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Lymphatic treatments after orthopedic surgery or injury: A systematic review

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ABSTRACT

Background: Orthopedic injuries in conjunction with extensive damage to tissues, bones and blood vessels, usually require a long recovery. Associated consequences are pain, movement limitations, decreased function and occasionally, prolonged edema, which can delay or interfere with the healing process. Lymphatic and compression therapy have become increasingly common, intending to reduce edema and pain, thus, promoting the recovery process.
Aims: To examine the efficacy of methods commonly used to reduce edema after orthopedic injury or surgery, i.e. decongestive therapy, manual lymphatic drainage, and compression bandaging.
Methods: English literature search was undertaken in January 2019, in the following databases: Cochrane Library, MEDLINE, PEDro. Inclusion criteria: randomized controlled or quasi-controlled trials in adults who have edema or pain after recent limb trauma or surgery. Two independent assessors rated study quality and risk of bias using the PRISMA recommendations and PEDro score.
Results: We evaluated 71 papers. After excluding duplicated and irrelevant papers, 15 met the eligibility criteria (6 on lymphatic treatment and 9 on compression). Quality of papers ranged from 3 to 7 on PEDro score; of them, 13 were 1b Level of Evidence and two were 1c.
Conclusion: After elective surgeries, when the significant edema appears or persists beyond recovery time, complex decongestive therapy and manual edema mobilization should be recommended in addition to conventional physical therapy. In acute injuries such as ankle or distal radius fractures, lymphatic treatments and compression bandaging should be considered as part of the therapeutic protocol. Nine studies evaluated different compression modalities found that only multilayer and long stretch compression significantly reduce edema.

1. Introduction

Edema is a normal response to injury (Villeco, 2012) and develops when the microvascular filtration rate exceeds lymph drainage for a sufficient period either because the filtration rate is high or the lymph flow is low or a combination of the two. Edema becomes a concern when it persists beyond the inflammatory phase or after two weeks, subsequently developing peripheral protein-rich edema in the interstitium (Stout, 2002). Peripheral edema differs from chronic venous and lymphatic obstruction, emerging immediately after a fracture or soft tissue injury. This type of edema increases during immobilization affects the distal extremity at the site of the injury and does not react immediately to diuretics or anti-inflammatory drugs. In contrast, venous edema develops slowly and only marginally responds to diuretics (Majewski-Schrage and Snyder, 2016). Untreated and persistent edema can exacerbate pain, and cause mobility and range of motion (ROM) difficulties. Furthermore, edema may increase the risk of infection in the affected area, decrease blood circulation and negatively affect the elasticity of the arteries - all complications that can delay wound healing (Földi et al., 2018). Scar tissue may

Abbreviations: ADL, activities of daily living; CDT, complex decongestive therapy; MEM, manual edema mobilization; MLD, manual lymph drainage; RCT, randomized controlled trial; ROM, range of movement; TKR, total knee replacement.

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obstruct the normal lymph flow. Free flaps used in reconstructive surgery appear to have no normally functioning lymphatic vessels (van Zanten et al., 2017).

Acute injuries and surgeries are associated with extensive soft-tissue and lymphatic vessels damage. Severe compound fractures of the tibia can result in significant lymphatic disruption and an increased risk for the development of chronic lymphedema (Van Zanten et al., 2017). After Total Knee Replacement (TKR) edema is reported in up to 35% of patients compared to pre-surgery and existed in 11% of patients after three months period. Edema may cause quadriceps muscle weakness, and as a result, slower walking speed (Pua, 2015), decrease knee extension strength and decrease functional performance (Holm et al., 2010). Joint replacements surgeries; Total hip Replacement (THR) and TKR and other orthopedic surgeries may create local ischemia, which increases postoperative pain through nutritional deprivation of the affected soft tissues.

Upper extremity injuries can cause prolonged swelling that may impact joint ROM, soft tissue mobility, quality of scar tissue formation, function, strength, and aesthetics of the hand. These factors may delay a patient's recovery, return to work, resumption of activities of daily living (ADL) and require frequent or increased outpatient appointments (Miller et al., 2017).

The efficacy of Complex Decongestive Therapy (CDT) on edema reduction has been reported in the context of lymphedema, especially for secondary lymphedema, after oncologic surgeries and radiation treatments (Finnane et al., 2015). The same techniques used for oncologic patients to reduce edema may be efficient in orthopedic conditions. CDT includes several components that are most effective together, including; 1) Manual Lymphatic Drainage (MLD); 2) compression bandaging; 3) exercises; and 4) meticulous skincare of the affected areas (Lasinski et al., 2012). In orthopedic conditions, physical therapy will usually be performed which includes gradual exercises and most often medical treatment will include maintaining skin hygiene and wound treatment. Regarding the components of lymphatic treatment and bandaging, there are still many questions, about the effectiveness of the treatments: When should treatment begin? Can it be an integral part of routine treatment or only when there is significant edema or long-lasting edema? Several case studies describe the success of MLD therapies, after extensive injuries, and demonstrated improvement in edema and skin condition after treatment, but these articles have low methodological value (Cohen, 2011; Weiss et al., 1998; Stout, 2002). Another case report demonstrated a significant decrease in edema using Manual Edema Mobilization (MEM) in different patients after injuries such as multiple fractures, carpal tunnel release surgery and a crushing injury (Priganc and Ito, 2008). One case report examined the use of the Godoy and Godoy technique after compound fracture of the tibia and fibula and found it to be beneficial in edema reduction (Pereira de Godoy et al., 2018).

