



The Effect of Bu Yang Huan Wu Decoction on Postoperative Bone Metabolism in Patients with Lumbar Spinal Stenosis and Cauda Equina Redundancy

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Abstract

Objective: To investigate the effects of Bu Yang Huan Wu Decoction on postoperative bone metabolism in patients with lumbar spinal stenosis complicated by cauda equina redundancy. **Methods:** A prospective, randomized, controlled study was conducted from March 2025 to December 2025 at the Department of Orthopedics and Traumatology of Bijie Traditional Chinese Medicine Hospital. Forty patients with lumbar spinal stenosis and cauda equina redundancy who underwent transforaminal lumbar interbody fusion (TLIF) were enrolled and randomly assigned to a control group and a study group, with 20 patients in each group. The control group received standard orthopedic treatment, while the study group received standard treatment supplemented with Buyang Huanwu Decoction. Bone density, serum levels of N-terminal propeptide of type I procollagen (PINP), β -C-terminal cross-linking telopeptide of type I collagen (β -CTX), osteocalcin (OST), 25-hydroxyvitamin D (25OHD), parathyroid hormone (PTH), serum alkaline phosphatase (ALP), and serum creatinine (Scr). **Results:** Bone mineral density in all patients increased significantly compared to preoperative levels ($P < 0.05$), and the study group showed markedly better outcomes than the control group, with statistically significant differences ($P < 0.05$). Compared with the control group, the study group showed more pronounced increases in serum PINP, OST, 25OHD, and PTH, with statistically significant differences ($P < 0.05$); statistically significant decreases in β -CTX and Scr ($P < 0.05$); and a decrease in ALP that was not statistically significant ($P > 0.05$). **Conclusion:** Bu Yang Huan Wu Decoction demonstrates definite clinical efficacy in treating bone metabolism in patients with lumbar spinal stenosis complicated by cauda equina redundancy; it can significantly increase bone density and improve levels of bone metabolism markers.

Keywords: Buyang Huanwu Decoction; Lumbar spinal stenosis; Redundant nerve roots of cauda equina; Bone metabolism.

1. Introduction

Lumbar spinal stenosis (LSS) with redundant cauda equina (Redundant nerve roots, RNRs) refers to a syndrome characterized by absolute or relative narrowing of the lumbar spinal canal due to factors such as primary degeneration or secondary injury, which in turn compresses the cauda equina and spinal nerve roots, leading to a series of chronic, progressive neurological dysfunction—with neurogenic intermittent claudication as the core symptom—accompanied by lower back and leg pain, numbness and weakness in the lower extremities, and urinary and bowel dysfunction (1). The typical MRI findings show dilation, bending, and entanglement of the cauda equina within the narrowed spinal canal; in some cases, this may be accompanied by nerve edema and signal abnormalities (2). As a degenerative spinal condition that is highly prevalent among middle-aged and elderly individuals, the incidence of this disease has been rising year by year amid the accelerating pace of population aging. It severely impairs patients' mobility and quality of life; if the condition continues to progress, it can lead to irreversible nerve damage and even serious complications such as lower-limb paralysis and urinary and fecal incontinence, placing a heavy medical and financial burden on patients' families and society (3). Currently, clinical treatment for LSS with RNRs primarily involves surgical intervention. Transforaminal Lumbar Interbody Fusion (TLIF) is the most widely used surgical procedure at present. Its primary purpose is to relieve compression of the cauda equina caused by spinal stenosis and restore lumbar spinal stability, thereby alleviating patients' clinical symptoms (4,5). However, surgical treatment can significantly alter levels of bone turnover markers in the human body, causing fluctuations in

