Original Article

An exploration of serum 25-hydroxyvitamin D levels after unstable femoral intertrochanteric fractures in community-dwelling elderly

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ABSTRACT

الأهداف: يرتبط نقص فيتامين د بزيادة خطر السقوط، مما يؤدي إلى كسور الورك بين كبار السن. لذلك، هدفت هذه الدراسة إلى استكشاف مستويات فيتامين د والمتغيرات التي قد تؤثر على إجمالي وقت المكوث في المستشفى للمرضى المسنين المقيمين في المجتمع والذين يعانون من كسور غير مستقرة بين المدورتين الفخذيه.

المنهجية: بين عامي 2020م و2024م، تم عمل تحليل بأثر رجعي لخمسة وسبعين مريضًا مسنًا عولجوا باستبدال مفصل الورك الكلي (THR). تم تقسيم المرضى إلى ثلاث مجموعات. مجموعه ناقصة (أقل من 20 نانوغرام/مل، العدد=46)، و مجموعه غير كافية (20 إلى 29.99 نانوغرام/مل، العدد=16)، ومجموعه طبيعية (أكثر من أو يساوي 30 نانوغرام/مل، العدد=13) لمصل فيتامين د –25هيدروكسي. تم تسجيل وجود حالة الهذيان، ودخول العناية المركزة بعد الجراحة، وعدد الأمراض المزمنة، والانتظار قبل الجراحة، وإجمالي وقت الاستشفاء بعد THR.

النتائج: كان متوسط مستوى فيتامين د –25هيدروكسي في المصل في جميع المجموعات 20.11 نانوجرام/مل. لم تظهر المجوعه الناقصة و المجموعه غير الكافية و المجموعة الطبيعية في مستوى فيتامين د –25هيدروكسي أي فرق من ناحية دخول العناية المركزة بعد الجراحة (p=547) ووجود الهذيان (p= 947). أشار نموذج الانحدار الخطي المتعدد إلى أن إجمالي مكوث المرضى المسنين في المستشفى يزداد مع زيادة المعاملات اثناء وقت الانتظار قبل الجراحة (β=0.466، p=0.001) و مع زيادة عدد الأمراض المزمنة (p=0011، β=0.263). لم يؤثر مستوى فيتامين د –25هيدروكسي في المصل على إجمالي وقت مكوث المرضى في المستشفى (p=0.474، β=–0.072).

الخلاصة: أشارت هذه الدراسة إلى أن المرضى المسنين المقيمين في المجتمع والذين يعانون من كسور غير مستقرة بين المدورتين الفخذيه لديهم مستويات منخفضة بشكل ملحوظ من فيتامين د –25هيدروكسي في المصل. قد يؤدي تقليل وقت الانتظار قبل الجراحة ومراقبة الأمراض المزمنة ومعالجتها إلى تقليل إجمالي فتره مكوث المرضى في المستشفى. يجب أن تركز الجهود على التحقق والحفاظ على مستويات كافية من فيتامين د من خلال المكملات الغذائية بعد دخول المستشفى.

Objectives: Inadequate vitamin D is related to increased fall risk, which leads to hip fractures among the elderly. Therefore, this study aimed to explore vitamin D levels and the variables potentially influencing the total hospitalization time of community-dwelling elderly patients with unstable femoral intertrochanteric fractures.

Methods: Between 2020-2024, 75 elderly patients treated with total hip replacement (THR) were retrospectively analyzed. Patients were divided into the deficient (<20 ng/mL, n=46), insufficient (20 to 29.99 ng/mL, n=16), and normal (≥30 ng/mL, n=13) serum 25-hydroxyvitamin D (25(OH)D) groups. Presence of delirium status, postoperative intensive care entrance, number of chronic diseases, preoperative waiting, and total hospitalization time after THR were recorded.

