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Impact of Pain Management and Rehabilitation Exercises on Ankle Fractures

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Abstract. The ankle joint is an important weight-bearing structure in the human body and is prone to fracture, so a comprehensive understanding of the anatomical structure of the ankle joint is essential for accurate diagnosis and targeted intervention. In this paper, we take ankle fractures as the research object, and while exploring its anatomical basis and clinical characteristics, we systematically analyze the role mechanism and synergistic effect of pain treatment and rehabilitation exercise in the treatment process. The results of the study show that pain treatment can not only relieve patients' discomfort, but also create favorable conditions for early recovery. Scientific rehabilitation exercises based on individual clinical characteristics can significantly promote the recovery of joint function and reduce the risk of long-term complications. These findings provide valuable theoretical support for improving the clinical treatment program of ankle fractures, which ultimately helps to improve the prognosis and quality of life of patients.

Keywords: Ankle fracture, pain management, rehabilitation exercise, therapeutic effect, prognosis.

1. Introduction

The ankle joint, a critical weight-bearing structure in the human body, is composed of the distal tibia, distal fibula, and talar trochlea, playing an indispensable role in daily activities such as walking, running, jumping, and weight-bearing [1]. With the acceleration of modern life rhythms and the growing popularity of sports, the incidence of ankle fractures has increased annually, particularly among professional athletes, manual workers, and the elderly [2]. Post-fracture, patients typically experience severe pain, swelling, and limited mobility, which impair quality of life and may induce negative emotions like anxiety and depression [1]. Without timely intervention, long-term complications such as muscle atrophy, joint adhesions, and traumatic arthritis can occur, and severe cases may even lead to permanent joint dysfunction [2]. Beyond basic treatments like reduction and fixation, scientific pain management and systematic rehabilitation training have emerged as key factors influencing treatment outcomes and prognosis [1].

Internationally, research on ankle fractures has advanced considerably. In terms of pain management, multimodal approaches combining non-steroidal anti-inflammatory drugs (NSAIDs), opioids, and regional anesthesia have been widely explored, with studies showing that early analgesia reduces stress responses and accelerates recovery [3]. For rehabilitation, staged protocols

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emphasizing early mobilization (e.g., isometric exercises within 48 hours post-fixation) have been validated to prevent joint stiffness [4]. However, debates persist regarding optimal timing for weight-bearing training, with some advocating delayed loading to avoid re-fracture, while others support controlled early loading to enhance proprioception [5,6].

Domestically, research has focused on integrating traditional Chinese medicine (TCM) with modern rehabilitation. Acupuncture and herbal compresses have been reported to alleviate pain by regulating local blood circulation, and clinical trials have shown that TCM-assisted rehabilitation reduces swelling duration by 30% compared to conventional methods [7,8]. In terms of surgical techniques, minimally invasive internal fixation has gained popularity, with studies highlighting its advantages in reducing soft tissue damage [9]. However, gaps remain: domestic pain management protocols lack standardization, and rehabilitation training adherence is often poor due to inadequate patient education [10]. Both domestic and international studies acknowledge the synergy between pain management and rehabilitation but rarely quantify their combined effects. Most research focuses on single modalities, leaving a need for integrated frameworks that address their interplay [3,7].

Despite progress, inconsistencies in pain management protocols and fragmented rehabilitation strategies hinder optimal patient outcomes. The aim of this study is to determine targeted analgesic methods by analyzing the pathophysiological basis of ankle fracture pain. At the same time, this article combines traditional Chinese medicine and modern technology to propose a phased rehabilitation model suitable for the severity of fractures, and evaluates the synergistic effect of pain management and rehabilitation on functional recovery. This comprehensive approach aims to provide evidence-based guidelines for clinical practice, ultimately promoting faster recovery and improved quality of life for patients [1,2].

2. Overview of ankle fractures

2.1. Anatomical structure of the ankle joint

The ankle joint is a joint composed of the lower end of the tibia, the lower end of the fibula and the talus pulley [1,2]. The medial malleolus is formed by the lower end of the tibia, while the lateral malleolus is formed by the lower end of the fibula. These two, together with the talus pulley, form the ankle tenon, which plays a role in stabilizing the talus. There are some ligaments around the ankle joint. Such as the medial deltoid ligament, the lateral anterior talufibular ligament, the posterior talufibular ligament and the calcaneus ligament, etc., these ligaments are key structures for maintaining joint stability. In addition, muscles and tendons such as the triceps brachii and anterior tibial muscles are responsible for driving the ankle joint to perform flexion, extension, inversion and eversion movements.

2.2. Etiology and classification of ankle fractures

Ankle fractures are mostly caused by violent factors and can be classified into two types: direct violence and indirect violence [1,2]. Direct violence situations, such as being hit by heavy objects or being involved in a car accident, can directly lead to fractures. Indirect violence is more common, such as sudden twisting of the foot while walking or uneven force on the foot when falling from a height, which can cause fractures through the transmission of force.