Recently, several studies (Härén et al 2000, 2006; Kessler et al., 2003; Knygsand-Roenhoej and Maribo, 2011) found that by adding lymphatic treatments to routine physical therapy during the post-operative and post-traumatic period, recovery of the orthopedic patient may be expediated nevertheless there is a need for more research to answer the remaining questions.

This review aimed to describe the different methods used to reduce edema after orthopedic injury or surgery; to examine the efficacy of those commonly used treatments i.e. CDT, MLD and compression bandaging, as a treatment for post-traumatic edema, decrease function and pain.

2. Methods

A systematic review of the literature was conducted with no time limit because lymphatic treatments after injuries or orthopedic surgery had become a popular treatment tool only in recent years, we wanted to include all the information on the subject.

Eligibility criteria: Studies were included if reported in English, were randomized controlled trials (RCTs) or quasi-control trials (methods of allocating participants to a treatment, which are not strictly random) with adult participants who suffer from subacute swelling, post a recent musculoskeletal injury or surgery (i.e., different orthopedic surgeries: THR and TKR). Studies reporting on lymphatic non-surgical non-pharmacological treatments or bandaging with reported outcomes were assessed using a clinician derived measure of volume.

Exclusion criteria: Studies including participants with non-orthopedic conditions (e.g., cancer lymphedema, bariatric, pregnancy, lipedema, venous disease, burn trauma patients, reflex sympathetic dystrophy**,** orthognathic surgery, etc.). Studies were excluded if they used only animals or laboratory trials. Studies that only used a medicinal product or invasive methods to treat the edema (such as cortisone injection and anti-inflammatory drugs) were also excluded.

Data extraction: Extracting data from the included studies was done by the lead author (I.G.) using a purpose-designed standardized data extraction form. This form summarized details on study design, sample, interventions, outcomes, and results. On occasions when there was doubt over the interpretation of the data being extracted, a second reviewer (L.K.) also conducted data extraction independently using the same form to verify the clarity of extracted data.

Assessment of methodological quality: The methodological quality of interventional studies was evaluated by the PEDro score (http://www.pedro.org.au) (De Morton, 2009). The PEDro scale considers two aspects of trial quality, namely the “internal validity” of the trial and whether the trial contains sufficient statistical information, thus making it interpretable. It does not rate the “external validity” of the trial or the size of the treatment effect.

Search protocol: We conducted a systematic review using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) recommendations (http://www.prisma-statement.org/index.htm) (Moher et al., 2009). The following electronic databases were searched: the Cochrane Library (Wiley Inter-Science), MEDLINE (via Ovid), PEDro (Physiotherapy Evidence Database). Search terms included: edema therapy, complex decongestive therapy, complex lymphatic therapy, manual lymphatic drainage, limb edema, complete decongestive physiotherapy, lymphatic massage, limb compression garments, compression bandage, lymphatic bandages, elastic bandages, short stretch bandage, compression sleeve, orthopedic surgery, open reduction internal fixation, ankle surgery, ankle sprain, total knee replacement, total hip replacement, total knee arthroplasty, lymphedema, cryotherapy, posttraumatic edema, and postoperative edema.

3. Results

Seventy-one articles related to edema treatment and orthopedic injury or surgery were reviewed by using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) recommendations (Fig. 1). Of the 71 articles, 15 studies met inclusion criteria 6 for lymphatic treatments and 9 for bandaging (Tables 1 and 2).

The different researchers used different lymphatic treatment methods that may be difficult to compare including MLD, CDT, MEM, and different bandage techniques including elastic bandage, medical compression stocking, multilayer compression, short stretch, and Velband or crepe.

Methodology level: Thirteen trials included in the review were RCT's, one quasi-control and one prospective trial (with no

