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Research Article

Evaluation of Bone Mineral Density in Patients Undergoing Total Hip Arthroplasty and Total Knee Arthroplasty

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Abstract

Background: Osteoarthritis and osteoporosis are the most prevalent musculoskeletal disorders (MSDs) in middle aged and elderly individuals and affect their quality of life (QOL). The presence of both these disorders is rarely reported in an individual patient. This study was conducted with the aim to assess this association using Dual-energy X-ray absorptiometry (DEXA) as a measure of bone mineral density (BMD) in patients undergoing hip and knee arthroplasty.
Methods: Between August 2015 and August 2018, 71 patients were selected as the study participants. The inclusion criteria included age of higher than 50 years and presence of primary or secondary arthritic conditions. The exclusion criteria were age of below 50 years, prolonged steroid intake (3 months), metabolic disease, and performance of arthroplasty for the management of fractures.
Results: The incidence rate of osteoporosis was found to be higher in higher age groups of patients undergoing arthroplasty. Furthermore, there was no statistical difference in the T-scores with respect to the sex of the patients.
Conclusion: Osteoarthritis and osteoporosis can occur simultaneously in an individual. The development of osteoarthritis does not prevent the development of generalized osteoporosis in an individual patient.

Keywords: Osteoarthritis; Dual-Energy X-Ray Absorptiometry; Arthroplasty; Osteoporosis

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Background

The disorders of the musculoskeletal system are the most common cause of chronic pain and disability. With the increase in average life expectancy, these disorders have gained importance worldwide (1-3). Both osteoarthritis and osteoporosis have a bearing on the overall quality of life (QOL) of an elderly individual.

The magnitude of osteoarthritis can be gauged from the number of patients undergoing hip and knee arthroplasty procedures. It is estimated that on average 70,000 hip replacements and 120,000 knee replacements are being annually performed in India. Joint replacement surgeries help to limit the pain and disability resulting from osteoarthritis.

Like osteoarthritis, osteoporosis is also a global problem in the elderly (4, 5). Khadilkar and Mandlik found that 1 out of every 5 Indian women above the age of 50 are osteoporotic, which is quite large given the large population that falls in this bracket (6). Given the alarming rate of osteoporosis among women, it seems essential to recognize the disease and start treatment. The number of men with osteoporosis has not been accurately documented in the literature (7).

The coexistence of osteoarthritis and osteoporosis in individual patients has been considered to be rare. Previous studies have shown that patients with osteoarthritis have a better bone mineral density (BMD) as compared to the control population (8-14). Therefore, it is believed that patients with osteoarthritis are less likely to develop osteoporosis (10, 15-17). Osteoarthritis has been found to delay the development of osteoporotic fractures, which is suggestive of a beneficial effect on bone density (18, 19).

However, despite the suggestion of its contrast in literature, the simultaneous presence of both these degenerative pathologies in a middle aged to elderly individual cannot be ruled out. Arthroplasty provides an opportunity for the clinician to detect and treat osteopenia, which can significantly affect the QOL of the patient as well as implant longevity.

The present study was conducted with the aim to assess this association using Dual-energy X-ray absorptiometry (DEXA) as a measure of BMD in patients undergoing hip and knee arthroplasty (7).

Methods

This prospective study was conducted on individuals with primary osteoarthritis of hip and knee joints who underwent arthroplasty at the Government Medical College and Hospital, Chandigarh, India. Between August 2015 and August 2018, 71 patients who met the study inclusion and exclusion criteria were selected as the study participants. The study was approved by the institutional ethics committee on the 3rd of May 2016 with the code GMCH-TA-III-143(Batch 2015)/2016/659594. The inclusion criteria were age of higher than 50 years and presence of primary or secondary arthritic conditions. The exclusion criteria included age of below 50 years, prolonged steroid intake (3 months), metabolic disease, and performance of arthroplasty for the management of fractures. The levels of serum calcium, serum phosphate, alkaline phosphatase, and vitamin D were determined at the

time of admission to rule out the possibility of metabolic bone disease. BMD was measured using DEXA using the Hologic DEXA system. A single-site lumbar DEXA was performed pre-operatively and the results were expressed as T-score and Z-score according to the World Health Organization (WHO) criteria. Follow-up DEXA scans were also performed 3, 6, and 12 months after the procedure.

