

Bone and Arthroscopy Science

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Bone and Arthroscopy Science

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Bone and Arthroscopy Science is a peer-reviewed articles across a wide spectrum of clinical treatise, basic research, review, frontier of orthopedics, case analysis and comment. This journal is aimed at professionals at all levels engaged in the basic and clinical work of orthopedics. Each issue is guest-edited by an acknowledged expert and focuses on a single topic or controversy.

It mainly reports new viewpoints, new achievements and new technologies in basic and clinical research of bone and joint surgery. The covered topics include, but are not limited to: sports medicine and arthroscopy, prosthetic design, biomechanics, biomaterials, metallurgy, biologic response to arthroplasty materials *in vivo* and *in vitro*.

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Songchao Bi

Clinical Observation of Anterolateral Thigh Perforator Flap for Reconstruction of Head and Facial Soft Tissue Defects

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Abstract: *Objective:* To evaluate the efficacy of the anterolateral thigh perforator flap in repairing head and face skin defects. *Methods:* Nineteen patients with head and facial skin defects, admitted to the 303rd Hospital and the 89th Hospital of the People's Liberation Army from May 2012 to May 2020, were selected as research subjects and underwent repair surgery. The primary method employed was free transplantation of the anterolateral thigh perforator flap. Following the operation, patients were closely monitored for 5 to 7 days. The viability of the blood vessels was assessed based on the healing, color, and vascular filling of the flaps. Patients were followed up for 6 to 18 months post-operation to evaluate the donor and recipient sites. *Results:* Out of the 19 transplanted flaps, 18 survived completely, yielding a survival rate of 94.73%. The recurrence rate of the original lesion post-operation was 10.52%. 94.44% of patients reported no impact on lower limb movement on the side where the flap was harvested, and only 16.66% of patients experienced noticeable numbness in the donor site skin after the operation. All 19 patients reported that initially, the flaps were stiff and had limited movement. However, after 6 months, they gradually softened and adhered more closely to the original skin tissue. *Conclusion:* The free anterolateral femoral perforator flap is an ideal option for repairing head and facial defects. It offers a reliable blood supply, a large harvestable area, and minimal impact on both donor and recipient sites. Its abundant blood supply remains unaffected by the repair surgery, resulting in a relatively high survival rate. It demonstrates good adaptability and is more readily accepted by patients.

Keywords: Perforator flap; Head and face skin defect; Skin repair

Online publication: Oct 31, 2025

1. Introduction

The formation of soft tissue defects in the head and face is primarily associated with factors such as trauma and

disease. The repair treatment or surgery for these defects involves multiple clinical anatomical areas, including the skull base, maxilla, and oral cavity^[1]. Dealing with issues such as radiotherapy-induced damage, tissue excision, and infections is quite complex, necessitating the transplantation of larger tissue sections for repair. Most wounds resulting from surgery or radiotherapy are accompanied by severe tissue damage and defects, disrupting the blood circulation in the soft tissues of the wound. Simple skin grafting procedures cannot meet the repair requirements. In recent years, free tissue flap transplantation has gradually become the preferred or even the only option for such injuries^[2]. The anterolateral thigh flap (ALTF) is the most commonly used in clinical practice, offering advantages such as rapid postoperative recovery, minimal patient discomfort, high satisfaction rates, and relatively low hospitalization costs. However, conventional excision inevitably leads to issues with excessive subcutaneous fat. Consequently, the anterolateral thigh perforator flap (ALTP) was developed. Long-term clinical practice has confirmed that it can provide sufficient tissue for filling and extensive skin coverage, often serving as the preferred option for donor site flaps in many cases^[3]. With the advancement of clinical diagnosis and treatment techniques, ALTP has been effectively applied in the repair of soft tissue defects in the head and face.

Against this backdrop, this study selected 19 patients with soft tissue defects in the head and face treated at the 303rd Hospital of the People's Liberation Army and the 89th Hospital of the People's Liberation Army from May 2012 to May 2020. ALTP was used to repair the defective areas, with the aim of further exploring its clinical efficacy. The findings are reported as follows.

2. Materials and methods

2.1. General information

A total of 19 patients with soft tissue defects in the head and face were selected, including 7 from the 303rd Hospital of the People's Liberation Army and 12 from the 89th Hospital of the People's Liberation Army, from May 2012 to May 2020. Among them, there were 9 males and 10 females; ages ranged from 31 to 67 years, with an average age of (50.7 ± 6.2) years. The smallest skin defect area was 2 cm × 3 cm, and the largest was 12 cm × 10.6 cm. The distribution of defects included the nose (2 cases), cheeks (3 cases), forehead (6 cases), and temporal region (8 cases). All patients underwent head and face debridement under general anesthesia, followed by free anterolateral thigh perforator flap transplantation to repair the wound.

2.2. Research methods

Patients who have soft tissue defect on the head was positioned supine on the operating table. The general anesthesia via nasal tracheal intubation and were performed (**Figure 1**). The surgical procedures were conducted simultaneously by two teams. One team performed debridement of the head and face or excision of diseased tissue, while the other team, responsible for preparing the free anterolateral thigh flap, could commence their procedure concurrently.

Typically, the lower limb contralateral to the recipient site is selected for flap harvesting. A line was drawn connecting the lateral aspect of the patella and the anterior superior iliac spine. Additionally, the location of the perforating vessels, as determined by preoperative ultrasound Doppler, was taken into consideration. Generally, the most common distribution of perforating vessels is found within a 3 cm radius of the midpoint of the aforementioned line (**Figure 2**). The size and shape of the required flap must be designed with the point where the perforating vessels emerge from the superficial fascia as the center.



Figure 1. Preoperative soft tissue defect on the head.

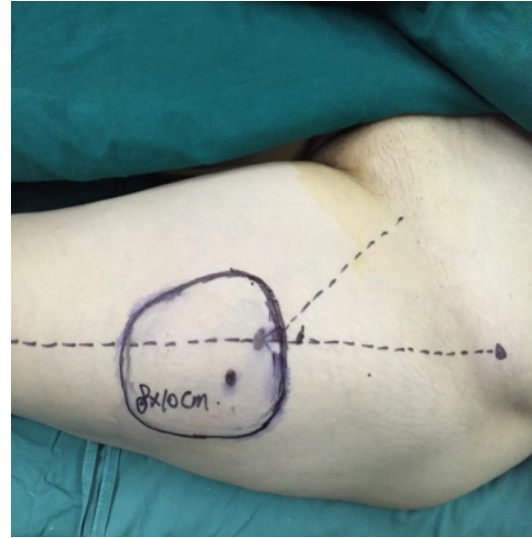


Figure 2. Design of the anterolateral thigh perforator flap.

The edge of the flap was incised to the level of the superficial fascia, and the fascia between the rectus femoris and vastus lateralis muscles was incised, with the rectus femoris muscle retracted medially. The perforating vessels were dissected from distal to proximal until reaching the descending branch of the lateral circumflex femoral artery. The neurovascular bundle of the descending branch of the lateral circumflex femoral artery was thoroughly exposed. Throughout the procedure, care was taken to protect the branches of the femoral nerve. Adjustments to the incision, management of the descending branches of the lateral circumflex femoral artery and vein, and creation of adequate operative space were made as necessary. The donor site could be closed by approximating the edges after appropriate subcutaneous undermining. The harvested flap was then used to cover the recipient site, and the axial vessels of the flap were anastomosed end-to-end or end-to-side with the previously isolated and prepared vessels at the recipient site (**Figure 3**).

High-quality vascular anastomosis was then aimed for to prevent intraoperative and postoperative anastomotic thrombosis (**Figure 4**).

The skin was sutured loosely and intermittently, with subcutaneous film drainage (see **Figure 5**).



Figure 3. Harvesting of the flap.

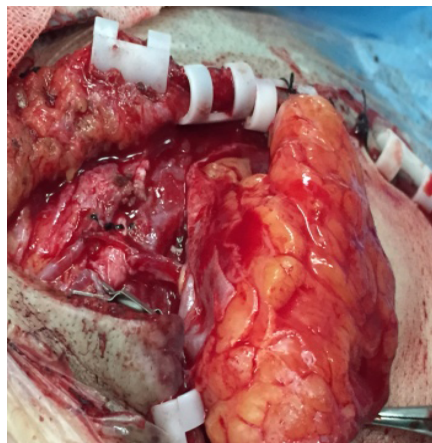


Figure 4. Vascular anastomosis (end-to-side anastomosis).



Figure 5. Skin suture.

2.3. Observation indicators

2.3.1. Definition of ideal flap survival in flap transplantation surgery

At least 7 days postoperatively, the flap exhibits good luster, temperature, blood supply, and elasticity, with no risk of vascular crisis (see **Figure 6**).



Figure 6. Postoperative recovery with good appearance.

2.3.2. Follow up

Patients were followed up for 6 to 18 months postoperatively to assess the functional impact of flap transplantation on the donor site. Follow-up methods included face-to-face interviews and telephone communication, covering four aspects: First, inquiry about the sensation at the repaired site (normal, good, or poor); second, assessment of lower limb motion restriction (severely affected, not significantly affected, or unaffected); third, evaluation of the aesthetic appearance of the scar at the donor site; and fourth, examination for significant numbness in the skin at the donor site.

2.4. Statistical processing

The obtained data were validated and processed using professional statistical software, specifically the SPSS 26.0 software package. For measurement data ($\bar{x} \pm s$) following a normal distribution pattern, the *t*-test is used; for technical or categorical data, the chi-square test (χ^2 test) is applied, with results presented as “n (%)”. A statistically significant difference between groups was indicated when $p < 0.05$.

3. Results

3.1. Postoperative flap healing

Among the 19 cases, one experienced flap margin necrosis due to early venous thrombosis at the anastomosis site, which worsened over four postoperative days, leading to impaired blood circulation. The remaining 18 transplanted flaps survived completely, yielding a survival rate of 94.73%. For the necrotic case, the residual viable flap was debrided, reshaped, and tension-relieving sutured to the original wound surface. All surviving patients' wounds met the criteria for primary healing. During the surgical procedure, skin perforators were identified in 5 cases involving the intermuscular septum and 14 cases involving the musculocutaneous perforators, accounting for 26.31% and 73.68%, respectively. All harvested free anterolateral thigh flaps exhibited distinct skin perforators. Additionally, although one case experienced vasospasm during surgery, it gradually normalized after timely intervention with papaverine injection, and the prognosis for flap survival was favorable.

3.2. Follow up results

The follow up results at 6 months showed that among the 18 patients with viable flaps, 17 reported no impact on lower limb mobility due to flap harvesting, accounting for 94.44%. Sixteen patients expressed satisfaction with the appearance; among them, 2 patients believed that the initial depression affected the overall aesthetics, but the impact gradually diminished and became barely noticeable over time. Additionally, 2 patients mentioned “large scars and poor aesthetics”. Regarding numbness at the donor site, 3 patients reported significant sensation, while the others reported minimal or no sensation. In terms of recovery at the recipient site, 3 patients with isthmus repair experienced voice changes postoperatively, but these gradually improved and returned to normal by 6 months. All surviving patients confirmed that the transplanted flaps were initially stiff and slightly restricted in movement, but they became increasingly softer over time.

4. Discussion

4.1. Requirements for an ideal flap for repairing head and facial tissue defects

The head and face are critical regions for human sensory perception, respiration, facial expressions, and swallowing, with relatively complex and unique anatomical structures. Large-area tissue defects in the head and face following trauma require repair and reconstruction. Defects in tissue or alterations in the color, texture, and shape of the repaired tissue after trauma can have an immeasurable impact on the patient’s physical and mental well-being ^[4]. Therefore, early repair of large-area defects in the head and face and restoration of the patient’s facial appearance are not only the responsibility of plastic surgeons but also pose a challenge for orthopedic surgeons ^[5].

An ideal flap for repairing head and facial tissue injuries should meet the following requirements, including as followed.

- (1) The flap preparation process should ideally not require a change in the patient’s position, be as convenient as possible, and shorten the surgical procedure and time
- (2) Sufficient tissue area
- (3) Good flexibility and toughness in flap design
- (4) Adequate length of the vascular pedicle of the flap
- (5) Concealed location with minimal damage to the donor site ^[6,7].

Perforator flaps are a new type of surgical flap that can be widely promoted, offering numerous advantages over traditional flaps, including smaller vessel diameters and less donor site damage, better cosmetic outcomes in the recipient area, and eliminating the need for secondary flap cosmetic surgery. They have gradually become a hot topic in the field of microsurgery ^[8]. In clinical practice, most scholars prefer the anterolateral thigh perforator (ALTP) flap with minimal variability. Although the perforating vessels of this flap are relatively constant, their origin is not unique and is uncertain. However, the uncertainty of the origin does not affect the application of this perforator flap ^[9].

4.2. Advantages and disadvantages of different perforator flaps for repairing head and facial tissue defects

There is a diverse range of flaps available for head and facial trauma reconstruction, such as the tensor fasciae latae flap and the medial sural artery perforator flap, all of which provide more options for tissue repair in the head and facial regions. Not only that, the deep inferior epigastric artery perforator flap offers a large amount of

tissue, can be harvested multiple times, and is highly malleable. During harvesting, it does not cause damage to the muscle belly or tendon sheath of the rectus abdominis, nor does it harm the relevant motor nerves of the rectus abdominis^[10]. However, its drawback lies in the fact that the vascular structure of the deep inferior epigastric artery perforator flap often exhibits variations, posing a significant risk of injury and presenting challenges in separation. Failure in this process means failure in flap selection^[11]. Compared to the aforementioned flaps, the anterolateral thigh perforator flap (ALTP) adopted in this study demonstrates more pronounced advantages. Xu Chuanda^[12] first reported the anterolateral thigh flap (ALTF) in 1984 and subsequently further developed the ALTP based on clinical applications. Starting from the anatomical structure of the ALTP, his research team conducted in-depth studies, integrating theory with clinical practice, and explored the practical applications of the ALTP in clinical settings. One of the significant technical adjustments required during ALTP harvesting is its application in scalp reconstruction, where maximizing the length of the vascular pedicle is crucial^[13]. In the actual research, the length of the vascular pedicle was maximized by performing intramuscular dissection from one side. Despite reports suggesting that necrosis may occur when dissecting to the anterolateral thigh perforator artery, in our study, by using facial or more proximal vessels as recipient vessels, which provided sufficient blood supply, this study did not encounter flap necrosis due to arterial dysfunction^[14]. In the patients described in this article, through intramuscular vascular dissection techniques, the length of the ALTP vascular pedicle was sufficient, allowing us to have a very low conversion threshold for the recipient vessel area. This enabled the transition from intact, small-sized superficial temporal vessels to more proximal, larger-caliber vascular systems without the use of vascular grafts, thereby avoiding complications associated with vascular graft usage.

5. Conclusion

In summary, ALTP transplantation can serve as an ideal method for repairing soft tissue defects in the head and face. According to the findings of this study, using ALTP for primary repair of small to medium-sized skin defects caused by head and facial trauma or tumors can achieve both functional and aesthetic outcomes. The flaps harvested from this area do not affect the overall aesthetics of the leg and can adequately avoid critical motor structures. The resulting “imperfections” are also acceptable to patients. Therefore, ALTP holds significant clinical value for the promotion and application in repairing soft tissue defects in the head and face.

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Disclosure statement

The authors declare no conflict of interest.

References

- [1] Zhao W, Ye J, Yang E, 2011, Repair of Skin Defects After Resection of Skin Tumors in the Head, Face, and Neck Using Local Skin Flaps. *Chinese Journal of Aesthetic Medicine*, 20(10): 1508–1510.
- [2] Ai Q, Zhang Z, Xiang H, 2017, Application of Adjacent Miniature Skin Flaps in the Repair of Facial Skin Defects. *Journal of Clinical Otorhinolaryngology Head and Neck Surgery*, 2017(14): 1100–1102.
- [3] Hsieh C, Yang E, Kuo Y, et al., 2003, Free Anterolateral Thigh Adipofascial Perforator Flap. *Plastic & Reconstructive Surgery*, 112(4): 976–982.
- [4] Li L, Wang D, Wang W, 2011, Application of Local Skin Flaps in the Repair of Facial Skin and Soft Tissue Defects. *Bethune Medical Journal*, 9(5): 350–351.
- [5] Feng Y, Li W, Wang N, 2010, Local Anatomy of the Tensor Fasciae Latae Perforator Flap and Its Significance in Head and Neck Repair. *Basic & Clinical Medicine*, 30(2): 151–154.
- [6] Kimata Y, Uchiyama K, Ebihara S, et al., 2000, Anterolateral Thigh Flap Donor-Site Complications and Morbidity. *Plast Reconstr Surg*, 106(3): 584–589.
- [7] Liu W, Liu X, Li H, 2008, Application of Anterolateral Thigh Perforator Flaps in Head and Neck Surgery. *Proceedings of the Fifth Chinese Oncology Academic Conference, the Seventh Cross-Strait Oncology Academic Conference, the International Society for Cellular and Gene Therapy in Oncology Conference, and the Second Sino-Japanese Academic Conference on Tumor Interventional Therapy*.
- [8] Tang M, Zhang W, Zhang S, 2011, Research Progress on Perforator Flaps. *Chinese Journal of Clinical Anatomy*, 29(6): 602–606.
- [9] Li W, Xu Z, Cheng Y, 2012, Application of Free Anterolateral Thigh Perforator Flap for Reconstruction of Defects After Radical Resection of Head and Neck Tumors. *Stomatology*, 32(5): 286–289.
- [10] Tang M, Xu Y, Zhang S, 2013, *Applied Anatomy and Clinical Practice of Perforator Flaps*. Science Press.
- [11] Lu M, Sun G, Hu Q, et al., 2015, Functional Assessment: Free Thin Anterolateral Thigh Flap Versus Free Radial Forearm Reconstruction for Hemiglossectomy Defects. *Medicina Oral Patologia Oral Y Cirugia Bucal*, 20(6): e757.
- [12] Xu D, 2006, *Advances in Anatomical Research and Clinical Application of the Anterolateral Thigh Flap*. National Microsurgery Academic Conference and International Microsurgery Symposium.
- [13] Huang Y, Hsieh T, Lai C, et al., 2014, In Situ Pedicle Lengthening of the Anterolateral Thigh Flap. *Plast Reconstr Surg*, 133(1): 85e–87e.
- [14] Lutz B, Wei F, Chen H, et al., 1998, Reconstruction of Scalp Defects with Free Flaps in 30 Cases. *Br J Plast Surg*, 51(3): 186–190.

