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Effects of Extracorporeal Shock Wave Therapy on Visual Analogue Scale Scores and Serum Osteocalcin in Patients with Old Thoracolumbar Compression Fractures

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Abstract: *Objective:* To investigate the effects of extracorporeal shock wave therapy (ESWT) on visual analogue scale (VAS) pain scores and serum osteocalcin (bone Gla protein, BGP) levels in patients with old thoracolumbar compression fractures. *Methods:* Ninety patients with old thoracolumbar compression fractures admitted between February 2023 and February 2026 were enrolled and randomized, using a random number table, into an observation group and a control group of 45 patients each. The control group received conventional anti-osteoporotic therapy and rehabilitation, while the observation group additionally underwent focused ESWT. VAS scores, serum BGP levels, and radiographic fracture healing were compared between the two groups before treatment and at 4 and 12 weeks of treatment. *Results:* At 4 and 12 weeks of treatment, all of the above indices were superior in the observation group compared with the control group ($P < 0.05$). *Conclusion:* ESWT can effectively alleviate pain, raise serum osteocalcin levels, and promote the fracture healing process in patients with old thoracolumbar compression fractures.

Keywords: Extracorporeal shock wave therapy; Thoracolumbar spine; Old fracture; Visual analogue scale; Osteocalcin

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1. Introduction

Thoracolumbar compression fracture is the most common type of fragility fracture in the osteoporotic population, with a particularly high incidence among postmenopausal women. Most fresh fractures heal satisfactorily with conservative treatment; however, some patients progress to old (chronic) fractures because of delayed presentation, inadequate immobilization, or a poor state of bone metabolism, manifesting as persistent low back pain, loss of vertebral body height, and arrested fracture healing. Such patients suffer from protracted, refractory pain and a marked decline in quality of life, and their clinical management is highly challenging [1]. Extracorporeal shock wave therapy (ESWT), as a non-invasive physical intervention,

has accumulated relatively robust evidence in the treatment of nonunion and delayed union of fractures [2]; its biological effects involve mechanical stress-induced microdamage stimulation, improvement of local blood supply, and activation of osteogenesis-related signaling pathways [3]. Osteocalcin (bone Gla protein, BGP) is synthesized and secreted by osteoblasts and is a classical serological marker reflecting osteoblastic activity [4]. Nevertheless, for the specific population of patients with old thoracolumbar compression fractures, systematic observation of the dynamic effects of ESWT on pain and osteocalcin levels is still lacking. Using a randomized controlled design, this study therefore investigates the effects of ESWT on VAS scores and serum BGP in patients with old thoracolumbar compression fractures, with a view to providing a reference for clinical decision-making.

2. Materials and methods

2.1. General information

Ninety patients with old thoracolumbar compression fractures who were diagnosed and treated between February 2023 and February 2026 were enrolled as the study sample and were randomized into two groups of 45 patients each. Among the 45 patients in the control group, the male-to-female ratio was 23:22; the age ranged from 35 to 78 years, with a mean of 51.16 ± 7.24 years; and the disease course was 2–10 months, with a mean of 5.44 ± 1.28 months. Among the 45 patients in the observation group, the male-to-female ratio was 24:21; the age ranged from 34 to 79 years, with a mean of 50.12 ± 6.82 years; and the disease course was 1–10 months, with a mean of 5.17 ± 1.65 months. There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$), indicating comparability.

2.1.1. Inclusion criteria

(1) Single-segment thoracolumbar (T10–L2) compression fracture confirmed by MRI and radiography, with the degree of vertebral compression between 15% and 40%;
(2) Disease course ≥3 months, with imaging showing a distinct fracture line but no continuous bridging callus, consistent with the diagnosis of an old fracture;
(3) Bone mineral density T-score ≤−2.5 SD;
(4) No physical pro-healing therapy such as shock wave or pulsed electromagnetic field therapy within 4 weeks before enrolment;
(5) Signed informed consent.

