

Postmenopausal Skeletal Health in Pakistani Women: Links Between Time Since Menopause, Estradiol Status, Bone-Turnover Indices, and DXA Measurements

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ABSTRACT

Background: The postmenopausal skeleton is exposed to a sustained change in remodeling after ovarian estrogen production falls. We assessed whether the interval since menopause, serum estradiol, selected bone-turnover markers, and DXA-derived bone mineral density (BMD) were related to osteoporosis in Pakistani women.

Methods: We performed an analytical cross-sectional study of 120 naturally postmenopausal women aged 45–70 years at Shaheed Mohtarma Benazir Bhutto Institute of Trauma, Karachi, from January 2024 through January 2025. Participants were grouped by time since menopause (≤ 5 versus > 5 years). Morning fasting samples were analyzed for estradiol, FSH, P1NP, β -CTX, 25-hydroxyvitamin D, calcium, phosphate, alkaline phosphatase, and parathyroid hormone. DXA measurements were obtained at the lumbar spine, femoral neck, and total hip. Factors associated with osteoporosis were examined by multivariable logistic regression.

Results: Thirty-four women (28.3%) had osteoporosis and 56 (46.7%) had osteopenia. Women more than five years beyond menopause had lower estradiol concentrations, higher β -CTX values, and lower BMD at each DXA site. Lumbar-spine BMD increased with estradiol ($r=0.48$, $P<0.001$) and decreased as β -CTX rose ($r=-0.46$, $P<0.001$). In adjusted analysis, a longer postmenopausal interval, lower estradiol, and higher β -CTX were independently associated with osteoporosis. BMI was inversely associated with the outcome, whereas P1NP was not independently significant. The estradiol-plus- β -CTX model produced an AUC of 0.82.

Conclusion: In this sample, the combination of a longer duration after menopause, diminished estradiol, and greater bone-resorption activity identified women with lower BMD and more osteoporosis. Hormonal and turnover measurements may add useful context to clinical evaluation, but they should complement rather than replace DXA.

Keywords: postmenopause; osteoporosis; DXA; bone mineral density; estradiol; β -CTX; P1NP

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INTRODUCTION

Osteoporosis is a condition in which the quantity and/or quality of bone is reduced to the point that it can no longer withstand normal stresses, such as those imposed by trauma, leading to fracture [1]. The repercussions are not just from the fracture itself, but a fracture in an older woman can result in chronic pain, decreased mobility, functional dependency, and a diminished quality of life [2]. Menopause is a transition of particular importance as the associated endocrine change promotes an increase in bone loss and increases the burden of osteoporosis and fracture in later life [3].

This process is mediated by the drop in ovarian oestrogen [4]. In normal situations, estrogen acts as a regulator of osteoclast, osteoblast and osteocyte activities and also modulates cytokine signalling associated with

remodeling [5]. When the availability of estrogen decreases, resorption can exceed formation and result in a high turnover state where bone mass is gradually lost [6].

This imbalance is mediated in part through the RANKL/osteoprotegerin axis and through changes in inflammatory mediators such as interleukin-1, interleukin-6, and tumor necrosis factor- α [7]. Estrogen also helps osteoblasts survive and stimulates their bone-forming properties, such as Wnt/ β -catenin signaling [8]. The increased osteoclastic activity and inadequate compensatory formation are most prominent near and following the menopausal transition, when remodeling activity may increase quickly [9].

Chronological age may thus be of importance, as well as the low estrogen state, and cumulative exposure to this condition. Women who experience earlier menopause, or who have more years after their last period, are under less estrogen stimulation for a longer period of time [10]. This concept is supported by evidence that earlier menopause is associated with fracture risk [11]. Therefore, in addition to age, age at menopause, years since menopause and circulating estradiol may be used to more precisely assess skeletal risk [12].

DXA is still the major clinical method in which BMD is measured at the lumbar spine, femoral neck and total hip [13]. The diagnostic-site T-score is conventionally used for osteoporosis at values of ≤ -2.5 and osteopenia at values of -1.0 to -2.5 in postmenopausal women. While BMD is strongly associated with fracture risk, it is the net effect of remodeling undertaken previously and not the rate of remodeling in the present [15].

