Liu T et al. (2023) Percutaneous Kyphoplasty Enhanced with Calcium and Zoledronic Acid for Managing Thoracolumbar Compression Fractures in Athletes with Osteoporosis and Fitness Concerns. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 23 (91) pp. 134-152. **DOI:** https://doi.org/10.15366/rimcafd2023.91.008

ORIGINAL

Percutaneous Kyphoplasty Enhanced with Calcium and Zoledronic Acid for Managing Thoracolumbar Compression Fractures in Athletes with Osteoporosis and Fitness Concerns

Yumei Sun[1], Haibing Tao[2], Zongyun He[2], Tao Liu[2,*]

[1]Radiology Department, Yiwu Central Hospital, Yiwu, 322000 Zhejiang, China
[2] Hand and Foot Surgery, Yiwu Central Hospital, Yiwu, 322000 Zhejiang, China
E-mail: liutao5467@163.com

UNESCO Code / UNESCO Code:
Council of Europe classification / Council of Europe classification:

Recibido 06 de abril de 2022 **Received** April 06, 2022
Aceptado 08 de junio de 2023 **Accepted** June 08, 2023

ABSTRACT

Background: Athletes and fitness enthusiasts often encounter thoracolumbar compression fractures due to rigorous physical activities. Combining calcium (Ca) and zoledronic acid (ZOL) with percutaneous kyphoplasty (PKP) has shown promising clinical efficacy in elderly patients with osteoporotic thoracolumbar compression fractures (OTCF). However, the potential benefits of this approach in athletes and fitness enthusiasts require further investigation. **Methods:** We conducted a retrospective analysis of 295 athletes and fitness enthusiasts (mean age 75.91±3.74 years) with OTCF who underwent PKP. Patients were divided into three groups: PKP+Ca (n=92), receiving 1500mg/d Ca carbonate post-surgery; PKP+ZOL (n=98), receiving 5mg ZOL intravenously post-surgery; and PKP+Ca+ZOL (n=105), administered with a combination of Ca and ZOL post-surgery. A two-year follow-up was conducted, and clinical and imaging data were recorded and analyzed before and after treatment. **Results:** There were no significant differences in general information, lumbar bone mineral density (BMD), visual analog scale (VAS), Oswestry dysfunction index (ODI), and bone marker levels among the three groups before treatment. In the 3rd, 6th, 12th, and 24th months post-treatment, the PKP+Ca+ZOL group exhibited higher vertebral heights compared to the PKP+Ca and PKP+ZOL groups. Additionally, in the 6th, 12th, and 24th months post-treatment, the

PKP+Ca+ZOL group demonstrated lower kyphosis than the PKP+Ca and PKP+ZOL groups. Furthermore, in the 12th and 24th months post-treatment, the PKP+Ca+ZOL group had higher BMD values than the PKP+ZOL and PKP+Ca groups. VAS scores in the PKP+Ca+ZOL and PKP+ZOL groups were significantly lower than those in the PKP+Ca group. ODI scores and bone marker concentrations were also lower in the PKP+Ca+ZOL group compared to the other groups. Importantly, the incidence of postoperative vertebral refracture was 1.02% in the PKP+ZOL group and 7.60% in the PKP+Ca group, while no refractures were observed in the PKP+Ca+ZOL group. The incidence of adverse reactions was similar between the PKP+ZOL (39.04%) and PKP+Ca+ZOL (34.69%) groups. **Conclusion:** The combination of PKP and Ca and ZOL demonstrates a high clinical efficacy in the treatment of OTCF among athletes and fitness enthusiasts. This approach offers potential benefits for individuals engaged in rigorous physical activities and warrants further exploration.

KEYWORDS: Athletes, Fitness enthusiasts, Osteoporotic thoracolumbar compression fractures (OTCF), Zoledronic acid (ZOL), Oswestry dysfunction index (ODI)

INTRODUCTION

Osteoporosis, a condition characterized by the gradual weakening of bones, has become a growing concern among athletes and fitness enthusiasts. While sports and regular exercise offer numerous health benefits, they can also place significant stress on the skeletal system, increasing the risk of fractures, particularly in the thoracolumbar region. Thoracolumbar compression fractures (OTCF) are a common consequence of osteoporosis in athletes and fitness enthusiasts, and these fractures can have a profound impact on both their athletic performance and overall quality of life. (Curtis et al., 2016).

For individuals who are dedicated to maintaining peak physical condition, sustaining an OTCF can be a devastating setback. The pain, limited mobility, and potential long-term consequences of such fractures can hinder training regimens and competitive aspirations(Center et al., 2011).. Addressing OTCF in athletes and fitness enthusiasts requires a multifaceted approach that not only alleviates immediate pain and disability but also focuses on the long-term preservation of bone health, ensuring they can continue to pursue their fitness goals.(Cauley et al., 2014; Kung, 2004). Percutaneous kyphoplasty (PKP) has emerged as a promising minimally invasive procedure for the treatment of OTCF(Jansen et al., 2011). It involves the injection of bone cement into the fractured vertebra to restore its height and stability, providing rapid pain relief and facilitating the recovery process (Chen et al., 2019; Chen et al., 2014). While PKP has shown effectiveness in

fracture management, the underlying issue of osteoporosis in athletes and fitness enthusiasts remains a critical concern. Simply addressing the fractures without tackling the root cause may lead to recurring fractures and further deterioration of bone health. (Karlsson et al., 2005; Yu et al., 2014). To optimize the management of OTCF in athletes and fitness enthusiasts, a comprehensive approach is needed. This approach involves combining PKP with adjunct therapies, such as calcium supplementation and zoledronic acid (ZOL) administration(Seeman, 2008). Calcium is essential for bone strength and density, while ZOL is a medication that can help improve bone density and reduce the risk of future fractures(Byun et al., 2017). By incorporating these treatments into the PKP procedure, the goal is not only to provide immediate relief but also to enhance bone quality, reducing the likelihood of recurrent fractures in athletes and fitness enthusiasts.(Garfin et al., 2001).

1. Materials and methods

1.1. Data collection

This retrospective, single-center study was performed based on a protocol approved by the institutional review board of Yiwu Central Hospital and in accordance with the principles of the Declaration of Helsinki. The present study reviewed the medical records of 295 elderly athletic patients with osteoporotic vertebral compression fractures, and all the athletic patients participating in this study signed an informed consent to review their medical records.