2.1.2. Exclusion criteria

(1) Disruption of the posterior vertebral wall or concomitant neurological injury;
(2) Pathological fracture (caused by tumor or infection);
(3) Skin breakdown or infection in the shock wave treatment area;
(4) Severe cardiovascular or cerebrovascular disease, coagulation dysfunction, or cognitive impairment precluding cooperation with assessments;
(5) Previous history of spinal surgery.

2.2. Methods

2.2.1. Control group

Basic anti-osteoporotic therapy was given, comprising calcium carbonate D3 tablets (600 mg/day, orally) combined with alendronate sodium (70 mg/week, orally), together with instruction in isometric contraction exercises of the lumbar and dorsal muscles and progressive weight-bearing activities. The course of treatment was 12 weeks.

2.2.2. Observation group

In addition to the regimen of the control group, focused extracorporeal shock wave therapy was applied. An electromagnetic shock wave device (Dornier AR2, Germany) was used. Before treatment, the fractured vertebral body and the adjacent endplate region were localized under fluoroscopic guidance, and the treatment target area was marked on the body surface. The parameters were set as follows: energy flux density 0.25 mJ/mm^2, frequency 4 Hz, 2,000 shocks per session, and focus depth set at 4–6 cm according to the position of the vertebral body. Treatment was administered once weekly, with four consecutive sessions constituting one course; one course was completed in total. During treatment, the patient was placed in the prone position; the superficial bone of the spinous and transverse processes was avoided, and the paraspinal musculature and the region around the fracture line served as the principal targets. The patient's tolerance was ascertained throughout the procedure, and the energy flux density was appropriately reduced if marked discomfort occurred.

2.3. Outcome measures

2.3.1. Visual analogue scale (VAS) for pain

A 0–10 point scale was used, with 0 indicating no pain and 10 indicating the worst imaginable pain. Assessments were performed before treatment and at 4 and 12 weeks of treatment by the same research nurse, who was blinded to group allocation. At each assessment, after the patient had rested in a seated position for 5 minutes, the current severity of low back pain was marked on the scale.

2.3.2. Serum osteocalcin (BGP)

Before treatment and at 4 and 12 weeks of treatment, 3 mL of fasting cubital venous blood was collected, centrifuged at 3000 r/min for 10 minutes, and the separated serum was stored at −80 °C until analysis. BGP levels were measured by electrochemiluminescence immunoassay (Roche Cobas e601), with an intra-assay coefficient of variation (CV) <5% and an inter-assay CV <8%.

2.3.3. Radiographic callus score

At 12 weeks of treatment, anteroposterior and lateral radiographs of the thoracolumbar spine were obtained, and healing was graded with reference to the Fernández-Esteve callus scoring criteria: 0 points, no callus formation; 1 point, indistinct fracture ends with a small amount of cloud-like callus; 2 points, callus formation but the fracture line still visible; 3 points, callus bridging the fracture line with blurring of the fracture line; 4 points, disappearance of the fracture line with bony union. The images were read independently by two senior radiologists, and disagreements were resolved by consensus.

2.4. Statistical analysis

Data were processed using SPSS 26.0 software. Measurement data and count data were expressed as mean ± standard deviation (SD) and (%) respectively, and comparisons were performed using the *t*-test and the χ^2 test accordingly. Statistical significance of the results was judged primarily by the *P* value, with $P < 0.05$ considered to indicate a statistically significant difference.

3. Results

3.1. Comparison of VAS scores between the two groups

Compared with the control group, the observation group had lower VAS scores ($P < 0.05$), as shown in **Table 1**.

