IBEX

WHITE PAPER:

BMD MEASUREMENT USING AN IBEX EQUIPPED DETECTOR

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Abstract

IBEX technology generates additional beam energy information in digital radiography (DR) systems. This allows DEXA style measurements of patient bone and tissue composition to be carried out on any IBEX equipped DR system. In this paper we demonstrate the ability of the IBEX equipped system to return BMD information alongside a standard radiograph image. Measurement of quantitative phantoms demonstrate good correlation between BMD values obtained from IBEX and DEXA systems. Results of a cadaver study demonstrate how the IBEX technology can be applied to real-world diagnostic scans to generate valuable additional BMD information with minimal effect on the diagnostic image.

Introduction

Dual Energy X-ray Absorptiometry (DEXA) measurements are the de-facto standard for bone health and body composition measurements in the UK and around the world. NICE guidelines suggest a clinical pathway for referral of patients considered at risk of osteoporosis for DEXA scans, however this is usually only done after the patient has presented with a fracture. Measurement of BMD on DR scans has several advantages that will to help improve procedures and outcomes:

1) ***Removal of the need for referral to a DEXA scan***

IBEX-equipped DR scans include accurate BMD information for the body part being imaged and a DEXA scan is therefore no longer needed. This increases the value of the original DR scan, and leads to a more efficient utilisation of staff and resources.

2) ***Analysis of bone health in the wider population***

With IBEX, any DR scan can give a routine measurement of BMD providing population-wide data on bone health, including those groups not currently considered "at risk". This can lead to a better understanding of the causes and prevention of bone health issues, and opportunities for significant reductions in fragility-related fractures and the cost of their treatment.

An IBEX-equipped system

Figure 1 shows a schematic of a conventional X ray imaging detector, with the IBEX MAP included.

The MAP replaces the cover plate of the detector and once added the IBEX equipped detector is indistinguishable from a standard model both in terms of overall thickness and weight.

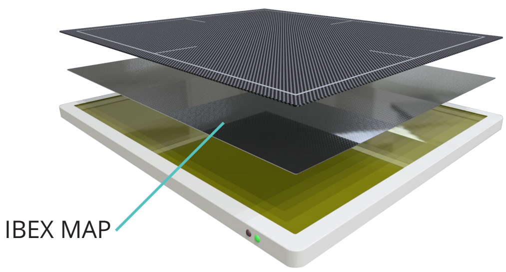

Figure 1: Standard DR configuration, with the addition of the IBEX MAP.

Experimental Methodology

A set of phantoms were constructed from layers of tissue and bone equivalent materials to build structures with varying BMD. These phantoms gave a range of tissue thicknesses up to 15cm with a bone insert of up to 10cm thick.

The phantoms were then measured on two systems; a standard DEXA system

(Hologic Discovery) and an IBEX equipped DR system.

The Hologic DEXA system was operated by a specialist at Freeman Hospital, in Newcastle upon Tyne, UK. Lumbar spine analysis mode was used to select a bone region and BMD reading were recorded for the analysis region.

An IBEX equipped DR system was built from a GE VMX Plus mobile x-ray source and Rayence 1417 (CsI) detector. A carbon-fibre encapsulated MAP replaced the detector cover plate. Source to detector distance was set to 115cm and source settings were adjusted to an appropriate clinical range for body parts, as recorded in Table 1.

Table 1: Source settings for experiments.

Body part	kV	mAs
Bone / tissue calibration phantom	80	5
Ankle	60	3.2

A linear model fitted to the DEXA measurements of the phantom was treated as a ground truth for the purposes of calibration giving an estimated BMD value for any thickness of bone simulant material. The IBEX system was used to calculate known bone thickness which was then converted to BMD units using this calibration.

Results

The graph in Figure 2 shows a plot of measured BMD against known bone simulant thickness for our range of phantom bone and tissue thicknesses.

For a perfect system, this graph should show a linear relationship between bone thickness and measured BMD.

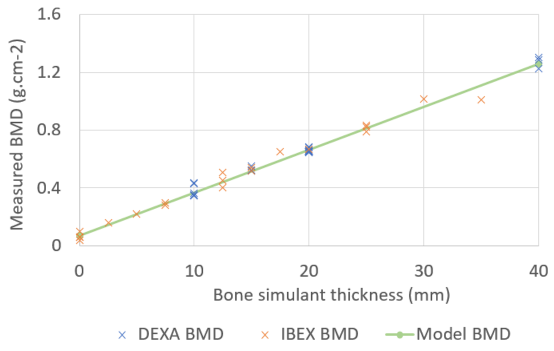

Figure 2: Graph comparing IBEX BMD measurements to a DEXA system for a range of phantom thicknesses and compositions.