Continuous and normally distributed data are presented in the form of mean and standard deviation. Student's t-test was used to compare the mean age, mean T-score at the beginning of the study, and the 3-month, 6-month, and 1-year follow-up, mean calcium levels, mean vitamin D levels, mean phosphate levels, and mean alkaline phosphate levels. Qualitative data were compared using the chi-square test, i.e., the number of men to women in each age group, men to women as per diagnosis, and the number of healthy, osteopenic, and osteoporotic individuals in each group.

Results

In total, 71 patients satisfied the inclusion criteria of which 19 patients had undergone total hip arthroplasty (THA) and 52 total knee arthroplasty (TKA) that were further divided into 4 age groups. The mean age, men to women ratio, and decade-wise distribution of men to women patients are presented in table 1.

Table 1. Mean age, men to women ratio, and decade-wise distribution of men to women patients

Variable	Hip OA (n = 19)	Knee OA (n = 52)	P
Mean age	56.63 ± 7.12	63.83 ± 8.03	< 0.01
Men: women ratio	13:6	13:39	< 0.01
50-59 years	11:4	5:9	0.04
60-69 years	1:1	3:22	0.14
70-79 years	1:1	5:5	0.99 <
80-89 years	0:0	0:3	

OA: Osteoarthritis

Statistical analysis showed a statistically significant difference in mean age (P < 0.01); patients with knee osteoarthritis had a higher mean age. The overall sex distribution in the 2 groups was highly significant statistically (P < 0.01), with a higher proportion of women in the knee osteoarthritis group. In the decade-wise distribution of patients, the difference in men to women ratio was significant in the first group (50-59 years), but it was not significant in the other groups.

The T-score was recorded at the beginning of the study, and the patients were divided into healthy, osteopenic, and osteoporotic categories as per their scores. The T-score in the hip and knee osteoarthritis groups was compared, and the difference was analyzed (Table 2).

Table 2. Division of patients as per T-scores with diagnosis

Variable	Hip OA (n = 19)	Knee OA (n = 52)	P
Healthy	7	11	0.17
Osteopenia	10	16	0.09
Osteoporosis	2	25	< 0.01

OA: Osteoarthritis

Out of a total of 71 patients, 18 patients (25.4%) had a normal bone density, while 53 patients (74.6%) had decreased bone density. The difference in the 3 groups was statistically significant (P = 0.01). In comparing the 2 groups in terms of the number of people with normal bone density and osteopenia, the difference was not statistically significant. However, this difference was highly significant statistically (P < 0.01) in osteoporotic individuals, which suggested that a significant number of osteoporotic individuals underwent TKA.

The sex distribution of arthroplasty cases compared as per their T-scores is presented in tables 3 and 4.

Statistical analysis showed that the sex distribution was not significant in hip osteoarthritis patients (P = 0.83), but was significant in the knee osteoarthritis patients (P = 0.02).

Table 3. T-score relation to sex in patients with osteoarthritis of the hip

Variable	Men	Women	P
Healthy	5	2	0.83
Osteopenia	7	3	0.88
Osteoporosis	1	1	0.55

In patients with hip osteoarthritis, the division between the 3 categories in terms of sex was not statistically significant. In patients with knee osteoarthritis, the division between healthy (P = 0.01) and osteoporotic individuals (P = 0.03) in terms of sex was significant, but was not significant between healthy and osteopenic individuals (P > 0.01).

Table 4. T-score relation to sex in patients with osteoarthritis of the knee

Variable	Men	Women	P
Healthy	6	5	0.01
Osteopenia	4	12	0.99 <
Osteoporosis	3	22	0.03

The number of healthy, osteopenic, and osteoporotic individuals in each age group was recorded separately in hip osteoarthritis and knee osteoarthritis patients. The distribution among hip osteoarthritis patients is shown in table 5. The maximum number of patients with normal bone density (46.7%) was observed in the 50-59 years age group, and there was no patient with normal bone density in the 60 years and higher age group. The maximum number of osteopenic individuals (46.7%) was also observed in the 50-59 years age group. There was only 1 patient with osteoporosis in the 50-59 years age group (6.67%).

Table 5. Age distribution of patients with respect to bone density in the hip osteoarthritis group

Age (year)	Hip OA		
	Healthy	Osteopenia	Osteoporosis
50-59	7	7	1
60-69		1	1
70-79		2	
80-89			

OA: Osteoarthritis

The age distribution in knee osteoarthritis patients is presented in table 6. Decreased bone density was observed in 71.4% (10 out of 14) of patients in the 50-59 years age group, 84% of patients (21 out of 25) in the 60-69 years age group, 70% of patients (7 out of 10) in the 70-79 years age group, and 100% of patients (3 out of 3) in the 80-89 years age group.

