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Applying Focused and Radial Shock Wave for Calcific Tendinitis of the Shoulder : Randomized Controlled Study

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Objective: Extracorporeal shock wave therapy (ESWT) is a nonsurgical treatment alternative to surgery for various musculoskeletal diseases that have traditionally been difficult to treat conservatively, including calcific tendinitis, tennis elbow, and plantar fasciitis.This study evaluated the effect of focused and radial shock wave therapy for calcific tendinitis of the shoulder.

Design: Randomized controlled study

Methods: Forty participants with calcific tendinitis were randomized into focused shock wave therapy (FSWT, n=20) and radial shock wave therapy (RSWT, n=20) groups. Patients were examined before and one week after treatment. Pain intensity was subjectively assessed using the visual analogue scale and function was assessed using theConstant-Murley score (CMS) and range of motion (ROM).

Results: The results showed a significant decrease in pain and significant increase in shoulder mobility and function in both groups. However, FSWT was significantly more effective than RSWT, based on CMS and ROM assessment.

Conclusions: Although it is possible to raise the energy intensity of RSWT to increase the depth at which the energy becomes dispersed, higher energy intensity is associated with a greater risk of severe neurovascular damage, and that high-intensity stimulation can cause adverse effects such as pain and petechiae . Therefore, FSWT is considered to be a safe and effective method for treating tendinous lesions while minimizing adverse effects. In conclusion, both FSWT and RSWT can reduce pain and increase mobility and function. FSWT can be considered as an alternative for calcific tendinitis of the shoulder.

Key Words: Focused extracorporeal shockwave, Radial extracorporeal shockwave, Shoulder joint, Calcification

Introduction

Shoulder dysfunction, severe pain, and restricted movement lead to difficulty performing activities of daily living (ADLs) [1]. Moreover, shoulder pain is one of the most common musculoskeletal disorders in adults [2], with calcific tendinitis accounting for 2.5–20% of the incidence [3]. Calcific tendinitis is characterized by deposition of calcium hydroxyapatite in the rotator cuff, and most often affects the supraspinatus [4]. Conservative treatment with physical therapy, nonsteroidal anti-inflammatory drugs, or steroid injections has generally been used to treat shoulder pain by calcific or noncalcific tendinitis [5]. When treatment using these methods is ineffective, surgery can be used to remove hydroxyapatite deposits [6].

Extracorporeal shock wave therapy (ESWT) is a nonsurgical treatment alternative to surgery for various musculoskeletal diseases that have traditionally been difficult to treat conservatively, including calcific

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tendinitis, tennis elbow, and plantar fasciitis [6]. ESWT was introduced in the 1980s for kidney stone lithotripsy, and uses high amplitude pressure outside the body to focus energy on a lesion [7]. ESWT has both physical and biological effects. Direct stimulation by shock waves induces a healing response at the cellular level, stimulates growth factors at the tissue level, promotes angiogenesis, and suppresses nociceptors, resulting in an increased pain threshold, reduced inflammation, and wound healing [8].

ESWT is broadly divided into focused and radial modes, based on the method of energy transmission [9]. In radial ESWT (RSWT), compressed air is released instantaneously, producing a pressure wave as it collides with a large number of linearly aligned electrons, in turn dispersing the energy radially [10]. In focused ESWT (FSWT), a large number of scattered piezoelectric particles on an internal conical electrostatic precipitator produce an effect under electrical stimulation; the individual shock waves are focused on a single point. These focused shock waves generate a pressure of 10－100 atm that is converted into vibrational energy, and this energy is focused on a single point [11]. These different modes of energy transfer are important in treating lesions with ESWT [9]. RSWT disperses energy radially, making it effective on broad areas, such as a large muscle [10]. Conversely, FSWT focuses high-pressure energy at a single point, making it effective on slightly smaller areas [11]. As the intensity decreases with increasing distance, radial shock waves are especially effective in areas within 3 cm of the skin, such as the epidermis and muscles, and are also effective on ligaments and tendons [10]. Conversely, the high-pressure shock waves in FSWT can penetrate to a maximum depth of 12 cm, making them effective on relatively firm and deep joints, tendons, and ligaments, while they are also effective on the epidermis and muscles [11].

