# Effect of Bisphosphonates or Teriparatide on Mechanical Complications after Posterior Instrumented Fusion for Osteoporotic Vertebral Fracture: A Multi-center Retrospective Study

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# Abstract

**Background:** The optimal treatment of osteoporosis after reconstruction surgery for osteoporotic vertebral fractures (OVF) remains unclear. In this multicentre retrospective study, we investigated the effects of typically used agents for osteoporosis, namely, bisphosphonates (BP) and teriparatide (TP), on surgical results in patients with osteoporotic vertebral fractures.

**Methods:** Retrospectively registered data were collected from 27 universities and affiliated hospitals in Japan. We compared the effects of BP vs TP on postoperative mechanical complication rates, implant-related reoperation rates, and clinical outcomes in patients who underwent posterior instrumented fusion for OVF and had been followed up at least for 2 years. Data were analysed according to whether the osteoporosis was primary or glucocorticoid-induced.

**Results:** A total of 165 patients who underwent posterior instrumented fusion for OVF were included. The overall mechanical complication rate was significantly lower in the TP group than in the BP group (BP vs TP: 73.0% vs. 55.7%, p = 0.018). The screw backout rate was significantly lower and the rates of new vertebral fractures and pseudoarthrosis tended to be lower in the TP group than in the BP group. However, there were no significant differences in lumbar functional scores and visual analogue scale pain scores or in implant-related reoperation rates between the two groups. The incidence of pseudoarthrosis was significantly higher in patients with glucocorticoid-induced osteoporosis (GIOP) than in those with primary osteoporosis; however,

the pseudoarthrosis rate was reduced by using TP. The use of TP also tended to reduce the overall mechanical complication rate in both primary osteoporosis and GIOP.

**Conclusions:** The overall mechanical complication rate was lower in patients who received TP than in those who received a BP postoperatively, regardless of type of osteoporosis. The incidence of pseudoarthrosis was significantly higher in patients with GIOP, but the use of TP reduced the rate of pseudoarthrosis in GIOP patients.


# Background

Osteoporotic vertebral fractures (OVFs) are the most common type of fragility fracture and are sustained by 25% of individuals in their early 70s and 43% of those aged over 80 years [1]. OVFs cause low back pain, which significantly impacts quality of life. Many cases can be cured by conservative treatment using a brace[2] [3], but surgery may be performed when early mobilization is desired, conservative treatment fails, or the posterior segment of the vertebra is destroyed, accompanied by neurological deficit [4]. The recent advent of the percutaneous pedicle screw has made it possible to perform minimally invasive surgery in these patients [5]. However, because of the bone fragility in the background, surgically treated patients may experience screw loosening or pseudoarthrosis and revision surgery may be required [6].

BP are the first-line agents for osteoporosis and have been shown to prevent fragility fractures by inhibiting osteoclasts [7]. TP is a recombinant form of human parathyroid hormone and is the first osteogenic agent to enter clinical use. Improvements in lumbar bone mineral density (BMD) of 4.54%–7.48% have been reported for BP, whereas 6.4% improvement of BMD was reported after 2 years of administration of TP [8]. However, because TP is expensive and its allowed duration of administration is limited, the use of TP is problematic in terms of timing [9]. In contrast, several studies have reported osteonecrosis of the jaw or atypical femoral fracture as adverse effects of BP [10-12], which are not observed under TP.

Previous studies have demonstrated the superiority of TP over BP in patients who have undergone conservative treatment for OVF according to bone union rates [13-15]. Other studies have shown the positive effects of TP on bony fusion after spinal fusion or correction surgery [16-21]. TP has bone anabolic ability and can reduce the chance of screw loosening, and so the use of TP may effectively enhance spinal fusion and reduce implant failure and/ or subsequent vertebral fracture in comparison with surgery [16-21]. However, there is limited literature on the relationship between administration of these agents and mechanical complications after posterior fusion surgery for OVF. Furthermore, few studies have investigated the effects of TP and BP in patients with glucocorticoid-induced osteoporosis (GIOP). Therefore, optimal treatment of osteoporosis after reconstruction surgery for OVF remains unclear. The aim of this nationwide multicentre retrospective study was to investigate the effects of these osteoporosis medications on surgical outcomes, specifically mechanical complications and reoperation rates in patients with primary OVF or GIOP.

