Extracorporeal Shock wave Therapy in the Treatment of Adhesive Capsulitis of the Shoulder: A Novel Approach-CapsuWave

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Abstract

Adhesive capsulitis, commonly known as frozen shoulder, is a musculoskeletal condition characterized by intense pain and progressive limitation of mobility in the glenohumeral joint, often associated with diseases such as diabetes and autoimmune conditions. Its etiology remains incompletely understood but involves inflammatory and fibrotic factors that lead to adhesions of the articular capsule. The clinical presentation is divided into three phases: Inflammatory, frozen, and resolution, each varying in duration and symptom intensity. Extracorporeal shock wave therapy (ESWT) has emerged as a non-invasive treatment approach for this condition, showing positive results in improving range of motion and reducing pain. ESWT works by modulating the inflammatory response and promoting tissue regeneration, as evidenced by studies demonstrating its beneficial effects, especially when combined with other therapies. A detailed case study of a 58-year-old patient with a trauma history indicating adhesive capsulitis is presented, highlighting the symptoms and limitations encountered. Treatment included shock wave applications, following the CapsuWave technique, which optimizes treatment administration. Results suggest that ESWT offers a more accelerated functional recovery compared to other therapies, such as corticosteroid injections. Continued investigation into the pathophysiology of adhesive capsulitis and the efficacy of shock wave therapy is crucial for developing more effective treatment options. A multidisciplinary approach, integrating diverse areas of medicine, is essential for the proper management of this complex condition, aiming not only for pain reduction but also for improving the patients' quality of life.
Keywords: Adhesive capsulitis, Shoulder pain, Extracorporeal shock wave therapy

Introduction

Adhesive capsulitis (Frozen shoulder)

Adhesive capsulitis, commonly referred to as frozen shoulder, is a musculoskeletal disorder characterized by spontaneous inflammation that may be associated with minor trauma, autoimmune conditions, or diseases such as diabetes mellitus. It leads to intense pain and weakness, accompanied by a progressive loss of the ability to move the glenohumeral joint in various directions, both voluntarily and passively. This condition is marked by progressive thickening and stiffness of the glenohumeral articular capsule, as well as the formation of adhesions [1].

This condition is more prevalent among middle-aged adults, with an incidence ranging from 2% to 5% in the general population [2], and it has a higher prevalence in women [3] compared to men, with an approximate ratio of 1.4:1 [4]. Although unilateral cases of adhesive capsulitis are more common, it is estimated that bilateral adhesive capsulitis affects 2%–5% of the general population [5].

The etiology of adhesive capsulitis is not yet fully understood [6], but it is believed to be triggered by various factors such as genetic, environmental, and systemic influences. Chronic inflammation of the joint capsule and subsequent fibrosis are central pathological mechanisms in the progression of the disease [3]. Previous shoulder trauma and prolonged immobilization are also considered significant risk factors for the development of adhesive capsulitis [5].

The pathophysiology of adhesive capsulitis still requires further elucidation but is thought to involve a combination of inflammatory

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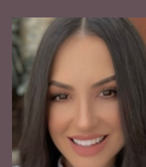
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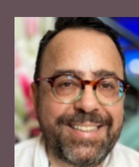
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and fibrotic factors. Studies indicate that initial synovial inflammation leads to fibrosis, resulting in capsular thickening and adhesions [7]. The presence of inflammatory cells, such as lymphocytes and macrophages, suggests an autoimmune component in the disease's pathogenesis [8]. In addition, biochemical alterations, such as increased levels of proinflammatory cytokines and growth factors, have been observed, contributing to the fibrosis and contracture of the articular capsule [9].

Cytokines also play a fundamental role in the activation of T cells and the production of Interleukin-17A. Studies on biopsy samples from patients with frozen shoulder have revealed a significant increase in the abundance of macrophage subsets, B cells, and dendritic cells, highlighting the complexity of the immune response involved in the pathophysiology of frozen shoulder. Understanding the molecular mechanisms involved in adhesive capsulitis can help guide more effective therapeutic strategies for this condition [9-12].

