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Bone Turnover Markers for Diagnosis and Management of Osteoporosis and Diseases Associated with High Bone Turnover

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Related Policies (if applicable)
None

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Coverage

Measurement of bone turnover markers **is considered experimental, investigational and/or unproven** to determine fracture risk in individuals with osteoporosis or with age-related risk factors for osteoporosis.

Measurement of bone turnover markers **is considered experimental, investigational and/or unproven** to determine response to therapy in individuals who are being treated for osteoporosis.

Measurement of bone turnover markers **is considered experimental, investigational and/or unproven** in the management of individuals with conditions associated with high rates of bone turnover, including but not limited to Paget disease, primary hyperparathyroidism and renal osteodystrophy.

Policy Guidelines

None.

Description

Bone turnover markers are biochemical markers of either bone formation or bone resorption. Commercially available tests are available to assess some of these markers in urine and/or serum by high performance liquid chromatography (HPLC) or immunoassay. Assessment of bone turnover markers is proposed to supplement bone mineral density (BMD) measurement in the diagnosis of osteoporosis and to aid in treatment decisions. Bone turnover markers could also potentially be used to evaluate treatment effectiveness before changes in BMD can be observed.

Bone Turnover

After cessation of growth, bone is in a constant state of remodeling (or turnover), with initial absorption of bone by osteoclasts followed by deposition of new bone matrix by osteoblasts. (1) This constant bone turnover is critical to the overall health of the bone, by repairing microfractures and remodeling the bony architecture in response to stress. Normally, the action of osteoclasts and osteoblasts is balanced, but bone loss occurs if the 2 processes become uncoupled. Bone turnover markers can be categorized as bone formation markers or bone resorption markers and can be identified in serum and/or urine. (2) There is interest in the use of bone turnover markers to evaluate age-related osteoporosis, a condition characterized by slow, prolonged bone loss, resulting in an increased risk of fractures at the hip, spine, or wrist. Measurement of bone turnover markers may aid in the diagnosis (by determining fracture risk) and therapeutic monitoring (by determining response to treatment) of osteoporosis. Bone turnover markers may also be used for the management of other diseases associated with high bone turnover (e.g., primary hyperparathyroidism, Paget disease, renal osteodystrophy). Table 1 summarizes the various bone turnover markers. (3)

Table 1. Bone Turnover Markers

Formation Markers	Resorption Markers
Serum osteocalcin	Serum and urinary hydroxyproline
Serum total alkaline phosphatase	Urinary total pyridinoline
Serum bone-specific alkaline phosphatase	Urinary total deoxypyridinoline
Serum procollagen I carboxy-terminal propeptide	Urinary-free pyridinoline (also known as Pyrilinks®)
Serum procollagen type 1 N-terminal propeptide	Urinary-free deoxypyridinoline (also known as Pyrilinks-D®)
Bone sialoprotein	Serum and urinary collagen type I cross-linked N-telopeptide (also referred to as Osteomark®)

	Serum and urinary collagen type I cross-linked C-telopeptide (also referred to as CrossLaps®)
	Serum carboxy-terminal telopeptide of type I collagen
	Tartrate-resistant acid phosphatase

Regulatory Status

Several tests for bone turnover markers have been cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k). Examples are listed in Table 2. FDA product codes: NEO, JMM, CIN.

Table 2. FDA-Cleared Tests for Bone Turnover Markers

Test	Manufacturer	Year	Indication
Pyrilinks®	Metra Biosystems	1995	Collagen type 1 cross-link, pyridinium
Osteomark®	Ostex International	1996	Cross-linked N-telopeptides of type 1 collagen
Serum CrossLaps® ELISA	Immunodiagnostic Systems	1999	Hydroxyproline
Ostase®	Beckman Coulter	2000	Bone-specific alkaline phosphatase
N-MID® Osteocalcin One-Step ELISA	Osteometer BioTech	2001	Osteocalcin
Elecsys® N-MID Osteocalcin	Roche Diagnostics	2005	Osteocalcin
IDS-iSYS Ostase® BAP	Immunodiagnostic Systems	2020	Bone-Specific alkaline phosphatase

ELISA: enzyme-linked immunosorbent assay; FDA: Food and Drug Administration.

Rationale

Medical policies assess whether a medical test is clinically useful. A useful test provides information to make a clinical management decision that improves the net health outcome. That is, the balance of benefits and harms is better when the test is used to manage the condition than when another test or no test is used to manage the condition.

The first step in assessing a medical test is to formulate the clinical context and purpose of the test. The test must be technically reliable, clinically valid, and clinically useful for that purpose. Medical policies assess the evidence on whether a test is clinically valid and clinically useful. Technical reliability is outside the scope of these reviews, and credible information on technical reliability is available from other sources.

