MEASUREMENT OF GRUEN ZONE BMD IN ORTHOPEDIC SCANS USING THE GE LUNAR PRODIGY

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INTRODUCTION

Low precision error is important for measuring changes in periprosthetic bone density with confidence. Total hip replacement, a popular procedure for treating patients with femora damaged by disease or injury, alters the normal stresses applied to weight-bearing bone of the proximal femur. Subsequent redistribution of bone through stress shielding and remodeling, coupled with cell damage caused by wear debris shed from the implant, often results in substantial bone loss surrounding the implant and loosening of the prosthesis. Both outcomes decrease prosthesis longevity and increase difficulties associated with revision surgery.

Dual-energy x-ray absorptiometry (DXA) precisely quantifies bone mineral density (BMD) adjacent to femoral prostheses in vivo, and measures bone remodeling changes and bone loss longitudinally. In this study, we evaluated the precision of BMD measurements from orthopedic scans using a fan-beam densitometer equipped with orthopedic software.

METHODS

Twenty-five subjects with total hip implants were studied. Orthopedic scans were performed twice with the Lunar Prodigy (GE Medical Systems), with repositioning between scans. Orthopedic software automatically created seven regions-of-interest corresponding to Gruen zones (Figure 1). Gruen zones are standardized regions designed originally for evaluating bone loosening around the prosthesis using radiographs [1]. Subsequently, Gruen zones have been used to evaluate localized changes in BMD surrounding the femoral prosthesis. Precision of Gruen zone BMD (Table 1) was calculated as the root-mean-square standard deviation (RMS-SD) and root-mean-square coefficient of variation (RMS-CV). The Least Significant Change (LSC) necessary to detect a biological change was calculated for the case of two measurements, one performed at baseline and one at follow-up, using the 95% level of statistical confidence (LSC = 2.8 x Precision) [2]. The time interval required to detect this LSC was calculated as: Time Interval = LSC/expected rate of change per time interval. The Time Interval for each Gruen zone was calculated for expected BMD loss rates of 10% and 20% during the first 6 months following implantation.

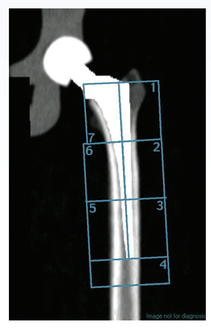


Figure 1. Prodigy orthopedic image showing standard Gruen zones

RESULTS

Precision error of 1% to 3% at all Gruen zones with the Lunar Prodigy was equivalent to or better than precision error of 2% to 5% shown previously with pencil-beam systems [3,4].

Table 1. Precision of Gruen zone BMD measurements

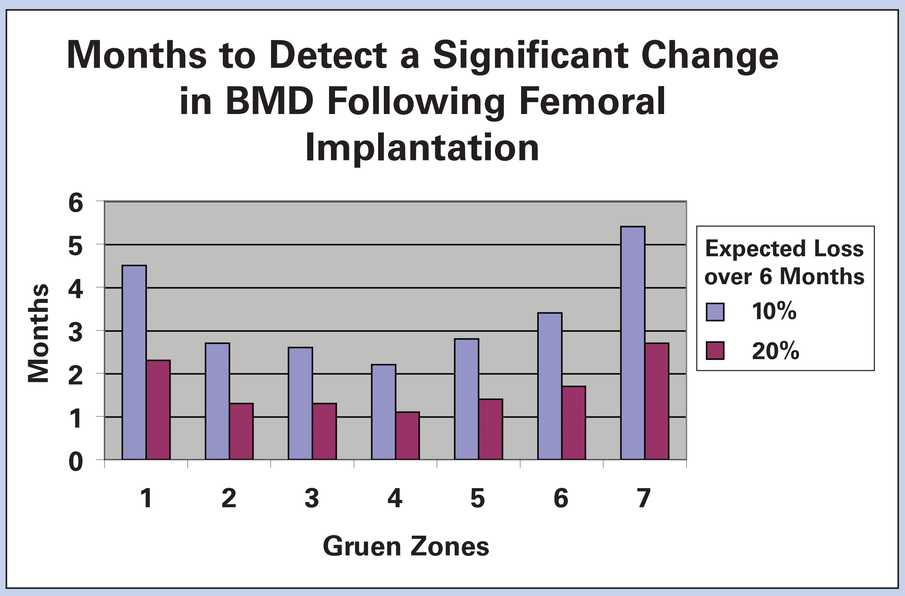
Gruen Zone	Mean BMD (g/cm²)	RMS-SD	RMS-CV
1	1.24	0.034	2.7%
2	2.11	0.034	1.6%
3	2.21	0.034	1.5%
4	2.08	0.028	1.3%
5	2.12	0.035	1.7%
6	1.83	0.037	2.0%
7	1.22	0.040	3.2%

The Least Significant Change was calculated for each Gruen zone (Table 2). The LSC was considerably less than the BMD loss of 10% to 20% seen typically during the first six months following implantation [3], allowing rapid detection of bone loss in this at-risk population. The months after implantation required to detect a significant biological change in BMD (with expected changes of 10% and 20% over a 6-month period) are presented in Table 2 and Figure 2. Precision errors were sufficiently low to detect a significant biological change within 3 months for zones 2 through 5 and within 6 months for zones 1, 6 and 7 when the expected loss rate was 10% over 6 months. Significant biological change was detected in less than 3 months for all Gruen zones given an expected 20% loss rate over 6 months.

Table 2. Least significant change and months required to detect biological change

			Months to detect a significant change in BMD with an expected loss over 6 months of:	
Gruen Zone	Precision (CV)	LSC	10%	20%
1	2.7%	7.6%	4.5 months	2.3 months
2	1.6%	4.5%	2.7 months	1.3 months
3	1.5%	4.3%	2.6 months	1.3 months
4	1.3%	3.7%	2.2 months	1.1 months
5	1.6%	4.6%	2.8 months	1.4 months
6	2.0%	5.6%	3.4 months	1.7 months
7	3.2%	9.0%	5.4 months	2.7 months

Figure 2. Months required to detect a significant biological change in BMD



DISCUSSION

Weight bearing is essential for maintaining bone density in the proximal femur. Resorption of bone around a femoral prosthesis is common due to stress shielding, a phenomenon that results when much of the weight-bearing function of periprosthetic bone is taken over by the femoral implant. In addition, there is evidence that the initial BMD of the femur prior to implantation has an important influence on the extent of post-operation bone loss. Stress shielding has been found to be greatest in femora with low BMD prior to implantation, resulting in greater bone resorption after surgery [5]. A low precision error is important for assessing femoral bone strength and detecting changes in periprosthetic BMD over time. In the present study, precision errors for measurements of Gruen zone BMD were similar to those reported for femoral neck BMD, but somewhat higher than those reported for total femur BMD. Bone resorption around femoral implants occurs rapidly, however, with BMD losses of 10% to 20% not uncommon during the first six months after implantation. Precision errors with the Prodigy were low enough to detect this level of biological change within 2-3 months for most Gruen zones.

CONCLUSION

Precision of Gruen zone BMD with the Prodigy fan-beam system was equivalent to or better than precision with DXA pencil-beam systems. The least significant change to detect a real biological change was considerably less than the BMD change seen typically during the first 6 months following implantation, allowing rapid detection of bone loss in this at-risk population.

References

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