Choice of Cross-Calibration Phantom for DXA of the Lumbar Spine and Total Hip.

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Introduction.

DXA technology has been in existence since 1987 and some of the original equipment is still in operation today. Since patients undergoing BMD examinations tend to be followed for many years, it has always been recommended that they are measured on the same machine. This is to avoid the inherent errors associated with calibration and scan mode differences between various models of DXA scanner. However, as the first generation of machines are currently being discontinued and tend to be no longer supported by the manufacturer, the prospect of a patient switching to a different machine and even a different manufacturer is becoming more frequent. Consequently, the need to cross-calibrate old and new DXA machines in now a common problem.

The ideal way to perform a cross-calibration is to scan a large number of subjects, with a range of BMD values, on both machines, and then calculate a regression equation. However, this approach may not always be appropriate for a variety of reasons, including cost, logistics and ethics. The use of static test objects (Phantoms) is another way to perform cross-calibration, but there are several issues to consider to determine the most appropriate phantom to use, which include cost, ease of use, coverage of clinical BMD range and relationship to human data.

Phantoms:

Several Phantoms are currently available for use in Bone Densitometry, and these are described below.

Bio-Imaging Bone Fide Spine Phantom (BFP)

(Bio-Imaging Technologies Inc. Newtown PA, USA)
The BFP is a calcium hydroxyapatite step wedge embedded in a tissue equivalent, physiologically normal acrylic (approximately 26% fat). The four vertebra (L1-L4) have densities ranging from 0.7 to 1.5 g/cm^2, which represents a clinically relevant scale.

The European Spine Phantom (ESP)

(QRM, Dorfstrasse 4, D-91096 Möhrendorf, Germany)
The ESP was developed as a universal standard for cross calibrating DXA and CT systems.
It consists of three pseudo-anthropomorphic vertebrae (L1-L3), made of bone equivalent plastic and calcium hydroxyapatite with BMD values of 0.5, 1.0, and 1.5 g/cm^2 respectively. The vertebrae are embedded in tissue equivalent plastic, which is shaped as an oval body section.

The GE Lunar Aluminum Spine Phantom (ASP)

(GE Lunar, Madison WI, USA)
Consists of a rectangular aluminum step wedge, measuring 16 cm x 4 cm x 1 cm and represents vertebral bodies L1-L4. The phantom is scanned in a 15 cm deep water bath to simulate soft tissue. The BMD of individual vertebra are 0.92, 1.076, 1.239 and 1.403 g/cm^2 for L1-L4 respectively.

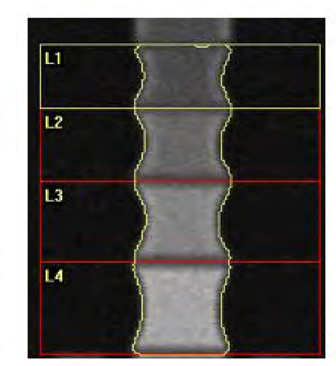
Hologic Anthropomorphic Spine Phantom.

(Hologic Inc, Waltham MA, USA)
This phantom is probably the most widespread of all test objects and consists of four molded vertebrae made from hydroxyapatite and embedded in epoxy resin. Use of this phantom is integral to the quality control and calibration procedures of Hologic DXA scanners. However, since this phantom does not exhibit a linear range of BMD values covering the typical clinical values, it is not suitable for cross calibration purposes, and is not included in this evaluation.

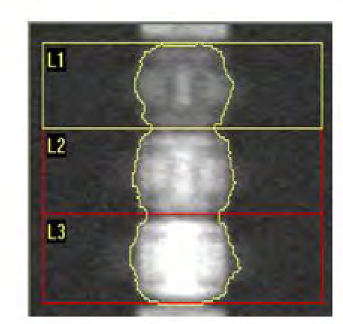
Methods.

This work compares human data to that of three phantoms which provide a suitable range of BMD values. The human data for spine (L1-L4) and Total hip were acquired on Hologic QDR 1000 and GE Lunar Prodigy scanners. The fifty subjects aged between 22 and 72 years, with BMD values covering the clinical range from normal to osteoporotic. The phantoms compared were the European Spine Phantom (ESP), the Lunar Aluminum step wedge (ASP) and the Bona Fide Spine Phantom (BFP). All phantoms were measured ten times on each machine and the means of individual vertebral sections used to calculate a simple linear regression relationship. A more rigorous regression analysis which compensates for the lack of truly independent data produces relationships which are slightly, but not significantly different at the 5% level. Consequently, the simpler analysis is presented here.

