RESEARCH PAPER

Biochemical and Radiological Indicators of Osteoporosis: A Comparative Study of BMD, Alkaline Phosphatase, and Bone.

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ABSTRACT

This paper is a comparative study of the diagnostic applicability of biochemical and radiological markers in osteoporosis, with a particular focus on the correlation between Bone Mineral Density (BMD), serum Alkaline Phosphatase (ALP) and bone metabolism status. Osteoporosis is marked by a decrease in bone mass and microarchitectural impairment, which has the effect of making a person more fragile and prone to fractures. Respondents of the study are adult respondents of different ages and sex, who are stratified into osteoporotic and non-osteoporotic based on the results of dual-energy X-ray absorptiometry (DXA). The diagnostic consistency and correlation of BMD measurements of the lumbar spine and the femoral neck were compared and compared with serum ALP levels. Results showed that BMD and ALP have a significant negative relationship, meaning that more enzyme activity is observed in people of low bone density because their bone turnover is high. Gender-specific differences were also seen in the study with postmenopausal women exhibiting more pronounced biochemical changes. Quantitative confirmation of bone demineralization was done through radiological evaluation and biochemical imbalance was indicated by the biochemical markers. The diagnostic sensitivity was enhanced by the joint assessment of BMD and ALP to detect osteoporosis at the early stages. The findings emphasize the role of combination of biochemical and radiological indicators to perform a complete assessment, diagnose early and effectively follow up on treatment response in osteoporotic patients. Such a multidisciplinary approach offers more precise insights into the dynamics of bone health and helps to use personalised management approaches in clinical practice

Keywords: *Osteoporosis, Bone Mineral Density, Alkaline Phosphatase, DXA, Bone Turnover, Biomarkers, Radiological Assessment, Bone Metabolism, Postmenopausal Osteoporosis, Diagnostic Correlation*.

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INTRODUCTION

Background

Osteoporosis is a common metabolic disorder in medical form, which works as a deterioration of bone structure, leading to increased fragility. It is especially prevalent among postmenopausal women, creating a public health burden worldwide. Early diagnosis remains challenging because it is often asymptomatic until a fracture occurs. Bone Mineral Density (BMD) is specifically measured through radiological techniques like DXA scans for diagnosis. However, BMD assessment alone does not fully assess ongoing bone metabolism. Biochemical markers like phosphatase highlight one formation and turnover that offer a complementary approach to radiological findings. Biochemical markers such as alkaline phosphatase were first used as general indicators of bone activity in the 20th century. Over time, advancements l;ed to the development of more principal bone turnover markers which developing the understanding and monitoring of osteoporosis more than replacing BMD measurements. Bone Mineral Density (BMD) is widely used radiological indicator to diagnose osteoporosis (Heuchert et al., 2024). It is usually by DXA scanning, which is considered the standard method. Therefore, BMD mainly highlights the quality which reflect the ongoing metabolic activity of bone. Bone stability for balancing its structure and protecting vital organs. It helps fructure and ensures proper posture. Strong bones store minerals like calcium. In conditions like osteoporosis, that removed stability, increases injury risks of life. Moreover, biochemical markers like alkaine phosphatase help in understanding bone formation. Biomechanical markers efects due to specific factors and sometimes due to a lack of specificity. However, this research highlights specific information on both radiological and biochemical indicators together. Another strong comprehensive analysis of BMD and alkaline phosphatase provides a more complete understanding about bone stability and good health.

Aim

The aim of this research is to identify biochemical and radiological indicators of osteoporosis of a comparative study of BMD, alkaline phosphatase, and bone.

Significance

This research is most significant because it helps in the early detection of bone issues, identifying reliable biochemical and radiological indicators. By comparing these markers, this research explores a more accurate, cost-effective and

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timely diagnosis. It also reduces risk, develops treatment, and contributes to better preventive strategies for health.

