

Densitometric kneecap changes after unilateral knee arthroplasty

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Abstract. – PURPOSE: To assess bone density of kneecaps in subjects with femoro-tibial prosthesis before and after surgery by means of DEXA examination.

SUBJECTS AND METHODS: We examined 34 patients with unilateral femoro-tibial prosthesis, 20 healthy subjects of the same age and non-carriers of knee replacement and 14 healthy young adult subjects.

All the data sets were analysed by two radiologists (AS and AM). The coincidence of the results between the two specialists was evaluated by means of Cohen's Kappa index and the results were considered statistically significant if p value is $<$ of 0.05.

RESULTS: The values of patellar BMD in the group of 34 patients, were: a minimum of 0.386 g/cm² ($K = 0.879$, $p = 0.0012$), a maximum 1.707 g/cm² ($K = 0.886$, $p = 0.0016$). The comparison between the left and right knee showed the following data: minimum difference 0.034 g/cm² ($K = 0.901$, $p = 0.0015$), maximum difference of 0.622 g/cm² ($K = 0.908$, $p = 0.0017$), the average was found to be of 0.277 g/cm² ($K = 0.894$, $p = 0.0018$). But this difference tends to decrease 6 months after surgery.

In the group of healthy young adults, we obtained the following values: a minimum of 0.782 g/cm² ($K = 0.907$, $p = 0.0025$), maximum 1.503 g/cm² ($K = 0.932$, $p = 0.0012$). Between both knees, the difference was minimal 0.006 g/cm² ($K = 0.951$, $p = 0.0035$) and maximum 0.096 g/cm² ($K = 0.926$, $p = 0.0007$) with an average difference of 0.058 g/cm² ($K = 0.954$, $p = 0.0026$).

In the group of healthy subjects of the same age and non-carriers of knee replacement the values were average higher. A maximum value of 1.134 g/cm² ($K = 0.894$, $p = 0.0028$) and a minimum value of 0.944 g/cm² ($K = 0.892$, $p = 0.0023$) were found; between both knees a minimum difference of 0.010 g/cm² ($K = 0.918$, $p = 0.0047$) and a maximum of 0.090 g/cm² ($K = 0.937$, $p = 0.0017$) were found, with an average difference of 0.052 g/cm² ($K = 0.956$, $p = 0.0024$).

CONCLUSIONS: DEXA examination of the patellar is recommended as a supplementary study to the clinical and radiological standard exams because it is able to provide additional

information to determine when to intervene surgically, on the basis of patellar bone density values.

Key words:

Patellofemoral arthroplasty, Bone mineral density, Knee osteoarthritis.

Introduction

For several years we have witnessed the development of several densitometric techniques for the non-invasive study of bone matrix, including DEXA (Dual Energy X-Ray Absorptiometry). Such techniques with the aid of dedicated software, enable the scanning of both specific bone segments, in particular the lumbar spine, hip and the "whole body" examination, providing an analysis of the three components of the body composition (bone mass, fat mass and lean body mass) plus possibly a fourth district which is the air¹⁻⁶.

The values of bone mass obtained from the scan are shown automatically on a standard reference chart for age, sex and ethnicity; the densitometric diagnosis is based on the T-score and the Z-score⁷⁻¹².

Hip replacement surgery is become a routine by now and in recent years there has been an increasingly spreading of knee arthroplasty especially in patients with severe degenerative and arthritic changes which may seriously compromise articular function.

Up to now standards regarding the densitometric characteristics of the kneecaps before and after surgery do not exist in the literature.

The aim of our study is precisely to assess bone density of kneecaps in subjects with femoro-tibial prosthesis before and after surgery.

The work was carried out regardless the cause of knee replacement (arthrosis or arthritis) and regardless the type of prosthesis implanted.

Subjects and Methods

This prospective study was approved by the Ethics Committee, and all patients gave written informed consent. From January 2010 to April 2012, 146 individuals divided into three distinct groups underwent DEXA examination for the assessment of the BMD of the knee. The first group was represented by 68 subjects (mean age 70.6 years) with unilateral femoro-tibial prosthesis, the second group was composed by 41 healthy subjects of the same age and non-carriers of knee prosthesis (mean age 60.4 years) and the third group by 37 healthy young adults (mean age 26.6 years).