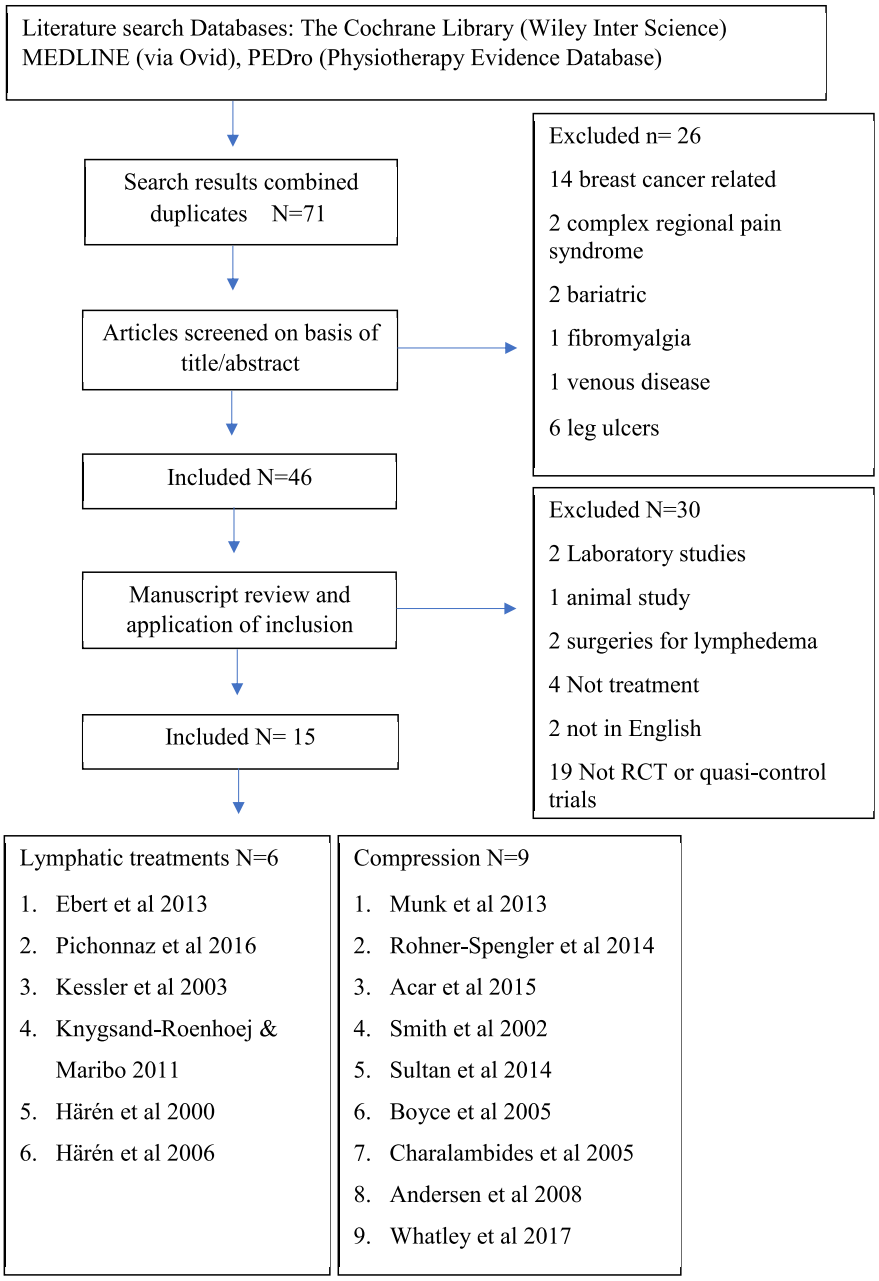

Fig. 1. PRISMA flow diagram.

randomization). The included trials had a mean PEDro score of 5.6 for lymphatic treatments and 6 for bandaging, ranging from 3 to 8 (Appendix 1 and 2). The sample size ranges from 12 to 47. None of the included studies had participant or therapist blinding, but 6 of the studies has assessors blinding. Eighth used concealed allocation, and only two of the studies used intention-to-treat analysis.

Participants: The review for lymphatic treatments included 163 participants (52.7% women), of whom 81 received lymphatic treatments (49.6%). Participants had a mean age of 60 years.

The bandaging trials included 712 participants (50% women), of whom 328 received treatment with different bandage modalities (46%). Participants had a mean age of 55.3 years. Participants went through TKR in five trials, ankle fractures in four trials and ankle sprains in two (total of 15 on lower extremity), while only three trials reported on distal radius fractures (upper extremity) (Tables 1 and 2).

Follow up: Three studies followed patient only at the time of hospital stay, three studies did flow up of for four weeks, one did a follow up of six weeks, two studies did two months follow up, and the other six studies had a longer follow-up of three up to twelve months.

Outcomes measures: In 10 trials limb volume was measured, three trials used volumeter, five trials used tape measure (one compared tape to bioimpedance swelling measurements, one of them used figure eight method) and one trial used water displacement method. Four trials used active knee flexion and extension ROM two trials used passive knee flexion and extension ROM. Different Questionnaires were used to evaluate function and quality of life, Oxford knee score, questionnaire for bilateral activities, Functional Olerud–Molander ankle score, the American

Table 1
Lymphatic treatments: research design, participants and key results.