For bone turnover markers to be considered clinically useful, studies need to demonstrate that tests for these markers are accurate and reliable and that their use can improve health outcomes. For example, to evaluate their utility for diagnosing osteoporosis as an adjunct to bone mineral density (BMD) measurements using dual-energy x-ray absorptiometry (DXA), studies would also need to show that bone turnover markers independently predict fracture risk beyond BMD and that the additional information provided by information on bone turnover has the potential to influence treatment decisions and clinical outcomes. Similarly, to be considered useful for monitoring osteoporosis treatment beyond follow-up BMD measurements, bone turnover test results would have to impact the decision to continue or change treatment in a way that improves patient outcomes.

Bone Turnover Markers to Determine Fracture Risk

Clinical Context and Test Purpose

One potential purpose of measuring bone turnover markers in individuals who have osteoporosis or who are at risk of age-related osteoporosis is to inform a decision whether to begin, continue, or discontinue therapy.

The following PICO was used to select literature to inform this policy.

Populations

The relevant population of interest is individuals with osteoporosis or age-related risk factors for osteoporosis.

Interventions

The test being considered is measurement of bone turnover markers as an adjunct to BMD. Variability in the measurement of bone turnover markers is related to a number of factors including sample handling and diurnal variation, postprandial status, menopausal status, exercise, alcohol use, medications, health conditions, and recent fractures. (4)

Comparators

The following practice is currently being used to make decisions of whether to start, continue, or discontinue therapy: bone density measurements with DXA.

Fracture risk is primarily based on measurements of BMD in conjunction with other genetic and environmental factors, such as a family history of osteoporosis, history of smoking, and weight. It is thought that the level of bone turnover markers may also predict fracture risk, possibly through a different mechanism than that associated with BMD. However, it must be emphasized that the presence of bone turnover markers in the serum or urine is not necessarily related to bone loss. For example, even if bone turnover is high, if resorption is balanced with formation, there will be no net bone loss. Bone loss will only occur if resorption exceeds formation. Therefore, bone turnover markers have been primarily studied as an adjunct, not an alternative, to measurements of BMD to estimate fracture risk and document the need for preventive or therapeutic strategies for osteoporosis.

Outcomes
The general outcomes of interest are test validity and morbid events, more specifically, the association between test results and bone health, and the impact of the test results on bone fracture and health.

The beneficial outcome of a true test result is confirming effective treatment. The beneficial outcome of a true-negative test is to modify ineffective treatment.

Harmful outcomes of a false-positive result are not receiving the correct treatment. Harmful outcomes of a false-negative test are receiving unnecessary treatment.

Changes in bone turnover are expected to be observed in 3 months. The impact of changes in treatment on bone strength would be observed in 2 to 5 years.

Study Selection Criteria
For the evaluation of clinical validity of the tests for bone turnover markers, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores).
- Included a suitable reference standard.
- Patient/sample clinical characteristics were described.
- Patient/sample selection criteria were described.

Clinical Validity
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

Systematic Reviews
A meta-analysis by Tian et al. (2019) examined whether bone turnover markers, specifically procollagen type 1 N-terminal propeptide (PINP or P1NP) and cross-linked C-telopeptide (CTX), are associated with fractures. (5) A total of 11,572 patients from 9 prospective cohort studies were included in the analysis. The crude and adjusted gradient of risk (GR) for PINP were extracted from 2 and 5 studies, respectively, while the crude and adjusted GR for CTX were extracted from 4 and 6 studies, respectively. PINP was not associated with fracture without adjusting covariates (crude GR, 1.03; 95% confidence interval [CI], 0.91 to 1.17). After adjusting for potential confounders (including age, body mass index, mobility score, past fractures, and hip BMD), PINP demonstrated a significant positive association with fracture (adjusted GR, 1.28; 95% CI, 1.15 to 1.42). For CTX, both the crude GR (1.16; 95% CI, 1.04 to 1.20) and adjusted GR (1.20; 95% CI, 1.05 to 1.37) showed a significant positive association with fractures. A subgroup analysis (performed based on gender, age, and site of fracture) found significant associations in elderly (age >65 years), female, and hip fracture patients. A sensitivity analysis that excluded 1 study per iteration confirmed the stability of the findings. Limitations of this meta-analysis include the use of GR as the metric of predictive power to create a common approximation of

risk. The included studies also had different settings for adjustment and various fracture endpoints.

A meta-analysis by Johansson et al. (2014) focused on PINP and CTX markers and examined their ability to predict future fracture risk. (6) Reviewers included ten prospective cohort studies in which bone turnover markers were measured at baseline and incident fractures were recorded. Pooled analyses were performed on a subset of these studies. Meta-analysis of 3 studies found a statistically significant association between baseline PINP and subsequent fracture risk (hazard ratio 1.23; 95% CI, 1.09 to 1.39). Similarly, a meta-analysis of 6 studies found an association between CTX and fracture risk (hazard ratio=1.18; 95% CI 1.09 to 1.29). None of the individual studies adjusted for BMD, and consequently, the pooled analyses do not reflect the ability of bone turnover markers to predict fracture risk beyond BMD. A high degree of heterogeneity was noted among the included studies.