# Methods

### -Data collected-

We retrospectively reviewed all patients who were treated surgically with instrumentation for OVF between 2005 and 2014 at 27 universities and affiliated hospitals that contribute data to the multicentre Japan Association of Spine Surgeons with Ambition□JASA□database. Institutional review board approval was obtained at each site for patient enrollment and the data collection protocols. The need for informed consent was waived by the ethics committees because this retrospective cohort study involved existing data and records at the time of investigation, and did not retain personal identifiers in the collected information.

### -Inclusion criteria-

The inclusion criteria were treatment with a BP or TP after surgery, follow-up for at least 2 years, and surgery with instrumented posterior spinal fusion. TP was administered more than 6 months and then followed by a BP for the purpose of secondary mineralization. Patients who received other osteoporosis medications, such as denosumab or a selective oestrogen receptor modulator, were excluded. The aetiology was primary osteoporosis or GIOP. The patients who have the history of hypothyroidism, rheumatoid arthritis, diabetes mellitus, chronic renal failure were excluded. The operative procedure in the

database was divided into anterior spinal fusion, posterior spinal fusion alone with or without vertebroplasty, and anterior and posterior three-column osteotomy. Patients who underwent posterior spinal fusion fixation for less than five levels were included in this study. Demographic data including age, sex, body mass index, BMD and preoperative and postoperative use of osteoporosis agents were collected. BMD was expressed as a paercentage of the young adult mean (aged from 20 to 44 years). YAM less than 70% was used to diagnose osteoporosis in Japan[22].

### -Analysis of data-

As previously described, postoperative mechanical complications were defined as screw loosening, screw backout, screw breakage, rod breakage, and an adjacent vertebral fracture with or without revision surgery [23]. Screw loosening and screw backout are common complications in spinal instrumentation surgeries. Loosening of screw was usually detected by radiolucent zones around the screw indicating a low extraction torque. Screw back out is defined as change in screw position due to screw loosening. Screw complication was defined as screw loosening, screw backout, and screw breakage. Adjacent vertebral fracture was defined as new compression fractures in adjacent spinal column after surgery. Clinical outcomes were evaluated using the Japanese Orthopaedic Association (JOA) scoring system for lumbar function [24, 25]. The visual analogue scale (VAS) score was used to grade the severity of low back pain and pain or numbness in the lower extremities (0, no symptoms; 10, worst symptoms imaginable). The clinical outcomes were obtained before surgery and 1 year postoperatively. The recovery rate of JOA was calculated using following formula: recovery rate (%)=(1 year postoperative score−preoperative score)/(29−preoperative score)×100[24]. The change in VAS was defined as reduction of VAS between preoperative and 1 year postoperative score. The patients were divided into those who received BP and those who received TP, postoperatively. We compared the patient's demographics and surgical outcomes, as well as postoperative complications between the BP and TP group. Further, we compared the effect of BP and TP for patients with primary osteoporosis and GIOP.

### -Statistics-

The *t*-test or chi-squared test was used to compare the two groups. The averages of continuous variables were compared between the groups using *t*-tests and the proportions of categorical variables were compared using chi-square tests. All statistical analyses were performed using IBM SPSS Statistics for Macintosh software version 25.0 (IBM Corp., Armonk, NY). A p-value $<0.05$ was considered statistically significant.

