

# Therapeutic Effects and influence factors of Extracorporeal Shock Wave in Treatment of Patellar Tendinitis

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**Abstract.** Patellar tendinitis is a common disease due to long-term overloading or incorrect exercise. There are many treatments for patellar tendinitis, but there is currently no accepted best treatment. Extracorporeal shock wave therapy, as a safe and promising treatment, has recently been used for patellar tendinitis. This article aims to analyze the therapeutic effect of different types of extracorporeal shock wave therapy on patellar tendinitis and their treatment parameters. Results show that it mainly includes focus shock waves therapy and radial shock waves therapy. Both types have the advantages of less trauma, obvious effect, and fewer complications compared with traditional treatment methods. The main influencing factors for the therapeutic effects of both methods on patellar tendinitis include the treatment cycle, energy selection, and types of shock waves.

**Keywords:** Extracorporeal Shock Wave Therapy; Patellar Tendinitis; Pain; Knee Joint Function

## 1. Introduction

Patellar tendinitis (PT) refers to an aseptic inflammatory reaction caused by repeated stretching and stimulation of the patellar ligament due to long-term overloading or incorrect exercise. It often causes knee pain, joint swelling, stiffness, and patellar tendon rupture symptoms, which can greatly affect activities of daily living.

There are many treatments for PT, but there is currently no accepted best treatment [1]. Conservative treatment is the mainstay, including local blocking, oral steroid anti-inflammatory drugs, and painless manipulation to relieve pain symptoms. However, these treatments have some limitations. For example, local blocking treatment may cause spontaneous rupture of the patellar tendon, so it has to be treated surgically; The effect of painless manipulation has only a short-term effect; Surgical treatment is invasive therapy, which is not easy to be accepted by patients, but also has the problem of long postoperative recovery time.

Considering the disadvantages and problems of conservative treatments, A new type of radiotherapy between conservative treatment and surgical treatment has attracted increasing attention. The new type of radiotherapy includes extracorporeal shock wave therapy (ESWT), laser acupuncture therapy, and minimally invasive surgery, of which ESWT has received more recognition in the past 10 to 15 years. It has been used for the treatment of muscle and bone and joint diseases, with the advantages of safety, effectiveness, and simple operation, the success rate of ESWT is around 80% with few side effects [2]. Thus, it has gradually been widely adopted and applied to tendon inflammation.

ESWT is a new type of radiotherapy between conservative and surgical treatment, which contains many branch types. Currently, there are a few studies related to ESWT and most of them only focus on a sole type of ESWT. The purpose of this article is to analyze the effects of ESWT on the treatment of PT compared with conservative treatments, and to explore the influence factors of ESWT efficacy and their controls on different ESWT types.

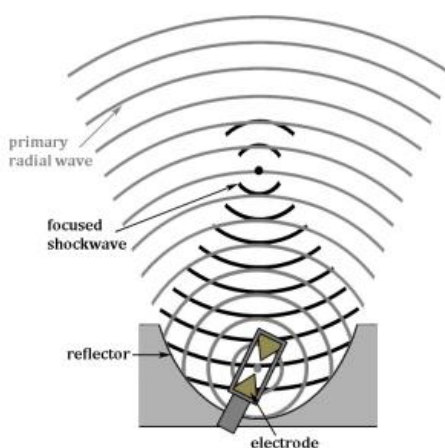
## 2. Effects of ESWT on patellar tendinitis

ESWT treatment equipment is generally divided into focus (FSWT) and radial shock waves therapy (RSWT). FSWT has been used for clinical randomized controlled studies of patellar tendinitis

in the early period, but RSWT treatment has only been used in the past 5 years. This study analyzes the effects of FSWT and RSWT on the treatment of patients with patellar tendinitis.