Adhesive capsulitis is often associated with systemic conditions, which may exacerbate the inflammatory and fibrotic response [10]. Individuals with metabolic diseases, such as diabetes mellitus, have a significantly increased risk, with a reported prevalence of up to 20% among diabetics [3]. Conditions such as thyroid diseases and heart diseases are also associated with a higher risk of developing adhesive capsulitis [11-14].

The clinical presentation is generally divided into three distinct phases, each with specific characteristics and durations. The initial phase, known as the inflammatory, painful, or freezing phase, is characterized by intense pain, which tends to be more pronounced at night, accompanied by a progressive loss of shoulder movement. This phase can last from 2 to 9 months [15, 16]. Pain is a predominant symptom during this phase, and the loss of movement may be gradual but significant.

Next is the stiffness phase (frozen), during which pain may decrease, but shoulder stiffness persists, significantly limiting the range of motion (ROM). This phase can last from 4 to 12 months, according to various studies [17]. Joint stiffness is a characteristic symptom of this phase, and the loss of movement may be more pronounced.

Finally, in the resolution (thawing) phase, there is a gradual improvement in ROM, which may last from 12 to 24 months. However, it is important to note that some patients may not fully regain shoulder mobility [13, 18]. Recovery can be slow and variable, and some patients may require additional treatment to achieve satisfactory mobility.

Shoulder Anatomy

The glenohumeral joint, also known as the shoulder joint, is one of the most mobile joints in the human body, allowing for a wide variety of movements and joint stability. This mobility is supported by a complex network of muscles, each receiving specific blood and nerve supply essential for their function. For better understanding, the muscles can be divided into quadrants:

In the posterosuperior quadrant of the shoulder, we find the supraspinatus and infraspinatus muscles. The supraspinatus, which plays a crucial role in arm abduction, is supplied by the suprascapular artery, a branch of the subclavian artery. This artery not only supplies blood to the supraspinatus but also to the infraspinatus, which is responsible for the external rotation of the upper limb. Both muscles are innervated by the suprascapular nerve, originating from the upper trunk of the brachial plexus, specifically from segments C5 and C6. This innervation ensures that the muscles can perform their functions efficiently.

Next, in the posteroinferior quadrant, we find the teres minor and the posterior portion of the deltoid muscle. The teres minor is supplied by the posterior circumflex humeral artery, a branch of the axillary artery. Along with the teres minor, the posterior deltoid portion also receives its vascular supply from the same artery. The innervation of both muscles is provided by the posterior branches of the axillary nerve, also originating from segments C5 and C6, allowing for external rotation and stabilization of the shoulder.

Moving to the anterosuperior quadrant, the subscapularis muscle stands out as the primary muscle responsible for internal rotation of the shoulder. It is supplied by the subscapular artery, which is also a branch of the axillary artery, ensuring that the muscle receives the oxygen and nutrients necessary for its functions. The subscapularis is innervated by the subscapular nerve, which comes from segments C5 and C6, ensuring that its action is robust and fluid. The pectoralis major and serratus anterior muscles, which also comprise this quadrant, receive blood from the internal thoracic and lateral thoracic arteries, respectively. While the pectoralis major is innervated by the medial and lateral pectoral nerves, the serratus anterior is innervated by the long thoracic nerve, both components of the brachial plexus.

In the anteroinferior quadrant, the anterior portion of the deltoid and the teres major work together to facilitate arm flexion and internal rotation. The vascular supply of the deltoid is provided by the acromial and deltoid arteries, both branches of the axillary artery. Meanwhile, the teres major is supplied by the scapular circumflex artery, ensuring a continuous blood supply. Both the deltoid and teres major are innervated by the axillary nerve, allowing for precise execution of their movements (Fig. 1).

