Coll. Antropol. **36** (2012) 3: 807–811
Original scientific paper

Clinical Importance of Changes to Femoral Bone Mineral Density around the Hip Endoprosthesis

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A B S T R A C T

The implanting of a hip endoprosthesis changes the mechanical loading in a hip. The changing in loading causes bone remodeling. The loss of loading leads to bone atrophy, whereas an increase in loading leads to hypertrophy of the bones. We investigated the relationship between the clinical result and change in periprosthetic bone mineral density. The Harris hip score was used to measure the clinical outcome. The dual photon densitometry method was used to measure periprosthetic bone mineral density. The obtained results showed that a loss in bone mass around the hip endoprosthesis does not affect the clinical outcome of the operation. Bone hypertrophy has a positive effect on the clinical outcome. The patient's age, sex and body weight in the investigated population did not have an negative impact on functional status. The time passing from the operation to measuring had a negative impact on the functional status.

***Key words**: hip prosthesis, BMD periprosthetic bone, clinical influence*

Introduction

Following primary hip arthroplasty, a change in the bones around the endoprosthesis occurs. Post-operative changes occur at the contact surface (interface) of the bone and implant, and in the bone structure. We researched the structural changes of bone around the cementless hips endoprosthesis. The cause of changes to periprosthetic bone mineral density (BMD) is the change occurring following hip arthroplasty. Hip endoprosthesis transfers mechanical forces from the acetabulum to the femur. The bone around the endoprosthesis is non-uniformly loaded, which directly affects its structure[1].

The aim of our study was to research the impact of changes on the femur bone density in regards to the functional outcome following a non-complicated primary hip arthroplasty. The comparison was carried out of the clinical results and bone mineral density measured with the use of a bone densitometry. The functional result was tested in relation to the age, sex, time of operation leading also to measurement of the body mass index (BMI). We investigated the impact of age, sex and time of the operation on periprosthetic bone mineral density. We used Gruen's division of the femur in seven zones and measured periprosthetic bone mineral density[2] (Figure 1). We recorded a lower value of periprosthetic bone mineral density in the proximal section of the femur[3]. We did not ascertain a link between a low BMD of the proximal femur and the clinical result of the operation.

Patients and Methods

We investigated in the study 108 randomly chosen patients with total hip endoprosthesis. The respondents were operated in various institutions. The operations for inserting a total hip prosthesis were carried in one of the twenty years prior to the research. All the respondents had a cementless hip endoprosthesis implanted from various manufacturers. There were 72 women and 36 men amongst the respondents. The average age was 67.7 years. The Harris hip score was used as an assessment of

Received for publication July 10, 2012

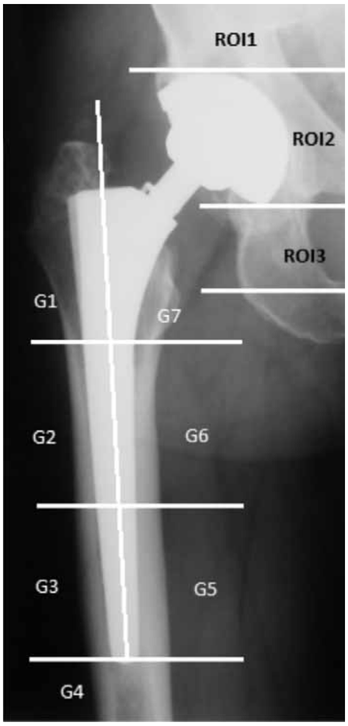

Fig. 1. Region of interest (ROI) according to Gruen.

the functional result of total hip prosthesis during the research period[4]. Respondents had their body mass index calculated in kg/m^2. Measuring the periprosthetic bone mineral density (BDM) in g/cm^2 was carried out by us on a device used for dual photon absorptiometry called the Lunar DPX, Madison, WI, USA. The device is used for bone densitometry (DXA) in the diagnosis of osteoporosis. The principle of densitometry is based on measuring the absorption of X-rays from two various energies (typically 38 and 70 keV). Two energies allowed a differentiation of soft and hard tissue in the scanned area. We used Lunar corp V1.2. software. The orthopaedic software automatically eliminates the absorption of X-rays in the metal body of endoprosthesis. The advantage of the DXA device is a low radiation dose (<1 μSv / scan), has a short scanning time and high precision. The absorption of laser X-rays is calculated as bone mineral content (BMC, g/cm^2), which is divided by the scanned surface area and gives the bone mineral density in g/cm^2. The periprosthetic bone mineral density of the femur was measured in seven zones as recommended by Gruen.