Table 1. Comparison of VAS scores between the two groups at different time points (points, mean ± SD)

Group	*n*	Before treatment	4 weeks of treatment	12 weeks of treatment
Observation group	45	6.24 ± 1.08	3.47 ± 0.92	2.16 ± 0.74
Control group	45	6.18 ± 1.12	4.52 ± 1.03	3.58 ± 0.89
t		0.259	5.100	8.229
P		0.796	0.000	0.000

3.2. Comparison of serum BGP levels between the two groups

Compared with the control group, serum BGP levels were higher in the observation group ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of serum BGP levels between the two groups at different time points (ng/mL, mean ± SD)

Group	*n*	Before treatment	4 weeks of treatment	12 weeks of treatment
Observation group	45	14.62 ± 3.27	19.85 ± 3.96	23.47 ± 4.12
Control group	45	14.38 ± 3.14	16.92 ± 3.58	19.04 ± 3.87
t		0.355	3.682	5.257
P		0.723	0.000	0.000

3.3. Comparison of radiographic callus scores between the two groups

The proportion of patients achieving bony union (4 points) was higher in the observation group than in the control group ($P < 0.05$), as shown in **Table 3**.

Table 3. Comparison of radiographic callus scores between the two groups at 12 weeks of treatment [*n* (%)]

Group	*n*	0 points	1 point	2 points	3 points	4 points
Observation group	45	0 (0.00)	5 (11.11)	12 (26.67)	15 (33.33)	13 (28.89)
Control group	45	3 (6.67)	11 (24.44)	16 (35.56)	10 (22.22)	5 (11.11)
χ^2	–	3.103	2.737	0.829	1.385	4.444
P	–	0.078	0.098	0.362	0.239	0.038

4. Discussion

Osteoporotic thoracolumbar compression fracture is a highly prevalent type of fragility fracture in the elderly: vertebral bone mass is reduced, and bone microarchitecture is disrupted, so that vertebral collapse can occur under only minor external force. Most fresh fractures heal gradually after standardized conservative treatment; however, in some patients, factors such as poor early pain control, prolonged bed rest, poor adherence to lumbar and dorsal muscle exercise, and a low baseline level of bone metabolism lead to arrest of the reparative process and evolution into an old compression fracture [5,6]. The cardinal manifestation in these patients is persistent chronic low back pain, which arises not solely from the fractured ends but is frequently compounded by paraspinal muscle spasm, vertebral instability, and local aseptic inflammation. Chronic pain restricts activity and further aggravates bone loss, creating a vicious circle of "pain → reduced activity → worsening osteoporosis → delayed fracture healing" that poses considerable difficulty for clinical treatment [7]. Current conventional regimens combining anti-osteoporotic medication with rehabilitation training can improve bone mass and relieve pain of muscular origin, but they provide limited osteogenic stimulation at the fracture site; in many patients, the fracture line persists for a long time, callus grows slowly, and painful symptoms linger for months or even longer. There is therefore an urgent need for a safe, minimally invasive pro-repair intervention that can be delivered in primary care settings [8].

Extracorporeal shock wave therapy is a non-invasive physical treatment that has been widely used for delayed union and nonunion of fractures, tendinopathies and chronic pain disorders. When shock waves reach the target tissue, they generate mechanical stress, producing controlled microdamage in bone and soft tissue and thereby initiating the reparative cascade [9]; at the same time, they dilate local microvessels, improve microcirculation, upregulate osteogenesis-related growth factors, and recruit mesenchymal stem cells to differentiate into osteoblasts, thereby enhancing local osteogenic activity—this constitutes the core mechanism by which ESWT promotes fracture repair. Osteocalcin is specifically secreted by osteoblasts and is a commonly used clinical marker of osteoblastic activity; an increase in serum BGP indirectly reflects active osteoblast proliferation and accelerated bone formation [10,11]. In the present study, there were no significant differences in VAS scores or serum BGP levels between the two groups before treatment, indicating balanced baselines; at 4 and 12 weeks of treatment, the observation group had lower VAS scores and higher serum BGP levels than the control group ($P < 0.05$). This suggests that adding focused ESWT to conventional anti-osteoporotic and rehabilitation therapy can both rapidly relieve resting low back pain and upregulate serum osteocalcin, activating systemic and local osteogenic metabolism [12].