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Effects of Aquatic Exercise Therapy on Joint Mobility and Inflammatory Markers in Patients with Rheumatoid Arthritis

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Abstract: This study aimed to investigate the effects of aquatic exercise therapy on joint mobility and inflammatory markers in patients with rheumatoid arthritis. Through a randomized controlled trial, patients in the experimental group underwent aquatic exercise therapy, with pre- and post-treatment data on joint mobility and inflammatory markers compared. Results demonstrated that aquatic exercise therapy significantly improved joint range of motion and reduced inflammation levels, indicating positive therapeutic effects for rheumatoid arthritis.

Keywords: Aquatic exercise therapy; Rheumatoid arthritis; Joint range of motion; Inflammation markers

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1. Introduction

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune disease primarily characterized by erosive, symmetrical polyarthritis. Its fundamental pathological changes involve chronic inflammation of the synovial membrane, synovial proliferation, and progressive destruction of articular cartilage and bone, ultimately leading to joint deformity and functional loss. Early diagnosis and treatment are crucial for delaying disease progression and improving patients' quality of life.

Currently, various treatment approaches exist for RA, including lifestyle interventions, physical therapy, medication, and surgery. While medication can control disease progression, long-term use may carry certain side effects. Surgical intervention is suitable for patients with severe late-stage joint damage but involves inherent risks. Aquatic exercise therapy, as a form of physical therapy, offers unique advantages. Water's buoyancy reduces joint stress, while its thermal properties help alleviate muscle spasms and promote blood circulation, providing a safe and effective rehabilitation pathway for RA patients. However, current research on the effects of aquatic exercise therapy on joint mobility and inflammatory markers in RA patients remain insufficient. Therefore, this study aims to thoroughly investigate the therapeutic efficacy of aquatic exercise therapy for this condition, providing scientific evidence for clinical practice.

2. Literature review

2.1. Pathological mechanisms and clinical manifestations of RA

The etiology and pathogenesis of RA are highly complex and remain incompletely understood. Genetic, hormonal, and environmental factors all contribute to its onset. Epidemiological studies indicate a strong association with hereditary factors, with family studies showing that first-degree relatives of individuals with active RA have an 11% probability of developing the condition. Numerous studies have identified mutations in the HLA-DRB1 allele as associated with disease onset. Infectious agents such as bacteria, mycoplasma, and viruses may activate T and B lymphocytes, leading to the secretion of pro-inflammatory factors and the production of autoantibodies, thereby influencing disease onset and progression. Smoking significantly increases the risk of developing RA and is particularly associated with ACPA-positive RA.

Its typical symptoms include joint pain, swelling, morning stiffness, and deformity. In the early stages, patients often experience joint pain and morning stiffness lasting over an hour before joints become mobile. Affected joints are typically symmetrical, most commonly involving proximal interphalangeal joints, followed by metacarpophalangeal joints, wrists, knees, and elbows. Swelling of the synovium and joint effusion limit both active and passive joint movement. Affected joints may dislocate or subluxate, presenting with visible deformities. Additionally, patients may experience systemic symptoms such as fever, fatigue, loss of appetite, weight loss, night sweats, and general malaise. Some patients may develop complications including pleurisy, valvular heart disease, interstitial pneumonia, and neurological damage.

2.2. Principles and advantages of aquatic exercise therapy

Aquatic exercise therapy refers to physical training conducted in the unique environment of water to alleviate patient symptoms or improve function. Water possesses distinctive physical properties; its buoyancy reduces the weight-bearing pressure on joints, significantly lowering the load on joints during exercise. This makes it particularly suitable for patients with RA experiencing pronounced joint pain. The thermal properties of water also play a crucial role. Warm water dilates superficial blood vessels, increasing blood supply to the skin and improving its nutritional status. As this warm blood reaches deeper muscles, muscle contraction becomes easier and more powerful while reducing muscle spasms, allowing patients to achieve near-normal movement patterns.

Compared to land-based exercise, aquatic exercise offers numerous advantages. Patients can perform multi-directional movements engaging multiple muscle groups while minimizing pain. For those with spasms, the thermal effect reduces spasm intensity. A well-structured aquatic therapy program begins with buoyancy-assisted movements, progresses to using buoyancy for support, and ultimately employs buoyancy as resistance. Varying movement speed and creating water turbulence achieve different therapeutic effects. Furthermore, swimming training stands out as a particularly beneficial aquatic exercise. Different strokes engage muscles in diverse ways, and many patients with severe functional limitations find movement easier in a hydrotherapy pool. This not only aids physical recovery but also provides significant psychological support.

2.3. Current application of aquatic exercise therapy in RA treatment

The use of aquatic exercise therapy in treating RA is gaining increasing attention. Several studies indicate that aquatic exercise can improve joint range of motion and muscle strength, alleviate pain, and enhance quality of life. For instance, research has shown that RA patients experience significant reductions in joint pain and stiffness, along with increased joint mobility after aquatic exercise. However, current studies still face certain limitations.

Regarding sample size, some studies have small sample sizes, potentially leading to biased results.

Some studies lack rigorous randomized controlled designs, compromising scientific rigor and reliability; standardization of intervention protocols also requires improvement, as variations in aquatic exercise methods, intensity, and frequency across studies hinder accurate comparisons and broader application. Therefore, more in-depth, standardized research is necessary to clarify the efficacy of aquatic exercise therapy in RA treatment.

3. Research methods

3.1. Study population

This study aimed to investigate the effects of aquatic exercise therapy on joint range of motion and inflammatory markers in patients with RA.

Inclusion criteria require patients meeting diagnostic criteria for RA, confirmed through comprehensive medical examinations and assessments including clinical symptoms, physical signs, and laboratory tests.

Exclusion criteria apply to patients with contraindications to aquatic exercise therapy, such as severe cardiopulmonary insufficiency, skin diseases, or open wounds. Patients with severe cardiopulmonary insufficiency may face risks during aquatic exercise due to increased cardiac load or respiratory limitations; those with skin diseases may develop infections or allergic reactions from aquatic chemicals or bacteria; and patients with open wounds are at risk of wound infection. Strict inclusion and exclusion criteria ensured participant safety and the reliability of study outcomes.

3.2. Intervention measures

This study implemented a 12-week aquatic exercise therapy intervention, conducted three times weekly for 45 minutes per session. Intervention content was selected based on the physical characteristics and exercise needs of RA patients, primarily including low-impact activities such as water walking, kicking exercises, and swimming. These exercise forms effectively strengthen muscle power and improve joint flexibility while reducing joint stress.

Water temperature was maintained between 28–32°C (82–90°F). This range ensures patient comfort during exercise while promoting blood circulation and relieving muscle tension. Prior to exercise, patients performed thorough warm-up activities, including simple joint rotations and stretches, to prevent injury. After exercise, participants promptly dried off and kept warm to avoid exacerbating symptoms through exposure to cold ^[1].

3.3. Evaluation indicators

3.3.1. Joint range of motion

Professional joint measurement instruments were used to precisely measure patients' joint mobility before and after intervention. Measurement indicators included range of motion in flexion, extension, external rotation, and internal rotation. These metrics comprehensively reflect joint function, providing objective evidence for assessing aquatic exercise therapy efficacy.

3.3.2. Inflammation markers

Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels were measured before and after intervention. ESR and CRP are key indicators reflecting disease activity in RA. Changes in their levels directly demonstrate the impact of aquatic exercise therapy on patients' inflammatory responses.

3.4. Statistical methods

Data analysis was performed using SPSS software. Quantitative data are presented as mean \pm standard deviation, clearly illustrating central tendency and dispersion. Between-group comparisons employed *t*-tests to determine significant differences between data sets. Categorical data were expressed as rates. Intergroup comparisons were performed using the chi-square (χ^2) test to analyze relationships between categorical variables. A *p*-value < 0.05 was set as the threshold for statistical significance to ensure the reliability of the research findings ^[2].

3.5. Research findings

3.5.1. Changes in joint range of motion

After 12 weeks of aquatic exercise therapy intervention, patients demonstrated significant improvement in joint range of motion. Compared to pre-intervention levels, post-intervention measurements showed increased range of motion in flexion, extension, external rotation, and internal rotation. Statistical analysis confirmed these changes were statistically significant ($p < 0.05$). This indicates aquatic exercise therapy effectively enhances joint range of motion, flexibility, and functional mobility in RA patients.

The improvement in joint range of motion achieved through aquatic exercise therapy is primarily attributable to water's unique physical properties. Water's buoyancy reduces joint loading, minimizing pain and discomfort during movement and allowing patients to perform joint activities more freely. Simultaneously, water resistance serves as a natural exercise tool, strengthening muscles surrounding the joints. This enhances muscle support and protection for the joints, further improving joint range of motion.

3.5.2. Changes in inflammatory markers

Following intervention, patients exhibited significantly reduced erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels. Compared to pre-intervention values, both ESR and CRP levels decreased post-intervention, with these changes being statistically significant ($p < 0.05$). This indicates aquatic exercise therapy effectively lowers inflammatory markers in RA patients, helping control disease activity.

The mechanism by which aquatic exercise therapy reduces inflammatory markers may involve multiple aspects. On one hand, exercise promotes blood circulation, accelerates the excretion of inflammatory metabolites, and reduces the accumulation of inflammatory factors in the body. On the other hand, aquatic exercise stimulates the secretion of neurotransmitters such as endorphins, which possess analgesic and anti-inflammatory effects, thereby alleviating inflammatory responses. Additionally, appropriate water temperature can regulate the body's immune function, suppress excessive immune responses, and further control the progression of inflammation.

In summary, this study employs rigorous research methods and objective evaluation metrics to confirm that aquatic exercise therapy exerts significant positive effects on RA patients. It effectively improves joint range of motion and reduces inflammatory marker levels, offering a safe and effective adjunctive treatment option for RA management ^[3].

4. Discussion

4.1. Mechanisms of aquatic exercise therapy in improving joint range of motion

The mechanisms by which aquatic exercise therapy enhances joint range of motion in RA patients primarily include the following aspects. The buoyancy of water reduces joint loading, significantly decreasing pressure on joints during exercise. This alleviates pain, enabling patients to perform joint movements more easily and increase

their range of motion. For example, in patients with knee joint damage, walking in water allows buoyancy to support part of the body weight, reducing the burden on the knee joint. This facilitates more comfortable flexion and extension of the knee.

The thermal effect of water dilates surface blood vessels, increasing blood supply to the skin and improving its nutritional status. As warm blood reaches deeper muscles, muscle contraction becomes easier and more powerful. Simultaneously, it reduces muscle spasms, relaxing the muscles surrounding the joints. This reduces restrictions on joint movement, helping patients achieve near-normal movement patterns. Exercising in warm water significantly reduces joint stiffness, allowing for more comprehensive joint mobilization ^[4].

During aquatic exercise, water resistance serves as natural resistance training, requiring patients to exert greater force during joint movements. This strengthens the muscles surrounding the joints. Enhanced muscle strength provides better support and stability for the joints, further improving range of motion. For example, when patients perform aquatic upper-limb press-ups, water resistance exercises the upper-limb muscles. Increased strength then better assists shoulder and elbow joint movements.

4.2. Mechanisms of aquatic exercise therapy in reducing inflammatory markers

The mechanism by which aquatic exercise therapy lowers inflammatory markers in RA patients may involve the following factors: Exercise promotes blood circulation and accelerates metabolism, aiding in the removal of inflammatory metabolites from the joints. This reduces the accumulation of inflammatory factors locally, thereby mitigating the inflammatory response. During aquatic exercise, accelerated systemic blood circulation enables more efficient transport of inflammatory substances from the joints to organs like the liver for metabolic processing.

Moderate aquatic exercise modulates immune system function, enhances the body's immune regulatory capacity, suppresses excessive immune responses, and reduces autoantibody production, thereby lowering inflammatory markers. Studies indicate that patients who consistently engage in long-term aquatic exercise experience improved immune cell function and restored immune balance, positively contributing to inflammation control.

The thermal and mechanical stimulation of water may regulate the endocrine system through neural reflex mechanisms, promoting the secretion of anti-inflammatory substances like endorphins. Endorphins possess analgesic and anti-inflammatory properties, alleviating patients' pain and inflammatory responses, thereby lowering inflammatory markers. Patients often report physical and mental relaxation with reduced pain after aquatic exercise, which correlates with endorphin secretion ^[5].

4.3. Comparison and analysis with other studies

Compared with previous relevant studies, the findings of this study align with some previous conclusions, all indicating that aquatic exercise therapy has a positive impact on joint range of motion and inflammatory markers in patients with RA. However, differences in sample size, research methods, and intervention measures among studies may lead to varying results. Some studies had small sample sizes, which may affect the stability and reliability of the results; others lacked a strict randomized controlled design, making it difficult to exclude interference from other factors.

This study employed a randomized controlled trial design with a relatively large sample size and highly standardized intervention measures, enabling more accurate assessment of aquatic exercise therapy's efficacy.

Nevertheless, certain limitations exist: the short study duration prevented observation of long-term effects; and the absence of stratified analysis for patients with different types or severity levels of RA may affect the generalizability of findings. Future research should extend the study duration, increase sample size, and incorporate stratified analysis to comprehensively and thoroughly explore the therapeutic value of aquatic exercise therapy in RA management.

5. Conclusion

This study demonstrates that aquatic exercise therapy significantly improves joint mobility and reduces inflammatory markers in patients with RA, yielding positive therapeutic outcomes. By leveraging water's buoyancy, thermal effects, and resistance, aquatic exercise provides a safe and effective rehabilitation approach. It not only alleviates symptoms and enhances joint function but also modulates the immune system to mitigate inflammatory responses.

Therefore, it is recommended to promote the application of aquatic exercise therapy in the clinical treatment of RA patients. However, during implementation, personalized exercise programs should be developed based on individual patient conditions, with strict control over exercise intensity and duration to ensure safety. Concurrently, health education and guidance for patients should be strengthened to improve treatment adherence. Future research may further explore the mechanisms of aquatic exercise therapy and optimize exercise protocols, providing more scientific and effective evidence for RA treatment.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Xiang A, Wang C, Zhang L, et al., 2025, Research Progress on Aquatic Exercise Therapy for Knee Osteoarthritis. *Chinese Journal of Rehabilitation Medicine*, 34(07): 50–54.
- [2] Wen F, Zhu H, Wang K, et al., 2024, Research Progress on the Intervention Effects of Aquatic Exercise Therapy for Common Chronic Diseases. *Bulletin of Sports Science and Technology Literature*, 32(02): 236–241.
- [3] Zeng Q, Wu J, Chen W, 2021, Advantages of Aquatic Exercise in Knee Osteoarthritis Rehabilitation. In: Chinese Society of Sports Science, Physical Training Branch; National School Sports Alliance (Swimming Division). *Proceedings of the Third International Aquatic Exercise Forum – Poster Exchange*. Graduate School, Shenyang Sport University: 66–67.
- [4] Zhao Y, Chen W, 2022, Effect Analysis of Acupuncture Combined with Rheumatic Arthritis Pills in Treating Knee Osteoarthritis. *Journal of Integrated Traditional Chinese and Western Medicine in Shenzhen*, 32(01): 71–73.
- [5] Wang M, 2019, Study on the Improvement of Joint Mobility in Patients with Rheumatoid Arthritis Using Exercise Therapy Combined with Infrared Treatment, thesis, Bengbu Medical College.

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The Effect of Ultrasound-Mediated Drug Delivery Combined with Core Muscle Group Training on the Lumbar Spine of Patients with Chronic Low Back Pain

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Abstract: *Objective:* To investigate the effects of ultrasound-mediated drug delivery combined with core muscle group training on lumbar spine function, pain intensity, and muscle function in patients with chronic low back pain (CLBP), providing evidence-based support for clinical treatment. *Methods:* A total of 120 CLBP patients admitted to the Department of Orthopedics in our hospital from January 2023 to December 2024 were selected as research subjects. They were randomly divided into a control group ($n = 60$) and an observation group ($n = 60$) using a random number table method. The control group received ultrasound-mediated drug delivery treatment alone, while the observation group received a combination of ultrasound-mediated drug delivery and core muscle group training. Both groups underwent continuous treatment for 8 weeks. The Visual Analogue Scale (VAS) scores, Oswestry Disability Index (ODI), and clinical efficacy were compared between the two groups before treatment, at 4 weeks, and at 8 weeks after treatment. *Results:* Before treatment, there were no statistically significant differences in VAS scores, ODI, or lumbar spine range of motion between the two groups ($p > 0.05$). After 4 and 8 weeks of treatment, both groups showed a significant decrease in VAS scores and ODI compared to before treatment ($p < 0.05$), with the observation group having lower scores than the control group ($p < 0.05$). The total effective rate in the observation group after 8 weeks of treatment was 93.33% (56/60), which was higher than the 78.33% (47/60) in the control group, with a statistically significant difference ($p < 0.05$). *Conclusion:* Ultrasound-mediated drug delivery combined with core muscle group training can effectively alleviate pain intensity, improve lumbar spine function and range of motion, enhance core muscle strength, and demonstrate good safety in CLBP patients. It is worthy of clinical promotion and application.