## Results

One hundred and sixty-five patients who underwent posterior instrumented fusion during the study period met the inclusion criteria. The mean patient age at the time of surgery was 75.4 ± 7.2 years and 141 patients (85.4%) were female. The mean YAM score was 73.0 ± 16.1%. The OVFs were caused by primary osteoporosis in 138 patients and by GIOP in 27 patients. The mean duration of the administration of TP

was 17.5 ± 6.5 months. 11 patietns has two vertebral fracture at the same time and the mean number of vertebral fracture was 1.07.

Table 1 shows the patient characteristics according to type of osteoporosis. Mean patient age at the time of surgery was significantly higher in the primary osteoporosis group than in the GIOP group (76.6 ± 6.4 years vs. 71.0 ± 6.1 years; p = 0.001). Significantly more patients in the GIOP group received a osteoporosis medication preoperatively (p < 0.001). However, there was no significant between-group difference in sex, body mass index, smoking history, BMD, or number of fixed levels. The preoperative JOA and VAS scores for back pain and leg symptoms were also similar between the two groups.

Table 1. Preoperative demographic and clinical characteristics according to whether osteoporosis was primary or glucocorticoid-induced

| | Total | Primary | GIOP | p-value |
|---|---|---|---|---|
| Cases, n | 159 | 132 | 27 | - |
| Age at time of surgery (years) | 75.6 ± 6.7 | 76.6 ± 6.4 | 71.0 ± 6.1 | 0.001 |
| Sex (male) | 23 (14.5%) | 21 (15.9%) | 2 (7.4%) | 0.371 |
| BMI | 22.3 ± 5.1 | 22.4 ± 4.7 | 22.3 ± 6.4 | 0.923 |
| Smoking history (yes/no) | 20 (12.6%) | 19 (14.4%) | 1 (3.7%) | 0.202 |
| BMD (YAM%) | 71.0 ± 16.1 | 70.4±14.5 | 73.5 ± 16.4 | 0.548 |
| Preoperative use of osteoporosis medication (yes/no) | 72 (45.3%) | 50 (37.9%) | 22 (81.4%) | <0.001 |
| BP | 53 (33.3%) | 41 (31.1%) | 12 (44.4%) | |
| Vit D | 12 (7.3%) | 7 (5.1%) | 5 (18.5%) | |
| BP+Vit D | 2 (1.3%) | 0 | 2 (7.4%) | |
| TP | 7 (4.4%) | 4 (3.0%) | 3 (11.1%) | |
| Number of fixed level | 3.1 ± 0.8 | 3.1 ± 0.8 | 3.0 ± 0.9 | 0.531 |
| Preoperative JOA score | 4.2± 3.4 | 4.3 ± 3.3 | 3.4 ± 3.9 | 0.268 |
| Preoperative VAS (back pain) | 71.5± 24.4 | 70.7± 24.3 | 75.3 ± 24.9 | 0.389 |
| Preoperative VAS (leg pain or numbness) | 55.0 ± 31.7 | 55.0 ± 31.9 | 54.7 ± 31.5 | 0.696 |

GIOP, glucocorticoid-induced osteoporosis; BMI, body mass index; BMD, bone mineral density; YAM, young adult mean; JOA, Japan Orthopaedic Association; VAS, visual analogue scale.

The demographic characteristics in the BP and TP groups are shown in Table 2. There was no significant difference in age, sex, body mass index, BMD, smoking status, number of previous vertebral fractures, or the preoperative JOA or VAS scores between the two groups. Preoperative use of osteoporosis medication

was significantly more common in the TP group than in the BP group (59.0% vs. 37.5%, p = 0.03). There was no significant difference in the number of fixed levels between the two groups.