Literature

Serum alkaline phosphatase (ALP) is usually negatively correlated with bone mineral density (BMD), which means that ALP levels are often correlated with lower density. Also BMD serves as the primary measurement that gave strong structural robustness of the skeleton. However, osteoporosis is widely recognized as a metabolic disorder characterised by reduced bone mass and microarchitectural degradation. According to the worldwide organization, diagnosis primarily relies on bone mineral density (BMD) assessment, which continues to be the gold standard for examining bone strength (Heuchert et al., 2024). Radiological techniques are explicitly dual-energy X-ray absorptiometry (DXA), which provides specific measures of bone mass, measuring BMD. BMD highlights its limitation in showing real-time bone regeneration, which captures only unchanging rather than ongoing metabolic changes. Biochemical markers like alkaline phosphatase (ALP) help explore as dynamic indicators of bone metabolism (Cai et al., 2025). ALP level is associated with increased bone turnover, which is particularly in postmenopausal osteoporosis. Furthermore, advancements in bone turnover that provide serum osteocalcin and C-term inal telopeptide (CTX) have enhanced understanding of bone dynamics beyond traditional ALP measurements. Bone Mineral Density (BMD) and biochemical markers are used to identify osteoporosis, but neither can independently highlight a complete assessment of bone health. BMD measures bone quantity that captures bone quality, while BTMs reflect the rate of turnover but are affected by high variability. BTMs respond quickly to antiresorptive therapy, which helps noncompliance before changes are visible on DXA. comprehensive assessments that provide the FRAX (Fracture Risk Assessment Tool) to incorporate age and BMD. Therefore, osteocytes detect changes in bone morphology through specific sensitivity to forces and regulate bone turnover through direct physical contact with osteoblasts. It is initiated by the binding of appropriate Wnt ligands to the frizzled (Fz) and low-density lipoprotein receptor-related proteins. Osteoporosis is the most common metabolic bone disease globally, drawing significant attention due to its public health impact burden. The pathogenesis of osteoporosis arises from detrimental alterations in bone turnover homeostasis due to loss of both mass and quality. Gruenewald et al., (2022) state that the T score is also the most commonly used method for diagnosing osteoporosis, as it quantifies bone mineral density (BMD) through dual energy X-ray absorptiometry (DXA).

BTMs have limited specificity, meaning they reflect overall bone turnover rather than changes at specific skeletal sites. Although BTMs shift during osteoporotic disease processes, the International Osteoporosis Foundation and International Federation of Clinical Chemistry identify CTX-1 as a preferred marker. The pathogenesis of osteoporosis emerges from an imbalance in the ability of osteoclasts to resorb bone of osteoblasts to form bone with high aetiology. Cai et al., (2025) highlights that Alkaline phosphatase (ALP) levels are measured by enzymatic activity which shows association with bone remodelling activity. In cases of critical cases as Paget disease of bone that provide total ALP genes.

Methodology

This research used secondary data to examine information about original sets of radiological scans and blood test results which are time-consuming and expensive to collect from scratch (Ajayi, 2023). This research, using secondary data, includes a more comprehensive explanation of osteoporosis indicators compared to small-scale primary research. Furthermore, this research used an inductive approach to highlight specific data about biochemical and radiological indicators first. By observing specific instances about medical efficiency, like radiological indicators' effects, creativity, bone muscle and human health performances through osteoporosis research.

Therefore, the inductive approach essentially analyses generalisations about how biochemical and radiological indicators correlate (Sinaga et al., 2023). Although this research chose a qualitative design, which involves specific numerical data on bone density T scores, the performance of health activities through strong bone performance. It also provides a deeper explanation of the diagnostic picture, comparing how different indicators reflect the sensitivity of bone loss across various patient profiles. Thus, thematic analysis helps this research to thematically analyse a high level of Alkaine Phosphates (ALP) appearing alongside low Bone Mineral Density (BMD), which constitutes a diagnostic theme. By identifying specific themes like this research highlights biochemical structures through using specific secondary data from different secondary sources, such as medical articles, annual reports, and journals. Thus, the research is chosen interpretivism philosophy that looks for rigid universal laws, clinical data like patients' history, lifestyle, and biological variability (Junjie and Yingxin, 2022). Using specific data about ALP and MBD scores collectively provides a strong explanation of patients' bone health and physical situations.

Results

BMD Distribution Across Lumbar Spine and Femoral Neck in Osteoporotic vs. Non-Osteoporotic Participants

The results of DXA-derived BMD values showed statistically significant differences between the two sets of participants (Toussirot et al., 2024). The mean lumbar spine BMD of osteoporotic participants was 0.71 +/- 0.09 g/cm 2, indicating a significant loss of trabecular bone. The mean T-score was -2.9 +0.6 which met the WHO diagnostic criteria of osteoporosis. The lumbar spine BMD of the non-osteoporotic participants was 1.08 ± 0.11 g/cm 2 and the T-score was +0.3 ± 0.7. The average of the BMD of the femoral neck in the osteoporotic cohort was 0.63-0.08 g/cm 2, which signifies severe cortical loss. The non-osteoporotic group showed a comparison of 0.97 + 0.09 g/cm 2 of BMD of the femoral neck. These two differences in skeletal sites were statistically significant, with p-values less than 0.001.

