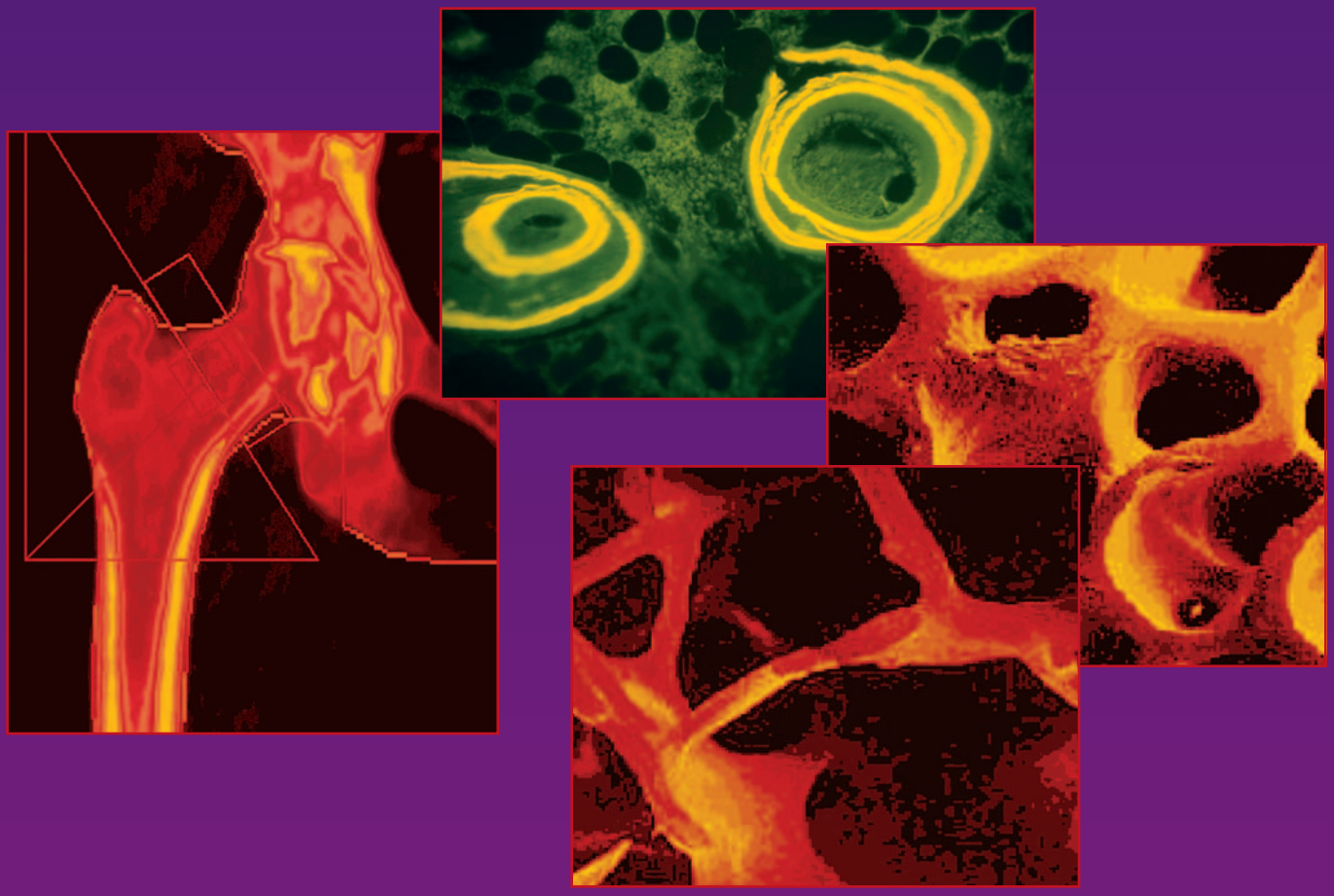
Volume 8 Number 3 Fall 2005 ISSN: 1094–6950

Journal of Clinical Densitometry

ISCD
The International Society For Clinical Densitometry

The Official Journal of
The International Society for Clinical Densitometry

Editor-in-Chief
Paul D. Miller, MD



Humana Press

Journal of Clinical Densitometry, vol. 8, no. 3, 261–266, 2005

1094-6950/05/8:261–266/$30.00
DOI: 10.1220/1094-6950

Original Article

Densitometer Type and Impact on Risk Assessment for Osteoporosis

*Asma Arabi, Mariana Salamoun, Hajar Ballout, and Ghada El-Hajj Fuleihan**

Calcium Metabolism and Osteoporosis Program, Department of Internal Medicine, American University of Beirut Medical Center, Beirut, Lebanon