The commonly used clinical classification methods are the Lauge-Hansen classification and the Danis-Weber classification [2]. The Lauge Hansen classification is based on damage mechanisms

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and can be specifically divided into types such as posterior adduction and posterior outward rotation. The Danis Weber classification is based on the relationship between the site of fibular fracture and the tibiofibular syndesmosis, and is divided into three types: A, B and C. Different classification methods have important guiding significance for the selection of treatment plans (such as conservative treatment or surgical treatment) and the development of rehabilitation plans.

2.3. Clinical manifestations of ankle fractures

After an ankle fracture occurs, the patient will show some typical symptoms [3]. The injured area will experience severe pain, and this pain will intensify with the progress of exercise. Swelling will quickly appear in the local area, and it is usually accompanied by subcutaneous ecchymosis. If the condition is more serious, Patients may experience ankle deformities, such as presenting as varus or valgus. In addition, due to the pain and structural abnormalities, the range of motion of the ankle joint has been greatly restricted, making it impossible for the patient to bear weight or walk. During the clinical examination process, imaging methods such as X-rays and CT scans can be used to determine the type and displacement of the fracture.

3. The impact of pain management on ankle fractures

3.1. The importance of pain management

After an ankle fracture occurs, pain becomes the most prominent symptom [3]. If the pain cannot be effectively controlled, it will trigger a series of chain reactions. The patient will find it difficult to fall asleep due to the pain. Insufficient sleep will reduce the body's recovery ability. Being in a state of pain for a long time. It is very easy to generate negative emotions such as anxiety and depression, which can affect confidence in treatment. Patients may refuse to engage in activities due to fear of pain, which may lead to complications such as muscle atrophy and joint adhesion, resulting in a decline in treatment compliance. It can be seen that pain management is a fundamental aspect in the treatment of ankle fractures.

3.2. Methods of pain management

The main methods of pain management include medication therapy, physical therapy, and psychological intervention therapy. Non-steroidal anti-inflammatory drugs such as ibuprofen and celecoxib can effectively alleviate discomfort and pain symptoms caused by inflammatory reactions in drug therapy. For moderate to severe pain, opioid analgesics such as tramadol can be used for the short term, but attention should be paid to the addictive nature of such drugs and their side effects on the gastrointestinal tract. Cold compress during the acute phase of physical therapy (within 48 hours of onset) can cause vasoconstriction and achieve the effect of reducing swelling and relieving pain [4,7]. After the acute phase, a hot compress can accelerate blood circulation and relieve muscle spasms. In addition, physical methods such as ultrasound therapy and transcutaneous electrical nerve stimulation (TENS) can also alleviate pain by suppressing pain signal transduction. Psychological intervention is achieved through communication between medical staff and patients, explaining the specific mechanism of pain and the entire treatment process, guiding patients to engage in deep breathing and progressive muscle relaxation training to alleviate inner fear and reduce pain sensitivity.

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3.3. The impact of pain management on treatment outcomes

Effective pain management can significantly improve treatment outcomes. For example, pharmacological pain management (using analgesic drugs) is suitable for acute, severe pain in the early fracture stage [4]. It acts quickly to relieve pain, but long-term use may cause side effects like gastrointestinal disturbances. So, it needs close monitoring, especially for elderly patients with weak liver and kidney function.

Non - pharmacological methods, such as psychological intervention-based pain management (cognitive-behavioral therapy), are better for chronic pain during rehabilitation. They enhance the body's self-healing ability by improving sleep quality. Good sleep boosts the body's self-repairing ability, creating favorable conditions for fracture healing [1,2]. When pain is relieved via these methods, patients are more willing to actively cooperate with treatment, laying a solid foundation for subsequent rehabilitation training.

Also, pain management can reduce the risk of muscle atrophy and complications like joint stiffness from drug withdrawal. For joint stiffness prevention, continuous passive motion (CPM) devices, a kind of physical pain-relieving and joint-maintaining method, are great in the early post-operative stage. But patients with severe joint swelling may not be suitable, as it could worsen inflammation. Thus, choosing the right pain-management method based on the patient's specific condition (fracture type, pain level, physical status) and closely watching for side effects or complications is key to promoting early joint function recovery.

4. The impact of rehabilitation exercises on ankle fractures

Rehabilitation training is a key approach in the treatment of ankle fractures to promote functional recovery. It has multiple functions. On the one hand, it can enhance local blood circulation, accelerate the supply of nutrients to the fracture site, and speed up the excretion of metabolic waste, thus speeding up the healing process [5,6]. On the other hand, it can prevent muscle atrophy (especially in the calf muscles) and joint adhesion through moderate activities. It can also gradually restore the range of motion, muscle strength and coordination of the ankle joint, ultimately achieving a full recovery of joint function. It can also promote fracture healing and improve local blood circulation. Regulate bone metabolism; Restore joint range of motion; Strengthen muscle strength. Rebuilding proprioception and so on can all enable patients to walk more freely and stably and carry out other activities. During the rehabilitation training process, patients can gradually restore joint function and observe positive changes in their physical condition, which can enhance their confidence in overcoming injuries and illnesses, improve negative emotions such as anxiety and depression caused by fractures, and face rehabilitation and life with a better attitude.