Haake et al. [12] used the Constant-Murley score (CMS) to analyze the effect of FSWT on calcific tendinitis of the rotator cuff, and observed significantly reduced pain, improved function, and reduced calcification size. Hsu et al. [13] used the CMS to compare the effects of conservative treatment and FSWT for calcific tendinitis of the shoulder, and observed significant differences in pain and function in the FSWT group. Thus, a number of studies have compared conservative treatment and ESWT for the treatment of calcific tendinitis of the shoulder, but there has been a lack of research comparing the effects of FSWT with RSWT [14]. Moreover, although different modes of ESWT are more effective for certain diseases and parts of the body, clinical practice and sports science have tended to favor one of the 2 methods [15]. By determining whether the 2 methods show a significant effect on calcific tendinitis, it should be possible to select the appropriate method for a given lesion, and thereby reduce treatment time and improve patient satisfaction. Thus, the present study compared the effects of focused and RSWT on calcific tendinitis of the shoulder, and determined whether the mode of energy transfer had an effect on shoulder pain, function, and joint ROM.

Methods

Participant

This study included 40 patients receiving physical therapy at D- Hospital located in K-City. We included patients who had been diagnosed with calcific tendinitis of the shoulder based on radiographic findings, who complained of restricted joint ROM and pain within the last 6 months and indicated a desire to participate in the study. Participants were randomly allocated into FSWT and RSWT groups, with 20 in each group. Consent was obtained after thorough explanation of experimental objectives and procedures. Exclusion criteria were age less than 20 years old; the presence of neurologic abnormalities, local inflammation or a malignant growth, rheumatoid arthritis, clotting disorders; pregnancy; and use of anti-inflammatory steroid medication within the prior month. Detailed patient characteristics are shown in Table 1. All protocols and procedures were approved by the institutional review board of Sahmyook University (Seoul, South Korea), and all of the participants signed a statement of informed consent.

Procedures

This study had a randomized controlled trial design. Forty participants were randomly allocated to either

Table 1. Subject characteristics (n = 40)

	Sex (M/F)	Age (yrs.)	Weight (kg)	Height (cm)
FSWT (n = 20)	8 / 12	52.80 ± 9.99	61.05 ± 9.32	163.65 ± 6.85
RSWT (n = 20)	8 / 12	52.70 ± 5.82	61.30 ± 8.55	163.45 ± 6.53

Values are Mean ± SD FSWT: focused shock wave therapy RSWT: radial shock wave therapy

the FSWT group or the RSWT group. All of the participants had an equal probability of assignment to the groups. External randomization was achieved by using the Random Allocation Software (Ver. 2.0) (Saghaei 2004).

ESWT was performed using a device capable of both air compression RSWT and piezoelectric FSWT (Dual wave; Medizen Medical, Korea). For FSWT, 2,000 stimuli were applied using a 10-mm pad at an intensity of 0.138 mJ/mm². For RSWT, 2,000 stimuli were applied at an intensity of 0.138 mJ/mm². The site of ESWT application was the point where rotator cuff tendon pain was most severe; if the lesion could be palpated, ESWT was applied after comparison with radiographs. To determine the effects of the different ESWT methods on pain, upper extremity function, and joint ROM, participants were examined before the experiment and 1 week after 3 weekly sessions of treatment, to allow time for the biological effects of ESWT to develop.

Outcome measurements

Pain testing

To evaluate pain, we used the subjective 100-mm visual analogue scale (VAS) [16]. When used in a study by Wagner et al. (2007), the VAS showed very high intrarater reliability ($r = 0.99$) and interrater reliability ($r = 0.99$) [17].

Upper extremity function test

To evaluate shoulder joint function, we used the CMS. The CMS uses a 100-point scale with several variables, and consists of 4 subdomains [18]. In a study by Rocourt et al. (2008), this instrument showed high intrarater reliability ($r = 0.94 - 0.96$) and interrater reliability ($r = 0.90$) [19].

Shoulder joint ROM

To evaluate shoulder joint ROM, we used a goniometer (Plastic Goniometer; Baseline, USA). We measured the angles of shoulder flexion and abduction [20]. In a study by Brosseau et al. (1997), a goniometer showed high interrater reliability ($r = 0.85 - 0.96$) [21].

Statistical Analyses

For all analyses, SPSS Ver. 22.0 (SPSS, Inc., Chicago, IL, USA) was used to calculate the mean and standard deviation. Normal distribution of participants was verified using the Shapiro-Wilk test. Descriptive statistics were used for general characteristics, and independent sample t-tests were performed to verify homogeneity between the groups. To examine differences between the groups, independent sample t-tests were performed on the VAS, CMS, and ROM measurements. To compare pre- and posttreatment data within groups, paired sample t-tests were performed on the VAS, CMS, and ROM measurements. For all data, we used a significance level of 0.05.