A presentation of the results was given using descriptive statistics. The assessment of the dispersion of results used standard deviation, and in treating the relationship for non-parametric values the χ^2-test was used.

Due to the asymmetry of the distribution of clinical results, logical regression was used, including the Kruskal-Wallis test and the Mann-Whitney test.

Results

The value of the Harris hip score (HHS) from the researched sample varied from 35 to 97, with a median of 80 (Figure 2). Five years following their operations, 81 patients (75%) had a HHS exceeding 84 (Table 1). The time passing from the endoprosthesis implantation procedure was divided into four groups. The first group had

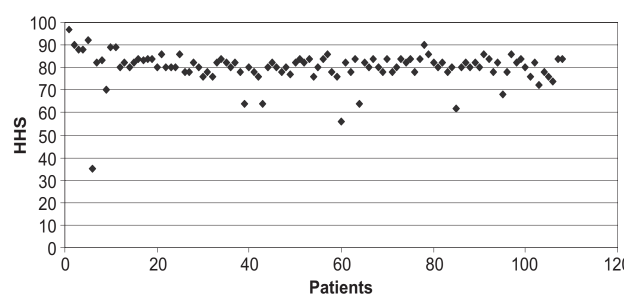

Fig. 2. Harris hip score in investigation pattern.

TABLE 1
VALUES HARRIS HIP SCORE IN RELATION TO GENDER AND TESTING OF THE DIFFERENCY

Gender	N	HHS Median	HHS 25%	HHS 75%	Minimum	Maximum	Mann Whitney Test
Male	36	82.00	78.00	84.00	35.00	97.00	Z=1.670
Female	72	80.00	78.00	82.75	62.00	90.00	p=–0.095

TABLE 2
HARRIS HIP SCORE VALUES BY YEARS OF OPERATION AND TESTING OF THE DIFFERENCY

Years after operation	N	HHS Median	25%	75%	Minimum	Maximum	Kruskal-Wallis test
1	21	82.00	86.00	86.00	76.00	92.00	χ^2=8.862 DF=3 p=–0.031
2-3	24	82.00	84.00	84.00	70.00	90.00	
3-5	25	80.00	84.00	84.00	64.00	89.00	
≥5	38	80.00	82.00	82.00	35.00	97.00	

DF – degree of freedom

their operation one to two years before, the second group had it two to three years beforehand, the third group from three to five years ago, whereas the fourth group had of more than five years ago. The clinical results deteriorated in the time leading from the operation (Table 2).

We did not find significant differences in functional results between men and women p>0.05, Table 1. All of the patients underwent a periprosthetic bone densitometry and standard densitometry of the lumbar spine. The BMD value of the spine was used for the control group.

The exactness of the device's operation for bone densitometry ensures a QA (quality assurance) protocol of daily measurements of phantom density. Without such measurements, the device cannot continue operating. Gruen's seven zones were divided up into four having similar loading conditions following implantation of the endoprosthesis: Gruen's 1 and 7, Gruen's 2 and 6, Gruen's 4 and Gruen's 3 and 5. The average values and their deviations are shown Table 3. Due to the asymmetrical distribution of functional results, a logical regression was carried out. A significant negative predictor on the functional result is the time passing from the operation to the time of undertaking research with a negative effect on clinical results.

The BMD of Gruen's zones 2 and 6, including 3 and 5, have a positive effect on the clinical outcome as measured by Harris' hip scale Table 4. Bone loss in Gruen's zones 1 and 7, the physical weight of the patient and age do not have an effect on the functional outcome of the researched population[5–7] (Table 5).

