

European Forearm Phantom

QRM-EFP

The standard for quality control in peripheral bone mineral densitometry by DXA and QCT.

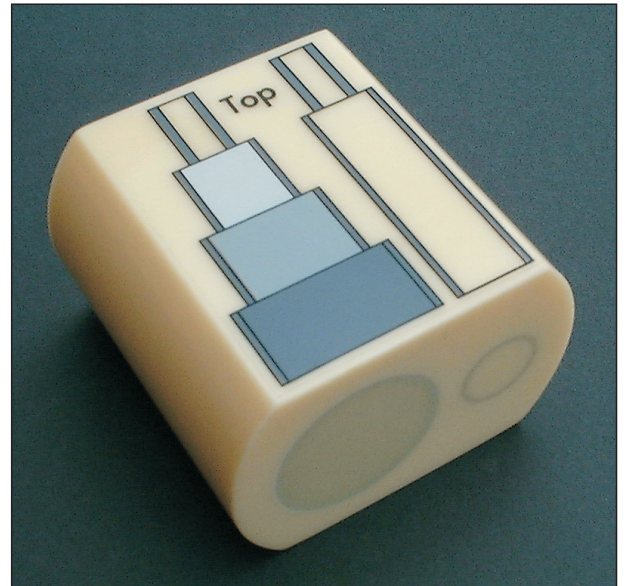
QRM-EFP, a phantom consisting of water- and bone-equivalent solid materials was devised to test peripheral bone densitometry systems. A prime design consideration of the forearm phantom was to use the same material as is used for the European Spine Phantom *QRM-ESP*. This not only allows for the comparison of trabecular bone examinations at different locations and different machines, but also to compare axial with peripheral bone measurements.

A circular cross section with a diameter of 60 mm was chosen, with the sides flattened by 10 mm to model the forearm. The inserts simulate trabecular bone and provide the basis for linearity checks of QCT systems. Density and thickness of the simulated compact bone is selected such that the phantom can be used to calibrate DXA and SPA (single photon absorptiometry) machines as well. The phantom should allow one to test reproducibility and accuracy of machines, both in clinical installations and at manufacturers' sites.

The following quantities are to be determined:

- (i) bone area in cm^2 ,
- (ii) thickness of cortical bone in mm,
- (iii) trabecular and cortical mineral density in g/cm^3 ,
- (iv) bone mineral content (BMC) in g/cm,
- (v) bone mineral area density (BMD) in g/cm^2 .

The three inserts of the phantom simulating large, medium and small bone have diameters of 28 mm, 21 mm and 14 mm, respectively. The calcium hydroxyapatite (HA) density of the simulated



