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Research Article

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Parathyroid Hormone Treatment Can Reverse Corticosteroid-induced Osteoporosis

Results of a Randomized Controlled Clinical Trial

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Abstract

Corticosteroid-induced osteoporosis is the most common secondary cause of osteoporosis. We conducted a 12-mo, randomized clinical trial of human parathyroid hormone 1-34 (hPTH 1-34) in postmenopausal women (mean age was 63 yr) with osteoporosis who were taking corticosteroids and hormone replacement therapy. Response to the treatment was assessed with bone mineral density (BMD) measurements of the lumbar spine by quantitative computed tomography (QCT); BMD measurements of the lumbar spine, hip, and forearm by dual-energy x-ray absorptiometry (DXA); and biochemical markers of bone turnover. The mean (±SE) changes in BMD of the lumbar spine by QCT and DXA in the PTH group were 35±5.5% and 11±1.4%, respectively, compared with a relatively small change of 1.7±1.8% and 0±0.9% in the estrogen-only group. The differences in mean percentage between the groups at 1 yr were 33.5% for the lumbar spine by QCT ($P < 0.001$) and 9.8% for the lumbar spine by DXA ($P < 0.001$). The changes in the hip and forearm were not significantly different between or within the groups. During the first 3 mo of PTH treatment, markers of bone formation increased to nearly 150%, whereas markers of bone resorption increased only 100%, suggesting an early uncoupling of bone turnover in favor of formation. These results suggest that parathyroid hormone dramatically increases bone mass in the central skeleton of postmenopausal women with corticosteroid-induced osteoporosis who are taking hormone replacement. (*J. Clin. Invest.* 1998. 102:1627–1633.) Key words: parathyroid hormone treatment • corticosteroid-induced osteoporosis

Introduction

Corticosteroid-induced osteoporosis is the most common cause of drug-related osteoporosis (1). Corticosteroid (CS)[1] therapy causes bone loss and fractures because it suppresses bone formation and inhibits intestinal calcium absorption, which leads to secondary hyperparathyroidism and increased osteoclastic bone resorption (1, 2). Histomorphometrically, there is low trabecular bone volume and a low bone formation rate (3). Drugs used to treat CS-induced bone loss include calcium, vitamin D, and anti-resorptive agents (4, 5, 6, 7, 8). All of these therapies seem to maintain or slightly increase bone mass. However, none of these agents reverse the main lesion in CS-treated patients, the low bone formation rate. Recently, studies have shown that daily subcutaneous injections of relatively low doses of parathyroid hormone (PTH) stimulate bone formation in osteopenic animals and osteoporotic women and men (9, 10, 11, 12). We hypothesized that CS-induced bone loss is the direct result of osteoblast suppression and that treatment with human PTH [hPTH (1-34)] would reverse bone loss by stimulating osteoblast activity. To test this hypothesis, we performed a 12-month, randomized, controlled clinical trial to determine if treatment with the aminoterminal fragment of hPTH 1-34 could increase bone mass in osteoporotic postmenopausal women taking hormone replacement therapy and low doses of CSs.

Methods

Study subjects. Postmenopausal women, 50–82 yr of age, with a variety of chronic noninfectious inflammatory diseases, were eligible for the study if they had osteoporosis defined by low bone mass (> 2.5 SD below mean young normal values at the lumbar spine or femoral neck), had been menopausal for ≥ 3 yr, had been taking hormone replacement therapy (Premarin 0.6 25 mg a day or an equivalent dose of another estrogen) for ≥ 1 yr, had been treated with prednisone or its equivalent for the previous 12 mo at a mean daily dose of 5.0–20 mg, and were expected to continue corticosteroid treatment for at least 1 yr. Patients were excluded from the study if they had secondary osteoporosis other than from rheumatic diseases and corticosteroids, renal or hepatic dysfunction, or abnormalities on spinal radiographs that precluded accurate measurements of the lumbar spine by quantitative computed tomography (QCT) or dual-energy x-ray absorptiometry (DXA). All patients gave informed consent and the study was approved by the Committee on Human Research of the University of California at San Francisco, San Francisco, California.