Results: The cohorts' mean serum 25(OH)D level was 20.11ng/mL. The deficient, insufficient, and normal serum 25(OH)D level groups displayed no significant difference in the postoperative intensive care entrance (p=0.547) and the presence of delirium (p=0.947). The multiple linear regression model indicated that elderly patients' total hospitalization increases with the coefficients as the preoperative waiting time (β=0.466, p=0.001) and the number of chronic diseases (β=0.263, p=0.011) increase. Serum 25(OH)D level did not impact patients' total hospitalization time (β=-0.072, p=0.474).

Conclusion: This study indicated that community-dwelling elderly patients with unstable femoral intertrochanteric fractures had significantly decreased serum 25(OH)D levels. Reducing preoperative waiting time and monitoring and addressing chronic diseases may decrease total hospitalization. Efforts should focus on achieving and maintaining adequate vitamin D levels through supplementation post-hospitalization.

Keywords: hip fractures, vitamin D, hospitalization, length of stay, delirium

Saudi Med J 2025; Vol. 46 (4): 372-377
doi: 10.15537/smj.2025.46.4.20241121

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Received 17th December 2024. Accepted 2nd March 2025.

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Fractures around the hip joint have recently received significant attention as they are associated with increasing morbidity and mortality.[1,2] As people live longer, hip fractures are predicted to increase in prevalence worldwide and will be both costly and challenging for patients to treat.[3,4] The elderly population is vulnerable to weaker bones, an increased tendency to fall, and comorbidities.[2] About one-third of elderly patients with hip fractures pass within the first year after injury, and many have difficulties returning to their pre-fracture functional capacity.[1,3,5]

Vitamin D is essential for calcium metabolism, which in turn is crucial for the mineralization of bones.[5] The risk of hip fracture in the elderly is linked to many aspects of vitamin D status and functional capacity.[4] The hip area is one of the parts of the body significantly impacted by vitamin D deficiency, and as a result, there is an increased risk of fragility around the hip.[2] Inadequate vitamin D is related to a faster loss of bone density and an increased fall risk, which leads to hip fractures among the elderly population.[1,5,6] Vitamin D deficiency in hip fractures ranges from 55% to 92% and is reported to be higher in the elderly. In addition, hip fracture patients with reduced vitamin D capacity present a slower fracture repair period and higher mortality.[1]

Serum 25-hydroxyvitamin D (25[OH]D) is commonly considered a marker of an individual's vitamin D level.[4] Values equal to or above 30 nanograms per milliliter (ng/mL) are considered adequate for vitamin D grades.[5] Maintaining normal levels greater than 30 ng/mL is not just a recommendation but a crucial aspect of health. Experts commonly define vitamin D deficiency as serum 25(OH) vitamin D levels below 20 ng/mL, while insufficiency is characterized by levels between 20 and 29.99 ng/mL.[7] Vitamin D supplementation is deemed necessary to prevent fractures among the elderly, but this is not always routinely practiced.[5] A study involving 30,970 participants found that vitamin D supplementation resulted in a 30% reduction in the risk of hip fractures.[8] Studies analyzing the association of vitamin D deficiency with unstable femoral intertrochanteric fractures treated with total hip replacement (THR) in the elderly are inconclusive. This study aimed (i) to explore the vitamin D levels after unstable femoral intertrochanteric fractures in the elderly after hospitalization. Our secondary aim (ii) was to compare the presence of delirium and the postoperative intensive care entrance after THR surgery deficient, insufficient, and normal serum 25(OH)D levels of the patients. The study's last aim (iii) was to explore the variables potentially influencing the total hospitalization time of elderly patients after THR surgery.

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

Methods. This investigation was planned as a retrospective cohort study. We investigated the records of community-dwelling elderly patients admitted to Private Medicabil Hospital's orthopedics and traumatology clinic between 2020 and 2024. The Muş Alparslan University Scientific Research and Publication Ethics Committee confirmed the ethical approval of the study (2024/134672). The study was conducted under the principles outlined in the Declaration of Helsinki.

