THE JOURNAL OF BONE & JOINT SURGERY (Br)

The influence of osteoporosis on varus osteoarthritis of the knee

Masanori Terauchi, Kenji Shirakura, Masayoshi Katayama, Hiroshi Higuchi, Kenji Takagishi

From Gunma University, Gunma-ken, Japan

We studied 37 patients with varus osteoarthritis of the knee to determine the influence of the bone mineral density (BMD) on the varus deformity. There were 15 men (21 knees) and 22 women (38 knees). The mean age of the men was 69 years and of the women 68 years. BMD was measured in the L1-L4 spinal region using dual X-ray absorptiometry.

In the women a low level of BMD was associated with varus deformity originating at the proximal tibia, but a high level was predominantly linked with deformity originating in the joint space. Similar findings were obtained in the men.

Our results suggest that a low BMD predisposes to trabecular microfractures and consequently increased stress on the articular cartilage. A low BMD does not preclude osteoarthritic change in the knee.

J Bone Joint Surg [Br] 1998;80-B:432-6.
Received 26 September 1997; Accepted after revision 13 November 1997

Osteoporosis and osteoarthritis commonly affect the elderly and there have been many studies concerning the relationship between the two, especially in patients with osteoarthritis of the hip[1-10] and with more generalised degenerative changes.[6,11-14] They rarely occur together and it has been suggested that there may be an inverse relationship between them.[15,16] There have, however, been relatively few studies in patients with osteoarthritis of the knee.[17-20]

The association between bone mineral density (BMD) and osteoarthritis of the knee is uncertain. Hannan et al[18] found in women that the femoral BMD was higher in those with osteophytes at the knee than in those without and was not necessarily associated with narrowing of the joint space. Those with a higher BMD had an increased tendency to produce osteophytes. Hart et al[6] reported a small, but significant, increase in BMD in middle-aged women with osteoarthritis of the knee. Yokozeki et al,[20] investigating the relationship between osteoporosis of the spine and osteoarthritis of the knee, showed that the BMD was significantly higher in those with severe osteoarthritis than in normal patients, but Malluche et al[19] observed osteoporosis in all of their 12 patients who had had total knee arthroplasty for degenerative arthritis. Burr et al,[17] in a study of the skeletons of Eskimos, identified sex-dependent links between the bone mineral content of the midshaft of the tibia and osteoarthritis of the tibia; in women the level was low whereas in men it was high. Cluster analysis suggested that a greater than average bone mineral content may contribute to joint deterioration, but that a low level did not preclude severe osteoarthritic change.

Varus deformity of the proximal tibia is seen in many patients with osteoarthritis of the knee.[21] Yagi[22] studied the relationship between torsional and varus deformities of the proximal tibia, and suggested that osteoporosis is an important factor in the development and aggravation of such deformities. Our aim was to evaluate the influence of the BMD on varus deformity of the knee.

Patients and Methods

Varus osteoarthritis at the knee is defined by narrowing of the joint space with a loss of space between the tibia and the femur in the medial compartment to 50% or less of the value for the lateral compartment of the same knee. We studied 37 patients with this condition. The mean age of the 15 men (21 knees) was 69 years (59 to 76) and of the 22 women (38 knees) 68 years (54 to 83). Nine men had unilateral and six bilateral involvement; six women had unilateral and 16 bilateral wear. We excluded patients with rheumatoid arthritis and those who had suffered a fracture, undergone operation or received a steroid injection into the joint.

Standing anteroposterior (AP) radiographs were taken of the knee using 35 × 43 cm films with the patella facing directly forwards. Four angles were then measured to assess the varus deformity of each knee: the femorotibial (FT) angle between the anatomical axis of the femur and

M. Terauchi, MD, Instructor
K. Shirakura, MD, PhD, Associate Professor
M. Katayama, MD, Orthopaedic Surgeon
H. Higuchi, MD, Orthopaedic Surgeon
K. Takagishi, MD, Professor and Chairman
Department of Orthopaedic Surgery, Gunma University School of Medicine, 3-39-22 Showa-machi, Maebashi-shi, Gunma-ken 371, Japan.

Correspondence should be sent to Dr M. Terauchi.