TABLE 3
INVESTIGATION PATTERN: GENDER, AGE, BMI, BMD IN THE REGION OF THE INTEREST, GRUEN'S ZONE 1 ET 7, 2 ET 6, 4 AND 3 ET 5

Gender		Age	BMI kg/m²	BMD g/cm²	BMD g/cm²	BMD g/cm²	BMD g/cm²
				Gruen 1 and 7	Gruen 2 and 6	Gruen 4	Gruen 3 and 5
Male	N	36	36	36	36	36	36
	Average	66.97	28.89	1.116	2.496	2.1605	2.049
	SD	8.772	3.223	0.237	0.433	0.402	0.355
	Minimum	45	22	0.615	1.253	1.169	1.152
	Maximum	83	34	1.495	3.025	3.100	2,758
Female	N	72	72	72	72	72	72
	Average	68.15	28.03	0.924	1.766	1.822	1.674
	SD	8.625	5.234	0.228	0.398	0.493	0,388
	Minimum	42	18	0.584	1.031	0.754	0.437
	Maximum	90	41	1.418	3.132	3.302	2.568
Total	N	108	108	108	108	108	108
	Average	67.76	2831	0.988	1.927	1.934	1.799
	SD	8.651	4.76	0.247	0.468	0.490	0.415
	Minimum	42	18	0.584	1.031	0.754	0.437
	Maximum	90	41	1.495	3.132	3.302	2.758

N – number, SD – standard deviation

TABLE 4
LOGISTIC REGRESSION PREDICTION OF SELECTED VARIABLES ON THE HARRIS HIP SCORE

Variable	B	SE	χ^2	DF	p	Relative risk	95% confidence interval	
							Lower	Upper
Years after operation	–0.131	0.059	4.904	1	0.027	0.877	0.781	0.985
Age	–0.059	0.031	3.679	1	0.055	0.943	0.888	1.001
BMI	0.057	0.060	0.910	1	0.340	1.059	0.941	1.191
Gruen 1 et 7	1.229	1.772	0.481	1	0.488	3.417	0.106	110.22
Gruen 2 et 6	2.506	1.124	4.968	1	0.026	12.254	1.353	110.99
Gruen 4	0.373	0.547	0.464	1	0.496	1.452	0.497	4.243
Gruen 3 et 5	–2.468	1.110	4.941	1	0.026	0.085	0.010	0.747

B – coeffitient of regression, SE – standard error, DF – degree of freedom, Relativ risk – e^B

TABLE 5
VALUES OF BODY MASS INDEX INRELATION TO THE HARRIS HIP SCORE AND TESTING DIFFERENCES

BMI	N	Median	25%	75%	Minimum	Maximum	Kruskal Wallis test
Normal <25 kg/m²	28	80.00	78.00	83.50	70.00	88.00	χ^2=1.312
Fat 25–30 kg/m²	46	82.00	78.00	84.00	35.00	89.00	DF=2
Obese >30 kg/m²	34	82.00	79.50	84.00	62.00	97.00	p=–0.519

Discussion

The most frequent indication of hip endoprosthesis is arthrosis, aseptic necrosis, trauma, post-traumatic state and tumors. The patient decides to have an operation with the onset of pain, contracture and limping associated with a shortened walked distance and reduced quality of life. Hip arthroplasty is an operational procedure used to remove a naturally ill joint and implant an endoprosthesis. The aim of the operation is to reduce difficulties, improve mobility and quality of life, and to maintain the recovered conditions for as long as possible. The clinical outcome is best described by scales containing standard questions relating to pain and functioning following a hip arthroplasty. We used the Harris hip score for measuring clinical results. We obtained good marks that were within the Harris score for asymmetric distribution. A good functional result is the goal of hip arthroplasty. Clinical results were good for both women and men $p>0.05$. The bone densitometry method allowed us to measure BMD of periprosthetic bones. The main part of the endoprosthesis is shaped like a wedge that is fixed along with adjacent dies to the femur. The area of best contact between the main section of the endoprosthesis and femur provides the greatest loading transfer[9]. These are zones 2 and 6, as well as 3 and 5 according to Gruen. The proximal part of the femur, Gruen's zones 1 and 7 remain without contact with the endoprosthesis and without any loading. The adaptation process on the applied loading commences immediately following implantation of the endoprosthesis and finishes at the end of the first year following the operation[10].

The roentgen image recording shows bone atrophy of the proximal femur, and an increase, or maintaining of the femur bone density around the lower section of the endoprosthesis. This occurrence in literature is called stress shielding[8]. The best way for fixation is a press fit system with wide and tight wedging[9]. A dual photonic densitometry provides an exact measurement of periprosthetic bone mineral density and eliminates a subjective assessment of the roentgen image recording measurement accuracy is 1%[11,12]. The results of our measurements showed as with all other authors a lower bone mass of the proximal femur, Gruen's zones 1 and 7, and more bone mass in the load transfer location, Gruen's zones 2 and 6, including 3 and 5. Measurements were carried out for various types of endoprosthesis implanted by various surgeons in various orthopaedic clinics. The time interval from the endoprosthesis implantation to the measurement varied from one to twenty years.

