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A systematic review of the use of shockwave therapy for knee osteoarthritis

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ABSTRACT

Introduction: Previous studies assessed the effect of extracorporeal shockwave therapy (ESWT) for knee osteoarthritis (OA) among different situations. Thus, results from a meta-analysis regarding this topic may not be reliable due to heterogeneity.
Methods: A systematic review was conducted on three internet databases, namely Cochrane Library, PubMed, and Embase, gathering pertinent papers from their establishment to March 2024. The search phrases were as follows: "shockwave" OR "shock wave" OR "extracorporeal shockwave" OR "Extracorporeal Shockwave Therapy [MeSH Term]" AND "knee" AND ("osteoarthritis" OR "arthritis" OR "arthritic" OR "osteoarthritis [MeSH term]").
Results: Twenty-four articles (n = 888) were included, with the resulting conclusions demonstrating that ESWT was effective for knee OA compared with sham ESWT; however, ESWT was not effective for patients with severe knee OA. Patients receiving higher energy or higher shock number had significant improvement than those receiving lower energy or less shock number, respectively. Adding ESWT in isokinetic muscular strengthening exercises (IMSE) was more effective than IMSE alone. The efficacy of ESWT was better than other therapies, including intravenously applied prostacyclin and bisphosphonate, corticosteroid injection, kinesiotherapy, hyaluronic acid injection, platelet-rich plasma injection, and physiotherapy.
Conclusions: This review demonstrated that ESWT was effective for knee OA. Higher energy and more shock numbers could obtain better efficacy. ESWT could be used as a replacement for some other therapies.

1. Introduction

One prevalent ailment is osteoarthritis (OA) of the knee, particularly in the elderly, which causes pain and reduces joint function, ultimately resulting in functional disability. Globally, a total of 654 million individuals, or 23 % of adults aged over 40 years, have suffered from knee OA.[1] Several key risk factors are related with knee OA, including female (Odds ratio [OR]: 1.68), obesity (OR: 2.66), and previous knee injury (OR: 2.38).[2] To prevent knee OA from progressing to the end-stage, extracorporeal shockwave therapy (ESWT) is one of the therapies.[3]

Shock waves are commonly generated by ballistic, piezoelectric, electromagnetic, or electrohydraulic sources[4–6] and these can be used to focus on a specific region of tissue for medical purposes. ESWT, which is a noninvasive method, was initially adopted to treat diseases such as salivary, kidney, and urinary calculi,[7] but recently has been widely adopted to treat various musculoskeletal conditions[5] as it has been demonstrated to not only increase subchondral bone remodeling but reduce articular cartilage degradation as well.[8]

Meta-analysis has been used to examine the effectiveness of ESWT in treating knee OA[9–11] While the results showed that ESWT is effective for treating knee OA, most of the meta-analyses had a high level of heterogeneity[10,11]; The heterogeneity of these meta-analyses is likely due to the use of different energy levels of ESWT, comparison groups, and patient types. These differences lead to limitations in meta-analyses, allowing only a few articles to be used for such analyses. A systematic review should be further performed to estimate the effect of ESWT on this disease under various conditions.

This study's goal was to organized the effectiveness of ESWT in treating knee OA in various conditions by means of a systematic review. For doctors considering the use of ESWT in treating knee OA, this review can provide comprehensive information to establish an optimal treatment strategy using ESWT for knee OA.

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2. Materials and methods

The related articles were searched from three internet databases, namely Cochrane Library, PubMed, and Embase, gathering pertinent papers from their establishment to March 2024. The search phrases were as follows: ("shockwave" OR "shock wave" OR "extracorporeal shockwave" OR "Extracorporeal Shockwave Therapy [MeSH Term]") AND "knee" AND ("osteoarthritis" OR "arthritis" OR "arthritic" OR "osteoarthritis [MeSH Term]"). The search procedure was independently performed by two authors (H.S.C. and C.L.S.). First, articles were identified from the three databases, and their duplicates were detected and removed. Then, the remaining articles were searched by title/abstract screening and possibly related articles were retained. Finally, the relevant articles were determined by full-text analysis. The two authors explored any differences to come to an agreement. Potential related articles were also searched from the included articles' reference lists.

Inclusion criteria were as follows: (1) the primary disease that was knee OA; (2) patients treated by ESWT; (3) articles that were designed by randomized controlled trial (RCT); and (4) clinical results pertaining to pain and bodily function. The following were the exclusion criteria: (1) not original articles, such as note, letter, comment, conference abstract, and review; (2) articles that were not published in Chinese or English; and (3) non-human studies.