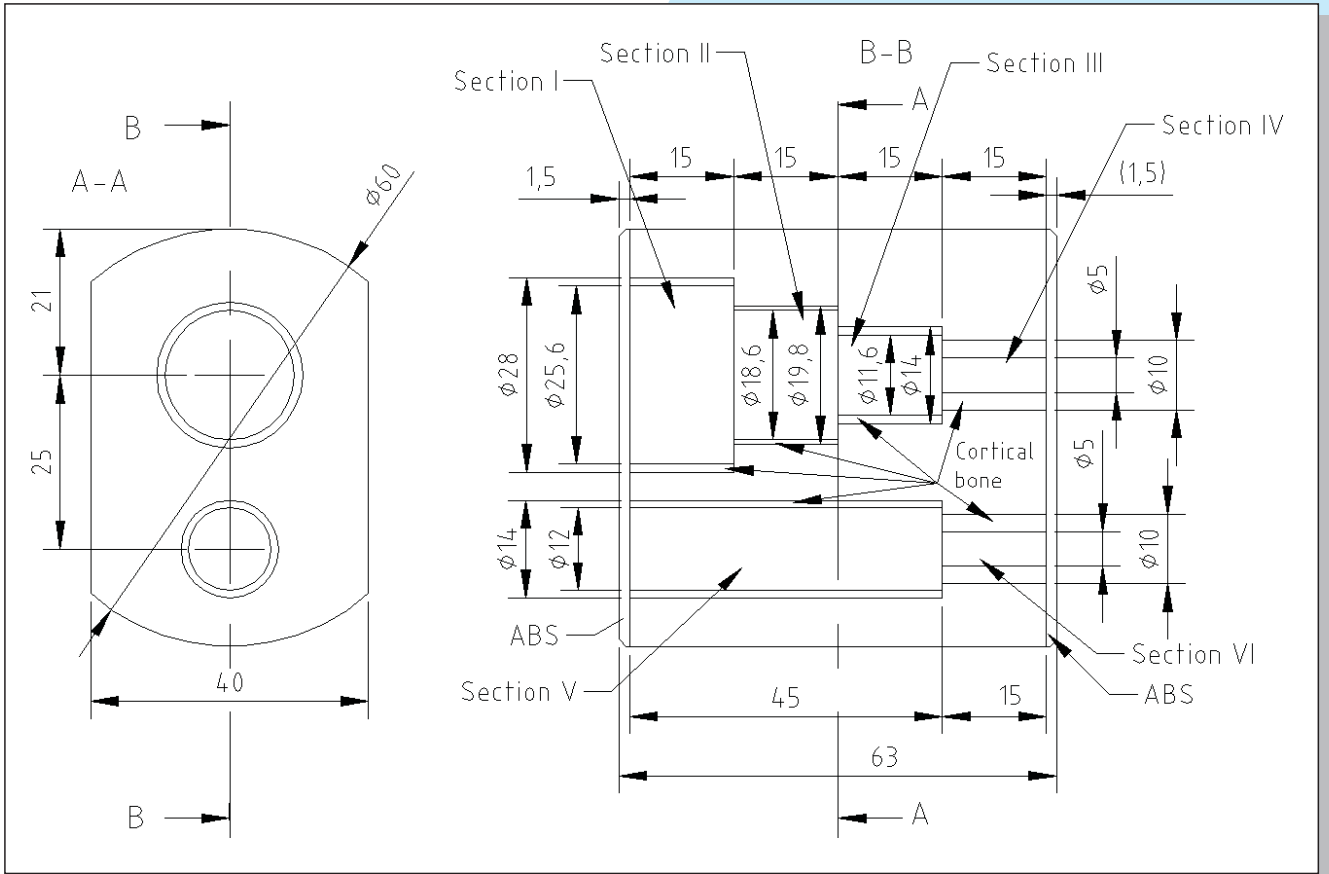
trabecular bone was selected according to the densities used in the European Spine Phantom *QRM-ESP*, namely 200, 100 and 50 $\text{mg HA}/\text{cm}^3$. 1.2 mm was selected as the thickness of the cortical bone, its HA density was chosen as 800 $\text{mg HA}/\text{cm}^3$.

In addition to the three inserts a fourth insert was added to also enable validations of SPA systems.

Quality control with CT guarantees a homogeneously distributed trabecular bone density with an average that deviates less than 1 mg/cm^3 from linearity.

The manufacturing tolerances were set to ± 0.1 mm for the geometric measures and at $\pm 0.5\%$ (at best 0.5 mg) for the calcium hydroxyapatite concentrations. Routine quality control of phantom production is carried out by CT.

European Forearm Phantom



Area measured with CT			
	Nominal area (cm ²)	Mean (cm ²)	Range (cm ²)
Section I	6.158 ±0.044	6.091	6.066-6.119
Section II	3.464 ±0.033	3.425	3.400-3.447
Section III	1.539 ±0.022	1.515	1.501-1.534
Density measured with CT			
	Nominal density (cm ⁻¹)	Mean (cm ⁻¹)	Range (cm ⁻¹)
Section I	0.4153 ±0.0008	0.4154	0.4148-0.4160
Section II	0.3393 ±0.0004	0.3391	0.3382-0.3400
Section III	0.3013 ±0.0004	0.3015	0.3006-0.3022

Specifications

- Base material water-equivalent resin
- Phantom cross section 60 mm x 40 mm
- Phantom length 100 mm
- Phantom weight 140 g
- Cortical bone 800 mg HA/cm³
- Section I 200 mg HA/cm³
- Section II 100 mg HA/cm³
- Section III 50 mg HA/cm³
- Section IV to VI water-equivalent resin

References: [1] Rügsegger, P., Kalender, W.A.: A phantom for standardization and quality control in peripheral bone measurements by PQCT and DXA. Phys. Med. Biol. (1993) 1963-1970