### 2.1. Effect of FSWT on Patellar Tendinitis

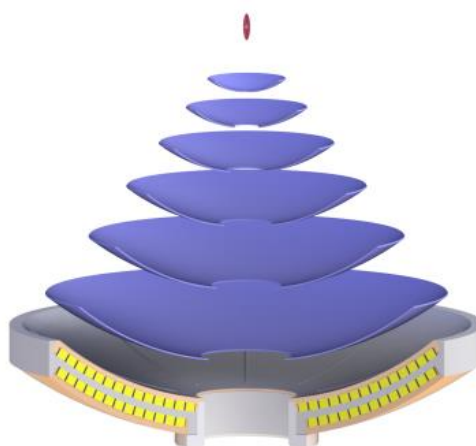
FSWT refers to the use of a special nonlinear pressure wave to generate a pressure field at a selected depth in the body tissue, focusing the energy at a specific focal point to achieve maximum pressure through reflections from an acoustic lens. It is mainly used for deep lesions and includes 3 types: electro-hydraulic (Figure 1), electromagnetic (Figure 2), and piezoelectric (Figure 3) [3].



**Figure 1.** Electrohydraulic shockwave transducer



**Figure 2.** Electromagnetic shockwave transducers



**Figure 3.** Piezoelectric shockwave transducer

Liu et al. proposed that high-energy FSWT within a certain range is more effective than low-energy FSWT in the treatment of PT. They divided 90 patients with PT into three groups: group A with impact energy 8KV, group B with impact energy 12KV, and the control group with partial steroid closure. Results showed that FSWT and steroid partial closure were effectively used in the treatment of patellar tendon inflammation. It is noted that FSWT is better than steroid drug partial closure, and local high energy (12KV) is more effective in improving pain and has better long-term efficacy [4].

Peng argued that FSWT is more effective than electroosmotic therapy in pain relief and knee function. The researcher used the VAS pain score, Victorian Institute of Sports Assessment-Patella (VISA-P) score, and Roles and Maudsley classification (RM) score to compare the efficacy of FSWT and ion in the treatment of PT. Both FSWT and ion therapy have significantly improved, and the efficiency of the FSWT is better than that of electroosmotic therapy, indicating that FSWT is an effective method in patients with PT [5].

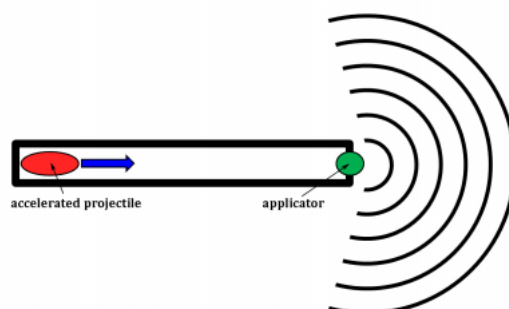
Peers et al. studied that EWST is even as valid as surgery. They selected 27 patients with chronic PT, 13 received surgery, and 14 received FSWT. FSWT shows functional outcomes comparable to surgery in a cross-sectional analysis of patients with chronic proximal PT resistant to conservative treatment, by the VISA score, VAS, and RM assessment [6].

Wang et al. proposed that FWST is beneficial to promote patellar ligament vascularization, thinning, and softening of the patellar ligament. They followed up the knee joints of 27 patients treated with FSWT and 23 patients treated conservatively for 2 to 3 years, the performance of the experimental group showed 43% excellent, 47% good, and 10% fair. The performance of the conservative treatment group had not excellent, but 50% good, 25% fair, and 25% poor. Ultrasonography revealed a significant increase in the vascularity of the patellar tendon after FSWT compared with conservative treatment and a trend toward a decrease in patellar tendon thickness [2].

However, the effect of FSWT is not obvious in some cases. For example, ZEWER argued that the efficacy of FSWT is very weak after a certain period of time (about 22 weeks). The researcher randomly assigned 62 eligible subjects to FSWT ( $n = 31$ ) or placebo ( $n = 31$ ). The ESWT group had a significant effect on VISA-P and VAS scores and time, but there was no interaction effect of treatment  $\times$  time. The only difference between the FSWT group and the placebo group after 22 weeks of follow-up was that more athletes reported subjective improvement. FSWT as a single treatment did not provide any benefit compared with placebo during competition season in actively competitive jumpers with patellar tendinopathy and symptoms lasting less than 12 months [7].