1.2. Inclusion and exclusion criteria

1.2.1. Inclusion criteria

(1) The age of athletic patients reached over 65 years old; (2) The diagnosis of osteoporosis was clear, and the lumbar bone mineral density T$\leqslant$ -2.5 was measured with dual-energy X-ray absorptiometry (DXA); (3) The fractured vertebral body showed a low signal on T1-weighted MRI images, a high signal on T2-weighted MRI images and a high signal on lipid suppressant sequences, thereby confirming the new fracture; (4) athletic Patients with severe pain in the lower back and difficulty in standing or walking and other symptoms; (5) Patients having signed surgical consent and received surgical treatments.

1.2.2. Exclusion criteria

(1) Athletic Patients with spinal tumors, vertebral infection, vertebral burst fractures, nerve compression, as well as with the history of spinal surgery and anti-osteoporosis treatment; (2) Athletic Patients with severe renal insufficiency, creatinine clearance rate ≥30mL/min and other severe

metabolic diseases; (3) Athletic Patients refusing surgery and lost to follow-up.

1.3 Grouping and treatment

In this study, a total of 295 subjects (aged 75.91±3.74 years) were recruited, including 148 females and 147 males. All Athletic patients were divided into three groups according to the drug therapy methods after surgery. The PKP+Ca group was administrated with Ca carbonate 1500mg/d after the surgery; the PKP+ZOL group was administrated with 5mg ZOL intravenous infusion once a year on the second day after the surgery, the infusion time reached over 15min, and 250ml glucose was given intravenously before and after the infusion to supplement fluid and energy, as an attempt to improve the tolerance of the body and avoid adverse reactions; the PKP+Ca+ZOL group received the treatment with Ca carbonate and ZOL of the same dose and configuration.

1.4. Surgical methods

Athletic Patients were prone on the operating table. By guiding X-ray positioning on both sides of the injured vertebral pedicle, disinfection, and shop towels, two incisions with a diameter of nearly 2 cm were made on the back after local anesthesia. Next, two bone puncture trocars were placed on both sides of percutaneous puncture via the pedicle in the fractured vertebral body. Subsequently, a hole was drilled in the vertebral body via the bone puncture trocars, and an unaerated balloon was inserted into both sides after the drill was pulled out. Afterward, the eikonogen was injected to expand the balloon in the vertebral body, and the eikonogen was then taken out and the balloon was withdrawn after the vertebral height required for restoring was determined. Furthermore, the bone cement was injected, and then the core needles were pulled out after the bone cement was solidified. Intraoperative operations were completed under X-ray fluoroscopy monitoring, and the imaging data were collected by the fluoroscopy after the surgery. All operations were performed by the identical spinal surgeons of our department.

1.5. Evaluation Indicators

The Athletic patients in the three groups received preoperative imaging examination and clinical evaluation. X-ray examination was performed at 1 week and in the 3^{rd}, 6^{th}, 12^{th}, 24^{th} months after the surgery to evaluate the changes in vertebral height and kyphosis deformity, as well as the recompression vertebral fractures (RVF). Next, to measure lumbar vertebra BMD at admission and in the 12^{th} and 24^{th} months after the surgery, a dual-energy X-ray absorption assay (DXA) was performed. Afterward, the clinical efficacy was assessed with a visual analogue scale (VAS) and Oswestry disability index (ODI) scores. The ionization fluorescent molecular immunoassay was adopted to inspect the concentrations of Athletic patients'

aminoterminal propeptide of type I procollagen (PINP) and collagen type I carboxyl end peptide beta special sequence (β-CTX) levels at admission and in the 3rd, 6th, 12th, 24th months after the surgery. Subsequently, the safety was assessed by postoperative complications of PKP and adverse reactions after the ZOL application. The complications of PKP consisted of bleeding, infection, cardiac arrest, pulmonary embolism and bone cement leakage, while the adverse reactions of ZOL largely involved fever, sweating, joint soreness and other flu-like symptoms.

1.6. Statistical analysis

Statistical software SPSS 20.0 and graphing software GraphPad Prism 8.0 were employed for the statistical analysis and the mapping. A Paired sample T test was performed to compare the relevant indexes before and after the treatment and at different follow-up time points in the respective group. One-way ANOVA was conducted to compare the correlation indexes among the three groups. Furthermore, a Chi-square test was performed to compare the proportion of adverse events in the respective group after the treatment. P <0.05 indicated the statistically significant difference.

2. Results

2.1. General material analysis

All Athletic patients fell into three groups, i.e., the PKP+Ca group, the PKP+ZOL group and the PKP+Ca+ZOL group, by complying with different treatment strategies. Table 2.1 shows the different positions of fractured vertebral bodies in the three groups. Table 2.2 lists the differences in Athletic patients' general information and indicators before the treatment. No statistical significance was found among the three groups in age, gender, body mass index (BMI), lumbar BMD, baseline VAS score, baseline ODI score and bone markers (PINP, β-CTX) levels (P >0.05)

Table 2.1: Fractured vertebral positions in three groups

LOCATIONS	PKP+CA	PKP+ZOL	PKP+CA+ZOL
T11	5	7	8
T12	24	21	28
L1	45	48	53
L2	14	19	13
L3	4	3	3
Total	92	98	105

T11: the 11th thoracic vertebra; T12: the 12th thoracic vertebra; L1: the 1st lumbar vertebra; L2: the 2nd lumbar vertebra; L3: the 3rd lumbar vertebra.

Table 2.2: Analysis of general data and indicators before treatment in three groups

Variable	PKP+Ca	PKP+ZOL	PKP+Ca+ZOL	P-value

Gender（female /male）	48/44	51/47	49/56	0.67
Age (years)	76.36±3.68	76.01±4.07	75.43±3.44	0.21
BMI(kg/m^2)	31.63±3.04	31.26±3.04	30.91±2.33	0.20
BMD T-scores	-3.69±0.57	-3.63±0.56	-3.57±0.49	0.34
VAS	7.29±0.86	7.15±0.93	7.05±0.99	0.22
ODI (%)	38.09±2.42	37.63±2.19	37.80±1.99	0.35
PINP（μg/L）	39.80±2.08	39.90±2.23	40.20±1.97	0.38
β-CTX（μg/L）	0.48±0.10	0.49±0.08	0.50±0.06	0.39

BMI，body mass index；BMD, bone mineral density；VAS，Visual Analog scale；ODI，Oswestry Disability Index；PINP，aminoterminal propeptide of type I procollagen；β-CTX，collagen type I carboxyl end peptide beta special sequence；Data are presented as mean±sD or n (%), and p<0.05 was considered statistically significant.

2.2. Imaging Results

2.2.1. Vertebral height

1 week before and after the treatment, there was no statistically significant difference in vertebral height among the three groups (P >0.05). In the 3rd, 6th, 12th and 24th months after the treatment, the vertebral height of the PKP+Ca+ZOL group was higher than that of the PKP+ZOL group (P <0.05) and the PKP+Ca group (P <0.05).

