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ORIGINAL ARTICLE

The efficacy of shock wave therapy in patients with knee osteoarthritis and popliteal cyamella

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Abstract This randomized, controlled study was performed to compare the effects of extracorporeal shockwave therapy (ESWT) and ultrasound on the rehabilitation of knee osteoarthritis with popliteal cyamella. One hundred and twenty patients with bilateral moderate knee osteoarthritis (Altman III) and popliteal cyamella were selected and randomly assigned to four groups (GI–GIV). Patients in Groups I–III received isokinetic muscular strengthening exercises three times weekly for 8 weeks. Group II received pulse ultrasound treatment for popliteal cyamella three times weekly for 8 weeks, Group III received weekly shock wave therapy for popliteal cyamella for the first 6 weeks, and Group IV acted as controls. The therapeutic effects were evaluated by changes in the arthritic knees range of motion (ROM), visual analogue scale, Lequesne's index, and muscle peak torques after treatment and at follow-up 6 months later. Each treated group exhibited increased muscle peak torques and significantly reduced pain and disability after treatment and at follow-ups. However, only patients in Groups II and III showed significant improvements in ROM after treatment, and only participants in Group III showed immediate improvement in ROM after each treatment. Patients in Group III also showed the greatest increase in muscular strength and the greatest decrease in disability after treatment and at the follow-ups. ESWT is better than pulse ultrasound in rehabilitation of patients with knee osteoarthritis and popliteal cyamella results in more functional improvements.

Conflicts of interest: All authors have no conflicts of interest to declare.

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Introduction

Osteoarthritis (OA) is the most common form of degenerative arthritis and is a widespread, slowly developing disease, with a high prevalence increasing with age [1,2]. The most commonly affected large weight-bearing joints are the knees, where the disease is particularly disabling because of difficulty in rising from a chair, climbing stairs, kneeling, standing, and walking. The presence of pain, combined with muscle weakness, increased body sway, and impaired balance, puts these individuals at risk of falls and decreased activity [3,4].

Although many older adults with arthritis tend to avoid activity, exercise is actually one of the most effective nonpharmacologic treatments for OA, particularly of the knee [5,6], specifically, long-term walking [7], isokinetic quadriceps exercise [8,9], and high and low intensity cycle ergometry [10]. The increasing number of studies demonstrating the benefits of exercise for knee OA clearly indicates that aerobics and strength training improve strength, exercise capacity, gait, functional performance, balance, and decrease the risk of falling. However, compliance is an issue, and those studies with high compliance produced better results. Patients' compliance depends on many elements, including consistent education, encouragement, and follow-up. Injury and complications as a direct consequence of inappropriate exercise, represent the major factor resulting in poor compliance [11]. In patients with chronic knee OA, the knee pain and deformity cause chronic inflammation and if cyamella appear in the popliteal region the flexion contracture of arthritic knee will progress, which results in inefficiency of rehabilitation.

The cyamella is a sesamoid bone that is embedded in the tendon of the lateral or, rarely, the medial head of the gastrocnemius muscle. The sesamoid bone is reported to occur in 10—30% of the population and to occur bilaterally in ~80% of these individuals [12]. In addition, cyamellae reportedly occur more frequently in Asians. The cyamella may act as a source of atypical knee pain, such as cyamella syndrome, posterior knee pain, chondromalacia, and common peroneal nerve palsy [13]. The posterior knee pain will result in more inactivity of the patients and progression of knee joint flexion contracture. For more efficiency of rehabilitation, further management of the cyamella of popliteal region was indicated. No specific treatment options are given in the literature, but the few articles which mention treatments seem to point towards conservative treatment such as local massage or local ultrasound (US) therapy [14].