Table 2. Preoperative demographic and clinical characteristics according to whether osteoporosis medication was BP or TP

| | BP | TP | p-value |
|---|---|---|---|
| Cases, n | 104 | 55 | - |
| Age at surgery, years | 75.2 ± 6.8 | 76.4 ± 6.4 | 0.46 |
| Sex (male) | 15 (14.4%) | 8 (14.8%) | 0.98 |
| BMI | 22.2 ± 4.8 | 22.6 ± 5.7 | 0.62 |
| Smoking history | 14 (13.5%) | 6 (10.9%) | 0.64 |
| Previous vertebral fracture | 28 (26.9%) | 18 (29.5%) | 0.72 |
| BMD*, YAM% | 72.5 ± 17.7 | 73.0 ± 13.9 | 0.87 |
| Preoperative drug use for osteoporosis | 38 (37.5%) | 29 (59.0%) | 0.03 |
| BP | 32 (30.8%) | 23 (41.8%) | |
| Vit D | 6 (5.8%) | 6 (10.9%) | |
| BP+Vit D | 1 (0.01%) | 1 (0.02%) | |
| TP | 0 | 7 (12.7%) | |
| Number of fixed levels | 3.0 ± 0.8 | 3.2 ± 0.8 | 0.21 |
| Preoperative JOA score | 4.8 ± 3.6 | 4.1 ± 3.3 | 0.146 |
| Preoperative VAS (back pain) | 71.2 ± 22.9 | 74.6 ± 27.1 | 0.254 |
| Preoperative VAS (leg pain or numbness) | 53.1 ± 31.6 | 58.4 ± 32.9 | 0.355 |

BP, bisphosphonate; TP, teriparatide; BMI, body mass index; BMD, bone mineral density; YAM, young adult mean; JOA, Japanese Orthopaedic Association; VAS, visual analogue scale;.

Table 3 shows the postoperative complications and clinical outcomes in the BP and TP groups. The overall mechanical complication rate was significantly higher in the BP group than in the TP group (73.1% vs. 58.2%, p = 0.045). The screw backout rate was significantly lower and the rates of development of new vertebral fractures and pseudoarthrosis tended to be lower in the TP group than in the BP group (screw backout, 1.8% vs. 12.5%; vertebral fracture, 32.7% vs. 45.2%; pseudoarthrosis, 1.8% vs. 8.7%). There were no significant differences in the rates of revision surgery or other complications, such as screw loosening and rod fracture, between the groups. Furthermore, there were no significant differences in the postoperative JOA and VAS scores or in their rates of improvement.

Table 3. Postoperative complications and clinical outcomes according to whether osteoporosis medication was BP or TP

| | BP | TP | p-value |
|---|---|---|---|
| Cases, n | 104 | 55 | - |
| Mechanical complications | 76 (73.1%) | 32 (58.2%) | 0.045 |
| New vertebral fracture | 47 (45.2%) | 18 (32.7%) | 0.175 |
| Screw complications | 42 (40.4%) | 19 (34.5%) | 0.293 |
| Screw loosening (yes/no) | 29 (27.9%) | 18 (32.7%) | 0.585 |
| Screw backout | 13 (12.5%) | 1 (1.8%) | 0.024 |
| Rod fracture | 0 | 0 | - |
| Pseudoarthrosis | 9 (8.7%) | 1 (1.8%) | 0.091 |
| Revision due to mechanical complications | 10 (9.6%) | 9 (16.4%) | 0.303 |
| Postoperative JOA | 9.7 ± 3.4 | 9.3 ± 3.3 | 0.450 |
| Recovery rate of JOA | 49.0 ± 27.5 | 52.1 ± 25.2 | 0.486 |
| Final VAS (back pain) | 29.8 ± 22.5 | 31.3 ± 24.5 | 0.705 |
| Change in VAS (back pain) | 40.4 ± 30.0 | 41.6 ± 32.3 | 0.826 |
| Final VAS (leg pain or numbness) | 18.4 ± 20.4 | 21.2 ± 25.3 | 0.464 |
| Change in VAS (leg pain or numbness) | 33.5 ± 27.1 | 35.8 ± 30.1 | 0.630 |

BP, bisphosphonate; TP, teriparatide; JOA, Japanese Orthopaedic Association; VAS, visual analogue scale. The recovery rate of JOA was calculated using following formula: recovery rate (%)=(1 year postoperative score−preoperative score)/(29−preoperative score)×100. The change in VAS was defined as reduction of VAS between preoperative and 1 year postoperative score.