For the study was used DEXA equipment model QDR 4500 W (Hologic, Massy, France) that uses Fan Beam technology with low dose incident to the patient, an automatic calibration and stabilization system and a system which produces two energy levels, named "pulsed power", so that the X-ray tube is rapidly switched on two different levels of 100-140 KVP.

All subjects underwent DEXA examination of both kneecaps. Given the lack of standard reference, it was considered appropriate to position the patients in lateral decubitus with the affected limb in contact with the bed and the knee flexed to approximately 30°-40°; the scan length was of about of 10-12 cm and the duration of about 120 sec. Two types of software were used, initially the one dedicated to the lumbar spine, which provides bone and soft tissue density and after the one dedicated to forearm, which as well as bone and soft tissue densities, takes also into account the the presence of air (because in forearm densitometry there is the measurement of X-rays in air, which does not happen at the level of the lumbar spine).

An area that included in addition to the patella also part of the femur and the leg (global region of interest) was determined. The next step was performed automatically by the apparatus which recognize bony parts; it is only at this point that the operator intervened bleaching everything that was not patella, to be sure that the BMD measured concern exclusively the patella. Then, an ROI (region of interest) that included only the bony structure involved was manually created: the BMD thus obtained was the mineral density of the patella in lateral projection.

The follow-up in patients who underwent surgery was performed at intervals of about 6 months for a total period of 2 years.

All the data sets were analysed by two radiologists (AS and AM). The coincidence of the results between the two specialists was evaluated by means of Cohen's Kappa index and the results were considered statistically significative if p value is $<$ of 0.05.

Results

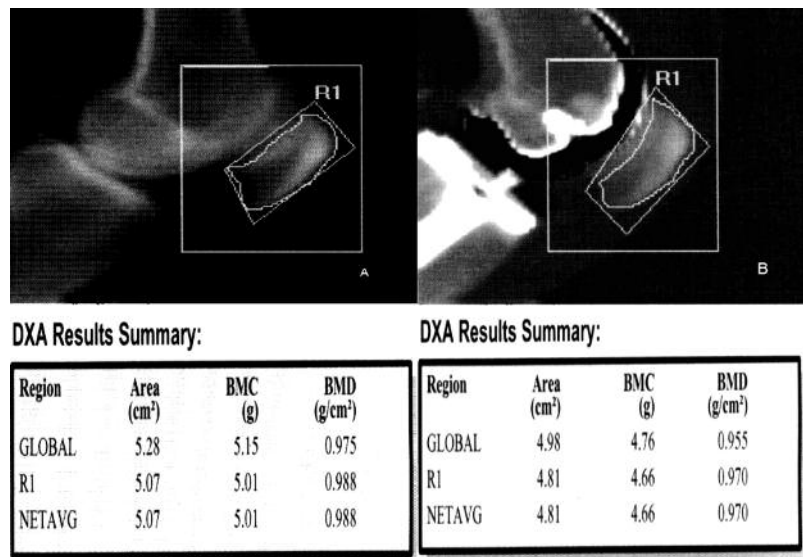
The results obtained from the subjects who underwent the DEXA examination of the patella with the software for the lumbar spine (78 patients) were excluded, as the data were unreliable, because the software used for the column does not include in its elaboration the presence of air, which is present in the region of the patella.

At the end the results were obtained from 68 subjects who underwent DEXA examination by means of software dedicated to the forearm, which was the most appropriate for our purpose.

Of 34 patients with unilateral femoro-tibial prosthesis examined, 16 underwent DEXA examination before and after surgery, the other 18 just after surgery; the healthy subjects of the same age and non-carriers of knee replacement examined were 20, while healthy young adult subjects were 14.

