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original article

Densitometric changes of the patella in patients undergoing unilateral knee arthroplasty

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SUMMARY: **Densitometric changes of the patella in patients undergoing unilateral knee arthroplasty**

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Introduction. *Although the intervention of knee arthroplasty became routine, there is no standard reference on the densitometric characteristics of the patella before and after surgery. Scope of this work is the evaluation of patellar bone density before and after unilateral knee arthroplasty.*

Patients and methods. *BMD was assessed by DEXA examination in 146 individuals, who have been divided into three distinct groups. Group I: 68 subjects with a mean age of 70.6 years, with an unilateral femoral-tibial knee prothesis. Group II: healthy subjects of similar age (average: 64) and without implants. Group III: healthy adults with a mean age of 26.6 years. The follow-up was performed at 6 months to a maximum of 2 years post surgery.*

Results. *The results were obtained from 68 subjects examined with the DEXA software dedicated to the forearm, which turned out to be the most appropriate for our purpose.*

The follow-up performed every 6 months after surgery showed a reduction of the density values in the operated knee in the 1st control with a return to the pre-surgiucal situation in the control performed after 1 year. In subsequent checks there was a further increase of the patellar density of the operated knee.

Conclusion. *Patellar DEXA examination is recommended as an addition to the clinical and radiological standard examination.*

KEY WORDS: Knee arthroplasty - Patellar bone density - DEXA examination - Osteoporosis.

Introduction

For several years we have witnessed the development of different densitometric techniques, including DEXA (Dual Energy X-ray absorptiometry) for the non-invasive examination of the bone matrix. These techniques, with the aid of special software to scan specific bone segments, the lumbar spine and the hip in particular, but also to perform "whole body" examination, are able to provide an analysis of the three components of body composition (bone mass, fat mass and lean mass) in total or in sections (1-6).

The data of bone mass obtained from the scan is shown automatically on a standard reference chart for age, sex and ethnicity; the densitometric diagnosis is based on the T score and Z score (7-12).

Hip replacement surgery has become routine and in recent years also involvement of knee arthroplasty in patients with especially severe arthritic and degenerative changes, that seriously affect the function, is increasing (3).

Although there is no standard reference in the literature regarding the densitometric characteristics of kneecaps before and after surgery.

The aim of our study was to precisely assess bone density in the kneecaps of patients with tibiofemoral knee prothesis with DEXA examination and to compare the bone density of the kneecaps before and after unilateral knee arthroplasty.

The study was carried out regardless of the type of surgical procedure performed and the type of prosthesis implanted.

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Patients and methods

BMD was assessed by DEXA examination in 146 individuals, who have been divided into three distinct groups.

The first group was represented by subjects with unilateral femoral-tibial knee protheses, the second group consisted of healthy individuals of the same age without a prosthetic knee and the third from healthy young adults.

The first group eas formed by 68 subjects: 20 males and 48 females, aged between 44 and 86 years, mean age of 70.61 years. Among males the age range was between 44 and 86 years, with an average age of 70.7 years, while for women the age range was between 55 and 79 years with a mean age of 70, 58. All patients had knee replacement surgery during the period 2012-2017. All subjects in this first group were suffering from knee arthritis, except for a 44 year old male suffering from rheumatoid arthritis. Within this group the patellar BMD of 32 subjects was examined before and after surgery, the other 36 were examined only after surgery.

The second group consisted of 44 subjects: 10 men and 34 women, aged between 46 and 85 years with a mean age of 64 years. The age range of males was between 49 and 85 with a mean age of 67.6 years, the women were between 46 and 78 years with a mean age of 62.94 years. This group represented the Z-Score control group.

The third group consisted of 34 subjects: 16 males between 24 and 27 with a mean age of 27.55 years and 18 females aged between 24 and 30 with a mean age of 26.58 years.

The subjects of group II and III were neither affected nor diagnosed with osteoarthritis and / or osteoporosis and the incidental finding of these diseases during the study led to their exclusion.

For the study the latest model of DEXA equipment has been used (QDR 4500W; Hologic, Massy, France) using fan beam technology with low-dose incident to the patient and an automatic calibration and stabilization.