Study/type of surgery	Study (design)	Age (range)	Sex female N (%)	Treatment and patients (N)	Outcomes	Follow-up	Key results	Level of evidence
Ebert et al. (2013) TKR	Prospective RCT	70 (48 −89)	14 (28)	Total 50 1. No MLD (24) 2. MLD (26)	Active knee flexion and extension ROM, lower limb girths, PNRS and KOOS	Preoperatively, days 2, 3, 4 and at 6 weeks	MLD in the early postoperative stages after TKR appears to improve active knee flexion up to 6 weeks post-surgery, in addition to conventional care.	PEDro 7/10; CEBM 1b
Pichonnaz et al. (2016) TKR	Prospective RCT	70 (62 −78)	39 (65)	Total 60 1. Placebo (30) 2. five MLD treatments (30)	Edema using bioimpedance spectroscopy, volume measure and active & passive ROM, knee function	Seven days and 3 months	MLD immediately post-operative didn't reduce edema, although did reduced pain with less contracture at 3 months.	PEDro score 7/10; CEBM 1b
Kessler et al. 2003 Hindfoot operations	Pilot RCT.	49 (29 −69)	12 (52)	Total 23 1. Control-standard physical therapy (12) 2. Experiment-Standard physical therapy + daily 30-min MLD (11)	Percentage reduction in excess limb volume, measured by the water displacement method	On the second postoperative day (t1) and the day of discharge (t2).	Results showed a decrease in lower extremity swelling at discharge. This result was reached without the use of additional compression bandaging techniques	PEDro 4/10; CEBM 1b
Knygsand-Roenhoej and Maribo (2011) Distal radius fracture	Single-blinded RCT. Two edema methods of treatment	62 (52 −71)	21 (70)	Total 30 1. Control- traditional edema treatment (14) 2. Experiment-modified MEM (15)	Subacute edema was measured with a volumeter. The pain was measured with a visual analog scale (VAS), active ROM, a questionnaire for bilateral activities.	One, three, six, nine, and 26 weeks.	Neither the traditional nor the modified MEM treatment program was superior in terms of edema reduction, although the modified MEM resulted in fewer sessions	PEDro 6/10; CEBM 1b
Härén et al., (2000) Fracture of the distal radius	Prospective RCT	61 (29 −85)	20 (76)	Total 26 All patients had the same conventional treatment with exercises, movement, edema control, and education. 1. Control-conventional treatment (14) 2. Experiment- 10 treatments of MLD (12)	Edema was assessed with a commercially available volumeter.	At 3,17,33,68 days after the external fixator was removed	The experimental group had significantly less edema in the injured hand. The author concluded that MLD reduces edema in the early posttraumatic stage compared with the conventionally-treatment, which reduces the risks of edema-associated complications.	PEDro 5/10; CEBM 1b
Härén et al. (2006) Fracture of the distal radius	Prospective RCT	63 (51 −80)	42(82)	Total 51 Both groups had conventional treatments. 1. Control (26) 2. Experiment-received six treatments of MLD, 40 min each (25)	Edema of the injured hand was measured with a volumeter and this was compared to the pre-treatment volume.	14 days and 60 days after the commencement of treatment.	Results indicate that MLD is a useful method for reducing post-traumatic edema of the hand in the early phase.	PEDro 5/10; CEBM 1b

N number, **PNRS** pain numeric rating scale, **KOOS** Knee Injury, and Osteoarthritis Outcome Score. **The PEDro scale** was developed by the Physiotherapy Evidence Database to determine the quality of clinical trials. Pedro scale includes 11 items that rank RCT into * high-quality PEDro score 6–10, fair quality PEDro score 4–5, poor quality = PEDro score ≤3. **CEBM** Oxford Center of Evidence-Based Medicine; 1a: Systematic reviews of RCTs, 1b: Individual RCTs, 1c: All-or-none studies, 2a: Systematic reviews of cohort studies, 2b: Individual cohort studies or low-quality RCTs (<80% follow-up), 2c: Outcomes research.

Orthopedic, Foot and Ankle Society score, foot and ankle 36 form and Karlsson scoring scale for the ankle. Five trials measured pain. one by visual analog scale (VAS) and two by numeric rating scale (Tables 1 and 2).

Intervention: In five of the six trials reporting on lymphatic treatments, the experiment group received MLD with conventional physical therapy while control received conventional physical therapy alone, one trial compared MLD to MEM.

On the research of bandaging one trial used multilayer compression, one used long stretch bandaging, one short stretch, one medical elastic bandage, one used Velband bandage with cotton crepe, one with compression stocking and Aircast and three with an elastic bandage.

The theoretical concepts of the potential efficacy of lymphatic treatments were shown in two studies (Szczesny et al 2000, 2001) demonstrating an increased lymph formation and lymphatic flow after mechanical and operative injuries of limbs, thus, indicating the response of the lymphatic system to the healing and recovery phase post-surgery or injury.

3.1. Lymphatic treatment methods for edema reduction

CDT is currently recognized as the gold standard of care in lymphedema treatment. Treatments are founded on the following beliefs that by 1) stimulating the lymphatic system via an increase in lymph circulation; 2) expediting the removal of biochemical wastes from the body tissues; 3) enhancing body fluid dynamics, thereby, facilitating edema reduction; and 4) decreasing sympathetic nervous system responses while increasing a parasympathetic nervous tone yielding a non-stressed body-framework (Földi et al., 2018).

MLD is a light massage technique using a repetitive skin stretching movement, following the lymphatic pathways. MLD is reported to augment lymphatic contractility, increase lymphatic

Table 2
Bandaging: research design, participants and key results.