Table 4 shows postoperative complications and clinical outcomes compared between the patients with primary osteoporosis and those with GIOP. The rate of pseudoarthrosis was significantly higher in patients with GIOP than in those with primary osteoporosis (14.8% vs. 4.3%, p=0.045). Other complications were not significantly different between the two groups. There were no significant differences in postoperative JOA and VAS scores or the recovery rates.

Table 4. Postoperative complications and clinical outcomes according to whether osteoporosis was primary or glucocorticoid-induced

| | Primary osteoporosis | GIOP | p-value |
|---|---|---|---|
| Cases, n | 132 | 27 | - |
| Mechanical complications | 91 (67.4%) | 17 (63.0%) | 0.544 |
| New vertebral fracture | 57 (42.8%) | 8 (29.6%) | 0.207 |
| Screw complications | 54 (39.1%) | 7 (25.9%) | 0.214 |
| Screw loosening | 42 (30.4%) | 5 (18.5%) | 0.251 |
| Screw backout | 12 (8.7%) | 2 (7.4%) | 0.778 |
| Rod fracture | 0 | 0 | - |
| Pseudoarthrosis | 6 (4.3%) | 4 (14.8%) | 0.045 |
| Revision due to mechanical complications | 17 (12.3%) | 2 (7.4%) | 0.425 |
| Postoperative JOA | 9.7 ± 3.5 | 8.8 ± 3.0 | 0.205 |
| Recovery rate of JOA | 50.7 ± 27.8 | 46.1 ± 20.1 | 0.449 |
| Final VAS (back pain) | 30.0 ± 23.7 | 32.1 ± 20.6 | 0.743 |
| Change in VAS (back pain) | 40.3 ± 30.9 | 39.4 ± 29.8 | 0.715 |
| Final VAS (leg pain or numbness) | 19.2 ± 22.1 | 22.3 ± 23.4 | 0.786 |
| Change in VAS (leg pain or numbness) | 34.2 ± 29.0 | 34.8 ± 23.3 | 0.995 |

BP, bisphosphonate; TP, teriparatide; JOA, Japanese Orthopaedic Association; VAS, visual analogue scale. The recovery rate of JOA was calculated using following formula: recovery rate (%)=(1 year postoperative score−preoperative score)/(29−preoperative score)×100[24]. The change in VAS was defined as reduction of VAS between preoperative and 1 year postoperative score.

Table 5 shows the postoperative complications and clinical outcomes in the BP and TP groups according to whether the cause of OVF was primary osteoporosis or GIOP. The overall mechanical complication, screw backout, and pseudoarthrosis rates tended to be reduced by the use of TP compared to the use of BP in patients with primary osteoporosis (overall mechanical complications, 72.0% vs. 61.5%, p = 0.16; screw backout, 11.8% vs. 2.2%, p = 0.080; pseudoarthrosis, 6.5% vs. 0%, p = 0.081). In patients with GIOP, the rates of these complications were smaller by using TP (overall complications, 81.8% vs. 50%, p = 0.093; screw backout, 18.2% vs. 0% p = 0.076; pseudoarthrosis, 27.3% vs. 6.3%, p = 0.13). The screw loosening and revision surgery rates were not different between the BP and TP groups in both types of osteoporosis. There were no significant differences in the postoperative JOA and VAS scores or their recovery rates.