0301-620X/98/38408 $2.00

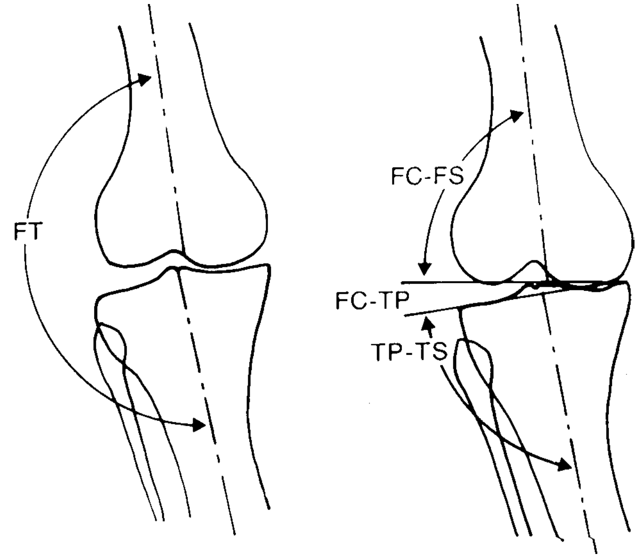

Fig. 1

Diagram to show the angles measured. The femorotibial (FT) angle was divided into three components: femoral condylar-femoral shaft (FC-FS) angle, femoral condylar-tibial plateau (FC-TP) angle, and tibial plateau-tibial shaft (TP-TS) angle.

Table I. Details of the 15 men and 22 women

	Men	Women
Mean (SD) age in years	69 ± 4.8	68 ± 7.9
Mean (SD) weight in kg	64.5 ± 6.7	60.0 ± 8.2*
Mean (SD) height in cm	160 ± 6.7	151 ± 4.8†
Mean (SD) BMD (g/cm^2)	0.990 ± 0.15	0.816 ± 0.14†
Mean (SD) BMI (kg/m^2)	25.7 ± 1.4	26.3 ± 3.3
Mean (SD) BMD:BMI ratio	0.386 ± 0.060	0.314 ± 0.065*

* significant at $p < 0.05$
† significant at $p < 0.01$

Table II. Measurements of the angles (degrees; mean ± SD) around the knee in both groups (see Fig. 1)

Angle	Men	Women
FT	182.6 ± 3.3	182.8 ± 3.0
FC-FS	81.3 ± 2.2	80.8 ± 1.8
FC-TP	6.0 ± 1.8	5.0 ± 2.4
TP-TS	95.4 ± 2.6	97.1 ± 2.2*
FC-FS/FT	0.446 ± 0.012	0.442 ± 0.010
FC-TP/FT	0.034 ± 0.009	0.027 ± 0.013*
TP-TS/FT	0.522 ± 0.11	0.531 ± 0.010*

* significant at $p < 0.05$

that of the tibia; the femoral condylar-femoral shaft (FC-FS) angle between the anatomical axis of the femur and the tangent to the subchondral plate of the femoral condyles; the femoral condylar-tibial plateau (FC-TP) angle between the tangents to the subchondral plates of the femoral and tibial condyles; and the tibial plateau-tibial shaft (TP-TS) angle between the tangent to the subchondral plate of the tibia and the anatomical axis of the tibia. The FT angle equals the sum of the FC-FS, FC-TP and the TP-TS angles (Fig. 1). The FC-FS/FT, FC-TP/FT, and TP-TS/FT angles were also calculated to determine which component angle was predominant in the varus deformity.

The BMD was measured in the L1-L4 region of the spine by dual X-ray absorptiometry using a Hologic QDR 1000 apparatus (Hologic, Waltham, Massachusetts). The body mass index (BMI), an indicator of obesity, was calculated as the weight divided by the height squared (kg/m^2) and the ratio of the BMD to BMI was calculated.

Statistical differences between the genders were analysed using Student's *t*-test. We used a linear regression model to evaluate the association between the BMD of the lumbar spine and varus deformity for both men and women.

Results

Table I gives details of the 15 men and 22 women. The BMD of the lumbar spine and the BMD:BMI ratio were significantly larger in the men than in the women. Table II summarises the values for the angles about the knee. There were no significant differences in the FT, FC-FS and the FC-TP angles between the genders, but the TP-TS and TP-TS/FT angles were significantly larger in the women, whereas the FC-TP/FT angle was greater in the men. The origin of the varus deformity was predominantly in the joint space in the men but at the proximal tibia in the women.