bone metabolism (6). At the same time, patients with RNRs experience slow postoperative neurological recovery and require long-term immobilization; however, long-term immobilization further inhibits osteoblast activity, promotes bone resorption, exacerbates bone metabolic imbalance, and increases the risk of complications (7) such as postoperative osteoporosis and poor vertebral fusion, thereby affecting surgical outcomes and patients' long-term recovery. Furthermore, relying solely on Western medicine's symptomatic and supportive treatment after surgery is unlikely to fundamentally address patients' bone metabolism disorders and slow nerve regeneration; there is an urgent clinical need for more effective adjunctive treatment options. According to Traditional Chinese Medicine (TCM) syndrome differentiation, patients with LSS accompanied by RNRs experience impaired circulation of qi and blood prior to surgery due to spinal canal stenosis and nerve compression; over time, this leads to qi deficiency and blood stasis, as well as malnutrition of the bone meridians. Postoperative trauma further depletes vital energy and exacerbates blood stasis; the lack of nourishment to the bone meridians and deficiency of qi and blood are precisely the core pathomechanisms leading to bone metabolism disorders and delayed nerve repair. Bu Yang Huan Wu Decoction, a classic TCM formula for tonifying qi, invigorating blood, and unblocking meridians, originates from Wang Qingren's **Corrections in Medical Literature** (Yilin Gai Cuo) of the Qing Dynasty. The formula features Astragalus (Huangqi) as the principal herb, combined with Angelica sinensis (Danggui), red peony root, and other ingredients that activate blood circulation and unblock meridians. The formula as a whole works to tonify qi, activate blood circulation, and unblock meridians, aligning closely with the pathogenesis of this condition—"qi deficiency with blood stasis and malnutrition of the bone meridians"—and is widely used in the treatment of orthopedic injuries.

2. Materials and Methods

2.1. General Information

Forty patients diagnosed with lumbar spinal stenosis with cauda equina redundancy and who underwent TLIF decompression surgery at Bijie Traditional Chinese Medicine Hospital between March 2025 and December 2025 were selected as the study subjects. A random sequence was generated using the Excel RAND function, and patients were randomly assigned to a control group and a study group (20 patients in each group) using the sealed-envelope method. The general characteristics of the two groups are shown in Table 1. As can be seen, there were no statistically significant differences ($P < 0.05$), indicating that the groups were comparable. This study was approved by the Ethics Committee of Bijie Traditional Chinese Medicine Hospital (ky-2025-02(2)).

Table-1. Comparison of General Clinical Characteristics Between the Two Groups ($\bar{x} \pm s$, $n=40$)

Item	Study Group	Control Group	Test Statistic	P
Age[years, ($\bar{x} \pm s$)]	58.20 $\pm$ 7.74	59.10 $\pm$ 7.89	0.364	0.718
Gender [cases (percentage, %)]			0.625	0.429
Height	158.25 $\pm$ 7.11	158.85 $\pm$ 6.41	0.280	0.781
Weight	58.10 $\pm$ 7.40	56.75 $\pm$ 8.32	-0.542	0.591

2.2. Diagnostic, Inclusion, Exclusion, and Withdrawal Criteria

2.2.1. Western Medical Diagnostic Criteria: Based on the **Guidelines for the Integrated Traditional Chinese and Western Medicine Diagnosis and Treatment of Lumbar Spinal Stenosis (2023)* (8) and the recommendations in the evidence-based clinical guidelines published by the North American Spine Society in 2013(9).

2.2.2. Traditional Chinese Medicine Differential Diagnosis Criteria: The differential diagnosis criteria for the "Qi Deficiency and Blood Stasis" pattern were formulated in accordance with the **Guidelines for the Integrated Traditional Chinese and Western Medicine Diagnosis and Treatment of Lumbar Spinal Stenosis (2023)** and the **Guidelines for Clinical Research on New Traditional Chinese Medicines (Trial)**. ① Primary Symptoms: Pain in the lower back and legs, numbness in the lower limbs, and weakness in the lower back and knees. ② Secondary Symptoms: Weakness in the lower limbs, local sensation of heaviness, distension, and stiffness, and mental fatigue and lethargy. ③ Tongue and Pulse: The tongue body is purplish-red with stasis, the coating is thin, and the pulse is string-like and tight. A diagnosis can be made if the tongue and pulse findings are consistent and the patient exhibits two primary symptoms plus one secondary symptom, or one primary symptom plus two or more secondary symptoms.