Results

Changes in shoulder pain according to ESWT type

The FSWT group showed a statistically significant decrease of 2.07 cm, from 5.89 cm preintervention to 3.82 cm postintervention ($p < 0.05$). The RSWT group also showed a statistically significant decrease of 1.81 cm, from 5.73 cm preintervention to 3.92 cm postintervention ($p < 0.05$). However, comparisons between the 2 groups showed no statistically significant difference according to ESWT type (Table 2).

Table 2. Changes in the Shoulder Joint Pain (N = 40)

		FSWT (n = 20)	RSWT (n = 20)	t(p)
VAS (cm)	pre	5.89 ± 1.10[a]	5.73 ± 1.02	
	post	3.82 ± 0.88	3.92 ± 1.06	
	(post-pre)	2.07 ± 0.46	1.81 ± 0.33	1.965 (0.057)
	t(p)	19.964 (0.000)	24.500 (0.000)	

Values are Mean ± SD FSWT: focused shock wave therapy RSWT: radial shock wave therapy, VAS: visual analogue scale.

Changes in shoulder function according to ESWT type

Total CMS improved significantly by 16.90 points in the FSWT group, from 54.65 points preintervention to 71.55 points postintervention ($p < 0.05$). The RSWT group also showed a significant improvement of 13.30 points, from 54.70 points preintervention to 68.00 points postintervention ($p < 0.05$). The FSWT group showed a significant increase compared to the RSWT group ($p < 0.05$) (Table 3).

Change in shoulder ROM according to ESWT type

For shoulder flexion ROM, the FSWT group showed a significant improvement of 22.35°, from 135.85° preintervention to 158.20° postintervention ($p < 0.05$). The RSWT group also showed a significant improvement of 13.50°, from 137.65° preintervention to 151.15° postintervention ($p < 0.05$). Improvement was significantly greater in the FSWT group ($p < 0.05$). For shoulder abduction ROM, the FSWT group showed a significant improvement of 24.80°, from 118.05° preintervention to 142.85° postintervention ($p < 0.05$). The RSWT group also showed a significant improvement of 16.35°, from 119.19° preintervention to 135.45° postintervention ($p < 0.05$). Improvement was significantly greater in the FSWT group ($p < 0.05$) (Table 4).

Table 3. Changes in the Shoulder Joint Constant-murley score (N = 40)

		FSWT (n = 20)	RSWT (n = 20)	t(p)
Total CMS (score)	pre	54.65 ± 12.68[a]	54.70 ± 16.69	
	post	71.55 ± 9.38	68.00 ± 12.95	
	(post-pre)	16.90 ± 5.04	13.30 ± 5.76	2.104 (0.042)
	t(p)	−15.009 (0.000)	−10.328 (0.000)	

Values are Mean ± SD FSWT: focused shock wave therapy RSWT: radial shock wave therapy, CMS: constant-murley score.

Table 4. Changes in the Shoulder Joint Range of Motion (N = 40)

		FSWT (n = 20)	RSWT (n = 20)	t(p)
flexion (°)	pre	135.85 ± 22.03[a]	137.65 ± 26.87	
	post	158.20 ± 17.16	151.15 ± 22.98	
	(post-pre)	22.35 ± 6.82	13.50 ± 6.15	4.540 (.000)
	t(p)	−14.649 (.000)	−9.814 (.000)	
abduction (°)	pre	118.05 ± 26.93	119.10 ± 29.61	
	post	142.85 ± 21.56	135.45 ± 23.47	
	(post-pre)	24.80 ± 7.07	16.35 ± 6.91	3.824 (.000)
	t(p)	−15.692 (.000)	−10.586 (.000)	

Values are Mean ± SD FSWT: focused shock wave therapy RSWT: radial shock wave therapy.

Discussion

This study investigated the differences between focused and radial delivery methods for ESWT in calcific tendinitis; specifically, we compared the effects on shoulder pain, upper extremity function, and shoulder joint ROM.

In the present study, the VAS showed a significant reduction in pain of 2.07 cm after FSWT, and a significant reduction in pain of 1.81 cm after RSWT ($p < 0.05$), but found no significant difference in pain reduction between the 2 groups. This suggests that rather than the different ESWT delivery methods showing a difference in pain alleviation, ESWT reduces pain by impairing the ability of nociceptors to transmit pain signals, in agreement with the conclusion of a previous study. Therefore, we conclude that either FSWT or RSWT can be used to alleviate pain.