## 2.2. Effect of RSWT on Patellar Tendinitis

RSWT uses compressed air to reach the maximum pressure at the source, and pushes the projectile to form a pneumatic shock wave, which acts on the skin surface, which is conducive to large-area analgesia, release, and tissue regeneration (Figure 4) [3].



**Figure 4.** Radial “shockwave” transducer

Xu et al. studied proved that the BTL-6000 pneumatic ballistic shock wave therapy (BPB-SWT) is effective and durable. They used BPB-SWT combined with painless manipulation therapy and painless manipulation alone to treat PT. Their results show that the visual analog scale (VAS) and

lysholm knee joint scores in both groups were improved compared with untreated patients; However, BPB-SWT combined with painless manipulation in the treatment of PT is more effective in reducing pain and improving knee joint function, and the efficacy is better than painless manipulation alone. Moreover, it has the characteristics of persistence and a relatively long treatment period, and can repair the damaged tissue and promote its regeneration [8].

Fan et al. proposed that the Swiss DolorClast radial shock wave (SD-RSWT) has good therapeutic efficacy. They divided 84 patients with patellar tendinitis into two groups: the SD-RSWT group and the partial sealing treatment group, respectively. The SD-RSWT has obvious timeliness in the relief of patellar tendinitis pain. The short-term effect is not as good as that of partial block therapy, but the effect is more durable and reliable than partial block therapy. Therefore, it is a better choice for patients who have sufficient time and want to achieve more durable and reliable results through non-invasive methods [9].

In addition, different disease sites have different therapeutic effects of RSWT. For example, Williams et al. argued that RSWT has better efficacy on patients with intraretinal changes. They divided 40 patients with PT into tendon itself (group A, 20) or extension of the posterior patellar fat pad (group B, 20), and group B underwent joint debridement without improvement in RSWT. 85% in group A were good or excellent, and in group B there was significant improvement after arthroscopic debridement. Therefore, RSWT has improved efficacy on MRI scans showing only intraretinal changes, and arthroscopic debridement should be performed without RSWT in patients with extension into the fat pad [10].

Both FSWT and RSWT treatments are affected by high training volume, longer symptom duration, and older age of patients. Van Rijn et al. studied Dutch basketball, handball, and volleyball players with PT, and showed significant clinical improvement in the eccentric training (ET) and ESWT plus eccentric training groups after 3 months of treatment. It means the effectiveness of eccentric training, while the role of ESWT remains uncertain[11].

### **3. Therapeutic Effect and influence factors of ESWT**

Both FSWT and RSWT appear to be safe and promising treatments for patellar tendinopathy, but there remain controversial on the setting of the treatment parameters such as the waveform selection, applied energy, pulse number, and frequency, treatment times, treatment cycle, and positioning method.

#### **3.1. Therapeutic Effects of ESWT**

On the premise of a long treatment period, the efficacy of ESWT is better than conservative treatments such as painless manipulation therapy, local blocking therapy, and electroosmotic therapy. Furthermore, ESWT combined with painless manipulation such as eccentric contraction and arthroscopic debridement for relief pain has better effects than ESWT alone. ESWT plays a role in the management of patellar tendon pain and knee function, so it should be incorporated into a more comprehensive exercise-based rehabilitation program. However, the current study on the efficacy of ESWT is not comprehensive. For example, the effectiveness of ESWT has not been demonstrated in a large number of athletes who continue to participate in sports with early or mildly symptomatic patellar tendinitis. Therefore, further studies are needed to determine the efficacy and value of ESWT for PT [12].

#### **3.2. Therapeutic influence factors of ESWT**

There are some influence factors controlling the therapeutic effects of ESWT on PT. The influence factors include the treatment cycle, energy selection, and types of shock waves. Moreover, these factors also further affect the difference between FSWT and RSWT in efficacy [13].