A systematic review by Biver et al. (2012) did not find a statistically significant association between osteocalcin (OC; another bone turnover marker) and fracture risk. (7) When findings from 3 studies were pooled, the mean difference in OC levels in patients with and without vertebral fractures was 1.61 ng/mL (95% CI, -0.59 to 3.8). Heterogeneity of included studies was a limitation of the systematic review.

Prospective and Retrospective Studies

An analysis of the Japanese Population-based Osteoporosis (JPOS) study data by Tamaki et al. (2013) included postmenopausal women and adjusted for BMD. (8) The study involved baseline surveys, bone turnover marker assessment and BMD measurements, and 3 follow-ups over 10 years. At baseline, 851 women who participated were ages 50 years or older and eligible for vertebral fracture assessment. Of these, 730 women had BMD measurements taken at the initial examination and at one or more follow-ups. Women with early menopause (i.e., <40 years old), with a history of illness or medication known to affect bone metabolism, or with incomplete data were excluded. After exclusions, 522 women were evaluated. Over a median follow-up of 10 years, 81 (15.5%) of 522 women were found on imaging to have an incident vertebral fracture. Risk of incident vertebral fractures adjusted for BMD T-scores was significantly associated with several bone turnover markers, specifically alkaline phosphatase (ALP), urinary total deoxypyridinoline, and urinary free deoxypyridinoline. For example, in a multivariate model adjusting for various covariates including femoral neck BMD, the risk of developing a fracture per standard deviation of change in ALP was increased by 33% (relative risk, 1.33; 95% CI, 1.06 to 1.66). Risk of incident vertebral fracture was not significantly associated with other bone turnover markers including OC and CTX. It is not clear how generalizable findings from this study are, given the association between subsequent fracture risk and certain bone turnover markers, and the lack of association between fracture risk and other bone turnover markers. Study analysis also excluded a large number of women due to incomplete data.

Bauer et al. (2009) reported on men in a subgroup analysis of prospectively collected data from the Osteoporotic Fractures in Men (MrOS) study, also adjusted for BMD. (9) Baseline levels of

bone turnover markers were compared in 384 men, ages 65 years or older, who had nonspine fractures over an average follow-up of 5 years, with 885 men without nonspine fracture. A second analysis compared 72 hip fracture cases and 993 controls without hip fracture. After adjusting for age and recruitment site, the association between nonspine fracture and quartile of the bone turnover marker PINP was statistically significant (for each analysis, $p<0.05$ was used). The associations between nonspine fracture and quartiles of the two-other bone turnover markers, beta C-terminal cross-linked telopeptide of type 1 collagen and tartrate-resistant acid phosphatase 5b were not statistically significant. Moreover, in the analysis adjusting only for age and recruitment site, when the highest quartile of bone turnover markers was compared with the lower 3 quartiles, the risk of nonspine and hip fractures was significantly increased for PINP and beta C-terminal cross-linked telopeptide of type 1 collagen, but not tartrate-resistant acid phosphatase 5b. After additional adjustment for baseline BMD, or baseline BMD and other potential confounders, there were no statistically significant relations between any bone turnover marker and fracture risk. The authors concluded that their results did not support the routine use of bone turnover markers to assess fracture risk in older men when measuring hip BMD was an option.

Zhang et al. (2019) studied the use of multiple bone turnover markers for diagnosis of osteoporosis in a prospective study of 9053 Chinese post-menopausal women (2464 with osteoporosis and 6589 without osteoporosis). (10) The markers were bone-specific alkaline phosphatase, bone sialoprotein, CTX, osteoprotegerin, OC, and soluble receptor activator of nuclear factor kappa-B ligand. When compared to BMD measured by DXA, no individual marker had sufficient diagnostic accuracy. However, a model using all 6 markers was found to have a sensitivity of 0.99, a specificity of 0.99, and an agreement of 0.978 compared to BMD. Several advantages of using serum BTMs compared to DXA were discussed. The study was funded by the National Natural Science Foundation of China, and there is currently no commercially available panel that includes all 6 markers.

Studies have also reported that bone turnover markers might be used along with other factors to determine who is likely to develop osteoporosis, with the goal of beginning treatment before skeletal deterioration. (11, 12) For example, a study by Shieh et al. (2019) found that baseline urinary N-telopeptide in combination with age, race/ethnicity, and body mass index was found to predict a significant bone loss in perimenopausal women. (12) No evidence was identified that has evaluated whether earlier treatment reduces fracture risk.