According to power analysis of the F-tests to determine a difference in total hospitalization between groups, assuming that we could achieve a similar effect size (d=0.41), a level of 0.05, and a power of 85%, the priori calculated sample size was at least 66 patients.[9] We retrospectively analyzed the data of 79 community-dwelling elderly patients admitted to a private hospital's orthopedics and traumatology clinic between January 2020 and 2024. A total of 4 patients were excluded due to missing data on the serum 25(OH)D level. The cohort included 75 patients with unstable intertrochanteric fractures who had encountered low-energy trauma or falls and were treated with THR and divided into the deficient (<20 ng/mL, n=46), insufficient (20 to 29.99 ng/mL, n=16), and normal (≥30 ng/mL, n=13) serum 25(OH)D groups, as depicted in the flow chart of the study (**Figure 1**).[10]

The inclusion criteria were being over 65 years of age and Evans-Jensen classification with unstable femoral intertrochanteric fractures due to low energy-trauma.[11] The exclusion criteria were fractures with a known history of high-energy trauma, multiple fractures, pathological fractures, and missing data on medical records, including unknown serum 25(OH)D levels.

Measurement of serum 25(OH)D level. The serum 25(OH)D levels during hospitalization (ng/mL) were measured in all patients. Blood samples were collected immediately after the patient's admission, before the surgical procedure, in a standard laboratory for all samples. The serum 25(OH)D was measured using the ADVIA Centaur XPT Immunoassay System autoanalyzer (Siemens Healthcare GmbH, Erlangen, Germany), employing the ADVIA Centaur Vitamin D test kit for accurate quantification.

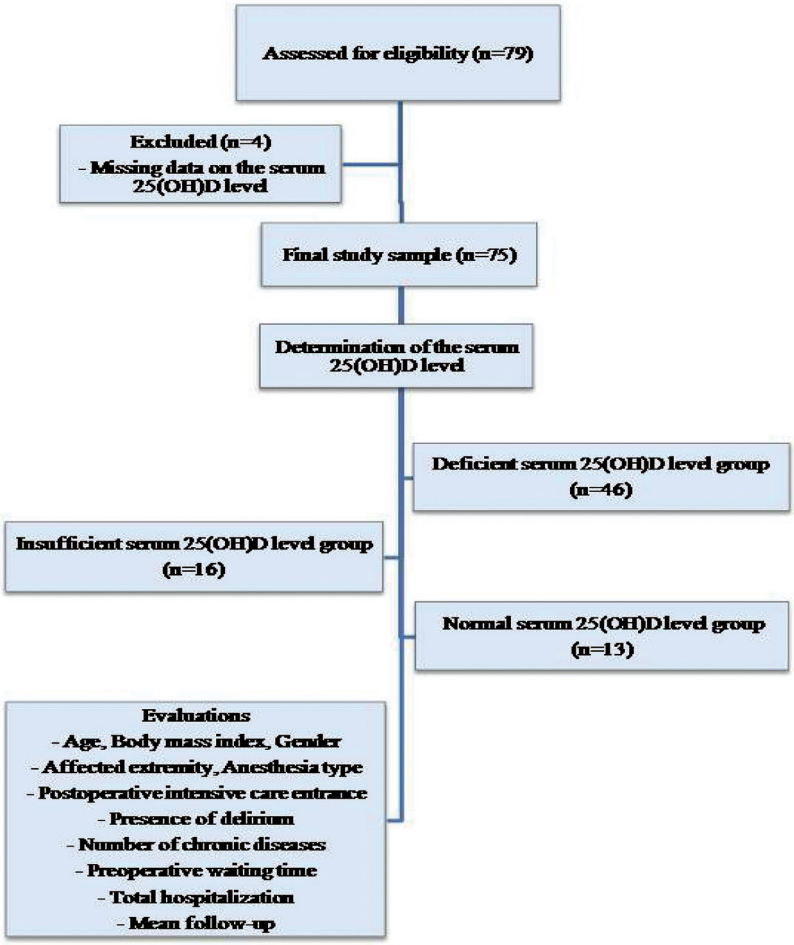

Figure 1 - Flow chart of the study. 25(OH)D: Serum 25-hydroxyvitamin D

Clinical data collection. Demographic characteristics of the patients, including age, gender, and body mass index, were recorded. The deficient, insufficient, and normal serum 25(OH)D groups' clinical data, including the affected lower extremity, anesthesia type, postoperative intensive care entrance, presence of delirium status by a psychiatrist, preoperative waiting time, and total hospitalization time after THR surgery (hours), number of chronic diseases, and the mean follow-up months after surgery, were analyzed and recorded.