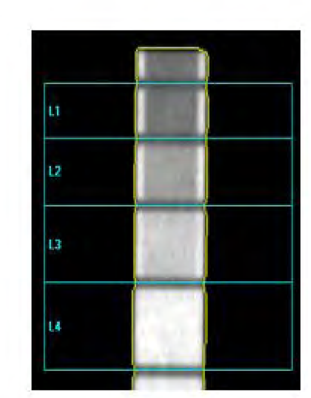
Bio-Imaging Bone Fide Spine Phantom (BFP)



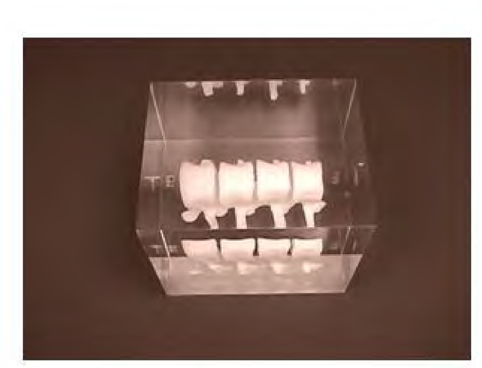
The European Spine Phantom (ESP)

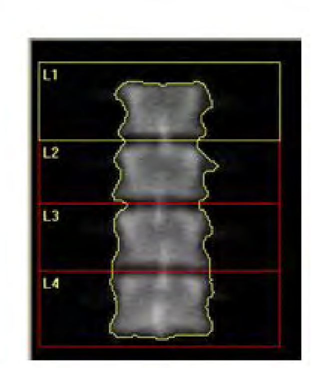


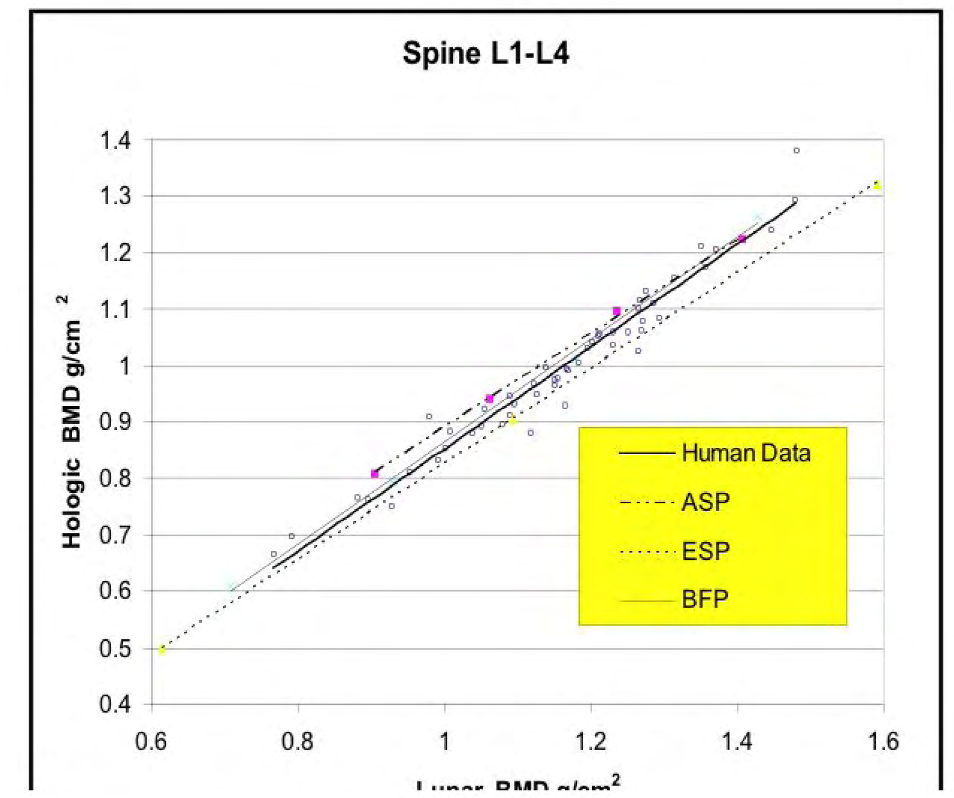
The GE Lunar Aluminum Spine Phantom (ASP)