All subjects underwent DEXA examination of the left and the right patella. We considered it appropriate (given the lack of reference standard) that the subject is positioned in a lateral decubitus with the limb of interest in contact with the bed and the knee flexed approximately 30 ° -40 °. We decided to run a scan length of about 10-12 cm, lasting about 120 seconds and to use the standard software installed in the Hologic densitometers for analysis. We used two analysing programs. One, originally dedicated to the lumbar spine, for two different densities of tissue: bone and soft. The other one is designed to scan the forearm, which involves in addition to soft tissue and bone, the presence of air, which is from importantce in the patellar examination in contrast to the scan of the lumbar spine. Then we created two subgroups by deviding each group in halves (patients, control Z-Score and control T-score) using for each half a different type of software. One half underwent DEXA examination of the patella with the software for the lumbar spine, the other one with the software dedicated to the forearm.

Then we determined an area that included not only the kneecap but also a part of the femur and leg (Global ROI). Further we manually created an ROI that included only the bone structure in question, so the result was exactly the bone mineral density (BMD) of the patella in lateral view.

The follow-up of the patients undergoing surgery was performed at intervals of about six months for a total of 2 years post intervention.

Results

The results obtained from the 73 subjects examined with DEXA software for the lumbar spine were excluded from the discussion and the following conclusions. The reason was that this program delivered less reliable data due to the problem that it does not include the air in the calculation, which is present in the region of the patella. In the end only the results from 68 subjects who underwent DEXA examination using the software dedicated to the forearm were included, which turned out to be the most appropriate for our purpose. 5 subjects were excluded because their results showed a bone disease. 2 of them were part of the Z-score group and 3 of the T-score.

Finally there remained 34 patients with unilateral femoral-tibial knee prothesis, of which 16 were examined densitometrically before and after surgery,

the other 18 only after the surgery. The second group was represented by 20 healthy subjects of the same age without a knee prothesis and the third group was composed of 14 healthy young adults.

The results of the patellar BMD, expressed in g/cm^2, obtained in the entire group of 34 patients, were as follows: a minimum of 0.386 g/cm^2 (knee with prosthesis, subject with pronounced porous bone - osteoporosis), value maximum 1,707 g/cm^2 (knee without prosthesis, subject with greater bone density - osteoarthritis), the discrepancy was 1.321 g/cm^2.

The comparison between left and right knee revealed the following data: 0.034 g/cm^2 minimum deviation (approximately equal BMD results between the kneecaps), maximum deviation 0.622 g/, the average is found to be 0.277 g/cm2.

In the 16 subjects underwent DEXA examination before surgery, however, the mean difference was slightly higher, 0.298 g/cm^2. The two values are close to each other. This is due to the fact that the follow-up of the subjects examined only after the intervention ranged to two years.

The BDM gap between the knee-caps of the operated patients tends to increase during the first six months of post operative follow-up, since then the difference in density is reduced by the increasing density of the patella of the knee with prosthesis (Fig. 1 and 2).

In the Z-Score group we obtained the following values for all subjects: a minimum of 0.782 g/cm2, a maximum of 1503 g/cm2, total difference 0.721 g/cm2. Between one knee and the other, the minimum gap was 0.006 g/cm2 and the maximum 0.096 g/cm2 with a mean of 0.058 g/cm^2.

In the T-score group results have appeared unsurprisingly higher on average in all subjects. Values went from 0.944 g/cm2 to 1.1342 g/cm^2 with a difference of 0.398 g/cm2 (lowest among the three groups). A comparison between the kneecaps showed a minimum difference of 0.010 g/cm^2 and a maximum of 0.090 g/cm^2 and an average of 0.052 g/cm^2.

The average difference of patellar bone density was therefore 0052 g/cm^2 for the T-Score group and 0058 g/cm^2 for the Z-Score group.

Discussion

The healthy young adults (T-score) showed a difference in bone density between their kneecaps of about 0.05 g/cm2, the group of healthy elderly subjects showed nearly the same difference in bone density between their kneecaps of about 0.05 g/cm^2.

We could call this number therefore the physiological difference in patella bone density. This is only a very small percentage of bone mass (5/1000).

In the group of patients we obtained much higher differences, 0.277 g/cm^2 for the group of subjects with prostheses and 0.298 g/cm^2 for those who are about to undergo prosthesis, which represent a bone mass difference of about 25%. In comparison to the control groups these are absolutely non-physiological values, we might even call them pathological. This is an important result, since in present scientific literature there is no standard reference value of density difference of the physiological and pathological patella.

It is interesting that with age you can face a lowering of patellar bone density or an increase of the same, but in spite of these fluctuations the density difference between both kneecaps tends to remain constant (0.05 g/cm^2) (13).