Treatment protocol and follow-up studies. 51 postmenopausal women currently on estrogen and CSs were randomly assigned by a computer-generated table either to receive hPTH (1-34) plus estrogen (n = 28), or to remain on estrogen only (n = 23). The patients were given a calcium supplement (calcium carbonate) which, when added to their individual dietary calcium, totaled 1500 mg per day. All study patients were maintained on their individual hormone replacement regimens and two multiplevitamins a day (800 IU vitamin D_3).

hPTH (1-34) was purchased from Bachem (Torrance, CA) as a lyophilized powder and reconstituted with 0.9% benzyl alcohol and normal saline. Patients were taught subcutaneous self-injection by the research nurse at the start of the study. Placebo injections were not used. hPTH (1-34) at a dose of 25 μg (400 U) was given daily for 12 mo. Compliance was estimated by measuring the remaining volume in the returned medication vials at each study visit and ranged from 80 to 90% of the daily doses.

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1. *Abbreviations used in this paper:* BMD, bone mineral density; CS, corticosteroid; DXA, dual-energy x-ray absorptiometry; hPTH, human parathyroid hormone; QCT, quantitative computed tomography.

Patients were evaluated at 1 mo and then every 3 mo for 1 yr to monitor the safety and efficacy of the treatment. Bone mass measurements of the lumbar spine by QCT were done at baseline and at 12 mo. Bone mass measurements by DXA of the spine, hip, and forearm were done every 6 mo. Biochemical tests for calcium homeostasis and bone turnover were done after the first month of the study and then at every 3 mo. If urinary calcium excretion exceeded 400 mg per day, calcium supplementation was decreased by 30%. If serum calcium concentration exceeded 10.5 mg/dl, the doses of hPTH (1-34) and calcium supplementation were decreased by 30%. A study patient was discontinued if significant hypercalcemia occurred (calcium $\geq$ 10.5 mg/dl) that did not respond to lowering the calcium supplement and the PTH dose.

Analytic procedures. Trabecular bone mass of the lumbar spine (L1 and L2) was measured by QCT using a scanner (GE9800; General Electric) (13). Bone mineral density (BMD) was measured by DXA of the lumbar spine, total hip region, and forearm using a Hologic 1000 instrument (Hologic Inc., Waltham, MA). Baseline DXA scans were obtained in duplicate and once every 6 mo thereafter. The average of the baseline duplicate scan values was used in the analysis. Quality assurance data was collected daily from the DXA scanner to assess performance. Long-term in vivo precision error was 1.5% for the lumbar spine, 1.0% for the total hip region, 2.0% for the trochanter, 1% for the proximal or mid-forearm, and 3% for the 1/3 distal radius.

Serum and 24-h urine samples were collected at the start of the study and at every 3 mo thereafter. Routine safety tests included automated blood cell counts, serum biochemistries, and biochemical indices of liver and renal function. Urine calcium was measured by an automated technique. Vitamin D metabolites (25 OHD_3 and 1,25 $(OH)_2D_3$) were measured by competitive protein binding and specific radioreceptor assays (Incstar Inc., Stillwater, MN), respectively. Intact hPTH (1-34) was measured by immunoradiometric assay (Nichols Institute, San Juan Capistrano, CA). The assay for intact PTH did not detect the 34 amino-acid PTH fragment administered in the study. Antibodies to hPTH (1-34) in serum were measured by the binding of ^{125}I PTH (1-34) by 1:4 or 1:8 dilutions of the patients' serum (14).

Biochemical markers of bone turnover (osteocalcin, bone-specific alkaline phosphatase, and deoxypyridinoline crosslinks) were measured at baseline and at every 3 mo thereafter. Additionally, the biochemical markers osteocalcin and deoxypyridinoline crosslinks were measured at month 1 in patients assigned to the hPTH (1-34) group. All biochemical markers were measured in duplicate by ELISA (Metra-Biosystems, Mountain View, CA). The respective intraassay and interassay coefficients of variation were 4% and 6% for intact PTH, 8% and 10% for osteocalcin, 9% and 9% for bone-specific alkaline phosphatase, and 6% and 7% for deoxypyridinoline crosslinks.

