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Fracture Risk Reduction with Alendronate in Women with Osteoporosis: The Fracture Intervention Trial

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ABSTRACT

We examined the effect of alendronate treatment for 3–4 yr on risk of new fracture among 3658 women with osteoporosis enrolled in the Fracture Intervention Trial. This cohort included women with existing vertebral fracture and those with osteoporosis as defined by T score of less than −2.5 at the femoral neck but without vertebral fracture. All analyses were prespecified in the data analysis plan.

The magnitudes of reduction of fracture incidence with alendronate were similar in both groups. The two groups were, therefore, pooled to obtain a more precise estimate of the effect of alendronate on relative risk of fracture (relative risk, 95% confidence interval): hip (0.47, 0.26–0.79), radiographic vertebral (0.52, 0.42–0.66), clinical vertebral (0.55, 0.36–0.82), and all clinical fractures (0.70, 0.59–0.82). Reductions in risk of clinical fracture were statistically significant by 12 months into the trial.

We conclude that reductions in fracture risk during treatment with alendronate are consistent in women with existing vertebral fractures and those without such fractures but with bone mineral density in the osteoporotic range. Furthermore, reduction in risk is evident early in the course of treatment. This pooled analysis provides a more precise estimate of the antifracture efficacy of alendronate in women with osteoporosis than that in prior reports. (*J Clin Endocrinol Metab* **85:** 4118–4124, 2000)

THE WORLD HEALTH Organization (WHO) has defined osteoporosis as a bone mineral density (BMD) value that is more than 2.5 SD below the young adult peak (1). Diagnosis of osteoporosis based on similar BMD cutoff values has been adopted by the Committee for Proprietary Medicinal Products European Public Assessment Report (2).

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Women with existing fracture, regardless of BMD, are also considered osteoporotic and have an increased risk of future fracture. Recent treatment guidelines from the National Osteoporosis Foundation recommend that older women with osteoporosis, as defined by BMD or existing vertebral fracture, should be treated with drugs to reduce fracture risk. BMD below the osteoporotic threshold and the presence of existing vertebral fracture have been used as entry criteria for recent large clinical trials with fracture end points (4–9).

We have previously shown that alendronate reduces risk of new vertebral, hip, and wrist fractures in women with vertebral fracture at baseline (9). More recently, we reported a study of alendronate among women with femoral neck T scores less than −1.6 (namely, BMD >1.6 SD below the mean of young adult women), but without vertebral fracture (10). The risk of new radiographic vertebral fracture was reduced in the entire group of women without such fracture at baseline. Significant reductions in hip and other clinical fractures were demonstrated in those with BMD below the WHO threshold (T score <−2.5 at the femoral neck). The purpose of the present investigation is to compare the effect of alendronate treatment on fracture risk reduction in women with existing vertebral fracture with that in women without existing vertebral fracture but with BMD T score less than −2.5 and to assess the effect of alendronate in these two groups of women combined. In addition, we examine the time course of the effect of alendronate on clinical fracture risk in these women with osteoporosis.

Methods

Protocol

The trial was conducted at 11 clinical centers in the United States with a coordinating center at the University of California, San Francisco (11). FIT had two study arms: the Vertebral Fracture Arm, which included women who had vertebral fractures identified on radiographs at baseline, and the Clinical Fracture Arm, which included women without vertebral fracture, but with femoral neck T score −1.6 or less at baseline. Analysis of study end points in the two arms combined and in BMD subgroups was prespecified in the FIT data analysis plan to provide more precise estimates of treatment and subgroup effects and to provide greater power to explore associations among variables. All clinical fractures and hip fractures were monitored during the trial by an independent data and safety monitoring board.