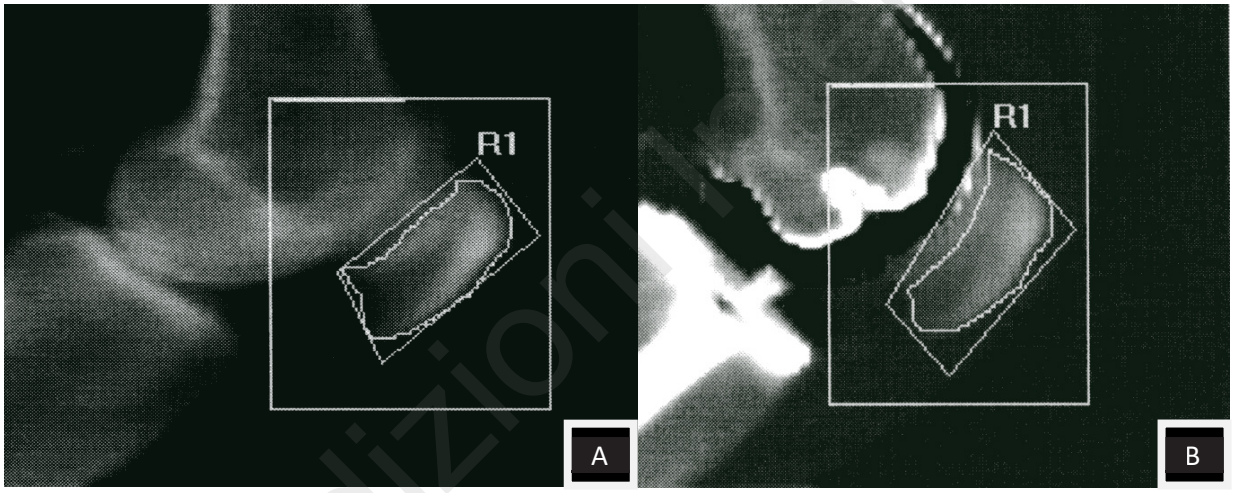
In fact, the density of the healthy knee patella (the non-arthritic) is higher than that of the arthritic knee (the one to undergo prosthesis) and deviation is high (Table 1). Furthermore there is an increase of density difference in the first six months after surgery (Figure 1 A, B). Afterwards the difference between the knee-caps tends to be reduced by the increasing density of the patella of the operated knee (Figure 2 A, B). However, the density of the not operated knee cap is never exceeded.

The reason for this process is supposed to be the immobility previous to the knee surgery. If a knee is arthritic and painfull, then it's also hypomobile and especially patellar bone mass is lost. Although the presence of patellar osteophytes suggests a thickening of bone mass, the results obtained in our study show that the patella is strongly porotic.

We asked about the functional recovery of the patients during interviews and it was shown that individuals with lower bone density difference bet-

TABLE 1 - SCHEME OF PATELLAR BONE DENSITY BEFORE AND AFTER INTERVENTION. THE DENSITY OF PATELLA OF THE OSTEOARTHRITIC KNEE IS LOW AND DECREASES EVEN MORE IN THE FIRST 6 MONTHS AFTER SURGERY. FROM 6 MONTHS TO 1 YEAR THEN A RECOVERY OF BONE MASS UP TO THE VALUE PREVIOUS TO THE INTERVENTION TAKES PLACE AND ABOUT 1 YEAR LATER THE INITIAL VALUE IS PASSED WITH A STEADILY INCREASING TREND.

Arthritic Knee	<density compared to the healthy knee (middle difference 0.298)	Before Surgery
Knee with prothesis	<<density compared to the healthy knee (average value of the scrap 0.306)	After Surgery (0-6 months)
Knee with prothesis	<density compared to the healthy knee (average value of the scrap 0.297)	After Surgery (6 months - 1 year)
Knee with prothesis	density approaches the healthy knee	After Surgery (from 1 year onwards)



DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)
GLOBAL	4.98	4.76	0.955
R1	4.81	4.66	0.970
NETAVG	4.81	4.66	0.970