**Table 1.** Overview of systematic reviews on the effectiveness of ESWT for PT

| ESWT type               | Treatment parameters                                                                                                                                | Group                                                                                         | Observation Metrics/Effects                                                                                                                              | follow-up time | Therapeutic effect                                           | Reference |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------------------------------------------------|-----------|
| FSWT (HK. ESWO-AJII)    | A: Trigger voltage: 8KV<br>Shock frequency: 3Hz<br>Focus area: 1.5cm <sup>2</sup><br>Impact times: 1000<br>B: Trigger voltage: 12KV<br>Interval: 7d | A: Shock energy 8KV<br>B: Shock energy 12KV<br>Control group: topical occlusion with steroids | Ipsilateral quadriceps peak torque and VAS improved                                                                                                      | 3 weeks        | High Energy > Low Energy > Steroid Drug<br>Partial Occlusion | [4]       |
| FSWT                    | /                                                                                                                                                   | A: ESWT<br>B: Electroosmosis therapy<br>Control group                                         | VISA-P, VAS, RM improved                                                                                                                                 | /              | Shockwave > Electroosmosis > Control group                   | [5]       |
| FSWT (Electromagnetic)  | ESWT:<br>Interval: 1week<br>1,000 impulses<br>4 Hz<br>0.2 mJ/mm <sup>2</sup><br>Decline squat training                                              | ESWT treatments<br>Control group                                                              | VISA-P, VAS, RM improved                                                                                                                                 | 12 weeks       | Functional Outcomes Comparable to Surgery with ESWT          | [6]       |
| FSWT (Electrohydraulic) | 1,500 impulses<br>0.18 mJ/mm <sup>2</sup>                                                                                                           | ESWT treatments<br>Conservative treatment                                                     | VISA-P improved                                                                                                                                          | 10-53 months   | ESWT > Conservative treatment                                | [2]       |
| FSWT (piezoelectric)    | Average energy density: 0.25 ± 0.07 mJ/mm <sup>2</sup><br>Maximum energy density: 0.42 ± 0.17 mJ/mm <sup>2</sup>                                    | ESWT (n = 31)<br>placebo group (n = 31)                                                       | VISA-P<br>Initial: 62.4 ± 13.4-59.4 ± 11.7<br>1 week: 66.3 ± 19.0-66.8 ± 16.2;<br>12 week: 68.9 ± 20.3-66.7 ± 17.5;<br>22 week: 72.7 ± 18.0-70.5 ± 18.9. | 22 weeks       | ineffective                                                  | [7]       |
| BPB-SWT                 | Energy: Initial: 1.5-                                                                                                                               | Observation group: ESW combined with                                                          | VAS: observation group:                                                                                                                                  | 2-6 years      | Combination Therapy > Painless                               | [8]       |

|         |                                                                                                                                 |                                                                                              |                                                                                                                                                                                                           |                 |                                                                                               |      |
|---------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------|------|
|         | 2bar; Final<br>2-3bar<br>Times:<br>2000<br>Frequency:<br>8-10Hz<br>Interval: 5-<br>7d<br>Total<br>number of<br>treatments:<br>3 | painless<br>manipulation<br>therapy<br>Control group:<br>painless<br>manipulation<br>therapy | 8.18±1.29-<br>1.38±0.56<br>Control<br>group:<br>8.78±1.47-<br>2.17±1.27<br>Lysholm knee<br>score:<br>observation<br>group:<br>15.84±3.55-<br>36.38±0.49<br>Control<br>group:<br>15.57±2.98-<br>25.24±0.50 |                 |                                                                                               |      |
| SD-RSWT | Energy:150<br>-250kPa<br>Times:<br>2000<br>Frequency:<br>8-10Hz<br>Interval: 7d<br>Total<br>number of<br>treatments:<br>5       | A: ESWT<br>B: partial sealing<br>treatment                                                   | VAS:1week<br>A:5.29±1.11-<br>1.71±1.29<br>B:5.19±1.02-<br>1.46±1.24<br>3months<br>A:5.29±1.11-<br>1.03±1.35<br>B:5.19±1.02-<br>1.72±1.56                                                                  | 3<br>mont<br>hs | A>B<br>No adverse<br>reactions                                                                | [9]  |
| RSWT    | /                                                                                                                               | A: RSWT<br>B:<br>RSWT+Arthrosc<br>opic debridement                                           | VISA-P score<br>A =50.2 -<br>65.0(p= 0.01)<br>B =39.6-<br>78.4(p=<br><0.001)                                                                                                                              | 2<br>years      | RSWT has<br>improved<br>efficacy for MRI<br>scans showing<br>only<br>intratendinal<br>changes | [10] |
| ESWT    | ESWT<br>combined<br>with<br>eccentric<br>contraction                                                                            | A: ET<br>B: FSWT<br>C: RSWT                                                                  | A: VISA-P<br>improved                                                                                                                                                                                     | 3<br>mont<br>hs | ESWT function<br>is still uncertain.                                                          | [11] |