Selection of participants

We enrolled 6459 women 55–80 yr of age who had been postmenopausal for at least 2 yr and had femoral neck BMD less than or equal to 0.68 g/cm^2 (Hologic QDR-2000). At the time of enrollment, this was believed to correspond to a BMD value of at least 2 SD below the mean of normal, young adult Caucasian women, based on the manufacturer's reference values. Subsequently, results from the third National Health and Nutritional Examination Survey (HNANES), a representative sample of the United States population, indicated that this femoral neck BMD cutoff corresponded, instead, to about 1.6 SD below the young normal mean (12). Consequently, only about one third of women in the trial had femoral neck T scores less than −2.5. Further details of inclusion and exclusion criteria and recruitment procedures have been described in detail (9–11).

A total of 6459 women were randomly assigned to treatment in FIT, 2027 in the Vertebral Fracture arm and 4438 in the Clinical Fracture Arm. Among the 4432 women in the Clinical Fracture arm, 1631 met the WHO definition of osteoporosis based on an entry femoral neck BMD T score of −2.5 or less (using the revised NHANES reference data). Combining these women with the 2027 in the Vertebral Fracture Arm (*i.e.* those with existing vertebral fractures) yielded a total of 3658 women with osteoporosis who are included in this analysis. All women provided written informed consent, and the study protocol was approved by the appropriate institutional review boards.

Treatment

The dose of alendronate was initially 5 mg/day for 2 yr but was increased to 10 mg/day at the second annual visit because other trials suggested that 10 mg had greater effects than 5 mg on bone density (6) and bone markers with similar tolerability. Women with existing vertebral fracture received alendronate for 3 yr; those without vertebral fracture received alendronate for 4 years. Eighty-two percent of participants in each treatment group had dietary calcium intakes at baseline of less than 1000 mg/day; they were given a daily supplement containing 500 mg elemental calcium (as the carbonate salt) and 250 IU of vitamin D.

Average duration of treatment and follow-up was planned for 3 yr in the Vertebral Fracture Arm and 4 yr in the Clinical Fracture Arm (11).

Assessment of outcomes

Clinical fractures. As has been previously reported (11), a clinical fracture was defined as a fracture diagnosed by a community physician and confirmed by written reports of radiographs or other tests. Fracture reporting and confirmation procedures were identical in the Clinical and Vertebral Fracture arms. Pathologic fractures (*e.g.* those due to malignant disease) and fractures caused by trauma sufficient to fracture normal bones in most young adults were excluded by a blinded Endpoints Adjudication Committee (9). Facial and skull fractures were excluded because they are not associated with osteoporosis or low bone density (13).

Clinical vertebral fractures were defined as those reported by participants to have been diagnosed by a physician during the study. For each reported clinical vertebral fracture a copy of the radiograph used by the participant's physician was obtained and compared with the baseline study radiograph by the study radiologist using semiquantitative criteria. Only those in which an incident fracture could be confirmed were included in the analyses.

Before study, unblinding, subgroups of clinical fractures were classified into the following prespecified categories: all clinical fractures, clinical vertebral fractures, nonvertebral fractures, hip fractures, and wrist fractures. In addition, for this analysis we examine a subgroup of nonvertebral fractures (including fractures of the clavicle, humerus, wrist, pelvis, hip, and leg), which we term "nonvertebral osteoporotic fractures." Participants could have more than one type of fracture and could, therefore, appear in more than one category.

Radiographic evidence of vertebral fractures. Lateral spine radiographs were obtained according to published guidelines at baseline and at approximately 2 and 3 yr (Vertebral Fracture Arm) and 4 yr (Clinical Fracture Arm) after randomization (9–11). The assessment of radiographic vertebral fractures at baseline has been described previously (9, 14–16). A new radiographic vertebral fracture was defined as a decrease of 20% and at least 4 mm in the height of any vertebral body from baseline to end of the study (9, 15). All fractures were confirmed by a repeat measurement of the involved vertebral body and review by a radiologic technician. All assessments were blinded to treatment allocation.

BMD. BMD was measured at the hip and posterior-anterior spine on all participants using Hologic QDR-2000 densitometers (Hologic, Inc., Waltham, MA); BMD measurements were repeated annually. Quality control measures have been detailed elsewhere (11).