This network of blood and nerve supply serving the shoulder muscles is fundamental to the harmony and smooth functioning of the glenohumeral joint. Adequate vascularization ensures the delivery of

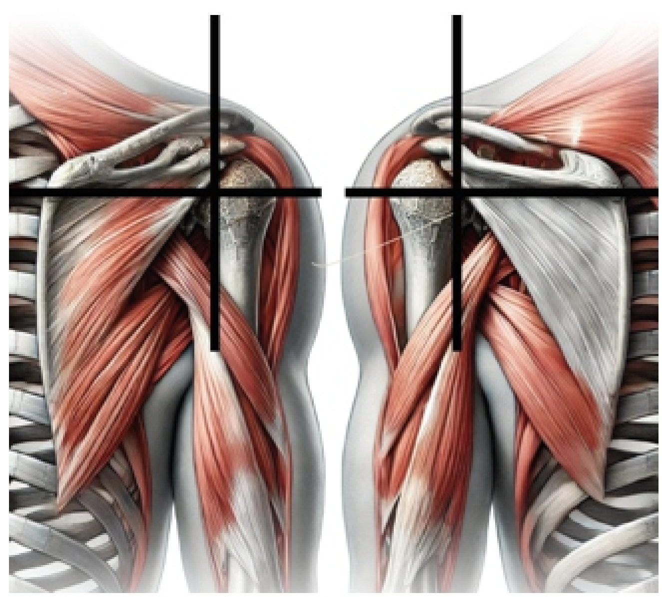

Figure 1: Shoulder divided into 4 quadrants: Anterolateral, posterolateral. (Moore, Keith L., Dalley, Arthur F, Agur, Anne M.R.- Clinicalli)

vital oxygen and nutrients, while innervation facilitates coordinated movement. Any impairment in either of these systems can lead to dysfunction, resulting in pain, weakness, or restricted movement, highlighting the importance of understanding the vascularization and innervation of the muscles that support this joint. This understanding is essential, especially in diagnosing and treating conditions that affect the shoulder, providing a solid foundation for rehabilitation and functional recovery [19].

Shock Waves

Shock waves are high-energy acoustic pulses that propagate rapidly through a medium, characterized by an initial high pressure followed by negative pressure. These pulses can transmit energy through different tissues, promoting therapeutic effects that have been explored in various areas of medicine, particularly in orthopedics and physical rehabilitation [20].

Shock waves can be classified into two main types: Radial pressure waves and focused shock waves. Radial pressure waves disperse from a point of application and have a more superficial energy peak, being used to treat larger areas and surface conditions. In contrast, focused shock waves concentrate energy on a specific point, allowing for deeper penetration into the tissue, which is ideal for treating localized conditions in deeper structures, such as bone tissue [21]. Focused shock waves are generated by three main technologies: Electrohydraulic, electromagnetic, and piezoelectric. Among these, the waves generated by piezoelectric technology are the most used. This is due to their relatively affordable costs both for the device and maintenance, making it a viable and efficient option for various clinical applications (Fig. 2).

