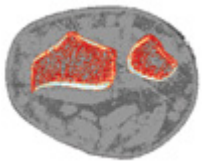
pQCT / xCT technology

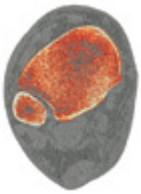
Peripheral Quantitative Computed Tomography - pQCT

pQCT - the third dimension in bone densitometry.

With conventional area-projected bone densitometry techniques (DXA) bone strength cannot be determined adequately because they are lacking information about bone geometry.



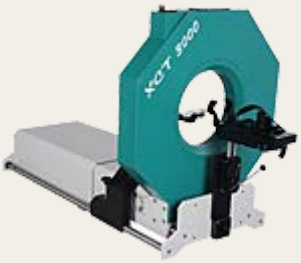
With the pQCT technology bone strength with respect to bending, torsion, and compression can be calculated from bone's cross sectional geometry. In addition the results are given as physically correct density units in g/cm³, whereas area projected techniques give only g/cm². Therefore the density values from the pQCT are independent from bone size. This is especially important for measurements on children. With the pQCT technology cortical and trabecular bone can be analysed separately and bone changes can be diagnosed reliably.



Additional morphometric parameter like endosteal and periosteal perimeter and bone cross sectional area are accessible in vivo. pQCT measurements at tibia or radius are performed in a wide range in clinical routine. In paediatrics the advantages of pQCT are especially distinct. It is the only method that allows to differentiate bone growth from other processes. In preclinical research specialised ultra high resolution scanner rare used in many pharmacological studies.

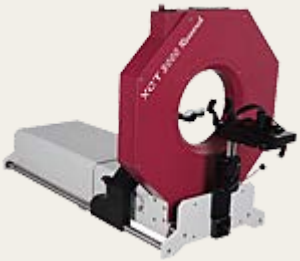
Product examples

Stratec xCT 2000L



Stratec xCT 3000

Stratec xCT

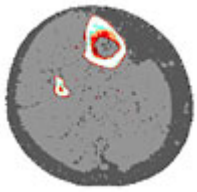


Research SA+
Research 3000

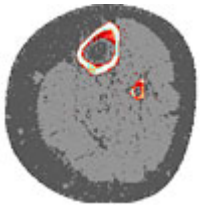
Stratec xCT

Relation between muscular demands and the resulting bone

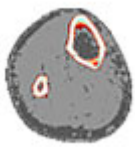
But pQCT is even one step further than traditional methods: In addition to bone parameters it also quantifies muscle properties. This allows to quantify the relation between muscle and bone which is essential for the step from Osteoporosis diagnostics to diagnostics of Sarcopenia, Dynapenia and Frailty.



Essential for bone geometry and bone mass is the muscular demand on the bone. Julius Wolf postulated “bone geometry follows function” and Harold Frost specified the more detailed “Mechanostat” theorem. Therefore bone diagnostics must always be accompanied by a sufficient analysis of muscular properties and abilities. pQCT measurements (e.g. at 66% distal tibia) utilize this concept: it allows to quantify the relation between muscular demands and the resulting bone geometry and bone mass on the individual and site-specific level.



This combined analysis is essential to differentiate for example between a primary Osteoporosis and the effects of diuse or lack of mobility. According to Frosts Mechanostat both will result in loss of muscle mass. The difference can therefore not be found in the bone but in its combination with muscle properties and function. Therefore it is essential to quantify the site-specific relation between muscle and bone. In this context the cross-sectional area of the muscle can be used as a surrogate for peak muscular forces, one of the key osteo-anabol parameters. The examples on the right show on the top a healthy muscle-bone relation, in the middle a primary osteoporosis and on the bottom the long-term effects of a spinal cord injury (SCI).



In addition, newest research results show that especially for Sarcopenia, Dynapenia and Frailty the parameter of muscle density (specific property of muscle tissue) in addition to the muscle geometry is essential. The reason for this is currently considered to be mainly the inter- and intra-muscular fatty infiltration. pQCT allowing the combination of geometry and density measurement at an extremely low cost of radiation is therefore the diagnostic method of choice. To add even more details the pQCT based quantification of muscle and bone can be extended by the quantification of muscle function and performance based on the Leonardo Mechanography systems.