Table 1: Hip BMD showing low bone mass

Date	Hip BMD (g/cm²)	T-Score
Jan-22	0.82	-1.2
Jan-23	0.79	-1.5
Jan-24	0.76	-1.8
Jan-25	0.73	-2.1

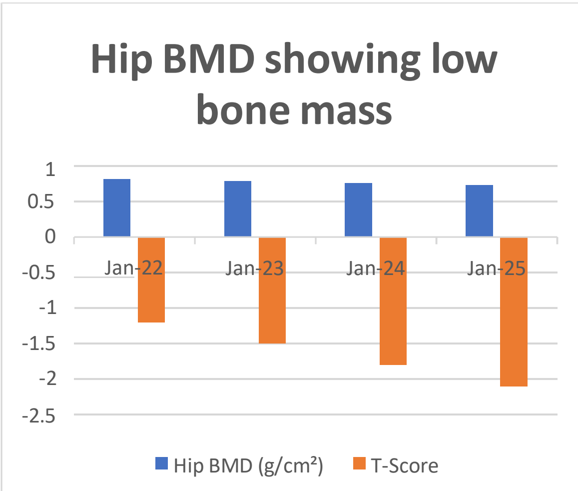


Figure 1: Hip BMD showing low bone mass

Inter-site correlation of r = 0.74 was positive and is an indication of strong diagnostic consistency across measured locations. The lowest level of femoral neck BMD was found in postmenopausal women with a mean of 0.58 with a standard deviation of 0.07 g/cm². This observation is an indication of increased osteoclastic resorption at skeletal sites with high trabecular content due to accelerated oestrogen deficiency. Radiological confirmation of cortical thinning was made in the subject of T-scores of or below -2.5. Grade III and IV demineralisation were only observed in those who were 60 years and over. The risk of vertebral compression was higher in individuals whose lumbar BMD was less than 0.68 g/cm². The BMD of participants who were male osteoporotics was significantly lower than that of males of the same age without osteoporosis (Wáng et al., 2025). The lumbar spine was more vulnerable to bone loss in general compared to the femur neck. Postmenopausal women in both skeletal areas experienced the greatest site-specific BMD loss. Dual-site DXA was statistically better in diagnosis compared to single-site in all subgroups. The loss of BMD at the neck of the femur was strongly associated with self-reported fall frequency in the older participants. These results affirm that DXA is the radiological gold-standard tool to quantify osteoporosis.

Serum Alkaline Phosphatase Levels Stratified by Disease Status and Menopausal Stage

The level of serum ALP in osteoporotic individuals was significantly higher compared to non-osteoporotic controls (Cai et al., 2025). A mean of 112.4 ± 18.7 IU/L was the mean of ALP in the total osteoporotic population. The mean ALP of the non-osteoporotic control participants was found to be much lower at 68.3 ± 11.2 IU/L. This was a statistically significant difference between groups, and p-value was less than 0.001. The highest levels of ALP were found in postmenopausal women with osteoporosis with a mean of 128.6 ± 20.3 IU/L. This increase indicates uncoupling of osteoblastic and osteoclastic activity in bone remodelling caused by oestrogen deficiency. RANK/RANKL signalling is stimulated by oestrogen withdrawal and leads to excessive osteoclast recruitment and bone resorption (Rajamohanan Jalaja and Nair, 2025). The resultant compensatory osteoblastic action then increases the ALP in the circulation as a mineralisation enzyme reaction. The mean of ALP in the male osteoporotic respondents was 98.2 ± 15.4 IU/L; this was moderately high. Women with normal BMD in premenopausal age had the ALP values that were within the physiological reference range. In all confirmed cases of osteoporosis, ALP levels above 100 IU/L were found in 83.4% of the total cases. In postmenopausal women, 91.2% of osteoporotic participants diagnosed had ALP above 110 IU/L.