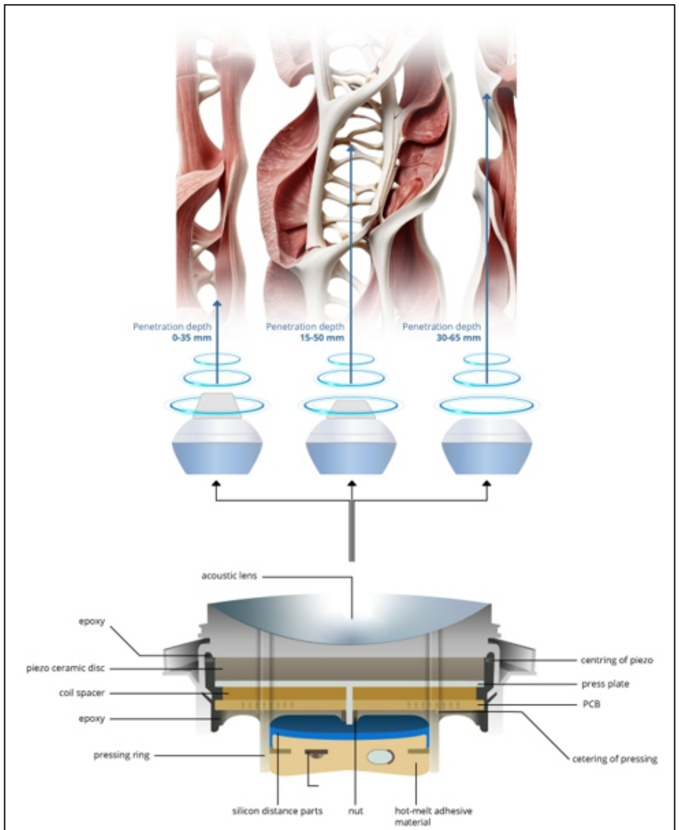

Figure 2: Focused shock waves, piezoelectric technology BTL, differences in penetration/depth according to the spacer or applicator used

The ability of shock waves to promote tissue regeneration has been extensively studied, particularly in tendon and ligament injuries. Shock waves stimulate the production of growth factors such as vascular endothelial growth factor (VEGF) [20, 22] and transforming growth factor beta (TGF-β), which are crucial for angiogenesis and tissue repair, improving oxygen delivery to cells [21, 23].

Another important mechanism is the modulation of inflammation. Shock waves can reduce inflammatory mediators, contributing to the modulation of the inflammatory response and pain relief. They regulate nitric oxide levels and favor endothelial synthesis while decreasing the expression of nuclear factor kappa B. These processes alter the composition of chemical mediators around nociceptors, reducing the perception of pain. Studies also indicate that shock waves can stimulate collagen production, improving tissue quality and accelerating the healing process [24, 25].

The analgesia provided by shock waves is one of the most immediate and noteworthy benefits of the therapy. The exact mechanism is still under investigation, but it is believed to involve the inhibition of pain pathways and modulation of inflammatory mediators. This is beneficial in the treatment of chronic pain conditions, where pain can be significantly reduced after just a few sessions [22, 25-27].

Extracorporeal Shock Wave Therapy (ESWT) in the Treatment of Adhesive Capsulitis

Adhesive capsulitis presents a significant therapeutic challenge due to its complex and multifactorial nature. ESWT has gained prominence as a promising non-invasive approach for treating this condition. Recent studies demonstrate that ESWT promotes significant short-term improvements in shoulder ROM, abduction, internal rotation, and pain and disability indices of the shoulder [28-30].

The efficacy of shock waves can be attributed to their ability to modulate the local inflammatory response and stimulate angiogenesis, facilitating functional recovery of the shoulder [31-33]. However, the response to treatment can vary among individuals, and the determination of optimal application parameters is still under ongoing investigation [34].

Evidence from recent meta-analyses suggests that ESWT is a beneficial therapeutic option for alleviating pain and improving function in patients with adhesive capsulitis, especially when used as an adjunct therapy. Despite limitations related to study heterogeneity, positive results, particularly regarding immediate and short-term analgesic effects, support its use as part of the therapeutic arsenal for this condition [32].

ESWT has shown effectiveness in improving ROM and reducing pain in patients with adhesive capsulitis, particularly when combined with other therapeutic modalities and rehabilitation exercises [32, 35, 36].

One study evaluated the efficacy of ESWT compared to conventional physical therapy in treating adhesive capsulitis in perimenopausal diabetic women, who experience hormonal changes contributing to musculoskeletal dysfunction and vascular endothelial damage due to high blood sugar levels. The use of shock waves aims to improve local circulation, facilitate neovascular changes, promote enzyme production, increase collagen fiber flexibility, and reduce inflammatory cytokine release, which can be particularly beneficial for perimenopausal diabetic patients [37].

The study investigated the efficacy of ESWT combined with fascial manipulation (ESWT-FM) in alleviating pain from adhesive capsulitis compared to conventional ESWT. Results indicated that the group receiving ESWT-FM exhibited a more rapid and significant reduction in pain, with a 50% decrease in pain scores after just one session[38].