The principal attributes listed below were extracted for the systematic review: type of patients, type of control group, clinical outcomes, process of treatment, and follow-up visits. The two authors separately extracted these data, then they discussed any differences until they came to an agreement.

A number of clinical outcomes were used to evaluate how well various treatments worked for treating OA in the knee. The visual analog scale (VAS) is a gauging tool for subjective pain. A 10-cm line was used to evaluate pain level, and 0 and 10 cm indicate "no pain" and "worst pain" respectively.[12] WOMAC, a self-administered questionnaire, is frequently employed to evaluate the clinical results of knee OA, containing pain, stiffness, and physical function. The Roles and Maudsley (RM) score was used to assess pain and limitations of activity, and it ranges from 0 to 4 points from "excellent" to "poor", while the Lequesne index (LI) containing an 11-item questionnaire was used to assess severity of knee OA, and the knee injury and osteoarthritis outcome scores (KOOS) were used to measure physical functional disability, with the Time-up-and-go test (TUG) being used to measure mobility level. The 10 m-walk test and a 20 m walk test were used to measure the walking time over a short distance, while the 40-m fast-paced walk test was used to assess short-distance walking activities. ROM was used to assess knee flexion and extension; the 36-Item short form survey (SF-36) evaluated individual patients' health status; the 9-step stair-climb test (SCT) measured the required time to go up and down 9 stairs; while the isokinetic test assessed five repeats at 60° per second and 15 repeats at 180° per second.

3. Results

After systematic review, 50 studies were analyzed using full-text screening (Fig. 1). Among these, 25 studies were included in this study, but the other 25 were removed with reasons, including not RCT, not original articles, and others The main characteristics of these articles were extracted and recorded in Table 1.

Six articles compared the efficacy between ESWT and sham ESWT for treating knee OA[13–18]; Zhang et al[17] adopted two energy levels of ESWT (energy flux density [EFD] = 0.12 mJ/mm^2 vs EFD = 0.24 mJ/mm^2) and two types of shock numbers (2000 impulses vs 4000 impulses) to compare with sham ESWT.[17] The results demonstrated that these ESWT groups had better improvement in VAS score at the 4-week follow-up compared with the sham group. Zhong et al[16] adopted low-dose ESWT (EFD = 0.105 mJ/mm^2 and 2000 impulses) to compare with sham ESWT. The ESWT group had better improvement in VAS, WOMAC, and LI than the sham group for all the follow-ups (5 and 12 weeks). Similar results were also observed in the study (EFD = 0.25 mJ/mm^2 and 4000 impulses) conducted by Zhao et al[13,13] Imamura et al[15] adopted ESWT (EFD = 0.10–0.16 mJ/mm^2 and 2000 impulses) to treat severe knee OA[15]; however, the results showed that the ESWT group did not have better improvement in VAS and WOMAC than the sham group for all the follow-ups (1 and 12 weeks). Using ultrasonographic characteristics, Choi et al.[18] provided objective evidence regarding to the impact of ESWT on knee OA.[18] The results demonstrated that with time, the suprapatellar effusion's height decreased in the ESWT group ($P < 0.05$).