2.2.3. Inclusion Criteria: ① Patients with a confirmed diagnosis of lumbar spinal stenosis at the L4/L5 level accompanied by neurogenic intermittent claudication; ② Patients whose imaging findings are consistent with clinical symptoms and who test positive for RNRs; ③ Patients who underwent laminectomy performed by the same spinal surgery team, with ≤ 3 surgical segments; ④ Patients diagnosed with "Qi deficiency and blood stasis" according to Traditional Chinese Medicine (TCM) syndrome differentiation.

2.2.4. Exclusion Criteria: ① History of previous lumbar spine surgery; ② Concurrent lumbar spine tumors, tuberculosis, infection, or severe scoliosis; ③ Concurrent severe osteoporosis (T-score < -3.5 or history of fragility fractures), Paget's disease, hyperthyroidism, or other metabolic bone diseases; ④ Allergy to any component of the Bu Yang Huan Wu Decoction; ⑤ Concurrent severe dysfunction of vital organs such as the heart, liver, or kidneys.

2.2.5. Withdrawal Criteria: ① Patients voluntarily withdraw or are lost to follow-up; ② Poor patient compliance; ③ Occurrence of adverse events or drug allergic reactions; ④ Worsening of the condition or death during the study

period. This study has been approved by the hospital's ethics committee, and all patients and their families have signed informed consent forms and voluntarily participated in this study.

2.3. Treatment Methods

2.3.1. Control Group Patients received standard Western medical treatment postoperatively, including methylcobalamin tablets (0.5 mg per dose, 3 times daily) and loxoprofen sodium tablets (60 mg per dose, 2 times daily) to alleviate postoperative inflammation and symptoms related to nerve damage. On the second postoperative day, patients were allowed to ambulate while strictly wearing a brace; functional exercises were instructed starting two weeks postoperatively.

2.3.2. Study Group In addition to the treatment provided to the control group, patients in the study group were administered Bu Yang Huan Wu Decoction orally (Astragalus 120 g, Angelica sinensis 6 g, Paeonia rubra 5 g, Lumbricus terrestris, Ligusticum chuanxiong, Carthamus tinctorius, and Prunus persica seeds, 3 g each). One dose was taken daily, taken warm half an hour after breakfast or dinner, 200 mL per dose, for a 4-week treatment course.

2.4. Observation Parameters and Methods

2.4.1. Bone Density Measurement

Bone density in the patients' lumbar spine was measured using an X-ray bone densitometer (Model: Prodigy Primo) before treatment and 3 months after treatment. The testing position and operational standards were standardized, and the corresponding bone density values were recorded.

2.4.2. Serum Bone Metabolism Marker Assays

Fasting venous blood samples were collected from both patient groups before treatment and 3 months after treatment. After standing for 1–2 hours, the samples were centrifuged at 3,000 r·min for 15 minutes at 4 °C to separate the serum for subsequent analysis. The levels of total serum N-terminal pro-type I collagen, osteocalcin, β -linker degradation products, parathyroid hormone, and total 25-hydroxyvitamin D were measured using chemiluminescence; serum alkaline phosphatase levels were measured using a rate assay. All testing procedures were performed in strict accordance with the instructions provided with the respective test kits, and the values for each bone metabolism indicator were accurately recorded.

2.4.3. Safety Parameter Testing

Fasting venous blood samples were collected from patients before treatment and 3 months after treatment. Serum creatinine levels were measured using an enzymatic assay to assess changes in safety parameters related to liver and kidney function and to monitor the safety of the body's basal metabolism during treatment.