Table 6. Age distribution of patients with respect to bone density in the knee osteoarthritis group

Age (year)	Knee OA			
	Total	Healthy	Osteopenia	Osteoporosis
50-59	14	4	4	6
60-69	25	4	9	12
70-79	10	3	2	5
80-89	3	0	1	2

OA: Osteoarthritis

The age distribution of men patients on the basis of T-score is presented in figure 1.

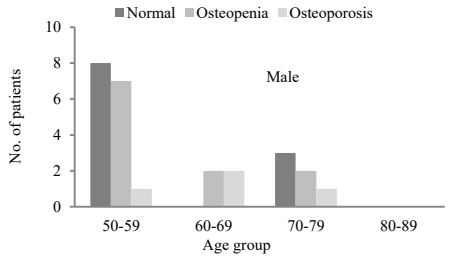

Figure 1. Age distribution of men patients on the basis of T-score

The age distribution of women patients on the basis of T-score is presented in figure 2.

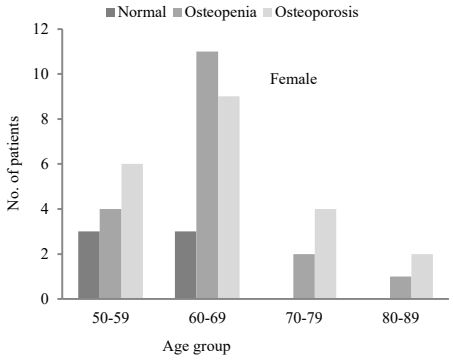

Figure 2. Age distribution of women patients on the basis of T-score

In the hip osteoarthritis group, the mean T-scores of men and women in each age group were compared with each other, as shown in table 7. The difference was not statistically significant.

Table 7. Age group comparison between men and women in total hip arthroplasty cases

Age group (year)	Men	Women	P
50-59	-1.07 ± 1.29 (n = 11)	-1 ± 1.21 (n = 4)	0.92
60-69	-1.7 (n = 1)	-3.1 (n = 1)	
70-79	-2.48 (n = 1)	-1.9 (n = 1)	

The mean T-scores of men and women in each age group were compared in the TKA group (Table 8).

Table 8. Age group comparison between men and women in total knee arthroplasty cases

Age group (year)	Men	Women	P
50-59	-0.8 ± 1.29 (n = 5)	-2.54 ± 1.14 (n = 9)	0.02
60-69	-2.1 ± 0.71 (n = 3)	-3.3 ± 0.94 (n = 22)	0.04
70-79	-0.84 ± 1.71 (n = 5)	-3.16 ± 0.46 (n = 5)	0.01
80-89		-2.8 ± 0.3	

Statistical analysis showed that the difference in the mean score was significant in all the age groups, with women having lower T-scores. The difference in the mean T-score of women in different age groups was not significant (P = 0.07).

The mean T-score at the beginning of the study was -1.89 ± 1.37. The mean T-scores at the 3-month, 6-month, and 1-year follow-ups were -1.73 ± 1.29, -1.54 ± 1.21, and -1.34 ± 1.15, respectively. The difference between the mean scores at the beginning of the study and 1-year follow-up was statistically significant (P = 0.01).

The mean T-score in men was -1.20 ± 1.38 at the beginning of the study, and -1.12 ± 1.01 at the 1-year follow-up (Table 9), but this difference was not statistically significant (P = 0.12).

Table 9. Follow-up T-scores of the men population

Age group (year)	T-score (Men)			
	0	3 months	6 months	12 months
50-59	-0.99	-0.89	-0.73	-0.53
60-69	-2.15	-2	-1.8	-1.5
70-79	-1.117	-1.107	-0.833	-0.65
80-89	-	-	-	-

The mean T-score in men at different time intervals during the span of 1-year is illustrated in figure 3.

The mean T-score in women was -2.30 ± 1.18 at the beginning of the study, and -1.46 ± 1.20 at the 1-year follow-up (Table 10).