This data shows that for non-complicated primary hip arthroplasty there is regularity of bone adaptation regardless of the time passing from implantation and type of endoprosthesis. Endoprosthesis is implanted into older people. The research sample included 72 women and 36 men with an average age of 67.7 years. At that age, there is osteoporosis in both sexes, especially in women. In regards to non-complicated hip endoprosthesis, adaption of the periprosthetic bone mineral density to changes in loading is noticeable also for osteoporotic bones. The control group using the tested sample was BMD of lumbar spine. There is a statistical link between the values of periprosthetic bone mineral density and spine ($p<0.05$). The respondents with a greater BMD of lumbar spine have a greater periprosthetic BMD. Adaptation of bone mass to a changed loading due to an implanted endoprosthesis differs from osteolysis around the endoprosthesis that occurs as an 'small particles' illness. In that case, granulomes occur which cause a looseness of the endoprosthesis with all the possible associated consequences[8]. This is an altogether different process whereby the mechanical factor has a supplementary role.

A smaller periprosthetic BMD was measured in women. Logistical regression showed that a loss of periprosthetic BMD in the proximal femur, Gruen's zones 1 and 7, are not statistically significant for clinical outcomes ($p>0.05$, Table 4). Larger values of BMD for Gruen's zones 2 and 6, including 3 and 5 are statistically significant for a better clinical outcome ($p<0.05$, Table 4). The time that passes from the operation had negatively affected the clinical result ($p<0.05$, Table 4). The BMD of Gruen's zone 4 under the hip endoprosthesis has a full loading, as does the healthy bone. A link was not established with the clinical outcome. It seems that adaptation of bone structure to a loading change according to Woolf's law is the best structural response to biomechanical changes caused by implanted endoprosthesis. The acquired results show that loading changes following arthroplasty is the main factor in remodelling and maintaining periprosthetic bone mineral density following an non-complicated hip arthroplasty[8,10,12–14].

Statistical analysis showed that adaptation of bone changes around the hip endoprosthesis did not have a negative effect on the clinical outcome. The Body mass index in the research sample did not negatively affect the functional outcome nor the periprosthetic BMD.

Conclusion

The results from our research showed a good functional result following hip arthroplasty and specific remodeled bone according to the mechanical influence of transferring forces from the endoprosthesis. In non-complicated primary arthroplasty, such a condition lasts for a number of years. Subjective assessments of roentgen image recordings can now be very precisely repeatedly measured using dual photonic densitometry. The statistical analysis of results shows that adaptation of bone structure to changes in mechanical loading does not have a negative impact on the clinical outcome.

Acknowledgements

We would like to express our gratitude to employees the Chair of Statistics at the Andrija Štampar School of Public Health, University of Zagreb. We thank to prof. Mirjana Kujundžić Tiljak and Mr. Milivoj Skiljevic for excellent help with the statistical analysis.

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KLINIČKI ZNAČAJ PROMJENE KOŠTANO MINERALNE GUSTOĆE OKO ENDOPROTEZE KUKA

SAŽETAK

Ugradnja endoproteze kuka mijenja mehanička opterećenja u kuku. Promjena opterećenja izaziva remodeliranje kosti. Gubitak opterećenja dovodi do atrofije kosti, a povećanje opterećenja dovodi do hipertrofije kosti. Istražili smo odnos kliničkog rezultata i promjene koštano mineralne gustoće periprotetičke kosti. Za mjerenje kliničkog ishoda korišten je Harris hip scor. Metodu dvostruke fotonske denzitometrije koristili smo za mjerenje koštano mineralne gustoće periprotetičke kosti. Obrađeni rezultati pokazali su da gubitak koštane mase oko endoproteze kuka nema utjecaja na klinički ishod operacije. Hipertrofija kosti ima pozitivan rezultat na klinički ishod. Dob bolesnika, spol i tjelesna težina u istraživanoj populaciji nisu imali negativni utjecaj na funkcionalni status. Vrijeme proteklo od operacije do mjerenja negativno utječe na funkcionalni status.