Keywords: Chronic low back pain; Ultrasound-mediated drug delivery; Core muscle group training; Lumbar spine function

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1. Introduction

Chronic low back pain (CLBP) is a common clinical condition in orthopedic surgery, characterized by lumbar pain or discomfort lasting more than 12 weeks, often accompanied by symptoms such as restricted lumbar mobility and radiating pain in the lower extremities, which severely impacts patients' quality of daily life and work capacity ^[1]. Epidemiological surveys indicate that the global incidence of CLBP is approximately 18–45%, and it has shown a trend of affecting younger populations in recent years, imposing a significant burden on social healthcare resources ^[2]. Currently, conservative treatments are the mainstay for CLBP management, including pharmacological therapy, physical therapy, and rehabilitation training. However, the efficacy of a single treatment modality is often limited: while pharmacological therapy alone can provide short-term pain relief, its long-term use is prone to causing gastrointestinal adverse reactions; physical therapy alone, such as ultrasound therapy has a weak effect on improving lumbar stability; and rehabilitation training alone is associated with slow pain relief ^[3].

Ultrasound drug delivery technology is a novel physical therapy modality that utilizes the mechanical vibration and thermal effects of ultrasound to disrupt the stratum corneum barrier of the skin, facilitating the targeted penetration of drug molecules into the affected area, achieving “targeted drug delivery” and combining the dual advantages of physical and pharmacological therapies ^[4]. The core muscle group, which includes the erector spinae, transverse abdominis, and multifidus muscles, is a critical structure for maintaining lumbar stability. Weakened or imbalanced function of the core muscle group is an important pathophysiological basis for the onset of CLBP ^[5]. Based on this, the present study proposes a synergistic treatment approach combining “ultrasound drug delivery with core muscle group training,” hypothesizing that the two modalities can achieve a therapeutic effect greater than the sum of their individual effects ($1 + 1 > 2$) through a progressive mechanism of “pain relief-lumbar stabilization-repair.” This study aims to compare and analyze the effects of ultrasound drug delivery alone versus the combined treatment on lumbar function and pain intensity in patients with CLBP, providing high-quality evidence-based data for optimizing clinical treatment strategies for CLBP.

2. Materials and methods

2.1. General information

Patients with CLBP admitted to the Orthopedics Department of our hospital from January 2023 to December 2024 were selected as the study subjects. The sample size was estimated based on the results of a preliminary experiment: setting $\alpha = 0.05$ and $\beta = 0.20$, and assuming a 15% difference in the overall response rate between the two groups, a sample size of 52 patients per group was required. Considering a 15% dropout rate, the final sample size was determined to be 60 patients per group, totaling 120 patients, continuous variables were expressed as $\bar{x} \pm s$ (mean \pm standard deviation).

2.1.1. Inclusion criteria

- (1) Meeting the diagnostic criteria for CLBP in the “Guidelines for the Diagnosis and Treatment of CLBP (2022 Edition)”: persistent low back pain lasting ≥ 12 weeks with a Visual Analog Scale (VAS) score ≥ 4
- (2) Aged between 25 and 65 years
- (3) Exclusion of organic diseases such as lumbar fractures, tumors, tuberculosis, and severe lumbar disc herniation (protrusion compressing nerve roots with decreased muscle strength) based on lumbar imaging examinations (X-ray, CT, or MRI)
- (4) No history of lumbar injection therapy, physical therapy, or rehabilitation training in the past month.

2.1.2. Exclusion criteria

- (1) Patients with severe cardiovascular and cerebrovascular diseases, hepatic and renal insufficiency, or coagulation disorders
- (2) Patients with skin allergies or skin damage, infection, or eczema on the lumbar area which may affect ultrasound-mediated drug delivery
- (3) Pregnant or lactating women
- (4) Patients with severe cognitive impairment, mental illness, or those unable to cooperate with the training
- (5) Patients with contraindications to core muscle group training, such as severe osteoporosis or abdominal hernia). There were no statistically significant differences in general information such as gender, age, disease duration, body mass index (BMI), and pain location between the two groups ($p > 0.05$), indicating comparability (Table 1).

Table 1. General information

Indicator	Control group (n = 60)	Observation group (n = 60)	t/χ^2	p
Gender (Male/Female, n)	32/28	34/26	0.133	> 0.05
Age (years, $\bar{x} \pm s$)	45.62 \pm 8.35	46.18 \pm 7.92	0.382	> 0.05
Disease Duration (years, $\bar{x} \pm s$)	3.85 \pm 1.26	4.02 \pm 1.31	0.701	> 0.05
BMI (kg/m ² , $\bar{x} \pm s$)	23.85 \pm 2.16	24.12 \pm 2.08	0.683	> 0.05
Pain Location (n)				
Lumbosacral Region	38	36	0.568	> 0.05
Lumbodorsal Region	22	24		

2.2. Methods

Both groups of patients received basic nursing care: avoiding prolonged sitting or standing, lifting heavy objects with a bent waist, and being instructed on proper sitting and sleeping postures (using a thin pillow under the waist when lying supine), with a daily water intake of ≥ 1500 mL.

2.2.1. Control Group: Ultrasound-mediated drug delivery therapy alone

- (1) Equipment and medication

The DS-UCMF2B ultrasonic electroconductive directional drug delivery therapy device from Nanjing Dingshi (frequency: 1.0 MHz, adjustable output power: 0–3 W/cm²) was used. The medication selected was Qingpeng Ointment (Tibet Qizheng Tibetan Medicine Co., Ltd., National Medical Product Approval Number Z54020140, specification: 55 g/tube).

- (2) Operational method

The patient was positioned prone, exposing the painful area of the waist. A sterile gauze (8 cm \times 10 cm) soaked in the medication was placed over the painful point. After applying a coupling agent to the ultrasonic probe, it was placed on the gauze. The probe was adjusted to be perpendicular to the skin, with the output power set at 1.5 W/cm². The treatment duration was 20 minutes per session, once daily, five times per week, for a continuous period of eight weeks. During the treatment, the patient's skin condition was closely monitored. If redness, swelling, or a stinging sensation occurred, the treatment was immediately suspended.

2.2.2. Observation group: Ultrasonic drug delivery combined with core muscle group training

The ultrasonic drug delivery procedure was conducted once daily in the morning, following the same protocol as that of the control group.

The core muscle group training was performed every afternoon under the guidance of rehabilitation therapists. The training program was designed in accordance with the Guidelines for Rehabilitation Medicine (2nd Edition) and implemented over a total period of eight weeks, progressing through three stages of increasing difficulty, each lasting two weeks.

Phase I (Weeks 1–2, Basic Activation Phase) focused on activating and improving control of the deep core muscles to enhance trunk stability. Exercises included Diaphragmatic Breathing, performed in a supine position with knees bent and hands placed on the abdomen. Patients inhaled slowly through the nose, allowing the abdomen to rise, and exhaled through the mouth while the abdomen fell, completing 10 repetitions per set, 3 sets per day. Then, Gluteal Bridge Exercise, performed by lying supine with knees bent and feet flat on the ground. The hips were slowly lifted until the torso and thighs formed a straight line, held for 3 seconds, and then lowered, for 15 repetitions per set, 3 sets per day. Next is the Bird-Dog Exercise, performed in a quadruped position. Patients extended the opposite arm and leg simultaneously, maintaining trunk stability, held for 2 seconds, then returned to the starting position, alternating sides for 10 repetitions per side, 3 sets per day.

Phase II (Weeks 3–4, Muscle Strength Enhancement Phase) aimed to further strengthen the abdominal and back muscles. The exercises included the Dead Bug Exercise, performed by lying supine with hips and knees at 90° and arms extended upward. The opposite arm and leg were lowered simultaneously until close to the ground, held for 1 second, then returned, alternating sides for 12 repetitions per side, 3 sets per day. Next is the Side Bridge Exercise, in which patients supported their body on one elbow, lifting the hips to form a straight line, held for 5 seconds, then lowered, for 10 repetitions per side, 3 sets per day. Besides, the Superman Exercise, performed in a prone position, lifting the chest and legs 5–10 cm off the bed, holding for 3 seconds, then lowering, for 12 repetitions per set, 3 sets per day.

Phase III (Weeks 5–8, Endurance Strengthening Phase) emphasized improving muscular endurance and dynamic stability. The exercises included Plank Exercise, performed by supporting the body with elbows and toes, maintaining a straight alignment for 30–60 seconds per repetition, 5 repetitions per set, 2 sets per day. Single-Leg Glute Bridge Exercise, performed supine with one knee bent and the other leg extended. The hips were lifted until the torso and supporting leg formed a straight line, held for 5 seconds, then lowered, for 12 repetitions per side, 3 sets per day, and the Dynamic Bird-Dog Exercise, performed from a four-point kneeling position, extending the opposite arm and leg, then bringing them toward the body until the elbow and knee touched, before returning to the start position, for 10 repetitions per side, 3 sets per day.

Throughout the training process, rehabilitation therapists provided real-time supervision to ensure correct posture and prevent compensatory movements such as excessive lumbar extension or pelvic sagging. If any participant experienced lumbar pain with a Visual Analog Scale (VAS) score of 6 or higher, training was immediately suspended and reassessed before continuation.

2.3. Observation indicators

2.3.1. Pain assessment

The Visual Analog Scale (VAS) is used for assessment: On a 10 cm line, the left end is labeled “0 points” (no pain) and the right end is labeled “10 points” (severe pain). Patients mark their perceived pain level on the line, and the

distance from the left end to the marked point is the VAS score. Assessments are conducted before treatment, at 4 weeks of treatment, and at 8 weeks of treatment.

2.3.2. Lumbar spine function assessment

The Oswestry Disability Index (ODI) was used for assessment, encompassing 10 dimensions including pain intensity, activities of daily living, lifting, walking, sitting, standing, sleeping, sexual life, social activities, and traveling. Each dimension was scored from 0 to 5, with a total score ranging from 0 to 50. A higher score indicates more severe lumbar spine dysfunction. Assessments were conducted before treatment, at 4 weeks of treatment, and at 8 weeks of treatment.

2.3.3. Clinical efficacy evaluation

The clinical efficacy evaluation result was formulated in accordance with the “Diagnostic and Therapeutic Efficacy Criteria for TCM Diseases and Syndromes” and was generally classified into four categories.

(1) Cure

Complete disappearance of low back pain, with a VAS score ≤ 1 point, an ODI score ≤ 5 points, and the restoration of normal lumbar spine range of motion (flexion $\geq 80^\circ$, extension $\geq 30^\circ$, lateral flexion $\geq 35^\circ$), enabling normal daily life and work

(2) Significant improvement

Marked relief of low back pain, with a VAS score reduction $\geq 50\%$, an ODI score reduction $\geq 40\%$, and an increase in lumbar spine range of motion by $\geq 30\%$ compared to before treatment

(3) Effective

Some relief of low back pain, with a VAS score reduction of 25% to 49%, an ODI score reduction of 20% to 39%, and an increase in lumbar spine range of motion by 10% to 29% compared to before treatment

(4) Ineffective

Failure to meet the aforementioned criteria for effectiveness. The overall effectiveness rate = (Number of cured cases + Number of significantly improved cases + Number of effective cases) / Total number of cases $\times 100\%$. The therapeutic effect was evaluated at 8 weeks post-treatment.

2.4. Statistical methods

Data analysis was performed using SPSS 26.0 statistical software. Continuous variables were expressed as “ $\bar{x} \pm s$ ”. For variables that follow a normal distribution and exhibit homogeneity of variance, paired *t*-tests were used for within-group comparisons before and after treatment, while independent sample *t*-tests were used for between-group comparisons.

Categorical variables are expressed as “number of cases (%)”, and comparisons were made using the χ^2 test. Ranked data (therapeutic efficacy) were compared using the rank-sum test. A *p*-value of < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of VAS scores before and after treatment in both groups

Before treatment, there was no statistically significant difference in VAS scores between the two groups ($p > 0.05$). After 4 and 8 weeks of treatment, VAS scores in both groups significantly decreased compared to before

treatment ($p < 0.05$), with the observation group having lower scores than the control group, and the difference was statistically significant ($p < 0.05$) (Table 2).

Table 2. Comparison of VAS scores before and after treatment in both groups

Group	n	Before treatment	4 weeks of treatment	8 weeks of treatment
Control	60	6.85 ± 1.02	4.23 ± 0.85	2.96 ± 0.71
Observation	60	6.92 ± 1.05	3.15 ± 0.78	1.58 ± 0.63
<i>t</i> -value	-	0.352	6.824	11.267
<i>p</i> -value	-	0.725	< 0.05	< 0.05

3.2. Comparison of ODI index between the two groups before and after treatment

Before treatment, there was no statistically significant difference in the ODI index between the two groups ($p > 0.05$). After 4 and 8 weeks of treatment, the ODI index in both groups significantly decreased compared to that before treatment ($p < 0.05$), with the observation group showing a lower index than the control group, and the difference was statistically significant ($p < 0.05$) (Table 3).

Table 3. Comparison of ODI index between the two groups before and after treatment

Group	n	Before treatment	4 weeks of treatment	8 weeks of treatment
Control	60	32.56 ± 4.28	21.35 ± 3.86	15.82 ± 3.15
Observation	60	33.12 ± 4.35	15.68 ± 3.24	8.95 ± 2.67
<i>t</i> -value	-	0.673	8.251	12.834
<i>p</i> -value	-	0.502	< 0.05	< 0.05

3.3. Comparison of clinical efficacy between the two groups

After 8 weeks of treatment, the total effective rate in the observation group was 93.33%, which was higher than the 78.33% in the control group, and the difference was statistically significant ($p < 0.05$) (Table 4).

Table 4. Comparison of clinical efficacy between the two groups

Efficacy Grade	Control Group (n = 60)	Observation Group (n = 60)
Cured (n)	8	22
Markedly Effective (n)	18	25
Effective (n)	21	9
Ineffective (n)	13	4
Total Effective Rate (%)	78.33	93.33
Z-value	-	2.853
<i>p</i> -value	-	0.004

4. Discussion

The ultrasound-mediated drug delivery technique promotes drug penetration through a dual mechanism of “cavitation effect” and “thermal effect”: The mechanical vibration of ultrasound can disrupt the lipid bilayer of the stratum corneum, forming temporary “pores” and increasing skin permeability. Simultaneously, the local thermal effect generated by ultrasound can dilate capillaries, accelerate blood circulation, and provide the driving force for the diffusion of drug molecules^[6]. The results of this study indicate that the VAS scores and ODI index in the observation group were significantly lower than those in the control group after 4 and 8 weeks of treatment, with a total effective rate of 93.33%. This suggests that the combined treatment regimen has significant advantages in the treatment of CLBP.

The core muscle group serves as the “internal scaffold” for maintaining lumbar spine stability. Weakening of its function can lead to biomechanical imbalance in the lumbar spine, increasing intervertebral disc pressure and facet joint wear, thereby forming a vicious cycle of “pain-muscle atrophy-dysfunction”^[7,8]. The stepped core muscle group training program adopted in this study adheres to the rehabilitation logic of “activation–enhancement–strengthening”.

In the first stage, actions such as abdominal breathing and gluteal bridge are employed to activate deep core muscle groups, including the transverse abdominis and multifidus, thereby improving muscle recruitment capabilities. In the second stage, exercises like the dead bug and side plank are utilized to enhance the strength of the core muscle groups, thereby boosting the lumbar spine’s resistance to load. In the third stage, actions such as plank and single-leg gluteal bridge are used to strengthen muscular endurance, maintaining long-term stability^[9].

While simple ultrasound drug delivery can provide short-term pain relief, it fails to improve lumbar spine stability, leading to a high likelihood of recurrence after medication cessation. In the early stages of simple core muscle group training, patient compliance is often poor due to pain, limiting training effectiveness. However, the combined treatment achieves “complementary advantages”: ultrasound drug delivery rapidly alleviates pain, enhancing patient tolerance to training; core muscle group training strengthens lumbar spine stability, reducing pain recurrence, and creating a virtuous cycle of “pain relief–training–spinal stabilization - pain reduction”^[10]. Additionally, core muscle group training promotes blood circulation in the lumbar region, accelerating the excretion of drug metabolites and reducing the risk of drug accumulation. Ultrasound drug delivery relieves muscle spasms, providing a more favorable environment for core muscle contractions and further enhancing training effectiveness.

The clinical value of this study lies in first, proposing a synergistic treatment approach combining “physical therapy + rehabilitation training,” offering a new option for conservative treatment of CLBP; then employing a stepped core muscle group training program that balances safety and effectiveness, suitable for patients with varying functional levels.

This study has the following limitations, where this study consists with a sample size of only 120 cases and being a single-center study, selection bias may exist, and the generalizability of the results requires validation through multi-center, large-sample studies. Besides that, the follow-up period is only 8 weeks, failing to observe long-term efficacy such as recurrence rates at 6 months and 1 year, necessitating further extension of the follow-up period. Moreover, the study did not analyze efficacy differences among patients with varying disease durations and ages. Subsequent research could conduct subgroup analyses to provide evidence for individualized treatment.

5. Conclusion

In conclusion, the combination of ultrasound-mediated drug delivery and core muscle group training can

effectively alleviate pain in patients with CLBP, improve lumbar spine mobility, enhance the muscle strength and stability of the core muscle group, and demonstrate good safety. This combined treatment approach is simple to operate and cost-effective, making it suitable for promotion and application in primary-level hospitals. It can serve as one of the preferred conservative treatment options for patients with CLBP.

Disclosure statement

The author declare no conflict of interest.