2.4.4. TCM Syndrome Score Assessment: Symptom improvement was assessed using a quantitative syndrome scoring system before treatment and 3 months after treatment. (10)

2.4.5. Evaluation of Clinical Efficacy

Clinical efficacy was assessed based on the difference in total TCM syndrome scores between baseline and 3 months after treatment, using the nimodipine method. The efficacy index (N) was calculated as (pre-treatment total score – post-treatment total score) / pre-treatment total score $\times$ 100%. A value of $70\% \leq N < 95\%$ was classified as “marked improvement”; $30\% \leq N < 70\%$ as “improvement”; and $N < 30\%$ as “no improvement”; Overall Efficacy Rate = [(Number of cases with marked improvement + Number of cases with improvement) / Total number of patients] $\times$ 100%

2.5. Blinded Assessment

Two attending physicians specializing in Traditional Chinese Medicine orthopedics, who were independent of this study and unaware of patient group assignments or bone metabolism results, served as raters. They received standardized training prior to scoring and independently reviewed, under blinded conditions, the TCM rounds records, medical progress notes, and nursing records from paper medical records or the electronic medical record system.

2.6. Statistical Analysis

Data analysis was performed using SPSS 26.0 statistical software. Continuous variables that followed a normal distribution were expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$); those that did not follow a normal distribution were expressed as median (interquartile range) [M (P25, P75)]. Categorical variables were expressed as frequency (percentage) [n (%)]. Two-tailed tests were performed with a significance level of $\alpha = 0.05$; a P-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of Overall Lumbar Spine Bone Mineral Density Between the Two Groups

After treatment, bone mineral density (BMD) values increased in both groups ($p < 0.05$), with a more pronounced increase in the study group, as shown in Table 2.

Table-2. Comparison of Overall Bone Mineral Density (L) Before and After Treatment in the Two Groups of Patients

Group	Bone Density		t	P
	Before Treatment	After Treatment		
Study Group	0.93±1.19	1.07±0.20	-3.152	0.005
Control Group	0.92±1.62	0.95±1.61	-9.990	P < 0.001
T	-0.148	-2.176		
P	0.883	0.036		

3.2. Comparison of Serum Bone Metabolism Markers

After treatment, levels of total type I procollagen C-terminal peptide and osteocalcin increased in both groups. Intragroup comparisons in the study group showed statistically significant increases ($p < 0.05$); however, intergroup comparisons revealed a statistically significant difference in total type I procollagen C-terminal peptide ($p < 0.05$) but no statistically significant difference in osteocalcin ($p > 0.05$), as shown in Table 3. After treatment, levels of β -linker degradation products decreased in both groups, with statistically significant changes observed in both between-group and within-group comparisons ($p < 0.05$). Total 25-hydroxyvitamin D levels increased in both groups, with statistically significant changes observed in both between-group and within-group comparisons ($p < 0.05$); see Table 4. After treatment, parathyroid hormone levels increased in both groups, with statistically significant changes observed both between and within groups ($p < 0.05$). Alkaline phosphatase levels decreased in both groups; while there was no statistically significant difference between groups ($p > 0.05$), a statistically significant difference was observed within the control group ($p < 0.05$), whereas no such difference was found in the study group ($p > 0.05$), though levels remained within the normal range.

Table-3. Comparison of Total Type I Procollagen N-Terminal Peptides and Osteocalcin Levels in the Two Groups Before and After Treatment

Group	Total Type I Procollagen N-Terminal Peptide		t	p	Osteocalcin		t	p
	Before Treatment	After Treatment			Before Treatment	After Treatment		
Study Group	50.64±15.25	74.00±21.98	-5.904	< 0.001	15.84±5.66	19.98±7.29	-2.710	0.014
Control Group	55.58±21.29	58.28±19.25	-0.868	0.396	17.36±4.87	17.88±6.92	-0.424	0.676
T	0.843	-2.407			0.910	-0.931		
p	0.404	0.021			0.368	0.358		

