A new accurate technology for the determination of bone mineral areal density - Dual X-ray and Laser (DXL)

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Introduction

The aim of the present study was to evaluate a new accurate device called Dual X-ray and Laser (DXL) for measurement of heel bone mineral areal density (BMD). The precision achieved in measuring BMD by conventional Dual-energy X-ray Absorptiometry (DXA) is very good, but the accuracy is generally considered to be insufficient. These errors arise because the DXA technology assumes a two-component model for the human body, i.e. bone mineral and soft tissue. Errors as large as 20-30% have been reported, due to the inhomogeneous distribution of adipose tissue (fat and yellow bone marrow) [1, 2]. This paper describes a new technology that uses a three-component model for human tissue and significantly reduces errors due to inhomogeneous distribution of adipose tissue.

We have examined the *in vitro* and *in vivo* precision and the accuracy of this new method for bone mineral determination.

Materials and methods

The reason that an inhomogeneous distribution of adipose tissue causes errors in conventional DXA technology is due to the basic assumption of a two-component tissue model consisting of only bone mineral and soft tissue. However, the X-ray absorption properties of adipose tissue are significantly different from those of both bone mineral and other tissue [3]. A more realistic model of tissue is a three-component model consisting of bone mineral, lean soft tissue and adipose tissue. It is well known that the volume of marrow adipose tissue increases with age and it is particularly large in patients with osteoporosis [4]. In order to be able to measure the bone mineral without influences of adipose tissue one has to use three different measured quantities. The Dual X-ray and Laser (DXL) technology has been developed with this in mind. This new technology uses two X-ray energies in combination with laser measurement of the object thickness in order to determine all three-tissue components with great accuracy. Since the total thickness of the object being measured is composed of the individual thickness of bone mineral, lean soft tissue and adipose tissue it is possible to combine the thickness measurement with the two X-ray measurements and get a unique solution of the three different components of the measurement site.

The method DXL Calscan measures the bone mineral areal density of the heel bone (Fig 1).

Materials and methods (continued)

Fig 1. The DXL Calscan instrument [5].

DXL Calscan is a portable device, weight 25 kg and has a fully automatic region of interest localization. The measurement time is less than a minute and effective dose to the patient is less than 0.2 µSv. The instrument makes use of an internal phantom that performs an automatic calibration of the instrument before each measurement.

The accuracy was determined from measurements of different combinations of hydroxyapatite (bone mineral), solid water (lean soft tissue) and polyethylene (adipose tissue). The measurements of the accuracy was done on two different levels of BMD, 0.2 and 0.6 g/cm², representing severe osteoporosis and young healthy individuals. For each combination the fat fraction of the total soft tissue composition was calculated and the accuracy in the bone mineral areal density determination expressed as standard error of estimate (SEE). The *in vitro* precision was assessed by 40 measurements of hydroxyapatite incorporated in a solid water based human-like phantom (Computerized Imaging reference Systems, Inc., USA). *In vivo* precision was assessed by duplicate measurements on 35 healthy volunteers (mean age 52 years, range 25 to 72 years).

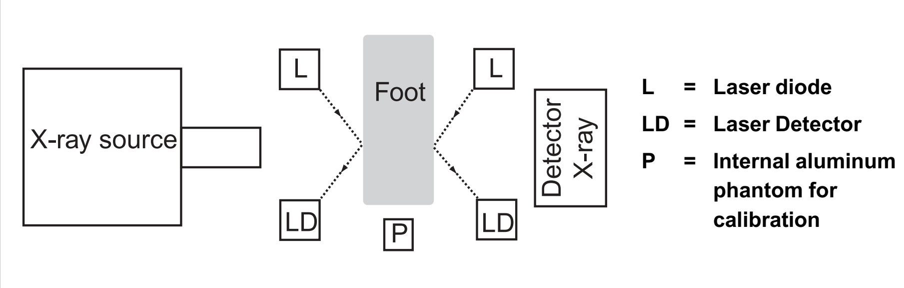

Fig 2. Schematic diagram of the DXL Calscan method.

Results

The accuracy in the measured bone mineral values was between 1.8 and 1.9%, expressed as standard error of estimate (SEE) for the different combinations of hydroxyapatie, lean soft tissue and adipose tissue (Fig 3). The *in vitro* precision, root-mean square (CV_{RMS}), was 0.52% and the *in vivo* precision (CV_{RMS}) 1.2%.

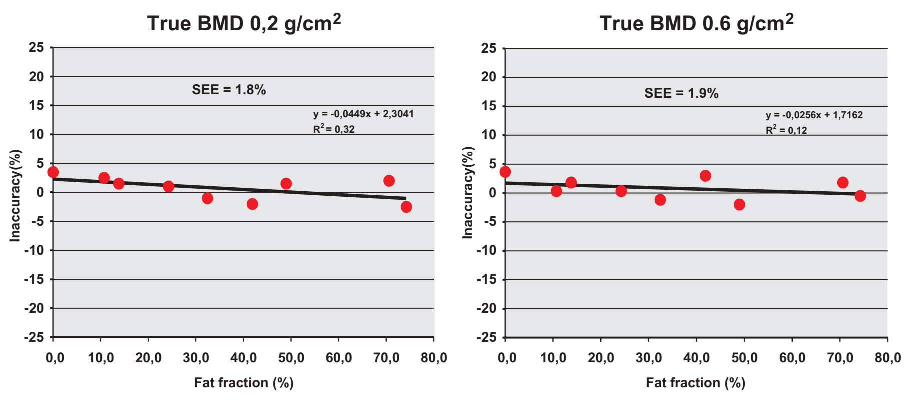

Fig 3. Accuracy in the BMD determination as a function of fractional (in percent) adipose tissue content.

Conclusion

The results shows that this new method DXL Calscan, based on the DXL technology, could determine the amount of bone mineral in the heel bone accurately and precisely without influence from adipose tissue (yellow bone marrow and fat) or lean soft tissue. Thus enabling a more reliable diagnosis of osteoporosis.

References

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