Table 5. Postoperative complications and clinical outcomes in the BP and TP groups according to whether the cause of OVF was primary osteoporosis or GIOP

| | Primary osteoporosis | | | GIOP | | |
|---|---|---|---|---|---|---|
| | BP | TP | p-value | BP | TP | p-value |
| Cases, n | 93 | 39 | - | 11 | 16 | - |
| Mechanical complications | 67 (72.0%) | 24 (61.5%) | 0.16 | 9 (81.8%) | 8 (50%) | 0.093 |
| New vertebral fracture | 42 (45.2%) | 15 (38.5%) | 0.304 | 5 (45.5%) | 3 (18.8%) | 0.14 |
| Screw complications | 39 (41.9%) | 15 (38.5%) | 0.43 | 3 (27.3%) | 4 (25.0%) | 0.90 |
| Screw loosening | 28 (30.1%) | 14 (35.9%) | 0.543 | 1 (9.1%) | 4 (25.0%) | 0.30 |
| Screw backout | 11 (11.8%) | 1 (2.6%) | 0.08 | 2 (18.2%) | 0 | 0.076 |
| Rod fracture | 0 | 0 | - | 0 | 0 | - |
| Pseudoarthrosis | 6 (6.5%) | 0 | 0.12 | 3 (27.3%) | 1 (6.3%) | 0.13 |
| Revision due to mechanical complications | 10 (10.8%) | 7 (17.9%) | 0.27 | 0 | 2 (12.5%) | 0.50 |
| Postoperative JOA score | 9.9 ± 3.3 | 9.6± 3.7 | 0.75 | 9.3 ± 3.2 | 8.3 ± 3.0 | 0.49 |
| JOA score recovery rate | 49.2 ± 30.1 | 54.4 ± 25.9 | 0.32 | 48.0 ± 19.8 | 44.7 ± 26.3 | 0.69 |
| Final VAS (back pain) | 30.9 ± 23.7 | 29.8 ± 26.0 | 0.95 | 27.2 ± 20.1 | 36.2 ± 20.3 | 0.30 |
| Change in VAS (back pain) | 40.5 ± 30.9 | 40.3 ± 32.1 | 0.98 | 40.3 ± 26.7 | 38.7 ± 33.6 | 0.90 |
| Final VAS (leg pain or numbness) | 18.9 ± 21.4 | 19.9 ± 24.8 | 0.81 | 15.0 ± 14.7 | 28.9 ± 28.2 | 0.15 |
| Change in VAS (leg pain or | 34.7 ± | 34.9 ± | 0.87 | 29.2 ± | 39.9 ± 25.1 | 0.28 |

| | | | |
|---|---|---|---|
| numbness) | 28.9 | 31.9 | 20.9 |

BP, bisphosphonate; TP, teriparatide; GIOP, glucocorticoid-induced osteoporosis; JOA, Japanese Orthopaedic Association; VAS, visual analogue scale. The recovery rate of JOA was calculated using following formula: recovery rate (%)=(1 year postoperative score−preoperative score)/(29−preoperative score)×100[24]. The change in VAS was defined as reduction of VAS between preoperative and 1 year postoperative score.

# Discussion

Previous studies have demonstrated that TP has a higher union rate in patients with OVF who were treated conservatively compared with those treated with BP [13-15]. However, little is known about the effect of these agents in patients with surgically treated OVF. Furthermore, there has been no comparison of the surgical outcomes between patients with primary osteoporosis and those with GIOP. In this study, we compared the surgical complications and clinical outcomes between patients with primary osteoporosis and GIOP. We then compared the effects of postoperative administration of teriparatide on surgical complications and reoperation rates with those of BP in patients with primary osteoporosis and in patients with GIOP.