A shock wave is a single-impulse acoustic wave generated by an electromagnetic, electrohydraulic, or piezoelectric source. Based on the energy at the focal point recorded in millijoules (mJ/mm^2), shock waves are classified as low-, medium- and high-energy: low-energy extracorporeal shock waves have an energy flux density below 0.08 J/mm^2, medium-energy shock waves from 0.08 mJ/mm^2 to 0.28 mJ/mm^2, and high-energy shock waves from 0.28 mJ/mm^2 to 0.60 mJ/mm^2 [15]. After the introduction of extracorporeal shockwave therapy (ESWT) for the treatment of nephrolithiasis, the indication of ESWT has been extended. In addition to use in the classical indication of kidney stones, ESWT is also used in gallstones, pancreatic stones, and salivary calculi. In orthopedics, ESWT has been widely used to treat enthesopathies in the past 20 years [16,17]. Trials have examined the effect of ESWT on plantar fascitis [18], and epicondylitis [19]. Good evidence is available to support the use of ESWT in calcific tendinopathy of rotator cuff [20,21]. Revenaugh et al. [22] applied ESWT for treatment of osteoarthritis in the horse for running performance and Wang et al. [23] reported the effects of ESWT on chondroprotection of rat knee OA. However, few reports focus on the clinical effects on sesamoid syndrome of knee OA. Therefore, we conducted a study to investigate the efficacy of ESWT on rehabilitation of patients who suffered from knee OA with popliteal cyamella and compared it with groups of patients who received ultrasound therapy and placebo.

Methods

Participants

One hundred and twenty patients with bilateral moderate knee OA (Altman III: patients over 40 years of age, knee pain, osteophytes, crepitus, and morning stiffness more than 30 minutes without bony enlargement) [24] and popliteal cyamella (Fig. 1A and B) were recruited and randomly assigned to four groups (30 participants in each group) followed by an intention-to-treat analysis by a secure system of sequentially numbered opaque sealed envelopes containing treatment allocation (I—IV) assigned randomly by computer. The doctor who assigned the patients was blinded to the treatment that the patients would receive. Patients in Groups I—III received isokinetic muscular strengthening exercises three times weekly for 8 weeks; patients in Group II received pulse US treatment for painful popliteal cyamella three times weekly for 8 weeks, those in Group III received weekly shock wave therapy for the first 6 weeks, and those in Group IV acted as controls. Patients in all groups received 20 minutes of hot packs and underwent passive range motion exercises on an electric stationary bike (20 cycles per minute) for 5 minutes to both knees before undergoing muscle strengthening exercises. The therapeutic effects of these exercises were evaluated by changes in the arthritic knees ROM [25], visual analogue scale (VAS) [26], Lequesne's index (LI) [27], and muscle peak torques (MPT) of knee flexion and extension measured by means of an isokinetic dynamometer (Kin-Com; Chattanooga Corp., Chattanooga, TN, USA) [28] before treatment, after treatment, and at follow-ups 6 months later. Compliance with the prescribed exercise program in each group was also analyzed after complete treatment. All participants gave informed consent for the study, and the study protocol was approved by the Ethical Review Committee of Kaohsiung Medical University.

Measurement of knee ROM

The assisted active ROM was measured with a large plastic goniometer with 25-cm movable arms, marked in 1-degree increments. This device is reportedly reliable if the patient

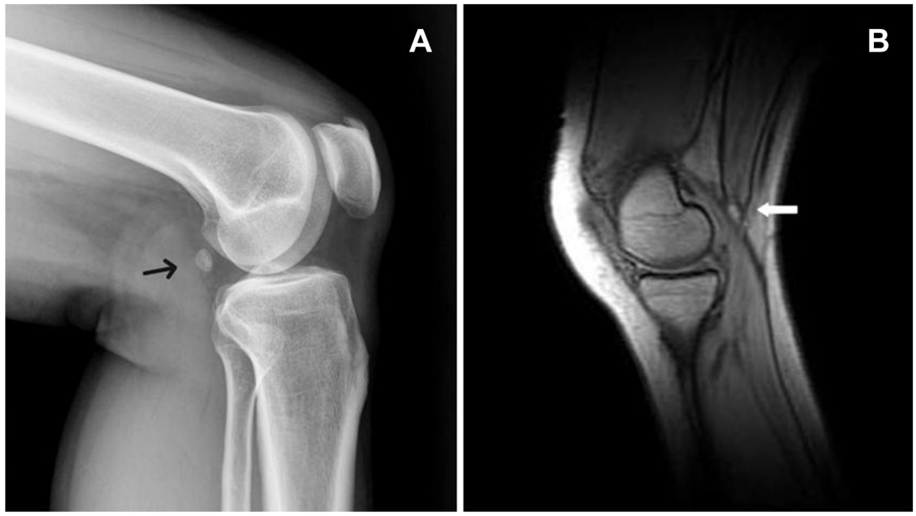

Figure 1. (A) X-ray of popliteal cyamella in knee OA, shown by black arrow; (B) MRI of cyamella of popliteal fossa in knee OA, shown by white arrow.

remains in the one position for all measurements [25]. Measurements of knee flexion and extension were taken with patients lying supine on an examination couch. The fully extended knee was considered as the zero position, and the degrees of maximum flexion, maximum extension, and extension deficit, when present, were recorded. A negative ROM score for extension indicated that the patient was unable to reach the zero position. The angle between maximum flexion and maximum extension was described as the excursion range.