Statistical analysis

We present the results as the percentage of women with fractures and the relative hazards [presented as relative risk (RR)] and confidence intervals (CIs), calculated by survival analysis techniques with the log-rank test (17) for clinical fractures and the Mantel-Haenszel estimate (18) for the odds ratio (also presented as RR) for radiographic vertebral fractures (19). Analyses were performed separately within each subgroup (women with existing radiographic vertebral fracture and those without fractures but with femoral neck T score <−2.5) and were also

performed for the pooled osteoporotic FIT cohort (women with femoral neck T score < -2.5 or an existing radiographic vertebral fracture) for the end point categories described above. The pooling of both arms of the study was prespecified in the data analysis plan.

We performed a true intention-to-treat analysis in which all events after randomization were analyzed. In the FIT study, all women continued follow-up regardless of whether or not they continued on study medication. We were, therefore, able to include in the analysis all fractures whether or not the participant was taking study medication at the time of the fracture. A total of about 15% of women discontinued study drug before closeout but fracture follow-up continued on about 98% of randomized survivors. All *P* values are two-sided. To test the statistical appropriateness of combining those patients with and without baseline vertebral fractures for the analysis of fracture end points, the Breslow-Day test for homogeneity of odds ratios was performed (19). This statistic tests the hypothesis that the odds ratios from the two cohorts are equal and, therefore, the two groups can be combined. For all of the pooled analyses presented, the Breslow-Day test results indicated consistency between the Vertebral Fracture Arm and Clinical Fracture Arm (low BMD) cohort results for the specified populations.

Parallel analyses were conducted using definitions of osteoporosis based on BMD at the total hip and at the lumbar spine to confirm the general findings with respect to femoral neck BMD.

If there was a significant reduction in the RR, we used a test proposed by Kalbfleisch and Prentice (20), as was prespecified in the data analysis plan, to determine whether there was an interaction between study time and treatment effect. If there was no interaction or if there was an interaction and the treatment effect increased with time, we reported the first time point (using 6-month intervals) when the risk reduction was significant ($P < 0.05$).

We estimated the "number needed to treat" (NNT) with alendronate for 5 yr to prevent one fracture. To estimate the 5-yr incidence of fracture, we extrapolated the observed cumulative incidence of first clinical fractures at 3 yr for the placebo group in women with existing vertebral fracture and at 4.5 yr in women without existing vertebral fracture to estimate the incidence at yr 5 in the placebo groups (I_{p5}). The RRs in Table 2 were then applied to these 5-yr placebo rates to estimate the 5-yr incidence in those randomized to alendronate (I_{a5}). The 5-yr NNT is then calculated as $1/(I_{p5}\text{-}I_{a5})$.

Results

Table 1 shows the baseline characteristics of the subset of women in FIT who had osteoporosis at baseline, which we defined as either having existing vertebral fracture or (for those without vertebral fracture) having a femoral neck T score of -2.5 or less. The women (53.5%) with vertebral fracture had a femoral neck T score of -2.5 or less. In general, the two groups (with fracture *vs.* without fracture) were similar, except that the women without vertebral fractures were about 2.0 yr younger and were less likely to have a history of clinical fracture since age 45. The mean BMD at both the hip and the femoral neck was lower in the patients without existing vertebral fracture. The mean BMD at the spine was similar in both groups.

Table 2 summarizes the observed annualized fracture rates and RRs (alendronate *vs.* placebo) for different categories of fractures among the FIT participants included in this subanalysis. The point estimates of the reductions were generally consistent in those with and without baseline vertebral fractures, particularly for vertebral fractures (0.53 and 0.51, respectively), for hip fractures (0.49 and 0.44, respectively) and for any clinical fracture (0.74 and 0.64, respectively). There was no significant heterogeneity in the reduction in risk between the two osteoporotic groups for any of the types of fractures. Rates of vertebral fracture were much higher, and rates of nonvertebral fracture were somewhat higher, in those patients with existing vertebral fracture.