### 3.2.1. Treatment Cycle

The pain relief of ESWT in the treatment of PT has the characteristics of timeliness, persistence, and a relatively long treatment period. The short-term effect remains to be verified. ESWT was less effective than local blocking therapy and corticosteroid injection in the short term, and ESWT and other therapies showed no significant improvement in pain and function. In long-term follow-up of function and pain, ESWT was superior to conservative treatment. Previous studies on ESWT in the treatment of PT mostly focus on the efficacy itself, and rarely involve pain relief after treatment or the relationship between clinical efficacy and time, so it is very important to seek an appropriate treatment cycle.

### 3.2.2. Energy Selection

The key to ESWT is to apply the appropriate energy to the exact site. The energy used and the selected site directly determine the therapeutic effect. If the energy is too low, the therapeutic effect will not be achieved, and if the energy is too high, adverse reactions will occur. Local high-energy shock waves are more effective for pain improvement [4]. This may be because the local high-energy

shock wave stimulates pain receptors with higher intensity, and can release pain-inhibiting chemicals to achieve long-term analgesia. However, some studies recommended low energy and low-frequency ESWT [12]. Therefore, the most suitable energy needs to be explored through basic experiments.

### 3.2.3. Types of Shock Waves

The International Society of Shockwave Medicine (ISMST) pointed out that RSWT is very different from FSWT due to its physical properties, launch speed, waveform, and biological effects [3]. First, the effect of RSWT is superficial compared to FSWT, which reaches its maximum energy at a focal point located deeper in the body tissue. Second, to date, basic research on the long-term effects of shock waves on biological effects has been largely based on FSWT. So many of the biological effects of RSWT such as healing and growth factor release are unproven. Many research show that most patients with ESWT improved pain and knee function. RSWT is effective in improving pain in patients with PT, but FSWT appeared to be more effective.

## 4. Conclusion

This study investigated the efficacy of ESWT on PT, discussed the characteristics, advantages, and disadvantages of both types of FSWT and RSWT from ESWT, and discussed their treatment effects and influencing factors.

ESWT is mainly divided into FSWT and RSWT. FSWT can treat superficial and deep tissues, over-stimulate nerves to relieve pain, stimulate growth factors, form new blood vessels, clear calcification, and promote bone healing. It can reach the replacement organs of the human body and gather energy in specific areas with high intensity, but basically large. Energy shock waves, and improper operation may cause damage to non-treatment parts. RSWT can treat superficial tissue and nerve overstimulation to relieve pain. The rest of the functions have not been proven. Radial shock wave decays rapidly in the axial and lateral directions.

ESWT seems to be safe, effective, and easy-to-operate for PT. Because ESWT treatment appears to have positive impacts on pain and knee joint function, it may be part of this rehabilitation program for chronic overuse injury. Its influencing factors include treatment cycle, energy selection, and types of shock waves. The efficacy of ESWT is time-effective, durable, and short-term effect remains to be verified; high-energy shock waves within a certain range are more conducive to improving pain, and FSWT is more effective than RSWT.

However, the most effective ESWT regimen (energy, type, duration, etc.) may not be elucidated. The mechanism and treatment parameters of ESWT in the treatment of PT require further basic and clinical research.

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