Further information

- **Product overview**
- **pQCT Concept**
- **Advantages compared to other systems (DXA)**
- **Aktuelle Current fields of research**

Corresponding topics

Muscle function and muscle performance diagnostics using **Leonardo Mechanograph®**.

pQCT – Concept

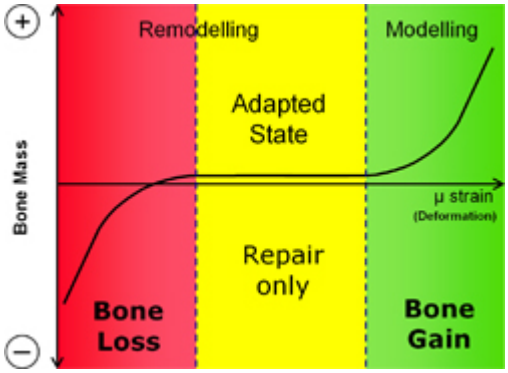
Muscle and bone form a functional unit. Muscle forces essentially regulate bone strength. Moreover, the muscle function is a crucial factor to prevent falls and fractures. Therefore, a diagnosis of osteoporosis is inadequate, if the muscle is not taken into consideration. An improvement in muscle function not only results in an increase in bone strength, but also prevents falls, thus reducing the risk of fracture.

Function of bone

The most important function of bone is to transmit force and hence enable locomotion. The highest forces acting on bone are caused directly by muscle contractions and are transmitted by tendons to the bone. Due to lever arms the muscle are acting one these forces can easily exceed the 10 fold of the body weight.

To fulfil these mechanical requirements bone must be able to adapt to changes in magnitude and direction of those forces in able to make sure that voluntary contraction cannot cause pain or even fractures. In addition bone has to be able to adapt to changes in metabolism an other external parameters.

Mechanostat



Bone strength (not bone mass) is a regulated quantity. In the sixties Harold Frost described a feedback control loop called mechanostat that explains the adaptation of bone to mechanical forces.

An essential characteristics of control loops is negative feedback. Muscle forces result in a deformation (strain) of bone. Osteocytes, the most abundant bone cells are able to detect this deformation.

If the bone strain exceeds a certain threshold osteoblasts add bone to make it stronger and the strain returns to values below the threshold. If a second, lower threshold is not exceeded regularly, osteoclasts remove bone so that the lower threshold is exceeded again. This mechanism optimises bone strength with a minimum of bone mass.

Diagnosis

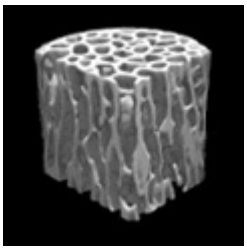
Fracture risk depends on bone strength and on the forces that act on it. The main goal of bone densitometry using pQCT is to determine bone strength. Bone strength is defined by the material properties and geometry. With the exception of some diseases bone's material properties are allmost constant and bone strength hence mainly depends on bone geometry. Changes in bone metabolism is detected at first in trabecular bone.

pQCT – Advantages over other techniques

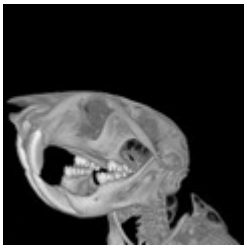
Employing pQCT it is possible to analyse cortical and trabecular bone separately. Because of the larger surface trabecular bone reacts faster to changes in bone metabolism than cortical bone. Bone loss or the success of a therapy can be diagnosed earlier and more significantly with pQCT than with methods that can not differentiate between cortical and trabecular bone.

Advantages compared to DXA and QCT

In contrast to DXA pQCT measures actual **density values in g/cm³** and not the area-projected mass in g/cm². When projecting bone mass to and area the information about the size of bone is lost. It is then no longer possible to separate between density and size. Therefore shorter subjects are often erroneously diagnosed as osteopenic or osteoporotic because of their smaller bone mass. Especially in children and adolescents it is not possible to differentiate between growth and an actual increase in bone density with projectional methods . As a consequence many children with chronic diseases that show growth retardation have been treated against osteoporosis. In contrast pQCT can determine size and density independently. Bone density is independent of bone size.