In a comparative study evaluating the efficacy of oral steroids versus ESWT in patients diagnosed with primary adhesive capsulitis, treatment results showed that both methods led to functional improvements. However, those undergoing ESWT experienced a faster and more significant recovery. The steroid group experienced pain relief in a shorter time frame, allowing for initial relief. However, full recovery of ROM and the ability to perform daily activities occurred in a more gradual and prolonged manner. In contrast, patients treated with ESWT noticed improvements in ROM and the ability to perform daily activities early in the treatment stages, suggesting that this therapy not only provides pain relief but also promotes accelerated functional recovery. The difference in outcomes indicates that ESWT may operate through distinct mechanisms compared to steroids, contributing to more effective functional recovery for patients [39].

Another study investigated the effect of radial pressure waves compared to intra-articular corticosteroid injection in treating adhesive capsulitis in diabetic patients, alongside traditional physical therapy. The results showed significant reductions in Shoulder Pain and Disability Index (SPADI) scores after treatment in both groups. However, the group that received shock waves exhibited greater improvements in all assessed outcomes, particularly in shoulder ROM, compared to the corticosteroid injection group after 2 and 3 months. Furthermore, radial pressure waves led to decreased pain and improved quality of life. The study also analyzed glucose levels, observing a significant increase in post-treatment levels only in the corticosteroid group. Radial pressure waves did not exhibit elevations in glucose levels, making it a safe and non-invasive approach for managing adhesive capsulitis in diabetic patients, showing better results in terms of pain, functionality, and glycemic control compared to intra-articular corticosteroid injections[40].

Clinical Case

The patient J.M.S.L., a 58-year-old male construction worker, presented to the consultation complaining of intense pain in his right shoulder following a traumatic episode that occurred 30 days prior. With a work history characterized by manual labor, including painting and heavy work, J.M.S.L. reported having experienced shoulder discomfort previously, although without a specific diagnosis. The trauma in question was an acute glenohumeral dislocation, resulting from a movement involving flexion and external rotation of the right arm, which also caused injury to the glenoid labrum.

Since the traumatic incident, the patient has developed a typical case of adhesive capsulitis, presenting as "frozen shoulder" in the right shoulder. During the anamnesis, J.M.S.L. described the pain as intense and continuous, rating it as 10 on the Visual Analog Scale. In addition to the pain, he exhibited significant movement limitations, especially in external rotation. During the physical examination, the initial inspection revealed symmetry of the shoulder at rest, although there was slight atrophy of the rotator cuff muscles, particularly of the deltoid, suggesting a disuse condition. On palpation, the patient experienced significant pain in the anterior and lateral regions of the right shoulder, particularly around the glenohumeral joint and in the subacromial area. It is noteworthy that no temperature changes or edema were observed in the examined region. In the assessment of ROM, results were concerning. Active movements showed shoulder flexion limited to 70°, extension to 30°, external rotation to only 15°, and internal rotation to 30°. During passive movements, the patient reported significant pain at flexion (90°), moderate pain at extension (40°), intense pain at external rotation (20°), and mild pain at internal rotation (40°). In addition, specific tests were performed to evaluate the presence of injuries and the condition of the shoulder. The Neer and Hawkins-Kennedy tests and the Apprehension test were positive. Regarding muscle strength, there was a reduction in the strength of the rotator cuff muscles, especially in the abduction and external rotation movements of the right shoulder. Finally, the neurological assessment revealed no deficits in the upper limbs.

X-Rays were normal (Fig. 3A). MRI showed: partial intratendinous thickness tear/detachment of the supraspinatus tendon and the upper fibers of the infraspinatus, thickening and increased signal of the subacromial/subdeltoid bursa, suggesting bursitis and small glenohumeral joint effusion with associated synovial thickening (Fig. 3B).

