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Muscular function and bone mass after knee arthroplasty

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Abstract We report a study of 28 women with severe primary gonarthrosis followed for 1 year. Variations in bone mineral density and in functional behaviour of knee extensors and flexors were studied before and after implantation of uncemented total knee prosthesis. A functional deficit was noted in the extensor apparatus, which increased in the first 6 months following surgery. This strength was not improved 1 year following the arthroplasty, but it was more efficient as shown by the reduction of muscle fatigue. Flexor strength was conserved and a pathological muscle balance was maintained, reaching maximum efficiency over a smaller joint range.

Résumé Etude des variations de la densité minérale osseuse et du comportement des extenseurs et fléchisseurs du genou avant et après implantation d'une prothèse totale non cimentée chez 28 femmes souffrant d'une gonarthrose primaire sévère et suivies pendant une année. Un déficit fonctionnel de l'appareil de l'extenseur à été noté avant l'intervention et a augmenté dans les six premiers mois suivant la chirurgie. La force d'extension n'était pas améliorée une année après l'arthroplastie, mais l'action était meilleure à cause d'une moindre fatiguabilité du muscle. La force des fléchisseurs a été conservée et un équilibre musculaire a été maintenu, en arrivant à l'efficacité maximale sur une plus petite amplitude articulaire.

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Introduction

The greatest changes in bone around porous implants occur during the 1st year after arthroplasty [3, 9, 16, 18]. Knee bone mass decreases in the first 3 months, but does this 'fall-off' continue [6, 12, 13, 15], or are the preoperative levels restored [3, 9, 18]? Most authors conclude that there is a bone mass loss behind the femoral shield [8, 10, 11, 13, 14, 15] and this is the reason that we studied bone mineral density variations at the femoro-patellar interface and in the region of the insertion of the patellar ligament.

Studies of the isokinetic muscular behaviour in gonarthrosis reveal wasting related to the degenerative process, but is this proportional to the degree of joint degeneration? Does it improve after surgery [17, 23] and when does recovery of muscle function begin?

This study seeks to answer these questions using a regional analysis of the bone mass together with examination of muscle behaviour in gonarthrosis during the 1st year after arthroplasty.

Patients and methods

We selected at random patients with primary gonarthrosis awaiting total knee athroplasty. The contralateral knees often with slight to moderate primary gonarthrosis were used as controls. To standardise the series, and because of their higher gonarthrosis rate, the sample was made up of 28 women with an average age of 65 (SD 4) years, average weight 72 (SD 9) kg., and average height 154 (SD 5) cm. None had undergone previous knee surgery and none had any relevant medical or orthopaedic conditions. The same type of porous biologically attached implant was used in all the patients (Tricon II; Smith & Nephew Richards, Memphis, Tenn., USA) with preservation of the posterior cruciate ligament and without osseous grafting or ligament balancing techniques. None of the patellae were resurfaced. Examinations were recorded preoperatively and at 6 months and 1 year after surgery.