In the women the BMD correlated with the FC-TP/FT and TP-TS/FT angles ($R = 0.33$, $p < 0.05$ and $R = -0.62$, $p < 0.001$, respectively), but not the FC-FS/FT angle ($R = 0.15$, $p = 0.36$). The BMD:BMI ratio correlated with the FC-TP/FT angle ($R = 0.50$, $p < 0.01$; Fig. 2) and the TP-TS/FT angle ($R = -0.70$, $p < 0.001$; Fig. 3), but not the FC-FS/FT angle ($R = 0.05$, $p = 0.80$). Thus varus knees in individuals with a low BMD had a large varus inclination

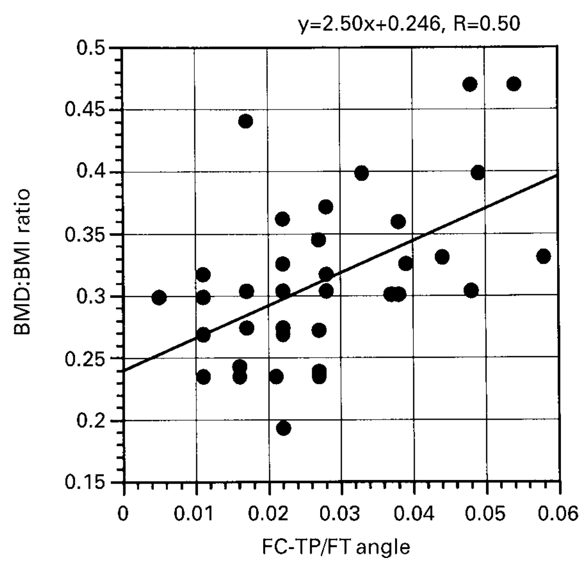

Fig. 2

The correlation between the FC-TP/FT angle and the BMD:BMI ratio in women.

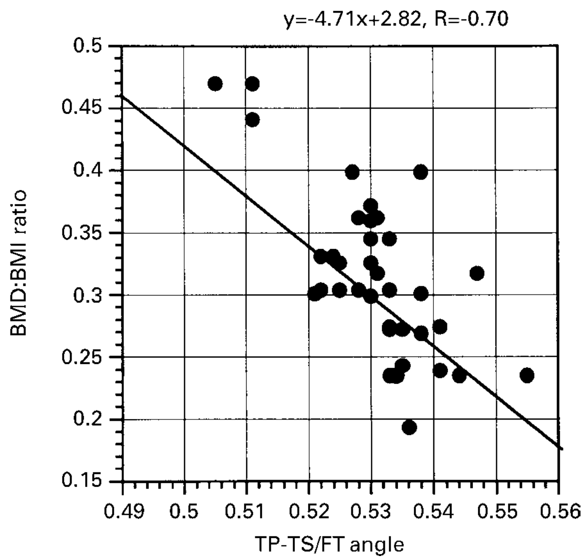

Fig. 3

The correlation between the TP-TS/FT angle and the BMD:BMI ratio in women.

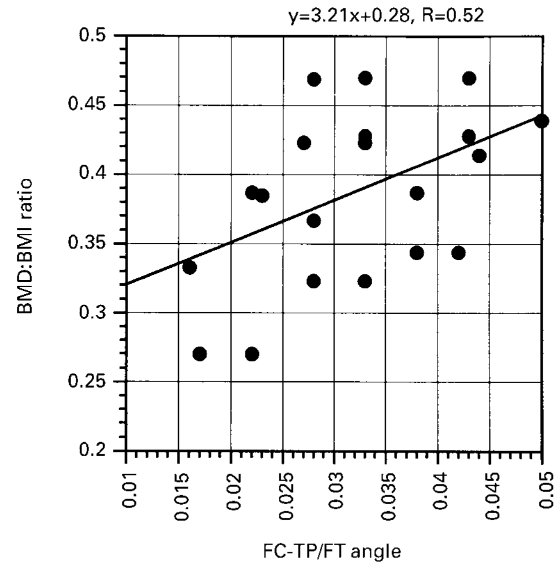

Fig. 4

The correlation between the FC-TP/FT angle and the BMD:BMI ratio in men.