Biochemical turnover markers give another level of information. P1NP is a formation marker, released during the synthesis of type I collagen, while β -CTX is a resorption marker which reflects degradation of type I collagen [16]. These markers are acknowledged by international recommendations if specimen collection, pre-analytical handling and assay procedures are standardized [17]. Markers measurements have been associated with increased risk of fracture at higher turnover, but are not considered a substitute for densitometric measurement [18].

Thus, a combined assessment may be more informative than any one measurement. Estradiol indicates the endocrine environment, P1NP and β -CTX show active remodeling, and DXA provides an indication of the skeletal outcome. Age, BMI, vitamin D levels, diet, exercise, parity and years since menopause should also be taken into account when interpreting as each of these factors may affect BMD [19].

However, in Pakistan, the issue is of particular relevance as postmenopausal osteoporosis is clinically important and yet remains poorly understood. Local work has shown decreased BMD post menopause, and there is national guidance for identifying and managing women at risk of fracture [20].

There are few studies in Pakistan that have investigated menopausal timing, oestrogen status, standardised turnover markers, metabolic variables and central DXA in the same cohort [1]. The study of these domains together could be helpful as biochemical and endocrine changes can occur before or with the reduction in skeletal mass [2].

We therefore evaluated the relationships of menopausal duration and estradiol deficiency with lumbar-spine, femoral-neck, and total-hip BMD, together with P1NP, β -CTX, and selected clinical and metabolic features [3]. Independent correlates of osteoporosis were also explored and whether estradiol and a resorption marker added complementary discriminatory information was also examined [4].

MATERIALS AND METHODS

Study Design and Participants

An analytical cross-sectional study was carried out at Shaheed Mohtarma Benazir Bhutto Institute of Trauma, Karachi, between January 2024 and January 2025. Consecutive recruitment yielded 120 women aged 45–70 years who had undergone natural menopause. Eligibility required at least 12 consecutive months without menstruation. We excluded women with surgical menopause, chronic renal or hepatic disease, thyroid or parathyroid disorders, malignancy, rheumatoid arthritis, malabsorption, or another condition known to alter bone metabolism. Current menopausal hormone therapy, prolonged systemic corticosteroid exposure, and anti-osteoporotic treatment were additional exclusion criteria.

Clinical and Laboratory Evaluation

For each participant, we documented age, age at menopause, years since menopause, parity, BMI, previous fracture, physical-activity history, and use of calcium or vitamin D supplements. The women were further classified into ≤ 5 years and > 5 years post-menopause. Venous blood samples were taken following an overnight fast between 08:00 and 10:00. Laboratory tests performed were estradiol, FSH, P1NP, β -CTX, 25-hydroxyvitamin D, calcium, phosphate, alkaline phosphatase, and parathyroid hormone. P1NP was considered as the formation marker, while β -CTX was considered as the resorption marker.

DXA Assessment

Areal BMD was measured by DXA at the lumbar spine (L1–L4), femoral neck, and total hip. Results were recorded in g/cm^2 and as T-scores. Classification used the lowest valid T-score: normal BMD was defined as ≥ -1.0 , osteopenia as < -1.0 but > -2.5 , and osteoporosis as ≤ -2.5 .

Statistical Analysis

Analyses were conducted in IBM SPSS Statistics. Continuous data were summarized as mean $\pm$ standard deviation or median with interquartile range, depending on distribution; categorical data were summarized as counts and percentages. Between-group comparisons used parametric or non-parametric procedures as appropriate. Associations between biochemical measures and BMD were quantified using Pearson or Spearman correlation coefficients. Independent associations with osteoporosis were examined in a multivariable logistic-regression model and are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). ROC analysis was used to evaluate discrimination by estradiol and β -CTX individually and in combination. Statistical significance was set at $P < 0.05$.

Ethical Considerations

The Institutional Review Board/Ethics Review Committee of Shaheed Mohtarma Benazir Bhutto Institute of Trauma approved the study protocol. Written informed consent was obtained from every participant, and the study procedures were conducted in accordance with the Declaration of Helsinki.

RESULTS

All 120 enrolled women were included in the analysis, with 60 in each menopausal-duration category. As anticipated from the grouping strategy, the >5-year group was older and had spent substantially more time since menopause. This group also had lower mean estradiol and 25(OH)D concentrations and higher FSH, P1NP, and β -CTX values. Mean BMI was similar between groups (Table 1).