Abstract

Studies have shown a high correlation between measurements of bone mineral density (BMD) obtained on different dual-energy X-ray absorptiometry machines. Challenger osteodensitometers (Diagnostic Medical System [DMS], Montpellier, France) are becoming widely used but little is known about their clinical performance. The aim of this study was to compare BMD measurements and the resulting patient classification based on T-scores obtained on a DMS Challenger device to those obtained on Hologic 4500A (Bedford, MA) device. Fifty-three volunteers were studied. The BMD of the spine and of the hip were simultaneously measured on both densitometers. BMD values obtained on the Challenger were significantly higher than those obtained with the Hologic QDR4500 ($p < 0.001$). The correlations coefficients between the Hologic QDR4500 and the DMS Challenger measured BMDs were $r = 0.70$ at the femoral neck, $r = 0.70$ at the trochanter, and $r = 0.83$ at the spine ($p < 0.001$). Among the 35 postmenopausal women, there was discordance in the WHO T-score-based classification in 28 subjects (80%) at the spine, 18 subjects (52%) at the femoral neck, and 14 subjects (42%) at the trochanter. The intermachine agreement was low: The kappa score was –0.10 at the spine, 0.2 at the femoral neck, and 0.3 at the trochanter. In conclusion, this study cautions against the use of nonestablished densitometers that leads to underdiagnosis of patients and, subsequently, to inappropriate treatment strategies.

Key Words: DXA devices; osteoporosis; underdiagnosis; pencil beam; fan beam.

Introduction

Osteoporosis is the commonest metabolic bone disorder, with fractures incurring substantial morbidity and mortality *(1)*. Bone mineral density (BMD) is a powerful predictor of fractures and a pivotal tool in the evaluation of patients at risk for osteoporosis *(2)*. Dual-energy X-ray absorptiometry (DXA) is one of the commonest means to measure BMD in the axial skeleton. Several types of DXA densitometer have been introduced to the market, with variations in the dual energy used and/or in the algorithm for edge detection between the different commercial systems. This could lead to differences in BMD measurements, with variations of up to 15 % *(3,4)*. Differences in the absolute BMD measured and in the normative databases used might lead to clinically relevant differences in normality assignment *(5,6)* and possibly in some instances to patient misclassification, thus undermining sound clinical decision-making.

The world market share of densitometry machines is largely dominated by two manufacturers: Hologic QDR4500 (Bedford, MA) and Lunar-General Electric. Both companies manufacture central DXA machines that have a solid track record in terms of reproducibility and that have been extensively used in clinical trials. Furthermore, both densitometer types have incorporated the NHANES database for hip measurements in their software, a particularly important point in view of the fact that NHANES is considered the database of choice because it is drawn from a large sample that is population based and that the hip, as opposed to other skeletal sites, is the site of choice to be used for diagnosis of osteoporosis

Received 10/27/04; Revised 12/20/04; Accepted 12/20/04.
*Address correspondence to: Ghada El-Hajj Fuleihan, Calcium Metabolism and Osteoporosis Program, American University of Beirut Medical Center, Bliss Street, Beirut, Lebanon, 113-6044. E–mail: gf01@aub.edu.lb

using DXA *(7,8)*. Relatively "new" products on the market are the Challenger DXA osteodensitometers (Challenger; Diagnostic Medical System [DMS], Montpellier, France). These densitometers are based on the pencil-beam technology, which is less expensive than the fan-beam system. Little is known on the accuracy and precision of measurements performed with these densitometers, as well as regarding the validation of the normative databases used. Because there are no published data on the comparison between these types of device with other well-established DXA devices used worldwide, information on the validity of measurements and, therefore, T-score derived from such measurements using these "new" densitometers is lacking. Therefore, physicians face uncertainties in their daily clinical practice in making decision based on scans performed with these machines.

The aim of the present study was to compare BMD measurements obtained on the DMS Challenger device to those obtained on the Hologic 4500A device in terms of tightness of correlation and patient classification based on BMD-derived T-scores *(9)*.

Materials and Methods

Subjects

Fifty-three volunteers were studied. These patients were referred to our densitometry unit by their physicians after having had their BMD measured on a Challenger device (DMS, Montpellier, France) at one local community health center. The BMD at the American University of Beirut Medical Center was measured on a Hologic 4500A densitometer (Hologic, Bedford, MA, USA) and was offered at no charge. The patients and their physicians were provided with a copy of the BMD scan pictures and report. For each subject, the standing height was recorded in centimeters, the weight was recorded in kilograms, and the body mass index (BMI) (kg/m^2) was calculated.