Rehabilitation training for ankle fractures is a comprehensive and dynamic process that encompasses multiple aspects of physiological healing, complication prevention, and functional restoration. By understanding and implementing these multifaceted mechanisms, healthcare professionals can optimize the recovery process for patients, enabling them to regain full ankle joint function and return to their normal lives.

4.1. Stages and methods of rehabilitation exercises

Rehabilitation exercises should follow the principle of "gradual progress" and develop a plan based on the stage of fracture healing: in the early stage of fracture (0-2 weeks), the main focus is on promoting blood circulation and preventing complications. Active movement of the interphalangeal

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joint, isometric contraction of the quadriceps (tightening and relaxing the thigh muscles), and straight leg lifting exercises can be performed. The key at this stage is to avoid ankle joint weight-bearing or vigorous activity. In the middle stage of fracture (2-6 weeks), if the fracture healing is good (X-ray shows callus formation), at this time, the ankle joint movement can be appropriately increased, such as performing slow flexion and extension movements of the ankle joint, as well as varus and valgus movements (within the range that does not cause obvious pain) [10]. It is also necessary to strengthen the training of calf muscle training. (such as resisted toe curling and foot pointing). In the late stage of fracture (6 weeks to 3 months), the focus is on restoring ankle joint function and weight-bearing ability. Weight training can be gradually carried out (from partial weight-bearing to full weight-bearing), balance training (such as standing on one leg), gait training and daily activity function exercises (such as following the stairs).

4.2. The impact of rehabilitation exercises on treatment outcomes

Clinical research shows that scientific rehabilitation training has a positive impact on treatment outcomes, not only effectively restoring ankle range of motion and muscle strength, improving patient functional scores (such as AOFAS ankle hind foot score), but also reducing the incidence of traumatic arthritis by preventing joint adhesion and muscle atrophy [7]. At the same time, patients gain a sense of achievement during the process of functional improvement, which can alleviate anxiety and enhance their confidence in rehabilitation. For special groups such as athletes and physical laborers, personalized rehabilitation training can specifically restore their athletic ability or labor function, helping them re-adapt to work and life, and improve their psychological state and life satisfaction. In short, rehabilitation training is a crucial link connecting "fracture healing" and "functional rehabilitation", directly determining the quality of treatment outcomes and serving as the core means to transform "anatomical healing" into "functional healing".

5. The synergistic effect of pain management and rehabilitation exercises

Pain is the most significant hindering factor for patients to participate in rehabilitation exercises. Effective pain management can alleviate patients' fear and resistance to activities, encourage them to cooperate more actively with training, and improve the compliance and quality of rehabilitation training [6]. For example, early postoperative use of cold compress and medication for pain relief can allow patients to start limb activities as early as possible while the pain is controllable. Rehabilitation training does not worsen pain. On the contrary, it can alleviate chronic pain by promoting local blood circulation, reducing the accumulation of inflammatory factors, and relieving muscle spasms. The recovery of muscle strength and joint stability can reduce abnormal stress at the fracture site, fundamentally reducing pain triggers.

The collaborative application of pain management and rehabilitation training can form a virtuous cycle of "pain reduction, active exercise, functional improvement, further pain relief" [8]. This synergistic effect can significantly enhance treatment efficacy, accelerate fracture healing and functional recovery, reduce the incidence of complications, and ultimately improve patients' quality of life, enabling them to return to normal work and life faster.

6. Conclusion

During the treatment of ankle fractures, pain management and rehabilitation training are indispensable steps. Pain management helps to alleviate pain and improve physical and mental

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conditions, creating conditions for rehabilitation; rehabilitation training promotes healing, restores function, and achieves the ultimate goal of treatment. The synergy of these two aspects can significantly enhance treatment efficacy, reduce complications, and improve the prognosis of patients. In clinical practice, individualized design is necessary, that is, to formulate pain management and rehabilitation plans based on factors such as fracture type, patient age, and physical condition. As emphasized in the "Diagnosis and Treatment Guidelines for Ankle Fractures (2020 Edition)", it is necessary to conduct individualized design in clinical practice, that is, to formulate pain management and rehabilitation plans based on factors such as fracture type, age, and patient's physical condition. For example, elderly patients may need to adjust drug doses, while athletes may need to strengthen functional training - this difference is also supported by Smith A et al. in their systematic review on pain management and rehabilitation of ankle fractures. Multidisciplinary collaboration is also crucial. Orthopedic doctors, rehabilitation therapists, nurses, and other team members need to work together throughout the treatment and rehabilitation process to provide comprehensive guidance to patients. This collaborative approach is consistent with the clinical insights on clinical research on bones and joint injuries, which advocates for a comprehensive care model. Moreover, patient education is very important. Informing patients about the importance of pain management and rehabilitation training, enhancing their self-management ability, and ensuring the continuity of treatment can draw on practical experiences. Looking to the future, it is recommended to formulate precise plans based on fracture classification, introduce virtual reality and intelligent rehabilitation equipment for training, conduct long-term follow-ups (such as over 5 years), and deeply explore the impact of collaborative intervention on long-term complications such as traumatic arthritis. Through continuous research and practice, more effective treatment plans can be provided for patients to promote their comprehensive rehabilitation.

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