References

- [1] Hu G, Zhuang Q, Lai Q, 2025, Clinical Observation on the Treatment of Chronic Non-Specific Low Back Pain with Thermosensitive Moxibustion Combined with Core Muscle Group Functional Training. *Chinese Journal of Folk Therapy*, 33(12): 51–54.
- [2] Luo Y, Li Y, Guo J, et al., 2025, Disease Burden of Psoriasis in China from 1990 to 2021 and Prediction of Trends for the Next 15 Years: An Analysis Based on Global Burden of Disease Data. *Chinese Journal of New Drugs and Clinical Remedies*, 25(09): 603–612.
- [3] Zhao C, Li D, Liao J, et al., 2025, Clinical Study on the Treatment of Chronic Non-Specific Low Back Pain of Liver and Kidney Deficiency Type with Bugan Jianyao Decoction Combined with Suspension Core Muscle Group Training. *Journal of New Chinese Medicine*, 57(06): 51–56.
- [4] Lu J, 2023, Multimodal Magnetic Resonance Study on the Changes of Target Core Muscle Groups in Patients with Chronic Low Back Pain after Rehabilitation Exercise Training, thesis, Kunming Medical University.
- [5] Zhang X, 2022, Research on the Intervention Effect of Aquatic Core Stability Training on Chronic Non-Specific Low Back Pain in College Students, thesis, Tianjin University of Sport.
- [6] Lu L, Ma S, Yao Y, 2022, Clinical Effect of Release Techniques Combined with Core Muscle Group Training in the Treatment of Chronic Low Back Pain in Patients with Lumbar Disc Herniation. *China Medical Herald*, 19(06): 89–92.
- [7] Hu X, Yang G, Wang X, et al., 2021, Clinical Effect of Release Techniques Combined with Core Muscle Group Training in the Treatment of Chronic Low Back Pain in Patients after Lumbar Disc Herniation Surgery. *Clinical Research and Practice*, 6(24): 33–35.
- [8] Tan W, Zhang X, An S, 2020, Analysis of the Effect of Small Needle Scalpel Combined with Core Muscle Group Training in the Treatment of Chronic Low Back Pain and JOA Score. *Contemporary Medicine*, 26(23): 29–30.
- [9] Qiu B, Wu J, 2019, Clinical Observation on the Treatment of Chronic Low Back Pain with Small Needle Scalpel Combined with Core Muscle Group Training. *Liaoning Journal of Traditional Chinese Medicine*, 46(08): 1724–1726.
- [10] Jiang J, 2019, The Effect of Respiratory Muscle Training on the Lumbar Posture Control Ability of Women with Non-Specific Chronic Low Back Pain, thesis, Capital University of Physical Education and Sports.

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Clinical Study on Minimally Invasive Sling Technique Fixation for the Treatment of Acromioclavicular Joint Dislocation with Double Endobutton by Bare-handed

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Abstract: *Objective:* To evaluate the clinical efficacy of minimally invasive, fluoroscopy-free, arthroscopy-free, coracoid tunnel-free double Endobutton plate sling technique for the treatment of acromioclavicular joint dislocation. *Methods:* A total of 60 patients with acromioclavicular joint dislocation admitted to our hospital between January 2021 and December 2023 were divided into two groups according to the treatment method. The control group underwent open reduction and internal fixation with a clavicular hook plate, while the study group received minimally invasive, fluoroscopy-free, coracoid tunnel-free double Endobutton plate sling fixation. The therapeutic outcomes were compared between the two groups. *Results:* All surgical outcome measures in the study group were superior to those in the control group ($p < 0.05$). The improvement in Constant scores and the reduction in visual analog scale (VAS) pain scores was significantly greater in the study group compared to the control group ($p < 0.05$). *Conclusion:* The minimally invasive, fluoroscopy-free, arthroscopy-free, coracoid tunnel-free double Endobutton plate sling technique for the treatment of acromioclavicular joint dislocation offers significant advantages, including minimal invasiveness, reduced trauma, reliable fixation, fewer complications, accelerated recovery, and improved joint function.

Keywords: Acromioclavicular joint dislocation; Bare-handed; Clavicular hook steel plate; Endobutton plate

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1. Introduction

Acromioclavicular joint dislocation is a common traumatic joint injury primarily caused by direct violence such as traffic accidents or falls^[1]. Traditional treatment methods include manual reduction and clavicular hook plate internal fixation. However, these approaches often suffer from drawbacks such as significant trauma, slow recovery, and the need for secondary surgery to remove internal fixation devices^[2]. Additionally, complications

may include loosening of internal fixation, erosion of acromial bone, postoperative shoulder pain, restricted joint mobility, and recurrence of joint dislocation after removal of internal fixation devices ^[3].

In recent years, with continuous advancements in medical technology, the double Endobutton technique has emerged as a novel treatment method and has been increasingly adopted in clinical practice, demonstrating remarkable advantages ^[4]. This study applied the minimally invasive, fluoroscopy-free, arthroscopy-free, coracoid bone tunnel-free double Endobutton internal fixation technique in the treatment of patients with acromioclavicular joint dislocation, achieving significant outcomes. A detailed report was provided in this study.

2. Materials and methods

2.1. General information

A total of 60 patients with acromioclavicular joint dislocation were selected as the study participants between January 2021 and December 2023. The patients were randomly assigned to two groups using a random number table method. There were no statistically significant differences in baseline characteristics between the two groups ($p > 0.05$), as shown in **Table 1**.

Table 1. Comparison of baseline characteristics between the two groups

Group	n	Gender		Age (years)		Injured Side	
		Male	Female	Range	Ill-defined	Present	Male
Study	30	12 (40.00)	18 (60.00)	21–66	41.42 ± 3.28	16 (53.33)	14 (46.67)
Control	30	13 (43.33)	17 (56.67)	22–65	42.86 ± 4.65	15 (50.00)	15 (50.00)
χ^2/t		0.391		0.076		0.582	
p		> 0.05		> 0.05		> 0.05	

2.1.1. Inclusion criteria

Diagnosed with acromioclavicular joint dislocation by imaging examination, and presenting with unilateral dislocation; No surgical contraindications; Signed informed consent.

2.1.2. Exclusion criteria

Combined with open injury or fracture of the shoulder joint; Allergic to medications used during surgery; Unable to tolerate the surgical procedure.

2.2. Treatment methods

Both groups of patients underwent comprehensive preoperative evaluations to exclude any surgical contraindications. Thorough preoperative preparations were completed, including blood glucose management and psychological counseling.

2.2.1. Control group

Open Reduction and Internal Fixation with a Clavicular Hook Plate. Patients were placed in the supine position under general anesthesia, with the upper body slightly elevated. The affected shoulder was supported with a pad, and the patient's head was turned to the opposite side. A 6–8 cm incision was made extending from the distal

clavicle to the acromioclavicular joint. A clavicular hook plate of appropriate height and length was inserted posterior to the acromioclavicular joint. Holes were drilled into the clavicle, and three to five screws of suitable length were inserted. The acromioclavicular ligaments were repaired, and after confirming correct reduction and fixation, the wound was irrigated and closed.

2.2.2. Study group

Internal Fixation with the Double Endobutton Technique. The procedure was typically performed with the patient in the beach-chair position, with the affected shoulder elevated. Anesthesia, either cervical plexus block or general anesthesia was selected based on the patient's condition and surgical requirements. The surgical area was routinely disinfected and draped. A 3–5 cm incision was made from the distal clavicle to the acromioclavicular joint. Two 2.5 mm diameter holes were drilled into the clavicle, located 2 cm and 4 cm from the distal end of the clavicle at the acromioclavicular joint. Using a right-angle clamp, a No. 2 high-strength suture was passed closely along the medial cortex of the coracoid process, looped around its base, and brought out laterally. This suture was then passed through the two clavicular bone tunnels to introduce two double-stranded high-strength sutures, each preloaded with an Endobutton plate. Under direct visualization, the acromioclavicular joint was reduced. The two high-strength sutures were sequentially tightened and tied to secure fixation. The stability of the acromioclavicular joint was confirmed, and the joint capsule and ligaments were repaired. Finally, the incision was closed.

2.3. Observation items

2.3.1. Comparison of surgical parameters

Including intraoperative blood loss, operation time, incision length, and hospital stay.

2.3.2. Comparison of shoulder joint function

Evaluated using the Constant-Murley score, which consists of a subjective section (total 35 points) and an objective section (total 65 points). A higher score indicates better shoulder function.

2.3.3. Comparison of pain intensity

Assessed objectively using the Visual Analog Scale (VAS). Pain severity was graded from mild to severe as follows: Grade I: 0 points (no pain) Grade II: < 3 points (mild pain) Grade III: 4–6 points (moderate pain) Grade IV: 7–10 points (severe pain)

2.4. Statistical analysis

Data analysis was performed using SPSS version 26.0. Measurement data is expressed as mean \pm standard deviation ($\bar{x} \pm s$) and were compared using the *t*-test. Enumeration data are presented as n (%) and analyzed with the chi-square test. A *p*-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of surgical parameters between the two groups

All surgical parameters in the study group were significantly better than those in the control group ($p < 0.05$), as shown in **Table 2**.

Table 2. Comparison of surgical parameters between the two groups ($\bar{x} \pm s$)

Group	n	Hospital Stay (days)	Incision Length (cm)	Operation Time (min)	Blood Loss (mL)
Study	30	7.15 \pm 0.49	3.91 \pm 0.44	48.93 \pm 5.27	64.77 \pm 6.15
Control	30	9.28 \pm 1.11	6.29 \pm 1.03	55.46 \pm 5.19	82.49 \pm 7.04
<i>t</i>		8.094	10.065	5.468	11.494
<i>p</i>		< 0.05	< 0.05	< 0.05	< 0.05

3.2. Comparison of constant-Murley score differences

The improvement in Constant-Murley scores was significantly greater in the study group compared to the control group ($p < 0.05$), as shown in **Table 3**.

Table 3. Comparison of cognitive scores between the two groups ($\bar{x} \pm s$)

Group	n	Subjective		Objective		Total Score	
		Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Control	30	18.05 \pm 3.26	22.20 \pm 3.62	36.52 \pm 3.21	45.14 \pm 2.06	55.52 \pm 5.12	67.25 \pm 4.26
Study	30	18.08 \pm 2.62	30.20 \pm 3.20	36.81 \pm 4.15	57.62 \pm 3.10	55.15 \pm 5.32	87.95 \pm 5.26
<i>t</i>		0.052	4.854	0.041	5.124	0.084	6.624
<i>p</i>		> 0.05	< 0.05	> 0.05	< 0.05	> 0.05	< 0.05

3.3. Comparison of VAS score differences between the two groups

The reduction in VAS scores was significantly greater in the study group compared to the control group ($p < 0.05$), as shown in **Table 4**.

Table 4. Comparison of VAS scores between the two groups ($\bar{x} \pm s$)

Group	n	Pre-treatment	Post-treatment
Study	30	7.38 \pm 0.54	2.17 \pm 0.42
Control	30	7.35 \pm 0.69	4.51 \pm 0.44
<i>t</i>		0.624	23.524
<i>p</i>		> 0.05	< 0.05

4. Discussion

Acromioclavicular joint dislocation is a common joint injury primarily caused by direct or indirect trauma leading to rupture of the acromioclavicular joint capsule and surrounding ligaments, resulting in upward displacement of the distal clavicle. Depending on the severity, it can be classified into different grades, ranging from mild pain to severe displacement^[5].

Clinical treatment options for acromioclavicular joint dislocation vary and include both conservative and surgical approaches. Conservative management mainly consists of four categories: cold and heat therapy, immobilization and bracing, medication, and functional exercises. It is typically indicated for patients with

Rockwood type I and II injuries. For those with type III or higher dislocations or acromioclavicular joint displacement exceeding 2 cm, conservative treatment often fails to achieve satisfactory outcomes, and surgical intervention is required^[6]. The goals of surgery are to restore stability and function of the acromioclavicular joint, reduce pain, and prevent complications.

The Endobutton plate, also known as a loop plate or button plate, is a device used in the treatment of acromioclavicular joint dislocations by reconstructing the coracoclavicular ligament structure through elastic fixation. Its principle lies in reestablishing an anatomical structure between the clavicle and the coracoid process that mimics the coracoclavicular ligament, providing internal fixation through its unique stiffness and strength^[7]. This elastic fixation method not only aligns with the micromotion physiological characteristics of the acromioclavicular joint but also preserves rotational movement of the clavicle, thereby restoring the physiological connection between the coracoid process and the clavicle to the greatest extent possible. Struhl first introduced the double Endobutton technique in 2007, with the original aim of reducing joint subluxation and fractures^[8]. By implanting a suture-button construct between the coracoid process and the distal clavicle, stability of the acromioclavicular joint can be maintained. Furthermore, this construct offers advantages in strength and stiffness compared to normal ligaments^[9]. Both Endobutton fixation and clavicular hook plate fixation demonstrate favorable clinical and radiological outcomes for the treatment of acromioclavicular joint dislocations^[10,11]. A meta-analysis including 179 patients compared the efficacy of these two techniques and concluded that both are effective in improving joint function and alleviating pain. However, Endobutton fixation provided additional advantages in terms of postoperative pain relief compared to the hook plate fixation^[12]. Another meta-analysis, which pooled data from 1,102 patients, thoroughly evaluated five surgical techniques, comparing their clinical efficacy, radiological outcomes, and safety. Although the clavicular hook plate is widely used for acromioclavicular joint dislocation repair, it is associated with more severe soft tissue trauma, greater blood loss, the necessity for a second surgery to remove the hardware, and a higher complication rate. The analysis concluded that its clinical application requires careful consideration^[13]. Endobutton fixation, due to its elastic properties, better aligns with the biomechanical behavior of the acromioclavicular joint and preserves rotational movement of the clavicle^[14]. This technique significantly reduces the likelihood of postoperative complications such as shoulder stiffness and subacromial impingement syndrome. As a result, Endobutton fixation has become an increasingly popular choice in recent years^[15].

This study applied a modified double Endobutton sling technique, which is a fluoroscopy-free, arthroscopy-free, and coracoid bone tunnel-free internal fixation method in the treatment of patients with acromioclavicular joint dislocation. As a minimally invasive procedure, it offers advantages such as a small incision, minimal tissue damage, reduced bleeding, shorter operative time, and faster postoperative recovery. Compared to the control group treated with clavicular hook plate fixation, the experimental group demonstrated superior outcomes across various surgical metrics, along with significantly greater improvements in Constant-Murley scores and Visual Analog Scale (VAS) scores ($p < 0.05$). These results indicate that the double Endobutton sling technique achieves excellent therapeutic outcomes with fewer complications.

5. Conclusion

In summary, for patients with acromioclavicular joint dislocation, the minimally invasive, fluoroscopy-free, arthroscopy-free, and coracoid bone tunnel-free double Endobutton suspension fixation technique can achieve

superior clinical outcomes. This procedure is a safe, effective, minimally invasive, and efficient treatment option associated with fewer complications. It not only aligns with the biomechanical characteristics of the acromioclavicular joint but also preserves clavicular rotation, thereby maximizing the restoration of shoulder joint function.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Sun C, Zhu Y, Zhang G, et al., 2023, Early Clinical Follow-Up Study of Coracoclavicular Loop Plate Suspension Fixation without Coracoid Bone Tunnel under Small Incision for the Treatment of Acromioclavicular Joint Dislocation. *Chinese Journal of Sports Medicine*, 42(2): 118–122.
- [2] He G, Gao D, Chen L, et al., 2022, A Mid-to-Long-Term Comparative Study of Conservative Treatment versus Clavicular Hook Plate Internal Fixation for Rockwood Type III Acromioclavicular Joint Dislocation. *Chinese Journal of Shoulder and Elbow (Electronic Edition)*, 10(2): 110–114.
- [3] Zhang L, Zhou X, Qi J, et al., 2018, Modified Closed-Loop Double-Endobutton Technique for Repair of Rockwood Type III Acromioclavicular Dislocation. *Experimental and Therapeutic Medicine*, 15: 940–948.
- [4] Ozmanevra R, Hapa O, Yanik B, et al., 2025, Comparison of Endobutton and Tendon Graft Techniques in Acromioclavicular Joint Dislocation: Early Treatment Yields Better Outcomes. *Medicine (Baltimore)*, 104(24): e42879.
- [5] Rockwood C, Williams G, Young D, 1998, Disorders of the Acromioclavicular Joint. In: Rockwood C, Matsen F III (eds.). *The Shoulder*, 2nd ed. Philadelphia: WB Saunders, 483–553.
- [6] Gorbaty J, Hsu J, Gee A, 2017, Classifications in Brief: Rockwood Classification of Acromioclavicular Joint Separations. *Clinical Orthopaedics and Related Research*, 475: 283–287.
- [7] He G, Gao D, Chen L, et al., 2022, Medium- to Long-Term Efficacy of Endobutton Loop Plate Fixation versus Clavicular Hook Plate Fixation for Rockwood Type III Acromioclavicular Joint Dislocation. *Chinese Journal of Shoulder and Elbow (Electronic Edition)*, 10(2): 105–109.
- [8] Struhl S, 2007, Double Endobutton Technique for Repair of Complete Acromioclavicular Joint Dislocations. *Techniques in Shoulder and Elbow Surgery*, 8: 175–179.
- [9] Zhang L, He A, Jin Y, et al., 2020, Novel Double Endobutton Technique Combined with Three-Dimensional Printing: A Biomechanical Study of Reconstruction in Acromioclavicular Joint Dislocation. *Orthopaedic Surgery*, 12: 1511–1519.
- [10] Johansen J, Grutter P, McFarland E, et al., 2011, Acromioclavicular Joint Injuries: Indications for Treatment and Treatment Options. *Journal of Shoulder and Elbow Surgery*, 20: S70–S82.
- [11] Simovitch R, Sanders B, Ozbaydar M, et al., 2009, Acromioclavicular Joint Injuries: Diagnosis and Management. *Journal of the American Academy of Orthopaedic Surgeons*, 17: 207–219.
- [12] Pan X, Lv R, Lv M, et al., 2020, TightRope versus Clavicular Hook Plate for Rockwood III–V Acromioclavicular Dislocations: A Meta-Analysis. *Orthopaedic Surgery*, 12: 1045–1052.
- [13] Yuan Y, Liao M, Lai H, et al., 2023, Comparison of Effectiveness and Safety in Treating Acute Acromioclavicular Joint Dislocation with Five Different Surgical Procedures: A Systematic Review and Network Meta-Analysis.