Table-4. Comparison of β -crosslinked degradation products and total 25-hydroxyvitamin D levels between the two groups before and after treatment

Group	β -crosslinked degradation products		T	p	Total 25-Hydroxyvitamin D		T	p
	Before Treatment	After Treatment			Before Treatment	After Treatment		
Study Group	279.33±97.05	158.57±52.38	7.849	< 0.001	18.50±7.29	32.11±10.89	-2.197	0.041
Control Group	285.60±103.38	233.56±80.56	3.096	0.006	20.56±9.29	24.50±11.10	-3.188	0.005
T	0.198	3.490			0.778	-2.292		
p	0.844	0.001			0.441	0.028		

Table-5. Comparison of Thyroid Hormone and Alkaline Phosphatase Samples Between the Two Groups

Group	Parathyroid hormone		t	p	Alkaline Phosphatase		t	p
	Before Treatment	After Treatment			Before Treatment	After Treatment		
Study Group	3.71±1.65	6.86±2.93	-4.439	< 0.001	97.45±20.56	89.80±24.72	1.407	0.176
Control Group	3.22±1.25	5.02±1.96	-5.392	< 0.001	94.15±30.80	77.55±26.29	3.183	0.005
t	-1.055	-2.335			-0.398	0.693		
p	0.298	0.026			-1.518	0.137		

Note: Parathyroid hormone is measured in pmol/L

3.3. Safety Indicators

After treatment, serum creatinine levels decreased in both groups. There was a statistically significant difference between the two groups ($p < 0.05$), a statistically significant difference within the study group ($p < 0.05$), and no statistically significant difference within the control group ($p < 0.05$). See Table 5.

Table-6. Safety Indicators

Group	Serum Creatinine		t	p
	Before Treatment	After Treatment		
Study Group	66.10±8.26	59.80±6.65	3.935	0.001
Control Group	70.30±10.22	66.40±12.82	1.587	0.129
t	1.429	2.043		
p	0.161	0.048		

3.4. Comparison of Traditional Chinese Medicine Syndrome Scores Before and After Treatment in the Two Patient Groups

The results are shown in Table 7

Group	Time	Lower Back and Leg Pain	Numbness in the lower limbs	Weakness and Lethargy in the Lower Back and Knees	Sensory abnormalities in the perineum and sacrococcygeal region
Study Group (n=20)	Before Treatment	4.80±1.19*	3.60±1.23*	3.80±1.70*	3.30±0.98* [△]
	3 months of treatment	2.30±0.98*	1.90±1.21*	2.20±1.44* [△]	1.50±1.10* [△]
Control Group (n=20)	Before Treatment	4.60±1.14*	4.20±1.44*	3.50±1.43*	2.40±1.39* [△]
	3 months of treatment	2.80±1.00*	2.50±1.28*	2.20±1.44* [△]	1.80±1.28* [△]
Group	Time	Weakness in the lower limbs	Localized sensation of heaviness and tightness	Divine Weariness	Total Score
Study Group (n=20)	Before Treatment	2.45±1.09*	2.00±0.97*	1.60±0.99*	21.55±4.94* [△]
	3 months of treatment	1.00±0.56*	0.85±0.75*	0.40±0.68*	8.85±3.59* [△]
Control Group (n=20)	Before Treatment	2.05±0.95*	2.00±1.12*	1.10±0.55*	19.90±3.39*
	3 months of treatment	1.35±0.67*	1.30±0.98*	0.55±0.69*	12.40±4.41*

Note: For comparisons within groups, * $P < 0.05$; for comparisons between groups, $\Delta P < 0.05$.

3.5. Comparison of Clinical Efficacy Between the Two Patient Groups

The results are shown in Table 7.