Radiographs of the thoracolumbar spine were done annually by a standard technique to assess fractures at baseline and fractures that occurred during the course of the study. Baseline fractures were defined as previously described (15). A new vertebral fracture was defined as a decrease of 20% and at least 4 mm in any vertebral height from baseline radiograph to that taken at year 1 (16). Each fracture was confirmed by a repeat digitization of the involved vertebrae.

Statistical analysis. Baseline differences between the groups were tested for significance with Student's *t* test for normally distributed variables. Differences between the hPTH (1-34) plus estrogen and the estrogen-only groups during the course of the treatment were analyzed by repeated-measures ANOVA. Tukey's method was used for post-hoc analysis.

Results

51 women were recruited into the study. 28 were randomized to hPTH (1-34) and estrogen, and 23 were randomized to estrogen only. Three patients withdrew from the study before the 12-mo visit. All three were in the estrogen-only group; two patients withdrew for health reasons, and 1 had a protocol violation. Demographic data are shown in Table I. There were no significant differences between the groups in age, years from menopause, duration of estrogen therapy, duration of CS therapy, daily dose of CSs, body mass index, or number of vertebral fractures. None of the study subjects was a current smoker. The mean daily CS dose was similar in the groups and remained the same throughout the 12-mo study period. The CS-requiring diseases were similar between the groups, with nearly 50% of all study subjects having rheumatoid arthritis. 63% of all subjects were taking disease-modifying agents for their rheumatic diseases, including methotrexate (n = 20), hydroxychloroquine (n = 9), azathioprine (n = 5), and cyclophosphamide (n = 1). The use of disease-modifying agents was similar in the two groups.

Measurements of bone mass and vertebral fractures. The BMD of the lumbar spine measured by QCT and DXA increased significantly ($\sim$ 1 SD) in the PTH-plus-estrogen group ($P < 0.001$), whereas it remained the same in the estrogen-only group (Table II). The mean differences between the treatment groups at 12 mo (calculated by analysis of covariance) were 33.5% for the lumbar spine by QCT ($P < 0.001$) and 9.8% by DXA ($P < 0.001$) (Table III, Fig. 1). In contrast to the spinal bone mass changes with PTH treatment, there was only a modest increase of 2% (0.02 g/cm^2) in the total hip, 2.9% (0.02 g/cm^2) in the femoral neck, and 1.3% (0.01 g/cm^2) in the trochanter (Tables II and III). There was no significant decline in BMD at the spine or the hip in the estrogen-only group (Tables II and III, Fig. 1). Bone mineral density of the forearm decreased $\sim$ 1% in both groups during the 12-mo study. No significant differences between the groups were found with respect to BMD of the total hip, femoral neck, trochanter, or 1/3 distal radius at 6 and 12 mo (Tables II and III).

The rate of response to treatment was also evaluated. A patient was considered to have a positive response to treat-

*Table I. Baseline Characteristics of the Study Subjects in the PTH + Estrogen and Estrogen Only Groups**

Characteristic	PTH + estrogen (n = 28)	Estrogen only (n = 23)	P values
Age (yr)	65.1±9.6	59.9±10.2	0.07
BMI (kg/m^2)	26.1±1.0	25.6±0.8	
Years since menopause	19.3±8.9	16.3±11.2	0.29
Years on estrogen therapy	16.6±11.1	11.4±10.3	0.09
Years on corticosteroid therapy	12.4±13.5	14.9±10.3	0.47
Mean dose of prednisone or equivalent (mg/d)	8.0±3.8	9.4±4.5	0.31
Vertebral fractures			
No. of patients (%)	8 (29%)	6 (26%)	NS
Diseases requiring corticosteroids			
No. of patients			
Rheumatoid arthritis	15	10	
Systemic lupus erythematosus	3	5	
Vasculitis	4	2	
Polymyalgia rheumatica	3	1	
Asthma	2	5	
Kidney transplant	1		

* ± values are mean±SD.