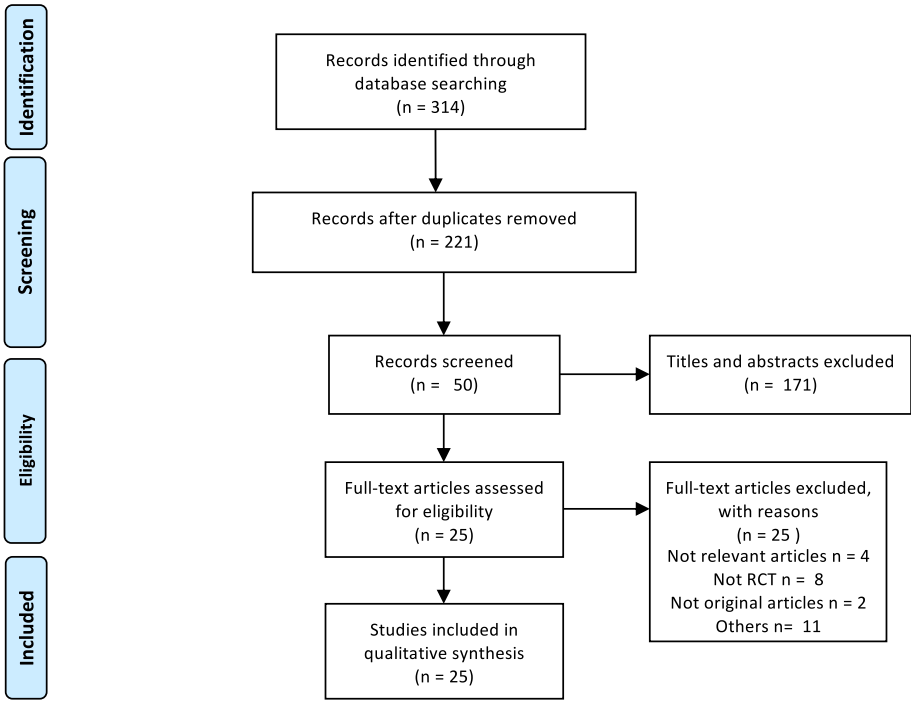

Fig. 1. Progress of systematic review for identifying related articles.

Table 1
Major characteristics of included articles.

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[19]	low-energy ESTW	knee OA	II ~ III	30	65.1 ± 6.3	26/4	1000	0.04	once a week for 3 weeks	VAS, RM, WOMAC, and LI	1, 4, and 12 weeks
	high-energy ESTW			30	63.5 ± 5.4	27/3	1000	0.093			
[17]	ESWT_group1	knee OA	II ~ III	19	60.8 ± 8.4	11/8	2000	0.12	once a week for 4 weeks	VAS and WOMAC	4 weeks
	ESWT_group2			19	62.7 ± 7.5	12/7	4000	0.12			
	ESWT_group3			19	58.2 ± 9.5	10/9	2000	0.24			
	ESWT_group4			18	63.7 ± 6.9	12/6	4000	0.24			
	sham ESWT			14	61.5 ± 5.4	8/6	1000	0.02			
[20]	low-energy ESWT	knee OA	II	15	50.4 ± 3.4	6/9	2000	0.02	once per week for 4 weeks	VAS, KOOS, and active repositioning	NA
	medium-energy ESWT			15	49.9 ± 2.6	5/10	2000	0.178			
	sham ESWT with strengthening exercise			15	49.7 ± 3.1	8/7	2000	0			
[21]	f-ESWT	knee OA	II ~ III	21	64.1 ± 11.4	9/12	NA	NA	once per week for 3 weeks	VAS, WOMAC, ROM, and 6-min walk test	4 and 8 weeks
	r-ESWT			21	63.1 ± 11.2	8/13	NA	NA			

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[23]	kinesio taping + home exercise	knee OA	I ~ III	22	NA	NA	NA	NA	twice a week for 6 weeks	VAS, TUG, 10 m walk test, and KOOS	6 and 12 weeks
	ESWT + home exercise			18	NA	NA	2000	NA	once a week for 6 weeks		
	home exercise			20	NA	NA	NA	NA	12 weeks		
[24]	IMSE	knee OA with popliteal cyamella	NA	30	63.0 ± 7.4	18/102	NA	NA	once a week for 6 weeks	ROM, VAS, and LI	not consistent
	IMSE + ultrasound			30			NA	NA			
	IMSE + ESWT			30			2000	0.03–0.4			
	control			30			NA	NA			
[22]	ESWT	knee OA	II	20	40.12 ± 9.45	9/11	1000	0.05	once a week for 4 weeks	VAS, WOMAC, 6 min waling test	NA
	Laser therapy			20	46.62 ± 8.68	10/10	NA	NA	Three times a week for 4 weeks		
[3]	ESWT + PT	knee OA	II ~ VI	18	65.6 ± 11	6/12	1600	0.24	3 sections a week for three weeks	VAS, WOMAC, and 7-min walk test	1 week
	sham ESWT + PT			18	64.6 ± 11.8	5/13	1600	0.24			

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[31]	ESWT	chronic stroke patients with	2.0 ± 1.1	9	75.5 ± 7.7	8/1	1000	0.05	once a week for 6 weeks	VAS, functional state	1 week
	sham ESWT	knee OA	1.8 ± 1.1	9	72.7 ± 5.9	7/2	1000	0			
[30]	ESWT	knee OA with bone marrow edema	II ~ III	40	69.74 ± 3.91	24/13	2500	0.12	twice a week for 5 weeks	VAS, WOMAC and LI	6 and 12 months
	ESWT	knee OA without bone marrow edema		40	70.48 ± 4.18	24/14	2500	0.12			
	sham ESWT	knee OA without bone marrow edema		40	69.65 ± 4.49	22/13	2500	~0			
Eftekharsadat 2020	ESWT + exercise	knee OA	NA	25	58.0 ± 5.97	0/25	2000	0.18	5 sections within 3 weeks	VAS, WOMAC, ROM, and TUG	3 and 7 weeks