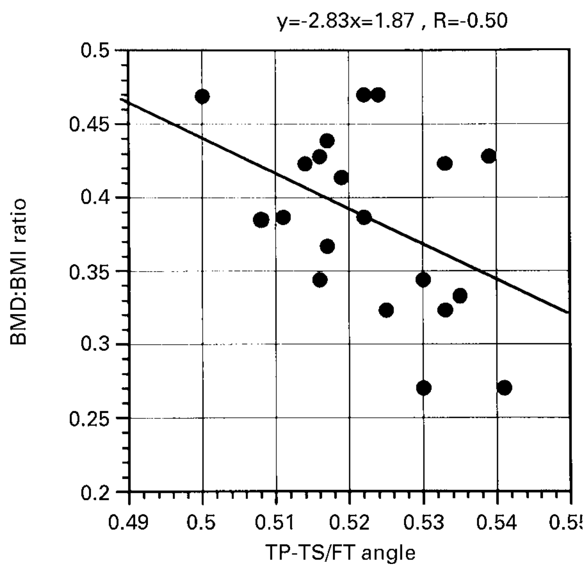

Fig. 5

The correlation between the TP-TS/FT angle and the BMD:BMI ratio in men.

of the proximal tibia, whereas a high BMD was associated with a large varus angulation at the joint.

In the men the BMD correlated with the FC-TP/FT angle ($R = 0.60$, $p < 0.01$), but not with the FC-FS/FT or the TP-TS/FT angle ($R = 0.24$, $p = 0.30$, and $R = -0.33$, $p = 0.14$, respectively). The BMD:BMI ratio correlated with the FC-TP/FT angle ($R = 0.52$, $p < 0.05$) (Fig. 4) and the TP-TS/FT angle ($R = -0.50$, $p < 0.05$) (Fig. 5), but not with the FC-FS/FT angle ($R = 0.03$, $p = 0.91$). Hence, when the influence of the body mass on BMD was not taken into account, a varus knee associated with a high BMD had a large varus angulation at the joint, but there was no relationship between BMD and varus deformity of the proximal tibia. When this was taken into consideration, the relationship between the BMD:BMI ratio and axial alignment was similar to that seen in the women.

Discussion

Previous studies on the relationship between osteoporosis and osteoarthritis have either compared the BMD of patients with osteoarthritis with that of normal subjects[1,2,9,12-14,19,20] or assessed its influence on the degree of osteoarthritis.[3,11,17,18] There has been none which has assessed the role of the BMD on varus deformity in osteoarthritis.

There is no clear standard classification of osteoarthritis. The most accepted method is that of Kellgren and Lawrence[23] which depends on the presence of osteophytes, but their significance in osteoarthritis of the knee is uncertain[24] and their presence may be more to do with ageing than with a specific disease process.[25] It is difficult to define osteoarthritis of the knee in normal elderly people simply by relying on the presence of osteophytes.

Altman et al[26] rated narrowing of the joint space as the most important means of assessing the progress of arthritic change on AP views. We therefore selected patients with narrowing of the joint space evident on weight-bearing films.[27] The effect of intra-articular steroid on joint cartilage has been described;[28,29] we therefore excluded patients who had received such injections from the study.

There is a clear link between obesity and osteoarthritis of the knee.[30,31] Davis, Ettinger and Neuhaus[32] thought this to be due to a mechanical rather than a metabolic mechanism and found that body-weight or the BMI generally correlated with the BMD.[33] Price et al[13] found an increase in trabecular BMD in osteoarthritic subjects when adjusting for age, but this difference disappeared on adjustment for

Fig. 6

Radiograph showing a varus deformity originating at the joint in a 54-year-old woman. The knee shows a large joint space opening with an FT angle of 186°, a TP-TS angle of 94° and an FC-TP angle of 10°. Her BMD was 1.18 g/cm^2.

Fig. 7

Radiograph showing a varus deformity originating at the proximal tibia in a 64-year-old woman. The knee shows a large varus inclination of the distal tibia with an FT angle of 182°, a TP-TS angle of 101° and an FC-TP angle of 2°. Her BMD was 0.74 g/cm^2.

skeletal size. Obesity may play an important role and we used the ratio of the BMD to the BMI to take account of the influence of body mass on BMD and the individual magnitude of joint load.

Varus deformity increases and concentrates the stress on the medial tibial condyle.[34] Wu et al[35] produced a model of malalignment by creating varus deformity in rabbit knees and noted degeneration of the cartilage. We used the FC-FS, FC-TP and the TP-TS angles to identify the relationship between the BMD and varus deformity.