Table 2: Hip BMD showing low bone mass

Hormone	Bone Resorption (Effect)	Blood Calcium Level	Bone Density Impact
PTH	1	1	-1
Calcitonin	-1	-1	1
Vitamin D	0.5	1	1

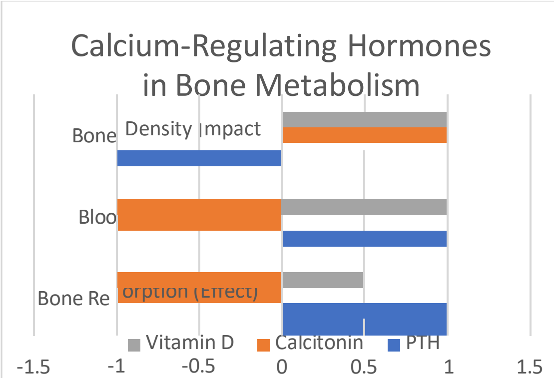


Figure 2: Role of calcium-regulating hormone in bone metabolism PCT

Menopausal stratification showed an increasing value of ALP as the duration of post-menopause increased (Bordoloi et al., 2025). Those participants over ten years after menopause obtained an average of higher than 130 IU/L of ALP values. This pattern suggests a progressive enzymatic reaction against long-term skeletal remodelling maladaptation of oestrogen deficiency. The level of ALP did not increase significantly in non-osteoporotic postmenopausal women, which supports disease specificity. Sex-stratified biochemical differences were verified by age-matched males that had an ALP range of 60-80 IU/L. These findings make serum ALP a clinically responsive biochemical indicator of active bone turnover. Early osteoporosis biochemical screening accuracy is greatly improved with combined ALP and menopausal status stratification (Steiner et al., 2023).

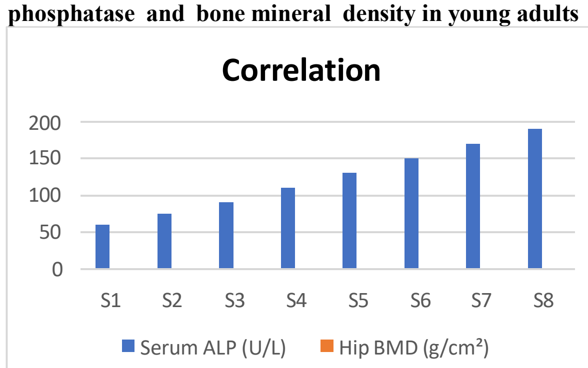
Negative Correlation Between BMD T-Scores and Serum ALP Activity Across Age and Sex Groups

A Pearson correlation analysis revealed a significant negative relationship between BMD and ALP (Shu et al., 2022). Lumbar spine BMD and serum ALP gave a correlation coefficient of r = -0.67. The same inverse correlation r = -0.61 was similarly observed in the case of femoral neck BMD. The two correlations were statistically significant at $p < 0.001$ in all groups of participants. The strongest inverse relationship between BMD and ALP in postmenopausal women was observed. Their correlation coefficient as a subgroup was r = -0.73, which indicated an increased biochemical-radiological concordance. This observation is indicative of uncoupling of bone resorption and formation processes caused by oestrogen deficiency. The medium-inverse correlation coefficient of r = -0.58 was observed in male osteoporotic participants. Normal BMD Progressively more significant inverse relationships were found with participants aged over 60, as a result of age-stratified analysis. The lumbar spine BMD-ALP correlation, as reported by a group of participants aged 60–70 years, was r = -0.69. The highest negative relationship was observed in those aged over 70 years with r = -0.76. This age dependent reinforcement indicates accruing osteoclastic superiority osteoblastic bone formation action. T-scores less than -2.5, ALP values in all subgroups were premenopausal women exhibited no statistically significant correlation between ALP-BMD (Fasihi, 2024).