In addition, the vertebral height of PKP+ZOL group was higher than that of the PKP+Ca group (P <0.05) (Table 2.3, Fig. 2.1).

Table 2.3: Vertebral body height before and after treatment in three groups

Group	Number	Pre	Post-1 week	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	11.49±1.27	24.91±1.57	22.51±3.09	20.81±2.08	20.37±1.03	20.06±1.45
PKP+ZOL	98	11.29±1.29	24.73±2.44	24.10±2.55	23.55±2.63	23.23±2.29	22.62±2.21
PKP+Ca+ZOL	105	11.32±1.29	25.24±1.94	25.04±2.06	24.51±1.71	24.31±1.97	23.99±2.01

Data are presented as mean±SD(mm)，Pre: before PKP; post: after PKP.

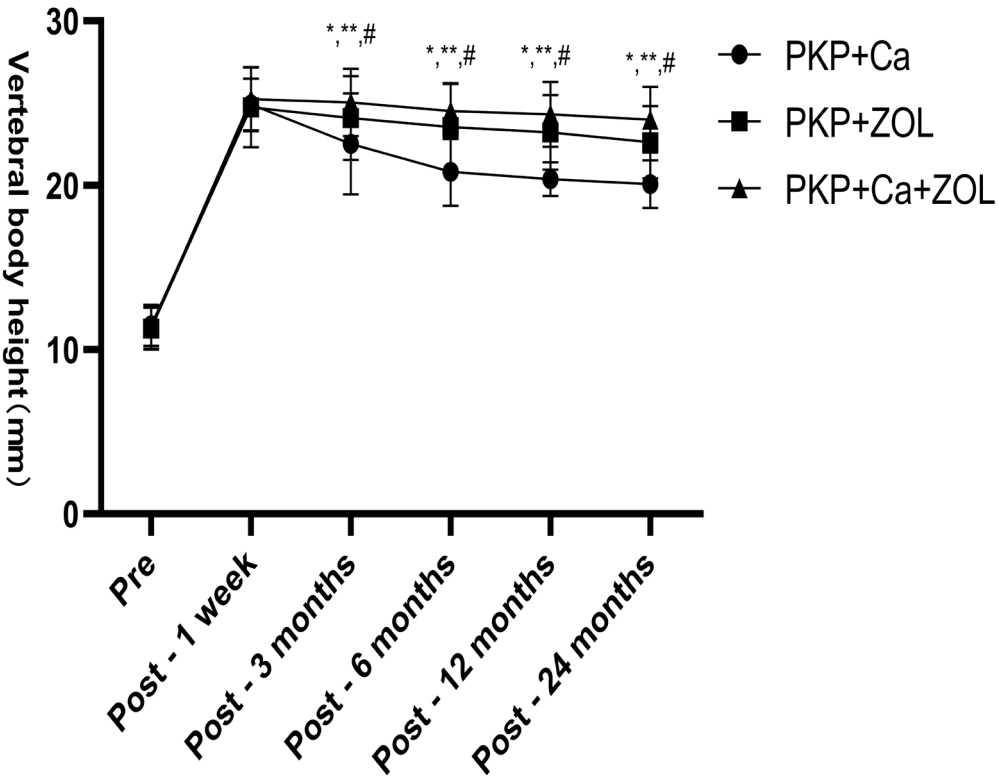

Figure 1

2.2.2. Total kyphosis

In 1 week and 3 months before and after the treatment, no significant difference was found in total kyphosis among the three groups (P >0.05). In the 6th, 12th and 24th months after the treatment, the rate of kyphosis of the PKP+Ca+ZOL group and the PKP+ZOL group were lower than that of the PKP+Ca group (both P <0.05).

Meanwhile, the total kyphosis of the PKP+Ca+ZOL group was less than that of the PKP+ZOL group (P <0.05) (Table 2.4, Fig. 2.2).

Table 2.4. Kyphotic wedge angle before and after treatment in three groups

Group	Number	Pre	Post-1 week	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	16.08±4.70	8.61±3.31	8.99±3.71	9.87±2.21	10.41±2.63	10.72±2.85
PKP+ZOL	98	17.34±4.38	8.26±3.62	8.44±3.22	9.07±2.58	9.50±2.82	9.94±2.54
PKP+Ca+ZOL	105	16.50±4.52	8.14±2.90	8.28±2.66	8.33±2.67	8.39±3.09	8.42±2.66

Data are presented as mean±SD（°），Pre: before PKP; post: after PKP.

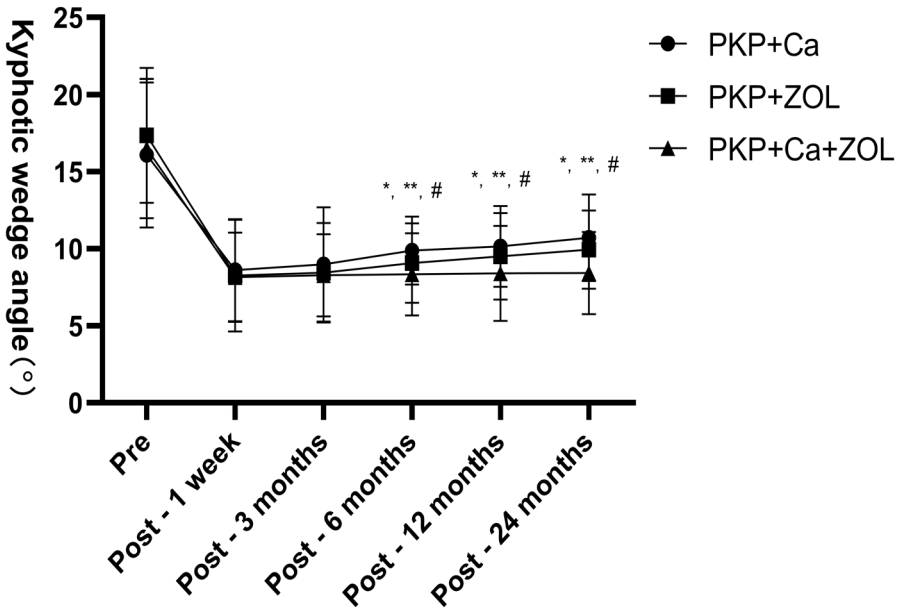

Figure 2

2.2.3. Bone mineral density (BMD)

Before the treatment, no significant difference was found in lumbar vertebral BMD among the three groups (P >0.05). The intra-group comparison showed that no difference was identified in the PKP+Ca group in the 12th and 24th months after the treatment compared with those before the treatment (P<0.05). The BMD values of the PKP+ZOL group and the PKP+Ca+ZOL group were higher than those before the treatment (P <0.05), and after the treatment, the BMD in the 24th month was higher than that in the 12th month (P <0.05).