Orthopaedic Surgery, 15: 1944–1958.

- [14] Sharma B, Tiwari A, Joshi S, et al., 2019, Minimally Invasive Double Endobutton in Patients with Acute Acromioclavicular Joint Dislocation Grade III and V: Functional Outcome and Complications. *National Clinical Orthopaedics*, 3: 41–47.
- [15] Cai L, Wang T, Lu D, et al., 2018, Comparison of the TightRope Technique and Clavicular Hook Plate for the Treatment of Rockwood Type III Acromioclavicular Joint Dislocation. *Investigative Surgery*, 31: 226–233.

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Observation on the Clinical Efficacy of Electroacupuncture in Treating Medial Proliferative Scar of the Patella after Surgery for Patellar Instability

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Abstract: *Objective:* To observe the clinical efficacy of electroacupuncture in treating medial proliferative scar of the patella after surgery for patellar instability. *Methods:* A total of 38 patients with medial proliferative scar of the patella after surgery for patellar instability were selected from the outpatient follow-up clinic of the Sports Medicine Department at Changzhou Traditional Chinese Medicine Hospital from March 2022 to December 2024. They were randomly divided into an observation group and a control group, with 19 patients in each group. The control group was treated with simple acupuncture, targeting the Ashi points around the medial scar of the patella, as well as Xuehai, Liangqiu, Zusanli, and Yanglingquan. The technique of even reinforcement and reduction was applied, with the needles retained for 30 minutes, twice a week for 4 consecutive weeks. The observation group, in addition to the acupuncture treatment used in the control group, had two pairs of adjacent acupoints in the scar area connected to an electroacupuncture device, with electrical stimulation applied for 30 minutes. The treatment frequency was the same as that of the control group. The Vancouver Scar Scale (VSS) score, Kujala patellofemoral joint function score, and clinical efficacy were compared between the two groups before and after treatment. *Results:* After 4 weeks of treatment, both groups showed a significant decrease in the total VSS score and scores in each dimension compared to before treatment ($p < 0.05$), along with a significant increase in the Kujala score ($p < 0.05$). The degree of improvement in the observation group was superior to that in the control group ($p < 0.05$). The total effective rate in the observation group was significantly higher than that in the control group ($p < 0.05$). *Conclusion:* Electroacupuncture is significantly effective in treating medial proliferative scar of the patella after surgery for patellar instability. It can synergistically improve the appearance of the scar and the function of the knee joint, outperforming simple acupuncture.

Keywords: Electroacupuncture; Patellar instability; Hypertrophic scar; Acupuncture therapy

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1. Introduction

Patellar instability is a common issue in sports injuries among young individuals, with clinical manifestations including “giving way”, pain, swelling, and limited range of motion, which are particularly exacerbated during knee-bending and weight-bearing activities such as squatting, standing up, and going up or down stairs. Surgical treatments often involve medial patellofemoral ligament reconstruction or medial patellar retinaculum repair^[1]. Surgical incisions are typically made along the medial border of the patella, a region that not only exposes the anterior aspect of the knee but also serves as a critical functional area for the attachment of the medial patellofemoral ligament and the vastus medialis muscle. Three to six months postoperatively, due to the high activity of dermal fibroblasts and robust local repair responses in young patients, hypertrophic scars tend to form on the medial side of the patella. These scars often appear as red, thickened, cord-like tissues, significantly affecting the aesthetic appearance of the anterior knee and posing a psychological burden on young patients, especially females during social activities. Functionally, scar contracture can pull on the soft tissues on the medial side of the patella, restrict the contractile function of the vastus medialis muscle, disrupt the biomechanical stability of the medial patellar retinaculum, and consequently lead to insufficient knee flexion angles, even induce peripatellar traction pain, and delay the postoperative recovery of motor function^[2]. Among the currently available clinical anti-scar methods, silicone gel can only slightly improve scar texture but fails to address the contracture issue of scars on the medial side of the patella; hormone injections can suppress hyperplasia but carry the risk of skin atrophy; simple acupuncture, while relieving discomfort through meridian regulation, lacks sufficient targeted intervention for scars on the medial side of the patella and struggles to simultaneously meet the dual demands of aesthetic improvement and functional recovery^[3].

Electroacupuncture, as a synergistic therapy combining “acupuncture + electrical stimulation”, offers unique advantages in the treatment of hypertrophic scars on the medial side of the patella. Electroacupuncture can not only precisely stimulate local acupoints, directly acting on scar tissue and surrounding functional structures while avoiding interference with intra-articular tissues, but also improve microcirculation in the scarred area on the medial side of the patella through sparse-dense waves, accelerate the clearance of inflammatory factors, inhibit excessive collagen deposition, and achieve scar softening and fading^[4]. Based on this, the present study focuses on hypertrophic scars at this specific site on the medial side of the patella following surgery for patellar instability, comparing the therapeutic effects of electroacupuncture and simple acupuncture, with the aim of providing references and insights for clinical practitioners.

2. Materials and methods

2.1. Patient sources

All patients in this study were sourced from the postoperative follow-up clinic of the Sports Medicine Department at Changzhou Hospital of Traditional Chinese Medicine, spanning from March 2022 to December 2024. A total of 38 eligible patients were included and randomly divided into an observation group and a control group, with 19 patients in each group. All patients signed informed consent forms, and the study was approved by the hospital’s medical ethics committee.

2.2. Diagnostic criteria

2.2.1. Surgical diagnostic criteria for patellar instability

Referencing the surgical indications for patellar instability in the “Sports Medicine Diagnosis and Treatment

Guidelines (3rd Edition)”

- (1) Diagnosis of medial patellofemoral ligament injury or medial patellar retinaculum tear confirmed through clinical examination and imaging studies
- (2) Persistent risk of patellar dislocation or knee pain despite 3 months of conservative treatment (bracing, rehabilitation exercises)
- (3) Surgical intervention involving medial patellofemoral retinaculum reconstruction or repair, with the surgical incision located along the medial edge of the patella (length 3–5 cm).

2.2.2. Diagnostic criteria for hypertrophic scarring on the medial aspect of the patella

Referencing the diagnostic criteria for hypertrophic scarring in the “Clinical Scar Management (2nd Edition)” and incorporating the specific characteristics of the “medial aspect of the patella”

- (1) The scar is confined to the surgical incision area on the medial aspect of the patella and does not extend beyond the incision margins
- (2) The scar appears red or dark red, is firm and tough in texture, and has a thickness greater than 2 mm upon palpation
- (3) Accompanied by or without the following symptoms: localized itching of the scar (VAS score ≥ 3), or a pulling sensation on the medial aspect of the patella during knee flexion
- (4) Postoperative duration of 3–6 months (scar is in an active proliferative phase and has not yet entered the maturation phase).

2.3. Inclusion and exclusion criteria

2.3.1. Inclusion criteria

- (1) Aged between 16 and 45 years
- (2) Meeting the aforementioned diagnostic criteria for surgical intervention for patellar instability and medial patellar hypertrophic scarring
- (3) Postoperative knee joint function restored to partial weight-bearing stage (able to walk independently with an active knee flexion angle of $\geq 90^\circ$ but $< 120^\circ$)
- (4) No use of any anti-scarring treatments (such as silicone gel, corticosteroid ointments, laser therapy) within one month prior to treatment
- (5) Willing to participate in this study voluntarily and able to cooperate with completing a 4-week treatment and a 3-month follow-up.

2.3.2. Exclusion criteria

- (1) Scarring accompanied by infection, ulceration, exudation, or skin allergy
- (2) Presence of postoperative complications (such as joint effusion, cartilage damage, and laxity of the medial patellofemoral ligament)
- (3) Contraindications to electroacupuncture or acupuncture (such as coagulopathy, installation of a cardiac pacemaker, and local skin damage)
- (4) Presence of other knee joint diseases (such as osteoarthritis and meniscal injury)
- (5) Pregnant or lactating women
- (6) Mental illness or cognitive impairment, rendering the patient unable to cooperate with the efficacy

evaluation.

2.4. Methods

2.4.1. Control group (acupuncture alone)

The acupoints were centered around the medial patellar scar area, with five surrounding Ashi points selected, along with the Xuehai, Liangqiu, Zusanli, and Yanglingquan points.

The patient was placed in a supine position with the knee joint extended and relaxed. After routine skin disinfection, disposable sterile acupuncture needles (0.30 mm × 40 mm) were rapidly inserted into the acupoints. After achieving the De Qi sensation, the reinforcing-reducing method was applied, with a twirling frequency of 120–150 times per minute and a twirling amplitude of 180–360°. The needles were retained for 30 minutes, with manipulation performed every 10 minutes during this period. Treatment was administered twice a week for four consecutive weeks.

2.4.2. Observation group (electroacupuncture)

The acupoint selection was consistent with that of the control group, and the acupuncture manipulation was the same as that of the control group. After achieving the De Qi sensation, two pairs of adjacent acupoints in the scar area were connected to an electroacupuncture device (Model: XW-6D Electronic Acupuncture Therapy Device). A continuous wave with a frequency of 2Hz was used, and the current intensity was adjusted to a level that the patient could tolerate without causing involuntary knee joint twitching. The treatment lasted for 30 minutes. Treatment was administered twice a week for four consecutive weeks.

2.5. Evaluation indicators for therapeutic efficacy

2.5.1. According to the efficacy evaluation criteria for hypertrophic scars in “Clinical Scarology (2nd Edition)”

(1) Markedly effective

The texture of the patient’s scar changes from hard to soft with good elasticity. The pain and itching at the scar site disappear, and the color of the scar changes from red to white or close to the color of normal skin.

(2) Effective

The texture of the patient’s scar becomes slightly softer than before, with reduced or nearly disappeared pain and itching at the scar site. The color of the scar becomes lighter than the previous red.

(3) Ineffective

There is no change in the scar site after treatment, and the pain and itching at the scar site do not decrease or disappear compared to before.

2.5.2. Scale and score

Observe the Vancouver Scar Scale (VSS) scores and Kujala patellofemoral joint function scores of patients before and after treatment.

2.6. Clinical statistical processing

Statistical analysis was performed using SPSS 16.0 software. Count data are expressed as percentages (%), and the χ^2 test was used. A *p*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Vancouver Scar Scale (VSS) scores of patients in both groups before and after treatment

Before treatment, there were no statistically significant differences in the total VSS scores and scores for each dimension (color, vascular distribution, thickness, and softness) between the two groups ($p > 0.05$). After 4 weeks of treatment, the total VSS scores and scores for each dimension in both groups significantly decreased compared to before treatment ($p < 0.05$), with a greater decrease observed in the observation group. All indicators were significantly lower in the observation group than in the control group ($p < 0.05$). Specific data are shown in **Table 1**.

Table 1. Comparison of VSS scores before and after treatment in both groups

Group	n	Before Treatment	After 4 Weeks of Treatment	<i>t</i> -value (Intragroup)	<i>p</i> -value (Intragroup)
Control Group	19	10.51 ± 2.12	6.94 ± 1.65	7.32	0.00
Observation Group	19	10.83 ± 2.36	4.13 ± 1.41	11.25	0.00
<i>t</i> -value		0.43	6.58		
<i>p</i> -value		0.66	0.00		

3.2. Kujala patellofemoral joint function score

Before treatment, there was no significant difference in Kujala scores between the two groups ($p > 0.05$). After 4 weeks of treatment, the scores in both groups increased significantly compared to those before treatment ($p < 0.05$), with the observation group showing significantly higher scores than the control group, and the difference was statistically significant ($p < 0.05$), as shown in **Table 2**.

Table 2. Comparison of knee joint function indicators between the two groups before and after treatment

Group	n	Before Treatment	After 4 Weeks of Treatment	<i>t</i> -value (Intragroup)	<i>p</i> -value (Intragroup)
Control Group	19	72.5 ± 5.3	82.3 ± 4.5	8.56	0.001
Observation Group	19	73.2 ± 5.6	91.8 ± 4.2	12.87	0.000
<i>t</i> -value		0.38	6.89		
<i>p</i> -value		0.71	0.000		

3.3. Comparison of clinical efficacy grades between the two groups

After 4 weeks of treatment, the total effective rate in the observation group was significantly higher than that in the control group, and the difference was statistically significant ($p < 0.05$), as shown in **Table 3**.

Table 3. Comparison of clinical efficacy grades between the two groups

Group (Intervention)	Markedly Effective	Effective	Ineffective	Total Effective Rate
Observation Group (Electro-acupuncture)	12 (63.2)	5 (26.3)	2 (10.5)	17 (94.7)
Control Group (Simple Acupuncture)	6 (31.6)	7 (36.8)	6 (31.6)	13 (68.4)
χ^2 value				7.938
<i>p</i> -value				0.005

3.4. Comparison of safety between the two groups

During the treatment period, no moderate or severe adverse reactions occurred in either group, and only mild local reactions were observed. In the observation group, 2 cases experienced slight bleeding at the acupuncture points, and 1 case had transient redness on the medial side of the patella. In the control group, 1 case experienced bleeding at the acupuncture point. All these issues were resolved through simple interventions.

4. Discussion

The treatment of hypertrophic scars on the medial side of the patella following surgery for patellar instability has consistently faced challenges. The existing mainstream approaches have significant limitations, failing to simultaneously improve joint range of motion and reduce scarring, a fact that has been confirmed in recent clinical studies^[5]. From a non-surgical perspective, silicone preparations are the primary clinical intervention, but their main limitation lies in low transdermal penetration efficiency. Traditional silicone gels only penetrate the epidermis for drug delivery to scars, failing to reach the fibroblast proliferation area in the dermis^[6]. This results in insufficient improvement in scar thickness and hardness and is nearly ineffective for established contractile scars.

Although local injection of glucocorticoids can rapidly inhibit scar hyperplasia, its safety issues are particularly prominent for young patients^[7]. Hormone injection leads to a high incidence of skin atrophy, and the recurrence rate at three months approaches 50%, which seriously conflicts with the needs of young patients for “no side effects and long-term stability”. Although fractional laser can stimulate collagen remodeling through microthermal damage zones, laser treatment requires multiple interventions and has a high cost per session, resulting in a “cost-effectiveness imbalance” for small-area scars such as those on the medial side of the patella. Additionally, the risk of post-laser hyperpigmentation is high, further limiting its application among young people^[8]. Even in the field of traditional Chinese medicine (TCM), the efficacy of simple acupuncture also has limitations. Previous literature shows that the improvement of scars by simple acupuncture mainly relies on the macro-regulation of “meridian dredging”, lacking continuous and stable local stimulation, and has a poor improvement rate for knee joint function^[9].

The results of this study show that the total effective rate reached 94.7% after 4 weeks of electroacupuncture treatment, which was significantly higher than that in the simple acupuncture group. Moreover, it demonstrated unique advantages in scar appearance, knee joint function, and long-term stability. This result is not only consistent with the logical framework of TCM theory but also supported by modern pathological mechanism research. From the perspective of TCM theory, oblique needling along the edge of the scar at Ashi points, combined with the use of dense-sparse waves to enhance the efficacy of “breaking stasis and dispersing nodules”, can directly improve local qi and blood stasis. The electrical stimulation of Neixiyan (Inner Eye of the Knee) and Xuehai (Sea of Blood) points strengthens “promoting blood circulation and removing blood stasis”, accelerating the metabolism of inflammatory factors stagnated in the scar area. This is highly consistent with the theory in the “Comprehensive Manual of Acupuncture and Moxibustion” that “for any scar accumulation, it is necessary to unblock the meridians and disperse the stasis”.

From the perspective of modern pathological mechanisms, the advantages of electroacupuncture are reflected in the precise regulation of key pathways for scar repair.

(1) Regulation of fibroblast activity

Zhao Ying et al. confirmed through animal experiments that the dense-sparse waves of electroacupuncture

can significantly reduce the expression of α -smooth muscle actin in scar tissue, inhibit the transformation of fibroblasts into myofibroblasts, and reduce excessive collagen deposition ^[10].

(2) Improvement of local microcirculation

Li Yancheng et al. used laser Doppler flowmetry to detect that electroacupuncture treatment can significantly increase blood flow in the scar area and accelerate the clearance of oxidative stress products (ROS) ^[11].

(3) Protection of joint function

Electroacupuncture stimulation of Zusanli (Stomach 36) and Yanglingquan (Gallbladder 34) can activate the muscle spindle receptors of the vastus medialis muscle, enhance electromyographic activity, and relieve the traction of the scar on the medial patellofemoral ligament ^[12].

This study has certain limitations, as this research is a single-center study, a small sample size was used. This relatively small number of samples may affect the extrapolation of the results, and it lacks validation through multi-center, large-sample randomized controlled trials (RCTs). Besides, the short follow-up period makes it difficult to evaluate long-term stability beyond one year. Future research should conduct multi-center, large-sample RCTs and incorporate objective imaging indicators to verify efficacy and safety.