With pQCT not only density but also **bone geometry** can be measured. Bone strength depends on the spatial distribution of bone material. From the cross sectional geometry the pQCT software calculates the moment of inertia and section modulus allowing to predict the fracture load with high accuracy. With the analysis of cortical bone in the diaphysis osteoporosis can be distinguished from and osteomalacia. Cortical density in patients with osteoporosis is normal (1100–1200 mg/cm³) while in patients with Osteomalacia it is reduced (<1000 mg/cm³).



Most DXA scans are done at the spine. With increasing age the number and severity of degenerative changes at the spine increases resulting in falsely high values. As a consequence an increase of degenerative changes can be misinterpreted as a success of a therapy. Therefore it is suggested not to measure the spine if degenerative changes are visible in the x-ray.

Measurements with DXA or QCT are influenced by changes in the fat content of the marrow. While at peripheral sites from the third decade on mostly fatty marrow is found, the composition of the marrow can change considerably at the spine and the proximal femur. In addition the DXA results can be influenced by the composition of the soft tissue surrounding the bone. In follow up measurements a change in the fat content can change the bone results by up to 11%.

The pQCT measurement allows the comparison of muscle and bone parameter. Bone strength is adapted to the maximum muscle force. With pQCT the muscle cross sectional area can be determined. With a comparison of muscle and bone cross sectional area it can be recognized if bone is adapted to muscle and an osteopenia caused by a sarcopenia can be differentiated from a primary osteoporosis. In the former case the reduced bone strength is a result of a physiological adaptation process to the reduced

muscle force. In this case bone is healthy and the muscle should be treated. In the latter case bone is not adapted to muscle and the bone must be treated.

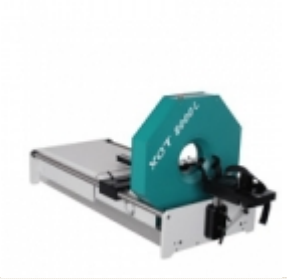
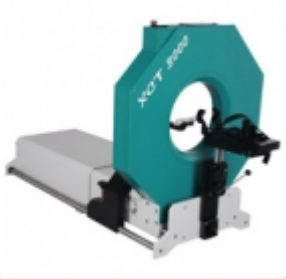
Advantages of pQCT over axial QCT

Axial QCT shares many advantages with pQCT as the measurement of true density units in g/cm³ and the separate analysis of cortical and trabecular bone. But there are also some disadvantages:

1. The radiation dose is considerably higher. (Effective Dose: 50 µSv for QCT, 1 µSv for pQCT)
2. Precision is better for pQCT (1% in vivo , 2% for QCT)
3. Osteophytes can also influence the results of axial QCT
4. Higher costs

pQCT Bone Density & Bone Geometry – Product Comparison

Product Comparison for pQCT Bone Density & Bone Geometry

	Product 1	**Product 2**	**Product 3**
	XCT 2000L	XCT 3000	XCT 3000 Research
			
Type numbers			
Categorisation	Human	Human	Animal
Dimensions (l/w/h)	1280 x 550 x 620 mm	1280 x 740 x 910 mm	1280 x 740 x 910 mm
Weight	45 kg	90 kg	90 kg
Numbers of detectors	12	12	12
CT Collimator	0.4x4	0.7x4	0.7x4
SV Collimator			
Angle between detectors	1°	1°	1°
Number of projections per block	180	180	180
Number of blocks	1	1	1
Spot size	50 µ	50 µ	50 µ
Filter	355 µ Cu	355 µ Cu	105 µ Cu
Source collimation	0.4 x 0.7	0.4x0.7	0.5
Slice thickness	2.0 mm	2.0 mm	0.5–2 mm
Measurement diameter	140 mm	270 mm	270 mm
Voxel size	0.2–1.0 mm	0.2–1.0 mm	0.2–1.0 mm

HV	56–60 kV	59–61 kV	58–62 kV
Nom. HV	58 kV	60 kV	60 kV
Anode current	< 550 µA	< 400 µA	< 550 µA
Nom. current	130 µA	200 µA	130 µA
Gantry opening	140 mm	300 mm	300 mm
Max. way of travel	400 mm	400 mm	400 mm
Scan time	90 s	90 s	90 s
Radiation dose CT	< 0.001 mSV	< 0.001 mSV	
Radiation dose CV	< 0.001 mSV	< 0.001 mSV	