Table-7. Comparison of the Response Rates Between the Two Groups of Patients

组别	显效	有效	无效	总有效率
研究组 (n=20)	3	15	2	90%
对照组 (n=20)	1	12	7	65%

4. Discussion

4.1. Exploring the Mechanism of Bu Yang Huan Wu Decoction in Regulating Postoperative Bone Metabolism from the Perspective of the “Meridians-Essence and Substances-Tendons and Bones” Theory

The Su Wen: Treatise on Regulating the Meridians states: “The pathways of the five zang organs all originate from the meridians, through which blood and qi circulate; when blood and qi are out of harmony, a hundred diseases arise.” The meridians are internally connected to the zang-fu organs and externally linked to the limbs and joints; they transport qi and blood, nourish the tendons and bones, and serve as the channels through which the body’s qi, blood, and essence are distributed. The Lingshu: On the Organs* states: “The meridians are the pathways that transport blood and qi to nourish yin and yang, moisten the tendons and bones, and facilitate the joints.” ” This

clearly indicates that the unobstructed flow of meridians is fundamental to ensuring that qi, blood, and the essence reach the tendons and bones and maintain normal bone metabolism. Bones are the repository of marrow and the partner of the kidneys; their firm and resilient nature relies entirely on nourishment from qi, blood, and the essence. If the meridians become obstructed, qi and blood cannot circulate, the essence cannot reach its destination, and the bones lose their nourishment, inevitably leading to bone metabolic disorders.

From the perspective of Traditional Chinese Medicine pathogenesis, the core pathogenesis in patients who have undergone surgery for lumbar spinal stenosis with cauda equina redundancy is “qi deficiency and blood stasis, with inadequate nourishment of the bone meridians.” Surgical trauma further depletes vital energy and exacerbates blood stasis, leading to inadequate nourishment of the bone meridians and a lack of resources for bone formation.

Bu Yang Huan Wu Decoction uses Astragalus (Huang Qi) as its principal herb to greatly tonify primordial qi; when qi is vigorous, blood circulation improves (11), providing the fundamental driving force for improved bone metabolism. Combined with herbs such as Angelica sinensis (Dang Gui), Red Peony Root (Chi Shao), and Sichuan Lovage (Chuan Xiong)—which promote blood circulation and unblock meridians—it dispels blood stasis, unblocks meridians, and nourishes the bone meridians, thereby resolving the issue of insufficient bone nutrition caused by blood stasis obstruction; Earthworms (Di Long) unblock meridians and activate collaterals, nourishing both the nerves and bone collaterals. This not only improves microcirculation in the cauda equina but also creates a favorable local environment for bone metabolism. The formula features a meticulously balanced combination of principal, auxiliary, and adjuvant herbs, directly targeting the core pathogenesis of “qi deficiency and blood stasis, with inadequate nourishment of the bones and meridians.” By regulating bone metabolism at the etiological level, it achieves therapeutic efficacy superior to that of conventional Western medical treatments alone.

From the perspective of the theory that “unblocking the meridians allows the essence and nutrients to reach the tendons and bones,” the mechanism of action of Bu Yang Huan Wu Decoction can be summarized as “one unblocking and three deliveries”: “one unblocking” refers to clearing stagnation in the meridians to improve the circulation of qi and blood; “three deliveries” refer to the essence and nutrients reaching the bone collaterals to nourish the bones, qi and blood reaching the nerves to facilitate repair, and the nutritive and defensive qi reaching the muscle surface to provide warmth. When the meridians are unblocked, qi and blood flow; when qi and blood flow, the essence and nutrients are distributed. The bone collaterals are nourished by qi and blood, osteoblasts are adequately nourished and their activity is enhanced, while osteoclasts are suppressed due to the improved environment. Bone formation and resorption return to balance, thereby increasing bone density and normalizing bone metabolism. This is highly consistent with the principle stated in the **Su Wen: On the Generation of Vital Energy and Its Connection to Heaven**: “When the bones are straight and the tendons supple, qi and blood flow freely.”

