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ORIGINAL STUDY

No change detected by DEXA in bone mineral density after periacetabular osteotomy

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The purpose of this study was to assess acetabular bone mineral density after periacetabular osteotomy and to examine whether bone mineral density correlates with postoperative migration of the osteotomised acetabular fragment. Twenty-five female and three male patients scheduled for periacetabular osteotomy were consecutively included. The patients were scanned by dual energy X-ray absorptiometry (DEXA) at 1 week, 1 year, and 2½ years after surgery. Radiostereometric analyses (RSA) were done at 1, 4, 8, and 24 weeks after surgery. Two and a half years after periacetabular osteotomy, no significant changes in bone mineral density or any biological effect on bone remodelling due a changed loading pattern in the acetabulum could be detected. There was no significant correlation between bone mineral density and migration of the acetabulum.

Dual energy X-ray absorptiometry is not an appropriate method to demonstrate the changes in bone mineral density after periacetabular osteotomy or to predict postoperative acetabular migration.

Keywords : periacetabular osteotomy ; bone mineral density ; DEXA.

INTRODUCTION

Periacetabular osteotomy (PAO) is a well-established joint preserving procedure (*7*) that offers good pain relief in symptomatic hip dysplasia (*16,24*). PAO increases acetabular coverage (*14*) and medialises the femoral head (*4*) (fig 1). As a result, the distribution of load in the hip joint is altered after surgery.

We conducted a study employing dual energy X-ray absorptiometry (DEXA) to estimate bone mineral density (BMD) in the acetabulum after surgery. In the same group of patients, radiostereometric analysis data (RSA) (*13*) were obtained to determine whether correlation exists between BMD and the postoperative migration of the acetabular fragment.

Our hypothesis was that bone density would decrease in the lateral part and increase in the medial part of the acetabulum after PAO and we hoped to find a biological confirmation of the effect of the PAO on the load redistribution within the hip joint. Increased bone density may be a remodelling

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Fig. 1(a-b). — Radiograph before and 6 months after periacetabular osteotomy. Preoperatively (1a), insufficient coverage of the femoral head and acetabular roof obliquity. Postoperatively (1b), the femoral head is covered by the acetabulum and the acetabular roof is horizontal.

response caused by changed load distribution in the hip joint or a higher level of physical activity (*15*), but it could also indicate progression of the osteoarthritis (*1,19*).

We also hypothesised that the degree of migration of the acetabular fragment was correlated to acetabular bone density. Low acetabular bone density might result in poor primary fixation of the cortical screws, and consequently to migration of the osteotomised acetabular fragment from the re-oriented position after surgery. If a correlation was found, dual energy X-ray absorptiometry (DEXA) could be helpful preoperatively to determine the risk of migration. If a threshold value was found, it could be an argument to avoid PAO in those patients at risk or to consider alternative fixations in these cases.

MATERIAL AND METHODS

The study was designed as a case series and accepted by the local ethics committee. After signed consent, 28 patients, 25 females and 3 males, scheduled for PAO were consecutively included. A minimally invasive transsartorial approach was used (*21*). The median age of the patients was 41 (19-53) years.

The patients were DEXA scanned three times : 7 days (5-12 days), 1 year, and 2½ years after PAO. A hologic QDR 2000 dual-energy X-ray densitometer, USA (200 Volts AC, 50 Hz, 8.5 Amps) was used. The patients were positioned supine in a standardised manner with the legs secured in neutral rotation by a frame (fig 2).

BMD was calculated on the DEXA images in two-well defined regions of interest (ROI). The ROI's were drawn starting at the acetabular joint line and extended 1.4 cm proximally (fig 3). ROI one (R1) was located laterally to the lateral screw, and ROI two (R2) between the lateral and the medial screw. These regions were not exactly the same from patient to patient because the position and size of the ROI depended on the individual's acetabular anatomy and the position of the screws. However, for each patient the same ROI's were used at all follow-up scans. All BMD analyses were completed by one technician 2 days after the whole series of DEXA images had been taken to ensure identical positioning of the ROI.

We examined whether we would obtain the same BMD value at a second measurement under identical conditions. Thus, to estimate the precision of the applied method, double scanning with complete repositioning of the patient and set-up was performed on five patients one year postoperatively. ROI location and BMD measurement were done by the same person who had performed all other measurements.

Fig. 2. — Patient positioned supine on scanner bed with legs secured in neutral rotation by a frame.