Measurement of pain intensity

The severity of knee pain was evaluated by the VAS after patients had remained in a weight-bearing position (walking or standing) for 5 minutes. The instrument consisted of horizontal lines 10 cm long, with anchor points of 0 (no pain) and 10 (maximum pain).

Measurement of disability

Disability of patients with osteoarthritis of the knee was evaluated with LI. The questionnaire included 11 questions regarding knee discomfort, endurance of ambulation, and difficulties in daily life [27]. A maximum score of 26 indicated the greatest degree of dysfunction, and a score of 1—3 indicated mild dysfunction. A score of less than 7 points indicated acceptable functional status.

Measurement of isokinetic peak torque of knee flexion and extension

To evaluate the maximum voluntary force capacity, the peak torque of the arthritic knee was measured using a modified form of the method used by Snow and Blacklin [28] in the following steps: (1) extension concentric (Ex/Con), knee extension with quadriceps contraction; (2) extension eccentric (Ex/Ecc), knee flexion with quadriceps contraction; (3) flexion concentric (Flex/Con), knee extension with biceps femoralis contraction; and (4) flexion eccentric (Flex/Ecc), knee flexion with biceps femoralis contraction. Patients were seated leaning against a backrest inclined at 16° from the vertical and with the seat inclined 6° from horizontal. The axis of the knee was aligned with the axis of the Kin-Com (Kin-Com 505, Chattanooga, TN, USA) exercise arm; accuracy of alignment was checked by allowing the patient to extend the leg while pushing against the shin pad positioned over the lower third of the leg. If the pad did not move up or down the leg over the range of motion to be tested, the knee was considered to be aligned with the axis of the exercise arm. Gravity-compensated torque values were corrected with the exercise arm positioned 15° from horizontal.

The Kin-Com's exercise arm was used to set the test range of motion. The angle at which knee flexor muscle shortening began (start angle) was set at 20° from horizontal, and the angle at which muscle lengthening began (return angle) was set at 85° from horizontal. To calculate torque, the distance between the point of application of the generated force and the axis of rotation of the exercise arm was measured using the scale on the arm itself and keyed into the computer. Each patient used the same radius for all tests. Exercise-arm velocity was set to 60°/second and 180°/second respectively for the above isokinetic peak torque measurements.

Isokinetic exercise

Isokinetic exercise is a mode of speed-constant exercise. The velocity of joint motion is constant, excluding acceleration to and deceleration from the designated speed, and the force is dependent upon how hard the individual pushes against the load cell.

After evaluation of each arthritic joint's pain and range of motion, and measurement of blood pressure and heart rate, and stretching of quadriceps and hamstrings following the application of hot packs, the patient then underwent a 5-minute warm-up exercise on a stationary bike set without

Table 1 Average range of motion (ROM) of knee in each group before and after treatment (mean ± SD).

	I	II	III	IV
Before	99 ± 11 (60)	101 ± 12 (60)	100 ± 13 (60)	99 ± 12 (60)
After	105 ± 17 (54)	112 ± 15 (56)[a,b]	121 ± 15 (56)[a,b,c]	100 ± 11 (54)
ΔROM	6 ± 12[b]	11 ± 13[b]	20 ± 14[b,c]	0 ± 13
Follow-up	109 ± 13 (50)[b]	116 ± 12 (50)[b]	126 ± 14 (52)[b,c]	100 ± 15 (48)

The number of knees in each group at various times is given in parentheses.
I = muscular strengthening exercises three times weekly for 8 weeks; II = as I and US treatment three times weekly for 8 weeks; III = as I and weekly shock wave therapy for first 6 weeks; IV = acted as controls; ROM = range of motion (degrees).
[a] Significant difference in ROM in each group after treatment compared with initial (with the paired t test).
[b] Significant difference in ROM in each group compared with the control group at various time-intervals (with the Dunnett test).
[c] Significant difference compared with other treated groups ($p < 0.05$) (with the Tukey test).