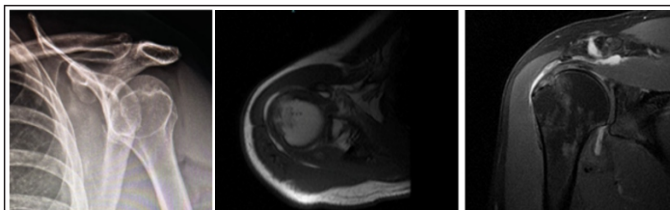

Figure 3: (a) Right shoulder X-ray, (b) right shoulder magnetic resonance imaging

Treatment

The management of frozen shoulder can be either conservative or surgical. Non-surgical approaches include rehabilitation, medications, laser therapy, and shockwave therapy. Surgery, such as manipulation under anesthesia and arthroscopic release of the joint, may be considered in persistent cases. In most instances, patients respond well to conservative treatment.

Conservative treatment for adhesive capsulitis, utilizing shockwave therapy in combination with oral analgesics and rehabilitation, offers an effective approach to this condition. The therapeutic process begins with a thorough clinical assessment of the patient, in which the physician conducts a detailed discussion about symptoms, medical history, and the patient's expectations regarding treatment. After this initial assessment, the physician guides the patient on the progression of the therapeutic process, providing crucial information such as the number of expected sessions and the average duration of treatment. This careful approach aims to ensure that the patient understands all the stages of the treatment and is prepared for its development.

The patient is advised to understand that treatment is not limited to the sessions alone, as its effects may last between 1 and 3 months after completion. At this point, it is vital to clarify expectations, ensuring that the patient has a realistic understanding of the expected outcomes. Before starting the applications, ultrasound marking is performed at the points where the intervention will take place, dividing the shoulder into quadrants (both anterolateral and posterolateral) for the application of shockwaves, ensuring precision in localization that favors optimal results.

Application technique-CapsuWave technique

The CapsuWave technique is an approach specifically developed for the treatment of the shoulder. Its goal is to provide better positioning during application, ensure a uniform approach to the involved areas, and promote patient comfort. Considering the difficulties associated with the clinical presentation of patients, this technique was designed to optimize the treatment experience, facilitating both the application and the patient's well-being.

Description of the technique

Proper patient positioning is fundamental for the success of the CapsuWave technique. The patient should be positioned lying on their side or supine, with the shoulder to be treated facing upward. The physician positions themselves alongside the patient, holding the arm at mid-shaft level, allowing for the mobilization of all necessary movements during the application. It is essential that, at no point, the patient's arm is resting on their chest. This precaution ensures that the technique comprehensively encompasses the entire treatment area while also facilitating access to myofascial points. Consequently, the treatment becomes more effective, promoting a thorough and detailed approach to the structures involved (Fig. 4).

Protocol

During the application of focused shockwaves, the process begins with a low intensity to ensure maximum comfort for the patient. The therapist uses between 2,000 and 3,000 pulses per session during the initial phase, with 300–500 pulses for analgesia, aiming to increase the energy to the maximum level that the patient can tolerate without causing discomfort [32, 38-40].

The treatment is planned to be conducted over five sessions, with one session per week, using the focused technique at frequencies preferably between 4 and 10 Hz, with an intensity of 0.10–0.20 mJ/mm2. Throughout the sessions, the frequency will be gradually decreased while the intensity is increased.

For myofascial points, the technique of Radial Pressure Waves will be combined, with also five sessions, one per week, using a sweeping technique, preferably at high frequencies and low intensities. Similar to the previous technique, the frequency will be gradually reduced after achieving analgesia, while the intensity will be increased [32].

At the end of the treatment, the physician reiterates the importance of not using anti-inflammatories throughout the process and recommends that the patient avoids physical activities or efforts that could compromise the efficacy of the treatment. After the session, the professional revisits the information discussed and obtains an informed consent form, ensuring that the patient understands all aspects of the treatment and feels comfortable with the proposed plan. This narrative approach not only informs but also establishes a trusting relationship between the patient and the healthcare professional, which is essential for the success of the treatment [39].