The reductions in risk with alendronate for the two groups combined are shown in Table 3. The reductions in risk in the alendronate group for the end points of radiologic vertebral fractures (48%), multiple radiologic vertebral fractures (87%), any clinical fracture (30%), and any nonvertebral clinical fracture (27%) were all highly significant ($P < 0.001$). Risk of hip fracture was reduced by 53% ($P = 0.005$), clinical vertebral fracture by 45% ($P = 0.003$), and wrist fracture by 30% ($P = 0.038$).

The 3-yr cumulative incidence curves for each type of clinical fracture are shown in Fig. 1. For all of the fracture types, some reduction in fracture risk was evident within the first year. The reduction in risk was first significant for clinical vertebral fracture (59%) by month 12 ($P < 0.001$), for any clinical fracture (27%) by month 18 ($P = 0.017$), for nonvertebral fracture (26%) by month 24 ($P = 0.011$), for hip fracture (63%) by month 18 ($P = 0.014$), and for wrist fracture (34%) by month 30 ($P = 0.046$) (Fig. 2).

The NNT to prevent clinical and hip fractures were similar in the two groups (Table 4), reflecting the similarity between groups in both fracture incidence and fracture reduction for these two fracture types. The lower NNT to prevent vertebral fracture among patients with existing vertebral fracture (8 *vs.* 29 in the other group) reflects an incidence of new vertebral fracture that was four to five times higher in patients with existing vertebral fractures than in those without.

Analysis of the women with BMD T scores less than -2.5 at either the total hip or the lumbar spine also showed that

TABLE 1. Patients characteristics at baseline

	Women with existing vertebral fracture (Vertebral Fracture Arm) (n = 2027: 1005 placebo, 1022 alendronate)	Women without vertebral fracture and femoral neck T score < -2.5 (Clinical Fracture Arm with low BMD) (n = 1631: 812 placebo, 819 alendronate)	*P*
Age (yr)	70.8	68.8	<0.001
Years since menopause	25.0	22.3	<0.001
Femoral neck BMD (g/cm^2)	0.57	0.53	<0.001
Total hip BMD (g/cm^2)	0.66	0.64	<0.001
Lumbar spine BMD (g/cm^2)	0.79	0.78	0.038
History of falls	31%	25%	<0.001
Maternal history of fracture	37%	41%	0.005
Health status: fair/poor	7%	5%	0.007
Regular exercise	44%	48%	0.032
Clinical fracture since age 45	58%	41%	0.001
Current smoker	11%	13%	0.202

TABLE 2. Effect of alendronate on risk of fracture in women with existing vertebral fracture at baseline or femoral neck T score of −2.5 or less

Fracture class	Women with existing vertebral fracture (Vertebral Fracture Arm)			Women without vertebral fracture and femoral T score <−2.5 (Clinical Fracture Arm with low BMD)		
	Annual incidence[a]		RR (95% CI)	Annual incidence[a]		RR (95% CI)
	PBO	ALN		PBO	ALN	
Radiologic vertebral[b]	5.01	2.61	0.53 (0.41, 0.68)	1.41	0.72	0.51 (0.31, 0.84)
Multiple vertebral (radiologic)[b]	1.62	0.17	0.10 (0.05, 0.22)	0.51	0.22	0.40 (0.08, 1.95)
Clinical vertebral	1.77	0.82	0.46 (0.28, 0.75)	0.41	0.35	0.84 (0.38, 1.83)
Any clinical	6.15	5.14	0.74 (0.59, 0.92)	5.12	3.30	0.64 (0.50, 0.82)
Nonvertebral	5.50	4.45	0.81 (0.64, 1.03)	4.81	3.11	0.65 (0.50, 0.83)
Nonvertebral (osteoporotic)	3.44	2.32	0.68 (0.49, 0.92)	2.88	1.73	0.60 (0.43, 0.83)
Hip	0.77	0.37	0.49 (0.23, 0.99)	0.53	0.23	0.44 (0.18, 0.97)
Wrist	1.44	0.75	0.52 (0.31, 0.87)	1.13	1.00	0.88 (0.55, 1.40)

PBO, Placebo; ALN, alendronate.
[a] Rate per 100 person-years.
[b] Percent per year.