resistance. The isokinetic muscle-strengthening exercise program was performed, as described in our previous study [8] for left and right knees, three times a week for 8 weeks (24 sessions). The isokinetic exercise program began with 60% of the average peak torque. Intensity of isokinetic exercise increased from one set to five sets during the first through to the fifth sessions, and it remained at six sets for the remaining 6th through to the 24th sessions. Each set consisted of five repetitions of concentric (Con/Ecc) contraction in angular velocities of 30°/second and 120°/second for extensors, and five repetitions of eccentric and concentric (Ecc/Con) contractions in angular velocities of 30°/second and 120°/second for flexors. The start and stop angles for extension exercise were 40° and 70°, and the start and stop angles for flexion exercise were 70° and 40°. Patients were allowed 5 seconds of rest between sets, 10 seconds of rest between different modes of training, and 10 minutes of rest between right and left knee training.

The ultrasound treatment

The patient was kept in a prone position with bilateral knee full extension. The ultrasound was set at a frequency of 1 MHz and a spatial and temporal peak intensity of 2.5 W/cm^2 (Sonopulus 590; Enraf Nonius, 2600 AL Delft, Netherlands). Ultrasound was pulsed at a duty cycle of 25%. The probe of ultrasound was applied 10 minutes for the popliteal cyamella indicated by the real time 5—12 MHz high-resolution linear scanner (Acuson Antares; SIEMENS, Buffalo, USA) and X-ray image of bilateral knees followed by tender point findings made during orthopedic examination: around 10 cm^2 in the total treated area. The ultrasound treatment was performed three times a week for 8 weeks. The intensity of ultrasound was adjusted to the level at which the patient felt a warm sensation or mild sting.

Shockwave therapy

Application of ESWT

The patient was kept in a prone position with bilateral knee full extension. ESWT was performed with the piezoelectric shock wave (F10G4 Richard Wolf GmbH, Knittlingen, Germany). After localization by the above instruments and biofeedback of the patient and marking by the guided sonography, ultrasound gel was applied to the skin and the applicator couple was put into place with an impulse energy flux density of 0.03—0.4 mJ/mm^2 (scaling from 1—20), a frequency of 1—8 Hz and a pressure range of 11—82 MPa, 2000 impulses for each popliteal cyamella weekly from the 1st week for 6 weeks. The dose of ESWT was applied according to the general therapeutic dose for calcific tendinopathy [15], and the level of density depended on the size of the popliteal cyamella: the larger the popliteal cyamella the greater the density applied, ranging from the scales 1—20. The average intensity was around 15—18 scales.

Compliance

Compliance was determined by the number of participants who completed the treatment course divided by the number of initial participants. The major causes of noncompliance and the times at which the exercise program was discontinued were also analyzed.

Statistical analysis

The paired t test was used to study the changes in ROM, VAS, LI values, and peak torques in each group immediately after treatment and at follow-up 6 months later. One-way ANOVA analysis with the Tukey test was used to compare the differences in ROM, VAS, LI, and peak torques between treated groups, and the Dunnett test was used to compare the difference between treated groups and the control group at zero time, after treatment, and 6 months later. A statistically significant difference was defined as $p < 0.05$.

Results

Patients

The 120 patients ranged from 48 to 76 years old (mean age: 63.0 ± 7.4), with a female: male ratio of 102:18. The duration of knee pain ranged from 10 months to 12 years.

Changes in range of motion

The changes in average ROM of the arthritic knees for each group are shown in Table 1. The average ROM of each group was initially similar, but ROM scores later increased significantly in all treated groups, with patients in Group III showing the greatest improvement of ROM, both after treatment and in the follow-up period.

Table 2 Average visual analogue scale for knee pain in each group before and after treatment (mean ± SD).