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Table 1 (*continued*)

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
	Physiotherapy + exercise			25	55.76 ± 6.06	2/23	NA	NA	10 sections within 3 weeks		
	exercise			25	58.16 ± 7.20	3/22	NA	NA	NA		
[25]	ESWT	knee OA	II ~ III	26	57.35 ± 8.3	4/22	3000	0.125	once a week for 3 weeks	WOMAC	1 and 3 weeks
	Physiotherapy			25	58.2 ± 6.2	2/23	NA	NA			

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[32]	ESWT	knee OA with bone marrow edema	NA	20	41.6 ± 9.7	11/9	3000–4000	>0.44	once a week for 2 weeks	VAS, WOMAC, and SF-36	1, 3. and 6 months
	intravenously applied prostacyclin			20	45.1 ± 8.9	9/11	NA	NA	NA		
[27]	ESWT	knee OA	I ~ II	38	59.84 ± 4.36	NA	2000	0.2	once a week for 5 weeks	VAS, WOMAC, and LI	5 weeks
	HA			39	60.21 ± 4.23	NA	NA	NA	one injection a week for 5 weeks		
[28]	NSAIDs	knee OA		15	49	1/14	NA	NA	200 mg daily for 3 weeks	VAS, functional score, blood test, and plain radiographies	1, 4, 12, 24, and 48 weeks
	HA			15	52	2/13	NA	NA	once a week for 3 weeks		
	ESWT			15	54	1/14	3000	0.22	3 sessions at bi-weekly interval		
[26]	ESWT	knee OA	2.3 ± 0.5	31	67.7 ± 5.5	25/6	1000	0.05	once per week for 3 weeks	VAS, WOMCA, LI, 40-m fast-placed walk test, and SCT	1 and 3 months
	HA		2.4 ± 0.5	30	69.1 ± 6.2	26/4	NA	NA	weekly for 3 weeks		

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[29]	PRP	knee OA	I-II	60	57.4	21/39	NA	NA	one injection a week for 5 weeks	VAS, WOMAC and LI	1, 3, and 5 weeks
	ESWT			60	58.6	20/40	1000~2000	0.12–0.20	once a week for 5 weeks		
	ESWT + PRP			60	59.7	19/41	1000~2000	0.12–0.21	once a week for 5 weeks		
[14]	ESWT	knee OA	II ~ III	20	51 ± 3.5	10/50	2000	NA	once a week for 3 weeks	VAS, WOMAC, and ROM	4, 8, and 24 weeks
	corticosteroid injection			20							
	sham ESWT			20			2000	~0	once a week for 3 weeks		
[33]	ESWT	knee OA	NA	20	63.5 ± 8.0	7/13	1600	0.4	once per week for 5 weeks	WOMAC and ROM	5 weeks
	kinesiotherapy			20	65.0 ± 8.4	9/11	NA	NA			
Uysal 2020	ESWT + exercises	knee OA	II ~ III	52	60.2 ± 6.3	10/42	2000	0.09–0.12	once per week for 3 weeks	VAS, ROM, 20-m waker test, WOMAC, LI, and isokinetic test	1 and 3 months
	sham ESWT + exercises			52	61.8 ± 6.0	9/43	0	NA			

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[13]	ESWT	knee OA	II ~ III	34	59.9 ± 11.3	14/20	4000	0.25	once per week for 4 weeks	VAS, WOMAC, and LI	1, 4, and 12 weeks
	sham ESWT			36	61.8 ± 9.8	11/25	0	0			
[18]	ESWT	knee OA	1.3 ± 0.5	9	73.7 ± 2.4	NA	1000	0.05	once per week for 3 weeks	VAS, WOMAC, LI, SEH	4 weeks
	sham ESWT		1.4 ± 0.5	9	72.6 ± 2.3	NA	1000	0			
Zhong 2019	ESWT	knee OA	II ~ III	32	62.5 ± 8.2	11/21	2000	0.105	once per week for 4 weeks	VAS, WOMAC, and LI	5 and 12 weeks

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Table 1 (*continued*)