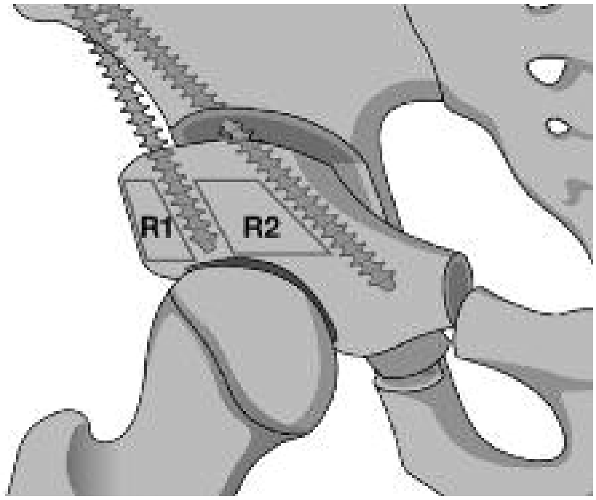

Fig. 3. — Position of the regions of interest : R1 and R2. The size of R1 is approximately 2 cm^2 and for R2 4 cm^2. The same technician placed all ROIs on all DEXA images to ensure similarity in positioning of the ROIs.

During PAO, five tantalum markers (1 mm) were inserted into the acetabular fragment and five markers (0.8mm) were inserted into the iliac bone above the fragment to enable radiostereometric analysis. With the patient supine on the scanner bed and a calibration box (Carbon Box Aarhus, MEDIS, Netherlands) placed beneath the patient, a 3D coordinate system of the tantalum markers was created. The patient was exposed to two simultaneously firing X-ray tubes (150 microSv, 96 kV and 13 mAs) positioned at a 40° angle to each other. One week after surgery, the first stereo radiograph was taken, and the initial position of the acetabular fragment was determined in relation to fixed points on the iliac bone. Follow-up radiostereometric examinations were performed at 4, 8, and 24 weeks postoperatively. The software (RSA-CMS, MEDIS, the Netherlands) allows a precise calculation of the migration of the acetabular fragment between examinations (*22,23*), expressed as translation and rotation of the centre of gravity of the markers inserted into the acetabular fragment.

Postoperative BMD data were tested for correlation with data for acetabular migration with Pearson's coefficient of correlation. Two-tailed tests were used and the p-values were considered significant if $p < 0.05$. The effect size for the paired t-test was calculated (*25*) to demonstrate the magnitude of the difference between BMD at baseline and 2½ years postoperatively, independent of sample size. Precision of the DEXA method used was calculated as 95% limits of agreement (*2*).

RESULTS

Three patients were lost to final follow-up and two DEXA images could not be analysed, leaving us with data concerning 23 patients of the 28 included. We found that BMD was unchanged 2½ years postoperatively compared with BMD immediately after and 1 year after surgery for the lateral ROI as well as for the medial ROI (table I).

There was no significant correlation between baseline BMD in the lateral ROI and postoperative migration of the acetabulum or between baseline BMD in medial ROI and postoperative migration of the acetabulum (table II).

The limits of agreement (LOA) between repeated BMD results obtained by double scanning were calculated. Given the first BMD measurement for the lateral ROI, we could expect with 95% confidence that the difference to the second measurement would be between - 0.21 – 0.16 g/cm^2 (fig 4). For the medial ROI, the LOA was - 0.17 – 0.01 g/cm^2 (fig 5).

Table I. — Bone mineral density (BMD) measured 1 week postoperatively (baseline), and 1 and 2½ years after surgery in a lateral and a medial region of interest (ROI)

	Lateral ROI			Medial ROI		
n = 23	Baseline	1 year	2½ years	Baseline	1 year	2½ years
Mean BMD g/cm^2	1.41	1.33	1.26	1.78	1.84	1.74
95% CI for mean	1.20 – 1.62	1.15 – 1.51	1.07 – 1.45	1.60 – 1.96	1.63 – 2.05	1.52 – 1.97
SD	0.52	0.43	0.46	0.43	0.52	0.55

Table II. — Correlations between bone mineral density (BMD) at baseline in lateral and medial regions of interest (ROI) and migration of the acetabular fragment in translation and rotation 6 months after surgery (n = 23)

		Lateral ROI (R1)	Medial ROI (R2)	Medial translation	Proximal translation	Posterior translation	Anterior tilt	Internal rotation	Adduction
Lateral ROI (R1)	Pearson Correlation	1	.140	.243	.192	.347	-.256	.248	.272
	Sig. (2-tailed)		.524	.222	.338	.076	.197	.212	.170
Medial ROI (R2)	Pearson Correlation		1	-.143	-.130	-.201	.303	-.298	.041
	Sig. (2-tailed)			.516	.554	.357	.159	.168	.854
Medial translation	Pearson Correlation			1	.792	.286	.025	.041	.006
	Sig. (2-tailed)				.000	.113	.893	.823	.975
Proximal translation	Pearson Correlation				1	.040	.138	-.076	-.119
	Sig. (2-tailed)					.828	.450	.678	.517
Posterior translation	Pearson Correlation					1	-.158	.133	.155
	Sig. (2-tailed)						.387	.469	.398
Anterior tilt	Pearson Correlation						1	-.993	-.998
	Sig. (2-tailed)							.000	.000
Internal rotation	Pearson Correlation							1	.993
	Sig. (2-tailed)								.000
Adduction	Pearson Correlation								1
	Sig. (2-tailed)								