The World Health Organization (WHO) criteria for the definition of osteoporosis was used only in postmenopausal females. The median interval between two scans was 2.5 wk (range: 0–8 wk).

BMD Measurements

Calcium Metabolism and Osteoporosis Program–American University of Beirut

Areal BMD (g/cm^2) at the antero-posterior lumbar spine (L2–L4) and the left femur (total hip, femoral neck, and trochanter) were measured by DXA using a Hologic 4500A device and using software 11.2.3 in the array mode according to manufacturer's recommended procedures (Hologic User's Manual, 080–0886 Revision C, 2002). T-Scores and Z-scores were derived using the databases provided by the manufacturers for the spine and the NHANES database for the hip.

The precision of densitometry measurements at our center based on daily duplicates for the period overlapping the study was 0.86 ± 0.7% at the lumbar spine (n = 279) and 0.84 ± 0.8% at the total hip (n = 282). These numbers are comparable to those we and others have previously published *(10–12)*.

At the Local Community Health Care Center

Areal BMD (g/cm^2) at the anteroposterior lumbar spine (L2–L4) and the left femur (femoral neck and trochanter) were measured by DXA using a Challenger device according to manufacturer's recommended procedures (Challenger User Manual Revision: 05, 2000). T-scores and Z-score were derived using the databases provided by the manufacturers. No details regarding the databases were provided in the user's manual. The precision of this densitometer as reported in the manual is ±1.5% in vivo (Challenger User Manual Revision: 05, 2000, p. 188). Because the DMS Challenger devices do not measure total hip BMD, only the lumbar spine, femoral neck, and trochanter were used in the analyses. Furthermore, because the choice of the region of interest might vary between the two densitometers and the skills of the operator can have an important impact on BMD values, additional comparisons were implemented on a subset of 22 scans of the spine, selected on the basis of high image quality of the scans acquired with DMS Challenger densitometer, where the scan images were the best and in which the region of interest defined by the two machines were the most identical (no reanalyses were performed).

Statistical Analyses

All results are expressed as mean ± SD. Differences between measurements obtained on different machines were evaluated by a paired t-test. Correlations between variables were evaluated by Pearson's correlation. Simple linear regression models were created using BMD measurements obtained with DMS Challenger machine as a dependent variable and the BMD measurements obtained with Hologic 4500A as a predictor, and R^2 was determined for each model. The 35 postmenopausal women were subdivided into three diagnostic subgroups according to the T-score obtained with each machine (T-score > –1: normal; –2.5 < T-score ≤ – 1: osteopenic; T-score ≤ –2.5: osteoporotic). The differences between two machines in the proportion of patients assigned to one diagnostic group or another were evaluated using the χ-square test. p-Values less than 0.05 were considered as statistically significant. Weighted κ statistics were calculated to assess the inter-machine agreement in the assigned diagnosis. If the measurements agree more often than expected by chance, κ is positive; if concordance is complete, $\kappa = 1$; if there is no more or less than chance concordance, $\kappa = 0$, and if the measurements disagree more than expected by chance, kappa is negative. Analyses were carried out using SPSS software, version 10.0 (SPSS, Chicago, IL).

Results

The age of the patients was 55.6 ± 11.2 yr. There were 14 premenopausal, 35 postmenopausal women, and 4 men. Their height was 153 ± 8 cm, weight was 70 ± 14 kg, and BMI was 30 ± 5 kg/m^2. Ten patients (19%) had previous history of fracture, 19 (36%) were smokers, 3 postmenopausal women were on hormone replacement therapy, 10 patients (19%) were on oral bisphosphonates, and 31 (58%) were on calcium, including 28 patients on vitamin D.

Table 1
BMD, T-Score, and Z-Score Values Obtained When Patients Had Simultaneous Measurements on a Hologic 4500A Device and on the DMS Challenger Device

	Hologic 4500 A	DMS Challenger	p^a
Lumbar spine BMD	0.837 ± 0.1	0.939 ± 0.1	<0.001
Lumbar spine T-score	–2.2 ± 1.0	–0.78 ± 0.9	<0.001
Lumbar spine Z-score	–1.0 ± 1.1	–0.05 ± 0.9	<0.001
Femoral neck BMD	0.677 ± 0.1	0.766 ± 0.1	<0.001
Femoral neck T-score	–1.5 ± 0.8	–0.78 ± 1.0	<0.001
Femoral neck Z-score	–0.44 ± 0.8	0.18 ± 1.0	<0.001
Trochanter BMD	0.579 ± 0.1	0.678 ± 0.1	<0.001
Trochanter T-score	–1.2 ± 0.9	–0.66 ± 1.4	<0.001
Trochanter Z-score	–0.51 ± 0.9	0.46 ± 1.5	<0.001

Note: Values are mean ± SD.
[a]*p*-Value for *t*-test.