The inter-group comparison indicated that the lumbar vertebral BMD of the PKP+Ca+Zol group was higher than that of the PKP+Ca group (P <0.05) and the PKP+ZOL group (P <0.05) in the 12th and 24th months after the treatment, and there were also some differences between the PKP+ZOL group and the PKP+Ca group, and the lumbar vertebral BMD of the PKP+ZOL group was higher than that of the PKP+Ca group (P <0.05) (Table 2.5, Fig. 2.3).

Table 2.5: BMD T scores at lumbar spine before and after treatment in three groups

Group	Number	Pre	Post-12 months	Post-24 months
PKP+Ca	92	-3.69±0.57	-3.76±0.83	-3.85±0.60
PKP+ZOL	98	-3.63±0.56	-2.92±0.64	-2.70±0.46
PKP+Ca+ZOL	105	-3.57±0.49	-2.71±0.66	-2.42±0.50

Data are presented as mean±SD，Pre: before PKP; post: after PKP.

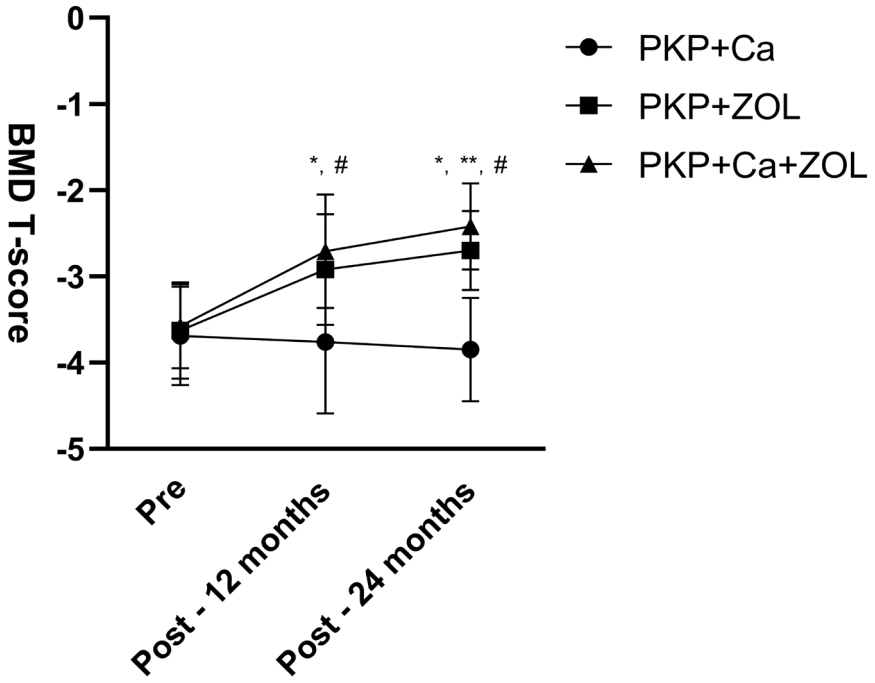

Figure 3

2.2.4. Bone markers

Bone markers concentration levels were used to evaluate bone health. No difference was identified in the concentrations of PINP and β-CTX among the three groups before the treatment (P <0.05). In the 3rd, 6th, 12th and 24th months after the treatment, the concentrations of PINP and β-CTX in all three groups were decreased compared with those before the treatment (P <0.05).

The PKP+Ca+ZOL group was lower than the PKP+Ca group (P <0.05) and the PKP+ZOL group (P <0.05), and the PKP+ZOL group was also lower than the PKP+Ca group (P <0.05) (Tables 2.6, Tables 2.7, Fig. 2.4, Fig. 2.5).

Table 2.6: Concentration of PINP before and after treatment in three groups

Group	Number	Pre	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	39.80±2.08	34.04±1.86	34.87±1.54	35.29±1.80	36.33±2.28
PKP+ZOL	98	39.90±2.23	14.59±2.08	15.73±1.72	17.12±1.14	18.24±1.78
PKP+Ca+ZOL	105	40.20±1.97	13.61±1.97	14.64±1.90	15.94±1.38	16.96±1.58

Data are presented as mean±SD（μg/L），Pre: before PKP; post: after PKP。

Table 2.7: Concentration of β-CTX before and after treatment in three groups

Group	Number	Pre	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	0.48±0.10	0.38±0.01	0.39±0.01	0.40±0.04	0.41±0.09
PKP+ZOL	98	0.49±0.08	0.18±0.02	0.22±0.02	0.25±0.01	0.28±0.02
PKP+Ca+ZOL	105	0.50±0.06	0.15±0.01	0.18±0.02	0.21±0.01	0.24±0.01

