

Comparison of Bone Mineral Density Measured by Dual X-ray, Axial Dual-energy Photon X-ray Absorptiometry and Laser Absorptiometry of Calcaneus

B. Forogh,¹ A. Ghasemzadeh²,
A. Salimzadeh³

Abstract

The objective of this study was to validate the use of bone mineral measurements of the calcaneus bone by dual X-ray and laser (DXL) in a cross-sectional study carried out in an osteoporosis clinic. Measurements of bone mineral density (BMD) at proximal femur and spine were obtained by dual-energy photon X-ray absorptiometry (DEXA). Osteoporosis was defined by a DEXA T-score <-2.5 at the femoral neck or lumbar spine. Sensitivity, specificity and kappa statistics for DXL were calculated, assuming the DEXA measurement as the gold-standard. The study included 475 women with a mean age of 54 ± 11.9 years. 15% had osteoporosis while 39% were osteopenic ($-2.5 < \text{T-score} < -1$) at the femoral neck or spine. A significant correlation ($p < 0.001$) was found between BMD values as measured by DXL at femoral neck and DEXA at the lumbar spine. Assuming the same T-score cut-off value for the diagnosis osteoporosis and a modified cut-off value for the diagnosis of osteopenia ($-2.5 < \text{T-score} < -1.5$), yields a sensitivity of 83% and a specificity of 74% to 86% for the DXL device. In conclusion, BMD measured at the calcaneal bone by DXL, has a good correlation with that measured by axial DEXA.

Iran J Med Sci 2005; 30(1): 34-37.

Keywords • Bone mineral densitometry • Calcaneus • Osteoporosis

Introduction

A Low bone mineral density (BMD) is an important risk factor for osteoporosis. About 80% of the variability in bone strength depends on the bone mineral content.¹ The lifetime prevalence for osteoporosis is more than 30% for women and 13% for men. The definition of osteoporosis is centered on the level of bone mass, measured as BMD. Osteoporosis denotes a value for BMD or bone mineral content that is 2.5 standard deviations (SD) or more below the young adult mean value (T-score <-2.5). Osteopenia means a T-score that lies between -1 and -2.5 . It is well-documented that measurements of BMD in the heel bone can be used for prediction of fracture risk.²⁻⁵ The World Health Organization (WHO) guidelines issued in 1994 is used to combat this disease and its severe consequences.⁶ Lack of access to diagnostic equipment, however, is one of the limiting factors for an efficient management of this disease; the only reliable and

¹Department of physical medicine & Rehabilitation,

Iran University of Medical Science,

²Department of radiology and Research Center Science & Technology in Medicine (RCSTIM),

³ Department of Rheumatology Tehran University of Medical sciences, Tehran, Iran.

Correspondence:

Bijan Forogh MD,
Department of physical medicine and Rehabilitation,
Iran University of Medical Science,
Tehran, Iran.

Tel/Fax: +98 021 2221577

E-Mail: bijhanfr@yahoo.com

Table 1: Correlation of T-score values at different measurement sites (Pearson coefficient of correlation). All correlations were highly significant ($p < 0.001$).

	DXL Calscan	Lumbar Spine	Femoral Neck
DXL Calscan	–	0.68	0.71
Lumbar Spine	0.68	–	0.65
Femoral Neck	0.71	0.65	–
Total Hip	0.73	0.62	0.90

endorsed technology has, nonetheless, been restricted to a few large hospitals. Axial dual-energy photon X-ray absorptiometry (DEXA) equipment is expensive, non-portable, requiring specialized training and is usually restricted to secondary-care hospitals. Given the considerable health problems posed by postmenopausal osteoporosis, a need is felt for low-cost diagnostic methods for identifying women at risk of having fragility fractures. Dual X-ray and laser (DXL) applied to the heel bone is a relatively inexpensive portable technique which may be used in ambulatory settings as well as at orthopaedic wards and osteoporosis clinics. Previous studies have shown that BMD measured by the DXL Calscan (Demetech AB, Sweden) device was in concord with the WHO criteria and in good agreement with measurements read at the femoral neck and spine.⁷ The objective of the present study was to determine the ability of DXL in measurement of the calcaneus BMD in an Iranian female population as compared with DEXA.