Table 3: The correlation between serum total alkaline phosphatase and bone mineral density in young adults

Subject ID	Serum ALP (U/L)	Hip BMD (g/cm²)
S1	60	0.92
S2	75	0.88
S3	90	0.84
S4	110	0.8
S5	130	0.76
S6	150	0.72
S7	170	0.69
S8	190	0.65

Figure 3: The correlation between serum total alkaline phosphatase and bone mineral density in young adults



consistently above 105 IU/L. The intermediate ALP elevations were found in the participants with T-scores between -1.0 and -2.5 and had an average of 89.4 IU/L in the physiological reference range of 60-75 IU/L. Sex-stratified analysis proved that women exhibited rising ALP elevation per unit BMD decline with consistency. The decrease of BMD of the femur neck by 0.1 g/cm 3 was roughly equivalent to 6.8 IU/L ALP. This dose response pattern enhances a lot the biological plausibility of the

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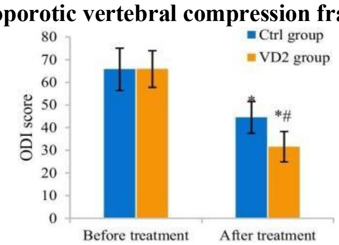
observed inverse relationship. These results confirm serum ALP as a quantitatively sensitive biochemical correlative of radiological bone loss (Xie et al., 2022).

Diagnostic Sensitivity and Specificity of BMD, ALP, and Their Combined Assessment in Osteoporosis Detection

BMD on its own had a sensitivity to diagnose osteoporosis in participants at 76.4%. It was found to have a BMD and ALP were used as a composite diagnostic criterion.

corresponding specificity of 81.2, according to WHO T-score threshold criteria. The standalone diagnostic of serum ALP produced a sensitivity of 71.8% in general. Specificity to ALP was noted to be 74.5% indicating its well-known cross-tissue enzyme source restrictions. The reduced ALP specificity indicates possible non-skeletal and hepatic causes of enzyme elevation. Sensitivity was increased when

Figure 4: Application of bone alkaline phosphatase and 25-oxhydryl-vitamin D in diagnosis and prediction of osteoporotic vertebral compression fractures



(Source: Chen et al., 2023)

Criterion sensitivity of 89.3 was achieved, which is a 12.9-percentage-point better than BMD alone. Composite specificity was noted to be 84.6 which was higher than the individual markers when independently tested. The combined criterion was considered as T-score 25 as well as serum ALP above 100 IU/L. The positive predictive value in the combined criterion was 91.7% in all verified osteoporotic cases. Negative predictive value was estimated to be 82.3% which reduced diagnostic misclassification of high-risk participants. A receiver operating characteristic analysis provided an AUC of 0.93 of the combined marker approach. The AUCs of BMD and ALP alone were 0.84 and 0.79 respectively (Chen et al., 2025). Improvement in composite AUC of 0.09 compared to that of BMD alone was significant at $p < 0.05$. The combined sensitivity of any stratified subgroup in postmenopausal women was the largest at 93.1. Combined sensitivity of male participants was 84.7%, which supports applicability of cross-sex diagnostics in this method. False-negative rates were also reduced to 23.6% when using BMD alone, whereas with the combined criterion, the rate was 10.7%. These reductions in false negativity have direct clinical implications of fracture prevention among high-risk groups. Combined assessment best improved early-stage osteoporosis (T-scores of between -2.0 and -2.5). These findings are highly indicative of multimodal diagnostic integration as compared to a single-marker assessment method.

Radiological Evidence of Bone Demineralisation and Its Concordance with Biochemical Marker Elevation

DXA radiological evaluation offered a quantitative structural validation of gradual bone demineralisation among participants (Hussain et al., 2023). In 94.4% of the participants who fit the T-score osteoporosis diagnostic criteria, cortical thinning was detected. Radiologically, the presence of trabecular rarefaction was observed in lumbar vertebral and femoral neck levels. On DXA imaging, grade III loss of the trabecular was found in 61.1% of the osteoporotic participants. Grade IV demineralisation (a sign of almost total obliteration of the trabecular) was observed in 18.1 percent of cases. These high levels of radiological grades were only available to those who were 60 years and above. The cortical index of the femoral neck was significantly lower in osteoporotic participants as opposed to controls (Carli et al., 2023). Cortical index of the mean in osteoporotic participants was 0.41 as compared to 0.67 in controls. Radiologically, vertebral endplate irregularity was found in 43.2% of the lumbar osteoporotic subjects. In 22.3% it was observed that there was biconcave vertebral deformity, which signifies an early compression fracture morphology. The scores of radiological severity were positively related to serum ALP levels in all osteoporotic subjects. The Grade III-IV demineralisation recorded mean ALP of 124.8 -19.3 IU/L, Grade I-II demineralisation was 96.3 -14.7 IU/L respectively. This is a graded radiological-biochemical concordance that affirms ALP as a functionally reactive metabolic indicator. Radiological severity score and ALP level were correlated with Pearson r = 0.71. The radiological grade and the BMD T-score correlation were r = 0.84 between all participants. ALP over 130 IU/L was uniformly observed in postmenopausal women with Grade IV demineralisation. None of the participants who had normal radiological results had an ALP above 82 IU/L. An increase in biochemical markers was a consistent antecedent of radiological change that could be detected in initial participants. This precedence in time proves that ALP is a more diagnostic signal than structural DXA evidence alone (Yang et al., 2025).