Bone Mineral Density Measurements

The mean BMD values obtained with the DMS Challenger device were higher by 12% at the spine, 13% at the femoral neck, and 17% at the trochanter, as compared to values obtained on the Hologic QDR4500 device. These differences were statistically significant ($p < 0.001$) (Table 1). BMD values obtained with the Hologic QDR4500 correlated with BMD values obtained with the DMS Challenger; the correlation's coefficients were $r = 0.70$ at the femoral neck and at the trochanter and $r = 0.83$ at the spine ($p < 0.001$).

When regression analyses were performed, Hologic QDR4500 BMD measurements were able to predict 70% of the DMS Challenger BMD measurements at the spine and 50% of the DMS Challenger BMD measurements at the hip (Fig. 1).

Z-Score, T-Score, and Diagnosis Assignment

At all sites, the mean T-scores and Z-scores derived from the Hologic QDR4500 device were significantly lower as compared to those obtained with the DMS device (Table 1). The mean ± SD differences in T-score were 1.4 ± 0.6 at the spine, 0.8 ± 0.7 at the femoral neck, and 0.6 ± 0.9 at the trochanter ($p < 0.001$). For the Z-score, the mean ± SD differences were 0.9 ± 0.6, 0.7 ± 0.6, and 1.0 ± 1.0 ($p < 0.001$) at the spine, femoral neck, and trochanter, respectively.

At the Lumbar Spine

T-scores derived from the Hologic QDR4500 densitometer were lower than T-scores derived from the DMS device in 48 out of 53 subjects. In the 35 postmenopausal women, 17 women (50% of all postmenopausal women) were defined as osteoporotic when measured on the Hologic QDR4500 densitometer, whereas only 2 (6%) were found to be osteoporotic when measured on the DMS device ($p = 0.005$ for difference between two machines). Overall, there was discordance in the assigned diagnosis in 28 postmenopausal women (80%) (Fig. 2A). The intermachine agreement was very low: κ score = –0.10.

When the analyses were done on the 22 scans comparable for the imaging quality and the region of interest, the rate of discordance in the assigned diagnosis was similar: 16 subjects (72%) were misclassified by the DMS Challenger device. The κ score was very low: 0.043.

At the Femoral Neck

T-scores obtained with the Hologic QDR4500 were lower than those obtained with DMS Challenger device in 43 out of 53 subjects. In the 35 postmenopausal women, the diagnosis of osteoporosis was assigned to 8 patients (23%) when measured on the Hologic QDR4500 machine and to 2 patients (6%) when measured on the DMS Challenger ($p = 0.006$ for difference between two machines). Overall, there was discordance in the assigned diagnosis in 18 postmenopausal women (52%) (Fig. 2B). The intermachine agreement was low: κ score = 0.20.

At the Trochanter

T-scores obtained with Hologic QDR4500 were lower than that obtained with DMS Challenger device in 36 out of 53 subjects. The diagnosis of osteoporosis was assigned to six subjects (17%) when measured on the Hologic QDR4500 machine and to only one patient (3%) when measured on the DMS Challenger densitometer ($p = 0.008$ for difference between proportions). There was discordance in the assigned diagnosis in 14 postmenopausal women (41%) (Fig. 2C). The intermachine agreement was low: κ score = 0.3.

Discussion

This study found a systematic intermachine difference in bone mineral measurements with T-score inconsistencies both at the spine and at the hip between the DMS Challenger device and the Food and Drug Administration (FDA)-approved 4500 DXA device by Hologic. In general, DMS Challenger BMD measurements underestimated the prevalence of osteoporosis at clinically important skeletal sites in patients referred for evaluation for osteoporosis.

