|
| 10 | Position (c | z | Width (cm | CSA alt (c | sqrt(Eigen | VA/h2/6 (c | Cortical CSA (cm2) | |
| 11 | 8.048271 | 10.58125 | 3.447696 | 12.415 | 1.065445 | 6.080155 | 2.075 | |
| 12 | 8.126396 | 10.48347 | 3.479049 | 12.03 | 1.054765 | 6.078751 | 2.38 | |
| 13 | 8.204521 | 9.937253 | 3.331416 | 11.792 | 1.047832 | 5.51752 | 2.448 | |
| 14 | 8.282646 | 9.933461 | 3.389205 | 11.359 | 1.046608 | 5.611089 | 2.551 | |
| 15 | 8.36077 | 9.377826 | 3.263496 | 10.876 | 1.050133 | 5.10075 | 2.753 | |
| 16 | 8.438895 | 8.925209 | 3.184235 | 10.315 | 1.056863 | 4.736661 | 2.96 | |
| 17 | 8.51702 | 8.832264 | 3.215162 | 9.949 | 1.076252 | 4.73286 | 3.198 | |
| 18 | 8.595145 | 8.381649 | 3.082811 | 9.741 | 1.085844 | 4.306507 | 3.326 | |
| 19 | 8.673269 | 8.362064 | 3.15398 | 9.418 | 1.09694 | 4.39563 | 3.339 | |
| 20 | 8.751394 | 7.915846 | 3.051821 | 9.113 | 1.103806 | 4.026291 | 3.339 | |
| 21 | 8.829519 | 7.576293 | 3.007296 | 8.801 | 1.122646 | 3.797369 | 3.18 | |
| 22 | 8.907644 | 7.832446 | 3.159051 | 8.618 | 1.131878 | 4.123849 | 3.235 | |
| 23 | 8.985769 | 7.271991 | 2.957554 | 8.527 | 1.151997 | 3.584551 | 3.174 | |
| 24 | 9.063893 | 7.016401 | 2.930848 | 8.301 | 1.178089 | 3.427334 | 3.058 | |
| 25 | 9.142018 | 6.922395 | 2.957066 | 8.142 | 1.203565 | 3.411663 | 2.954 | |
| 26 | 9.220143 | 6.748404 | 2.976068 | 7.935 | 1.231042 | 3.347285 | 2.863 | |
| 27 | 9.298268 | 7.059533 | 3.176556 | 7.916 | 1.278978 | 3.737501 | 2.765 | |
| 28 | 9.376393 | 6.622479 | 3.006878 | 7.855 | 1.299138 | 3.318831 | 2.71 | |
| 29 | 9.454517 | 6.529516 | 3.043701 | 7.843 | 1.353894 | 3.312316 | 2.698 | |
| 30 | 9.532643 | 6.655149 | 3.1542 | 7.88 | 1.413013 | 3.498611 | 2.527 | |
| 31 | 9.610768 | 6.503696 | 3.12047 | 7.965 | 1.486278 | 3.382432 | 2.472 | |
| 32 | 9.688893 | 6.587656 | 3.166673 | 7.983 | 1.512428 | 3.476825 | 2.405 | |
| 33 | 9.767019 | 6.515451 | 3.159337 | 8.032 | 1.547908 | 3.430751 | 2.448 | |
| 34 | 9.845144 | 6.577456 | 3.210362 | 8.105 | 1.579029 | 3.519336 | 2.429 | |
| 35 | 9.923269 | 6.78892 | 3.325027 | 8.124 | 1.593417 | 3.762224 | 2.466 | |
| 36 | 10.00139 | 6.772612 | 3.314058 | 8.337 | 1.651913 | 3.740805 | 2.6 | |
| 37 | 10.07952 | 6.784368 | 3.285379 | 8.478 | 1.711566 | 3.714869 | 2.631 | |
| 38 | 10.15765 | 6.959592 | 3.390023 | 8.655 | 1.765627 | 3.932197 | 2.686 | |
| 39 | 10.23577 | 7.227424 | 3.478869 | 8.978 | 1.82068 | 4.190531 | 2.863 | |
| 40 | 10.3139 | 7.715034 | 3.638779 | 9.601 | 2.011029 | 4.678884 | 3.07 | |
| 41 | 10.39202 | 8.148848 | 3.808494 | 10.248 | 2.168443 | 5.172473 | 3.302 | |
| 42 | 10.47015 | 8.000301 | 3.672525 | 10.938 | 2.310593 | 4.896884 | 3.485 | |
| 43 | 10.54827 | 8.696395 | 3.934762 | 13.336 | 1.951119 | 5.703041 | 4.089 | |
| 44 | 10.6264 | 9.128157 | 4.005804 | 14.728 | 1.979416 | 6.094267 | 5.298 | |
| 45 | 10.70452 | 9.930453 | 4.209994 | 15.71 | 2.010253 | 6.967858 | 6.506 | |
| 46 | 10.78265 | 10.72076 | 4.43597 | 17.029 | 2.106194 | 7.926163 | 7.025 | |
| 47 | 10.86077 | 10.56506 | 4.254368 | 17.767 | 2.135367 | 7.491277 | 7.257 | |