Table 1. Clinical and biochemical measures by postmenopausal interval

Characteristic	≤ 5 years after menopause (n=60)	> 5 years after menopause (n=60)	P value
Age, years	52.4 $\pm$ 3.8	61.1 $\pm$ 5.2	<0.001
Years since menopause	2.9 $\pm$ 1.3	11.2 $\pm$ 4.1	<0.001
BMI, kg/m ²	28.0 $\pm$ 4.2	27.2 $\pm$ 4.5	0.31
Estradiol, pg/mL	29.7 $\pm$ 10.3	17.6 $\pm$ 7.2	<0.001
FSH, mIU/mL	56.3 $\pm$ 15.7	70.1 $\pm$ 18.4	<0.001
P1NP, μ g/L	46.2 $\pm$ 15.4	53.8 $\pm$ 18.9	0.018
β -CTX, ng/mL	0.41 $\pm$ 0.14	0.59 $\pm$ 0.20	<0.001
25(OH)D, ng/mL	21.4 $\pm$ 8.0	18.2 $\pm$ 7.1	0.023
Calcium, mg/dL	9.22 $\pm$ 0.42	9.10 $\pm$ 0.46	0.14
PTH, pg/mL	44.1 $\pm$ 15.8	51.3 $\pm$ 18.7	0.025

Data are mean $\pm$ standard deviation. BMI, body mass index; FSH, follicle-stimulating hormone; P1NP, procollagen type I N-terminal propeptide; β -CTX, β -isomerized C-terminal telopeptide of type I collagen; 25(OH)D, 25-hydroxyvitamin D; PTH, parathyroid hormone.

DXA values were lower at every measured site in women who were more than five years beyond menopause. Lumbar-spine BMD averaged 0.931 $\pm$ 0.110 g/cm² in the ≤ 5 -year group and 0.812 $\pm$ 0.121 g/cm² in the > 5 -year group, with comparable group differences at the femoral neck and total hip. In the full cohort, 34 women (28.3%) met the osteoporosis criterion, 56 (46.7%) had osteopenia, and 30 (25.0%) had normal BMD. Osteoporosis affected 26 of 60 women (43.3%) in the > 5 -year group versus 8 of 60 (13.3%) in the ≤ 5 -year group ($P < 0.001$) (Table 2).

Table 2. DXA measurements and bone-density categories by years since menopause

DXA measure / category	≤ 5 years after menopause (n=60)	> 5 years after menopause (n=60)	P value
Lumbar-spine BMD, g/cm ²	0.931 $\pm$ 0.110	0.812 $\pm$ 0.121	<0.001
Femoral-neck BMD, g/cm ²	0.785 $\pm$ 0.095	0.697 $\pm$ 0.101	<0.001
Total-hip BMD, g/cm ²	0.829 $\pm$ 0.101	0.744 $\pm$ 0.108	<0.001
Lowest T-score	-1.58 $\pm$ 0.81	-2.36 $\pm$ 0.88	<0.001
Normal BMD, n (%)	23 (38.3)	7 (11.7)	<0.001
Osteopenia, n (%)	29 (48.3)	27 (45.0)	
Osteoporosis, n (%)	8 (13.3)	26 (43.3)	

Correlation analysis supported the same pattern. Estradiol was positively related to BMD at the lumbar spine, femoral neck, and total hip, with the largest coefficient at the lumbar spine ($r = 0.48$, $P < 0.001$). By contrast, β -CTX and years since menopause were negatively related to BMD at all three sites. P1NP showed smaller inverse coefficients, whereas 25(OH)D showed modest positive coefficients (Table 3).

Table 3. Correlation coefficients between selected variables and site-specific BMD

Variable	Lumbar-spine BMD	Femoral-neck BMD	Total-hip BMD
Estradiol	$r = 0.48$; $P < 0.001$	$r = 0.43$; $P < 0.001$	$r = 0.41$; $P < 0.001$
β -CTX	$r = -0.46$; $P < 0.001$	$r = -0.41$; $P < 0.001$	$r = -0.38$; $P < 0.001$
P1NP	$r = -0.22$; $P = 0.016$	$r = -0.19$; $P = 0.038$	$r = -0.18$; $P = 0.047$
Years since menopause	$r = -0.52$; $P < 0.001$	$r = -0.47$; $P < 0.001$	$r = -0.44$; $P < 0.001$
25(OH)D	$r = 0.25$; $P = 0.006$	$r = 0.22$; $P = 0.015$	$r = 0.20$; $P = 0.029$
BMI	$r = 0.18$; $P = 0.049$	$r = 0.21$; $P = 0.021$	$r = 0.23$; $P = 0.012$

The adjusted model identified three independent positive correlates of osteoporosis: longer menopausal duration, lower estradiol, and higher β -CTX. For every 10-pg/mL reduction in estradiol, the adjusted odds were 1.96 times

higher (95% CI 1.24–3.11). Each 0.1-ng/mL increase in β -CTX corresponded to an aOR of 1.39. BMI retained a modest inverse association, while P1NP did not remain significant after adjustment (Table 4).