We found a high BMD in women to be associated with varus deformity primarily involving the joint space (Fig. 6) and a low BMD was associated with lesions at the proximal tibia (Fig. 7). The relationships still held when the BMI was taken into account. Radin, Paul and Rose[36] and Radin and Rose[37] have proposed that the health of the articular cartilage depends on the mechanical properties of its bony subchondral bed. Increasing the stiffness of the underlying subchondral bone will increase the stress on the overlying cartilage, but osteoporotic bone is a good shock absorber and may protect the cartilage against peak overload. In the presence of repeated loading, the former results in cartilage damage while the latter predisposes to fractures.

Behrens, Walker and Shoji[38] showed that the compressive strength of trabecular bone correlated with the BMD of the knee and that trabecular bone could sustain compression microfractures which, in turn, resulted in varus deformity of the proximal tibia. Such malalignment concentrates stress on the medial tibial condyle and the trabecular microfracture stiffens the subchondral bone resulting in varus osteoarthritis of the knee. This may explain the occurrence of osteoarthritis of the knee and osteoporosis together.

In men, when the BMI is taken into account, the relationship between the BMD:BMI ratio and the axial alignment parameters was similar to that seen in women, but the characteristic varus deformity differed between the two. In the men it was predominantly in the joint space while the proximal tibia was mostly involved in the women. The simple explanation for this is that the BMD in men is significantly higher than in women and the subchondral bone is strong enough to prevent compression fractures of the proximal tibia.

There are therefore two types of varus deformity of the knee; one has its origin in changes in the joint space and the other results from abnormality of the proximal tibia. The BMD is high in the former but low in the latter. A low BMD does not preclude osteoarthritic change in the knee.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. **Alhava EM, Kettunen K, Karjalainen P.** Bone mineral in patients with osteoarthrosis of the hip. *Acta Orthop Scand* 1975;46:709-15.
2. **Carlsson Å, Nilsson BE, Westlin NE.** Bone mass in primary coxarthrosis. *Acta Orthop Scand* 1979;50:187-9.
3. **Cooper C, Cook PL, Osmond C, Fisher L, Cawley MI.** Osteoarthritis of the hip and osteoporosis of the proximal femur. *Ann Rheum Dis* 1991;50:540-2.
4. **Foss MV, Byers PD.** Bone density, osteoarthrosis of the hip and fracture of the upper end of the femur. *Ann Rheum Dis* 1972;31:259-64.
5. **Gotfredsen A, Riis BJ, Christiansen C, Rodbro P.** Does a single local absorptiometric bone measurement indicate the overall skeletal status? Implications for osteoporosis and osteoarthritis of the hip. *Clin Rheumatol* 1990;9:193-203.
6. **Hart DJ, Mootoosamy I, Doyle DV, Spector TD.** The relationship between osteoarthritis and osteoporosis in the general population: the Chingford study. *Ann Rheum Dis* 1994;53:158-62.
7. **Healey JH, Vigorita VJ, Lane JM.** The coexistence and characteristics of osteoarthritis and osteoporosis. *J Bone Joint Surg [Am]* 1985;67-A:586-92.
8. **Pogrund H, Rutenberg M, Makin M, et al.** Osteoarthritis of the hip joint and osteoporosis: a radiological study in a random population sample in Jerusalem. *Clin Orthop* 1982;164:130-5.
9. **Roh YS, Dequeker J, Mulier JC.** Bone mass in osteoarthrosis, mesured in vivo by photon absorption. *J Bone Joint Surg [Am]* 1974;56-A:587-91.
10. **Weintroub S, Papo J, Ashkenazi M, et al.** Osteoarthritis of the hip and fractures of the proximal end of the femur. *Acta Orthop Scand* 1982;53:261-4.
11. **Belmonte-Serrano MA, Bloch DA, Lane NE, Michel BE, Fries JF.** The relationship between spinal and peripheral osteoarthritis and bone density measurements. *J Rheumatol* 1993;20:1005-13.
12. **Gevers G, Dequeker J, Martens M, et al.** Biomechanical characteristics of iliac crest bone in elderly women according to osteoarthritis grade at the hand joints. *J Rheumatol* 1989;16:660-3.
13. **Price T, Hesp R, Mitchell R.** Bone density in generalized osteoarthritis. *J Rheumatol* 1987;14:560-2.
14. **Reid DM, Kennedy NS, Smith MA, Tothill P, Nuki G.** Bone mass in nodal primary generalised osteoarthrosis. *Ann Rheum Dis* 1984;43:240-2.

15. **Dequeker J.** The relationship between osteoporosis and osteoarthritis. *Clin Rheum Dis* 1985;11:271-96.