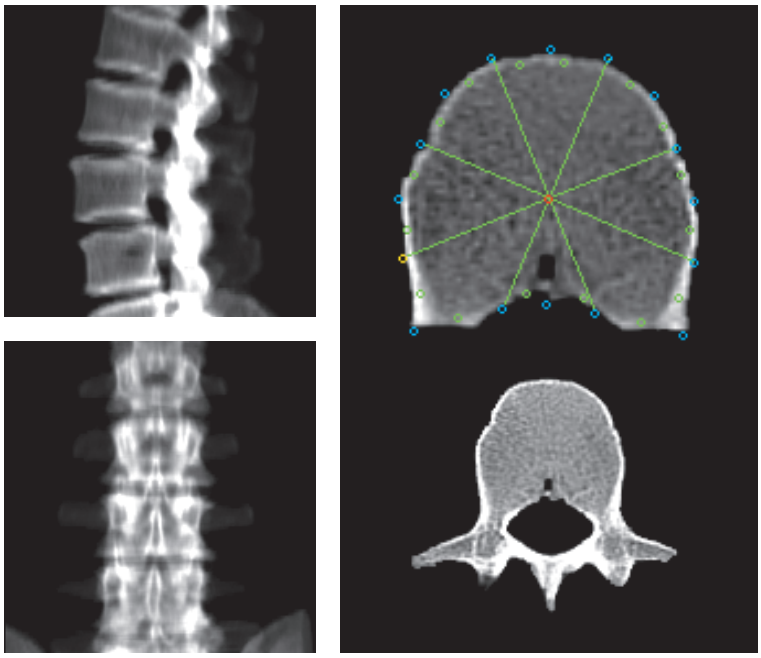



fnsrch_output_example | example_graphs | example_cross-section_analysis

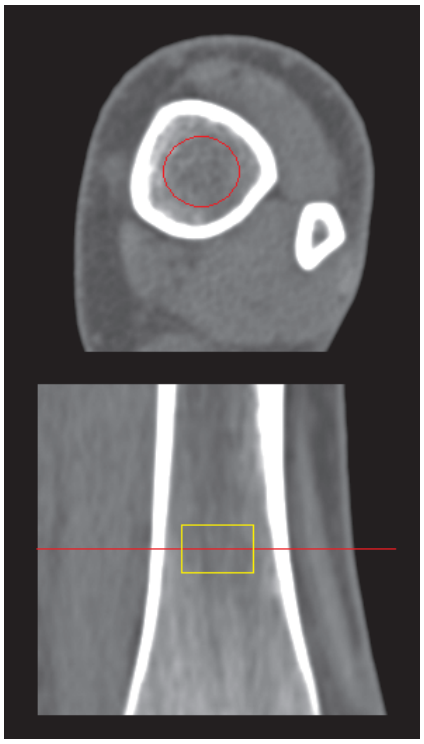
Ready

# Extensibility

While the QCT PRO Bone Investigational Toolkit was designed around analyses of the proximal femur, and it includes tools specific to this region, many tools available in BIT can be applied to cross-sectional images from other anatomical regions. Works in progress include developing additional tools within the BIT framework customized for other anatomical regions such as the spine and long bones such as the tibia.



**Projection, volumetric and geometric analysis of the spine.**



**Bone density and bone geometry assessment at peripheral sites.**


**Mindways Software, Inc.**
3001 South Lamar Blvd, Ste 302
Austin, TX 78704-4799 USA

Tel: +1 512 912 0871
Fax: +1 512 912 0872

Email: info@qct.com

www.qct.com


**The QCT PRO Bone Investigational Toolkit includes:**

- DICOM File Import Tools
- Supplementary Femoral Neck Analysis and Image Export Tools
- Cross-Sectional Image Analysis Module
- QCT PRO Header Editor for anonymizing cases
- QCT PRO Image Editor
- QCT PRO Database Export Utility



Mindways



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