Pain relief is likely to occur through three pathways. First, shock waves inhibit the release of local inflammatory mediators and reduce the sensitivity of nociceptors, thereby directly alleviating the pain of chronic aseptic inflammation. Secondly, they improve blood supply to the paraspinal soft tissues and release spasm of the lumbar and dorsal muscles, thus reducing referred pain caused by muscular tension. Thirdly, once osteogenic activity has been enhanced and callus has formed at the fracture ends, vertebral stability improves, and the irritating pain provoked by micromotion is consequently attenuated [13]. In this study, treatment was delivered with the patient prone, targeting the paraspinal region and the area around the fracture line while avoiding danger zones such as the spinous processes and the spinal canal, at a moderate energy flux density once weekly for four sessions—an approach that balances efficacy and safety. No adverse events such as nerve irritation, subcutaneous hematoma, or further vertebral collapse occurred, indicating that the protocol is suitable for patients with old osteoporotic vertebral compression fractures, whose tolerance

is relatively poor. In the control group, as anti-osteoporotic therapy and rehabilitation training progressed, VAS scores also fell, and BGP rose slightly, showing that standardized basic treatment can itself improve bone metabolism and muscle-derived pain; however, its onset is slower and its osteogenic stimulation at the fracture site is insufficient, and the difference from the observation group was marked [14].

At 12 weeks of treatment, the proportion of patients with callus bridging and bony union (4 points) was higher in the observation group than in the control group ($P < 0.05$), while the remaining grades showed no statistically significant between-group differences. This indicates that ESWT does not achieve rapid bony union in all patients; rather, its principal advantage lies in increasing the proportion achieving complete bony union. Some patients still achieved only scant callus or blurring of the fracture line, suggesting that repair of old vertebral compression fractures is a lengthy process for which a single shock wave intervention has limitations. In old fractures, the vertebral trabeculae are collapsed, local blood supply is poor and, superimposed on persistent osteoporosis, the osteogenic microenvironment is unfavorable. Shock waves serve mainly to "initiate repair"; anti-osteoporotic medication is still required to continuously improve systemic bone metabolism, together with lumbar and dorsal muscle training to maintain the mechanical stability of the vertebral body, and only the synergy of all three yields a satisfactory outcome. This also demonstrates the rationality of the combined regimen used in this study: shock waves alone cannot correct osteoporosis, osteogenic activity is difficult to sustain, and the fracture remains at risk of impaired healing [15,16].

This study has certain limitations. First, it was a single-center study with a relatively small sample size and a follow-up period of only 12 weeks; only short-term VAS scores, osteocalcin levels, and radiographic callus scores were observed, and longer-term indices (at 6 months and 1 year), such as maintenance of vertebral body height, risk of re-fracture, and disability indices, were not assessed, so the long-term efficacy remains unclear. Secondly, serum BGP was used as the marker of osteogenesis; being a systemic index, it cannot reflect local osteogenic changes at the fractured vertebra with complete specificity, and future studies could combine several bone metabolism markers—such as bone-specific alkaline phosphatase and N-terminal propeptide of type I procollagen—for a more comprehensive assessment. Thirdly, no subgroup comparisons of different shock wave energy levels, numbers of shocks, or treatment courses were performed, so the optimal treatment parameters remain to be explored. Fourthly, radiography has a limited ability to identify fine callus; where conditions permit, thin-slice CT reconstruction could be used to evaluate fracture healing and improve the objectivity of assessment.

5. Conclusion

In summary, focused extracorporeal shock wave therapy combined with conventional anti-osteoporotic and rehabilitation therapy can effectively reduce VAS scores for low back pain, upregulate serum osteocalcin levels, promote callus growth at the fracture ends, and increase the proportion of bony union in patients with old thoracolumbar compression fractures. Being minimally invasive and having a favorable safety profile, it is suitable for use as a conservative treatment for such patients in primary care hospitals, and offers a new therapeutic option for old osteoporotic vertebral compression fractures in patients who are unwilling to undergo vertebroplasty or have no surgical indication. In clinical application, the indications must be strictly observed, pre-operative imaging should be used for precise localization, shock wave energy and targets should be carefully controlled, and long-term anti-osteoporotic treatment and functional exercise should be

maintained, so that the therapeutic effect can be continuously consolidated.

Disclosure statement

The author declares no conflict of interest.

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