The values of patellar BMD, expressed in g/cm^2 , obtained in the group of 34 patients, were as follows: a minimum of $0.386 \text{ g}/\text{cm}^2$ (knee prosthesis, patients affected by osteoporosis) ($K = 0.879$, $p = 0.0012$), maximum value $1.707 \text{ g}/\text{cm}^2$ (knee without prosthesis, subject affected by osteoarthritis) ($K = 0.886$, $p = 0.0016$); the difference was of $1.321 \text{ g}/\text{cm}^2$ ($K = 0.892$, $p = 0.0011$). The comparison between the left and right knee showed the following data: minimum difference $0.034 \text{ g}/\text{cm}^2$ (BMD value approximately equal in both the kneecaps) ($K = 0.901$, $p = 0.0015$), maximum difference of $0.622 \text{ g}/\text{cm}^2$ (value of BMD more unequally between both kneecaps) ($K = 0.908$, $p = 0.0017$), the average was found to be of $0.277 \text{ g}/\text{cm}^2$ ($K = 0.894$, $p = 0.0018$). In the 16 subjects who underwent DEXA examination before surgery, however, the average of differences was slightly higher, that is $0.298 \text{ g}/\text{cm}^2$ ($K = 0.905$, $p = 0.0021$), because the values of bone density of the kneecaps of the knees which had to be restored, tend to be lower. The two values are close together, and this is to be attributed to the fact that the follow-up of the subjects after the intervention of prosthesis was between one and two years.

Figure 1. BMD evaluation in a patient prior to surgery (A) and 6 months after knee replacement (B) where a slight reduction of patellar BMD is shown.



Regarding the values of the differences between the two kneecaps encountered in patients who underwent a follow-up every six months after surgery, it was showed a further increase of the gap after the surgery between the knee and the unoperated knee prosthesis. The gap tends to increase during the six months following surgery, from that moment on, the difference in density between the kneecaps tends to decrease due to the increased density of the patella of the knee prosthesis (Figures 1 and 2).

In the group of healthy young adults, the following values were obtained: a minimum of 0.782 g/cm² (K = 0.907, *p* = 0.0025), a maximum 1.503 g/cm² (K = 0.932, *p* = 0.0012), total difference 0.721 g/cm² (K = 0.948, *p* = 0.0009). Between both

knees, the difference was minimal 0.006 g/cm² (K = 0.951, *p* = 0.0035) and maximum 0.096 g/cm² (K = 0.926, *p* = 0.0007) with an average difference of 0.058 g/cm² (K = 0.954, *p* = 0.0026).

In the group of healthy subjects of the same age and non-carriers of knee replacement the values were average higher. A maximum value of 1.134 g/cm² (K = 0.894, *p* = 0.0028) and a minimum value of 0.944 g/cm² (K = 0.892, *p* = 0.0023) with a difference of 0.190 g/cm² (K = 0.937, *p* = 0.0017) were found; between both knees a minimum difference of 0.010 g/cm² (K = 0.918, *p* = 0.0047) and a maximum of 0.090 g/cm² (K = 0.937, *p* = 0.0017) with an average difference of 0.052 g/cm² (K = 0.956, *p* = 0.0024) were found.

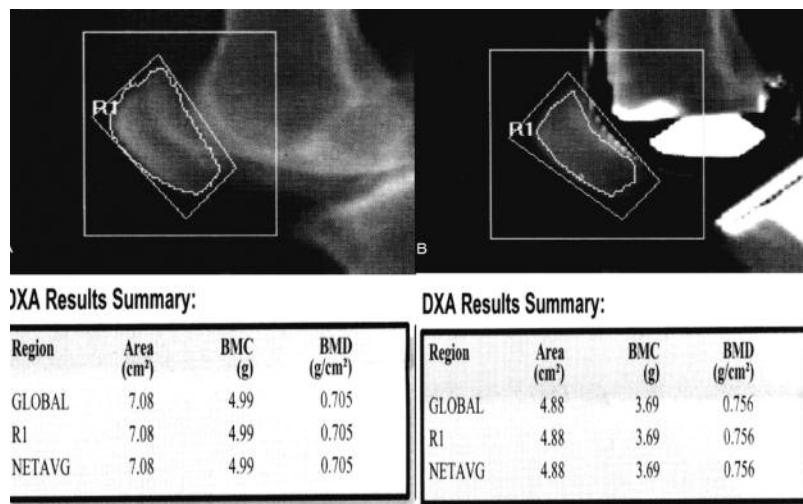


Figure 2. BMD evaluation in a patient prior to surgery (A) and 1 year after knee replacement (B) where an increase of patellar BMD is shown.