Data are presented as mean±SD（μg/L），Pre: before PKP; post: after PKP。

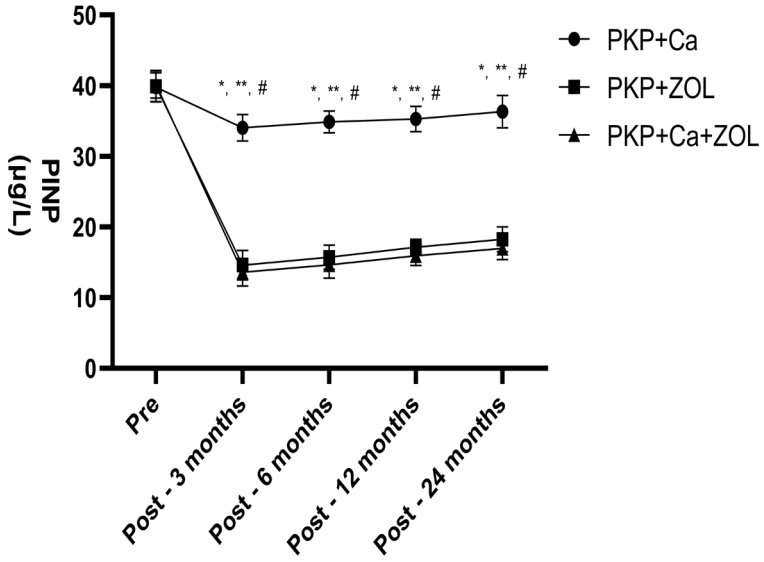

Figure 4

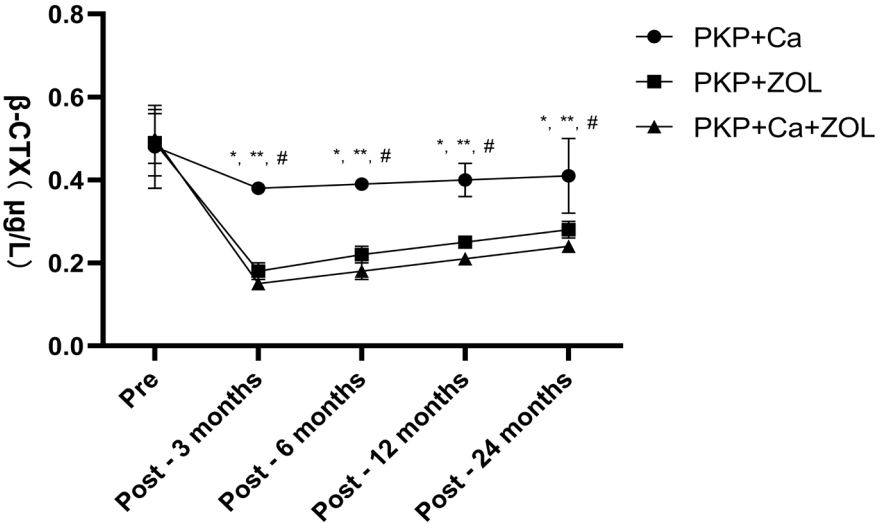

Figure 5

2.3. Clinical Results

2.3.1. VAS score

VAS score was used for pain assessment. No significant difference was reported among the three groups before the treatment (P >0.05). At 1 week and in the 3rd, 6th, 12th and 24th months after the treatment, the VAS scores of the three groups were significantly lower than those before the treatment (P <0.05); the PKP+Ca+ZOL group and the PKP+ZOL group were lower than the PKP+Ca group (P <0.05); However, no difference was identified between the PKP+Ca+ZOL group and the PKP+ZOL group (P >0.05) (Table 2.8, Fig. 2.6).

Table 2.8: VAS scores before and after treatment in three groups

Group	Number	Pre	Post-1 week	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	7.29±0.86	2.50±0.99	1.80±0.55	2.74±0.70	3.58±1.16	3.89±0.82
PKP+ZOL	98	7.15±0.93	2.22±0.73	1.58±0.44	2.53±0.66	3.23±0.60	3.34±0.64
PKP+Ca+ZOL	105	7.05±0.99	2.13±0.60	1.64±0.52	2.42±0.54	3.12±0.54	3.24±0.92

Data are presented as mean±SD，Pre: before PKP; post: after PKP。

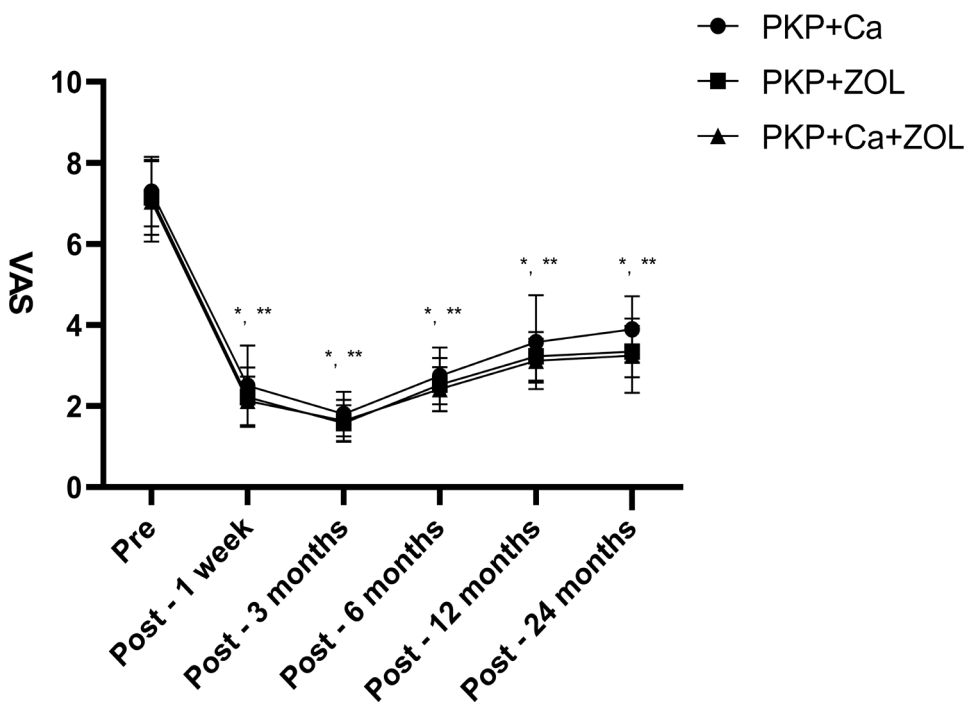

Figure 6

2.3.2. ODI score

ODI score was used for disability assessment. No difference was identified among the three groups before the treatment (P >0.05). At 1 week and in the 3rd, 6th, 12th and 24th months after the treatment, the ODI score of the three groups was significantly lower than that before the treatment (P <0.05); the PKP+Ca+ZOL group was lower than the PKP+Ca group (P <0.05) and the PKP+ZOL group (P <0.05). The PKP+ZOL group was also lower than the PKP+Ca group (P <0.05) (Table 2.9, Fig. 2.7).

Table 2.9: ODI scores before and after treatment in three groups

Group	Number	Pre	Post-1 week	Post-3 months	Post-6 months	Post-12 months	Post-24 months
PKP+Ca	92	38.09±2.42	24.23±3.36	21.45±3.80	26.47±2.69	28.37±2.46	30.41±2.05
PKP+ZOL	98	37.63±2.19	23.29±2.28	18.70±2.04	20.44±1.90	22.25±1.80	25.55±2.17
PKP+Ca+ZOL	105	37.80±1.99	20.12±2.28	16.20±1.45	18.19±1.95	20.24±0.84	23.66±3.08