5. Conclusion

In summary, electroacupuncture for the treatment of medial patellar hyperplastic scars following surgery for patellar instability can achieve synergistic improvement in scar appearance and knee joint function, with high safety and stable long-term efficacy. It is significantly superior to simple acupuncture and is particularly suitable for young patients. Despite the current limitations of the study, electroacupuncture provides a new and effective approach for scar treatment after surgery for patellar instability. Further research on mechanisms and larger-scale clinical validation is needed in the future to refine its treatment system and promote the standardized application of traditional Chinese medicine techniques in postoperative scar rehabilitation.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zheng T, Xu J, Zhao J, 2023, Risk Factors and Treatment Strategies for Patellar Instability. *International Journal of Orthopaedics*, 44(02): 67–71.
- [2] Yang B, Kou B, Fan J, et al., 2019, Observation on the Effect of Arthroscopic Lateral Patellar Retinaculum Release Outside the Capsule Combined with Suture Anchor Repair of the Medial Retinaculum in the Treatment of Acute Patellar Dislocation. *Ningxia Medical Journal*, 41(12): 1123–1124.
- [3] Yang B, 2023, Pathogenesis, Diagnosis, and Treatment Progress of Hypertrophic Scars and Keloids. *Journal of Dermatology and Venereology*, 30(06): 481–488.
- [4] Chen J, Wang Y, Meng Y, et al., 2023, Research Progress in the Treatment of Keloids with Traditional Chinese Medicine. *Beijing Journal of Traditional Chinese Medicine*, 42(11): 1277–1281.
- [5] Ran X, Liu Y, Zhu S, et al., 2023, Research Progress on the Principle and Application of Core Excision Technique for

Keloids. Chinese Journal of Reparative and Reconstructive Surgery, 37(12): 1569–1577.

- [6] Yuan D, Xue M, Li Z, et al., 2025, Research Progress on the Treatment of Pathological Scars. Anhui Medical and Pharmaceutical Journal, 29(06): 1065–1070.
- [7] Feng J, Zhao Y, 2023, Research Progress on the Treatment of Auricular Keloids with Surgery Combined with Glucocorticoids. Chinese Journal of Aesthetic and Plastic Surgery, 34(11): 677–679 + 709.
- [8] Luo X, Yi Q, Huang Z, 2024, Effects of Human Epidermal Growth Factor Gel Combined with Fractional Laser on Skin Barrier Function and Quality of Life in Patients with Acne Scars. Medical Innovation of China, 21(25): 148–152.
- [9] Xie J, Wang L, Yu J, 2017, Observation on the Effect of Acupuncture on Labor Progress and Safety in Vaginal Delivery of Re-pregnancy with Scarred Uterus. Chinese and Foreign Women's Health Research, 2017(09): 23 + 30.
- [10] Zhao Y, Chen S, Yu W, et al., 2010, Effects of Electroacupuncture Stimulation on Endogenous EPCs and Related Serum Cytokines in Rats with Cerebral Ischemia. Journal of Biomedical Engineering, 27(06): 1322–1326.
- [11] Li Y, 2020, Imaging Study on the Improvement of Microcirculation in Rats with Ischemia-Reperfusion by Electroacupuncture at Shuigou and Zusanli, thesis, Yunnan University of Traditional Chinese Medicine.
- [12] Li Q, Li S, Du J, 2024, Clinical Study on the Effect of Electroacupuncture Therapy on Postoperative Rehabilitation Training in Patients with Knee Fractures. China Journal of Orthopaedics and Traumatology, 37(04): 368–373.

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Musculoskeletal Ultrasound to Evaluate the Effect of 4D PRO Suspension Rope Training Combined with Mulligan Technique on Non-specific Low Back Pain: A Single-blind Randomized Controlled Trial

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Abstract: This trial was designed to evaluate the effects of 4D PRO suspension rope exercise combined with the Mulligan technique in non-specific low back pain (NLBP) patients by musculoskeletal ultrasound and clinical indicators. Sixty patients were randomly divided into the suspension group and the control group for eight weeks. The two groups were also treated with the Mulligan manipulation. The suspension group was treated combined with suspension rope training, while the control group was treated combined with traditional rehabilitation training. Pain, lumbar function and spinal range of motion were measured by a specialist before and after treatment. In addition, musculoskeletal ultrasound was used to measure the thickness of bilateral transversalis and multifidus muscles. After eight weeks, muscle thickness of bilateral transversalis and multifidus muscles, NRS, ODI and spinal range of motion in two groups were significantly better than those before treatment ($p < 0.05$). The suspension group showed significantly improvement compared to the control group regarding pain, lumbar function, spinal range of motion and the thickness of bilateral transversalis and multifidus muscles ($p < 0.05$). 4D PRO Suspension rope training may be an effective exercise as an adjunctive therapy with Mulligan technology in non-specific low back pain.

Keywords: Musculoskeletal ultrasound; Suspension rope exercise; Non-specific low back pain; Mulligan technique; Clinical trial

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1. Introduction

Non-specific Low Back Pain is a group of symptoms with lower back, lumbosacral and hip pain, which is very

common in orthopedics and rehabilitation departments ^[1-3]. Generally, there is no clear cause, such as a tumor, infection, spinal stenosis, lumbar disc herniation, osteoporosis, and more ^[4]. About 85% of patients with LBP cannot find an exact histopathological change clinically, nor can they confirm the causes through objective clinical examination ^[5]. However, the pain of these patients in clinical practice brings many troubles to their work and lives. Statistics show that about 84% of people will experience LBP ^[6]. In addition, most people do not have much time to cure in the hospitals or rehabilitation clinics, so they are more likely to expect appropriate behavior or exercise advice from rehabilitation therapists, which can help them.

For NLBP, current adjunctive therapy still favors a combination of exercise and manipulation, which can improve core stability while controlling NLBP symptoms ^[7]. Especially in recent years, suspension training, as a new type of exercise therapy, is considered to activate and enhance proprioception and achieve the effect of enhancing local structural stability ^[8-10]. Thus, the suspension training can reduce pain, improve impaired postural adjustment ability, and restore normal muscular response patterns. Kang studied the Bobath ball to assist bridge movement and conventional bridge exercise, and investigated their effects on local and global trunk muscles of patients with LBP ^[11]. He also found that the surface EMG signals of the muscles related to suspension such as obliquus externus abdominis, multifidus, rectus abdominis muscles were greater than those of the above ball movement and bridge movement. Therefore, suspension exercise can increase the activation of local and global muscles of the trunk. In addition, spinal mobilization is a common clinical manipulative intervention, especially the Mulligan technique is based on the biomechanics of correcting joint errors. It achieves the effect of alignment correction by applying forces to the joint treatment plane to achieve the sliding treatment. In addition, guide patients to conduct self-help Mulligan technology with the help of a treatment belt, and the results are immediate ^[12].

In conclusion, the treatment of NLBP with multi-means combined intervention is the general direction of future research. The comprehensive treatment program with manipulation combined with exercise is undoubtedly the focus of the study. Currently, suspension training and Mulligan technology have been gradually recognized by most researchers. However, suspension training equipment widely used in clinical practice mostly uses Norway red rope, which is difficult to be widely used as a rehabilitation exercise in life due to its high cost and large size. In this study, the suspension training adopted the 4D PRO suspension elastic band created by Dr. Homayun Gharaiv's team. Using elastic and neopren straps to partially or fully suspend the body, the 4D PRO suspension device is simple and portable, suitable for a variety of occasions and environments. Then the body is in an unstable state of open chain or closed chain training so as to stimulate the core stable muscle group physical rehabilitation training. The purpose of this study was to evaluate the efficacy of 4D PRO suspension rope exercise combined with the Mulligan technique in the treatment of NLBP by musculoskeletal ultrasound and clinical indicators.

2. Methods and study design

2.1. Trial design

A single-center, single-blind, randomized (1:1) controlled trial was designed. The subjects were randomly grouped by the researchers using computer-generated random numbers. The researchers did not participate in the entire evaluation and treatment intervention process. The manipulation therapist, data processor and subjects were unaware of the grouping.

To ensure that the subjects were not aware of the grouping situation, the agreed treatment time of the suspension group and the control group was staggered and arranged in the treatment rooms on different floors.

The same data collector evaluated the clinical effect before and after the intervention to ensure the reliability and reliability of the data.

2.2. Participants

This study has been approved by the Medical Ethics Committee of Hebei Provincial People's Hospital, China. Participants were the patients with non-specific low back pain who visited our outpatient department of Hebei Institute of Sports Science from September 2023 to October 2024. All participants underwent an essential physical examination before enrollment and were told in person the purpose of the trial, but no details of other interventions were known. The patients signed the informed consent voluntarily and had the right to opt-out during the study without any reason ^[13].

2.2.1. Inclusion criteria

- (1) Pain from the 12th pair of ribs to the crease below the hip
- (2) Tenderness or muscle spasm
- (3) CT or MRI showed no obvious 3
- (4) Duration > 12 weeks
- (5) The age range is from 20 to 45
- (6) The NRS score is greater than 3

2.2.2. Exclusion criteria

- (1) Symptoms of nerve root irritation
- (2) Complicated with pathological changes of the lumbar spine (fracture, lumbar disc herniation, infection, and other pathological conditions)
- (3) Disturbance of consciousness
- (4) Severe cardiopulmonary dysfunction

2.2.3. Shedding criteria

- (1) Failure to complete treatment as prescribed
- (2) Receiving other treatment during this study
- (3) Adverse reactions or difficulty in continuing treatment

2.3. Interventions

The two groups were treated with Mulligan manipulation. On this basis, the suspension group was combined with suspension rope training, while the control group was combined with traditional rehabilitation training, including double bridge exercises, left and right plank exercises and plank exercises. Each movement was held for 6–8 seconds, and 2 groups were repeated 10 times per group. Patients in both groups received treatment 3 times per week for 8 weeks. Specific operations were as follows.

2.3.1. Mulligan technique

Participants were subjected to lumbar of sustained natural apophyseal glides (SNAGs) and self-SNAGs techniques ^[12].

2.3.2. 4D PRO suspension rope training

The portable 4D PRO suspension training belt was used (refer **Figure. 1**). The suspension rope training was completed under the guidance of a professional physiotherapist, 20–30 min each time, 3 times/week, for a total of 8 weeks.

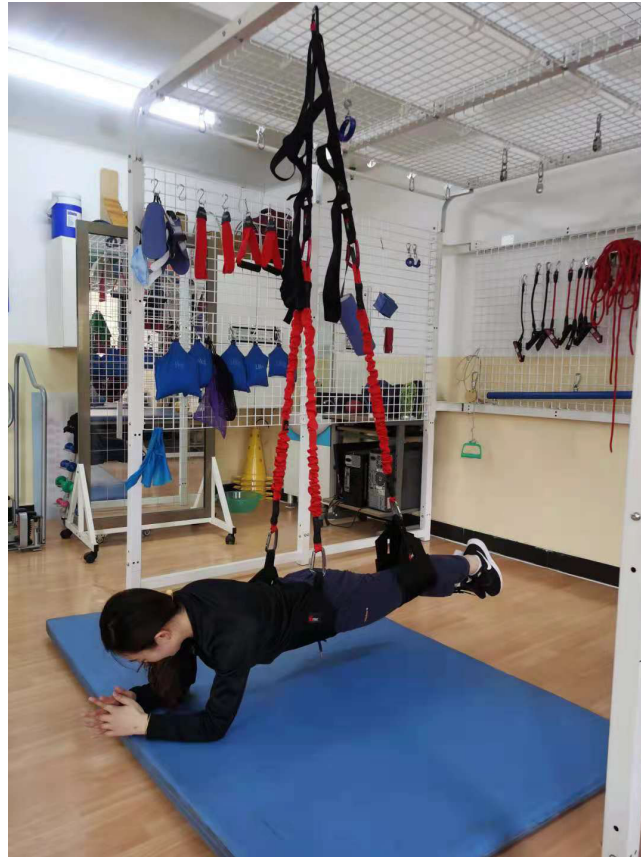


Figure 1. 4D PRO suspension rope training.

(1) Dorsal chain training

The patient is in the supine position, puts hands on both sides of the body, and bends one knee 90 degrees. Place one suspension belt on the patient's pelvis and the other on the popliteal fossa on the flexion side of the knee. The suspension height is the height of knee flexion. Let the patient straighten the leg in the suspension belt, lift the pelvis to the neutral position, keep the body in a straight-line position, and be careful not to tilt the pelvis. It mainly trains the dorsal motor chain of the core muscle group.

(2) Lateral chain training

The patient lies on his side and rests on his lower hand, the upper hand is placed on the patient's side, and the suspension belts are placed at the patient's pelvis and knee joint respectively. The suspension height is horizontal with the lateral condyle of the lower leg and the greater trochanter of the upper leg. Let the patient raise the upper leg, extend the lower hip joint, and press the lower leg down the suspension belt to raise the body in the same straight line. It mainly trains the lateral movement chain of the core muscle group.

(3) Inner chain training

The patient lies on his side and rests on his lower hand, with the upper hand on his side. Place one suspension belt on the patient's pelvis and the other on the knee joint of the upper leg. The suspension height is at the medial condyle of the upper leg, at the same level as the shoulder joint. Let the patient raise the lower leg, press the lower leg down the suspension belt to raise the body in the same straight line. It mainly trains the inner motor chain of the core muscle group.

(4) Front chain training

The patient lies prone with both upper limbs supporting the body. The suspension belts are placed at the patient's pelvis and knee joint respectively. The suspension height is at the level of the shoulder joint. Let the patient straighten the legs in the suspension belt, raise the pelvis to the middle area, and keep the body in a straight-line position. It mainly trains the anterior motor chain of the core muscle group.

All the above training should be maintained for 60 seconds each time, with an interval of 40 seconds, and 4–6 groups was trained.

2.4. Outcome measures

2.4.1. NRS score

The number 0–10 indicates the pain degree, in which 0 indicates no pain and 10 indicates the most severe pain. The degree of pain was evaluated by numbers according to the patients' subjective feelings ^[14].

2.4.2. ODI score

ODI score is a scale to judge the lumbar function based on whether the patient can carry out relevant daily life behavior. This scale includes 10 aspects of patients with low back pain, such as pain intensity and self-care. The higher the score, the more serious the lumbar dysfunction is. Considering the privacy of the subjects involved, the scoring option of sexual life in the ODI questionnaire was deleted. The highest score of ODI is 45 points ^[15].

2.4.3. Spinal mobility score

Spinal mobility score is mainly used to evaluate the quantitative table of spinal mobility of patients with low back pain. Patients stand and bend as low as they can, the score was based on the standard that the fingertips of both hands could reach the lowest part of the lower limbs. It is divided into seven levels. The higher the score, the smaller the range of activity of the lumbar spine and the more serious the corresponding symptoms.

2.4.4. Musculoskeletal ultrasound assessment

Musculoskeletal ultrasound was used to evaluate the muscle thickness of bilateral transverse abdominal muscle and multifidus muscle ^[16–18]. ALOKA DF-37 ultrasonic equipment was used, and the linear array ultrasonic probe frequency was 5.0–13.3MHZ. The thickness of the transverse abdominal muscle and multifidus muscle of the subjects in the resting position is measured before and after the intervention. The room temperature of the color ultrasound room is kept at 23–28 °C, and the same professional ultrasound doctor measures the subjects before and after the intervention, and the doctor does not know the grouping of the subjects.

2.5. Statistical analyses

All analyses were conducted by professionals who did not participate in the study using SPSS version 24.0. The measurement data of normal distribution were represented by Mean ± Standard deviation (SD). After the homogeneity of variance test, an independent sample *t*-test was used for comparison between-group, and paired

sample *t*-test was used for within-group comparison. Count data were expressed by frequency. And χ^2 test was used. $p < 0.05$ was set as the significance level.

3. Results

3.1. Study population

The inclusion period was from September 2023 to October 2024. Among the patients with nonspecific low back pain who came to our clinic, 100 patients accepted the study and signed informed consent, of which 37 did not meet the inclusion criteria of the study and were excluded. The remaining 63 people were randomly divided into 33 cases in the suspension group and 30 cases in the control group according to the random number table generated by the computer. 3 cases in the suspension group and 2 cases in the control group fell off due to various reasons within the period, as shown in **Figure 2**.

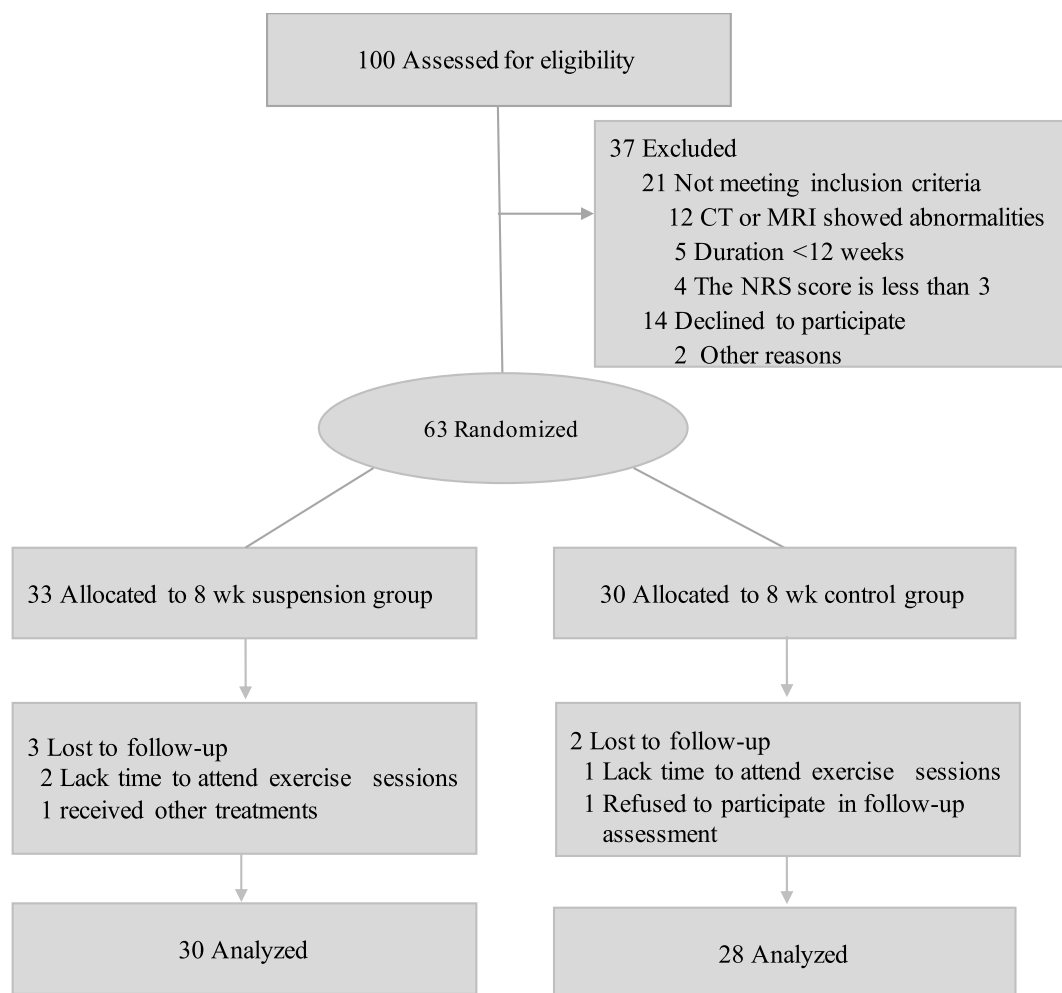


Figure 2. Flow diagram depicting the study design.