The demographic data showed that patients with GIOP were younger at the time of surgery than those with primary osteoporosis. This finding indicates that vertebral fractures can occur at a relatively younger age in patients with GIOP. Consistent with this result is a review describing vertebral fractures occurring at a relatively young age in patients with GIOP, and the severity of the collapse was unexpectedly disproportionate to the age of the patients [26]. In our study, patients with GIOP had a relatively higher BMD than those with primary osteoporosis. A previous review also reported that patients on glucocorticoids experienced fractures at a higher BMD than the general population (i.e., the “BMD and bone fragility paradox”) [27]. The effect of glucocorticoids on bone is mediated by multiple pathophysiologic mechanisms resulting in an inhibition of bone formation and an increase in bone resorption. Glucocorticoids also impair the function of osteocytes and thus lead to impaired bone architecture [26] [27]. Saito et al. reported that deterioration of bone material properties advances with glucocorticoid use and the resulting alterations in bone quality are not captured by BMD [28].Thus, dual-energy X-ray absorptiometry may underestimate the risk of fracture, which is estimated to be high even though the value of BMD is relatively high in patients treated with glucocorticoids.

In our study, the overall mechanical complication and screw backout rates were significantly lower and the new vertebral fracture and pseudoarthrosis rates tended to be lower in the TP group. Previous studies suggested that rates of screw loosening and bone union are significantly lower in patients with osteoporosis who have undergone posterolateral fusion with a local bone graft or posterior interbody fusion and received TP than in their counterparts treated with BP [21]. In a prospective comparison of these osteoporotic medications in 58 surgically treated patients with adult spinal deformity, Seki et al. found that adjacent vertebral fracture, implant failure, and fusion failure rates were significantly lower in

their TP group than in their BP group [16]. In accordance with these studies, our result also suggested that it may be considered useful for reducing mechanical complications and pseudoarthrosis in surgically treated case of OVF.

In the comparison of primary and steroid-induced osteoporosis, our study showed that the rate of pseudoarthrosis was significantly higher in the patients with GIOP than in those with primary osteoporosis. Previous studies have reported that systemic corticosteroid therapy interfered with bony healing in a rabbit model, with a 60% lower union rate in the steroid group [29, 30]. Consistent with these studies, our results suggested that glucocorticoid use hindered bony union of fracture sites in patients who underwent posterior spinal fusion. However, our study also demonstrated a favourable effect of TP compared with BP for prevention of pseudoarthrosis in patients with GIOP. Thus, administration of TP may be a viable option to improve the rate of bony healing especially for patients with GIOP.

We found that TP tended to reduce mechanical complications and pseudoarthrosis regardless of whether osteoporosis was primary or glucocorticoid-induced when compared with BP. Furthermore, the effect of TP on prevention of new vertebral fractures was stronger in our patients with GIOP than in those with primary osteoporosis. Saag et al. have demonstrated that TP is an effective treatment for GIOP and that it was superior to alendronate for prevention of vertebral fractures at 36 months (1.7% vs. 7.7%) [31]. In accordance with the previous study, we found that TP had a positive effect on the mechanical complication rate. However, there has been a suggestion that the effect of TP is attenuated when the glucocorticoid dosage is higher than 15 mg/day [27]. Only four patients in our study were on glucocorticoid doses higher than 15 mg/day, thus a further study is needed to clarify the association between high-dose glucocorticoids and the effect of TP.

Previous studies have found better quality of life and VAS scores for back pain in patients treated with TP than in those treated with BP. In a crossover study by Jakob et al, postmenopausal women with osteoporosis who switched from a BP to TP reported better health-related quality of life and had improved VAS scores for back pain [13]. In our study, despite the positive effect of TP on mechanical complications, postoperative JOA and VAS scores for back pain were not significantly different between the TP and BP group. A possible explanation for this result is that posterior fusion itself results in marked improvement in the VAS score and quality of life. Therefore, symptoms in patients who received BP were also sufficiently improved by surgery, such that the effect of TP may not have been significant. However, the difference in mechanical complication rates between TP and BP may further increase during long term follow-up, which may result in marked differences in pain and quality of life in the patients with spinal fusion for OVFs.