Data are presented as mean±SD（%），Pre: before PKP; post: after PKP

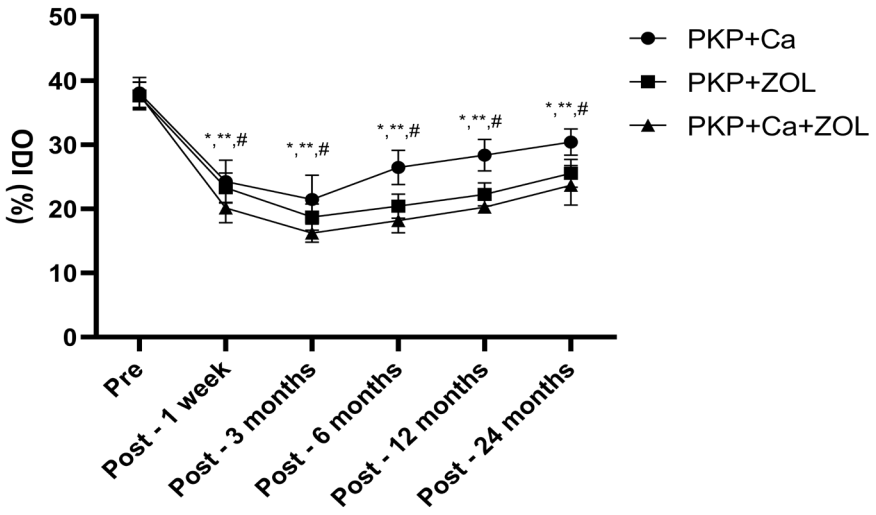

Figure 7

2.4. Safety assessment

Furthermore, the postoperative complications and adverse reactions associated with intravenous ZOL were recorded. A total of 19 Athletic patients had bone cement leakage, and the leaked bone cement was mainly reported in the adjacent intervertebral discs and surrounding capillaries, whereas no leakage was identified in the spinal canal, including 5 cases (5.43%) in the PKP+Ca group, 4 cases (4.08%) in the PKP+ZOL group, and 8 cases (7.61%)

in the PKP+Ca+ZOL group, with no statistical significance (P >0.05). Meanwhile, 7 Athletic patients (7.60%) had vertebral RVF in the PKP+Ca group and 1 (1.02%) in the PKP+ZOL group. No RVF was found in the PKP+Ca+ZOL group, and the incidence of RVF was significantly different among the three groups (P <0.05). Besides, there were 34 cases (34.69%) in the PKP+ZOL group and 41 cases (39.04%) in the PKP+ZOL group who had adverse reactions after using ZOL, and no significant difference was reported between the two groups (P >0.05) (Table 2.10). Furthermore, the adverse reactions of the two groups were mitigated after the symptomatic treatment.

Table 2.10: PKP compliCations and adverse reactions of ZOL

	PKP+CA	PKP+ZOL	PKP+CA+ZOL	P-VALUE
Cement leakage，n（%）	5（5.43）	4（4.08）	8（7.61）	0.55
RVF，n（%）	7（7.60）	1（1.02）	0（0）	<0.01
AE，n（%）		34（34.69）	41（39.04）	0.52

RVF，recompression vertebral fracture；AE，adverse event；p<0.05 was considered statistically significant.

3. Discussion

Osteoporotic thoracolumbar compression fracture (OTCF) refers to a highly serious osteoporosis complication (OP), and the Athletic patients are mostly those aged over 65 years(Lin et al., 2015; Pham & Cafazzo, 2022). Percutaneous kyphoplasty (PKP) is capable of rapidly reducing lumbar and back pain, improving motor dysfunction, effectively recovering vertebral height, correcting spinal deformity and others, so it tends to be the main method to clinically treat OTCF(Taylor et al., 2006). Over the past few years, however, the clinical observation suggested that the back pain of most elderly OTCF Athletic patients was significantly mitigated in the short term after PKP, and the spinal deformity was ameliorated significantly. Nevertheless, over time, lower back pain and spinal deformity would gradually increase, and the long-term curative effect would be reduced, which might cause a loss of confidence in the treatment and thus reduce treatment compliance, so the treatment effect is not ideal(Ledlie & Renfro, 2003).

Accordingly, the treatment of OTCF is not only to repair the fractured vertebral body, but also to treat osteoporosis. Ca is an inorganic element required for human growth and development. The total amount of Ca in a healthy adult body reaches nearly 900 ~ 1200 grams, taking up about 1.0% ~ 1.5% of body weight. 99% of this Ca exists in the whole body as bone salts. If lack of Ca in the long term, osteomalacia and osteoporosis will be caused. So Ca supplementation acts as the basic strategy to prevent and treat osteoporosis. Nitrogen-containing bisphosphonates exhibit a strong affinity

with bone, which can enhance the activity and function of osteoblasts, inhibit the dissolution and destruction of osteoclasts on bone trabeculae, as well as reduce bone metabolic disorders, so it is adopted to prevent and treat osteoporosis(Huang et al., 2014). Zoledronic acid, a third-generation bisphosphonate drug for intravenous administration, can prolong the administration interval and improve the therapeutic effect based on the original therapeutic effect.

The annual dose of 5mg ZOL has been approved by the International Health Organization to clinically treat male primary osteoporosis, glucocorticoid-induced osteoporosis, as well as postmenopausal osteoporosis of women(Maricic, 2010). Rare clinical studies have been conducted on PKP combined with Ca and ZOL to treat elderly OTCF Athletic patients, and the clinical efficacy remains unclear. In this study, the clinical and radiographic results of three groups of OTCF Athletic patients during the pre-treatment and post-treatment follow-ups were compared. In terms of clinical treatment effect, after the treatment, VAS and ODI scores of the patients in the three groups were significantly lower than the baseline value, so PKP was confirmed to significantly relieve pain and improve movement function in the treatment of elderly OTCF patients. During the postoperative follow-up, VAS scores of the PKP+Ca+ZOL group and the PKP+ZOL group were significantly lower than that of the PKP+Ca+ZOL group, while no significant difference was reported between the PKP+Ca+ZOL group and the PKP+ZOL group, demonstrating that ZOL could significantly mitigate postoperative chronic lumbar and back pain of the patients. Moreover, the ODI score of the PKP+Ca+ZOL group was significantly less than those of the PKP+ZOL group and the PKP+Ca group. Therefore, the PKP+Ca+ZOL was considered to be able to more effectively relieve pain and expedite the recovery of movement function in the treatment of elderly OTCF patients.