TABLE 3. RR of alendronate *vs.* placebo in combined osteoporotic group (existing vertebral fracture at baseline or femoral neck T score of −2.5 or less)

Fracture class	RR (95% CI)	*P*
Radiologic vertebral	0.52 (0.42, 0.66)	<0.001
Multiple vertebral (radiologic)	0.13 (0.07, 0.25)	<0.001
Clinical vertebral	0.55 (0.36, 0.82)	0.003
Any clinical	0.70 (0.59, 0.82)	<0.001
Nonvertebral	0.73 (0.61, 0.87)	<0.001
Nonvertebral (osteoporotic)	0.64 (0.51, 0.80)	0.002
Hip	0.47 (0.26, 0.79)	0.005
Wrist	0.70 (0.49, 0.98)	0.038

alendronate was associated with significant reductions in clinical and vertebral fractures in these groups. For example, when osteoporosis was defined on the basis of total hip BMD rather than femoral neck BMD, there was a 45% reduction in hip fracture risk ($P = 0.028$) and a 23% reduction in nonvertebral fracture risk ($P = 0.005$) in the combined osteoporotic groups. On the basis of BMD at the spine, the risk reductions in the combined osteoporotic groups were 47% ($P = 0.026$) for hip fracture and 25% ($P = 0.002$) for nonvertebral fracture.

Discussion

This analysis demonstrates that alendronate reduces the risk of all major fracture types in women with osteoporosis, as defined by BMD according to WHO criteria or by presence of a vertebral fracture. Only a modest number of such osteoporotic women need to be treated to prevent fracture. The effect of alendronate on the risk of clinical fracture was statistically significant as early as 12–18 months after the start of treatment.

In previous reports from FIT, we had shown that, among women with existing vertebral fracture, reductions in clinical fracture risk with alendronate were significant for a wide variety of fracture types and did not depend on baseline BMD (9, 21). More recently, the results among women without prior vertebral fracture suggested that the reduction in risk of clinical fractures with alendronate in these women depended on the level of baseline BMD (10). In the current analysis, the magnitude of the fracture reductions with alendronate are similar both in women who meet the WHO BMD criterion for osteoporosis without vertebral fracture, and in those who have existing vertebral fracture but who do not meet the WHO BMD criterion.

The reductions in fracture risk for the women with femoral neck T scores less than −2.5 included significant reductions in hip fractures. Hip fractures account for the greatest costs and are associated with greater increases in morbidity and mortality than other types of fractures. The only other study of a pharmacologic agent to show a reduction of hip fracture is a study of calcium in combination with vitamin D in a group of older women living in nursing homes and group residences (22). However, many of these women were both calcium and vitamin D deficient; therefore, the response may represent treatment of osteomalacia rather than treatment of osteoporosis *per se.* We have shown here that, among community-dwelling women with osteoporosis (whether defined by existing vertebral fracture or femoral neck BMD below the WHO threshold), alendronate given over 3–4 yr can significantly reduce hip fracture risk. Women in FIT either had calcium intake at baseline exceeding 1000 mg/day (17%) or were using the study-provided calcium and vitamin D supplements (83%), suggesting that alendronate reduces hip fracture risk over and above any effects attributable to calcium and vitamin D.