Statistical analysis. The IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, N.Y., USA) was utilized to evaluate statistical data. The variables' conformity to the normal distribution was analyzed employing visual (histogram and probability graphs) and analytical (Kolmogorov-Smirnov) testing methods. The Pearson correlation coefficient was used to determine the relationships between the categorical variables. One-way analysis of variance (ANOVA) was utilized to analyze normally distributed data, and Bonferroni's multiple comparisons test was employed to determine whether or not there were significant differences between groups. The multiple linear regression analysis (R^2) was performed to determine the factors likely to affect the total hospitalization time. The statistical significance was set at $p<0.05$.

Results. A total of 75 patients were included in the study. The mean follow-up of the cohort was 23.77 months. The cohorts' mean age was 81.77 years, and the mean serum 25(OH)D level was 20.11 ng/mL during the hospitalization admission. The cohorts' vitamin D deficiency rate was 61.3%, the insufficiency rate was 21.3%, and the normal vitamin D level rate was 17.3%. The deficient 25(OH)D level group was comprised of 16 (34.8%) males and 30 (65.2%) females; the insufficient 25(OH)D level group included 2 (12.5%) males and

14 (87.5%) females, and the normal serum 25(OH)D level group was 4 (30.8%) males and 9 (71.2%) females (p=0.239). There was no difference in age (p=0.582, F=0.545), body mass index (p=0.382, F=0.975), number of chronic diseases (p=0.688, F=0.376), preoperative waiting time (p=0.413, F=0.896), total hospitalization time after THR (p=.819, F=0.200), mean follow-up time (p=0.763, F=0.272), affected extremity (p=0.481), anesthesia type (p=0.081), postoperative intensive care entrance (p=0.547), and the presence of delirium (p=0.947) between deficient, insufficient, and normal serum 25(OH)D level groups (Table 1).

According to the results of multiple linear regression model analysis, serum 25(OH)D level during hospitalization (ng/mL), preoperative waiting time, and the number of chronic diseases explaining 25.6% of the variance were found as independent determinants of the total hospitalization (p<0.001) The order of magnitude of the effects of the statistically significant variables on the total hospitalization was the preoperative waiting time (β=0.466, p=0.001) and the number of chronic diseases (β=0.263, p=0.011). However, the linear regression analysis showed that reduced serum 25(OH)D level was not a related factor in patients' total hospitalization (β=-0.072, p=0.474). Specifically, the multiple linear regression model indicated that the patients' total hospitalization increases with the coefficients as the preoperative waiting time and the number of chronic diseases increase (Table 2).

Discussion. This study was conducted to explore vitamin D levels (i) and to compare whether the presence of delirium and the postoperative intensive care entrance in elderly patients with deficient, insufficient, and normal serum 25(OH)D levels (ii) and the variables potentially influencing the total hospitalization time (iii) of elderly patients with unstable femoral intertrochanteric fractures treated with THR surgery. According to the study's findings, the cohorts displayed an average serum level of 20.11 ng/mL for 25(OH)D, which falls below the required level. The presence of delirium and entrance to the intensive care unit after surgery did not differ between deficient, insufficient, and normal serum 25(OH)D level groups. Linear regression analyses indicated that the elderly patients' total hospitalization increased as the waiting

Table 1 - Comparison of the groups regarding demographic and clinical data.