3.2. Baseline characteristics

There were no pronounced differences between the two groups in baseline characteristics such as age, sex, body weight, body mass index, average duration, NRS, ODI, and spinal mobility score (**Table 1**).

Table 1. Baseline demographic and clinical characteristics

Characteristic	Mean (SD)		<i>p</i> -value
	Suspension group (n = 30)	Control group (n = 28)	
Age, y	32.37 ± 5.95	33.93 ± 5.28	0.296
Male, No. (%)	18(60)	16(57)	0.825
Weight, kg	68.83 ± 11.31	70.29 ± 13.20	0.654
Body mass index ^a	24.45 ± 0.55	24.21 ± 2.59	0.710
Average duration (Month)	5.00 ± 1.34	5.11 ± 1.20	0.750
NRS	6.80 ± 0.66	6.64 ± 0.91	0.454
ODI	22.23 ± 3.84	21.50 ± 3.50	0.451
Spinal mobility	3.53 ± 0.78	3.75 ± 0.84	0.313

3.3. Outcomes

In both groups, the results were significantly better during the study in NRS, ODI and spinal motion scores. In the suspension group, the mean reduction in NRS was 6.17 compared with 4.72 in the control group. Scores related to waist function also showed significant differences between the groups. In particular, the duration of sitting, standing and walking had remarkably improved compared to the control group (**Table 2**).

Table 2. Results for the outcome

Characteristics Suspension group (n = 30)		Mean (SD)		p-value
		Control group (n = 28)		
NRS	BL	6.80 ± 0.66	6.64 ± 0.91	0.454
	8 weeks	0.63 ± 0.67	1.92 ± 0.81	0.000
ODI	BL	22.23 ± 3.84	21.50 ± 3.50	0.451
	8 weeks	2.27 ± 1.17	7.36 ± 2.30	0.000
Spinal Mobility	BL	3.53 ± 0.78	3.75 ± 0.84	0.313
	8 weeks	1.07 ± 0.58	2.21 ± 0.69	0.000
ITA Thickness	BL	2.35 ± 0.18	2.37 ± 0.25	0.668
	8 weeks	3.21 ± 0.15	3.03 ± 0.29	0.005
NTA Thickness	BL	3.29 ± 0.15	3.29 ± 0.15	0.880
	8 weeks	3.71 ± 0.15	3.36 ± 0.14	0.000
IM Thickness	BL	10.17 ± 0.17	10.20 ± 0.15	0.403
	8 weeks	12.09 ± 0.13	10.35 ± 0.19	0.000
NM Thickness	BL	14.33 ± 0.17	14.31 ± 0.20	0.727
	8 weeks	17.13 ± 0.26	14.55 ± 0.19	0.000

Suspension training improved core stability while controlling NLBP clinical symptoms. Studies have shown that suspension training based on the principle of neuromuscular activation can realize static and dynamic training of core muscle group in an unstable state. It also can increase the stimulation of stable muscle group in the core

area. In particular, for maintaining the balance and rotation stability of the vertebral body in sagittal and coronal positions, the transversus abdominis and multifidus muscle are of great significance.

Musculoskeletal ultrasound was used to measure the thickness of the transversus abdominis and multifidus muscle before and after the intervention. This also proved that the stimulation of suspension training on the lumbar stable muscle group was obvious, especially the stimulation of the transversus abdominis and multifidus muscle. The result was in line with the research expectation.

4. Discussion

In this study, muscle bone ultrasound technology is used to objectively evaluate the functional state of locally stable muscles before and after the intervention, which has the characteristics of objectivity, quantification and accuracy. It makes up for the diagnostic assessment defects that the commonly used clinical evaluation scales cannot obtain the quantitative data that truly reflect the functional state of patients, and can only subjectively evaluate the functional state. Since animal and human experiments have confirmed that the muscle structure of patients with nonspecific low back pain is characterized by the reduced cross-sectional area of paraspinal muscles, increased muscle fiber stiffness, reduced muscle contractility, and increased fat deposition^[19-21].

Many studies also found that the degree of multifidus and transversus abdominis atrophy was positively correlated with the duration of non-specific low back pain^[22, 23]. Therefore, through the measurement of the thickness and cross-sectional area of the target muscle transversus abdominal muscle and multifidus muscle, the prevalence and recovery of patients with nonspecific low back pain can be truly reflected. In addition, Standaert et al. also found that the flexion and extension ratio and flexion and extension strength of trunk were significantly improved after suspension training^[24]. This study showed that after 8 weeks of 4D PRO suspension rope training combined with Mulligan technology, the NRS, ODI and spinal activity scores of patients were significantly better than those before treatment; In addition, the evaluation of muscle-bone ultrasound also showed that the thickness of transversus abdominal muscle and multifidus muscle increased significantly on both involved and non-involved sides; Mulligan technology was also used in the control group, combined with the traditional rehabilitation training program. The results showed that after 8 weeks of comprehensive treatment, the clinical functional indexes and the thickness of transversus abdominal muscle and multifidus muscle also changed correspondingly, but the change range was significantly weaker than that in the suspension group.

This paper further proves the therapeutic effect of the comprehensive intervention scheme of exercise therapy combined with manipulation. Many scholars have confirmed that spinal muscle is an important influencing factor in the whole spinal system. For the muscle atrophy and disability of trunk core muscle group in patients with NLBP, the training of core muscle group, especially the joint activation of trunk front and rear chain extension and flexion muscle group, is very important to maintain the stability of the spine, to avoid repeated attacks after “recovery”^[25-27]. Compared with traditional rehabilitation training, suspension rope training increases more unstable factors, improving the delayed activation or non-activation state of muscles, correcting the original adverse action feedback mode of the body, giving the opportunity for the reconstruction of long-term damaged spine-related muscles, and finally improving the phased control and adjustment ability of patients to the spine, which improve the functional state of patients^[28]. At the same time, the simple and portable suspension rope training equipment is worthy to be popularized and applied in clinical work or home fitness.

5. Adverse events

There have been no reports of adverse events in either group.

6. Conclusion

In conclusion, this study has discovered that eight weeks of 4D PRO suspension rope training combined with Mulligan significantly reduced the symptoms of lumbar pain, improved lumbar function, and enhanced the muscle circumference of transverse abdominis and multifidus muscles compared with the control group. Since suspension rope training emphasizes core stability, especially by stimulating the transverse abdominis and multifidus muscles, patients with non-specific low back pain with core stability imbalance may benefit more.

Disclosure statement

The authors declare no conflict of interest.

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References

- [1] Kalichman L, Li L, Guermazi A, et al., 2008, Facet Joint Osteoarthritis and Low Back Pain in the Community-Based Population. *Spine*, 33(23): 2560–2565.
- [2] Chou R, Qaseem A, Snow V, et al., 2007, Diagnosis and Treatment of Low Back Pain: A Joint Clinical Practice Guideline from the American College of Physicians and the American Pain Society. *Ann Intern Med*, 147: 478–491.
- [3] Benjamin H, Laurent P, Toby H, 2015, Short-Term Effects of Mulligan Mobilization with Movement on Pain, Disability, and Kinematic Spinal Movements in Patients with Nonspecific Low Back Pain: A Randomized Placebo-Controlled Trial. *J Manipulative Physiol Ther*, 38: 365–374.
- [4] Garcia J, Hernandez-Castro J, Nunez R, et al., 2014, Prevalence of Low Back Pain in Latin America: A Systematic Literature Review. *J Pain Physician*, 17(5): 379–391.
- [5] Wand B, O’Connell N, 2008, Chronic Non-Specific Low Back Pain—Sub-Groups or a Single Mechanism. *BMC Musculoskeletal Disorders*, 9: 1–15.
- [6] Maher C, Underwood M, Buchbinder R, 2017, Non-Specific Low Back Pain. *Lancet*, 389: 736–747.
- [7] Park H, Jeong T, Lee J, 2017, Effects of Sling Exercise on Flexibility, Balance Ability, Body Form, and Pain in Patients with Chronic Low Back Pain. *Rehabil Nurs*, 42: E1–E8.
- [8] Yoo Y, Lee Y, 2012, The Effect of Core Stabilization Exercises Using a Sling on Pain and Muscle Strength of Patients with Chronic Low Back Pain. *J Phys Ther Sci*, 24: 671–674.
- [9] Roh H, Cho W, Ryu W, et al., 2016, The Change of Pain and Lumbosacral Sagittal Alignment After Sling Exercise Therapy for Patients with Chronic Low Back Pain. *J Phys Ther Sci*, 28: 2789–2792.
- [10] Tinto A, Campanella M, Fasano M, 2017, Core Strengthening and Synchronized Swimming: TRX Suspension Training in Young Female Athletes. *J Sports Med Phys Fitness*, 57(6): 744–751.

- [11] Kang H, Jung J, Yu J, 2012, Comparison of Trunk Muscle Activity During Bridging Exercises Using a Sling in Patients with Low Back Pain. *J Sports Sci Med*, 11(3): 510.
- [12] Ali M, Sethi K, Noohu M, 2019, Comparison of Two Mobilization Techniques in Management of Chronic Non-Specific Low Back Pain. *J Bodyw Mov Ther*, 23(4): 918–923.
- [13] Hoy D, Bain C, Williams G, et al., 2012, A Systematic Review of the Global Prevalence of Low Back Pain. *Arthritis Rheum*, 64(6): 2028–2037.
- [14] Price D, Bush F, Long S, et al., 1994, A Comparison of Pain Measurement Characteristics of Mechanical Visual Analogue and Simple Numerical Rating Scales. *Pain*, 56(2): 217–226.
- [15] Fairbank J, Pynsent P, 2000, The Oswestry Disability Index. *Spine*, 25: 2940–2953.
- [16] Hides J, Miokovic T, Belavy D, et al., 2007, Ultrasound Imaging Assessment of Abdominal Muscle Function During Drawing-In of the Abdominal Wall: An Intrarater Reliability Study. *J Orthop Sport Phys Ther*, 37: 480–486.
- [17] Mannion A, Pulkovski N, Gubler D, et al., 2008, Muscle Thickness Changes During Abdominal Hollowing: An Assessment of Between-Day Measurement Error in Controls and Patients with Chronic Low Back Pain. *Eur Spine J*, 17: 494–501.
- [18] Ferreira P, Ferreira M, Nascimento D, et al., 2011, Discriminative and Reliability Analyses of Ultrasound Measurement of Abdominal Muscles Recruitment. *Man Ther*, 16: 463–469.
- [19] Kim W, Lee S, Lee D, 2011, Changes in the Cross-Sectional Area of Multifidus and Psoas in Unilateral Sciatica Caused by Lumbar Disc Herniation. *J Korean Neurosurg Soc*, 50(3): 201.
- [20] Lee S, Chan C, Lam T, et al., 2006, Relationship Between Low Back Pain and Lumbar Multifidus Size at Different Postures. *Spine*, 31(19): 2258–2262.
- [21] John E, Beith I, 2017, Can Activity Within the External Abdominal Oblique Be Measured Using Real-Time Ultrasound Imaging? *Clin Biomech*, 22(9): 972–979.
- [22] Kiesel K, Uhl T, Underwood F, et al., 2007, Measurement of Lumbar Multifidus Muscle Contraction with Rehabilitative Ultrasound Imaging. *Man Ther*, 12(2): 161–166.
- [23] Panjabi M, 1992, The Stabilizing System of the Spine. Part I. Function, Dysfunction, Adaptation, and Enhancement. *J Spinal Disord*, 5(4): 383.
- [24] Standaert C, Herring S, Pratt T, 2004, Rehabilitation of the Athlete with Low Back Pain. *Curr Sports Med Rep*, 3(1): 35–40.
- [25] Ferreira P, Ferreira M, Maher C, et al., 2010, Changes in Recruitment of Transversus Abdominis Correlate with Disability in People with Chronic Low Back Pain. *Br J Sports Med*, 44(16): 1166–1172.
- [26] Cho S, Park S, 2008, Immediate Effects of Isometric Trunk Stabilization Exercises with Suspension Device on Flexion Extension Ratio and Strength in Chronic Low Back Pain Patients. *J Back Musculoskelet Rehabil*, 23(7): 1–6.
- [27] Qaseem A, Wilt T, McLean R, et al., 2017, Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline from the American College of Physicians. *Ann Intern Med*, 116(7): 514–530.
- [28] Yue Y, Wang X, Xie B, et al., 2014, Sling Exercise for Chronic Low Back Pain: A Systematic Review and Meta-Analysis. *PLoS One*, 9(6): e99307.

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Observation on the Clinical Efficacy of Platelet-rich Plasma Combined with Intra-articular Injection of Sodium Hyaluronate in the Treatment of Mild to Moderate Knee Osteoarthritis

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Abstract: *Objective:* To explore the clinical efficacy of platelet-rich plasma (PRP) combined with intra-articular injection of sodium hyaluronate in the treatment of mild to moderate knee osteoarthritis (KOA) and its effects on cartilage metabolism, oxidative stress status and cartilage structure. *Methods:* A total of 120 patients diagnosed with mild to moderate KOA in the orthopedics department of the hospital from January 2023 to October 2024 were selected and randomly divided into a control group and a study group, with 60 cases in each group. The control group was treated with intra-articular injection of sodium hyaluronate, while the study group was treated with PRP in combination on this basis. The treatment course was 4 weeks. The clinical efficacy, serum matrix metalloproteinase-13 (MMP-13), type II collagen degradation products (CTX-II), superoxide dismutase (SOD), malondialdehyde (MDA) levels and MRI-T2 mapping results of the two groups after 12 months of treatment were compared. *Result:* The total effective rate of the study group was 91.67%, which was higher than 75.00% of the control group ($p < 0.05$). After 12 months of treatment, the levels of serum MMP-13, CTX-II and MDA in the study group were all lower than those in the control group, and the level of SOD was higher than that in the control group ($p < 0.01$). MRI-T2 mapping showed that the average T2 value of cartilage in the study group was significantly lower than that in the control group, while the cartilage thickness increased significantly ($p < 0.05$). No serious adverse reactions occurred in either group. *Conclusion:* Intra-articular injection of PRP combined with sodium hyaluronate can significantly relieve pain in patients with KOA, improve joint function, inhibit cartilage degradation, reduce oxidative stress levels and promote cartilage repair. Its therapeutic effect is superior to that of sodium hyaluronate alone, and it has good safety.

Keywords: Platelet-rich plasma; Sodium hyaluronate; Knee osteoarthritis; Oxidative stress; MRI-T2 mapping; Cartilage metabolism

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1. Introduction

Knee osteoarthritis (KOA) is a chronic degenerative disease characterized mainly by degeneration of articular

cartilage and osteophyte formation. It is mainly manifested as knee pain, stiffness and limited mobility, which seriously affects the quality of life and mobility of patients^[1]. Epidemiological studies have shown that approximately 10% to 20% of middle-aged and elderly people have KOA lesions to varying degrees, and the incidence rate increases significantly with age^[2]. Common conservative treatment measures include oral non-steroidal anti-inflammatory drugs, functional exercises, and intra-articular injection of sodium hyaluronate, etc. However, their efficacy is limited, and some patients still experience recurrent joint pain and persistent cartilage degeneration after long-term use^[3]. Platelet-rich plasma (PRP) is a high-concentration platelet-rich plasma prepared by centrifugation and concentration of autologous blood. It is rich in various active components such as platelet-derived growth factor (PDGF), transforming growth factor β (TGF- β), vascular endothelial growth factor (VEGF), and epidermal growth factor (EGF). It can exert tissue repair and anti-degenerative effects by promoting chondrocyte proliferation, inhibiting inflammatory responses and improving local microcirculation^[4]. At present, there are relatively few clinical studies on the combined application of PRP and sodium hyaluronate. This article explored its impact on patients with mild to moderate KOA.

2. Materials and methods

2.1. General information

A total of 120 patients with mild to moderate KOA who were diagnosed in the orthopedic outpatient department or inpatient department of the hospital from January 2023 to October 2024 were selected. Follow up for one year. The patients were divided into the control group and the study group, with 60 cases in each group, by the random number table method. In the control group, there were 26 males and 34 females. There were 25 male cases and 35 female cases in the research group.

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

All patients met the diagnostic criteria of the “Guidelines for the Diagnosis and Non-surgical Treatment of Early Knee Osteoarthritis (2024 Edition)”^[5]. It was confirmed as K-L grade I - II by imaging examination (X-ray or MRI). Knee pain for ≥ 3 months, significantly aggravated after activity; No glucocorticoids or other intra-articular injection drugs have been used in the past month. No blood system diseases or severe heart, liver or kidney function disorders; Sign the informed consent form and voluntarily accept treatment.