*Table II. BMD and SD below Peak Bone Mass (T Scores) at Baseline and after 12 Mo in Postmenopausal Women with Corticosteroid-induced Osteoporosis Treated with PTH Plus Estrogen or Estrogen Only**

	PTH + estrogen			Estrogen only		
Site	No.	Baseline	12 mo	No.	Baseline	12 mo
Lumbar spine						
BMD by QCT (g/cm^3)	28	91.4±28.6	123.3±44.1$^+$	20	90.2±25.9	89.4±25.4
T score		−3.58±1.06	−2.40±1.63		−3.62±0.96	−3.65±0.94
Lumbar spine by DXA						
BMD (g/cm^2)	28	0.85±0.13	0.94±0.14$^+$	20	0.88±0.16	0.89±0.18
T score		−1.81±1.15	−0.97±1.30		−1.48±1.43	−1.38±1.62
Femoral neck						
BMD (g/cm^2)	28	0.60±0.07	0.62±0.08	20	0.63±0.08	0.63±0.08
T score		−2.87±0.75	−2.70±0.80		−2.60±0.85	−2.53±0.76
Trochanter						
BMD (g/cm^2)	28	0.54±0.09	0.54±0.09	20	0.54±0.08	0.55±0.08
T score		−1.94±0.96	−1.86±1.02		−1.97±0.92	−1.78±0.85
Total hip						
BMD (g/cm^2)	28	0.69±0.10	0.71±0.10	20	0.71±0.08	0.72±0.07
T score		−2.33±0.80	−2.22±0.84		−2.22±0.65	−2.14±0.61
1/3 Distal radius						
BMD (g/cm^2)	25	−0.61±0.10	0.60±0.10	18	0.61±0.09	0.63±0.07
T score		−1.37±1.67	−1.41±1.71		−1.26±1.55	−0.98±1.22

* ± values are mean±SD for subjects with bone mass measurements at baseline and after 12 mo of treatment. The *P* values were calculated with one-way ANOVA for significant differences within groups at + = $P < 0.01$.

ment if the change in BMD of the spine measured by QCT and/or DXA was > 0, calculated on two measurements, baseline and 12 mo. 96% (27/28) of subjects were classified responders by both measurements in the PTH-plus-estrogen group. 40% (8/20) by QCT and 45% (9/20) by DXA were classified as responders in the estrogen-only group.

No patients in the PTH group (0/26) and one patient in the estrogen-only group (1/18) had a new vertebral fracture at the 12-mo visit. During the treatment period, two patients in the PTH-plus-estrogen group had nonvertebral fractures (radius and pelvic) as did two patients in the estrogen-only group (sacrum and rib).

No significant differences between groups at baseline were found in biochemical indices of calcium homeostasis or bone turnover (Table IV). Serum calcium and 1,25 $(OH)_2D_3$ increased slightly and intact PTH levels decreased slightly in the hPTH-treated group ($P < 0.05$ from baseline to 6 mo) but remained within the normal range. There were no significant changes in serum phosphorus, $25(OH)D_3$, and 24-h urinary calcium during the study in either group. Two subjects (one

*Table III. Mean Change from Baseline, 6, and 12 Mo in BMD in Postmenopausal Women with Corticosteroid-induced Osteoporosis Treated with PTH Plus Estrogen or Estrogen Only**

		PTH + estrogen		Estrogen only		
Site		% Change	No. of patients	% Change	No. of patients	*P* value[§]
Lumbar spine by QCT[‡]	12	35.2±5.5	28	1.7±1.7	20	$P < 0.001$
Lumbar spine by DXA	6	6.1±1.1	28	1.2±0.5	22	$P < 0.001$
	12	11.1±1.4	28	1.3±0.8	20	$P < 0.001$
Femoral neck	6	2.9±1.1	28	0.2±1.1	22	NS
	12	2.9±1.1	28	1.2±1.5	20	NS
Trochanter	6	1.7±0.7	28	1.3±0.9	22	NS
	12	1.3±0.7	28	0.9±0.9	20	NS
Total hip	6	1.6±0.6	28	0.8±0.7	22	NS
	12	1.9±0.8	28	0.4±0.8	20	NS
1/3 Distal radius	6	−0.3±0.4	25	−0.1±0.6	21	NS
	12	−0.9±0.6	25	−0.6±0.5	18	NS