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mJ/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
	sham ESWT			31	63.2 ± 7.7	11/19	2000	0.2 bar			
[15]	ESWT	knee OA	II ~ VI	52	70.0 ± 6.5	NA	2000	0.1–0.16	once a week for 3 weeks	VAS, and WOMAC	1 and 12 weeks
	sham ESWT			53	72.4 ± 6.5	NA	2000	0			

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mj/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[31]	ESWT	chronic stroke	2.0 ± 1.1	9	75.5 ± 7.7	8/1	1000	0.05	once a week for 6 weeks	VAS, functional state	1 week
	sham ESWT	patients with knee OA	1.8 ± 1.1	9	72.7 ± 5.9	7/2	1000	0			
[30]	ESWT	knee OA with bone marrow edema	II ~ III	40	69.74 ± 3.91	24/13	2500	0.12	twice a week for 5 weeks	VAS, WOMAC and LI	6 and 12 months
	ESWT	knee OA without bone marrow edema		40	70.48 ± 4.18	24/14	2500	0.12			
	sham ESWT	knee OA without bone marrow edema		40	69.65 ± 4.49	22/13	2500	~0			
Eftekharsadat 2020	ESWT + exercise	knee OA	NA	25	58.0 ± 5.97	0/25	2000	0.18	5 sections within 3 weeks	VAS, WOMAC, ROM, and TUG	3 and 7 weeks
	Physiotherapy + exercise			25	55.76 ± 6.06	2/23	NA	NA	10 sections within 3 weeks		
	exercise			25	58.16 ± 7.20	3/22	NA	NA	NA		
[32]	ESWT	knee OA with bone marrow edema	NA	20	41.6 ± 9.7	11/9	3000–4000	>0.44	once a week for 2 weeks	VAS, WOMAC, and SF-36	1, 3. and 6 months
	intravenously applied prostacyclin and bisphosphonate			20	45.1 ± 8.9	9/11	NA	NA	NA		
[26]	ESWT	knee OA	2.3 ± 0.5	31	67.7 ± 5.5	25/6	1000	0.05	once per week for 3 weeks	VAS, WOMCA, LI, 40-m fast-placed walk test, and SCT	1 and 3 months
	hyaluronic acid injection		2.4 ± 0.5	30	69.1 ± 6.2	26/4	NA	NA	weekly for 3 weeks		

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mj/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[14]	ESWT	knee OA	II ~ III	20	51 ± 3.5	10/50	2000	NA	once a week for 3 weeks	VAS, WOMAC, and ROM	4, 8, and 24 weeks
	corticosteroid injection			20							
	sham ESWT			20			2000	~0	once a week for 3 weeks		
[33]	ESWT	knee OA	NA	20	63.5 ± 8.0	7/13	1600	0.4	once per week for 5 weeks	WOMAC and ROM	5 weeks
	kinesiotherapy			20	65.0 ± 8.4	9/11	NA	NA			
Uysal 2020	ESWT + exercises	knee OA	II ~ III	52	60.2 ± 6.3	10/42	2000	0.09–0.12	once per week for 3 weeks	VAS, ROM, 20-m waker test, WOMAC, LI, and isokinetic test	1 and 3 months
	sham ESWT + exercises			52	61.8 ± 6.0	9/43	0	NA			
[13]	ESWT	knee OA	II ~ III	34	59.9 ± 11.3	14/20	4000	0.25	once per week for 4 weeks	VAS, WOMAC, and LI	1, 4, and 12 weeks
	sham ESWT			36	61.8 ± 9.8	11/25	0	0			

(*continued on next page*)

Table 1 (*continued*)

Author	Treatment group	Patients	K-L grade	Sample size	Mean age	Sex ratio (M/F)	Shock number	Energy flux density (mj/mm^2)	Treatment duration	Clinical outcomes	Follow-up periods
[18]	ESWT	Knee OA	1.3 ± 0.5	9	73.7 ± 2.4	NA	1000	0.05	Once per week for 3 weeks	VAS, WOMAC, LI, SEH	4 weeks
	sham ESWT		1.4 ± 0.5	9	72.6 ± 2.3	NA	1000	0			
[16]	ESWT	knee OA	II ~ III	32	62.5 ± 8.2	11/21	2000	0.105	once per week for 4 weeks	VAS, WOMAC, and LI	5 and 12 weeks
	sham ESWT			31	63.2 ± 7.7	11/19	2000	0.2 bar			
[15]	ESWT	knee OA	II ~ VI	52	70.0 ± 6.5	NA	2000	0.1–0.16	once a week for 3 weeks	VAS, and WOMAC	1 and 12 weeks
	sham ESWT			53	72.4 ± 6.5	NA	2000	0			