DISCUSSION

Several factors may explain why acetabular bone density did not change over time as a result of PAO. First of all, the resolution of DEXA images is poor, making it difficult to clearly identify the acetabular joint line and to position the ROI at exactly the same place on all images. Secondly, our ROIs were small (2-4 cm^2) and thus more sensitive to small changes in positioning in the same patient. The operator had to construct the ROI to suit the individual anatomy of the patients, and she attempted to choose the same ROI on later images obtained from the same patient. Thirdly, our method, based on double scanning, was not sufficiently precise. Other studies show that DEXA of the hip joint is a precise method for determining BMD when positioning and rotation are strictly controlled (*5,6,10,18*). But in this study, the LOA for the lateral ROI was - 0.21 – 0.16 g/cm^2, meaning that if we have a first BMD measurement of 1 g/cm^2, the next measurement on the same patient could show everything from 0.79 g/cm^2 to 1.16 g/cm^2. This is not precise enough to identify the small changes in BMD expected to occur in our study. After having analysed our data statistically, we knew the variation of the data, and we were able to calculate the number of patients that should have been included in the study to detect

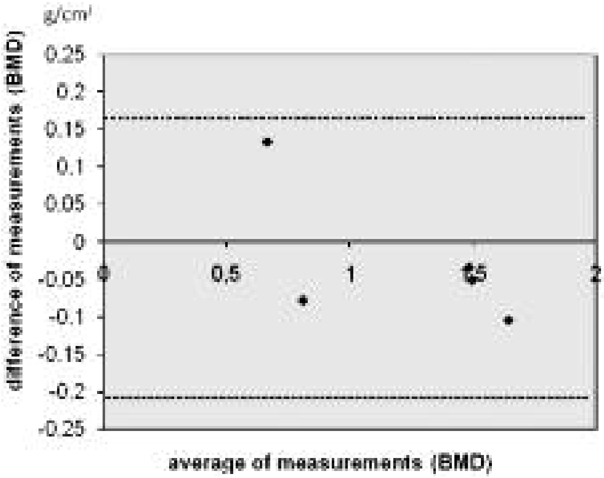

Fig. 4. — Bland-Altman plot of the difference against the average BMD measurement, based on five repeated measurements. The dotted lines represent the 95% limits of agreement for the lateral ROI.

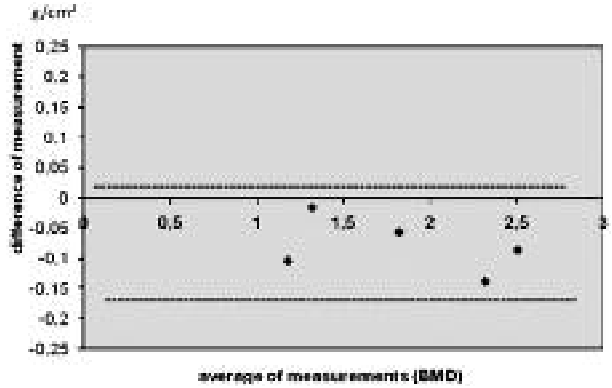

Fig. 5. — Bland-Altman plot of the difference against the average BMD measurement, based on five repeated measurements. The dotted lines represent the 95% limits of agreement for the medial ROI.

a difference in BMD with this method. We found that with a power of 0.80 and alpha = 0.05, the sample size should have been 88 patients.

Contact pressures in dysplastic hips are higher than in normal hips (*8,12,17*), and stress distribution is concentrated in a smaller weight-bearing area (*11*). PAO results in reduced contact stress (*9,20*) and a changed load distribution (*3*). Postoperatively, load on the lateral part of the acetabulum is decreased and load on the medial part is increased. It is plausible that this change in load distribution will affect bone density of the acetabulum over time, although the biological effect of PAO in terms of bone remodelling due to changes in loading pattern could not be clearly objectivised in this study because no changes in BMD were found after PAO. Neither did we find evidence for our initial hypothesis about a correlation between BMD and migration of the acetabulum. However, there was hardly any postoperative migration of the acetabular fragment (*13*) and hence no correlation with BMD. The degree of acetabular migration correlated significantly in a few directions of translation and rotation.

In conclusion, there was no correlation between BMD in the acetabulum and the amount of migration of the osteotomised fragment after PAO, and we did not find changed acetabular BMD over time. DEXA, as applied in this study, is not an appropriate method to demonstrate the changes in BMD in the hip due to changed loading or a suitable method to predict postoperative acetabular migration.

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