Clinical Utility

A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence

Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the

preferred evidence would be from randomized controlled trials (RCTs). No RCTs were identified that evaluated the effect of measurement of bone turnover markers on health outcomes.

Chain of Evidence
Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

To provide clinical utility, bone turnover markers would have to provide information, beyond that offered by BMD measurements, that has an impact on treatment decisions, and/or that leads to improved health outcomes. Bone turnover markers can be measured more frequently than BMD and thus could provide information with clinical utility. For example, biochemical markers of bone turnover might be used to predict the extent of fracture risk reduction when measured 3 to 6 months after starting osteoporosis treatments approved by the U.S. Food and Drug Administration.

Section Summary: Bone Turnover Markers to Determine Fracture Risk
Few studies have directly addressed whether any bone turnover markers beyond BMD measurements are independent predictors of fracture risk. Among the body of evidence, only 1 meta-analysis has investigated the independent role of bone turnover markers in fracture risk prediction (by adjusting for potential confounders including BMD); a statistically significant but modest association between PINP or CTX and future fracture risk was found, although the study was limited since it used GR as the metric of predictive power. Some other studies have found statistically significant associations between bone turnover markers and fracture risk, but there is insufficient literature on any specific marker. For example, an analysis of MrOS data found a significant association between PINP and risk of nonspine fracture in men, and the JPOS study from Japan found a significant association between ALP, urinary total deoxypyridinoline, and urinary free deoxypyridinoline and risk of incident vertebral fracture in women. Overall, further evidence is needed from well-designed prospective studies that assess bone turnover markers in a standard manner for a single fracture type.

Bone Turnover Markers to Determine Response to Osteoporosis Treatment
Clinical Context and Test Purpose
Bone turnover markers might provide a more immediate assessment of treatment response and predict a change in BMD in response to treatment. Treatment-related changes in BMD occur very slowly. This fact, coupled with the precision of BMD technologies, has suggested that clinically significant changes in BMD could not be reliably detected until at least 2 years. In contrast, changes in bone turnover markers could be anticipated after 3 to 6 months of therapy.

The purpose of measuring for bone turnover markers in individuals who have suspected osteoporosis is to inform a decision whether to change therapy.

The following PICO was used to select literature to inform this policy.

Populations
The relevant population of interest is individuals who are being treated for osteoporosis.

Interventions
The test being considered is bone turnover markers as an indicator of response to therapy. Variability in the measurement of bone turnover markers is related to a number of factors including sample handling and diurnal variation, postprandial status, menopausal status, exercise, alcohol use, medications, health conditions, and recent fractures. (4)

Comparators
The following practice is currently being used to manage osteoporosis: BMD measurements with DXA.

Outcomes
The general outcomes of interest are test validity and morbid events, more specifically, the association between test results and bone health, and the impact of the test results on bone fracture and health.

The beneficial outcome of a true test result is confirming effective treatment. The beneficial outcome of a true-negative test is to modify ineffective treatment.

Harmful outcomes of a false-positive result are not receiving the correct treatment. Harmful outcomes of a false-negative test are receiving unnecessary treatment.

Changes in bone turnover are expected to be observed in 3 to 6 months. The impact of changes in treatment on bone strength would be observed in 2 to 5 years.

Study Selection Criteria
For the evaluation of clinical validity of the tests for bone turnover markers, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores).
- Included a suitable reference standard.
- Patient/sample clinical characteristics were described.
- Patient/sample selection criteria were described.

Clinically Valid
Studies have examined the ability of bone turnover markers to evaluate response to osteoporosis treatment.

Randomized Controlled Trials
A subgroup analysis of the randomized Fracture Intervention Trial (FIT) by Bauer et al. (2006) found that pretreatment levels of the bone turnover marker PINP significantly predicted the anti-fracture efficacy of alendronate. (13) The analysis included 6186 women who completed

the FIT trial and had complete baseline and follow-up measurements. Over a mean follow-up of 3.2 years, there were 492 nonspine and 294 vertebral fractures. Compared with the placebo group, the efficacy of alendronate for reducing nonspine fractures was significantly greater in women who were in the highest tercile of PINP (>56.8 ng/mL) than in those in the lowest tercile (<41.6 ng/mL). Baseline bone turnover rates were not associated with alendronate efficacy in reducing vertebral fractures. The authors indicated that this result needed confirmation in additional studies, and, even if verified, the impact on treatment recommendations was unclear.

Observational Studies

Kashii et al. (2023) reported a prospective review of 63 treatment-naive patients with postmenopausal osteoporosis commencing 12 months of treatment with romosozumab. (14) Multiple regression analysis revealed that PINP value was significantly and independently associated with at least a 3% increase in BMD in both total hip and femoral neck (p=.019). The optimal PINP cutoff was 53.7 mcg/L, with 54.3% sensitivity and 92.3% specificity.