Table 4. Multivariable model for osteoporosis

Model variable	Adjusted OR	95% CI	P value
Age, per 5-year increase	1.28	0.92–1.78	0.14
Menopausal duration, per 5 years	1.71	1.18–2.49	0.005
Estradiol, per 10-pg/mL decrease	1.96	1.24–3.11	0.004
β -CTX, per 0.1-ng/mL increase	1.39	1.15–1.68	<0.001
P1NP, per 10- μ g/L increase	1.09	0.89–1.34	0.40
Vitamin D deficiency	1.81	0.91–3.60	0.091
BMI, per kg/m ² increase	0.90	0.82–0.99	0.032

On ROC analysis, estradiol alone yielded an AUC of 0.75 and β -CTX alone an AUC of 0.76. Their combined model improved the AUC to 0.82 (95% CI 0.74–0.90), indicating stronger discrimination when endocrine status and resorption activity were considered together.

DISCUSSION

The central finding was that skeletal status tracked closely with the duration of the postmenopausal state. Women more than 5 years after menopause had lower BMD at spine and hip, lower estradiol, and higher β -CTX and a much higher prevalence of osteoporosis than women in the earlier postmenopausal window. This is in line with the known model of sequential bone loss in the case of chronic estrogen deficiency [1–3].

The burden of low bone mass was high—only 25% of the population had a normal BMD while 28.3% of the population had osteoporosis and 46.7% had osteopenia. Such proportions are generally in line with the Pakistani studies which have found high prevalence of impaired bone density post menopause [4–7]. Naeem et al. and other local investigators reported similar observations among women referred for BMD testing [8–10].

Estradiol was positively associated with BMD at all DXA sites and remained independently associated with osteoporosis when adjusted for. Biologically, this makes sense as decreased estrogen signaling is associated with increased osteoclast generation and survival and changes the regulation of RANKL signaling that promote resorption [2]. This slight correlation increase at the lumbar spine may be due to the greater remodeling of the trabecular bone, which may react more quickly during periods of high turnover [6].

Complementary information was provided by β -CTX. Higher values were related to lower BMD at the lumbar spine, femoral neck and total hip as well as to osteoporosis independently. It is a resorption marker and its behaviour is consistent with this role, while P1NP is a marker of formation activity [3]. Current consensus statements also recommend that standardized turnover-marker measurements be used as supplemental data along with BMD [4].

In the present data, P1NP was not similar to β -CTX. However, correlations with BMD were smaller and P1NP was not statistically significant in the adjusted model. One is remodeling coupling, in which formation increases with an increase in resorption, but the response may not be adequate to prevent net bone loss. Different associations of individual turnover markers with skeletal outcomes have also been reported previously [5]. Within this untreated group, β -CTX seemed to be more in line with postmenopausal bone loss [11].

After the inclusion of biochemical variables and age, years since menopause remained associated with osteoporosis [12]. This observation implies that the duration of exposure to the PM endocrine environment may provide information which is not entirely covered by chronological age. In fact, there is already a focus on the importance of recognizing postmenopausal women at risk and densitometric evaluation in the Pakistani guidance. Current evidence favors the consideration of reproductive history (especially years since menopause) in that clinical appraisal [13].

The later postmenopausal group had lower vitamin D levels and moderate positive associations with BMD. This is in line with the reports from Pakistan which revealed that vitamin D deficiency is common in post menopausal women and is linked to poor skeletal health [9]. Although vitamin D deficiency was not independently significant in the final regression model, it is important for calcium balance, bone mineralization and muscle function [14].

There was an inverse association between BMI and adjusted odds of osteoporosis. A higher BMI is not necessarily globally protective, although greater body mass will lead to increased mechanical loading and may lead to increased areal BMD. Obesity might occur alongside vitamin D deficiency, inactivity, metabolic disturbance and poor muscle function, which all have potential effects on falls and fracture risk. Thus, the BMD results need to be evaluated in the context of the whole clinical profile and not just from body weight alone [15,16].