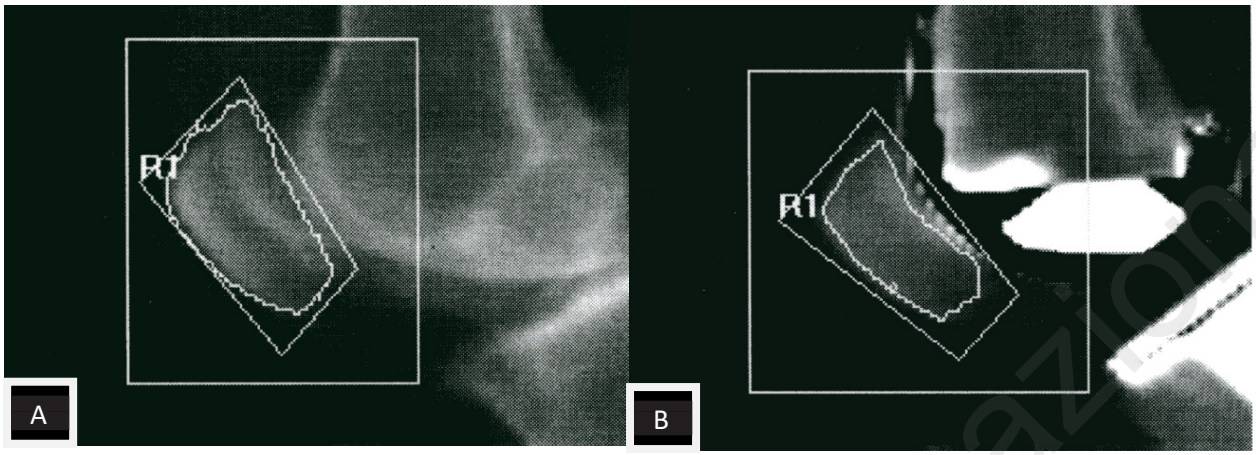
DXA Results Summary:

Region	Area (cm²)	BMC (g)	BMD (g/cm²)
GLOBAL	5.28	5.15	0.975
R1	5.07	5.01	0.988
NETAVG	5.07	5.01	0.988

Figure 1 A, B - Evaluation of BMD in patients before surgery and 6 months after surgery. A modest reduction of patellar bone density is shown.

ween the kneecaps had a better functional recovery, whereas those with a higher difference within the knee-caps, had a more difficult recovery.

At present there are no scientific studies about BMD of the patella before and after total knee arthroplasty. However, it exists an article by Soninvaara et al. about the DEXA examination of the distal femur with a single post operative follow up after one year and the BMD results are very similar to those we encountered in the same period. They reported that after one year the bone mineral density is indeed substantially similar to the pre-interventional status, thus corroborating our data, which show also an increase in density with recovery to the pre-



DXA Results Summary:

Region	Area (cm^2)	BMC (g)	BMD (g/cm^2)
GLOBAL	4.88	3.69	0.756
R1	4.88	3.69	0.756
NETAVG	4.88	3.69	0.756

DXA Results Summary:

Region	Area (cm^2)	BMC (g)	BMD (g/cm^2)
GLOBAL	7.08	4.99	0.705
R1	7.08	4.99	0.705
NETAVG	7.08	4.99	0.705

Figure 2 A, B - Evaluation of BMD in patients before surgery and 1 year after surgery. An increase of the bone density values of the patella can be seen.

interventional values after a first phase of reduction in the follow up after six months (14). There is also another work of Ishi et al. regarding the BMD of the proximal femur, which shows that there is an increase in BMD in the second year after total knee arthroplasty also in this area (15).

A recent work by Van Jonbergen et al. of 14 patients who underwent unilateral patellofemoral arthroplasty also demonstrated a small decrease in bone density of 15% in the peri-prothetic area and of 8% at the distal diaphysis of the operated femur after approximately one year and does not show significant differences in the not operated knee (16).

Conclusion

Physiologically, the kneecaps both have the same bone density that was found to be 1.21 g/cm2 in average (T-score), with a slight difference in density between one patella and the other of about 0.05 g/cm^2. This density difference is physiological in young healthy adults with peak bone mass and in healthy elderly. In the absence of pathological events this discrepancy tends to remain constant.

The kneecaps in the group of subjects with protheses are presenting a density difference much greater than 0.05 g/cm^2, in average 0.277 g/cm2 and 0.298 g/cm^2, values that seem abnormal. In fact, a lack of patellar homogeneity implies a pathological event.

The density of the patella of the arthritic knee is lower than the patellar density of the healthy knee. After implantation of the prosthesis the patellar density continues to decline for a period of about six months. In the following six months the kneecap tends to restore bone mass.

Patellar DEXA examination is recommended as a study supplement to the clinical and radiological standard because it is able to provide additional information to determine when to intervene surgically, based on the values of patellar bone density.

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