Dual-energy X-ray absorptiometry is the state-of-art technique for measurement of BMD, DXA devices from the major manufacturers have good accuracy and precision. Differences in X-ray production and edge detection algorithms might cause

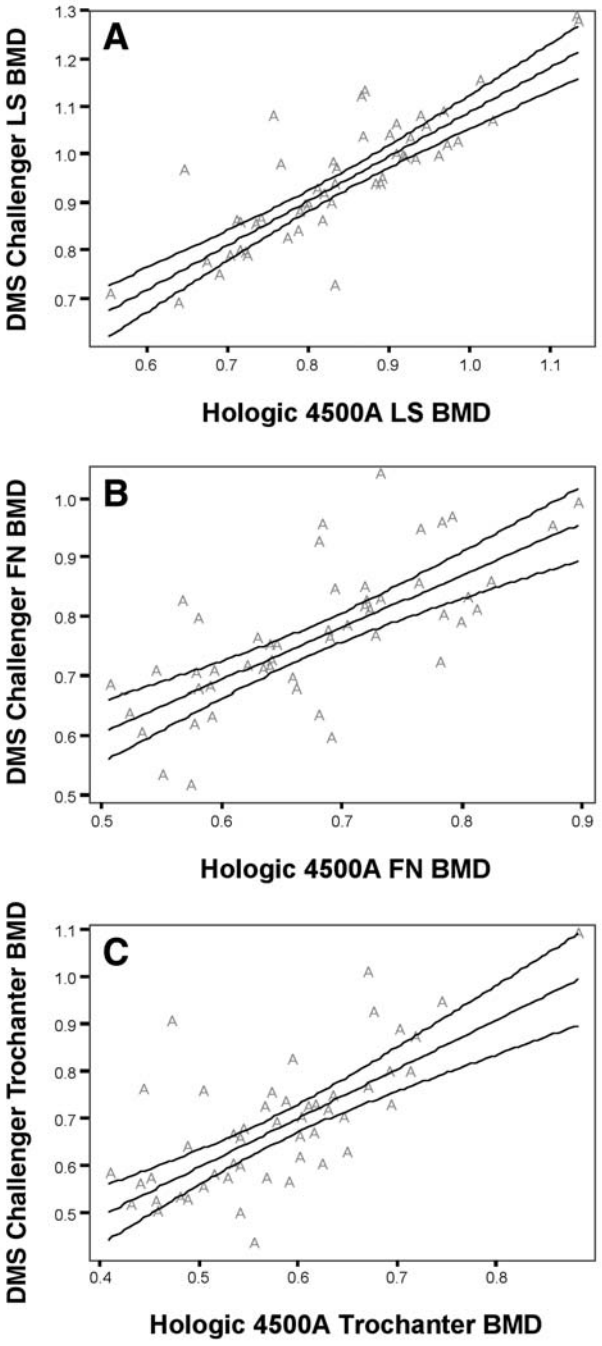


Fig. 1. Simple linear regression with 95% mean prediction interval. The BMD was obtained with Hologic as a predictor and the BMD was obtained with DMS Challenger as a dependent variable. At the lumbar spine, Challenger BMD = 0.16 + 0.93 × Hologic BMD, R^2 = 0.70: **(A);** at the femoral neck, Challenger BMD = 0.17 + 0.88 × Hologic BMD, R^2 =0.50: **(B);** and at the trochanter, Challenger BMD = 0.08 + 1.04 × Hologic BMD, R^2 = 0.50 **(C)**.

differences between machines in areas measured and in the values obtained for bone mineral *(13,14)*. These differences vary according to the machines compared and to the skeletal sites, and they might be as high as 15% *(4,5)*. In the present study, BMD values obtained with the QDR 4500 were lower than those obtained with the DMS Challenger at the spine, femoral neck, and trochanter by 12% to 17%.