Variables	Serum 25(OH)D level						p^1
	Deficient[1] (n=46)		Insufficient[2] (n=16)		Normal[3] (n=13)		
	Mean ± SD	IQR 25-75%	Mean ± SD	IQR 25-75%	Mean ± SD	IQR 25-75%	
Age (years)	82.14 ± 6.73	78-87	81.06 ± 7.12	76-85.5	80.38 ± 7.25	74-85	0.582 (F=.545)
Body mass index (kg/m^2)	26.56 ± 2.54	24.57–27.82	25.80 ± 2.34	24.25-27.86	25.69 ± 2.28	24.29-26.18	0.382 (F=.975)
Serum 25(OH)D level during hospitalization (ng/mL)	13.33 ± 4.43	9.57-17.10	23.22 ± 2.62	20.55-25.42	40.24 ± 7.79	34.55-48	**0.001**[1-2, 1-3, 2-3] **(F=158.01)**
Number of chronic diseases	2.02 ± 0.90	1-3	2 ± 0.81	1.25-2	1.76 ± 1.16	1-2.5	0.688 (F=.376)
Preoperative waiting time (hours)	12.76 ± 3.84	11-14	13.93 ± 3.69	12-15.75	14.15 ± 5.01	10-18	0.413 (F=.896)
Total hospitalization time (hours)	67.95 ± 13.93	56-79.25	66.18 ± 15.76	56-79.25	69.69 ± 17.13	55.50-85.50	0.819 (F=.200)
Mean follow-up time (months)	23.04 ± 12.29	12.75-32	25.81 ± 13.89	12-39	23.84 ± 14.05	9.50-36.50	0.763 (F=.272)
	n	%	n	%	n	%	p[2]
Gender							
Male	16	34.8	2	12.5	4	30.8	0.239
Female	30	65.2	14	87.5	9	69.2	
Affected extremity							
Dominant	16	34.8	8	50	4	30.8	0.481
Non-dominant	30	65.2	8	50	9	69.2	
Anesthesia type							
General	17	37	5	31.5	8	61.5	0.202
Regional	29	63	11	68.5	5	38.5	
Postoperative intensive care entrance							
Yes	7	15.2	3	18.8	3	23.1	0.792
No	39	84.8	13	81.2	10	76.9	
Presence of delirium							
Yes	7	15.2	3	18.8	2	15.4	0.944
No	39	84.8	13	81.2	11	84.6	

Significant p-values highlighted in bold. p[1]: One-way analysis of variance (ANOVA), p^2: Pearson Chi-square analysis, SD: Standard deviation, CI: 95% confidence interval, kg: kilogram, m: meter, ng/mL: nanograms per milliliter, 25(OH)D: 25-hydroxyvitamin D,

Table 2 - The linear regression analysis regarding the factors likely affecting the total hospitalization (variables).

Variables	ΔR^2 0.256	F 9.474	β	t	*P*-value <0.001
Serum 25(OH)D level during hospitalization (ng/mL)			-0.072	-0.719	0.474
Preoperative waiting time (hours)			0.466	4.447	0.001*
Number of chronic diseases			0.263	2.617	0.011*

*Significant p-values. ΔR^2: Adjusted coefficient of determination, F: F-test statistics, β: Beta standardized coefficients, t: t-test statistics, *p*-value: The statistical value in the linear regression analysis model.

time before surgery and the number of chronic diseases increased.

Vitamin D deficiency is prevalent among older people, as demonstrated by earlier reports on femoral intertrochanteric fractures.[7,12] In the earlier reports, the prevalences of vitamin D deficiency were between 50 and 83.2%,and insufficiency rates were 60% and 86%.[7,13,14] According to a recent report, low levels of serum 25(OH)D are discovered in a significant percentage of patients with proximal femoral fractures in both the United States (50% of women) and Italy (21.6%).[14] The current study's deficiency and insufficiency prevalences were 61.3% and 21.3%, respectively. The elevated incidence of vitamin D deficiency observed within the study cohort may be attributable to several factors, including insufficient dietary calcium and vitamin D intake, a lack of vitamin D enrichment in nutritionally relevant foods, and inadequate exposure to sunlight.