	I	II	III	IV
Before	5.5 ± 1.4 (60)	5.7 ± 1.5 (60)	5.8 ± 1.2 (60)	5.6 ± 1.4 (60)
After	4.2 ± 0.9 (54)[a,b]	3.2 ± 1.6 (56)[a,b]	2.6 ± 1.4 (56)[a,b,d]	5.2 ± 1.1 (54)
ΔVAS	1.3 ± 1.5[b]	2.6 ± 1.7[b]	3.3 ± 1.6[b,d]	0.4 ± 1.4
Follow-up	4.0 ± 1.4 (50)[b]	3.0 ± 1.5 (50)[b]	2.2 ± 1.3 (52)[b,c,d]	6.5 ± 1.3 (48)[c]

The characteristics of patients in Groups I—IV are as per Table 1. The number of knees in each group at various times are given in parentheses.
[a] Significant difference in visual analogue scale (VAS) in each group after treatment compared with initial (with the paired *t* test).
[b] Significant difference in VAS in each group compared with the control group at various time-intervals (with the Dunnett test).
[c] Significant difference compared follow-up with after treatment (with the paired *t* test).
[d] Significant difference compared with other treated groups ($p < 0.05$) (with the Tukey test).

Table 3 Average Lequesne's index of patients in each group before and after treatment (mean ± SD).

	I	II	III	IV
Before	7.8 ± 1.2 (30)	7.9 ± 1.6 (30)	8.1 ± 1.3 (30)	8.0 ± 1.1 (30)
After	5.1 ± 0.9 (27)[a,b]	4.5 ± 1.1 (28)[a,b]	4.1 ± 1.6 (28)[a,b,d]	7.4 ± 1.3 (27)
Δ LI	2.2 ± 1.3[b]	3.3 ± 1.7[b]	4.2 ± 1.4[b,d]	0.6 ± 1.4
Follow-up	5.4 ± 1.7 (25)[b]	4.0 ± 1.6 (25)[b,c]	2.5 ± 1.5 (26)[b,c,d]	7.6 ± 1.6 (24)

The characteristics of patients in Groups I—IV are as per Table 1. The number of patients in each group at various times are given in parentheses.
[a] Significant difference in Lequesne's Index (LI) in each group after treatment compared with initial (with the paired *t* test).
[b] Significant difference in LI in each group compared with the control group at various time-intervals (with the Dunnett test).
[c] Significant difference compared with after treatment (with the paired *t* test).
[d] Significant difference compared with other treated groups ($p < 0.05$) (with the Tukey test).

Changes in knee pain

The changes in average scores for knee pain in each group are shown in Table 2. Pain scores for Groups I—IV were initially similar, but pain scores decreased significantly in all treated groups, and pain scores continued to decrease significantly in Groups II and III during the follow-up, whereas pain scores increased in the controls. Patients in Group III showed the greatest degree of pain reduction, both after treatment and in the follow-up period.

Changes in LI

Initially, the treated and control groups showed no significant LI differences, but average LI scores decreased significantly in all treated groups after treatment, and at

Table 4 Mean peak torque (MPTs) of knee flexion and extension in concentric and eccentric contraction at 60°/second in each group before and after isokinetic treatment (Nm/second).

		I	II	III	IV(control)
60° (Ex/Con)	Before	33.5 (60)	33.6 (60)	34.3 (60)	34.0 (60)
	After	39.0 (54)[a,b]	42.7 (56)[a,b]	50.6 (56)[a,b,d]	35.2 (54)
	Follow-up	40.1 (50)[b]	46.5 (50)[b]	59.3 (52)[b,c,d]	33.5 (48)
60° (Ex/Ecc)	Before	55.5 (60)	56.6 (60)	55.9 (60)	56.9 (60)
	After	71.3 (54)[a,b]	77.7 (56)[a,b]	84.3 (56)[a,b,d]	56.0 (54)
	Follow-up	72.4 (50)[b]	82.8 (50)[b,c]	90.2 (526)[b,c,d]	54.7 (48)
60° (Flex/Con)	Before	40.3 (60)	39.4 (60)	41.3 (60)	40.9 (60)
	After	45.2 (54)[b]	47.9 (56)[a,b]	52.8 (56)[a,b,d]	40.5 (54)
	Follow-up	47.5 (50)[b]	51.5 (50)[b]	57.6 (52)[b,c,d]	40.3 (48)
60° (Flex/Ecc)	Before	50.6 (60)	51.5 (60)	51.0 (60)	50.2 (60)
	After	55.1 (54)	58.3 (56)[a,b]	62.0 (56)[a,b,d]	50.5 (54)
	Follow-up	58.2 (50)[b]	63.1 (50)[b,c]	68.3 (52)[b,c,d]	48.1 (48)

The characteristics of patients in Groups I—IV are as per Table 1. The number of knees in each group at various times are given in parentheses.
[a] Significant difference in mean peak torque (MPT) in each group after treatment compared with initial (with the paired *t* test).
[b] Significant difference in MPT in each group compared with the control group at various time-intervals (with the Dunnett test).
[c] Significant difference compared with after treatment (with the paired *t* test).
[d] Significant difference compared with other treated groups ($p < 0.05$) (with the Tukey test).