Author/date	Study design	Age	Sex Female N (%)	Treatment and patients (N)	Outcomes	follow-up	Key results	Level of evidence
Munk et al. 2013 TKR	Prospective RCT	63 (56 −70)	40 (48)	Total 85 1. Control- no stocking (42) 2. Experiment- Medical elastic compression stocking from the first postoperative day and the following 4 weeks (43)	Knee swelling in the first 2 weeks after surgery. calf and ankle swelling, postoperative pain, knee flexion ROM, and patient-reported knee function, Oxford knee score questionnaire.	At 2, 7, 14 and 30 days.	Medical elastic compression stocking does not reduce swelling and pain or improve knee flexion during the first month after TKR surgery.	PEDro 5/10; CEBM 1b
Rohner-Spengler et al. (2014) Ankle and hindfoot fractures	RCT, single-blinded Three groups of treatments	–	–	Total 65 1. Control- ice gel packs (21) 2. Bandage (multilayer compression bandages) (21) 3. Impulse compression (23)	Edema, figure-of-eight-20, measured in millimeters. Ankle plantar flexion and dorsiflexion, measured in degrees. VAS for pain, patient satisfaction, number of inpatient days, use of medication, Wound-healing Foot and Ankle Ability Measure-Short Form-36	At 2, 12 weeks and 12 months.	Multilayer compression therapy results in a faster reduction of ankle and hindfoot edema, although with less ankle dorsiflexion on a postoperative day three than the control group.	PEDro 8/10; CEBM 1b
Acar et al. 2015 Acute ankle sprains	Prospective, single-blinded RCT	36 (25 −47)	41 (58)	Total 73 All patients received standard therapy which includes rest, elevation and ice. 1. Kinesio group taping was applied for 5 days (38) 2. Elastic bandages were applied for 5 days (35)	Ankle girth, Karlsson scoring scale, NPRS. Active ROM was measured with a standard manual goniometer.	At 0, 3, 7, and 28 days.	Kinesio taping as effective as an elastic bandage in the treatment of acute stable ankle sprains.	PEDro 8/10; CEBM 1b
Smith et al. 2002 TKR	Prospective RCT	72 (65 −79)	42 (50)	Total 84 1. Compression bandaging of Velband and cotton crepe for 24 h (42) 2. Cryo-pad technology (42)	Wound drainage, transfusion volumes, pain by VAS, and knee flexion and swelling (not reported how measured)	At 1, 2 and 3 days.	No statistically differences were found for a total length of stay, knee swelling, flexion, wound drainage, transfusions, or hemoglobin.	PEDro 3/10; CEBM 1b
Charalambide et al. 2005 TKR	Prospective study of three groups	76 (51 −86)	101 (67)	Total 150 1. Compression (long stretch) over a double layer of Velband wool (50) 2. Crêpe bandage alone, (50) 3. Crêpe bandage and suction drain (50)	Edema (was not measured quantitatively only observation), intraarticular pressure, length of hospital stay, ROM (goniometer), blood loss and transfusion requirements and complications.	Complications were evaluated at 48 h and discharge, ROM at discharge and 4.5 months postoperatively.	The results showed that patients treated with compression bandaging recovered quicker post-op, had a shorter hospital stay, a greater flexion ROM on discharge, no swelling of the limb.	Not RCT CEBM 1c
Sultan (2014) ankle fracture	Prospective, stratified, single-blinded RCT	47 (16 −79)	54 (60)	Total 90 1. compression using ankle injury stockings plus an Aircast boot (44). 2. Tubigrip plus an Aircast boot (46).	Functional Olerud−Molander ankle score, the American Orthopedic Foot and Ankle Society score; the Short Form (SF)-12v2 QOL score; and the frequency of deep vein thrombosis (DVT) with Duplex ultrasound, edema (measured circumference), ROM using goniometer	At 2, 4, 8 and 12 weeks and at six months.	Compression using ankle injury stockings plus an Aircast, applied early following a fracture of the ankle, improved function, and quality of life outcome.	PEDro 8/10; (CEBM) 1b
Andersen et al. (2008) TKR	Prospective RCT	71 (63 −77)	30 (62)	(48) 1. No compression (n = 24) 2. Compression double layer of soft padding overlapping layer of elastic adhesive bandage (n = 24)	Pain using NPRS, duration of the hospitalization period and function at home.	NPRS, was assessed every hour for the first 8 postoperative hours, and 24 h postoperatively	A compression bandage is recommended to improve analgesia after high-volume local infiltration analgesia after TKR. The application of a compression bandage does not restrict patient mobilization.	PEDro 5/10; CEBM 1b
Boyce et al., 2004 Lateral ligament ankle sprains	Prospective RCT	34 (–)	14 (40)	Total 35 Aircast ankle brace (18) elastic support bandage (17)	Modified Karlsson scoring scale for ankle joint function, ankle girth using circumferential measurement and pain (VAS)	48−72 h, 10 days, and one month	Aircast ankle brace was superior in ankle joint function and girth compared with an elastic bandage.	PEDro 5/10; CEBM 1b
Whatley et al. (2017) Pilon fracture	Retrospective study	44 (34 −55)	34 (41)	Total 82 1. Control (35) 2. Experiment-Compression (short-stretch bandages) (47)	Wound complications, time to internal fixation surgery. No edema measurement was used.	90 days after definitive fixation.	Lymphedema treatment is useful in the acute care setting for the management of pilon fractures. Compression for posttraumatic edema was effective in reducing the time needed for definitive surgical fixation without increasing the risk of wound complications.	Not RCT CEBM 1c