Baxter et al. (2013) (15) reported a retrospective review of 200 patients commencing treatment with bisphosphonates for osteoporosis or osteopenia. Investigators found a statistically significant inverse correlation between change in urine N-terminal telopeptide at 4 months and change in spine BMD at 18 months ($r=0.33$, $p<0.001$). There was no significant association between change in urine N-terminal telopeptide and hip BMD.

<u>Clinically Useful</u>

A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence

Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs. No RCTs were identified that managed therapy based on results of the test.

Several RCTs have addressed whether measurement of bone turnover markers can improve adherence to oral bisphosphonate treatment. A systematic review by Burch et al. (2014) identified 5 RCTs and did not find significant differences in compliance rates between groups that did and did not receive feedback on bone turnover marker test results. (16) Study data were not pooled. Reviewers noted a high baseline compliance rate that limited the studies' ability to detect an impact of feedback. As an example, an industry-sponsored study by Roux et al. (2012) from France randomized physicians to manage patients on oral ibandronate given monthly with a collagen cross-links test or usual care. (17) In the collagen cross-links group, bone marker assessment was done at baseline and week 5 for the week 6 visit. A standardized message was delivered to patients regarding a change in CTX since baseline. If the decrease in

CTX was more than 30% of the baseline value, patients were told that the treatment effect was optimal. If not, they were told that the treatment effect was suboptimal and given additional advice. Patients told they had a suboptimal response were retested with CTX at week 13 for the week 14 visit. The primary outcome was the proportion of patients who were adherent at one year. After one year, rates of adherence to ibandronate were 74.8% in the collagen cross-links group and 75.1% in the usual care group; the difference between groups was not statistically significant (p=0.93). There was also no statistically significant difference in the proportion of patients having taken at least 10 of 12 pills (82.4% in the collagen cross-links group vs 80.0% in the usual care group). In this study, monitoring bone markers and providing this information to patients did not improve adherence to oral osteoporosis medication.

Chain of Evidence
Indirect evidence on clinical utility rests on clinical validity. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Evidence is insufficient to support that results of bone marker tests would affect patient management; therefore, no inferences can be made about clinical utility.

Section Summary: Bone Turnover Markers to Determine Response to Osteoporosis Treatment
The available evidence on the association between any specific bone turnover marker and response to osteoporosis treatment is limited in quantity and quality. While some individual studies have reported positive correlations for markers (e.g., PINP in the FIT trial) a body of evidence in support of any specific marker is lacking. As a result, the evidence does not permit conclusions about whether bone turnover markers are an independent predictor of treatment response. Individual RCTs and a systematic review of these RCTs have not found that feedback on bone turnover marker results improves adherence rates. No studies were identified that evaluated whether the use of bone turnover markers leads to management changes that are expected to improve outcomes.

Other Conditions Associated with High Rates of Bone Turnover
Clinical Context and Test Purpose
Bone turnover markers have been evaluated as markers of diseases associated with markedly high levels of bone turnover, such as Paget disease, primary hyperparathyroidism, and renal osteodystrophy. The purpose of measuring bone turnover markers in individuals who have conditions associated with high rates of bone turnover is to inform a decision whether to alter management.

The following PICO was used to select literature to inform this policy.

Populations
The relevant population of interest is individuals who have conditions associated with high rates of bone turnover.

Interventions

The test being considered is measurement of bone turnover markers.

Comparators
The following practices are currently being used to manage other conditions associated with high rates of bone turnover: bone density measurements with DXA and bone scintigraphy.

Outcomes
The general outcomes of interest are test validity and morbid events, more specifically, the association between test results and bone health, and the impact of the test results on bone fracture and health. Changes in bone turnover are expected to be observed in 3 months. The impact of changes in treatment on bone strength would be observed within 2 to 5 years.

The beneficial outcome of a true test result is undergoing correct treatment. The beneficial outcome of a true-negative test is to avoid unnecessary or incorrect treatment.

Harmful outcomes of a false-positive result are unnecessary treatment. Harmful outcomes of a false-negative test are not receiving the correct treatment.

Study Selection Criteria
For the evaluation of clinical validity of the tests for bone turnover markers, studies that meet the following eligibility criteria were considered:

- Reported on the accuracy of the marketed version of the technology (including any algorithms used to calculate scores).
- Included a suitable reference standard.
- Patient/sample clinical characteristics were described.
- Patient/sample selection criteria were described.

Clinically Valid
A test must detect the presence or absence of a condition, the risk of developing a condition in the future, or treatment response (beneficial or adverse).

There is little published literature on the use of bone turnover markers in the management of conditions associated with high rates of bone turnover (e.g., primary hyperparathyroidism, Paget disease, renal osteodystrophy), and many available studies were published ten or more years ago.