More importantly, although the correlations between BMD values obtained with the Hologic QDR4500 and DMS Challenger devices in the current study were significant, they were quite suboptimal and not as close to linearity as those obtained with other machines *(15–18)*. Indeed, the coefficients of correlations obtained in the current study (0.83 at the spine and 0.70 at the hip) were substantially lower than those reported by comparing BMD measurements obtained on Lunar and Hologic densitometers: $r = 0.98$ at the spine, $r = 0.94$ at the femoral neck, and $r = 0.97$ at the trochanter *(15)*. Similarly higher coefficients of correlations were reported comparing measurements obtained on two Hologic devices ($r = 0.99$ at the spine and $r = 0.97$ at the hip *[16]*) or comparing Hologic densitometers, Lunar and Norland by pairs ($r = 0.98$ at the spine, 0.92–0.95 at the femoral neck, and 0.89–0.93 at the trochanter *[17]*). We did not confirm the same r values reported in a previous study posted on the Internet, comparing measurements obtained on DMS Challenger and Hologic QDR4500 devices and showing coefficients of correlations of 0.88 at the spine, 0.93 at the femoral neck, and 0.94 at the trochanter *(19)*. The weak correlation between BMD measurements obtained on the two devices in this study can be related to one or more reasons: the defective accuracy and/or weak precision of one or both machines or to the skills of the operator. Whereas the accuracy of Hologic devices has been well established and these machines were used in major multicenter clinical trials assessing bone density and fracture risk *(20–23)*, nothing was published regarding the accuracy of the DMS Challenger device and, to our knowledge, this machine has not been approved by the FDA and has not been used in clinical trials. The Hologic 4500A device used in the current study had an excellent precision, well below 1%, and was comparable to equivalent estimates in the literature *(10–12)*. The region of interest (ROI) at the hip and, to a much lesser extent, at the spine is subject to manufacturer-specific definition *(5,17)*. The skills of the operator, the image quality, and the determination of the ROI all affect the results and play major roles in the accuracy of measurements. However, even at the spine and with the best scan images where the location and size of the ROI did not differ, 72% of patients were still misdiagnosed using the DMS Challenger device. Moreover, we have previously reported, as a part of multicenter study, cross-calibration data on 45 women having simultaneously BMD measurements on Hologic 2000, Hologic 4500W, or Lunar DPX-L at all skeletal sites, performed by three different technicians, at three centers in Beirut; the correlations among the three measurements obtained on the three machines were much higher than those found in the current study: $r = 0.97$ vs $r = 0.83$ at the spine and $r = 0.90$ vs 0.70 at the hip *(24)*. Therefore, it is unlikely that the weak correlation between BMD measurements obtained on the two different machines was solely the result of the issue of technician skills. Rather, it seemed in large part to be related

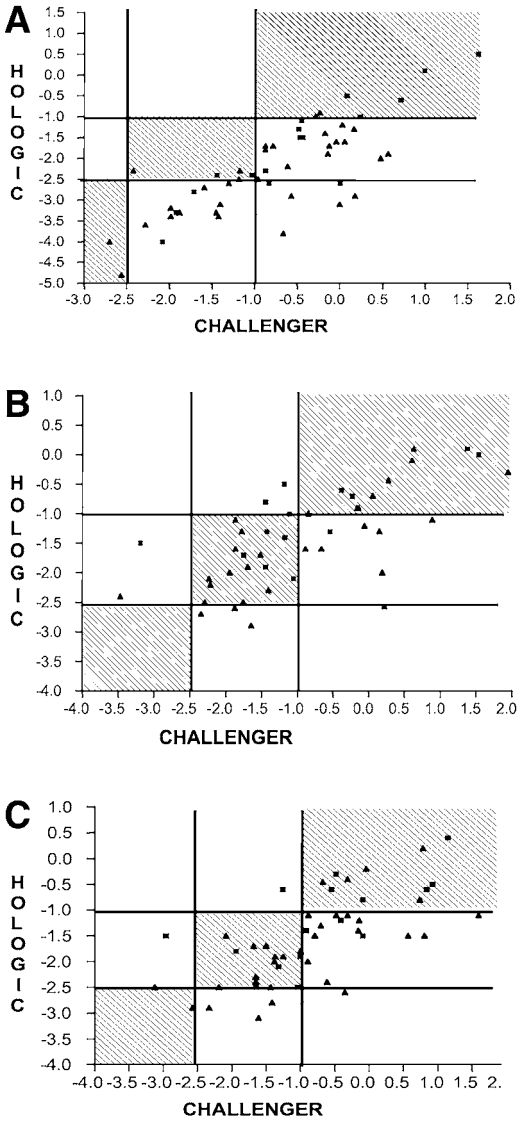


Fig. 2. (A) Plot of the lumbar spine T-score values derived from BMD obtained on a Food and Drug Administration (FDA)-approved device (Hologic) compared with T-score values derived from BMD measurements obtained a nonapproved DXA device (DMS Challenger). The *x*- and *y*-axes were divided into three zones as determined by the WHO cutoff for osteoporosis and osteopenia. The shaded areas represent the area of agreement between the two different machines. ■: T-score in premenopausal women and men: ▲: T-score in postmenopausal women. **(B)** Plot of the femoral neck T-score values derived from BMD measurements obtained on an FDA-approved device (Hologic) compared with T-score values derived from BMD measurements obtained a non-approved DXA device (DMS Challenger). The *x*- and *y*-axis were divided into three zones as determined by the WHO cutoff for osteoporosis and osteopenia. The shaded areas represent the area of agreement between the two different machines. ■: T-score in premenopausal women and men; ▲: T-score in postmenopausal women. **(C)** Plot of the trochanter T-score values derived from BMD measurements obtained on an FDA-approved device (Hologic) compared with T-score values derived from BMD measurements obtained a non-approved DXA device (DMS Challenger). The *x*- and *y*-axis were divided into three zones as determined by the WHO cutoff for osteoporosis and osteopenia. The shaded areas represent the area of agreement between the two different machines. ▲: T-score in premenopausal women and men; ▲: T-score in postmenopausal women.