This study has several limitations. First, the multicentre retrospective design of the study meant that we could not evaluate the duration of drug administration in all cases. Although TP should be administered for 2 years in Japan, information on the exact treatment duration could not be obtained. Therefore, it is possible that there were patients in the study who had received TP for a shorter duration. Second, we could not investigate the preoperative use of osteoporosis medications. However, the BMD was similar

between the two treatment groups, suggesting that any difference in the effect of drugs administered preoperatively was negligible. Further studies with more appropriate study designs are needed.

# Conclusions

In this study, the effect of postoperative TP on the overall mechanical complication rate was more favourable than that of a BP regardless of whether the osteoporosis is primary or glucocorticoid-induced. The incidence of pseudoarthrosis was significantly higher in patients with GIOP. The use of TP reduced the rate of pseudoarthrosis in GIOP patients.

# Abbreviations

BMD, bone mineral density; BP, bisphosphonate; GIOP, glucocorticoid-induced osteoporosis; JOA, Japanese Orthopaedic Association; OVF, osteoporotic vertebral fracture; TP, teriparatide; VAS, visual analogue scale; YAM, Young Adult Mean

# Declarations

### Ethics approval and consent to participate

This study was approved by the ethics committee of all participating institutions. The need for informed consent was waived by the above ethics committees because the retrospective cohort study involved existing data and records at the time of investigation, and did not retain personal identifiers in the collected information.

Ethics committee, Niigata University School of Medicine (approval number 2015-1385)

Ethics committee, Osaka University School of Medicine (approval number 11360-3)

Ethics committee, Tokyo Medical University (approval number 2605)

Ethics committee, Osaka City University School of Medicine (approval number 3170)

Ethics committee, Nagasaki University School of Medicine (approval number 17032715)

Ethics committee, Tokyo Medical and Dental University (approval number M2016-055)

Ethics committee, Kyushu University School of Medicine (approval number 28-359)

Ethics committee, Jichi Medical University (approval number A13-82)

Ethics committee, Kitasato University School of Medicine (approval number B16-34)

Ethics committee, Osaka Medical College (approval number 2169)

Ethics committee, Tokai University School of Medicine (approval number 16R-033)

Ethics committee, Shinshu University School of Medicine (approval number 3456)

Ethics committee, Chiba University School of Medicine (approval number 2481)

Ethics committee, Nagoya University School of Medicine (approval number 2016-0177)

Ethics committee, Kochi University School of Medicine (approval number 2016-116)

Ethics committee, Kanazawa University School of Medicine (approval number 2015-075)

Ethics committee, University of Toyama School of Medicine (approval number 21-22)

Ethics committee, Akita University School of Medicine (approval number 1879)

Ethics committee, Kobe University School of Medicine (approval number 160004)

Ethics committee, Nihon University Itabashi Hospital (approval number RK-160913-21)

Ethics committee, Hokkaido University School of Medicine (approval number 015-0396)

Ethics committee, Iwate Medical University (approval number H28-88)

Ethics committee, University of Tsukuba School of Medicine (approval number H27-133)

Ethics committee, Hiroshima University School of Medicine (approval number Epi-139)

Ethics committee, Keio University School of Medicine (approval number 20110141)

## Consent for publication

Not applicable

## Availability of data and materials

The datasets generated during and/or analysed during this study are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

## Funding

Not applicable.

## Authors' contributions

AK1: study design, analyses and interpretation of data, draft of manuscript with tables and figures; TY: substantial contributions to conception and critical revision for important intellectual content; TH1, SU, TK, YM, HT, AT, KH, KK2, AK2, GI, AN, DS, SI1, SO1, TF, SI2, KK4, HM, SS, MH, KK5, YA, MO2, MT, HE, TA, KN, KW2, NH, KI, and TH2: substantial contributions to study design and data acquisition; KK1, MO1, YS, TY, HF, YN, HS, HN, KT, SY, SA, NY, HO, TD, HI, MM, WS, TN, MS, TF, SO2, KA, KK3, KY, TY, AI, TT, SS, NI, EO, HF, SU, YS, and KN: data acquisition. All authors read and approved the final manuscript.

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