16. **Verstraeten A, van Ermen HV, Haghebaert G, et al.** Osteoarthrosis retards the development of osteoporosis: observation of the coexistence of osteoarthrosis and osteoporosis. *Clin Orthop* 1991;264:169-77.

17. **Burr DB, Martin RB, Schaffer MB, et al.** Osteoarthrosis: sex-specific relationship to osteoporosis. *Am J Phys Anthropol* 1983;61:299-303.

18. **Hannan MT, Anderson JJ, Zhang Y, Levy D, Felson DT.** Bone mineral density and knee osteoarthritis in elderly men and women: the Framingham study. *Arthritis Rheum* 1993;36:1671-80.

19. **Malluche HH, Faugere MC, Dorr LD.** Systemic changes in bone structure and bone formation in patients with osteoarthritis (OA). *Trans Orthop Res Soc* 1983;8:139.

20. **Yokozeki H, Igarashi M, Karube S, Shiraki M, Kurokawa T.** The relation between osteoporosis of the spine and osteoarthritis of the knee: a study using dual energy X-ray absorptiometry and radiographs. *Int Orthop* 1995;19:282-4.

21. **Cooke TDV, Pichora D, Siu D, Scudamore RA, Bryant JT.** Surgical implications of varus deformity of the knee with obliquity of the joint surfaces. *J Bone Joint Surg [Br]* 1989;71-B:560-5.

22. **Yagi T.** Tibial torsion in patients with medial-type osteoarthrotic knees. *Clin Orthop* 1994;302:52-6.

23. **Kellgren JH, Lawrence JS.** Radiological assessment of osteoarthrosis. *Ann Rheum Dis* 1957;16:494-501.

24. **Danielsson LG, Hernborg J.** Clinical and roentgenologic study of knee joints with osteophytes. *Clin Orthop* 1970;69:302-12.

25. **Hernborg J, Nilsson BE.** Age and sex incidence of osteophytes in the knee joint. *Acta Orthop Scand* 1973;44:66-8.

26. **Altman RD, Fries JF, Bloch DA, et al.** Radiographic assessment of progression in osteoarthritis. *Arthritis Rheum* 1987;30:1214-25.

27. **Ahlbäk S.** Osteoarthrosis of the knee: a radiographic investigation. *Acta Radiol Suppl* 1968;277:7-72.

28. **Mankin HJ, Conger KA.** The acute effects of intra-articular hydrocortisone on articular cartilage in rabbits. *J Bone Joint Surg [Am]* 1966;48-A:1383-8.

29. **Moskowitz RW, Davis W, Sammarco J, Mast W, Chase SW.** Experimentally induced corticosteroid arthropathy. *Arthritis Rheum* 1970;13:236-43.

30. **Felson DT, Anderson JJ, Naimark A, Walker AM, Meenan RF.** Obesity and knee osteoarthritis: the Framingham study. *Ann Intern Med* 1988;109:18-24.

31. **van Saase JL, Vandenbroucke JP, van Romunde LK, Valkenburg HA.** Osteoarthritis and obesity in the general population: a relationship calling for an explanation. *J Rheumatol* 1988;15:1152-8.

32. **Davis MA, Ettinger WH, Neuhaus JM.** The role of metabolic factors and blood pressure in the association of obesity with osteoarthritis of the knee. *J Rheumatol* 1988;15:1827-32.

33. **Felson DT, Zhang Y, Hannan MT, Anderson JJ.** Effects of weight and body mass index on bone mineral density in men and women: the Framingham study. *J Bone Miner Res* 1993;8:567-73.

34. **Maquet P.** The biomechanics of the knee and surgical possibilities of healing osteoarthritic knee joints. *Clin Orthop* 1980;146:102-10.

35. **Wu DD, Burr DB, Boyd RD, Radin EL.** Bone and cartilage changes following experimental varus or valgus tibial angulation. *J Orthop Res* 1990;8:572-85.

36. **Radin EL, Paul IL, Rose RM.** Role of mechanical factors in pathogenesis of primary osteoarthritis. *Lancet* 1972;1:519-22.

37. **Radin EL, Rose RM.** Role of subchondral bone in the initiation and progression of cartilage damage. *Clin Orthop* 1986;213:34-40.

38. **Behrens JC, Walker PS, Shoji H.** Variations in strength and structure of cancellous bone at the knee. *J Biomech* 1974;7:201-7.