Table 5 Mean peak torque (MPTs) of knee flexion and extension in concentric and eccentric contraction at 180°/second in each group before and after isokinetic treatment (Nm/second).

		I	II	III	IV (control)
180°(Ex/Con)	Before	30.3 (60)	28.3 (60)	28.5 (60)	28.1 (60)
	After	48.5 (54)[a,b]	50.5 (56)[a,b]	57.6 (56)[a,b,d]	30.1 (54)
	Follow-up	50.6 (50)[b]	52.8 (50)[b]	60.7 (52)[b,d]	29.5 (48)
180° (Ex/Ecc)	Before	68.2 (60)	69.3 (60)	70.0 (60)	69.6 (60)
	After	83.4 (54)[a,b]	89.3 (56)[a,b]	100.4 (28)[a,b,d]	70.7 (54)
	Follow-up	86.5 (50)[b]	99.2 (50)[b,c]	115.7 (52)[b,c,d]	68.4 (48)
180° (Flex/Con)	Before	27.5 (60)	26.5 (60)	25.8 (60)	26.1 (60)
	After	36.6 (54)[a,b]	41.6 (56)[a,b]	50.2 (56)[a,b,d]	25.8 (54)
	Follow-up	40.9 (50)[b]	51.6 (50)[c,b]	64.5 (52)[b,c,d]	24.8 (48)
180° (Flex/Ecc)	Before	44.4 (60)	43.3 (60)	44.8 (60)	45.0 (60)
	After	53.3 (54)[a,b]	57.5 (56)[a,b]	63.2 (56)[a,b,d]	43.9 (54)
	Follow-up	54.9 (50)[b]	61.4 (50)[b]	70.5 (52)[b,c,d]	44.2 (48)

The characteristics of patients in Groups I—IV are as per Table 1. The number of knees in each group at various times are given in parentheses.
[a] Significant difference in mean peak torque (MPT) in each group after treatment compared with initial (with the paired *t* test).
[b] Significant difference in MPT in each group compared with the control group at various times intervals (with the Dunnett test).
[c] Significant difference compared with after treatment (with the paired *t* test).
[d] Significant difference compared with other treated groups ($p < 0.05$) (with the Tukey test).

the follow-up 6 months later. Patients in Group I had the least reduction in LI scores after treatment, and patients in Group III had the greatest reduction in disability after treatment and during the follow-up period. The changes in mean LI values in each patient group are shown in Table 3.

Changes in muscle power

The changes in mean peak torques of knee flexion and extension in concentric and eccentric contraction in all patient groups are shown in Table 4 (60°/second) and Table 5 (180°/second). The average peak torques of 60°/second in Ex/Con, Ex/Ecc, Flex/Ecc, and Flex/Con increased significantly in all treated groups, both after treatment and at the follow-up. Patients in Group I showed the least improvement in peak torques after treatment, but Group I patients still showed significant improvements in muscle peak torques when compared with the control group at follow-up. Group III had the greatest improvement in peak torque at 60°/second and 180°/second in all contraction modes (Ex/Con, Ex/Ecc, Flex/Con, and Flex/Ecc) after treatment and at follow-up, which correlates closely with joint stability.

Changes in popliteal cyramella

There were no case of popliteal cyamella disappearing radiologically after treatment, and in only nine patients in Group III was the size found to have reduced at the follow-up 3 months later (Fig. 2).

Compliance

Compliance was 90.0% (27/30) in Group I, 93.3% (28/30) in Group II, 93.3% (28/30) in Group III, and 90.0% (27/30) in the control group. Reasons for withdrawal from the treatment included intolerable knee pain (70.0%, 7/10) induced by the prescribed exercises and leg muscle weakness.