K-L: Kellgren-Lawrence. ESWT: extracorporeal shockwave therapy. OA: knee osteoarthritis. NA: not available. f-ESWT: focused extracorporeal shock wave therapy. r-ESWT: radial extracorporeal shockwave therapy. RM: Roles and Maudsley. VAS: visual analog scale. WOMAC: Western Ontario and McMaster Universities Arthritis Index. LI: Lequesne index. KOOS: knee injury and osteoarthritis outcome score.
K-L: Kellgren-Lawrence. ESWT: extracorporeal shockwave therapy. IMSE: isokinetic muscular strengthening exercises. PT: physiotherapy. OA: knee osteoarthritis. NA: not available. VAS: visual analog scale. WOMAC: Western Ontario and McMaster Universities Arthritis Index. LI: Lequesne index. KOOS: knee injury and osteoarthritis outcome score. TUG: timed up & go test. ROM: range of motion. SF-36: 36-Item short form survey.
K-L: Kellgren-Lawrence. ESWT: extracorporeal shockwave therapy. IMSE: isokinetic muscular strengthening exercises. OA: knee osteoarthritis. NA: not available. RM: Roles and Maudsley. VAS: visual analog scale. WOMAC: Western Ontario and McMaster Universities Arthritis Index. LI: Lequesne index. KOOS: knee injury and osteoarthritis outcome score. TUG: timed up & go test. ROM: range of motion. SF-36: 36-Item short form survey. SCT: 9-step stair-climb test.
K-L: Kellgren-Lawrence. ESWT: extracorporeal shockwave therapy. NSAIDs: non-steroidal anti-inflammatory drugs. OA: knee osteoarthritis. NA: not available. RM: Roles and Maudsley. VAS: visual analog scale. WOMAC: Western Ontario and McMaster Universities Arthritis Index. LI: Lequesne index. ROM: range of motion. SCT: stair-climb test.
K-L: Kellgren-Lawrence. ESWT: extracorporeal shockwave therapy. PRP: platelet-rich plasma. OA: knee osteoarthritis. NA: not available. WOMAC: Western Ontario and McMaster Universities Arthritis Index. LI: Lequesne index.
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This reduction was significantly different from the sham group at the 1-month follow-up ($P < 0.05$).

Three articles compared different energy levels of ESWT in the treatment of knee OA[17,19,20] Kim et al[19] compared two energy levels of ESWT (EFD = 0.04 mJ/mm^2 vs EFD = 0.093 mJ/mm^2) and followed up the outcomes at 1, 4, and 12 weeks after treatment.[19] The results demonstrated that the higher energy group had significant improvement in VAS score (at 12 weeks), RM score (at 1 and 4 weeks), and LI (at 12 weeks) compared with the lower energy group. Hammam et al[20] also compared two energy levels of ESWT (EFD = 0.02 mJ/mm^2 vs EDF = 0.178 mJ/mm^2) and these therapies were combined with strengthening exercises. These results demonstrated that the higher energy group had significant improvement in VAS score, KOOS, and active repositioning after treatment compared with the lower energy group. Zhang et al[17] compared two energy levels of ESWT (EFD = 0.12 mJ/mm^2 vs EFD = 0.24 mJ/mm^2) and two shock numbers (2000 impulses vs 4000 impulse), and the outcomes were followed up for 4 weeks. The results showed that the higher energy group had significant improvement in VAS and WOMAC scores at the 4-week follow-up compared with the lower energy group. The more shock number group had significant improvement in WOMAC score at 4 weeks compared with the less shock number group. These results indicate that higher energy level and more shock number had better improvement in efficacy in the treatment of knee OA. Ko et al.[21] compared two types of ESWT for treating knee OA.[21] The results indicated that focused ESWT resulted in more significant improvements in pain and function than radial ESWT during the follow-up visits at 4 and 8 weeks. Mostafa et al[22] compared ESWT with high-power laser therapy for treating knee OA.[22] The results showed that high-power laser therapy had better improvement in pain and function than ESWT.

Günaydin et al[23] compared the efficacy among ESWT with home exercise, kinesio taping with home exercise, and home exercise alone, and the clinical outcomes were followed up at 12 weeks.[17] The results demonstrated that there was no superiority in isokinetic strength, function, and pain relief among the three groups after treatment. Adding ESWT in home exercise seemed not to have better improvement than home exercise alone.