The combination of estradiol and β -CTX was better at discriminating osteoporosis than either one alone [2–6]. Both measurements represent different sides of the same biological event: estradiol is an indicator of endocrine deficit and β -CTX is an indicator of resorption intensity. Nevertheless, neither of the markers can be used as a diagnostic alternative to DXA. Central DXA, history of fracture and known clinical risk factors remain the

mainstays of routine assessment with biochemical markers playing a supportive role [4].

The strength of this study was that multiple parameters of reproductive history, clinical parameters, endocrine parameters, standardized measures of turnover and central DXA were all assessed within the same cohort. Additionally, the morning fasting collection for β -CTX decreased an important pre-analytical source of variability highlighted in international guidance [13-17]. Some caveats should be taken into consideration when interpreting the data. Since the design was cross sectional, it was not possible to determine the temporal sequence or the causality between the estrogen depletion, the turnover alteration and the bone loss. Limitation of recruitment from a single institution and small sample size also limit generalizability to all women in Pakistan who are in post-menopausal period [18]. Biological variability exists in single measurements of estradiol and other turnover markers, and there are potential confounding factors related to diet, sun exposure, physical activity and other lifestyle factors. Prospective, larger multicenter studies should be conducted to assess the additive value of both hormonal and biochemical profiles for predicting future BMD loss or fragility fracture [19,20].

CONCLUSION

In this population of Pakistani postmenopausal women, those with lower bone status had a longer time since menopause, lower circulating estradiol and higher bone resorption as measured by circulating β -CTX. Women were more likely to be osteoporotic and have lower BMD 5 years or more after menopause. Both estradiol and β -CTX were independently associated with osteoporosis classification and the model combining the two markers had improved discrimination compared to each individual marker. These findings suggest that an integrated assessment should be used which takes all of these factors into consideration (reproductive history, conventional clinical risk factors, biochemical measurements, and DXA). Bone-turnover markers should be used in addition to densitometry, and could help to further characterize risk. Future studies with larger and more heterogeneous Pakistani populations are needed to ascertain if these relationships are predictive of future bone loss and fragility fracture.

REFERENCES

1. Bhattoa HP, Vasikaran S, Trifonidi I, Kapoula G, Lombardi G, Jørgensen NR, et al. Update on the role of bone turnover markers in the diagnosis and management of osteoporosis: a consensus paper from ESCEO, IOF, and IFCC. *Osteoporos Int.* 2025;36(4):579-608. doi:10.1007/s00198-025-07422-3.
2. Lombardi G, Jørgensen NR, Harvey NC, McCloskey EV, Åkesson KE, Eastell R, et al. Guidelines for the correct use of the nomenclature of biochemical indices of bone status: a position statement of the Joint IOF Working Group and IFCC Committee on Bone Metabolism. *Clin Chem Lab Med.* 2025;63(4):704-711. doi:10.1515/cclm-2024-1148.
3. Cosman F, Lewiecki EM, Eastell R, Ebeling PR, De Beur SJ, Langdahl B, et al. Goal-directed osteoporosis treatment: ASBMR/BHOF task force position statement 2024. *J Bone Miner Res.* 2024;39(10):1393-1405. doi:10.1093/jbmr/zjae119.
4. Yang JL, Hodara E, Sriprasert I, Shoupe D, Stanczyk FZ. Estrogen deficiency in the menopause and the role of hormone therapy: integrating the findings of basic science research with clinical trials. *Menopause.* 2024;31(10):926-939. doi:10.1097/GME.0000000000002407.
5. de Villiers TJ. Bone health and menopause: osteoporosis prevention and treatment. *Best Pract Res Clin Endocrinol Metab.* 2024;38(1):101782. doi:10.1016/j.beem.2023.101782.
6. Pervez A, Chandran M, Khan AH. Guiding postmenopausal care for osteoporosis: first evidence-based clinical practice guidelines for Pakistan. *J Pak Med Assoc.* 2024;74(6):1202-1203. doi:10.47391/JPMA.10632.
7. Nadeem S, Pervez A, Abid MA, Khalid RN, Rizvi NA, Aamdani SS, et al. GRADE-ADOLOPMENT of clinical practice guideline for postmenopausal osteoporosis management: a Pakistani context. *Arch Osteoporos.* 2023;18(1):71. doi:10.1007/s11657-023-01258-2.
8. Zelzer S, Meinitzer A, Enko D, Makris K, Tournis S, Trifonidi I, et al. Vitamin D and vitamin K status in postmenopausal women with normal and low bone mineral density. *Clin Chem Lab Med.* 2024;62(7):1402-1410. doi:10.1515/cclm-2023-1443.
9. Sornay-Rendu E, Duboeuf F, Chapurlat RD. Postmenopausal women with normal BMD who have fractures have deteriorated bone microarchitecture: a prospective analysis from the OFELY study. *Bone.* 2024;182:117072. doi:10.1016/j.bone.2024.117072.
10. Nasimi N, Jamshidi S, Askari A, Zolfaghari N, Sadeghi E, Nouri M, et al. Effect of vitamin D supplementation or fortification on bone turnover markers in women: a systematic review and meta-analysis. *Br J Nutr.* 2024;131(9):1473-1487. doi:10.1017/S0007114524000060.
11. Chen X, Shen L, Gao C, Weng R, Fan Y, Xu S, et al. Vitamin D status and its associations with bone mineral density, bone turnover markers, and parathyroid hormone in Chinese postmenopausal women with osteopenia and osteoporosis. *Front Nutr.* 2024;10:1307896. doi:10.3389/fnut.2023.1307896.
12. Mobasser M, Tarverdzadeh N, Mirghafourvand M, Salehi-Pourmehr H, Ostadrahimi A, Farshbaf-Khalili A. The role of bone turnover markers in screening low bone mineral density and their relationship with fracture risk in the