N number, **VAS-** Visual analog scale. **NPRS**- numeric pain rating scale. **The PEDro scale** was developed by the Physiotherapy Evidence Database to determine the quality of clinical trials. Pedro scale includes 11 items that rank RCT into * high-quality PEDro score 6−10, fair quality PEDro score 4−5, poor quality = PEDro score ≤3. **CEBM** Oxford Center of Evidence-Based Medicine**;** 1a: Systematic reviews of RCTs**,** 1b: Individual RCTs, 1c: All-or-none studies**,** 2a: Systematic reviews of cohort studies**,** 2b: Individual cohort studies or low-quality RCTs (<80% follow-up)**,** 2c: Outcomes research.

flow through cutaneous lymphatics, and reduce lymphatic fluid in affected extremities, thus reducing limb swelling (Gordon and Mortimer, 2018). MLD is designed to optimize the lymphatic system by clearing lymphatic drainage areas adjacent to the regions of edema and thus, develop new pathways for the lymph flow. MLD was reported to reduce levels of inflammatory mediators, which are often associated with edema and pain (Földi et al., 2018).

MEM can be thought of as American equiveillance to the European CDT and is accomplished by activating the lymphatic system to reduce excess tissue fluid, protein molecules, and other large molecules impermeable to the venous system. MEM is characterized by 1) a massage of the MEM pump points and 2) exercises in the segment just massaged. The MEM technique differs from the MLD technique in terms of the following: 1) MLD is used in patients with permanent edema, whereas MEM is used in patients with subacute edema, 2) massage of the MEM pump points and 3) exercises in the segment just massaged (Knygsand-Roenhoej and Maribo, 2011).

The Godoy and Godoy technique incorporates manual lymphatic therapy with an electromechanical device. Manual lymphatic therapy uses linear movements that manually displace the lymph along the anatomic path of the lymphatic vessels. The RAGodoy® mechanical device performs continuous passive flexion and extension of the ankle. Mechanical lymph drainage is considered a promoter for drainage of both the superficial and deep lymphatic chains (Pereira de Godoy et al., 2018).

3.2. Compression therapy

Compression therapy is an important therapeutic tool causing: 1) displacement of fluid from the interstitium and reduction in venous pressure. The compression promotes lymphatic drainage, resulting in augmentation of the lymphatic pump; 2) reduction of the lymphatic preload; and 3) increased lymph flow in functioning lymph vessels, particularly when combined with exercise. Compression acts as a counterforce to muscle activity. The contraction and relaxation of the skeletal muscles lead to an increase of pressure, thus, providing the most powerful stimulus to lymph drainage (Hobday, 2016; Rockson, 2018). All methods of compression found in the review are described in Table 2.

Compression bandages are divided into two types: a) elastic, maximal extension >100% (crepe, medical elastic compression); and b) inelastic, maximal extension <100% (short stretch). Inelastic, low-stretch bandages is the preferred compression tool due to the high-pressure amplitudes produced during movement (Rockson, 2018).

Multilayer bandages are usually applied in the form of overlapping layers of strong, non-elastic (short-stretch) which results in multiple layers of fabric that overlay a point of the surface of the limb. For example, if a bandage is applied in a spiral with a 50% overlap then this will result in two layers of bandage, while spiral with a 33% overlap will result in three layers of bandage. Multilayer bandages may involve the use of several layers of different types of materials to apply compression to the limb (Al Khaburi et al., 2011). For instance, tube gauze, two layers of wool and two or three layers of a short-stretch bandage. This type of bandage can be easily placed on the injured and swollen area and furthermore, can be used with external fixation post-fractures. Multilayer bandages can be used to reduce limb volume but have the added benefit of restoring limb shape (Rockson, 2018).

Compression hosiery (stockings) is mainly used during the maintenance phase of lymphedema treatments. Hosiery may be indicated for prophylaxis in patient groups at high risk for developing edema. Hosiery may not be optimal during decongestive treatment as its more dynamic and more adjustable modality is needed. Garment pressure, stiffness, type of weave, comfort level, ease of use, are all potential barriers to compliance of compression hosiery (Stout et al., 2012).

3.3. Summary of the literature on the efficacy of lymphatic treatments

CDT: The review found two studies conducted by the same researcher (Härén et al., 2000) (Härén and Wiberg, 2006), on patients with distal radius fractures. In both studies, MLD was performed in addition to exercises and bandaging and as a result, therefore were entered the CDT section, hence listed in Table 1. The authors found that CDT is a useful method for reducing post-traumatic edema of the hand in its early phase.