Chen et al[24] compared the efficacy among isokinetic muscular strengthening exercises (IMSE), ultrasound with IMSE, ESWT with IMSE, and control in the treatment of knee OA with popliteal cyamella, and the clinical outcomes were followed up.[24] The ESWT with IMSE group had better improvement in ROM, VAS, and LI compared with the other groups. Adding ESWT in IMSE for treating knee OA with popliteal cyamella could significantly improve the efficacy compared with IMSE alone. Eftekharsadat et al. (2020) compared the efficacy among ESWT with exercise, physiotherapy (PT) with exercise, and exercise, with results showing no significant differences in WOMAC score, TUG, and ROM between the ESWT and PT groups at the 3-week follow-up, and both therapies were better than exercise alone except for knee stiffness (WOMAC subscale); however, these differences between groups become insignificant at the 7-week follow-up. Arslan and Kul[25] compared the effectiveness of ESTW and PT in treating knee OA.[25] The findings revealed no discernible variation in VAS, WOMAC, ROM, and TUG test between ESTW and PT at 10- and 21-day follow-up visits.

Three articles compared the efficacy of ESWT versus hyaluronic acid (HA) injection in treating knee OA[26–28] Lee et al[26] reported that no significant differences in VAS and WOMAC between ESWT and HA groups at 1- and 3-month follow-up visits. However, Jhan et al[28]

reported that the ESWT group had better improvement in VAS, KOOS, and WOMAC than HA group at the 12-month follow-up visit. The similar results also reported by Liu et al.[27]

Su et al.[29] compared the effectiveness of ESWT, platelet-rich plasma (PRP), and the combination of ESWT and PRP in treating knee OA.[29] The results showed that the ESWT combined with PRP had better improvement in VAS and WOMAC compared with the ESWT or PRP group at 1-, 3, and 5-weeks follow-up visits. However, there was no significant difference in joint activity among the three groups at any follow-up visits.

Ediz et al[30] compared the efficacy of ESTW for treating patients with knee OA with and without bone marrow edema[30] and showed that the medial joint width protection after receiving ESWT was more prominent in knee OA with bone marrow edema than that without bone marrow edema at the 1-year follow-up. Cho et al[31] investigated the chronic stroke patients with knee OA[31] and showed that the patients after receiving ESTW had significant improvement in VAS score after 1 week compared with the baseline level. This result indicated that ESTW in the treatment of knee OA was also effective for chronic stroke patients.

Gao et al[32] compared the efficacy between ESWT and intravenously applied prostacyclin and bisphosphonate (IAPB) for knee OA with bone marrow edema,[32] with results demonstrating that the ESWT group had better improvement in VAS, WOMAC, and SF-36 scores than the IAPB group at the three follow-ups (1, 3, and 6 months), while Lee et al[26] compared the efficacy between ESWT and hyaluronic acid (HA) injection for treating knee OA[26]; however, the results demonstrated no significant differences in VAS, WOMAC, LI, 40-m fast-paced walk test, and stair-climb test between the two groups at 1- and 3-month follow-ups. Elerian et al[14] compared the efficacy between ESWT and corticosteroid injection[14] and showed that the ESWT group had better improvement in VAS, ROM, and WOMAC than the corticosteroid injection group after treatment. Lizis et al[33] compared the efficacy between ESWT and kinesiotherapy (KIT) for treating knee OA,[33] revealing that the ESWT group had better improvement in WOMAC scores (pain, stiffness, function, and total scores) and ROM than the KIT group at 5-week follow-up visit.

4. Discussion

This study widely organized the RCTs investigating the efficacy of ESWT for knee OA. The ESWT with energy level ranged from 0.10 to 0.24 mJ/mm^2 and shock number ranged from 2000 to 4000 impulses showed significantly better improvement than sham ESWT. Higher energy levels or more shock numbers adopted in ESWT showed better improvement in efficacy than lower energy levels or less shock numbers respectively. ESWT was also effective for chronic stroke patients with knee OA but seemed not to be effective for patients with severe knee OA. ESWT could be used as a replacement for other therapies such as HA, PRP, and PT.

Some studies investigated the efficacy of adding ESWT in physical exercises, although adding ESWT in home exercise seemed not to have better improvement than home exercise alone. Adding ESWT in IMSE for treating knee OA with popliteal cyamella could significantly improve the efficacy compared with IMSE alone. Other studies compared the efficacy between ESWT and other therapies, with results demonstrating the ESWT group had better improvement than IAPB, corticosteroid injection, HA, PRP, and KIT groups. Otherwise, the combination of ESWT and PRP showed a significant improvement compared to ESWT alone.