- postmenopausal period. *J Res Med Sci.* 2023;28:54. doi:10.4103/jrms.jrms_612_22.
13. Shieh A, Ruppert KM, Greendale GA, Lian Y, Cauley JA, Burnett-Bowie SA, et al. Associations of age at menopause with postmenopausal bone mineral density and fracture risk in women. *J Clin Endocrinol Metab.* 2022;107(2):e561-e569. doi:10.1210/clinem/dgab690.
14. Khan AA, Abu Alrob H, Ali DS, Dandurand K, Wolfman W, Fortier M. Guideline No. 422g: menopause and osteoporosis. *J Obstet Gynaecol Can.* 2022;44(5):527-536.e5. doi:10.1016/j.jogc.2021.09.013.
15. ACOG Committee on Clinical Practice Guidelines-Gynecology. Management of postmenopausal osteoporosis: ACOG Clinical Practice Guideline No. 2. *Obstet Gynecol.* 2022;139(4):698-717. doi:10.1097/AOG.0000000000004730.
16. Gregson CL, Armstrong DJ, Bowden J, Cooper C, Edwards J, Gittos NJL, et al. UK clinical guideline for the prevention and treatment of osteoporosis. *Arch Osteoporos.* 2022;17(1):58. doi:10.1007/s11657-022-01061-5.
17. Yu JS, Krishna NG, Fox MG, Blankenbaker DG, Frick MA, Jawetz ST, et al. ACR Appropriateness Criteria® osteoporosis and bone mineral density: 2022 update. *J Am Coll Radiol.* 2022;19(11S):S417-S432. doi:10.1016/j.jacr.2022.09.007.
18. Wei X, Zhang Y, Xiang X, Sun M, Sun K, Han T, et al. Exploring the relationship of bone turnover markers and bone mineral density in community-dwelling postmenopausal women. *Dis Markers.* 2021;2021:6690095. doi:10.1155/2021/6690095.
19. Cavalier E, Eastell R, Jørgensen NR, Makris K, Tournis S, Vasikaran S, et al. A multicenter study to evaluate harmonization of assays for C-terminal telopeptides of type I collagen (β -CTX): a report from the IFCC-IOF Committee for Bone Metabolism. *Calcif Tissue Int.* 2021;108(6):785-797. doi:10.1007/s00223-021-00816-5.
20. Bhattoa HP, Cavalier E, Eastell R, Heijboer AC, Jørgensen NR, Makris K, et al. Analytical considerations and plans to standardize or harmonize assays for the reference bone turnover markers PINP and β -CTX in blood. *Clin Chim Acta.* 2021;515:16-20. doi:10.1016/j.cca.2020.12.023.