Whatley et al. performed a retrospective study of lower evidence level to evaluated if CDT can shorten the time needed between external fixation for pilon fractures to the time the tissue is suitable for internal fixation surgery. They found that CDT promotes the time required for surgery without related complications (Whatley et al., 2017). Disadvantages of the study which is non-random retrospective and not measures edema volumes or pain values, and relative low-level 1c of evidence.

MLD: During treatment, therapists will select the appropriate treatment tool for each patient, from the different components of CDT. We found three studies that separately examined the efficacy of lymphatic massage or drainage components. In the first study of Ebert et al., MLD in addition to conventional care did not reduce limb girth after TKR but had a beneficial effect on active knee flexion 6 weeks post-surgery (Ebert et al., 2013). The second study presented similar findings, MLD treatments applied immediately after TKR surgery did not reduce swelling, although, it did reduce pain and knee passive flexion contracture at three months post-operatively (Pichonnaz et al., 2016). The third study compared a small sample of 22 patients in a pilot RCT, found that MLD after hindfoot operations, in combination with standard physiotherapy exercises, achieved greater limb volume reduction than exercise alone (Kessler et al., 2003). To conclude, as to MLD efficacy, only one out of three RCTs found a beneficial effect in edema reduction after orthopedic surgeries. MLD might affect the patient's active ROM, passive ranges and contractures (reported in Table 1).

MEM: In Knygsand-Roenhoej and Maribo study MEM was compared with CDT treatment for patients with distal radius fractures. The authors concluded that MEM is effective as MLD for decreasing subacute edema in the rehabilitation of hand patients, MEM resulted in fewer sessions (Knygsand-Roenhoej and Maribo, 2011) (reported in detail in Table 1).

3.3.1. Summary of the literature on the efficacy of compression therapy

In this review, nine studies reported six different modalities of compressions (Table 2).

The crepe bandage was found ineffective in reducing edema (Charalambides et al., 2005), likewise, it was as effective as cold therapy (Smith et al., 2002).

Long stretch compression bandaging: of four trials reporting on different use of long stretch bandaging, one trial of low methodological value, reported that the Setopress bandage helped shorten hospitalization duration with improved ROM of flexion on discharge, after TKR, with no swelling of the limb (although did not quantify this), and fewer complications (Charalambides et al., 2005). Three trials reported on ankle injuries; in the first, elastic bandage was found to be as effective as kinesio taping in the treatment of acute ankle sprains (Acar et al., 2015). The two following compared elastic bandages with Aircast ankle brace. One reported Aircast was superior to tubular elastic support bandage for

the treatment of lateral ligament ankle sprains, improved ankle joint function (Boyce et al., 2005). The second found tubular elastic bandage applied early following fracture of the ankle reduced swelling and improved functional outcome comparing to Aircast (Sultan et al., 2014).

Short stretch medical elastic compression stocking was found in Munk et al. study as ineffective in reducing edema vs no stocking from the first postoperative day and the following 4 weeks after TKR (Munk et al., 2013).

Short stretch multilayer compression therapy was found to reduce edema much quicker than ice, although with less ankle ROM (Rohner-Spengler et al., 2014). Andersen et al. found acrylastic short-stretch elastic bandages with high initial and permanent adhesion over an inner double layer of soft padding, kept during the entire 24-h postoperative period, improve analgesia with the local infiltration analgesia technique (Andersen et al., 2008). Whatley et al. evaluated if the treatment given by a lymphatic specialist using short-stretch compression bandages could shorten the time needed for external fixation after pilon fractures (the authors did not report if lymphedema treatment including MLD were done). Although the trial is of low methanological value, the authors found compression as a useful tool in shortening the amount of time required to replace the external fixation, without causing any further complications (Whatley et al., 2017).

4. Discussion

Of the five RCTs who examined acute to sub-acute phase treatment after TKR or after radius fractures with external fixation (treatment began on average 18–42 days after fracture), only three reported significant edema reduction after lymphatic treatment. ROM improved in two studies and only one study demonstrated lower pain levels. The reviewed information suggests a partial benefit of lymphatic treatment after orthopedic surgery, on edema reduction and ROM. Nevertheless, it cannot be concluded from the review whether it enhances the recovery at the acute phase, we can conclude that when edema progresses beyond the reasonable recovery time or when there is extensive edema, pain and/or ROM limitation, various lymphatic therapies can be used as effective therapeutic tools in combination with conventional therapy. Our results are consistent with results of the systematic review by Majewski-Schrage and Snyder who found moderate evidence to support the use of MLD and MEM techniques for improving patient- and disease-oriented outcomes, including edema, ROM, and ADL in patients with orthopedic injuries (Majewski-Schrage and Snyder, 2016). Miller et al. reviewed the effectiveness of CDT, MEM, cold therapy and high voltage pulses after an upper limb injury, surgery or cerebrovascular accident concluding that lymphatic treatment should be considered in conjunction with conventional therapies, in cases of excessive edema or when the edema has not responded to conventional treatment alone, however, not as a routine intervention (Miller et al., 2017). There is a lack of high-quality research examining the effect of early vs subacute edema reduction intervention in orthopedic injuries or surgeries to determine whether early intervention can prevent the development of delayed edema.