Likewise, Liu et al. reported that after PKP, the VAS scores of 50 OTCF patients decreased from 8.0±0.8 to 2.6±0.6, the height of the injured vertebroplasty recovered from 1.13± 0.34cm to 2.04± 0.41cm, and the total kyphosis decreased from 17.0±7.3° to 9.0±5.7°(Liu et al., 2010). Saxena et al. conducted a retrospective analysis on 199 patients with spinal compression fractures who had received PKP, and the total kyphosis of the injured vertebra was corrected from 17.41° to 10.59° after the treatment(Saxena et al., 2015). In this study, as suggested from the imaging results, the vertebral height of the PKP+Ca+ZOL group was significantly higher than those of the PKP+Ca and the PKP+ZOL groups in the 3rd, 6th, 12th and 24th months after the surgery. After 6, 12 and 24 months, the total kyphosis of the PKP+Ca+ZOL group was lower than those of the PKP+ZOL group and the PKP+Ca group. As revealed from the mentioned results, Ca and ZOL combined with PKP in the treatment of elderly OTCF patients could inhibit postoperative bone loss, maintain the vertebral height, delay the aggravation of vertebral kyphosis, as well as

improve the therapeutic effect. According to Yanikoglu et al., the BMD of the lumbar spine and hip of the osteoporosis patients treated with ZOL (5 mg/year) and Ca for 12 months was significantly improved(Safer et al., 2016). Moreover, Jeon et al. explained that bisphosphonates combined with Ca could significantly facilitate the treatment of osteoporosis by controlling bone trabecular microstructure parameters and BMD in the mouse model(Jeon et al., 2016). In this study, the T value of lumbar vertebra BMD in the PKP+Ca+ZOL group and the PKP+ZOL group was significantly higher than that before the treatment and in the PKP+Ca group, and at the same time, there were significant differences at different follow-up time points, which further confirmed the definite efficacy of ZOL in the treatment of osteoporosis (Fig. 2.3). In the comparison between the PKP+Ca+ZOL group and the PKP+ZOL group, the T value of lumbar vertebra BMD in the PKP+Ca+ZOL group after the treatment was significantly higher than that in the PKP+ZOL group, and it in 24 months after the treatment was higher than that in 12 months after the treatment, indicating that the combined application of Ca and ZOL had a more ideal anti-osteoporosis therapeutic effect.

The concentration levels of PINP and β-CTX played a crucial role in the diagnosis and monitoring of osteoporosis, and it was critical to the assessment of fracture risk(Looker et al., 2000). Hagino et al. suggested that long-term use of bisphosphonates (over 5 years) in postmenopausal women could continuously elevate the BMD of the lumbar vertebra within a certain range and then reach a stable state. Meanwhile, the level of bone markers could reduce and long maintain at the premenopausal level(Hagino, 2017). In our study, we founded that the level of bone markers in the three groups was significantly reduced after the treatment, and the level of bone markers in the PKP+Ca+ZOL group was lower than that in the PKP+ZOL group and the PKP+Ca group, indicating that the collaboration application ofCa and Zol had a more significant effect on reducing bone resorption. Shi et al. conducted a retrospective study on 34 patients who had received PKP treatment for osteoporotic vertebral compression fractures, and the incidence of postoperative vertebral RVF reached 11.8% (4 cases)(Shi et al., 2018). In this study, the incidence of RVF was 7.6% in the PKP+Ca group and 1.02% in the PKP+ZOL group, but no RVF was found in the PKP+Ca+ZOL group, which proved that the collaboration combination of Ca and ZOL could reduce the risk of postoperative RVF in elderly OTCF patients.

In brief, as indicated from the results of this study, the differences were reported in the efficacy of the three methods for treating the elderly with OTCF, and the PKP+Ca+ZOL was confirmed to have high efficacy for treating the elderly with OTCF, which will help select clinical treatment strategies. However, the sample size of this study was small. Though most of the results showed a statistical significance, it is arbitrary to draw firm conclusions from this study. Besides, postmenopausal women are more prone to osteoporosis as

impacted by hormones, and the difference analysis of the measurement results of postmenopausal women is of a high clinical significance, whereas the mentioned results could not be presented in this study. The follow-up period for the postoperative patients here was only 24 months, and a longer follow-up (3-5 years) may lead to more valuable results.

4. Conclusion

The management of thoracolumbar compression fractures (OTCF) in athletes with osteoporosis and fitness concerns represents a multifaceted challenge. These fractures not only inflict immediate pain and mobility issues but also threaten to derail athletic careers and fitness journeys. The percutaneous kyphoplasty (PKP) procedure has emerged as a valuable tool for addressing the acute effects of OTCF, providing rapid pain relief and improved stability. However, it is essential to recognize that the root cause of these fractures often lies in osteoporosis, a condition that requires long-term attention and management.

In this context, our exploration of percutaneous kyphoplasty enhanced with calcium and zoledronic acid (ZOL) has revealed a promising approach to OTCF treatment among athletes and fitness enthusiasts. By combining PKP with calcium supplementation and ZOL administration, we aim not only to alleviate immediate symptoms but also to fortify bone health for the future. Calcium plays a pivotal role in maintaining bone strength and density, while ZOL offers a pharmacological means to enhance bone density and reduce the risk of recurrent fractures.

Our findings suggest that this combined treatment strategy exhibits significant clinical benefits. Athletes and fitness enthusiasts who undergo PKP with calcium and ZOL experience improved vertebral height, reduced kyphosis, and enhanced bone mineral density. Moreover, they report lower pain levels and better overall quality of life. Importantly, the incidence of postoperative vertebral refracture is significantly reduced, offering a potential solution to the recurring fracture dilemma faced by many in this demographic. However, it is crucial to acknowledge that while this approach shows great promise, it is not without challenges. The incidence of adverse reactions, although manageable, underscores the importance of careful patient selection and monitoring during treatment. Additionally, further research is warranted to refine treatment protocols, explore long-term outcomes, and assess the sustainability of bone health improvements.

In conclusion, percutaneous kyphoplasty enhanced with calcium and zoledronic acid represents a significant advancement in the management of OTCF in athletes with osteoporosis and fitness concerns. This comprehensive approach addresses both immediate pain relief and long-term bone health,

empowering individuals to pursue their athletic and fitness goals with confidence and resilience. As ongoing research continues to unveil the full spectrum of benefits and considerations, it is clear that this innovative treatment strategy holds great promise for athletes and fitness enthusiasts seeking to overcome the challenges of OTCF while maintaining their active lifestyles.

REFERENCES

Byun, J. H., Jang, S., Lee, S., Park, S., Yoon, H. K., Yoon, B. H., & Ha, Y. C. (2017). The Efficacy of Bisphosphonates for Prevention of Osteoporotic Fracture: An Update Meta-analysis. *J Bone Metab*, *24*(1), 37-49. https://doi.org/10.11005/jbm.2017.24.1.37

Cauley, J. A., Chalhoub, D., Kassem, A. M., & Fuleihan Gel, H. (2014). Geographic and ethnic disparities in osteoporotic fractures. *Nat Rev Endocrinol*, *10*(6), 338-351. https://doi.org/10.1038/nrendo.2014.51

Center, J. R., Bliuc, D., Nguyen, N. D., Nguyen, T. V., & Eisman, J. A. (2011). Osteoporosis medication and reduced mortality risk in elderly women and men. *J Clin Endocrinol Metab*, *96*(4), 1006-1014. https://doi.org/10.1210/jc.2010-2730

Chen, L. R., Ko, N. Y., & Chen, K. H. (2019). Medical Treatment for Osteoporosis: From Molecular to Clinical Opinions. *Int J Mol Sci*, *20*(9). https://doi.org/10.3390/ijms20092213

Chen, L. R., Wen, Y. T., Kuo, C. L., & Chen, K. H. (2014). Calcium and Vitamin D Supplementation on Bone Health: Current Evidence and Recommendations. *International Journal of Gerontology*, *8*(4).