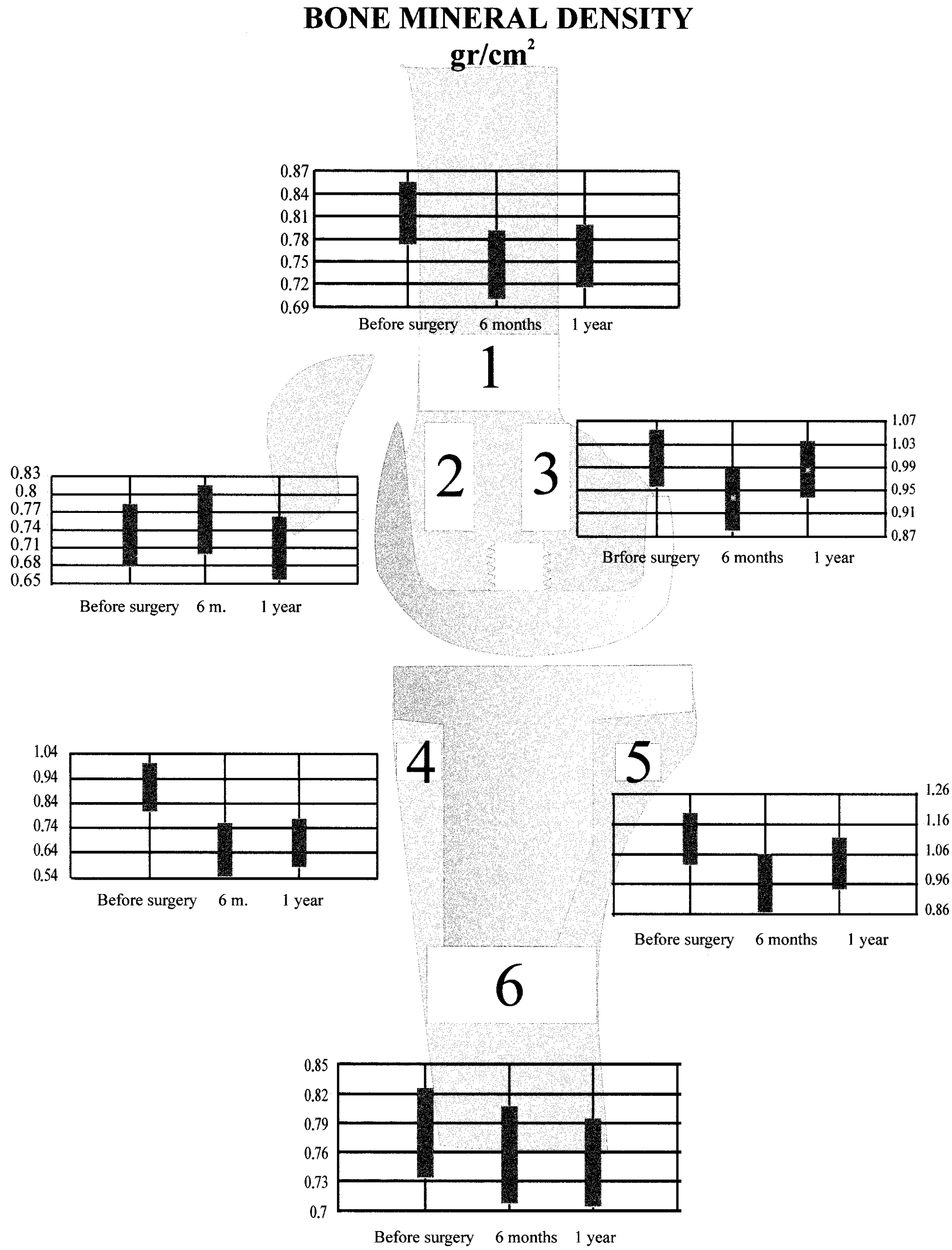

Fig. 1 Zones studied and bone mineral density preoperatively and at 6 months and 1 year postoperatively

The densitometric study was made using a dual X-ray photon absorptiometry (DEXA) with a Norland XR-26 densitometer (Norland, Fort Atkinson, Mo., USA). The bone mineral density (BMD) was measured in g/cm^2. The patients were placed in a standard position for the exploration in order to obtain the same lateral projections of the same areas in all the subjects. The zones studied are shown in Fig. 1. A whole-body study was also carried out to assess any changes in the bone mineral content of the trunk and body soft tissues.

An electromagnetic dynamometer (Biodex Medical Systems, Shirley, N.Y., USA) was used for the isokinetic study and in the concentric isokinetic mode at a speed of 60°/s. The following parameters were studied in flexion and extension and in both lower limbs: the maximum force momentum in Nm, the hamstrings-to-quadriceps relationship, the percentage fatigue rate, the joint angle at which maximum force momentum occurred ‘total work’ (*J*), and the average power developed (*W*).

Arthroplasty produced a mean angular correction of 9° (SD=7°), leaving an average varus angular deviation of 3°. According to the scale of the Hospital for Special Surgery [7] the mean preoperative score was 48/100 (SD=10) and at 1 year after replacement it was 82/100 (SD=9).

Statistical analysis was performed by calculation of one-way analysis of variance (ANOVA), and values below 0.05 were considered significant.

Results

Before operation, the areas of greatest bone mineral density (BMD) in both knees were in the intercondylar femoral (zone 3) and in the posterior tibia (zone 5; $P<0.05$;

Table 1 Angle-to-flexion maximum force momentum (angle-to-peak torque) in degrees

Exploration time	Side	Mean	Standard deviation	Mean standard deviation	Range
Before surgery	Control	61.08	13.201	2.940	43.0–93.0
	Gonarthrosis	64.90	15.022	3.453	31.0–90.0
6 months after surgery	Control	57.87	15.632	3.288	29.0–90.0
	Arthroplasty	48.28	18.645	3.861	0.0–72.0
1 year after surgery	Control	54.50	10.738	2.940	34.0–74.0
	Arthroplasty	52.95	12.855	3.453	36.0–81.0

Table 2 Angle-to-extension maximum force momentum (angle-to-peak torque) in degrees

Exploration time	Side	Mean	Standard deviation	Mean standard deviation	Range
Before surgery	Control	97.50	134.352	22.454	47.0–667.0
	Gonarthrosis	71.33	9.884	2.418	53.0–90.0
6 months after surgery	Control	68.50	13.711	25.105	45.0–90.0
	Arthroplasty	57.88	12.576	2.703	34.0–72.0
1 year after surgery	Control	89.15	99.651	22.454	54.0–511.0
	Arthroplasty	62.66	10.181	2.418	35.0–81.0

Fig. 1). When comparing both knees significant differences were found only in the anterior tibial region (zone 2), with significantly higher rates (P<0.05) in the knee awaiting operation. Six months after surgery the same BMD distribution persisted but had slightly decreased in both knees in 80% of the relevant areas. In the anterior tibial region a significant drop was observed in BMD (P<0.05) under the plateau anterior to the stem of the implant (zone 4). After 1 year the BMD distribution was the same as before surgery. In the anterior tibial area anterior to the stem of the implant the final decrease of BMD was significant (P<0.05), while there was no alteration in the control knee.