Upper extremity dysfunction causes pain and reduces joint ROM, delays the response time of movements, and restricts activity. This results in reduced efficiency of ADLs, and in work ability. ESWT helps restore function in calcific tendinitis patients with restricted upper extremity function via 2 mechanisms: physically, the pressure from the shock wave causes cavitation at the cellular level; this results in the formation of bubbles that break apart the calcific deposits as they burst. At the same time, shock wave stimulation induces the production of healing substances, resorption of the fragmented deposits into adjacent pockets of mucus, and angiogenesis [22].

Magosch et al. [23] used the CMS to evaluate shoulder function in 35 patients with calcific tendinitis of the rotator cuff, with the aim of investigating the effects of RSWT on upper extremity function. That study showed an improvement of 12 points, from 68.5 points preintervention to 80.5 points postintervention. We also used the CMS to measure upper extremity function. We observed a mean improvement of 16.90 points in the FSWT group and 13.30 points in the RSWT group, with the 2 groups showing a significant difference following treatment ($p < 0.05$). Thus, our results are in agreement with the conclusion of a previous study, stating that ESWT is effective for recovery of upper extremity function in calcific tendinitis patients, and that these effects vary according to the treatment mechanism.

Lohrer et al. [14] studied functional changes in the feet of plantar fasciitis patients after receiving one of the 2 types of ESWT once per week, 3 times in total. That study showed significantly greater improvement in the Foot Function Index and neuromuscular motor performance in the FSWT group compared to that in the RSWT group.

When we used the CMS to measure upper extremity function in our study, we found a significantly greater improvement in CMS in the FSWT group compared to that in the RSWT group ($p < 0.05$). Consistent with a previous study reporting a difference in effect between the 2 delivery methods, our results show significantly better recovery of upper extremity function after FSWT, which is effective at treating narrower, deeper areas such as bone and tendons, compared to RSWT, which is effective for shallower, broader areas such as muscle. Moreover, we observed this significantly greater improvement in upper extremity function for FSWT compared to RSWT while using the same treatment frequency and high energy flux density for both methods ($p < 0.05$). Compared to other studies, these results are thought to show that the use of FSWT for functional recovery from tendinous lesions could lead, indirectly, to a reduction in treatment frequency or duration relative to RSWT.

Normal joint ROM is essential to performing various ADLs, and restricted movement reduces the efficiency of ADL performance [24]. Inflammation and long-term immobility caused by calcific tendinitis and other musculoskeletal disorders restrict joint ROM by causing shortening and deformity, via adhesion, of the periarticular tissues such as the joint capsule, ligaments, tendons, and muscles. Muscle contraction, which acts as a protective mechanism to prevent lesion-related pain, also restricts joint movement [25].

Chen et al. [26] studied the effects of FSWT on shoulder mobility in 40 patients with adhesive capsulitis, and found that after 1 session of ESWT every 2 weeks for a total of 3 sessions, joint ROM, as measured with a goniometer, showed significant improvements in flexion, abduction, lateral rotation, and medial rotation ($p < 0.05$).

In our study, we also used a goniometer to measure joint ROM, and observed significant changes after treatment in both the FSWT group and the RSWT group ($p < 0.05$), as well as a significant difference between the 2 groups ($p < 0.05$). Thus, it is thought that the physical and biological effects of ESWT, which aids tissue recovery by inducing a cellular healing response, helped to increase joint ROM that had been restricted by inflammation-related changes in the tendons. The difference between the 2 groups can be explained as follows: although the shock waves were directed to the area of the most severe pain with both methods, in RSWT, energy is dispersed with increasing depth, resulting in decreased intensity; on the other hand, in FSWT, the energy can be focused on deep tissues such as bone or tendon, which is thought to have led to greater improvement of the tendon at the same energy flux density. Although it is possible to raise the energy intensity of RSWT to increase the depth at which the energy becomes dispersed, Hammer et al. [27] reported that higher energy intensity is associated with a greater risk of severe neurovascular damage, and that high-intensity stimulation can cause adverse effects such as pain and petechiae. Therefore, FSWT is considered to be a safe and effective method for treating tendinous lesions while minimizing adverse effects.

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Conflict of Interest

The authors declare no conflict of interest.

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