From this graph we can conclude that the relationships between the DEXA measurement, IBEX measurement and known bone phantom thickness are very linear. The IBEX BMD and DEXA BMD measurements show a similar standard deviation of errors from a linear model fitted to the DEXA data as seen below in Table 2.

Table 2: Standard deviation of IBEX and DEXA BMD error, when compared to a linear model fitted to the DEXA data.

	IBEX BMD	DEXA BMD
Standard deviation of error	0.0376 g.cm^{-2}	0.0262g.cm^{-2}

By applying our calibration, we can now generate BMD values for human body parts providing that the training set covers the range of possible tissue and bone thicknesses.

In the following section, we show an example of BMD measures on a cadaveric donor taken with a clinically relevant experimental setup.

Figure 3 shows a standard X-ray of an ankle region demonstrating that the IBEX technology returns a clean diagnostic image at a standard clinical dose.

Figure 4 shows the additional IBEX materials information generated from the same clinical scan, in the form of a BMD "heat map" showing changes in BMD throughout the ankle. This heat map has been generated by combining information from the material measurements for each region of the detector with the high resolution diagnostic radiograph, allowing for a high quality interpretation of material information across the body part.

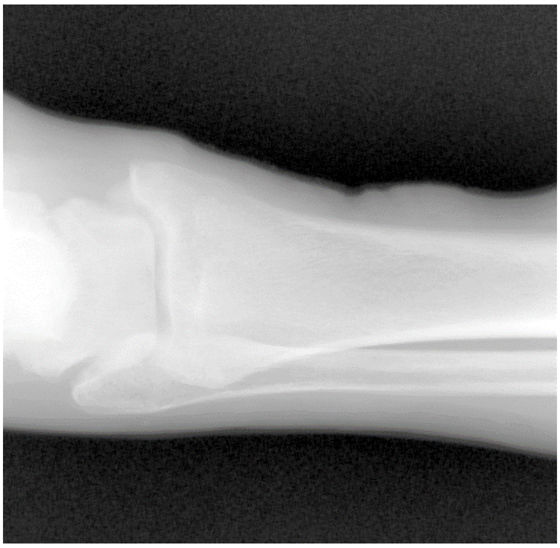

Figure 3: Diagnostic image generated by an IBEX-equipped detector.

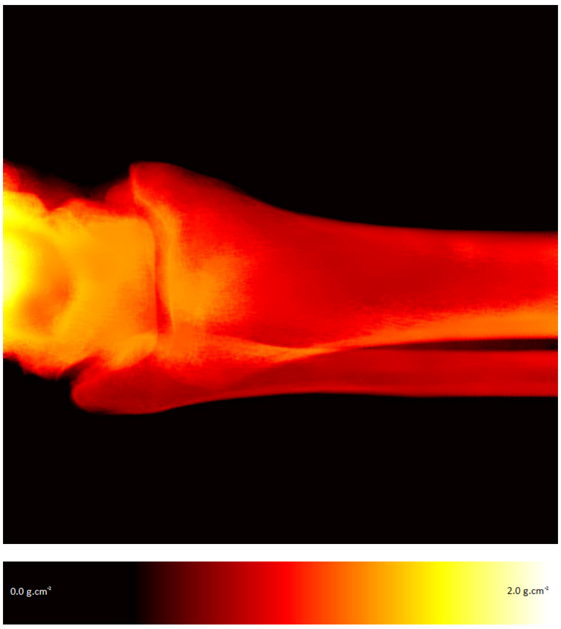

Figure 4: BMD heat map showing changes in bone density across the body part.

Looking at the heat map in Figure 4 tissue regions have clearly been suppressed into the background as would be expected since its mineral content is assumed to be low. Changes towards the cortical-bone regions at the edge of bones are also expected due to the higher density of cortical bone. Measured BMD values lie within the expected range, though in this cadaveric case a ground truth is unknown.

Summary

IBEX technology has been tested with quantitative phantoms to demonstrate the ability of our system to generate BMD data for a quantitative phantom. With simple calibrations, for this phantom, we are able to align our measurements to a DEXA system, giving a familiar measure of BMD. Applying this same calibration to a cadaver ankle, we are able to generate BMD values which lie within an expected range for this particular body part. With further development, we expect the IBEX technology to become a simple standard upgrade for OEMs and system integrators to add extra information and value to DR scans and systems.

Acknowledgments

This technology has been developed in collaboration Durham University with testing carried out in partnership with clinicians and medical physicists at the Freeman Hospital and Newcastle Surgical Training Centre.

Patents

IBEX technology is covered by UK patents GB2498615, GB2532634, GB2532897, GB2533233 and US patent US9519068. Patents in other territories pending.

About IBEX

IBEX Innovations Limited was created in 2010 to develop and commercialise an innovative X-ray detector technology.

IBEX is based in modern facilities on the NETPark Science Park in the North-East of England, where it employs a team of highly skilled scientists, engineers and business professionals.

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