The maximum force momentum in extension of the treated knee dropped during the first 6 months after surgery (P<0.05), so that after 1 year its values were similar to those at the outset, with lower values (P<0.05) than in all the control knees. The angle of maximum force momentum dropped significantly after surgery (P<0.01) in the treated knees from 65° to 53° for flexion (Table 1), and from 71° to 62° for extension (Table 2), while the control knees revealed no significant differences when applying maximum forces in flexion and extension at greater angles (P<0.05). The index between hamstrings and quadriceps muscles was increased before operation in both knees (P<0.05) and it increased further during the 1st year after surgery. Muscular fatigue in extension dropped in the surgically treated knee (P<0.05) while the total work and mean power developed by the control knee were always higher (P<0.05) than in the surgically treated knee.

Discussion

In patients with degenerative knee disease the quadriceps activity drops by up to 50% [2] decreasing joint pressures and creating an abnormal walking pattern [1, 20, 23]. Berman et al. [2] found that the maximum force momentum in flexion with advanced gonarthrosis is 68% and in extension 59% of the value in the healthy knee, and that there were no significant variations 6 months after arthroplasty [21]. Our isokinetic study found a significant decrease of the maximum force in extension 6 months after surgery and that this recovers independent of rehabilitation. However, the extensor wasting of gonarthrosis persists, so that the maximum quadriceps force in the surgically treated knee was only 77% of the preoperative control knee, 69% after 6 months and 80% after 1 year. This suggests that it is necessary to wait at least 1 year before assessing post-arthroplasty muscle power. The reduction of fatigue resulting from the arthroplasty in the most demanding quadriceps function is explained by decreased patellar pain when the joint is subjected to high pressures. The surgically treated knee's maximum force occurs at smaller flexion angles after surgery and is always lower than that of the control knee. This means that the knee arthroplasty functions over a smaller range of flexion because the flexor-extensor muscles lose a substantial part of their efficiency above 60° flexion. The flexor-extensor relation initially was increased similarly in both knees although the joint degeneration was much more severe in one knee, thus making this relationship a sensitive measurement of joint degeneration. The total work and mean power developed in gonarthrosis and after arthroplasty were approximately 50% of that of young subjects [20].

Most authors mention that bone mass loss following arthroplasty [6, 9, 12, 15, 18] stabilises after 1 year and then decreases [3, 9, 18]. Our study revealed a non-significant drop in BMD after 6 months in 80% of the areas studied in both knees, and that this was related to factors such as postoperative trophic disorders, reduced muscular activity and assisted loading. During this initial period and after 1 year the BMD of the treated knee did not recover to its previous values. Overall, BMD variations were not significant during the 1st year post operation and this means that the arthroplasty did not alter the knee's overall BMD. Measurements of trunk BMD, total body fat, total soft tissue mass and fat and water in the lower limbs did not show significant differences at the end of the monitoring period.

Most authors [4, 8, 10, 11, 13, 14, 15] mention bone mass loss in the anterior region of the distal femur following knee arthroplasty. This is an asymptomatic phenomenon which arises during the 1st year, then ceases and can be explained by the so-called stress-shielding or local dysfunction due to proximal transfer toward the metaphysis of the physiological patellar pressures on the anterior femoral cortex, thus transforming it into a zone of low pressure leading to osteopenia which may allow either loosening of the implant, or the development of a fracture. In our study BMD in the anterior femoral region increased until the 6th month and then dropped after 1 year to below the preoperative levels although this was not statistically significant. If the concomitant anterior tibial dysfunction is taken into account, the bone mass in this region depends more on femoral-patellar pressures than on the joint load, whose main forces act posteriorly. This implies that patellar-femoral pressure varies little following an arthroplasty. It must be remembered that the anterior femoral area considered in this study does not extend distally toward the implant, and that this small distal zone adjacent to the femoral shield is the one which experiences dysfunction. This does not extend proximally and is limited to the anterior bevel surgical resection.

While most authors [3, 5, 22] have not reported post-arthroplasty changes in the tibia, in the present study a significantly higher BMD was found in the anterior tibial region of the knee which was to be operated on than in the healthy joint. This disappeared after arthroplasty and at 1 year; the values were similar in both knees. This suggests that there is an anomalous distribution of loads associated with the degenerative process, and a functional deficit in the extensor apparatus in gonarthrosis. This increased stress on its tendon, which produces an increased bone mass in the region of the anterior tibial tuberosity, disappears after arthroplasty.

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