Systematic Reviews
A systematic review and meta-analysis by Al Nofal et al. (2015) assessed the literature on bone turnover markers in Paget disease. (18) Reviewers focused on the correlation between bone markers and disease activity before and after treatment with bisphosphonates. All study design types were included, and bone scintigraphy was used as the reference standard. Reviewers identified 18 studies. Seven assessed bone markers in patients with Paget disease before treatment, six considered both the pre- and posttreatment associations, and five included only the posttreatment period. Only one study was an RCT; the rest were prospective cohort

studies. There was a moderate-to-strong correlation between several bone turnover markers (bone ALP, total ALP, PINP, N-terminal telopeptide) and pretreatment disease activity. In a pooled analysis of available data, there was a statistically significant correlation between levels of a bone turnover marker and disease activity after treatment with bisphosphonates (p=0.019). Reviewers did not address the potential impact on the bone turnover measurement on patient management or health outcomes.

Observational Studies
A study by Martli et al. (2023) reported on 55 patients with primary hyperparathyroidism who underwent parathyroidectomy. (19) The investigators sought to determine the relationship between preoperative P1NP and CTx levels and the risk of postoperative hypocalcemia. Results demonstrated that a CTx value exceeding 2.665 pg/dL was an independent risk factor for postoperative hypocalcemia (p=.036).

A study by Rianon et al. (2012) reported on 198 patients with primary hyperparathyroidism who underwent parathyroidectomy. (20) The investigators found a statistically significant association (p<0.05) between preoperative serum OC levels and persistent postoperative elevation of parathyroid hormone six months after the surgery.

Clinically Useful
A test is clinically useful if the use of the results informs management decisions that improve the net health outcome of care. The net health outcome can be improved if patients receive correct therapy, or more effective therapy, or avoid unnecessary therapy, or avoid unnecessary testing.

Direct Evidence
Direct evidence of clinical utility is provided by studies that have compared health outcomes for patients managed with and without the test. Because these are intervention studies, the preferred evidence would be from RCTs.

No RCTs of bone turnover markers in these conditions have been identified.

Chain of Evidence
Indirect evidence on clinical utility rests on clinical validity and evidence that test results would change patient management. If the evidence is insufficient to demonstrate test performance, no inferences can be made about clinical utility.

Evidence is insufficient to support that results of bone marker tests would affect patient management; therefore, no inferences can be made about clinical utility.

Section Summary: Other Conditions Associated With High Rates of Bone Turnover
There is a lack of evidence on how the measurement of bone turnover markers can change management or improve health outcomes in patients who have diseases associated with high bone turnover other than age-related osteoporosis. Although observational studies have

demonstrated an association between bone markers and disease activity, the clinical utility of monitoring bone turnover markers for the management of diseases associated with high bone turnover is uncertain. Large prospective trials are needed to establish clinical validity.

Summary of Evidence

For individuals with osteoporosis or risk factors for age-related osteoporosis who receive a measurement of bone turnover markers to determine fracture risk, the evidence includes observational studies on the association between markers and osteoporosis and fracture risk, and systematic reviews of those studies. Relevant outcomes are test validity and morbid events. Few studies have directly addressed whether any bone turnover markers beyond bone mineral density (BMD) measurements are independent predictors of fracture risk. One meta-analysis investigated the independent role of bone turnover markers in fracture risk prediction and found a statistically significant but modest association between bone turnover markers (specifically, PINP and CTX) and future fracture risk after adjusting for BMD and clinical risk factors. Other studies have suggested that bone turnover marker levels may be independently associated with osteoporosis and fracture risk in some groups, but there is insufficient evidence reporting on an association with any specific marker. Questions remain whether bone turnover markers are sufficiently sensitive to determine reliably individual treatment responses. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who are being treated for osteoporosis who receive a measurement of bone turnover markers to determine response to therapy, the evidence includes observational studies, randomized controlled trials (RCTs), and a systematic review of these RCTS. Relevant outcomes are test validity and morbid events. There is a limited amount of evidence on the impact of bone turnover markers on the management of osteoporosis. Individual RCTs and a systematic review of these RCTs have not found that feedback on bone turnover marker improves treatment adherence rates. No studies were identified that evaluated whether the use of bone turnover markers leads to management changes that are expected to improve outcomes. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

For individuals with conditions associated with high rates of bone turnover other than age-related osteoporosis (e.g., primary hyperparathyroidism, Paget disease, renal osteodystrophy) who receive a measurement of bone turnover markers, the evidence includes observational studies on the association between markers and disease activity and a systematic review of those studies. Relevant outcomes are test validity and morbid events. The largest amount of evidence has been published on Paget disease; a systematic review found correlations between several bone turnover markers and disease activity prior to and/or after bisphosphonate treatment. There is a lack of evidence on how the measurement of bone turnover markers can change patient management or improve health outcomes. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

Practice Guidelines and Position Statements

American Association of Clinical Endocrinologists and the American College of Endocrinology

The 2020 guidelines from the American Association of Clinical Endocrinologists and the American College of Endocrinology (AACE/ACE) gave a Grade B recommendation to consider using bone turnover markers for assessing patient compliance and therapy efficacy. (21) AACE/ACE reviewed evidence that markers respond quickly to therapeutic intervention, and changes in markers have been associated with bone response to therapy and fracture risk reduction.