For this analysis, we chose criteria for osteoporosis (low femoral neck BMD or presence of vertebral fracture) primarily based on the WHO definition. However, there were several secondary considerations derived from the earlier work in FIT that also supported selection of these specific groups. Among women with vertebral fracture, a previous analysis showed that the effect of alendronate did not vary by baseline BMD (21). Among women without vertebral fracture, those with the lowest BMD (specifically those with femoral neck T scores <−2.5) experienced the largest reductions in clinical and hip fractures (10). Although while there are clear reductions in clinical fracture among those women with T scores less than −2.5, it is not clear if there is an exact threshold above which alendronate does not reduce fracture risk. Rather than a threshold phenomenon, an analysis among the

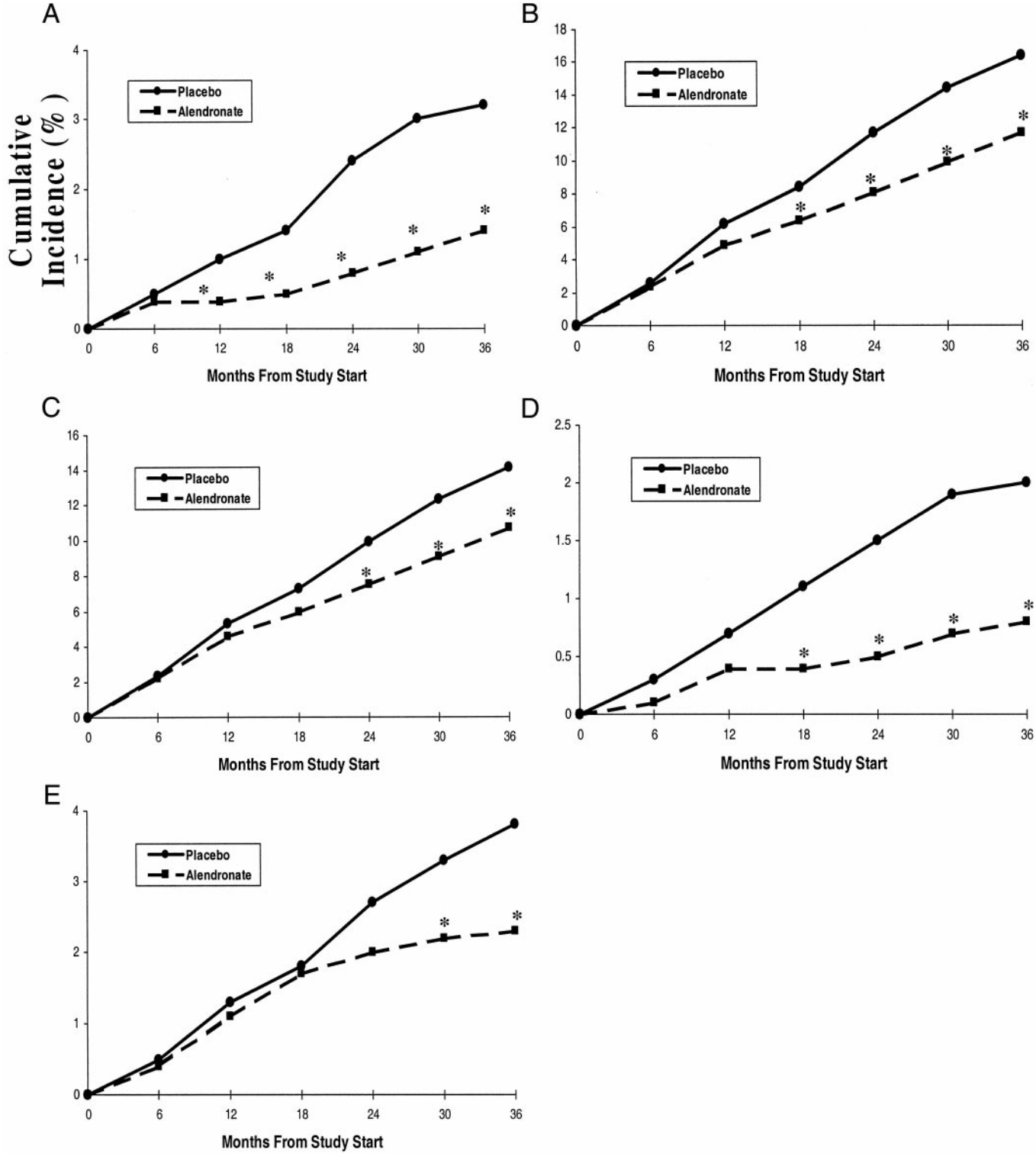

FIG. 1. Cumulative proportion of women with each fracture type in women randomized to alendronate or placebo among women with vertebral fractures or femoral neck BMD T score less than −2.5 at baseline. *Asterisks* indicate each 6-month analysis point where the cumulative difference is significantly different ($P < 0.05$).