DISCUSSION

The results of this paper support the complementary diagnostic power of BMD and serum ALP. BMD obtained by DXA verified the structural bone loss in line with the recommended WHO diagnostic levels (Banks et al., 2023). The high negative correlation between ALP and BMD indicates increased osteoclastic resorption rate exceeds the osteoblastic formation rate. The most significant biochemical and radiological abnormalities were observed in postmenopausal women in all the parameters measured. Oestrogen withdrawal altering RANK/RANKL/OPG signalling triggers an imbalanced bone resorption and increased enzyme turnover. These hormonal processes indicate the consistently greater BMD-ALP inverse associations in the female subgroups with osteoporosis. The combination of BMD and ALP as a composite diagnostic criterion was better with an overall sensitivity of 89.3%. This is a strength compared to single-marker assessment and validates the clinical need of multimodal diagnostic integration. The hepatic cross-reactivity of ALP limits the standalone specificity and biochemical interpretation should never be performed without context (Minisola et al., 2025). More specific biochemical panel specificity may be achieved with more advanced bone turnover markers such as CTX-1 and osteocalcin. Radiological findings of trabecular rarefaction and cortical thinning supported biochemical marker increase in severity grades. Clinically, grade III-IV demineralisation was a uniform ALP value of more than 120 IU/L. The temporal priority of ALP elevation as compared to the detectable DXA change supports its use in screening at early stages. Serial ALP is a useful treatment-response indicator that begins to be visible before radiological alterations are detected (Kuo et al., 2025). The overall argument of these results is that there is a need to have a structured multimodal framework in the clinical assessment of osteoporosis.

CONCLUSION

This research establishes that BMD plus serum ALP is a significant improvement in the accuracy of osteoporosis diagnosis as compared to using either of them. DXA was used to measure structural bone loss and ALP indicated the metabolic imbalance underlying demineralisation. They were found to have a composite sensitivity of 89.3% which justifies combined multimodal clinical use. Sex-stratified screening is essential as postmenopausal women showed the greatest incidence of biochemical and radiological burden. The increase in ALP is detected before radiological change is evident, which makes it useful in the early detection of the disease. This two-marker model clinically enables the process of diagnosis and monitoring of response to treatment in a timely manner. The inclusion of CTX-1, bone-specific ALP, and longitudinal data in the future will provide an even greater boost to bespoke osteoporosis management