Discussion

Small accessory bones residing in tendons and muscles are known as sesamoid bones, which are small accessory bones usually embedded in tendons or muscles, typically near joints. They seem to be part of the fetal skeletal development and regress with a tendency to fuse in adults. Sesamoid bones may be asymptomatic or symptomatic, causing considerable pathology. They may make bony or cartilaginous pseudoarticular connections with neighboring bones that in case of an osteoarthritic destruction of these articulations may be a cause of considerable pain and rupture of the tendon involved as is described clinically and radiologically [29]. Therefore, symptomatic popliteal sesamoid bone in knee OA needs further management for more compliance of knee OA rehabilitation as shown in our study results.

Gärtner and Simons [30] reported that the macroscopic appearance of acute calcifying tendinitis resembled a murky emulsion; by contrast, it resembled a granular conglomerate during the chronic phase. X-ray diffraction showed a poorly crystallized hydroxyapatite lattice in both phases. Infrared spectroscopy revealed variable H_2O, CO_3, and PO_4 contents in all samples, but no significant differences in these proportions were seen in the two phases. The disintegration of the conglomerates probably depends on a change in the bonding capacity of the organic molecules, which in turn initiate phagocytosis in the resorptive phase. Maier et al. [31] found a high variability in the proportion by weight of calcium and phosphorus. Patients with the highest relative proportions by weight of calcium and phosphorus in the calcific deposit had a history of unsuccessful ESWT. Our results showed that there were no visible changes to popliteal cyamella from X-ray imaging

Figure 2. Comparison of popliteal cyamella deposits before and after ESWT. (A1) Popliteal cyamella before treatment; (B1) 3 months later in the same patient. (A2) The cyamella with maximal length and maximal width in size (mm); (B2) the cyamella at follow-up 3 months later.

after treatment, and only 34.6% (9 patients) of patients had decreased calcified areas during the follow-up periods, which implies that the popliteal cyamella of knee OA may have higher proportions of calcium and phosphorus.

Comparison of the results in treated Groups I–III showed that the addition of either ultrasound treatment (Group II) or ESWT (Group III) had better therapeutic effects in reduction of knee pain, inactivity, and increase in range of motion and muscle peak torques. It was revealed that an intensive management of popliteal cyamella in knee OA is important in the rehabilitation program. Furthermore, the improvement in Group III was better than in Group II both for immediate effects and the follow-ups. It demonstrated that ESWT has a better therapeutic effect than ultrasound in management of popliteal cyamella syndrome. The immediate improvement of range of motion of arthritic knee after ESWT also implied that disintegration and lengthening of cyamella tendinopathy resulted in more muscle peak torque improvement later.

Studies showed that shock waves enable substance P release from nonmyelinated nerve and periosteum, which induces plasma extravasation and stimulation of proliferation of various types of cells [32]. ESWT was also shown to cause upregulation of VEGF as demonstrated by immunohistochemistry which provide the evidence of local tissue regeneration after ESWT and prolonged pain reduction [33,34]. All these demonstrate the greater extant of pain reduction in Group III.

As shown in Table 3, participants in Group III had continuous improvement in functional status but this was not found in other groups. This correlates with the continuous improvement in knee pain and muscle peak torques, and it implies that the bioeffects of ESWT not only focus on the immediate pain reduction, and range of motion of joints, but also on the reconditioning of the treated tissue.

As reported by Tabira et al. [12], cyamella occur more frequently in Asians. The cyamella was usually found in patients with symptomatic knee OA, especially in patients with the symptom of morning stiffness. Another finding in our study showed that the morning stiffness subsided gradually after completion of the ESWT therapy course, and the compliance of patients who received ESWT was more than 90%. Although there was some sensation of pain during ESWT application, there were no specific side-effects such as local swelling, erythema, or skin erosion during or after ESWT management, and patients evinced satisfaction with the immediate effect of arthritic knee relaxation after ESWT.

The weaknesses of our study include lack of epidemic study of incidence of popliteal cyamella in knee OA due to too few recruited participants, and lack of further quantitative measurement of cyamella size changes after treatment and at the follow-up due to our focus on the functional improvement in the patients' rehabilitation. However, further quantitative evaluation of popliteal cyamella change is warranted to clarify the relationship with functional improvement and therefore to develop a more comprehensive rehabilitation program for knee OA.

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