to the low ability of the machine to accurately detect bone edges and to differentiate bone and soft tissue in order to derive accurate BMD and T-score measurements.

Because patient's results are compared to normative databases that are different between machines, it is expected to find differences in T-scores. Hologic uses the NHANES database at the hip. This is considered the database of choice because it is drawn from a large sample *(25)*. We did not find any information in the DMS Challenger manual about the database incorporated in the DMS device. Faulkner et al. *(6)* showed a difference of 0.1 SD at the spine and 0.9 SD at the hip when measurements obtained on Hologic and Lunar devices were compared to the manufacturer's databases. These differences resulted in disagreement in the patient's classification in 7% of cases at the spine and in 29 % at the femoral neck, as opposed to 80 and 52%, respectively, in the current study.

Although the DMS Challenger device tended to underestimate the prevalence of osteoporosis in general, the discordance in the patient's classification was not systematic throughout the entire study population, as indicated from the scatter plots of the intermachine comparisons (Fig. 2).

QDR-4500 devices use fan-array system and DMS Challenger devices use a pencil-beam system. The pencil-beam scanners employ a narrow X-ray beam that moves in a rectilinear pattern with the detector. The fan-beam scanners utilize an array of detectors and a fan-shaped beam enabling the simultaneous acquisitions of data across an entire scan line. Scan times are reduced to as short as 10 s for the lumbar spine and image resolution is enhanced with the fan-array scanner, which allows definition of intervertebral spaces and bone edges, correct ROI placement, and better identification of artifacts that might affect BMD measurements *(26,27)*. Studies showed an unavoidable difference between pencil-beam and fan-array scans *(16,27–29)*, because there is magnification of the images obtained with fan-array densitometers that affects area, bone mineral content, and, to a lesser extent, BMD data. However, although these differences should be kept in mind when a patient presents with baseline and follow-up scans done on two different machines, the mean differences from duplicate scans obtained simultaneously using a pencil-beam densitometer and a fan-beam densitometer are less than those anticipated from precision measurements using the same machine *(16,27–29)*. This is in contradiction with what we found in the present study, where the difference led to misclassification of up to 80% of patients. This could have serious implications on the management of patients, especially those at high risk for fracture.

Conclusion

In conclusion, a high proportion of patients having their BMD measured on a DMS Challenger osteodensitometer were assigned falsely high T-scores and missed the appropriate diagnosis of osteoporosis. Such densitometers are becoming widely used. Therefore, if not recognized, this underdiagnosis will have major impact on the management of osteoporosis.