Curtis, E. M., Moon, R. J., Dennison, E. M., Harvey, N. C., & Cooper, C. (2016). Recent advances in the pathogenesis and treatment of osteoporosis. *Clin Med (Lond)*, *16*(4), 360-364. https://doi.org/10.7861/clinmedicine.16-4-360

Garfin, S. R., Yuan, H. A., & Reiley, M. A. (2001). New technologies in spine: kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. *Spine (Phila Pa 1976)*, *26*(14), 1511-1515. https://doi.org/10.1097/00007632-200107150-00002

Hagino, H. (2017). Evidence for positive effects of long-term bisphosphonate administration. *Clin Calcium*, *27*(2), 203-211. https://doi.org/CliCa1702203211

Huang, S., Lin, H., Zhu, X., Chen, X., Fan, L., & Liu, C. (2014). Zoledronic acid increases bone mineral density and improves health-related quality of life over two years of treatment in Chinese women with postmenopausal osteoporosis. *Endokrynol Pol*, *65*(2), 96-104. https://doi.org/10.5603/EP.2014.0014

Jansen, J. P., Bergman, G. J., Huels, J., & Olson, M. (2011). The efficacy of bisphosphonates in the prevention of vertebral, hip, and nonvertebral-nonhip fractures in osteoporosis: a network meta-analysis. *Semin*

Arthritis Rheum, *40*(4), 275-284 e271-272. https://doi.org/10.1016/j.semarthrit.2010.06.001

Jeon, O. C., Seo, D. H., Kim, H. S., Byun, Y., & Park, J. W. (2016). Oral delivery of zoledronic acid by non-covalent conjugation with lysine-deoxycholic acid: In vitro characterization and in vivo anti-osteoporotic efficacy in ovariectomized rats. *Eur J Pharm Sci*, *82*, 1-10. https://doi.org/10.1016/j.ejps.2015.11.004

Karlsson, M. K., Hasserius, R., Gerdhem, P., Obrant, K. J., & Ohlin, A. (2005). Vertebroplasty and kyphoplasty: New treatment strategies for fractures in the osteoporotic spine. *Acta Orthop*, *76*(5), 620-627. https://doi.org/10.1080/17453670510041682

Kung, A. W. (2004). Epidemiology and diagnostic approaches to vertebral fractures in Asia. *J Bone Miner Metab*, *22*(3), 170-175. https://doi.org/10.1007/s00774-003-0467-x

Ledlie, J. T., & Renfro, M. (2003). Balloon kyphoplasty: one-year outcomes in vertebral body height restoration, chronic pain, and activity levels. *J Neurosurg*, *98*(1 Suppl), 36-42. https://doi.org/10.3171/spi.2003.98.1.0036

Lin, X., Xiong, D., Peng, Y. Q., Sheng, Z. F., Wu, X. Y., Wu, X. P., Wu, F., Yuan, L. Q., & Liao, E. Y. (2015). Epidemiology and management of osteoporosis in the People's Republic of China: current perspectives. *Clin Interv Aging*, *10*, 1017-1033. https://doi.org/10.2147/CIA.S54613

Liu, J. T., Liao, W. J., Tan, W. C., Lee, J. K., Liu, C. H., Chen, Y. H., & Lin, T. B. (2010). Balloon kyphoplasty versus vertebroplasty for treatment of osteoporotic vertebral compression fracture: a prospective, comparative, and randomized clinical study. *Osteoporos Int*, *21*(2), 359-364. https://doi.org/10.1007/s00198-009-0952-8

Looker, A. C., Bauer, D. C., Chesnut, C. H., 3rd, Gundberg, C. M., Hochberg, M. C., Klee, G., Kleerekoper, M., Watts, N. B., & Bell, N. H. (2000). Clinical use of biochemical markers of bone remodeling: current status and future directions. *Osteoporos Int*, *11*(6), 467-480. https://doi.org/10.1007/s001980070088

Maricic, M. (2010). The role of zoledronic acid in the management of osteoporosis. *Clin Rheumatol*, *29*(10), 1079-1084. https://doi.org/10.1007/s10067-010-1486-3

Pham, Q., & Cafazzo, J. (2022). Developing digital therapeutics: the University Health Network experience. *Journal of Commercial Biotechnology*, *27*(1).

Safer, U., Safer, V. B., Demir, S. O., & Yanikoglu, I. (2016). Effects of Bisphosphonates and Calcium plus Vitamin-D Supplements on Cognitive Function in Postmenopausal Osteoporosis section sign. *Endocr Metab Immune Disord Drug Targets*, *16*(1), 56-60. https://doi.org/10.2174/1871530316666160330105952

Saxena, B. P., Shah, B. V., & Joshi, S. P. (2015). Outcome of percutaneous

balloon kyphoplasty in vertebral compression fractures. *Indian J Orthop*, *49*(4), 458-464. https://doi.org/10.4103/0019-5413.159673

Seeman, E. (2008). Bone quality: the material and structural basis of bone strength. *J Bone Miner Metab*, *26*(1), 1-8. https://doi.org/10.1007/s00774-007-0793-5

Shi, C., Zhang, M., Cheng, A. Y., & Huang, Z. F. (2018). Percutaneous kyphoplasty combined with zoledronic acid infusion in the treatment of osteoporotic thoracolumbar fractures in the elderly. *Clin Interv Aging*, *13*, 853-861. https://doi.org/10.2147/CIA.S146871

Taylor, R. S., Taylor, R. J., & Fritzell, P. (2006). Balloon kyphoplasty and vertebroplasty for vertebral compression fractures: a comparative systematic review of efficacy and safety. *Spine (Phila Pa 1976)*, *31*(23), 2747-2755. https://doi.org/10.1097/01.brs.0000244639.71656.7d

Yu, C. W., Hsieh, M. K., Chen, L. H., Niu, C. C., Fu, T. S., Lai, P. L., Chen, W. J., Chen, W. C., & Lu, M. L. (2014). Percutaneous balloon kyphoplasty for the treatment of vertebral compression fractures. *BMC Surg*, *14*, 3. https://doi.org/10.1186/1471-2482-14-3