* ± values are mean±SE. [‡]BMD values are only available by QCT at 0 and 12 mo only. [§]The *P* values were calculated with one-way ANOVA and include significant differences between groups.

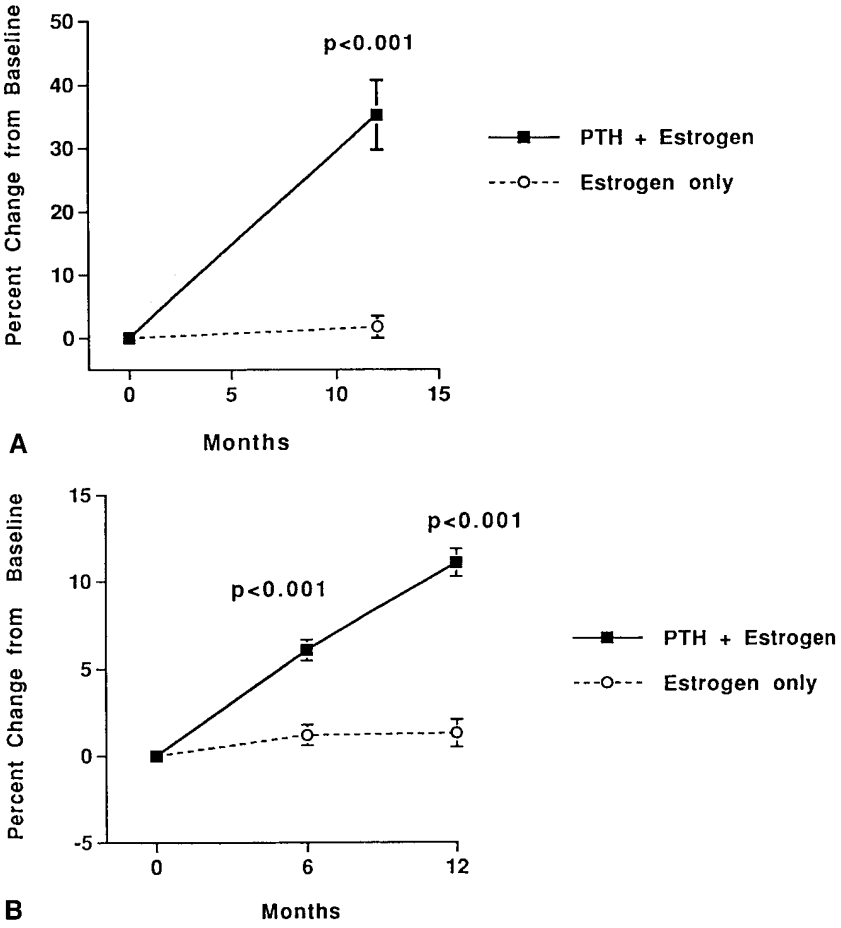

Figure 1. Percentage of change from baseline for lumbar BMD measured by QCT and DXA. $P <$ 0.001 between groups at 6 and 12 mo.

PTH, one estrogen-only) developed hypercalciuria (defined as a urine calcium of $>$ 400 mg/d) that returned to normal when the calcium intake was reduced. After 3 mo of PTH treatment, three women developed hypercalcemia of $>$ 10.5 mg/dL, which returned to normal when the dose of PTH was decreased to 20 μg daily and the calcium intake was reduced. No changes in other safety endpoints were seen. There was no evidence of specific antibody to hPTH (1-34) in the blood in a few selected hPTH treated patients.