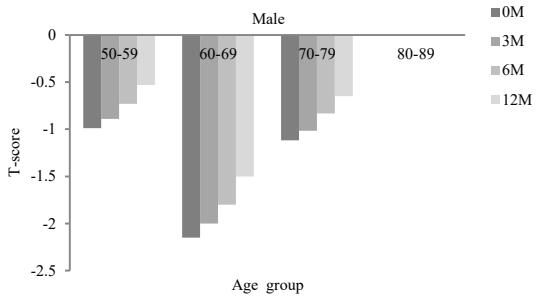

Figure 3. T-scores vs. follow-up of age groups in the men population

This difference was statistically significant (P = 0.03).

Table 10. Follow-up T-scores of the women population

Age group (year)	T-score (Women)			
	0	3 months	6 months	12 months
50-59	-2.07	-1.93	-1.7	-1.51
60-69	-2.178	-2.013	-1.83	-1.648
70-79	-2.95	-2.617	-2.35	-2
80-89	-2.867	-2.567	-2.367	-2.3

The mean T-score in women at different time intervals during the span of 1-year is shown in figure 4.

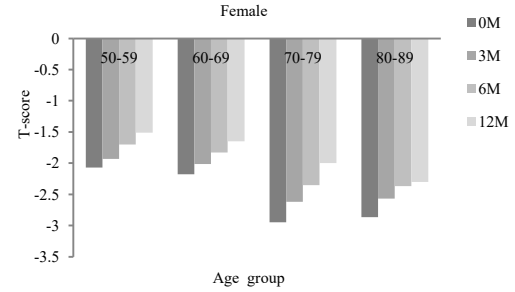

Figure 4. T-scores vs. follow-up of age groups in the women population

The mean age, mean vitamin D levels, mean calcium levels, mean phosphate levels, mean alkaline phosphatase levels, and the mean T-scores in men and women are presented in table 11.

Table 11. Comparison of various parameters of the men and women population

Variable	Men (n = 26)	Women (n = 45)	P
Age	59.7±8.92	63.2±7.85	0.09
Vitamin D	37.21±24.90	26.13±16.88	0.02
Calcium	7.8±1.10	8.5±1.10	0.01
Phosphate	2.87±0.64	3.06±0.66	0.24
ALP	82.83±20.89	105.09±34.89	< 0.01
T-score	-1.20±1.38	-2.30±1.18	< 0.01

A significant difference was found between men and women in terms of mean vitamin D levels, mean calcium levels, mean alkaline phosphatase levels, and mean T-scores. The women had higher mean calcium, phosphate, and alkaline phosphatase levels, but lower vitamin D levels and lower T-scores.

The correlation between T-score and vitamin D levels, calcium levels, phosphate levels, and alkaline phosphate levels was analyzed statistically using Spearman's correlation coefficient in men and women. A moderately strong correlation was found between T-score and vitamin D levels in men (rho = 0.4), and a weak correlation between T-score and calcium levels (rho = 0.3) and T-score and phosphate levels (rho = 0.3). There was no correlation between T-score and alkaline phosphatase levels (rho = -0.03).

In women, no correlation was found between T-score and calcium levels (rho = 0.06), T-score and vitamin D levels (rho = -0.04), T-score and phosphate levels (rho = 0.01), and T-score and alkaline phosphatase levels (rho = -0.04).

Discussion

The association between osteoarthritis and osteoporosis is subject of debate. Nevitt et al. in 1965 and Hannan et al. in 1993 found better BMD in patients with osteoarthritis (10, 17). They also found a decrease in the propensity of fragility fractures in patients with osteoarthritis, which is suggestive of a beneficial effect on osteoporosis.

However, recent cohort studies have suggested the exact opposite by reporting an increase in the risk of fragility fractures in osteoarthritis cases (20-24). Chang et al., in 2014, concluded that a considerable proportion of elderly women patients with advanced knee osteoarthritis have osteoporosis, and its prevalence is similar to that in the community-based control group when matched for age and body mass index (BMI) (25). Thus, a consensus is still lacking in this regard.

Osteoarthritic patients referring for arthroplasty present an opportunity for the assessment of BMD. Lingard et al. concluded that BMD measurements of joints affected by osteoarthritis are non-representative of the entire skeleton framework, and thus, used site distant to these joints (26). For the same reason, we performed the BMD measurements at a distance from the hip and knee joints.