Discussion

Both healthy young adults subjects and elderly ones, showed a difference in bone density between the two kneecaps of about 0.05 g/cm^2 .

The value 0.05 g/cm^2 could be defined as a physiological value of difference of patellar bone density, which represents a percentage of bone mass very small ($5/1000$).

If instead the results obtained by the group of patients with knee prosthesis are analyzed, a much higher values are reached i.e. 0.277 g/cm^2 and 0.298 g/cm^2 , which represent a difference in percentage of bone mass by approximately of 25%; these ones are absolutely non-physiological values, which could also be defined as pathological.

This is an important result, because nowadays it does not exist in the scientific literature a standard value of the different physiological and pathological patellar density.

It is interesting to note that with the increasing of age it goes towards a lowering or rising of the patellar bone density, but in any case the density difference between kneecaps tends to keep steady (0.05 g/cm^2)¹³.

The maximum difference in density between the kneecaps there is in the group of subjects with implants (0.277 g/cm^2) and in those who are candidate to undergo prosthesis (0.298 g/cm^2).

In fact, the density value of the patella of healthy knee is higher than that of the arthritic one and the difference of density values is high. After surgery a further increase of the density value difference between the knee not operated and knee with prosthesis takes places; such difference tends to increase again in the six months following surgery and then, from that moment on, the difference in density between the kneecaps tends to decrease due to the increased density of the patella of the knee prosthesis.

The density of the patella of the knee joint affected by arthrosis is lower compared to healthy one and is even lower after the surgery for about 6 months; from 6 months to 1 year occurs then a recovery of bone mass up to reach the value before surgery and from about 1 year on, the initial value previous surgery is exceeded with a tendency to a steady increase which in any case does not exceed the density value of the patella of healthy not operated knee.

The reason for this event is supposedly due to immobility of the knee prior to surgery, that is, the more an arthritic knee is injured and, therefore immobile, the more patellar bone mass is dispersed.

Although the presence of patellar osteophytes in the arthritic knee suggests a thickening of bone mass, the results obtained from our study, however, show that the patella is strongly porotica.

Functional recovery of patients with prostheses was evaluated during anamnesis and we observed that individuals with lower bone density difference between the kneecaps, had a better articular functional recovery; on the contrary, those with a difference in bone density between the kneecaps highest presented a more difficult functional recovery.

At present, there are no scientific works that deal with the study of BMD of the patella before and after total knee arthroplasty. Nevertheless Soninvaara et al¹⁴, performing the examination at the distal femur in an only post-operative follow-up after one year, show BMD data very similar to those we encountered in the same period at the patellar level. In the follow-up at one year after surgery they reported the bone mineral density value substantially similar to that pre-surgery.

Ishi et al¹⁵ in a work concerning the BMD of the proximal portion of the femur show that even in this area there is an increase of BMD after 2 years after total knee arthroplasty, that is the analogue result we found at patellar level after a similar period of time.

In a recent work Van Jonbergen et al¹⁶ show in 14 patients at approximately one year after unilateral patellofemoral arthroplasty, a limited bone density decrease of 15% in the peri-prosthetic bone and of 8% in the distal diaphysis of the femur operated without significant differences in the non-operated knee.

Conclusions

The kneecaps have physiologically the same bone density that is on average of 1.21 g/cm^2 , with a slight difference in density between both patellae of about 0.05 g/cm^2 .

This difference in patellar density is physiological in young healthy subjects with peak bone mass and in healthy adult and elderly subjects; this data tends to keep steady over time, in the absence of pathological events.

Subjects with total femoral-tibial prostheses have instead a difference of patellar bone density greater than 0.05 g/cm^2 , that we estimated in 0.277 g/cm^2 and 0.298 g/cm^2 on average.

The density of the patella of the arthritic knee is lower than the density of the patella of the healthy

knee; after the implantation of prosthesis, the patellar density continues to decrease for a period of about 6 months, within six months after the kneecap tends to recover pre-surgery bone mass and within a period of 2 years after surgery has a bone density greater than that of presurgery time.

Conclusions

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

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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