After 1 mo of hPTH (1-34) treatment, osteocalcin, a marker of bone formation, had increased $>$ 150% ($P < 0.01$) above baseline. This was maintained until the end of the treatment period (Table IV and Figs. 2 and 3). Bone-specific alkaline phosphatase, another marker of bone formation, had similar increases. However, the urinary excretion of deoxypyridinoline crosslinks, a marker of bone resorption, increased by only 70% ($P < 0.01$) above baseline after 1 mo of hPTH (1-34) treatment. Similar increases from baseline levels were seen in all bone markers at 6 mo. These levels continued to the end of the treatment period.

Safety. Adverse events were recorded at each study visit. Self-administered injections of hPTH (1-34) were well tolerated. Many patients complained of mild headaches at the initiation of the injections that resolved after 1–2 wk of treatment. Mild injection-site tenderness was also reported. No patients dropped out of the study because of PTH injection discomfort.

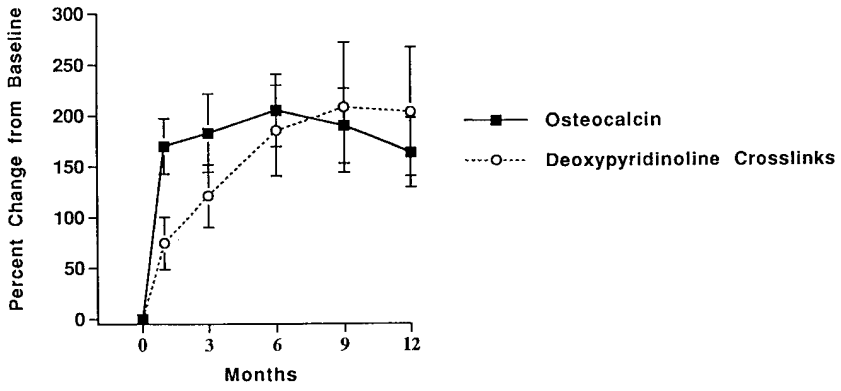

Figure 2. Percentage of change in biochemical markers of bone turnover to PTH. Osteocalcin ng/dL and deoxypyridinoline crosslinks at nM/mMCr.

*Table IV. Serum and Urine Biochemical Values in Study Subjects with CS-induced Osteoporosis Treated with PTH Plus Estrogen (PTH + E) or Estrogen Only (E)**

Variable	Baseline	No.	6 mo	No.	12 mo	No.
Osteocalcin (ng/dl)						
PTH + E	5.8±0.4	28	15.5±1.5‡§	28	14.4±2.2‡	28
E	5.4±0.6	23	5.4±0.5	22	6.5±1.2	20
BSAP (U/L)						
PTH + E	14.0±1.1	28	28.8±2.2‡§	28	26.9±2.7‡§	28
E	15.4±1.9	23	14.7±1.6	22	13.7±1.3	20
Ionized calcium (mg/dl)						
PTH + E	5.2±0.1	28	5.5±0.1	28	5.2±0.1	28
E	5.2±0.1	23	5.2±0.1	22	5.1±0.2	20
DPD nM/mMCr						
PTH + E	4.4±0.6	28	8.2±0.8‡§	28	8.3±0.8‡§	27
E	4.4±0.3	23	4.1±0.4	22	4.6±0.5	20
PTH (ng/ml)						
PTH + E	36.9±7.4	28	22.1±5.7§	28	31.9±11.3	28
E	36.5±5.3	23	27.0±5.8	22	29.1±6.7	20
1,25 vitamin D (pg/ml)						
PTH + E	40.4±3.4	28	42.4±4.4	28	55.6±5.3	28
E	47.5±4.7	23	45.0±5.6	22	43.4±7.4	20
24 h Urine calcium (g/24 h)						
PTH + E	150.5±14.7	28	204.8±26.0	28	141.4±17.7	28
E	230.9±39.7	23	164.7±27.7	22	173.1±23.1	20

* ± values are mean±SE. The *P* values were calculated with one-way ANOVA and include significant differences between groups at ‡ $P < 0.01$ and within groups at § $P < 0.01$.