Bu Yang Huan Wu Decoction can regulate bone metabolism through multiple pathways and targets. Astragalus in the formula improves microcirculation and energy metabolism, alleviates local inflammatory responses and oxidative stress damage, and provides a favorable microenvironment for the proliferation and differentiation of osteoblasts. Herbs that promote blood circulation and dispel blood stasis—such as Angelica sinensis, Ligusticum chuanxiong, and peach kernels—can improve local blood perfusion, alleviate postoperative stasis and edema, reduce the inhibitory effects of inflammatory factors on bone formation, and provide osteoblasts with adequate nutrition and oxygen. (12) This, in turn, increases serum alkaline phosphatase levels, promotes bone matrix synthesis and mineralization, and accelerates the bone repair process. Working synergistically, these herbs regulate the balance between osteogenesis and resorption through multiple targets and pathways, thereby achieving a virtuous cycle of bone metabolism.

In summary, Bu Yang Huan Wu Decoction can significantly improve postoperative bone metabolism in patients with lumbar spinal stenosis complicated by cauda equina redundancy through multiple mechanisms, including promoting osteoblast activation, inhibiting osteoclast function, and regulating calcium and vitamin D metabolism, and increase bone density. With its good safety profile, this formula provides an effective traditional Chinese medicine intervention for optimizing postoperative rehabilitation plans for such patients and reducing bone metabolism-related complications, further confirming the significant value of the “tonifying qi and invigorating blood” approach in regulating postoperative bone metabolism in orthopedic surgery.(13)

4.2. Analysis of the Efficacy of Bu Yang Huan Wu Decoction in Treating Bone Metabolism in Patients with Lumbar Spinal Stenosis Following Cauda Equina Redundancy Surgery

The results of this study show that, in patients with lumbar spinal stenosis who underwent cauda equina decompression surgery, those who received conventional treatment combined with Bu Yang Huan Wu Decoction intervention exhibited a significantly greater increase in lumbar bone density compared to the group receiving conventional treatment alone. Furthermore, serum bone metabolism markers demonstrated characteristic changes, with an increase in osteogenesis-related indicators and a decrease in bone resorption-related indicators. This confirms that this formula has a definite therapeutic effect in improving postoperative bone metabolism imbalance in such patients. The treatment principle of Traditional Chinese Medicine principles of “tonifying qi, invigorating blood, and nourishing the bones and meridians,” as well as the mechanisms of action in modern medicine that regulate bone metabolism.(14)

In terms of osteogenesis-related markers, the postoperative serum levels of PINP, OST, 25OHD, and PTH in the study group were all significantly higher than those in the control group, and the differences within the group before and after treatment were all statistically significant. As a specific marker of type I procollagen synthesis, elevated PINP levels directly reflect increased osteoblast proliferation and enhanced bone matrix synthesis activity. OST is