Bone Health and Osteoporosis Foundation

In 2022, the Bone Health and Osteoporosis Foundation (formerly the National Osteoporosis Foundation) published updated guidelines on the prevention and treatment of osteoporosis to prevent fractures. Regarding biochemical markers of bone turnover, the guidelines stated: "Biochemical bone turnover markers can play a role in assessing fracture risk in appropriate individuals." (22)

Furthermore, biochemical markers of bone turnover may

- Predict rapidity of bone loss in untreated postmenopausal women
- Predict extent of fracture risk reduction when repeated after 3-6 months of treatment with FDA [Food and Drug Administration]-approved therapies
- Predict magnitude of BMD [bone mineral density] increases with FDA-approved therapies
- Help determine adequacy of patient compliance and persistence with osteoporosis therapy using a serum CTX for an antiresorptive medication and P1NP for an anabolic therapy (least significant change [LSC] is approximately a 40% reduction in CTX)
- Help determine duration of 'drug holiday' and when and if medication should be restarted (Data are quite limited to support this use, but studies are underway.)

Endocrine Society

The 2019, guidelines from the Endocrine Society recommend that in postmenopausal women with a low BMD and at high-risk of fractures who are being treated for osteoporosis, monitoring should be conducted by dual-energy X-ray absorptiometry at the spine and hip every 1 to 3 years. (23) The Society considers measuring bone turnover markers (serum CTX for antiresorptive therapy or PINP for bone anabolic therapy) as an alternative way of monitoring for poor response or nonadherence to therapy. The Society notes that there is uncertainty over what constitutes an optimal response to treatment, but some experts suggest that a meaningful change is approximately 40% when compared from before to 3 to 6 months after starting treatment. A guideline update was published in 2020, in which the statements concerning measurement of bone turnover markers remained unchanged. (24)

The Endocrine Society also published guidelines regarding the management of Paget disease in 2014. (25) The guideline states:

- "We recommend measurement of serum total alkaline phosphatase or, when warranted, a more specific marker of bone formation or bone resorption to assess the response to treatment or evolution of the disease in untreated patients."

- “In patients with monostotic disease who have a normal serum total alkaline phosphatase, we suggest that a specific marker of bone formation and bone resorption be measured, although these may still be normal. Serial radionuclide bone scans may determine the response to treatment if the markers are normal.”
- "In assessing the response to treatment: “For most patients, measurement of total ALP [alkaline phosphatase] or other baseline disease activity markers at 6 to 12 weeks, when bone turnover will have shown a substantial decline, is an acceptable and cost-effective option.”

North American Menopause Society

In 2021, the North American Menopause Society (NAMS) issued a position statement on the management of osteoporosis in postmenopausal women. (26) Per the NAMS:

- “Bone turnover markers cannot diagnose osteoporosis and have varying ability to predict fracture risk in clinical trials. Bone turnover markers have been used primarily in clinical trials to demonstrate group responses to treatment. Although used by some osteoporosis specialists, the routine use of bone turnover markers in the evaluation of patients with osteoporosis is not recommended.”
- “Although changes in bone turnover markers are used by some specialists to assess adherence and effectiveness of therapy, routine use of bone markers is not recommended.”

International Society for Clinical Densitometry

In 2011, a joint statement by the International Society for Clinical Densitometry and the International Osteoporosis Foundation on the Fracture Risk Assessment Model (FRAX) fracture risk prediction algorithms indicated that the “Evidence that bone turnover markers predict fracture risk independent of BMD [bone mineral density] is inconclusive. Therefore, bone turnover markers are not included as risk factors in FRAX.” (27)

In the 2019 ISCD position statement on repeating measurement of BMD when monitoring with DXA, there is a comment on bone turnover markers: “Serial BMD testing in combination with clinical assessment of fracture risk, bone turnover markers, and other factors…can be used to determine whether treatment should be initiated in untreated patients, according to locally applicable guidelines.” (28)

U.S. Preventative Services Task Force Recommendations

The U.S. Preventive Services Task Force (2018) recommended screening for osteoporosis with bone measurement testing to prevent osteoporotic fractures in women 65 years and older. (29) The Task Force recommended screening for osteoporosis with bone measurement testing to prevent osteoporotic fractures in postmenopausal women younger than 65 years who are at increased risk of osteoporosis, as determined by a formal clinical risk assessment tool. The recommendations on osteoporosis screening addressed DXA testing but did not mention bone turnover markers.