2.2.2. Exclusion criteria

Combined with rheumatoid arthritis, gouty arthritis or other types of joint lesions; Combined with suppurative arthritis, tuberculous arthritis or intra-articular infection; A history of severe deformity or traumatic fracture of the knee joint; Those with abnormal coagulation function or using anticoagulant drugs; Pregnant or lactating women.

2.3. Methods

The control group was treated with intra-articular injection of sodium hyaluronate injection. The patient was placed in a supine position with the knee joint flexed to approximately 30 degrees. After routine skin disinfection and laying a towel, the puncture point was selected at the outer upper edge of the patella, and a 22 G puncture needle was inserted into the knee joint cavity. After drawing out a small amount of synovial fluid and confirming its insertion into the cavity, inject 2 mL (25 mg) of sodium hyaluronate once a week for a total of 4 times.

The research group was treated with autologous PRP injection on the basis of the control group. 20 mL of elbow venous blood was collected from the patient and placed in a sterile anticoagulant tube. After centrifugation twice (the first time at 1800 r/min × 10 min, and the second time at 3500 r/min × 10 min), approximately 3 mL of platelet-rich plasma was taken from the middle layer for later use. Before injection, 2 mL of sodium hyaluronate and 3 mL of PRP are thoroughly mixed and slowly injected into the knee joint cavity at the same injection point. After the injection, the patient was instructed to lie flat for 30 minutes and avoid weight-bearing activities for 24 hours. Both drugs are injected once a week for a total of four times.

2.4. Observation indicators

2.4.1. Therapeutic effect

All patients were followed up for one year. At 12 months of treatment, the Visual Analogue Scale (VAS) and the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) were used for assessment.

(1) Cure

The VAS decreased by $\geq 70\%$ compared to the baseline, and the total WOMAC score decreased by $\geq 60\%$ compared to the baseline, accompanied by disappearance of knee swelling and normal movement.

(2) Improvement

Meeting any of the following conditions: a 30% to 69% decrease in VAS or a 20% to 59% decrease in WOMAC, with symptoms and activity levels improving compared to before

(3) Ineffective

VAS decreases by less than 30% and/or WOMAC decreases by less than 20%, or symptoms worsen. The total effective rate (%) is calculated as (cure + improvement)/total number of cases × 100%.

2.4.2. Cartilage metabolism markers

The levels of serum matrix metalloproteinase-13 (MMP-13) and type II collagen degradation products (CTX-II) were detected using ELISA. Tests were conducted before treatment and at 12 months of treatment respectively.

2.4.3. Regulatory indicators of oxidative stress

The levels of serum superoxide dismutase (SOD) and malondialdehyde (MDA) were detected, respectively before treatment and 12 months after treatment.

2.4.4. Quantitative assessment of MRI-T2 mapping

Knee joint MRI examination was performed. The T2 mapping technique was applied to quantify the changes in cartilage signals, and the thickness and T2 value of articular cartilage were measured. Tests were conducted before treatment and at 12 months of treatment respectively.

2.4.5. Adverse reactions

All patients were followed up for one year, and the occurrence of infection, bleeding, joint effusion, and pain at the injection site during the treatment period was statistically analyzed in detail.

3. Results

3.1. Comparison of clinical efficacy

The effective rate of treatment in the study group was higher than that in the control group ($p < 0.05$). As shown in Table 1.

Table 1. Comparison of clinical efficacy [n (%)]

Group	n	Cure	Improvement	Invalid	Total effective rate (%)
Control group	60	23 (38.33)	22 (36.67)	15 (25.00)	45 (75.00)
Research group	60	31 (51.67)	24 (40.00)	5 (8.33)	55 (91.67)
χ^2					6.000
p value					0.014

3.2. Comparison of cartilage metabolism markers

After 12 months of treatment, the levels of serum MMP-13 and CTX-II in the study group were lower than those in the control group, as shown in Table 2.

Table 2. Comparison of cartilage metabolic markers levels ($\bar{x} \pm s$)

Group	n	MMP-13 (pg/mL)		CTX-II (ng/mL)	
		Before treatment	The treatment lasted for 12 months	Before treatment	The treatment lasted for 12 months
Control group	60	145.08 \pm 24.87	115.65 \pm 19.76	7.79 \pm 1.36	5.98 \pm 1.18
Research group	60	146.52 \pm 25.38	96.47 \pm 18.32	7.83 \pm 1.42	4.92 \pm 1.10
χ^2		0.314	5.514	0.158	5.090
p value		0.754	0.000	0.875	0.000

3.3. Comparison of oxidative stress indicators

After 12 months of treatment, the SOD level in the study group was higher than that in the control group, while the MDA level was lower than that in the control group ($p < 0.05$). As shown in Table 3.

Table 3. Comparison of oxidative stress indicators ($\bar{x} \pm s$)

Group	n	SOD (U/mL)		MDA (nmol/mL)	
		Before treatment	The treatment lasted for 12 months	Before treatment	The treatment lasted for 12 months
Control group	60	78.92 \pm 9.07	95.72 \pm 9.61	5.29 \pm 1.05	4.12 \pm 0.91
Research group	60	79.34 \pm 9.12	108.46 \pm 10.58	5.38 \pm 1.02	3.41 \pm 0.83
χ^2		0.253	6.904	0.476	4.465
p value		0.801	0.000	0.635	0.000

3.4. Quantitative imaging results of MRI-T2 mapping

After 12 months of treatment, the average T2 value of cartilage in the study group was lower than that in the

control group, and the cartilage thickness was higher than that in the control group ($p < 0.05$). As shown in **Table 4**.

Table 4. Comparison of MRI-T2 mapping indicators ($\bar{x} \pm s$)

Group	n	SOD (U/mL)		MDA (nmol/mL)	
		Before treatment	The treatment lasted for 12 months	Before treatment	The treatment lasted for 12 months
Control group	60	46.10 \pm 4.52	42.91 \pm 4.08	2.45 \pm 0.29	2.68 \pm 0.33
Research group	60	46.32 \pm 4.58	40.15 \pm 3.94	2.47 \pm 0.31	2.86 \pm 0.34
χ^2		0.265	3.769	0.365	2.943
p value		0.792	0.000	0.716	0.004

3.5. Adverse reactions

No serious adverse events such as infection, bleeding or joint effusion occurred in either group. In the study group, there were 3 cases (5.00%) with mild acid and distension at the injection site, and in the control group, there were 2 cases (3.33%). The symptoms were all relieved within 24 hours. There was no statistically significant difference ($\chi^2 = 0.209, p > 0.05$).

4. Discussion

KOA is a degenerative disease driven by mechanical stress, inflammatory response and metabolic abnormalities. Its core pathological features are articular cartilage degradation, synovitis and subchondral osteosclerosis. Research indicates that inflammatory factors such as tumor necrosis factor- α (TNF- α) and interleukin-1 β (IL-1 β) can promote the overexpression of matrix metalloproteinases (MMPs) by activating the nuclear factor- κ B (NF- κ B) signaling pathway, thereby accelerating the degradation of type II collagen and proteoglycans, and causing damage to cartilage structure and functional degeneration^[6]. Sodium hyaluronate, as an injection material for viscoelastic joints, can lubricate the joints, reduce friction and improve the rheological properties of synovial fluid, thereby alleviating pain and delaying cartilage wear^[7]. However, sodium hyaluronate alone has limited effects on cartilage regeneration and inflammation regulation. PRP is rich in various growth factors and cytokines, and can regulate the synovial environment and cartilage metabolism balance by stimulating chondrocyte proliferation, promoting type II collagen synthesis and inhibiting the release of inflammatory factors^[8].

Sodium hyaluronate provides a favorable repair environment for PRP by improving the viscoelasticity of synovial fluid, reducing friction and lowering the stress within the joint. Therefore, the PRP combined with sodium hyaluronate regimen takes into account the dual effects of “mechanical buffering” and “biological repair”, making the recovery of joint function more comprehensive. In this study, after 12 months of treatment, the levels of MMP-13 and CTX-II in the study group were lower than those in the control group, suggesting that the combination of PRP and sodium hyaluronate has a better effect in inhibiting the degradation of cartilage matrix^[9]. MMP-13 is a key enzyme for degrading type II collagen, and its high expression is closely related to the degeneration of KOA cartilage. CTX-II reflects the metabolic status of type II collagen. The growth factors released in PRP can down-regulate the expression of MMP-13 and reduce the degradation of type II collagen by regulating the local inflammatory microenvironment and inhibiting the continuous activation of the NF- κ B signaling pathway^[10]. Meanwhile, sodium hyaluronate works together to slow down the imbalance of cartilage

metabolism by improving the viscosity of the joint cavity, alleviating mechanical friction damage and reducing the stress response of chondrocytes. In recent years, many high-quality studies abroad have further verified the clinical and imaging advantages of PRP in the treatment of mild to moderate KOA. Yoshioka et al. conducted a randomized, double-blind, placebo-controlled clinical trial and found that leukocyte-rich platelet-rich plasma (LP-PRP) used in patients with mild to moderate KOA accompanied by joint effusion or bone marrow lesions could significantly improve pain and joint function, and its efficacy was better than that of the control group, suggesting that PRP has good adaptability in various pathological conditions ^[11]. Aalishan et al. found based on MRI quantitative analysis that after intra-articular injection of autologous PRP in patients with moderate KOA, the T2 value of cartilage significantly decreased, and the joint pain and functional scores improved ^[12]. This suggests that PRP can effectively improve the hydration state of cartilage and the arrangement of collagen fibers, promoting cartilage repair, which is consistent with the MMRI T2 mapping results of this study. Favian et al. reported that after LP-PRP treatment for mild to moderate KOA, the values of cartilage T1ρ and T2 in patients decreased, and both WOMAC and VAS scores improved significantly, indicating that PRP can bring continuous benefits in both imaging and subjective outcomes ^[13]. The experimental study by Prathap et al. demonstrated that leukocyte-rich PRP (LR-PRP) has a more significant anti-inflammatory effect compared to leukocyte-poor PRP, and can inhibit the release of inflammatory mediators, indicating that the proportion of internal components of PRP may affect the difference in its therapeutic effect ^[14]. Furthermore, Elena et al. pointed out in a follow-up analysis that PRP combined with high tibial osteotomy for the treatment of patients with severe KOA can further improve joint stability and structural reconstruction, providing a new idea for the combined application ^[15].

The results of this study show that after 12 months of treatment, the SOD level in the study group increased and the MDA level decreased, indicating that PRP combined with sodium hyaluronate can effectively alleviate oxidative stress damage. Oxidative stress is one of the important mechanisms for the chronic progression of KOA. Excessive production of reactive oxygen species can induce chondrocyte apoptosis and promote inflammatory cascade reactions ^[16]. PRP can enhance the activity of antioxidant enzymes, eliminate free radicals, and alleviate lipid peroxidation reactions in cell membranes, thereby improving the microenvironment of cartilage ^[17]. Meanwhile, sodium hyaluronate has the ability to eliminate oxygen free radicals. When used in combination, it can further enhance the antioxidant effect. The MRI-T2 mapping results showed that after 12 months of treatment, the T2 value in the study group decreased significantly and the cartilage thickness increased, suggesting that the cartilage structure was repaired at an early stage. The T2 value mainly reflects the hydration of cartilage and the arrangement of collagen. A decrease indicates that the collagen fiber structure within the cartilage tissue becomes more complete and the water content returns to normal. PRP promotes the synthesis of type II collagen by chondrocytes, and sodium hyaluronate improves lubrication and nutrient supply. The synergy of the two can alleviate microdamage between cartilage layers and promote matrix reconstruction ^[18,19]. PRP is derived from autologous blood and has no risk of immune rejection or transmission, so its safety is relatively good ^[20].

5. Conclusion

In conclusion, the intra-articular injection of PRP combined with sodium hyaluronate can significantly relieve pain in patients with KOA, improve joint function, inhibit cartilage degradation, reduce oxidative stress levels and promote cartilage repair. Its therapeutic effect is superior to that of sodium hyaluronate alone, and it has good safety.

Disclosure statement

The author declares no conflict of interest.

References

- [1] Zhang R, Wang Q, Jiang X, et al., 2024, The Clinical Efficacy of Jinggu Xiaotong Powder Combined with Platelet-Rich Plasma in Patients with Knee Osteoarthritis. *Chinese Patent Medicine*, 46(02): 465–469.
- [2] Ma X, Yuan X, Zhang L, et al., 2020, Study on the Protective Effect and Mechanism of Ozone Combined with Platelet-Rich Plasma on IL-1 β -Induced Inflammatory Injury of Human Chondrocytes. *Chinese Journal of Pain Medicine*, 31(08): 602–611.
- [3] Cui B, Li D, Li B, 2025, The Effect of Platelet-Rich Plasma Compound Vibration on OPF Rats. *Chinese Journal of Osteoporosis*, 31(08): 1137–1141 + 1151.
- [4] Zhang W, Ma X, Zhang D, et al., 2020, The Immunomodulatory Effect of White Blood Cell-Rich Platelet-Rich Plasma (L-PRP) on the Microenvironment of Spinal Cord Injury. *Chinese Journal of Pathogenic Biology*, 20(08): 982–987 + 993.
- [5] Bone and Joint Branch of China Association of Geriatric Health Care, 2024, Guidelines for Diagnosis and Non-Surgical Treatment of Early Knee Osteoarthritis (2024 Edition). *Chinese Medical Journal*, 104(31): 2895–2909.
- [6] Dong H, Wang W, Lu Y, et al., 2024, Protective Effect of Passive Exercise on Articular Cartilage in Rats with Knee Osteoarthritis Based on the NF- κ B Signaling Pathway. *Chinese Journal of Gerontology*, 44(05): 1141–1145.
- [7] Shang X, Wang F, Yang Q, et al., 2020, Clinical Study on the Treatment of Cold-Dampness Obstruction Syndrome in Knee Osteoarthritis by Platelet-Rich Plasma Injection Combined with Warm Acupuncture. *Journal of Beijing University of Chinese Medicine*, 48(02): 270–279.
- [8] Zhang Y, Liu S, Xie S, et al., 2020, Re-Evaluation of the Systematic Review of Platelet-Rich Plasma and Hyaluronic Acid in the Treatment of Knee Osteoarthritis. *Chinese Journal of Tissue Engineering Research*, 29(28): 6138–6145.
- [9] Mei B, Rao Y, Cai Y, et al., 2024, Influence of Internal Heat Injection Combined with PRP Injection on Serum TNF- α and NF- κ B Levels in Patients with Knee Osteoarthritis. *Shi Zhen Chinese Medicine and Chinese Materia Medica*, 35(07): 1664–1666.
- [10] Chen X, Dong H, Wang X, et al., 2024, Efficacy of Combined PRP and Ozone in the Treatment of Knee Osteoarthritis. *Chinese Journal of Gerontology*, 44(05): 1065–1068.
- [11] Yoshioka T, Arai N, Sugaya H, et al., 2024, Effectiveness of Leukocyte-Poor Platelet-Rich Plasma Injections for Symptomatic Mild to Moderate Osteoarthritis of the Knee with Joint Effusion or Bone Marrow Lesions in a Japanese Population: A Randomized, Double-Blind, Placebo-Controlled Clinical Trial. *The American Journal of Sports Medicine*, 52(10): 3635465241263073.
- [12] Aalishan S, Ahmed A, Majid J, et al., 2024, MRI-Based Cartilage Changes and Clinical Effectiveness of Autologous Intra-Articular Platelet-Rich Plasma Injections in Symptomatic Patients with Moderate Osteoarthritis of the Knee. *Egyptian Journal of Radiology and Nuclear Medicine*, 55(1): 23–27.
- [13] Su F, Tong M, Lansdown D, et al., 2023, Leukocyte-Poor Platelet-Rich Plasma Injections Improve Cartilage T1 ρ and T2 and Patient-Reported Outcomes in Mild-to-Moderate Knee Osteoarthritis. *Arthroscopy, Sports Medicine, and Rehabilitation*, 5(3): e817–e825.
- [14] Jayaram P, Mitchell P, Shybut B, et al., 2023, Leukocyte-Rich Platelet-Rich Plasma Is Predominantly Anti-Inflammatory Compared with Leukocyte-Poor Platelet-Rich Plasma in Patients with Mild-Moderate Knee Osteoarthritis: A Prospective, Descriptive Laboratory Study. *The American Journal of Sports Medicine*, 51(8): 2133–

2140.

- [15] Elena T, 2023, Letter to the Editor Regarding “Clinical Benefit of High Tibial Osteotomy Combined with the Intervention of Platelet-Rich Plasma for Severe Knee Osteoarthritis.” *Journal of Orthopaedic Surgery and Research*, 18(1): 207–207.
- [16] Xu H, Zhang T, Yin Q, et al., 2025, Effect of Hip Cavity Injection of Platelet-Rich Plasma Under Ultrasound Combined with Silver Needle in the Treatment of Femoral Head Necrosis. *Journal of Practical Medicine*, 41(11): 1711–1717.
- [17] Chen C, Liu Y, Yin H, 2024, Microscopic Clearance of Platelet-Rich Plasma for the Treatment of Mild to Moderate Knee Osteoarthritis. *Chinese Journal of Orthopedic Surgery*, 32(04): 314–319.
- [18] Ma C, Pan H, Cui R, et al., 2024, Effect of Platelet-Rich Plasma Combined with Sodium Hyaluronate on Osteoporotic Fracture Rats. *Chinese Journal of Osteoporosis*, 30(01): 44–49.
- [19] Dong W, Wang X, Gu Y, et al., 2024, HTO Combined with Platelet-Rich Plasma for Joint Cleanup in the Treatment of Medial Knee Osteoarthritis. *Chinese Journal of Orthopedic Surgery*, 32(01): 11–17.

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