Different serum 25(OH)D categories may be closely associated with impaired cognition in elderly patients.[13] It is crucial to recognize the presence of delirium in the elderly with hip fractures, as it may significantly increase the risks of complications and mortality.[15] According to a previous study, among elderly patients with hip fractures, 18% of those who were vitamin D-deficient and 15% of those who were not deficient exhibited the presence of delirium.[16] Similarly, a previous analysis reported that vitamin D deficiency was strongly linked with an increased risk of delirium at 5.8% in the deficient group.[17] The authors of these studies concluded that lacking vitamin D levels are at a higher risk of emerging delirium. However, our research indicates that the prevalence of delirium was similar among the groups, regardless of their vitamin D status, whether they were deficient, insufficient, or normal. Specifically, during the hospitalization, we noted a delirium incidence of 15.2% in the vitamin D-deficient group, 18.8% in the insufficient group, and 15.4% in the normal group. Our findings provide substantial evidence that vitamin D levels do not affect the prevalence of delirium.

Elderly patients with low levels of serum 25(OH) D are closely related to severe chronic diseases and a higher risk of mortality and morbidity rates.[13] A prior study indicated a critical correlation between higher serum vitamin D levels and reduced mortality risk in acute intensive care units.[18] Based on our findings, the entrance rates to intensive care following THR surgery were similar across the groups, regardless of their vitamin D status—deficient, insufficient, or normal. This suggests that vitamin D levels may not significantly influence the need for intensive care following this type of surgery. This finding is crucial as it indicates that factors other than vitamin D levels may play a more prominent role in determining the postoperative care requirements of patients undergoing THR surgery.

Proximal femoral fractures represent prolonged hospitalization in the elderly due to related surgical procedures.[5] Lower vitamin D levels are predicted to double the risk of hospitalization for more than 14 days in the acute care unit for the elderly.[13] In a previous study, the authors found that the mean length of hospitalization in patients with proximal femoral fractures was 6.3 days in the vitamin D-deficient group and 6.2 days in the normal group.[16] Earlier studies included elderly patients with proximal femoral fractures treated surgically and investigated hospitalization. The results indicated the mean length of hospitalization was 27.7 days in the vitamin D deficient group and 2.9 to 10.08 days in the insufficient groups.[17,18] The multiple linear regression model we established in our study revealed that longer preoperative waiting time and the increase in the number of chronic diseases had an increasing effect on the total duration of hospitalization. However, contrary to the results of previous studies, the regression model we established in our study revealed that elderly patients, regardless of their vitamin D status, whether deficient, insufficient, or normal, did not influence total hospitalization time.

This study had several limitations. Firstly, we did not make follow-up assessments regarding the serum 25(OH)D levels and physical functional status after the intertrochanteric fractures. Second, we did not evaluate the elderly patients' sarcopenia status, which may be linked with vitamin D. Lastly, it is uncertain whether the patients in our study had osteoporosis

and took vitamin D supplements before the femoral intertrochanteric fractures.

In conclusion, our results suggest that the elderly patients with unstable femoral intertrochanteric fractures treated with THR showed a similar prevalence of delirium and intensive care requirements regardless of their vitamin D status, whether they were deficient, insufficient, or normal. Prolonged preoperative waiting time before surgery and the increased number of chronic diseases had a substantial association with the longer hospitalization time after THR surgery. Reduced vitamin D levels did not relate to longer total hospitalization time after THR surgery in the elderly. Further comprehensive studies are needed to investigate the factors that could affect the length of hospital stay, such as osteoporosis, sarcopenia, or mental status, in elderly patients with unstable femoral intertrochanteric fractures, especially the association with vitamin D levels and functional recovery capability.