Medicare National Coverage

In November 2002, the Centers for Medicare & Medicaid Services issued a national coverage determination on collagen cross-links. (30) The Centers for Medicare & Medicaid Services identified a set of clinical conditions for which collagen cross-links would be considered eligible for coverage. The decision is limited to urine-based collagen cross-link tests and does not address serum-based collagen cross-link tests.

Previously, the *Federal Register* (2001) noted that Medicare carriers have the discretion to make their own determinations on the medical necessity of serum-based collagen cross-link tests for assessing or monitoring bone loss therapy. (31) The *Federal Register* also noted that the U.S. Food and Drug Administration approved serum-based collagen cross-link tests under 510(k) review, as substantially equivalent to the urine-based collagen cross-link test. It should be noted that the serum-based collagen cross-link tests are more commonly performed than urine collagen cross-link tests.

Note that the Centers for Medicare & Medicaid Services analysis focused on the technical feasibility of collagen cross-links and anticipated outcomes. The discussion above focused on the impact on health outcomes as documented in controlled studies.

Ongoing and Unpublished Clinical Trials

A search of ClinicalTrials.gov in November 2023 did not identify any ongoing or unpublished trials that would likely influence this policy.

Coding

Procedure codes on Medical Policy documents are included **only** as a general reference tool for each policy. **They may not be all-inclusive.**

The presence or absence of procedure, service, supply, or device codes in a Medical Policy document has no relevance for determination of benefit coverage for members or reimbursement for providers. **Only the written coverage position in a Medical Policy should be used for such determinations.**

Benefit coverage determinations based on written Medical Policy coverage positions must include review of the member's benefit contract or Summary Plan Description (SPD) for defined coverage vs. non-coverage, benefit exclusions, and benefit limitations such as dollar or duration caps.

CPT Codes	82523, 83937, 84080
HCPCS Codes	None

*Current Procedural Terminology (CPT®) ©2024 American Medical Association: Chicago, IL.

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Centers for Medicare and Medicaid Services (CMS)

The information contained in this section is for informational purposes only. HCSC makes no representation as to the accuracy of this information. It is not to be used for claims adjudication for HCSC Plans.

The Centers for Medicare and Medicaid Services (CMS) does have a national Medicare coverage position. Coverage may be subject to local carrier discretion.

A national coverage position for Medicare may have been changed since this medical policy document was written. See Medicare's National Coverage at <https://www.cms.hhs.gov>.

Policy History/Revision

Date	Description of Change
04/01/2025	Reviewed. No changes.
08/15/2024	Document updated with literature review. Coverage unchanged. References 1-3, 5, 14, 19, 22, 24-26, 28, 30, and 31 were added; others removed.
12/01/2023	Reviewed. No changes.
10/01/2022	Document updated with literature review. Coverage unchanged. The following reference was added/updated: 16.
09/01/2021	Reviewed. No changes.
07/01/2020	Document updated with literature review. The following change was made to Coverage: First coverage statement divided into two statements; the first statement is on determining fracture risk and the second statement is on monitoring response to therapy. The intent of the coverage statements is unchanged. References 6-8, 15-16, 19 were added; others removed.
04/15/2019	Reviewed. No changes.
04/15/2018	Document updated with literature review. Coverage unchanged. Reference 18 added.
04/15/2017	Reviewed. No changes.
04/15/2016	Document updated with literature review. Coverage unchanged. Document title changed from “Bone Turnover Markers for Diagnosis and Management of Osteoporosis and Diseases Associated with Increased Bone Turnover”.
03/15/2015	Reviewed. No changes.
06/01/2014	Policy updated with literature review. Coverage unchanged. The title was changed from “Bone Turnover Markers for Diagnosis and Management of Osteoporosis and Other Conditions Associated with Increased Bone Turnover.”
10/15/2013	Policy updated with literature review. Coverage changed as follows: “Collagen cross links as measurements of bone turnover are considered

	experimental, investigational and unproven for other conditions associated with increased bone turnover" was changed to "Measurement of bone turnover markers is considered experimental, investigational, and unproven in the management of patients with conditions associated with high rates of bone turnover, including but not limited to Paget's disease, primary hyperparathyroidism and renal osteodystrophy". CPT/HCPCS code(s) updated.
03/01/2010	Policy updated with literature review. Scope changed to include bone turnover markers other than collagen cross links, title and policy statement changed to reflect expanded scope.
01/01/2009	Revised/updated entire document
06/15/2006	Revised/updated entire document
11/01/2000	New Medical Document