In the present study, a statistically significant difference was observed in the mean age of hip and knee osteoarthritis patients. The mean age of hip osteoarthritis patients was 56.63 ± 7.12 years, and the mean age of knee osteoarthritis patients was 63.83 ± 8.03 years. Gunther et al. reported the mean ages of hip and knee osteoarthritis patients as 60.4 years and 66.3 years, respectively (27). Fang et al. reported the mean ages of these patients as 65 years and 67 years, respectively (28). Thus, the mean ages of these patients in previous studies differed.

Sex distribution also differed between the hip and knee osteoarthritis patients. A larger proportion of women had knee osteoarthritis and a larger proportion of men had hip osteoarthritis. Heidari, in a meta-analysis, found increased chances of development and severity of knee osteoarthritis in women of more than 55 years of age as compared to men (29). Chidambaram and Cobb showed that a larger proportion of young men are now undergoing THA, with the mean age being 66 years and the mean age of women being 71 years (30). The mean age of men undergoing THA dropped from 71 years in 1993 to 66 years in 2005, with the proportion of patients of less than 60 years of age increasing from 8% to 23%. They observed no change in the age of patients undergoing knee replacement (30). Thus, an increasing number of men patients are undergoing THA, as also observed in the present study.

The present study found a significant difference in the association of osteoporosis with THA and TKA. There were more osteoporotic cases among the knee arthroplasty patients as compared to hip arthroplasty patients. This difference can be attributed to the higher proportion of women in the knee osteoarthritis group and their higher mean age. This difference has not been previously highlighted in the literature.

In comparing bone density in hip osteoarthritis patients with relation to sex, no significant difference was observed. However, among the knee osteoarthritis patients, a significant number of women were osteoporotic as compared to men. Lingard et al., in their study on 199 patients with equal numbers of men and women, concluded that osteoporosis and osteopenia occurred in a significant proportion of women patients as compared to men patients (26).

In analyzing the patients for bone density in the hip osteoarthritis group, it was observed that out of the total 19 patients, 7 (36.8%) had normal bone density, 10 (52.6%) had osteopenia, and 2 (10.5%) had osteoporosis. Domingues et al., in their study on 29 patients awaiting hip arthroplasty, reported that 37.9% of patients had osteopenia and 20.7% of patients had osteoporosis (31). Makinen et al. found osteopenia in 45% of patients and osteoporosis in 28% of the patients scheduled for THA (32). Moreover, Glowacki et al. reported osteoporosis in 25% of patients undergoing THA (33). In age group-wise analysis, we observed that in the 50-59 years age group, 53.7% of patients had bone density below the normal range. Maier et al. in their survey of 433 orthopedic surgeons about osteoporosis and hip arthroplasty, concluded that 72% of surgeons preferred to use cementless implants, but 26% would change their strategy if the patient's T-score was between -1.5 and -2, 40% if the score was between -2 and -2.5, and 29% if the T-score was less than -2.5 (20). Thus, the T-score can help surgeons choose between cemented and cementless implants and prevent subsequent loosening and periprosthetic fractures (PF).

In analyzing the patients for bone density in the knee osteoarthritis group, it was observed that out of the total 52 patients, 11 (21.2%) had normal bone density, 16 (30.8%) had osteopenia, and 25 (48%) had osteoporosis. Chang et al., in their study on 347 patients undergoing TKA, reported normal bone density, osteopenia, and osteoporosis in 14.7%, 54.2%, and 31.1% of patients (25). Sadigursky et al., in their study on 60 patients awaiting TKA, found osteopenia in 15% and osteoporosis in 16.7% of cases (34). Holzer and Holzer, in their study, found an increased incidence of implant migration, osteolysis, and both intra-operative and postoperative PF in patients with joint replacement and osteoporosis (35).

Huang et al., in their study on 43 patients, showed that patients with lower bone quality have increased pain and decreased functional outcome in the postoperative period as compared to age-matched controls (36). Thus, the evaluation of osteoporosis before surgery can help predict both the functional outcome and longevity of the implant.

The mean T-score in men patients at the beginning of the study was -1.6 ± 1.18, and at the 1-year follow-up was -1.12 ± 1.01, but this difference was not statistically significant. The mean T-score in women was -2.06 ± 1.44 at the beginning of the study and -1.46 ± 1.20 at the 1-year follow-up, and the difference was statistically significant. All the patients with T-scores of less than -1.5 were supplemented with calcium, vitamin D, and bisphosphonates. Safer et al., in their study on 45 women, also showed that supplementation led to a significant improvement in the T-score (37). Gielen et al. also highlighted the beneficial effects of supplementation in men patients, leading to a decrease in fracture risk (38).