Discussion

In this randomized controlled study, we found daily administration of hPTH (1-34) for 1 yr significantly increased spinal bone mass in osteoporotic postmenopausal women taking chronic CSs and estrogen. Increased spinal bone mass was seen in almost all patients who completed the 1 yr of hPTH (1-34) treatment, with a mean increase in spinal trabecular bone of 35% and in integral bone of 11%. The bone mass of the hip increased modestly (2%) and cortical bone mass in the forearm did not change after 1 yr of hPTH (1-34) treatment.

CS therapy causes bone loss and fractures because it suppresses bone formation and inhibits intestinal calcium absorption, which leads to secondary hyperparathyroidism and increased osteoclastic bone resorption (1, 2). Supplementation with calcium and vitamin D and treatment with anti-resorptive agents can prevent bone loss and modestly increase bone mass in patients on chronic CS therapy (4, 6, 7, 8). However, hPTH (1-34) therapy in patients on chronic CSs was able to override the suppressive effects of corticosteroids on osteoblasts and stimulate bone formation. While anti-resorptive agents are able to increase spinal bone mass ~ 2–5% in 1 yr (6, 8), hPTH (1-34) treatment increased mean bone mass 11% (~ 1 SD in this study population) by DXA and QCT. In population-based studies of postmenopausal women, an increase of 11% (or 1 SD) by DXA of the lumbar spine, is associated with a 40–50% reduction in vertebral and hip fracture risk (17). However, in CS-induced osteoporosis, we do not yet know if the increases we have observed in spinal bone mass will be associated with a reduction in fracture risk.

Trabecular bone is the most susceptible to CS-induced bone loss because of its high turnover rate (1, 3). Histomorphologic studies show that CS therapy causes trabecular thinning (2). Studies of PTH in animal models of osteopenia show that PTH increases bone mass by thickening existing trabeculae and not by creating new trabeculae (18, 19). In spite of this, PTH causes an increase in bone strength (20). Our data support the results from other clinical studies that demonstrate that the major increase in bone mass with PTH treatment is primarily in the trabecular bone compartment because the changes in bone mass are greater with QCT than with DXA (9, 10, 11, 12).

Our results are similar to those of Lindsay et al. in which hPTH (1-34) was given for 3 yr to osteoporotic postmenopausal women taking hormone replacement therapy (9). In that study, spinal bone mass increased 13%, total body bone mass increased 8%, and total hip bone mass increased 2–7% (all by DXA). Our study differed in that our patients were taking chronic low doses of CSs. Interestingly, the changes in BMD at the spine in the two studies are quite similar in magnitude. All of our study subjects were on stable low doses of CSs. It is possible that the ability of PTH to increase bone formation might be impaired with higher doses of CSs.

Although the anabolic effects of PTH were significantly smaller or absent in the hip and forearm region, there was no evidence of a detrimental effect of PTH at these sites, as has been previously reported (11). It has been suggested that PTH may increase vertebral bone mass at the expense of cortical bone by inducing increased cortical bone remodeling (11). Activation of cortical bone remodeling has been reported in animals treated with PTH and in primary hyperparathyroidism (21, 22). We found no evidence for this in our study, as we found no decline in bone mass at any skeletal site. Our use of estrogen, an agent that reduces cortical bone remodeling, in