Acknowledgment. *We would like to thank Grammarly for the English Language editing.*

References

1. Hublikar AA, Nayak AR, Kenganal PB, Kulkarni S, Bagewadi RM, Basavaraj MK, et al. Association of serum vitamin-D and calcium levels with the severity of hip fragility fractures in the elderly: A prospective study. *Int J Acad Med Pharm* 2023; 5: 1697-1702.
2. Jamal AB, Hasan Khan MN, Sadiq M. Intertrochanteric hip fractures and vitamin D deficiency; A significant association. *J Ayub Med Coll Abbottabad* 2021; 33: 257-261.
3. Bernstein DN, Davis JT, Fairbanks C, McWilliam-Ross K, Ring D, Sanchez HB. Lower Bone Mineral Density is Associated with Intertrochanteric Hip Fracture. *Arch Bone Jt Surg* 2018; 6: 517-522.
4. Steingrimsdottir L, Halldorsson TI, Siggeirsdottir K, Cotch MF, Einarsdottir BO, Eiriksdottir G, et al. Hip fractures and bone mineral density in the elderly--importance of serum 25-hydroxyvitamin D. *PLoS One* 2014; 9: e91122.
5. Guerra MT, Feron ET, Viana RD, Maboni J, Pastore SI, Castro CC. Elderly with proximal hip fracture present significantly lower levels of 25-hydroxyvitamin D. *Rev Bras Ortop* 2016; 51: 583-588.
6. Sharma DK, Sawyer RK, Robertson TS, Stamenkov R, Solomon LB, Atkins GJ, et al. Elevated serum 25-hydroxyvitamin D levels are associated with improved bone formation and microstructural measures in elderly hip fracture patients. *J Clin Med* 2019; 8: 1988.
7. Han J, Cho Y, Jee S, Jo S. Vitamin D levels in patients with low-energy hip fractures. *Hip Pelvis* 2020; 32: 192-198.
8. Weaver CM, Alexander DD, Boushey CJ, Dawson-Hughes B, Lappe JM, LeBoff MS, et al. Calcium plus vitamin D supplementation and risk of fractures: an updated meta-analysis from the National Osteoporosis Foundation [published correction appears in Osteoporos Int. 2016 Aug;27(8):2643-6]. *Osteoporos Int* 2016; 27: 367-376.
9. Hershkovitz A, Maydan G, Ben Joseph R, Nissan R. Vitamin D levels in post-acute hip fractured patients and their association with rehabilitation outcomes. *Disabil Rehabil* 2022; 44: 6722-6729.
10. Kuriacose R, Olive KE. Vitamin D insufficiency/deficiency management. *South Med J* 2014; 107: 66-70.
11. Jensen JS. Classification of trochanteric fractures. *Acta Orthop Scand* 1980; 51: 803-810.
12. Seng WR, Belani MH, Ramason R, Naidu G, Doshi HK. Functional Improvement in Geriatric Hip Fractures: Does Vitamin D Deficiency Affect the Functional Outcome of Patients With Surgically Treated Intertrochanteric Hip Fractures. *Geriatr Orthop Surg Rehabil* 2015; 6: 186-191.
13. Maier GS, Horas K, Seeger JB, Roth KE, Kurth AA, Maus U. Vitamin D insufficiency in the elderly orthopaedic patient: an epidemic phenomenon. *Int Orthop* 2015; 39: 787-792.
14. Dadra A, Aggarwal S, Kumar P, Kumar V, Dibar DP, Bhadada SK. High prevalence of vitamin D deficiency and osteoporosis in patients with fragility fractures of hip: A pilot study. *J Clin Orthop Trauma* 2019; 10: 1097-1100.
15. Maffulli N, Aicale R. Proximal femoral fractures in the elderly: A few things to know, and some to forget. *Medicina (Kaunas)* 2022; 58: 1314.
16. Ingstad F, Solberg LB, Nordsletten L, Thorsby PM, Hestnes I, Frihagen F. Vitamin D status and complications, readmissions, and mortality after hip fracture. *Osteoporos Int* 2021; 32: 873-881.
17. Lim C, Roh YH, Kim S, Nam KW. Preoperative vitamin D deficiency is associated with postoperative functional recovery and complications after hip fracture surgery. *J Bone Metab* 2021; 28: 333-338.
18. Annweiler C, Pochic S, Fantino B, Legrand E, Bataille R, Montero-Odasso M, et al. Serum vitamin D concentration and short-term mortality among geriatric inpatients in acute care settings. *Adv Ther* 2010; 27: 245-249.