A moderately strong correlation was observed between T-score and vitamin D levels in men in the present study, which is in concordance with the results published by Bouillon et al. (39). However, no correlation between vitamin D levels and T-score was observed in women in their study.

The present study had its limitations. A study with a larger sample size and an equal proportion of patients in the hip and knee osteoarthritis groups would have increased the power of the study. The strength of the present study is its pre-defined protocol for data collection and the inclusion of all consecutive patients during the study period.

Conclusion

Osteoarthritis and osteoporosis can occur simultaneously in an individual. The development of osteoarthritis does not prevent the development of generalized primary osteoporosis. In our study, 74.6% of the patients undergoing arthroplasty had decreased BMD. The prevalence of low BMD value was higher among women and TKA patients. The age group of 50-59 years was equally affected compared with the older age groups; thus, physiological age is not sufficient for predicting osteoporosis. The supplementation with calcium, vitamin D, and bisphosphonates led to a significant improvement in BMD. The low BMD in men has a moderately strong correlation with vitamin D levels, but not in women. The diagnosis of osteoporosis in osteoarthritis patients would help the selection of the type of arthroplasty in hip osteoarthritis patients, and improve the functional outcome in knee and hip osteoarthritis patients, and prevent the complications of loosening and PF.

Conflict of Interest

The authors declare no conflict of interest in this study.

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References

1. Simonelli C, Killeen K, Mehle S, Swanson L. Barriers to osteoporosis identification and treatment among primary care physicians and orthopedic surgeons. *Mayo Clin Proc*. 2002;77(4):334-8. doi: 10.4065/77.4.334. [PubMed: 11936928].
2. Labuda A, Papaioannou A, Pritchard J, Kennedy C, DeBeer J, Adachi JD. Prevalence of osteoporosis in osteoarthritic patients undergoing total hip or total knee arthroplasty. *Arch Phys Med Rehabil*. 2008;89(12):2373-4. doi: 10.1016/j.apmr.2008.06.007. [PubMed: 18976978]. [PubMed Central: PMC5101053].
3. Garg SK. Diagnosis and treatment of osteoporosis: are we doing enough? *Bone Rep Recommendations*. 2016;1:1. doi: 10.4172/2469-6684.10004
4. National Joint Registry. National Joint Registry for England and Wale. 7th Annual Report 2010 [Online]. [cited 2010]; Available from: URL: https://www.njrcentre.org.uk/njrcentre/Portals/0/NJR%207th%20Annual%20Report%202010.pdf
5. Pachore JA, Vaidya SV, Thakkar CJ, Bhalodia HK, Wakankar HM. ISHKS joint registry: A preliminary report. *Indian J Orthop*. 2013;47(5):505-9. doi: 10.4103/0019-5413.118208. [PubMed: 24133312]. [PubMed Central: PMC3796925].
6. Khadilkar AV, Mandlik RM. Epidemiology and treatment of osteoporosis in women: An Indian perspective. *Int J Womens Health*. 2015;7:841-50. doi: 10.2147/IJWH.S54623. [PubMed: 26527900]. [PubMed Central: PMC4621228].