women without vertebral fracture suggested that there was a continuous gradient of benefit (those with lower BMD had greater risk reductions) (10).

We observed a decrease in the risk of clinical vertebral as well as nonvertebral fracture as early as 6 months after the start of treatment. This supports the results from a recent randomized trial of alendronate (10 mg/day) that showed a significant reduction in nonvertebral fracture after 12 months

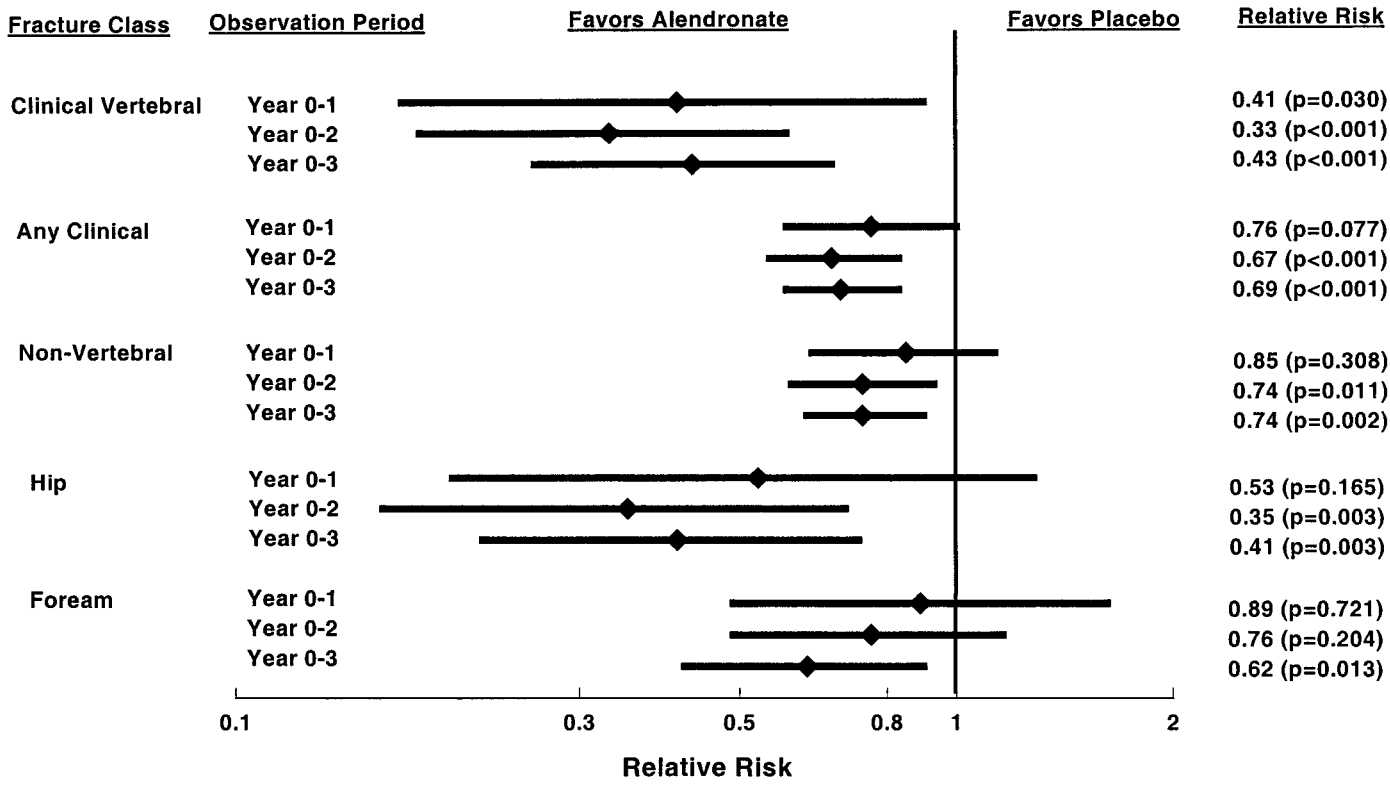

FIG. 2. Cumulative reductions in fracture risk in the 1st, 2nd, and 3rd yr of FIT among women with vertebral fractures or femoral neck BMD T score less than −2.5 at baseline.

TABLE 4. Number needed to treat with alendronate for 5 yr to prevent selected types of fracture

Fracture class	Women with existing vertebral fracture (Vertebral Fracture Arm)	Women without vertebral fracture and T score <−2.5 (Clinical Fracture Arm/low BMD)
Any radiologic vertebral	8	29
Any clinical	13	11
Any nonvertebral	21	12
Hip	46	66

of therapy (23) and the results from a trial of risedronate showing a significant reduction in morphometric vertebral fractures after 12 months (5). The fact that bisphosphonates are effective so quickly in reducing fracture risk, with only modest early effects on BMD, suggest that mechanisms other than BMD improvements, such as the rapid decreases in bone remodeling rates, play some role in fracture reduction.

This study has a number of strengths. The decision to pool the data was prespecified. Clinical fractures (especially hip and clinical spine) were prespecified and were carefully adjudicated by a blinded endpoints committee. A very conservative intention-to-treat analysis was used to evaluate the risk reduction. However, despite its large size, this study has some important limitations. The study was not powered specifically to examine the effect of alendronate within subgroups—the sample sizes within femoral neck BMD subcategories are, in some cases, too small to adequately address within-subgroup efficacy. Furthermore, our power to detect significant differences in fracture reductions between the two subgroups (with and without existing vertebral fracture) is