secreted by mature osteocytes and serves as a key indicator of bone formation and bone remodeling; its upregulation suggests an acceleration of the bone formation process and enhanced bone mineralization. As the primary circulating form of vitamin D, 25OHD plays a crucial role in calcium absorption and the regulation of bone metabolism. The Bu Yang Huan Wu Decoction can significantly increase serum levels of this substance; this is thought to be related to the formula's ingredients—such as *Astragalus* and *Angelica sinensis*—which improve microcirculation, promote intestinal calcium absorption, and facilitate the activation of vitamin D in the kidneys; Meanwhile, a moderate increase in PTH promotes the release of calcium from bone and enhances renal calcium reabsorption, thereby synergistically improving postoperative calcium metabolism disorders and providing an adequate calcium source for bone formation. The combined action of these two mechanisms lays the material foundation for the osteogenesis process. The concurrent increase in the aforementioned indicators confirms that Bu Yang Huan Wu Decoction promotes bone formation through multiple mechanisms—including bone matrix synthesis, regulation of calcium metabolism, and osteoblast activation—thereby reversing the postoperative suppression of osteogenic function. Regarding bone resorption-related indicators, the study group showed significantly lower postoperative β -CTX levels than the control group, with both between-group and within-group differences being statistically significant. β -CTX is a specific product of Type I collagen degradation; a decrease in its levels suggests that osteoclast activity is suppressed and the bone resorption process is attenuated. This is closely related to the effects of the blood-activating and stasis-resolving herbs in the Bu Yang Huan Wu Decoction. Ingredients such as *Chuanxiong*, *Honghua*, and *Taoren* can improve local blood circulation, alleviate postoperative stasis and edema around the spinal canal, and reduce the activation of osteoclasts by inflammatory factors, thereby inhibiting bone resorption; simultaneously, *Diling* unblocks meridians and activates collaterals, improving the microenvironment at the neuro-osseous interface, reducing bone metabolism disorders mediated by nerve damage, and further lowering the rate of bone resorption. This dual effect of promoting bone formation and inhibiting bone resorption is the core mechanism behind the significant increase in bone density observed in the study group. It effectively corrects the bone metabolic imbalance caused by postoperative stress and prolonged immobilization, thereby reducing the risk of complications such as osteoporosis and poor vertebral fusion.

Regarding changes in serum ALP and serum creatinine (Scr), this study found that ALP levels in both groups showed a downward trend postoperatively, with no statistically significant difference between the groups; furthermore, ALP levels in the study group remained within the normal range throughout the study. As a marker enzyme of osteoblasts, ALP levels did not show the expected increase, which is presumed to be related to the phasic characteristics of bone metabolism in the early postoperative period: In the short term after surgery, the stress response triggered by surgical trauma may temporarily inhibit ALP synthesis in the liver and bone tissue. Although Bu Yang Huan Wu Decoction promotes osteoblast activation, it has not yet been able to completely reverse this short-term inhibitory effect; furthermore, its regulation of ALP may be more evident in maintaining normal ALP activity rather than simply elevating it. In terms of safety indicators, the study group showed a significant postoperative decrease in Scr levels, with statistically significant differences within the group. This suggests that while Bu Yang Huan Wu Decoction improves bone metabolism, it has no adverse effects on renal function; on the contrary, it may protect renal function to some extent by improving microcirculation and alleviating renal stasis, thereby confirming the safety of this formula for postoperative use.

4.3. Limitations and Future Directions

The follow-up period in this study was relatively short, making it impossible to observe trends in bone density changes in patients more than 6 months postoperatively. Consequently, the study was unable to confirm the extent of Bu Yang Huan Wu Decoction's impact on long-term bone metabolism following lumbar spinal fusion, nor could it determine the specific changes in bone density and bone metabolism markers after discontinuation of the formula; Furthermore, the study did not conduct long-term tracking of key indicators such as lumbar fusion rates, long-term neurological recovery, and the incidence of osteoporosis-related complications, making it difficult to fully validate the formula's long-term efficacy and safety. Additionally, the study sample size was relatively limited; no dose-controlled groups were established, making it impossible to determine the optimal clinical dosage, nor were comparisons made with other formulas designed to tonify qi and activate blood circulation.

Future studies will extend the follow-up period to enable dynamic monitoring of relevant bone metabolism indicators throughout the entire postoperative rehabilitation process; simultaneously, the sample size will be expanded, and dose-controlled groups will be established to determine the optimal dosage and treatment duration, thereby systematically evaluating long-term efficacy and safety. In the future, it may also be possible to conduct pattern differentiation studies based on the clinical symptoms and tongue and pulse manifestations of patients with LSS accompanied by RNRs to clarify the core diagnostic criteria for the “Qi Deficiency and Blood Stasis” pattern. On this basis, Bu Yang Huan Wu Decoction could be individually modified; furthermore, the differences in efficacy between this formula and other qi-tonifying and blood-activating formulas (such as *Tao Hong Si Wu Decoction*) could be compared to provide guidance for clinical formula selection.

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