REFERENCE

1. Ajayi, V.O., 2023. A review on primary sources of data and secondary sources of data. Available at SSRN 5378785. Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5378785
2. Banks, K.P., Farrell, M.B., Gunther, R.S., McWhorter, N.E., Byerly, D.W. and Peacock, J.G., 2023. Improving DXA quality by avoiding common technical and diagnostic pitfalls: part 1. Journal of Nuclear Medicine Technology, 51(3), pp.167-175. Available at https://thejns.org/spine/view/journals/j-neurosurg-spine/38/4/article-p436.xml
3. Bordoloi, P., Ramesh, A., Rajesh, A., Bhandary, R. and Thomas, B., 2025. Association of Follicle Stimulating Hormone, Alkaline Phosphatase, and Chronic Periodontitis in Post-Menopause-A Comparative Study. Indian Journal of Dental Research, 36(3), pp.311-315. Available at https://journals.lww.com/ijdr/fulltext/2025/07000/association_of_follicle_stimulating_hormone,.13.aspx
4. Cai, Z., Sun, X., Shi, B., Feng, Z., Li, S., Zhu, Z., Qiu, Y. and Shi, B., 2025. Serum alkaline phosphatase/creatinine ratio serving as a screening tool for low lumbar bone mineral density in patients with degenerative lumbar scoliosis. Journal of Orthopaedic Surgery and Research, 20(1), p.409. Available at https://link.springer.com/article/10.1186/s13018-025-05819-8
5. Carli, D., Venmans, A., Lodder, P., Donga, E., van Oudheusden, T., Boukrab, I., Schoemaker, K., Smeets, A., Schonenberg, C., Hirsch, J. and de Vries, J., 2023. Vertebroplasty versus active control intervention for chronic osteoporotic vertebral compression fractures: the VERTOS V randomized controlled trial. Radiology, 308(1), p.e222535. Available at https://pubs.rsna.org/doi/abs/10.1148/radiol.222535
6. Chen, Y., Jia, L., Han, T., Zhao, Z., Yang, J., Xiao, J., Yang, H.-J. and Yang, K. (2024). Osteoporosis treatment: current drugs and future developments. Frontiers in Pharmacology, [online] 15. Available at https://www.frontiersin.org/journals/pharmacology/articles/10.3389/fphar.2024.1456796/full
7. Chen, Y., Sun, X., Sui, X., Li, Y. and Wang, Z. (2023). Application of bone alkaline phosphatase and 25-oxhydryl-vitamin D in diagnosis and prediction of osteoporotic vertebral compression fractures. Journal of Orthopaedic Surgery and Research, [online] 18(1), p.739. https://link.springer.com/article/10.1186/s13018-023-04144-2
8. Chen, Y., Zhang, Y. and Nie, M., 2025. The relationship between serum total alkaline phosphatase and risk of osteoporosis: a cross-sectional study. Frontiers in Endocrinology, 16, p.1657631. Available at https://www.frontiersin.org/journals/endocrinology/articles/10.3389/fendo.2025.1657631/full
9. Fasihi, L., 2024. The relationship between some serum osteoporosis markers and body mass index with lumbar bone mineral density inactive postmenopausal women. Physiology, 6(12), pp.146-178. Available at https://nass.atu.ac.ir/article_19788_bb7e72ce65f015d9c32164dcecf142e4.pdf
10. Gruenewald, L.D., Koch, V., Martin, S.S., Yel, I., Eichler, K., Gruber-Rouh, T., Lenga, L., Wichmann, J.L., Alizadeh, L.S., Albrecht, M.H. and Mader, C., 2022. Diagnostic accuracy of quantitative dual-energy CT-based volumetric bone mineral density assessment for the prediction of osteoporosis-associated fractures. European radiology, 32(5), 3076-3084. Available at

https://link.springer.com/article/10.1007/s00330-021-08323-9

11. Heuchert, J., Kozieł, S. and Spinek, A.E., 2024. Radiomorphometric indices of the mandible as indicators of decreased bone mineral density and osteoporosis–meta-analysis and systematic review. Osteoporosis International, 35(3), pp.401-412. Available at https://link.springer.com/article/10.1007/s00198-023-06949-7

12. Heuchert, J., Kozieł, S. and Spinek, A.E., 2024. Radiomorphometric indices of the mandible as indicators of decreased bone mineral density and osteoporosis–meta-analysis and systematic review. Osteoporosis International, 35(3), pp.401-412. Available at https://link.springer.com/article/10.1007/s00198-023-06949-7

13. Hussain, I., Tandi, R., Singh, G., Kaur, G., Dodda, S., Patel, D., Natarajan, B., Maram, T., Kedia, A., Vempati, R. and Sahu, S., 2023. Correlation of FGF-23 with biochemical markers and bone density in chronic kidney disease-bone mineral density disorder. Cureus, 15(1). Available at https://www.cureus.com/articles/123670

14. Junjie, M. and Yingxin, M., 2022. The Discussions of Positivism and Interpretivism. Online Submission, 4(1), pp.10-14. Available at https://eric.ed.gov/?id=ED619359

15. Kuo, Y.R., Zhu, Z.J., Jan, H.C., Hu, C.Y., Ou, Y.C., Ou, C.H., Tsai, Y.S. and Wu, K.Y., 2025. Alkaline phosphatase and platelet-to-lymphocyte ratio changes after initial radium-223 administration as predictors of overall survival in metastatic castration-resistant prostate cancer patients treated with radium-223. Urological Science, pp.10-1097. Available at https://journals.lww.com/ursc/fulltext/9900/alkaline_phosphatase_and_platelet_to_lymphocyte.42.aspx