Patients and Methods

The measurement of BMD in the non-dominant calcaneus bone by DXL was made in 475 female patients with the mean age 54 ± 11.9 yrs, body weight $69.312.4$ kg, height 154.2 ± 6.3 cm, BMI 29.2 ± 5.2 kg/m², PA spine BMD 1.031 ± 0.218 g/cm², total hip BMD 0.871 ± 0.147 g/cm², and calcaneus BMD 0.368 ± 0.085 g/cm². The participants were routinely referred for assessment of BMD. The BMD in these patients was also measured in their spine (L₂–L₄) in anterior-posterior projection, the femoral neck and their hip by DEXA using a Lunar DPX MX densitometer (Madison, USA). The patients were positioned for the scanning according to the manufacturer's instructions.

The data on reference sample for the axial device, used in our patients, was that of NHANES III population. For the heel device, the reference sample data was from a North European origin,⁸ provided by the manufacturer. Each subject was categorized as being normal if she had a T-score ≥ -1.0 ; osteopenic if $-2.5 < \text{T-score} < -1.0$; or osteoporotic if $\text{T-score} \leq -2.5$.⁹ For the axial DEXA the lowest T-score value read in

Table 2: Sensitivity and specificity (%), for diagnosis of osteoporosis and osteopenia (values in parenthesis are for the T-score threshold < -1.5).

	Osteoporosis (T-score < -2.5)	Osteopenia ($-2.5 < \text{T-score} < -1.0$)
Sensitivity %	83	96
Specificity %	86 (86)	42 (74)

femoral neck or lumbar spine was used for the diagnostic categorization.

Results

Of the studied group, 70 (15%) had osteoporosis, 185 (39%) had osteopenia and 220 (46%) were healthy, according to the axial bone densitometry using DEXA. The Pearson correlation coefficient between T-score values estimated at different measurement sites are presented in Table 1.

The sensitivity and specificity for DXL in diagnosing osteoporosis and osteopenia as compared with that diagnosed by DEXA, were calculated (Table 2). We had excellent sensitivity and specificity for the diagnosis of osteoporosis. A cut-off T-score of ≤ -2.5 for DXL Calscan identifies about the same number of patients as osteoporotic as do measurements of DEXA. However, in our study, the high sensitivity for the diagnosis of osteopenia is not followed by a high specificity for the diagnosis of osteopenia. Recalculation of the sensitivity and specificity using a different cut-off value for osteopenia ($-2.5 < \text{T-score} < -1.5$) yields a sensitivity of 83% and a specificity of 74% for osteopenia (Table 3). The Kappa statistic of 0.61 denotes a good agreement between the measurements made by DXL Calscan and DEXA for the diagnosis of osteoporosis.

Discussion

Vitamin D deficiency which affects bone mineral metabolism, is reported in Iranian women.^{10,11} The low calcium intake in the region influences the skeletal health. However, the importance of timely diagnosis, accessibility of measurement devices and the cost of measurements are limiting factors for finding the patients at risk. This study, which is confirmed by many recent reports,^{12,13} showed that diagnosis and evaluation of osteoporosis could be established with limited resources, say a DXL device.

The DXL technique uses two X-ray energies in combination with laser measurement of the object thickness in order to determine three tissue components with a high accuracy. Since the total thickness of the object being measured is composed of the individual thicknesses

of bone mineral, lean soft tissue and fat, it is possible to combine the thickness measurement with the two X-ray measurements and obtain a unique solution of the three different components of the measurement site.

An axial DEXA device can normally measure the BMD in 15–20 persons a day. The peripheral device used in this study is much cheaper and can normally handle about 70 to 80 patients a day. This device is mobile, and requires no trained personnel.

This study showed a high correlation between the DXL Calscan and axial DEXA measurements. We also found that the WHO criteria could be used with a high sensitivity and specificity with present reference data. However, the cut-off value for diagnosis of osteopenia should be modified to a T-score between -1.5 and -2.5, if complete agreement with the WHO definition using DEXA, is the goal.