7. Black DM, Cummings SR, Genant HK, Nevitt MC, Palermo L, Browner W. Axial and appendicular bone density predict fractures in older women. *J Bone Miner Res*. 1992;7(6):633-8. doi: 10.1002/jbmr.5650070607. [PubMed: 1414481].
8. Foss MV, Byers PD. Bone density, osteoarthrosis of the hip, and fracture of the upper end of the femur. *Ann Rheum Dis*. 1972;31(4):259-64. doi: 10.1136/ard.31.4.259. [PubMed: 5045904]. [PubMed Central: PMC1005923].
9. Pogrund H, Makin M, Robin G, Menczel J, Steinberg R. Osteoporosis of the spine, pelvis and hand. A comparative study in a femoral neck fracture series. *Clin Orthop Relat Res*. 1979;(139):156-63.. [PubMed: 455833].
10. 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(12):1671-80. doi: 10.1002/art.1780361205. [PubMed: 8250986].
11. 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(3):158-62. doi: 10.1136/ard.53.3.158. [PubMed: 8154931]. [PubMed Central: PMC1005278].
12. Marcelli C, Favier F, Kotzki PO, Ferrazzi V, Picot MC, Simon L. The relationship between osteoarthritis of the hands, bone mineral density, and osteoporotic fractures in elderly women. *Osteoporos Int*. 1995;5(5):382-8. doi: 10.1007/BF01622261. [PubMed: 8800789].
13. Burger H, van Daele PL, Odding E, Valkenburg HA, Hofman A, Grobbee DE, et al. Association of radiographically evident osteoarthritis with higher bone mineral density and increased bone loss with age. The Rotterdam Study. *Arthritis Rheum*. 1996;39(1):81-6. doi: 10.1002/art.1780390111. [PubMed: 8546742].
14. Stewart A, Black A, Robins SP, Reid DM. Bone density and bone turnover in patients with osteoarthritis and osteoporosis. *J Rheumatol*. 1999;26(3):622-6. [PubMed: 10090173].
15. Sowers M, Lachance L, Jamadar D, Hochberg MC, Hollis B, Crutchfield M, et al. The associations of bone mineral density and bone turnover markers with osteoarthritis of the hand and knee in pre- and perimenopausal women. *Arthritis Rheum*. 1999;42(3):483-9. doi: 10.1002/1529-0131(199904)42:3<483::AID-ANR13>3.0.CO;2-O. [PubMed: 10088771].
16. Lethbridge-Cejku M, Tobin JD, Scott WW, Reichle R, Roy TA, Plato CC, et al. Axial and hip bone mineral density and radiographic changes of osteoarthritis of the knee: data from the Baltimore Longitudinal Study of Aging. *J Rheumatol*. 1996;23(11):1943-7.. [PubMed: 8923372].
17. Nevitt MC, Lane NE, Scott JC, Hochberg MC, Pressman AR, Genant HK, et al. Radiographic osteoarthritis of the hip and bone mineral density. The Study of Osteoporotic Fractures Research Group. *Arthritis Rheum*. 1995;38(7):907-16. doi: 10.1002/art.1780380706. [PubMed: 7612040].
18. Verstraeten A, Van EH, Haghebaert G, Nijs J, Geusens P, Dequeker J. Osteoarthrosis retards the development of osteoporosis. Observation of the coexistence of osteoarthrosis and osteoporosis. *Clin Orthop Relat Res*. 1991;(264):169-77. [PubMed: 1997232].
19. Dequeker J, Johnell O. Osteoarthritis protects against femoral neck fracture: the MEDOS study experience. *Bone*. 1993;14(Suppl 1):S51-S56. doi: 10.1016/8756-3282(93)90350-j.