References

1. Johnell O, Kanis JA, Oden A et al. 2004 Mortality after osteoporotic fractures. Osteoporos Int 15:38–42.
2. Marshall D, Johnell O, Wedel H. 1996 Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. Br Med J 312:1254–1259.
3. Laskey MA. 1996 Dual-energy X-ray absorptiometry and body composition. Nutrition 12:45–51.
4. Peel NF, Eastell R. 1995 Comparison of rates of bone loss from the spine measured using two manufacturers' densitometers. J Bone Miner Res 10:1796–1801.
5. Pocock NA, Sambrook PN, Nguyen T, Kelly P, Freund J, Eisman JA. 1992 Assessment of spinal and femoral bone density by dual X-ray absorptiometry: comparison of lunar and hologic instruments. J Bone Miner Res 17:1081–1084.
6. Faulkner KG, Roberts LA, McClung MR. 1996 Discrepancies in normative data between Lunar and Hologic DXA systems. Osteoporosis Int 6:432–436.
7. Eddy DM, Delmas P, Buckhardt P et al. 1998 Osteoporosis, Review of the evidence for prevention, diagnosis, treatment and cost-effectiveness analysis. Osteoporosis Int 8(Suppl 4):7S–80S.
8. Kanis JA, Delmas P, Buckhardt P, Cooper C, Togerson D. 1997 Guidelines for diagnosis and management of osteoporosis on behalf of the European Foundation of Osteoporosis. Osteoporosis Int 7:390–406.
9. Kanis JA. 1994 Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. Osteoporos Int 4:368–381.
10. El-Hajj Fuleihan G, Testa M, Angell J, Porrino N, LeBoff MS. 1995 Reproducibility of DEXA densitometry: a model for bone loss estimates. J Bone Miner Res 10:1004–1014.
11. LeBoff MS, El-Hajj Fuleihan G, Angell JE, Chung S, Curtis K. 1992 Dual-energy X-ray absorptiometry of the forearm: reproducibility and correlation with single photon absorptiometry. J Bone Miner Res 7:841–846.
12. Mazess R, Chesnut CH III, McClung M, Genant H. 1992 Enhanced precision with dual energy X-ray absorptiometry. Calcif Tissue Int 51:14–17.
13. Gillette-Guyonnet S, Andrieu S, Nourhashemi F, Cantet C, Grandjean H, Vellas B. 2003 Comparison of bone mineral density and body composition measurements in women obtained from two DXA instruments. Mech Ageing Dev 124:317–321.
14. Laskey MA, Flaxman ME, Barber RW et al. 1991 Comparative performance in vitro and in vivo of Lunar DPX and Hologic QDR-1000 dual energy X-ray absorptiometers. Br J Radiol 64:1023–1029.
15. Pocock N, Noakes K, Griffiths M, et al. 1997 A comparison of longitudinal measurements in the spine and proximal femur using Lunar and Hologic instruments. J Bone Miner Res 12:2113–2118.
16. Barthe N, Braillon P, Ducassou D, Basse-Cathalinat B. 1997 Comparison of two Hologic DXA systems (QDR 1000 and QDR 4500/A). Br J Radiol 70:728–739.
17. Genant HK, Grampp S, Gluer CC, et al. 1994 Universal standardization for dual energy X-ray absorptiometry: Patient and phantom cross-calibration results. J Bone Miner Res 9:1503–1514.
18. Lai KC, Goodsitt MM, Murano R, Chesnut CH 3rd. 1992 A comparison of two dual-energy X-ray absorptiometry systems for spinal bone mineral measurement. Calcif Tissue Int 50: 203–208.
19. Gagnepain C, Clary L, Grando R, Kotzki PO. Correlation between pencil DXA (Challenger) and fan beam DXA (QDR 4500) BMD measurements. available at http://www.dms.com/telechargement/etude6.doc. Date accessed: 2005.
20. Cauley JA, Robbins J, Chen Z et al. 2003 Effects of estrogen plus progestin on risk of fracture and bone mineral density: the Women's Health Initiative randomized trial. JAMA 290:1729–1738.
21. Black DM, Thompson DE, Bauer DC et al. 2000 Fracture risk reduction with alendronate in women with osteoporosis: the Fracture Intervention Trial. J Clin Endocrinol Metab 86: 4118–4124.
22. Stone KL, Seeley DG, Lui LY, et al. 2003 BMD at multiple sites and risk of fracture of multiple types: long-term results from the Study of Osteoporotic Fractures. J Bone Miner Res 18:1947–1954.
23. Espeland MA, Bush TL, Mebane-Sims I, et al. 1995 Rationale, design, and conduct of the PEPI Trial. Postmenopausal Estrogen/Progestin Interventions. Control Clin Trials 16:4(Suppl): 3S-19S.
24. El-Hajj Fuleihan G, Baddoura R, Awada H, et al. 2002 Low peak bone mineral density in healthy Lebanese subjects. Bone 31:520–528.
25. Kanis JA, Gluer CC. 2000 An update on the diagnosis and assessment of osteoporosis with densitometry. Committee of Scientific Advisors, International Osteoporosis Foundation. Osteoporos Int 11:192–202.
26. Theodorou DJ, Theodorou SJ. 2002 Dual-energy X-ray absorptiometry in clinical practice: application and interpretation of scans beyond the numbers. Clin Imaging 26:43–49.
27. Blake GM, Parker JC, Buxton FM, Fogelman I. 1993 Dual X-ray absorptiometry: a comparison between fan beam and pencil beam scans. Br J Radiol 66:902–906.
28. Mazess R.B, Barden, H.S. 2000 Evaluation of differences between fan-beam and pencil-beam densitometers. Calcifi Tissue Int 67:291–296.
29. Pocock NA, Noakes KA, Majerovic Y. 1997 Magnification error of femoral geometry using fan beam densitometers. Calcif Tissue Int 60:8–10.