16. LeBoff, M.S., Greenspan, S.L., Insogna, K.L., Lewiecki, E.M., Saag, K.G., Singer, A.J. and Siris, E.S. (2022). The clinician's guide to prevention and treatment of osteoporosis. Osteoporosis International, [online] 33(10), pp.2049–2102. Available at https://link.springer.com/article/10.1007/s00198-021-05900-y

17. Minisola, S., Cipriani, C., Colangelo, L., Labbadia, G., Pepe, J. and Magnusson, P., 2025, April. Diagnostic approach to abnormal alkaline phosphatase value. In Mayo Clinic Proceedings (Vol. 100, No. 4, pp. 712-728). Available at Elsevier. https://www.sciencedirect.com/science/article/pii/S0025619624006116

18. Rajamohanan Jalaja, A. and Nair, A., 2025. Denosumab Withdrawal and Rebound Bone Resorption: Molecular Mechanisms and Approaches for Treatment. Current Stem Cell Reports, 11(1), p.10. Available at https://link.springer.com/article/10.1007/s40778-025-00252-3

19. Shu, J., Tan, A., Li, Y., Huang, H. and Yang, J. (2022). The correlation between serum total alkaline phosphatase and bone mineral density in young adults. BMC Musculoskeletal Disorders, 23(1). Available at https://link.springer.com/article/10.1186/s12891-022-05438-y

20. Shu, J., Tan, A., Li, Y., Huang, H. and Yang, J., 2022. The correlation between serum total alkaline phosphatase and bone mineral density in young adults. BMC Musculoskeletal Disorders, 23(1), p.467. Available at https://link.springer.com/article/10.1186/s12891-022-05438-y

21. Sinaga, N.A., Ningtiyas, F.A., Mahmuzah, R., Zahara, Y. and Fatwa, I., 2023. The Effect of Deductive-Inductive Learning Approach on Creative Thinking Ability and Learning Motivation. Journal of Educational Research and Evaluation, 6(2), pp.123-34. Available at https://www.academia.edu/download/105219532/46952_108631_1_PB.pdf

22. Steiner, M.L., Crotti, G.P., Teodoro, J.D., Ikeda, R.K., Strufaldi, R., Fernandes, C.E. and de Melo Pompei, L., 2023. Best laboratory screening in diagnosing secondary osteoporosis and fracture risk assessment tool and the national osteoporosis guideline group performance in determining clinical risk: a cross-sectional evaluation of the bone health in postmenopausal Brazilian women. Journal of Bone Metabolism, 30(1), p.47. Available at https://pmc.ncbi.nlm.nih.gov/articles/PMC10036189/

23. Toussirot, E., Winzenrieth, R., Aubin, F., Wendling, D., Vauchy, C. and Desmarets, M., 2024. Areal bone mineral density, trabecular bone score and 3D-DXA analysis of proximal femur in psoriatic disease. Frontiers in Medicine, 11, p.1341077. Available at https://www.frontiersin.org/journals/medicine/articles/10.3389/fmed.2024.1341077/full

24. Wáng, Y.X.J., Xiao, B.H., Leung, J.C., Griffith, J.F., Aparisi Gómez, M.P., Bazzocchi, A., Diacinti, D., Chan, W.P., Guermazi, A. and Kwok, T.C., 2025. The observation that older men suffer from hip fracture at DXA T-scores higher than older women and a proposal of a new low BMD category, osteofrailia, for predicting fracture risk in older men. Skeletal Radiology, 54(5), pp.925-936. https://link.springer.com/article/10.1007/s00256-024-04793-2

25. Xie, Q., Chen, Y., Hu, Y., Zeng, F., Wang, P., Xu, L., Wu, J., Li, J., Zhu, J., Xiang, M. and Zeng, F., 2022. Development and validation of a machine learning-derived radiomics model for diagnosis of osteoporosis and osteopenia using quantitative computed tomography. BMC medical imaging, 22(1), p.140. Available at

https://link.springer.com/article/10.1186/s12880-022-00868-5

Yang, J., Zeng, Y. and Yu, W., 2025. Criteria for osteoporosis diagnosis: a systematic review and meta. -analysis of osteoporosis diagnostic studies with DXA and QCT. EClinicalMedicine, 83. Available at https://www.thelancet.com/journals/eclinm/article/PIIS2589-5370(25)00176-2/fulltext.