The results of the compression bandage section-long stretch compression bandages are the cheapest and most affordable tool in hospitals and clinics and were found to be useful in edema reduction (Acar et al., 2015; Sultan et al., 2014). Multilayer compression may be beneficial in edema reduction although reported in only one trial (Rohner-Spengler et al., 2014), further research is needed to strengthen the evidence. Medical elastic compression stocking (Short stretch) was found to be ineffective in edema reduction (Munk et al., 2013) together with Velband and crepe bandage (Smith et al., 2002). No conclusion could be made regarding ROM, pain or function.

5. Conclusions

In elective surgeries such as joint replacements, a small proportion of patients develop prolonged postoperative edema, in which case it can be concluded that lymphatic treatments can be used as effective tools for edema reduction, although with low evidence on functioning improvement. CDT and MEM should be recommended in addition to conventional physical therapy when the edema persists beyond recovery time or when significant edema appears and there are pain and dysfunction. In circumstances of an acute injury such as sprains and ankle injuries or distal radius fractures, lymphatic treatments and compression bandaging should be considered as part of the therapeutic protocol to reduce edema and improve function.

In the matter of the use of compression; long stretch compression bandaging and multilayer compression were found to be useful in edema reduction.

Limitations

On each treatment method, few studies were found, making it difficult to examine in-depth each method. For the same reason, elective orthopedic surgery and orthopedic trauma were combined, while the recovery process and the pathophysiology are different.

Because we reviewed a variety of different edema treatments, intermittent pneumatic compression research was not addressed, as it is not a frequent part of treatment and is not usually done in the acute to acute subgroup.

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CRediT authorship contribution statement

Ifat Klein: Conceptualization, Methodology, Writing - original draft. **Dorit Tidhar:** Conceptualization, Methodology, Supervision, Writing - review & editing. **Leonid Kalichman:** Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of competing interest

None.

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Appendices

Appendix 1
Validity scores of RCTs (PEDro scale) for lymphedema treatments MLD.

Authors, Year	Ebert (2013)	Pichonnaz (2016)	Kessler (2003)	Knygsand Roenhoej 2011	Haren 2000	Haren 2006
1. Eligibility criteria were specified*	Yes	Yes	Yes	Yes	Yes	Yes
2. Subjects were randomly allocated to groups	Yes	Yes	Yes	Yes	Yes	Yes
3. Allocation was concealed	Yes	Yes	No	No	Yes	No
4. The groups were similar at baseline	Yes	Yes	No	Yes	No	Yes
5. Blinding of all subjects	No	No	No	No	No	No
6. Blinding of all therapists	No	No	No	No	No	No
7. Blinding of all assessors	Yes	Yes	No	Yes	No	No
8. Measures of at least one key variable	Yes	Yes	Yes	Yes	Yes	Yes
9. "Intention to treat"	No	No	No	No	No	No
10. Between-group statistical are reported	Yes	Yes	Yes	Yes	Yes	Yes
11. The study provides both point measures	Yes	Yes	Yes	Yes	Yes	Yes
PEDro score	7/10	7/10	4/10	6/10	5/10	5/10
Level of Evidence (CEBM)**	1b	1b	1b	1b	1b	1b

* This item is not used to calculate the validity (PEDro) score. **Oxford Center of Evidence-Based Medicine.

Appendix 2
Validity scores of RCTs (PEDro scale) for compression garments.

Authors, Year	Munk 2013	Rohner 2014	Smith 2002	Acar 2015	Sultan 2014	Andersen 2008	Boyce (2005)	Charalambide (2005)	Whatley (2017)
1. * Eligibility criteria	Yes	Yes	No	Yes	Yes	No	Yes	–	–
2. Randomly allocated	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–	–
3. Allocation concealed	No	Yes	No	Yes	Yes	Yes	Yes	–	–
4. Groups were similar at baseline	Yes	Yes	No	Yes	Yes	Yes	Yes	–	–
5. Blinding of all subjects	No	No	No	No	No	No	No	–	–
6. Blinding of all therapists	No	No	No	No	No	No	No	–	–
7. Blinding of all assessors	No	Yes	No	Yes	Yes	No	No	–	–
8. Measures of at least one key variable outcome were obtained	Yes	Yes	No	Yes	Yes	No	No	–	–
9. "Intention to treat"	No	Yes	No	No	Yes	No	No	–	–
10. The results of between-group comparisons	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–	–
11. Provides both point measures and measures of variability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	–	–
PEDro score	5/10	8/10	3/10	8/10	8/10	5/10	5/10	–	–
Level of Evidence (CEBM)	1b	1b	1b	1b	1b	1b	1b	1c	1c

* This item is not used to calculate the validity (PEDro) score. **Oxford Center of Evidence-Based Medicine.

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