The somewhat higher cut-off value for osteopenia by DXL Calscan device found in this study as compared to the WHO criteria may be due to the large amount of trabecular bone in the heel bone. Calcaneus is weight-bearing and composed of more than 90% trabecular bone. The proximal femur consists of about 43%,¹⁴ and lumbar spine about 42% trabecular bone.¹⁵ The turnover rate of trabecular bone is 6–8 times faster than cortical bone. The trabecular bone has a higher remodeling rate than cortical bone and the heel bone density may therefore be measured for early diagnosis of osteoporosis. The calcaneus bone has been shown to predict the relative risk of all fractures in the hip and lumbar spine. For the prediction of vertebral fracture, calcaneus mineral density (BMD) measurements are similar to those of the spine and better than values for the forearm and hip.¹⁶

One limitation of our study was that it referred to a population in Teheran, and its external validity needs, therefore, to be confirmed. Our patients selection were not without bias; inclusion of those women attending the osteoporosis clinic could represent a bias towards cases with higher incidence of the disease. However, given that these were the real life conditions in the everyday practice in an osteoporosis clinic, this factor might improve the validity of our results.

In light of the high prevalence of osteoporosis in the population and its severe complications, a peripheral measurement technique may have great potential in lessening the burden of osteoporosis for the society and the patients.

References

- 1 Cummings SR, Black D. Bone mineral measurements and risk of fracture in Cau-

- casian white women: A review of findings from prospective studies. *Am J Med* 1995; 98: 24S-8S.
- 2 Cummings SR, Nevitt MC, Browner WS, et al. Risk factors for hip fracture in white women. Study of Osteoporotic Fractures research Group. *N Engl J Med* 1995; 332: 767-73.
- 3 Black DM, Cummings SR, Genant HK, et al. Axial and appendicular bone density predict fractures in older women. *J Bone Miner Res* 1992; 7: 633-68.
- 4 Vogel JM, Wasnich RD, Ross PD. The clinical relevance of calcaneus bone mineral measurements: a review. *Bone and mineral* 1988; 5: 35-58.
- 5 Siris ES, Miller PD, Barrett-Connor E, et al. Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women: results from the National Osteoporosis Risk Assessment. *JAMA* 2001; 286: 2815-6.
- 6 Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. *Osteoporos Int* 1994; 4: 368-81.
- 7 Kullenberg R, Falch JA. Prevalence of osteoporosis using bone mineral measurements at the calcaneus by dual X-ray and laser (DXL). *Osteoporosis Int* 2003; 14: 823-7.
- 8 Kullenberg R. Reference database for Dual X-ray and Laser (DXL) Calscan bone densitometer. *Journal of Clinical densitometry* 2003; 367-71.
- 9 Hakulinen M, Saarakkala S, Töyräs J, et al. Dual Energy X-ray Laser Measurement of Calcaneal Bone Mineral Density. *Physics in Medicine and Biology* 2003; 1741-52.
- 10 Bassir M, Laborie S, Lapillonne A, et al. Vitamin D deficiency in Iranian mothers and their neonates: a pilot study. *Acta Paediatr* 2001; 90: 577-91.
- 11 Rassouli A, Milani I, Moslemi-Zadeh M. Determination of serum 25-hydroxyvitamin D(3) levels in early postmenopausal Iranian women: relationship with bone mineral density. *Bone* 2001; 29: 428-30.
- 12 Siris ES, Miller PD, Barrett-Connor E, Faulkner KG et al. Identification and fracture outcomes of undiagnosed low bone mineral density in postmenopausal women. *JAMA* 2001; 286: 2815-22.
- 13 Miller PD, Siris ES, Barrett-Connor E, et al. Prediction of Fracture Risk in postmenopausal White Women With Peripheral Bone Densitometry: Evidence From the National Osteoporosis Risk Assessment. *J Bone Miner* 2002; 17: 2222-30

- 14 Bohr H, Schaadt O Bone mineral content of the femoral neck and shaft: relation between cortical and trabecular bone. *Calcif Tissue Int* 1985; 37: 340-4.
- 15 Nottestad S, Baumel J, Kimmel D, Recker R, Heaney R. The proportion of trabecular bone in human vertebrae. *J Bone and Miner Res* 1987; 2: 221-9.
- 16 Marshall, Johnell, Wedel. Meta analysis of how well measures of bone density predict occurrence of osteoporotic fractures. *British Med J* 1996; 312: 1254-9.