Although the efficacy of ESWT for knee OA has been confirmed, the optimal dose level or shock number is still unclear. A systematic review showed that EFD should be as high as the patients can tolerate for achieving the best efficacy.[34] Our review also demonstrated higher EFD had better improvement in efficacy than lower EFD; moreover, it also showed that more shock numbers had better improvement than less shock numbers, although the number of shocks that could achieve the best efficacy is still unclear. More RCTs should be conducted to investigate the optimal shock number adopted in ESWT for treating knee OA.

Exercises are traditional methods for treating knee OA. Adding ESWT in exercises may increase the efficacy, and two articles have investigated this topic[23,24]; Their results demonstrated that adding ESWT in exercises had better improvement than IMSE alone, but not just home exercise alone. However, the two articles included different type of patients. Chen et al[24] adopted several therapies in the treatment of knee OA with popliteal cyamella.[19] They concluded that ESWT could reduce the size of popliteal cyamella, indicating that ESWT seemed to be more effective for knee OA with popliteal cyamella. The patients in the study of Günaydin et al[23] were not specific to knee OA with popliteal cyamella. This may be the reason why adding ESWT in home exercise did not show better improvement than home exercise alone; however, it is still unclear if ESWT alone had better efficacy than these exercises.

Our review showed the efficacy of ESWT in the treatment of patients with different situations. ESWT was adopted to treat chronic stroke patients with knee OK and the efficacy of ESWT seemed not to be affected by chronic stroke.[31] However, ESWT was not effective for disabling pain due to severe knee OA.[15] J Once knee OA reaches an advanced stage, the only treatment left is joint replacement surgery. Bone marrow edema, which is reversible, could increase in interstitial fluid and cause pain[35,36]; The results demonstrated that the efficacy of ESTW in the treatment of knee OA with bone marrow edema was better than that without bone marrow edema[30]; moreover, ESWT had better efficacy for knee OA with bone marrow edema than IAPB.[32]

Several articles have compared the efficacy between ESWT and other therapies in the treatment of knee OA[14,26,32] The patients receiving ESWT had better improvement than those receiving IAPB, corticosteroid injection, or KIT, but there were no significant differences in efficacy between ESWT and HA groups. Our review showed that ESWT with energy level ranging from 0.10 to 0.24 mJ/mm^2 and shock number ranging from 2000 to 4000 impulses had significantly better improvement than sham ESWT, although a study by Lee et al[26] adopted lower energy (0.05 mJ/mm^2) and less shock number (1000 impulses) in ESWT to treat knee OA,[26] and found that lower EFD and less shock number could decrease the efficacy of ESWT, resulting in no significant difference in efficacy between ESWT and HA injection.[26] A previous meta-analysis reported a dose-response relationship between the use of ESWT energy and the improvement in VAS and WOMAC in knee OA patients.[37]

This study has certain drawbacks. First, our review showed that higher EFD and higher shock number adopted in ESWT had better efficacy, although the exact EFD and shock number that could archive the best efficacy is still unclear. Secondly, this review showed that the efficacy of ESWT in the treatment of knee OA was better than IAPB, corticosteroid injection, or KIT. Although these articles were RTCs with high level of evidence, only a limited number of RCTs have been conducted to compare the efficacy between ESWT and other therapies. More RTCs comparing the efficacy between ESWT and other therapies should be further conducted to validate these results. Finally, the follow-up periods were not similar among the included RCTs. Some RCTs followed up the clinical outcomes in a short-term period while others used a long-term period. The efficacy of ESWT would decrease with time after treatment, and the results might not be consistent.

5. Conclusion

The RCTs investigating how well ESWT worked in treating knee OA were thoroughly reviewed, and the findings had a high degree of evidence. ESWT was effective for knee OA even for chronic stroke patients, an increasing EFD or shock numbers could raise the efficacy of ESWT for treating knee OA. ESWT seemed to be more effective for knee OA with popliteal cyamella compared with ultrasound or IMSE; however, ESWT was not effective for patients with severe knee OA but was superior in efficacy to other therapies for treating knee OA, such as IAPB, corticosteroid injection, HA, PRP, and KIT. Although we widely reviewed the RCTs investigating ESWT for treating knee OA, some topics were

conducted via a limited number of articles. Additional RCTs should be conducted in the future, and more RCTs can be adopted in meta-analysis to provide high level of evidence.

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Not application.

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