Results

After 5 treatment sessions, the assessment on the Visual Analog Scale (VAS) indicated pain level 1, accompanied by a significant gain in joint mobility. The results of the range of motion (ROM) assessment were surprising. Active movements showed abduction at (120°), shoulder flexion at (140°), extension at (80°), external rotation at (60°), and internal rotation at (80°). During passive movements, the patient reported minimal pain, with VAS 1, during abduction (170°), flexion (160°), extension (80°), external rotation (80°), and internal rotation (80°). Regarding muscle strength, there was an improvement in the strength of the rotator cuff muscles, although moderate pain was still present.

Discussion

Adhesive capsulitis, or frozen shoulder, presents a significant clinical challenge, not only due to the debilitating pain it causes but also because of the functional limitations and potential sequelae it imposes on patients. The possibility of functional recovery following the initial onset of the condition is often uncertain, and therapeutic approaches vary widely, ranging from conservative to surgical treatments, reflecting the complexity of the underlying pathophysiology. Studies indicate that adhesive capsulitis affects a considerable proportion of the population, particularly those with systemic conditions such as diabetes mellitus, who are at a higher risk of developing the pathology. Therefore, early identification and effective initial treatment are essential [41, 42].

Figure 4: Patient in lateral decubitus position, with the upper limb being mobilized by the physician during the application of focused shockwaves

The pathophysiology associated with adhesive capsulitis is multifactorial and complex. Evidence of chronic inflammation, fibrosis, and the role of pro-inflammatory cytokines underscores the need for interventions that not only relieve pain but also modify disease progression. In this context, ESWT shows promise, with studies demonstrating significant improvements in ROM and pain reduction. Thus, ESWT may offer a non-invasive therapeutic approach that could modulate the inflammatory response, promoting tissue regeneration and repair [42-44].

However, it is important to recognize that the response to treatment can vary and be influenced by multiple individual factors, such as the severity of the condition and the physiological characteristics of the patients. The heterogeneity of studies evaluating the efficacy of shockwave therapy also limits the generalization of findings. New controlled and structured studies are needed to accurately define the ideal treatment parameters, including the frequency and number of shockwave sessions [45].

Furthermore, future research directions may include investigations comparing the efficacy of shockwave therapy in combination with other modalities, such as fascial manipulation and rehabilitation exercises with structured protocols, in specific populations, such as diabetics. This is particularly relevant given the exacerbated inflammatory response observed in these individuals [46].

The subjective aspects of the patient experience, including pain and quality of life, should be integrated into the assessment of treatment efficacy. The implementation of validated tools to measure the functional and psychological impact of adhesive capsulitis will allow for a broader understanding of the condition and the effectiveness of therapeutic interventions [47].

Finally, the importance of a multidisciplinary approach cannot be underestimated. Professionals from various fields, including sports medicine and rheumatology, should collaborate in the management of adhesive capsulitis. A well-coordinated treatment protocol that involves not only shockwave therapy but also rehabilitation and guidance on physical activity can optimize patient outcomes and decrease the risk of recurrence of the condition.

In summary, adhesive capsulitis is a complex condition that requires a deep understanding of its pathophysiology and an integrated therapeutic approach. The ongoing development of innovative approaches, such as shockwave therapy, may democratize and enhance the treatment of this debilitating condition, providing pain relief and improving patient functionality [48].

Conclusion

Frozen shoulder is a condition that causes significant stiffness in the shoulder joint, often resulting in functional limitations even after treatment. A variety of therapies, such as injections, rehabilitation, shockwave therapy, and physiotherapy, are utilized for symptom management. Further research into the understanding of the pathophysiology of this condition may lead to more effective treatment options in the future. Investigating the molecular and cellular processes involved is crucial for enhancing the understanding of the intensity and frequency of shockwaves used in treatment. This research continues to be fundamental in uncovering innovations that clarify the factors contributing to the efficacy of interventions in the management of frozen shoulder [45-48].

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

Conflicts of Interest: Nil. **Source of Support:** None.

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