limited. Secondly, we prespecified in our analysis plan that we would analyze all the data from both arms of the study. The analysis presented included only those considered to be osteoporotic, solely because of the interaction between femoral neck BMD and clinical fractures in the Clinical Fracture Arm (10). Although it is possible that this slightly decreases the strength of our inference, we feel that the strong significance and consistency of these findings overcomes this limitation. Lastly, whereas this analysis focused on BMD at the femoral neck, analysis of BMD at the total hip and lumbar spine by dual x-ray absorptiometry supported similar risk reductions among those with T score less than −2.5 at these sites. However, we cannot directly determine the extent to which osteoporosis defined from other sites (*e.g.* wrist, calcaneus) or fracture risk assessment by other techniques (*e.g.* ultrasound) would yield similar results.

In summary, we found that women who meet currently accepted criteria for osteoporosis based on femoral neck BMD T score of −2.5 or less or an existing vertebral fracture—a cohort comprising approximately 57% of the entire FIT cohort—experienced statistically significant reductions in fracture risk for all prespecified fracture endpoints, including all clinical fractures, nonvertebral fractures, morphometric vertebral fractures, clinical vertebral fractures, hip fractures, and wrist fractures. Among women with no spine fracture but with femoral neck BMD within the WHO osteoporotic range, the magnitudes of observed risk reductions with alendronate therapy were generally similar to those previously shown among women with existing vertebral

fracture. The NNT to prevent any clinical fracture or hip fracture were similar, therefore, the overall clinical benefit is largely similar in these two groups of osteoporotic patients. These results suggest that women with osteoporosis based on WHO BMD criteria or with existing vertebral fracture will benefit in terms of early and substantial reductions in both vertebral and nonvertebral clinical fractures over a 3- to 4-yr period of alendronate therapy.

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