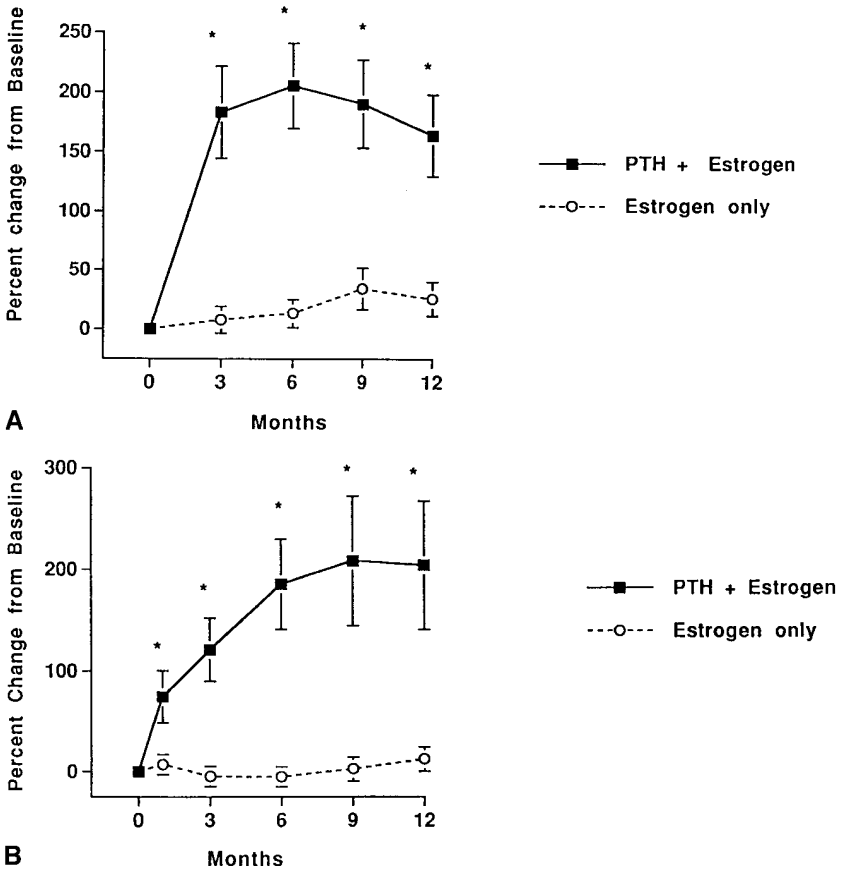

Figure 3. Percentage of change from baseline in biochemical markers of bone turnover. Osteocalcin ng/dL and deoxypyridinoline crosslinks at nM/mMCr. $*P < 0.05$ between groups.

combination with PTH, may also have prevented cortical bone loss.

Fluoride therapy increases bone mass significantly in corticosteroid-treated patients (8% after 2 yr), mainly in the central skeleton (23). However, there is concern that fluoride therapy may not recreate normal boney architecture and quality such that the increase in mass may not be accompanied by increased strength (24).

Estrogen use in combination with calcium and vitamin D supplements resulted in a 1–2% increase in spine and total hip bone mass. Other investigators have found that estrogen and other anti-resorptive agents (6, 7, 8) are also effective in preventing bone loss with CSs (5, 25). Some protection against bone loss in the estrogen-only group may also have derived from the high calcium (1500 mg/d) and vitamin D_3 (800 U/d) supplements. A recent study reported that calcium and vitamin supplementation alone in CS-treated patients maintains bone mass (4).

PTH administration increased serum levels of biochemical markers of bone remodeling. Bone formation markers were maximally increased within 1–3 mo of starting PTH, whereas the marker for bone resorption was slower to rise and did not reach its maximum levels until 6 mo. Increased bone remodeling could not by itself increase bone mass, unless there was an uncoupling of these functions in favor of bone formation. With daily PTH administration, the serum PTH level rises above normal for several hours and then falls below normal for many hours (26). The changes in the serum PTH levels after daily injections may be important in increasing bone mass because continuously elevated serum concentrations of PTH do not increase bone mass (27). Localization of the PTH receptor to osteoblasts and bone marrow stromal cells (28, 29) suggests a pathway whereby a daily injection of PTH may uncouple bone turnover by first signaling osteoblasts to mature and form bone, and then indirectly signaling osteoclasts through osteoblasts to mature and resorb bone.

Treatment with hPTH (1-34) by daily subcutaneous injection to women with osteoporosis taking chronic estrogen and CSs significantly increased bone mass in the spine. Modest increases in bone mass were observed in the hip region, and no significant loss of cortical bone was found. PTH appears to be a safe and effective means of reversing CS-induced osteoporosis, a therapeutic strategy that has long eluded us.

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