[PubMed: 8110521].
20. Maier GS, Kolbow K, Lazovic D, Maus U. The importance of bone mineral density in hip arthroplasty: Results of a survey asking orthopaedic surgeons about their opinions and attitudes concerning osteoporosis and hip arthroplasty. *Adv Orthop*. 2016;2016:8079354. doi: 10.1155/2016/8079354. [PubMed: 27999686]. [PubMed Central: PMC5141559].
21. Arden NK, Griffiths GO, Hart DJ, Doyle DV, Spector TD. The association between osteoarthritis and osteoporotic fracture: the Chingford Study. *Br J Rheumatol*. 1996;35(12):1299-304. doi: 10.1093/rheumatology/35.12.1299. [PubMed: 9010060].
22. Bergink AP, van der Klift M, Hofman A, Verhaar JA, van Leeuwen JP, Uitterlinden AG, et al. Osteoarthritis of the knee is associated with vertebral and nonvertebral fractures in the elderly: the Rotterdam Study. *Arthritis Rheum*. 2003;49(5):648-57. doi: 10.1002/art.11380. [PubMed: 14558050].
23. Dequeker J, Mokassa L, Aerssens J. Bone density and osteoarthritis. *J Rheumatol Suppl*. 1995;43:98-100. [PubMed: 7752151].
24. James SJ, Mirza SB, Culliford DJ, Taylor PA, Carr AJ, Arden NK. Baseline bone mineral density and boneturnover in pre-operative hip and knee arthroplasty patients. *Bone Joint Res*. 2014;3(1):14-9. doi: 10.1302/2046-3758.31.2000218. [PubMed: 24443424]. [PubMed Central: PMC3904490].
25. Chang CB, Kim TK, Kang YG, Seong SC, Kang SB. Prevalence of osteoporosis in female patients with advanced knee osteoarthritis undergoing total knee arthroplasty. *J Korean Med Sci*. 2014;29(10):1425-31. doi: 10.3346/jkms.2014.29.10.1425. [PubMed: 25368498]. [PubMed Central: PMC4214945].
26. Lingard EA, Mitchell SY, Francis RM, Rawlings D, Peaston R, Birrell FN, et al. The prevalence of osteoporosis in patients with severe hip and knee osteoarthritis awaiting joint arthroplasty. *Age Ageing*. 2010;39(2):234-9. doi: 10.1093/ageing/afp222. [PubMed: 20032523].
27. Gunther KP, Sturmer T, Sauerland S, Zeissig I, Sun Y, Kessler S, et al. Prevalence of generalised osteoarthritis in patients with advanced hip and knee osteoarthritis: the Ulm Osteoarthritis Study. *Ann Rheum Dis*. 1998;57(12):717-23. doi: 10.1136/ard.57.12.717. [PubMed: 10070270]. [PubMed Central: PMC1752518].
28. Fang M, Noiseux N, Linson E, Cram P. The Effect of advancing age on total joint replacement outcomes. *Geriatr Orthop Surg Rehabil*. 2015;6(3):173-9. doi: 10.1177/2151458515583515. [PubMed: 26328232]. [PubMed Central: PMC4536505].
29. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. *Caspian J Intern Med*. 2011;2(2):205-12. [PubMed: 24024017]. [PubMed Central: PMC3766936].
30. Chidambaram R, Cobb A. Change in the age distribution of patients undergoing primary hip and knee replacements over 13 years: An increase in the number of younger men having hip surgery. *J Bone Joint Surg Br*. 2009;91.
31. Domingues VR, de Campos GC, Plapler PG, de Rezende MU. Prevalence of osteoporosis in patients awaiting total hip arthroplasty. *Acta Ortop Bras*. 2015;23(1):34-7. doi: 10.1590/1413-78522015230100981. [PubMed: 26327793]. [PubMed Central: PMC4544518].
32. Makinen TJ, Alm JJ, Laine H, Svedstrom E, Aro HT. The incidence of osteopenia and osteoporosis in women with hip osteoarthritis scheduled for cementless total joint replacement. *Bone*. 2007;40(4):1041-7. doi: 10.1016/j.bone.2006.11.013. [PubMed: 17239668].
33. Glowacki J, Hurwitz S, Thornhill TS, Kelly M, LeBoff MS. Osteoporosis and vitamin-D deficiency among postmenopausal women with osteoarthritis undergoing total hip arthroplasty. *J Bone Joint Surg Am*. 2003;85(12):2371-7. doi: 10.2106/00004623-200312000-00015. [PubMed: 14668507].
34. Sadigursky D, Barretto LJ, Lobao DMV, Carneiro RJF, Colavolpe PO. Osteoporosis in brazilian patients awaiting knee arthroplasty. *Acta Ortop Bras*. 2017;25(3):74-7. doi: 10.1590/1413-785220172503167325. [PubMed: 28642665]. [PubMed Central: PMC5474407].
35. Holzer G, Holzer L. Osteoporosis and joint replacement. *Journal of the Grodno State Medical University*. 2018;16:251-6. doi: 10.25298/2221-8785-2018-16-3-251-256
36. Huang CC, Jiang CC, Hsieh CH, Tsai CJ, Chiang H. Local bone quality affects the outcome of prosthetic total knee arthroplasty. *J Orthop Res*. 2016;34(2):240-8. doi: 10.1002/jor.23003. [PubMed: 26222735].
37. Safer U, Safer VB, Demir SO, Yanikoglu I. Effects of Bisphosphonates and Calcium plus Vitamin-D Supplements on Cognitive Function in Postmenopausal Osteoporosis section sign. *Endocr Metab Immune Disord Drug Targets*. 2016;16(1):56-60. doi: 10.2174/1871530316666160330105952. [PubMed: 27026340].
38. Gielen E, Boonen S, Vanderschueren D, Sinnesael M, Verstuyf A, Claessens F, et al. Calcium and vitamin d supplementation in men. *J Osteoporos*. 2011;2011:875249. doi: 10.4061/2011/875249. [PubMed: 21876835]. [PubMed Central: PMC3163142].
39. Bouillon R, Lips P, Bilezikian JP. Vitamin D supplementation and musculoskeletal health. *Lancet Diabetes Endocrinol*. 2019;7(2):85-6. doi: 10.1016/S2213-8587(18)30348-6. [PubMed: 30683216].