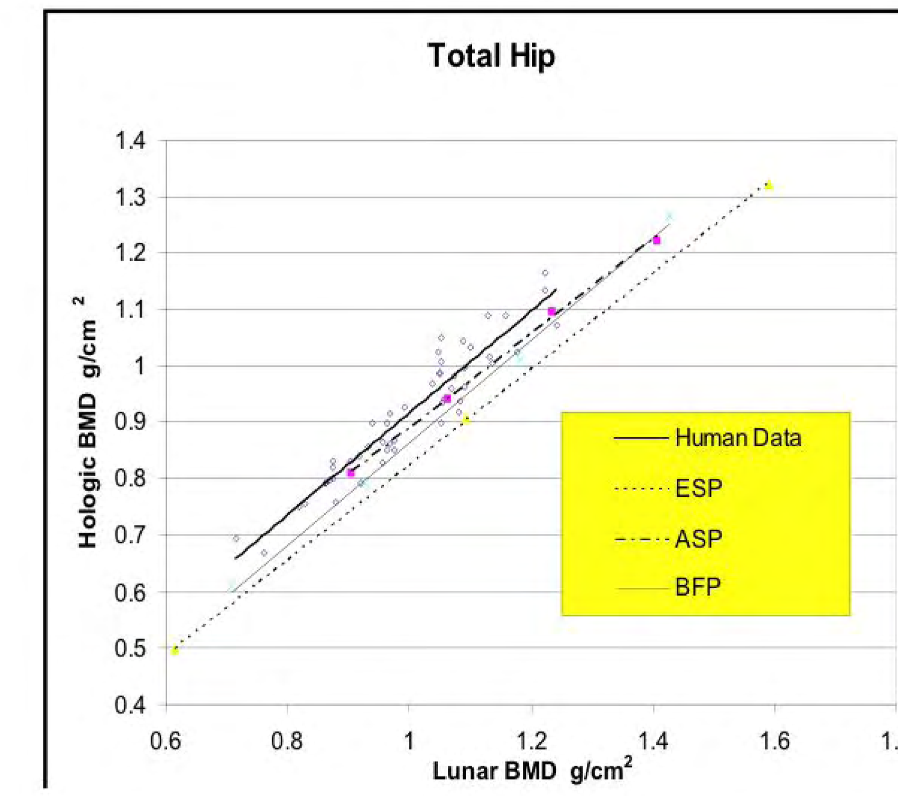


Hologic Anthropomorphic Spine Phantom.









Results.

Linear Regression Relationships.

Hologic BMD (Human Spine) = 0.91 x Lunar BMD - 0.06
Hologic BMD (Human Total Hip) = 0.90 x Lunar BMD + 0.01
Hologic BMD (BFP) = 0.91 x Lunar BMD - 0.04
Hologic BMD (ESP) = 0.84 x Lunar BMD - 0.02
Hologic BMD (ASP) = 0.83 x Lunar BMD + 0.06

To be useful for cross-calibration, the ideal phantom will have the same regression equation as the human data.

For the spine, both the ESP and the ASP regressions exhibit different slopes to the human data which translates to errors of between -4.4 and 19.4% over the 0.5 to 1.5 g/cm^2 BMD range (Lunar).

The BFP data has a virtually identical slope to the human data with a minimal offset of approximately 0.02 g/cm2. which is well within the measurement error, typical of DXA instruments.

For the total hip a similar relationship occurs with the BFP and human data regressions exhibiting the same slope with a constant offset of 0.05 g/cm^2.

Conclusions.

Of the three commercially available phantoms studied, the BFP exhibits the closest regression to human data, particularly for the ***spine*** where the relationship is almost identical, and well within measurement errors. Therefore, the BFP can reliably be used for both cross-calibration purposes and longitudinal quality assurance, where observed changes in phantom BMD will accurately reflect any changes to human data caused by calibration shifts, over a wide range of densities.

For measurements of ***total hip*** BMD, the BFP phantom also provides the most utility. A one to one correspondence is not to be expected since the spine and hip are structurally dissimilar. However, a similar slope in the BMD relationship with a constant offset should be expected, and this is exactly what is observed with the BFP phantom. Since the slopes between human and BFP phantom data are basically identical, absolute shifts in phantom BMD can reliably reflect any changes to human data caused by calibration shifts. In addition, by adjusting for the small constant offset of 0.05 g/cm2 in the total hip, the BFP phantom can be used for cross calibrations in clinical trials and DXA machine changes.

The magnitude of the constant offset with total hip data will likely vary with make and model of machine and scan mode used. Although this variability will probably be small, it should be determined for each combination of parameters.

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